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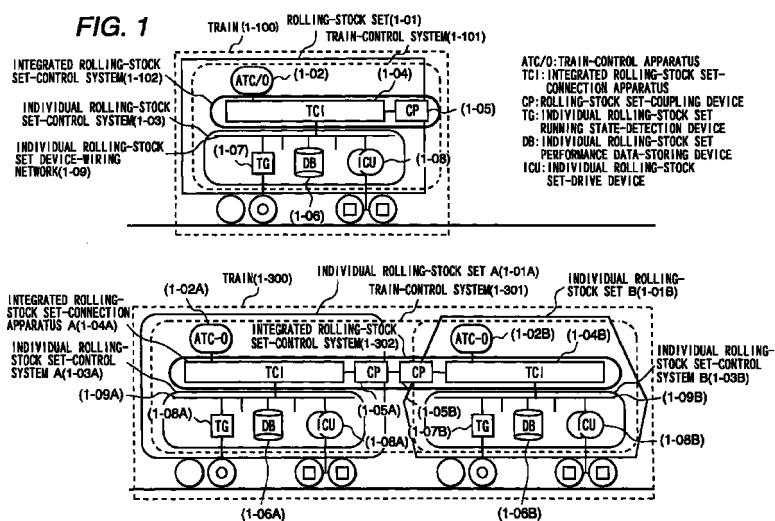
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(54) Train control system

(57) A train-control system includes a train-control apparatus for generating a control-command that controls the running of a train as a whole; an individual rolling-stock set-control system, which is situated in each of rolling-stock sets composing the train, for controlling the running of each set in the train; and an integrated rolling-stock set-control system, which is situated between the train-control apparatus and the individual rolling-stock set-control system, for mediating the com-

munication between the train-control apparatus and the individual rolling-stock set-control system. Further, an integrated rolling-stock set-connection device, which is set up in the integrated rolling-stock set-control system, performs the conversion between the contents of information used in the train-control apparatus and those used in the respective individual rolling-stock set-control systems.



Description**BACKGROUND OF THE INVENTION**

5 **[0001]** The present invention relates to a train-control system, and especially to an automatic train-control system or an automatic train-operation system.

[0002] Railway transportation is a transportation form in which a plurality of trains run on a railway where the degree of freedom in motion is restricted. However, to respond to needs for reinforcement of transportation capacity, or for manifold traffic-flow modes, a more complicated running system, which makes it possible to frequently change and set running plans of respective plural trains, corresponding to manifold stop-patterns, has recently been required. In order to achieve such a complicated running system, what is called a coupling/dividing method has been examined for its practicality. In the coupling/dividing method, the limited transportation capacity of the railway can be improved by coupling a plurality of trains, and operate those coupled trains as if these were one train, operating in a divided interval in a railway, where the plurality of trains to which various originating and terminating stations are allocated, are planned to be run. Further, in other railway intervals, the virtual single train is separated into respective individual trains, according to their terminating stations.

[0003] Also, in railway transportation, an automatic control system (a train-control system) has been introduced to operate trains safely and efficiently. An automatic train-control system (ATC) which restricts the speed of a succeeding train corresponding to the current position of; or the open/closed state of a way ahead of a preceding train, is used. Further, an automatic train-operation system (ATO) which performs a series of operations of a train, from starting from the originating station to arriving at the terminating station, is also used.

[0004] First, the coupling/dividing method used for conventional train-control systems is explained below. In the conventional train-control systems, a mounted control unit for outputting control-commands to control the running of a train, is provided in each rolling-stock set, which is a unit set, with which the coupling/dividing method is implemented. A drive unit, which outputs drive force for a rolling-stock set, is mounted in each rolling-stock set, and operates according to a control command sent from the mounted control unit.

[0005] During the dividing operation mode in the above train-control system, each rolling-stock set is independently operated as one train. Accordingly, the mounted control unit of each train operates separately, in each rolling-stock set, and controls the running of each train consisting of a single rolling-stock set.

30 **[0006]** On the other hand, during the coupling operation mode, a group of coupled plural rolling-stock sets is operated as if they were a single train. That is, the running of a train composed of a plurality of rolling-stock sets is controlled in a lot. In this control, although there is a plurality of mounted control units located in the respective rolling-stock sets in the train, only one of the mounted control units is used, and the other ones are not used.

[0007] Usually, in the conventional coupling operations, one of the mounted control units in the train composed of a plurality of coupled rolling-stock sets, controls not only its own rolling-stock set, but also the other ones as mentioned above. Such a control method is generally called an integrated control.

40 **[0008]** Further, in the conventional integrated control method, it is assumed that if a train is composed of a plurality of rolling-stock sets, the type of all the plurality of rolling-stock sets is the same, or a specific combination of types of sets, is used for the train. Furthermore, as per the content (indicated by the number of notches) of a control command, sent from the mounted control unit for controlling the running of the train as a whole (referred to as the whole train), the same notch number is allocated to all the rolling-stock sets.

[0009] Moreover, in the above conventional control methods, the same driving performance is allocated to each rolling-stock set of a specific combination of types of sets in the coupling operation mode, in addition to a proper driving performance of each set in the dividing operation mode, and the operation mode is switched between the coupling and dividing operation modes. This control method is called a co-operation control.

[0010] Conventional techniques of the above integrated or co-operation control are disclosed, for example; in a paper titled "Development of Integrated Control Operation Systems for EC/DC", the proceedings of the 34th national symposium on application of cybernetics to the railway transportation, pp 512, the Council of Cybernetics-Application in the Japanese Railway Transportation; or in Japanese Patent Application Laid-Open Hei 7-115711.

50 **[0011]** However, there are the following problems in the above conventional integrated-control for a train-control system.

[0012] First, since the above integrated-control is restricted to a train composed of the same-type rolling-stock sets, or a train consisting of a predetermined combination of types of rolling-stock sets, implementing the coupling/dividing operation modes is limited by the types of rolling-stock sets used in the railway transportation system.

55 **[0013]** Further, in the case where a train is composed of different-type rolling-stock sets, that is, rolling-stocks with different performances, the above integrated control does not take the performance of the whole train into consideration. This is a problem in realizing a single-step-braking train-protection control, typical of the next-generation TACs, capable of corresponding to a train composed of manifold-type rolling-stock sets. Also, consideration of the perform-

ance of the whole train composed of manifold-type rolling-stock sets, is indispensable in realizing an ATC system which should momentarily perform a running-control of the train, in all intervals among the stations for the train.

[0014] Furthermore, in the conventional techniques, a control command, indicated with the same number of notches, sent from the mounted control unit for controlling a train, to all rolling-stock sets in a train. However, the acceleration/deceleration generated in response to the same notch number in powering/braking, is different in respective rolling-stock sets with different running-performances, composing the train as a whole. Accordingly, the above conventional integrated-control generates unnatural force between the rolling-stock sets, which in turn may cause strength degradation, due to fatigue, and defacement of a rolling-stock set-coupling unit for coupling the rolling-stock sets of the train.

[0015] Thus, to control the whole train appropriately, it is newly required that the running-performance of the train as a whole be considered, and the train is controlled as such, recognizing the manifold composition-state of the train, that is, whether the running is performed in the coupling or dividing operation mode, and/or recognizing what types and number of rolling-stock sets compose the train in the coupling operation mode.

[0016] Moreover, it is also newly required that a control command for each rolling-stock set is sent, corresponding to the manifold composition-state of the train, to optimize the driving state of the respective rolling-stock sets in the train.

SUMMARY OF THE INVENTION

[0017] An objective of the present invention is to provide a train-control system which can optimize the operation of a train by recognizing the running-performance of the whole train, and the driving states of respective rolling-stock sets composing the train, and realizing a running-control to adaptively control the train, for all the assumed combinations of the types and number of the rolling-stock sets, in the train-operation in which the coupling or dividing operation mode is executed.

[0018] To solve the above problems, the present invention provides the following functions in a train-control system. One of the main functions is to generate information on the running-performance of the whole train by using running-performances of respective rolling-stock sets which compose the train.

[0019] Another main function is to generate control-commands for controlling the running of each rolling-stock set by using a control command for controlling the running of a train as a whole.

[0020] To realize the above functions, a train-control system according to the present invention has the following composition.

[0021] A first train-control system comprises:

a train-control apparatus for generating a control-command for controlling a running of the whole train in a lot; and an integrated rolling-stock set-control apparatus for controlling the running of each of rolling-stock sets composing the train, adapted to a train composition state of the train.

[0022] Further, the above integrated rolling-stock set-control apparatus includes:

an individual rolling-stock set-control unit, which is provided in each rolling-stock set, for controlling the running of each individual rolling-stock set; and an integrated rolling-stock set-control unit, which is provided between the train-control apparatus and the individual rolling-stock set-control unit, for mediating communication between the train-control apparatus and the individual rolling-stock set-control unit.

[0023] A second train-control system comprises:

an integrated rolling-stock set-control unit for creating control-commands for controlling respective rolling-sets composing a train, and for sending the control-commands to the respective rolling-stock sets; and an individual rolling-stock set-control unit, which is provided in each rolling-stock set, for controlling the running of each rolling-stock set.

[0024] Further, the above integrated rolling-stock set-control apparatus includes:

a train-control apparatus for creating a control-command for controlling the running of the whole train in a lot; and an integrated rolling-stock set-control unit, which is provided between the train-control apparatus and an individual rolling-stock set-control unit, for mediating the communication between the train-control apparatus and the individual rolling-stock set-control unit.

[0025] A third train-control system comprises:

a train-control apparatus for creating a control-command for controlling the running of a train as a whole (referred to as the whole train);

an individual rolling-stock set-control unit, which is provided in each rolling-stock set, for controlling the running of each individual rolling-stock set; and

an integrated rolling-stock set-control unit, which is provided between the train-control apparatus and the individual rolling-stock set-control unit, for mediating the communication between the train-control apparatus and the individual rolling-stock set-control unit.

[0026] Further, the above integrated rolling-stock set-control unit includes:

an integrated rolling-stock set-connection device for receiving/sending information on the running-control of the whole train, with the train-control apparatus, and information on running-control of each individual rolling-stock set, with the individual rolling-stock set, and

a rolling-stock set-coupling device for mediating communication between rolling-stock sets in the train.

[0027] Also, the above integrated rolling-stock set control unit includes:

an integrated rolling-stock set-connection device for receiving information on performances of the respective individual rolling-stock sets, which represents a running-performance of the respective rolling-stock sets, from the respective rolling-stock set-control units; and sending information on an integrated performance of the whole train, which represent the running-performance of the whole train, to the train-control apparatus.

[0028] Further, the above integrated rolling-stock set-connection device included in the integrated rolling-stock set control unit includes:

means for generating information on the performance of the whole train, which generates the information on the running-performance of the whole train, based on information on running-performances of the respective individual rolling-stock sets, adapted to a train composition state of the train.

[0029] Also, the above integrated rolling-stock set control unit includes:

an integrated rolling-stock set-connection device for receiving a control command to control running of the whole train, from the train-control apparatus; and sending control commands to control running of the respective individual rolling-stock sets, to the respective individual rolling-stock set-control units.

[0030] Further, the above integrated rolling-stock set-connection device provided in the integrated rolling-stock set control unit includes:

means for generating control-commands for controlling the respective individual rolling-stock sets, adapted to a train composition state of the train, based on the control command for the running of the whole train.

[0031] Further, the above means for generating control-commands for the respective rolling-stock sets generates the respective control-commands so as to reduce the combined quantity of interactive force acting between the rolling-stock sets.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032]

Fig. 1 is a diagram showing a schematic composition of a train-control system of an embodiment 1 according to the present invention.

Fig. 2 is a diagram showing an information flow in an integrated rolling-stock set-control system in the embodiment 1 in the case where the rolling-stock sets are operated in the dividing operation mode.

Fig. 3 is a diagram showing an information flow in an integrated rolling-stock set-control system in the embodiment 1 in the case where the rolling-stock sets are operated in the coupling operation mode.

Fig. 4 is a diagram showing the functional composition of an integrated rolling-stock set-connection device in an

embodiment 2 according to the present invention.

Fig. 5 is a flow chart showing processing executed by the integrated rolling-stock set-connection device in an embodiment 2 according to the present invention.

Fig. 6 is a diagram showing an information flow in an integrated rolling-stock set-control system in the embodiment 2 in the case where the rolling-stock sets are operated in the dividing operation mode.

Fig. 7 is a diagram showing an information flow in an integrated rolling-stock set-control system in the embodiment 2 in the case where the rolling-stock sets are operated in the coupling operation mode.

Fig. 8 is a diagram showing the functional composition of a means for generating information on the performance of the whole train in the embodiment 2 according to the present invention.

Fig. 9 is a flow chart of processing executed by the means for generating information on the performance of the whole train in the embodiment 2 according to the present invention.

Fig. 10 is an illustration conceptually showing a compound performance of the whole train in which rolling-stock sets with different running-performances are coupled.

Fig. 11 is a flow chart showing a process of generating a braking performance $\beta_{\text{train}}(V)$ at an assumed speed V , which is executed by a means for generating the compounded braking-performance of the whole train, in the embodiment 2 according to the present invention.

Fig. 12 is a diagram showing input information and output information, which are expressed in Tables, in the process shown in Fig. 11, in the case where the train is composed of rolling-stock sets A and B, with different running-performances.

Fig. 13 is an illustration conceptually showing the compounded braking-performance with respect to speed, obtained by the process shown in Fig. 12 in the case where the train is composed of rolling-stock sets A and B, with different running-performances.

Fig. 14 is a flow chart showing a process of generating a powering performance $\alpha_{\text{train}}(V)$ at an assumed speed V , which is executed by a means for generating the compounded powering-performance of the whole train, in the embodiment 2 according to the present invention.

Fig. 15 is a diagram showing input information and output information, which are expressed in Tables, in the flow chart shown in Fig. 14, in the case where the train is composed of rolling-stock sets A and B, with different running-performances.

Fig. 16 is an illustration conceptually showing the compounded powering-performance with respect to speed, obtained by the flow chart shown in Fig. 14 in the case where the train is composed of rolling-stock sets A and B, with different running-performances.

Fig. 17 is an illustration conceptually showing the compounded powering-performance with respect to speed, obtained by the flow chart shown in Fig. 14, which is executed in an embodiment 3, in the case where the train is composed of rolling-stock, sets A and B, with different running-performances.

Fig. 18 is a diagram showing the functional composition of an integrated rolling-stock set-connection device in an embodiment 4 according to the present invention.

Fig. 19 is a flow chart showing processing executed by the integrated rolling-stock set-connection device in the embodiment 4 according to the present invention.

Fig. 20 is a diagram showing an information flow in an integrated rolling-stock set-control system in the embodiment 4 in the case where the rolling-stock sets are operated in the dividing operation mode.

Fig. 21 is a diagram showing an information flow in an integrated rolling-stock set-control system in the embodiment 4 in the case where the rolling-stock sets are operated in the coupling operation mode.

Fig. 22 is a diagram showing the functional composition of a means for generating control-commands for individual rolling-stock sets in the embodiment 4 according to the present invention.

Fig. 23 is an illustration conceptually showing an example of respective force acting between rolling-stock sets composing the whole train in which rolling-stock sets with different running-performances are coupled.

Fig. 24 is an illustration conceptually showing another example of respective force acting between rolling-stock sets composing the whole train in which rolling-stock sets with different running-performances are coupled.

Fig. 25 is an illustration conceptually showing another example of respective force acting between rolling-stock sets composing the whole train in which rolling-stock sets with different running-performances are coupled.

Fig. 26 is a flow chart showing powering-control executed by a means for converting a train-control command in the embodiment 4 to control-commands for respective individual rolling-stock sets.

Fig. 27 is an example of a Table describing information on the relationship between a train-control command and corresponding control-commands for respective individual rolling-stock sets, which is used in the processing shown in Fig. 26.

Fig. 28 is a flow chart showing a process of generating the information described in the Table which is used in the processing shown in Fig. 26.

Fig. 29A and Fig. 29B are illustrations showing examples of the relationship between a train control command and

control commands for respective individual rolling-stock sets, which are obtained by the processing executed by the means for converting a train control-command to control commands for respective individual rolling-stock sets, in the embodiment 4.

Fig. 30 is a flow chart showing powering-control executed by a means for converting a train-control command in an embodiment 5 to control-commands for respective individual rolling-stock sets.

Fig. 31 is an example of a Table describing information on the relationship between a train-control command and corresponding control-commands for respective individual rolling-stock sets, which is used in the processing shown in Fig. 30.

Fig. 32 is a flow chart showing a process of generating the information described in the Table which is used in the processing shown in Fig. 30.

Fig. 33A and Fig. 33B are illustrations showing examples of the relationship between a train-control command and control commands for respective individual rolling-stock sets, which are obtained by the processing executed by the means for converting a train-control command in the embodiment 5.

Fig. 34 is a diagram showing the functional composition of a means for generating information on a performance of the whole train in an embodiment 6 according to the present invention.

Fig. 35 is a diagram showing the functional composition of a means for generating information on a performance of the whole train in an embodiment 7 according to the present invention.

Fig. 36 is a diagram showing the functional composition of a means for generating information on a performance of the whole train in an embodiment 8 according to the present invention.

Fig. 37 is a diagram showing an example of a schematic composition of a train-control system in an embodiment 9 according to the present invention.

Fig. 38 is a diagram showing another example of a schematic composition of a train-control system in an embodiment 9 according to the present invention.

Fig. 39 is a diagram showing another example of a schematic composition of a train-control system in an embodiment 9 according to the present invention.

Fig. 40 is a diagram showing another example of a schematic composition of a train-control system in an embodiment 9 according to the present invention.

Fig. 41 is a diagram showing an example of a schematic composition of a train-control system in an embodiment 10 according to the present invention.

Fig. 42 is a diagram showing an example of a schematic composition of a train-control system in an embodiment 11 according to the present invention.

Fig. 43 is a diagram showing another example of a schematic composition of a train-control system in the embodiment 11 according to the present invention.

Fig. 44 is a diagram showing an example of a schematic composition of a train-control system in an embodiment 12 according to the present invention.

Fig. 45 is a diagram showing another example of a schematic composition of a train-control system in the embodiment 12 according to the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Embodiment 1:

[0033] Hereafter, details of the embodiments according to the present invention will be explained with reference to the drawings.

[0034] Fig. 1 shows a schematic composition of a train-control system of an embodiment 1 according to the present invention.

[0035] A train in this embodiment includes a single or a plurality of rolling-stock sets. Further, each rolling-stock set includes a single or a plurality of vehicles.

[0036] First, a train (1-100) consists of a single rolling-stock set (1-01).

[0037] A train-control system (1-101) for the train (1-100) is provided in each rolling-stock set, and this control system includes a train-control apparatus (1-02) for creating a control-command which controls the running of the whole train (1-100); an individual rolling-stock set-control system (1-03), which is provided in each individual rolling-stock set, for performing the running-control of each individual rolling-stock set; and an integrated individual rolling-stock set-control system (1-102), which is provided between the train-control apparatus (1-02) and the individual rolling-stock set-control system (1-03), for mediating communication between the train-control apparatus (1-02) and the individual rolling-stock set-control system (1-03).

[0038] The train-control apparatus (1-02) is connected to the integrated individual rolling-stock set-control system (1-102), and this control apparatus performs the sending/receiving of information on the running-control of the whole

train (1-100), together with the integrated individual rolling-stock set-control system (1-102). The connection of the train-control apparatus (1-02) and the integrated individual rolling-stock set-control system (1-102) is carried out by an integrated rolling-stock set-connection device (1-04) included in the integrated individual rolling-stock set-control system (1-102).

5 **[0039]** The integrated individual rolling-stock set-control system (1-102) includes the integrated rolling-stock set-connection device (1-04) and a rolling-stock set-coupling device (1-05). The integrated rolling-stock set-connection device (1-04) is connected to the rolling-stock set-coupling device (1-05), and these devices exchange information with each other.

10 **[0040]** The integrated rolling-stock set-connection device (1-04) is connected to an individual rolling-stock set device-wiring network (1-09) in the individual rolling-stock set-control system (1-03), the train-control apparatus (1-02), and the rolling-stock set-coupling device (1-05).

15 **[0041]** Also, the integrated rolling-stock set-connection device (1-04) performs the sending/receiving of information on running-control of the whole train (1-100) with the train-control apparatus (1-02). As per the information on running-control of the whole train (1-100); a control-command for the train (1-100), to control the running of the train (1-100), is sent from the train-control apparatus (1-02), and information on a running-performance of the whole train (1-100) is sent to the train-control apparatus (1-02).

20 **[0042]** Further, the integrated rolling-stock set-connection device (1-04) performs the sending/receiving of information on running-control of the individual rolling-stock set (1-01) with each device in the individual rolling-stock set-control system (1-03). As per the information on running-control of the individual rolling-stock set (1-01); information on a running-performance of the individual rolling-stock set (1-01) is received from the individual rolling-stock set-control system (1-03), and a control-command for the individual rolling-stock set (1-01), to control the running of the individual rolling-stock set (1-01), is sent to the individual rolling-stock set-control system (1-03).

25 **[0043]** Furthermore, if a train includes a plurality of rolling-stock sets, the integrated rolling-stock set-connection device (1-04) performs the sending/receiving of information on running-control of each individual rolling-stock set with other integrated rolling-stock set-connection devices via the rolling-stock set-coupling device (1-05).

30 **[0044]** Moreover, the integrated rolling-stock set-connection device (1-04) mediates communication between the train-control apparatus (1-02) and the individual rolling-stock set-control system (1-03), and executes an information-converting operation for the information exchanged between the train-control apparatus (1-02) and the individual rolling-stock set-control system (1-03), by reflecting the train composition state of the train (1-100) on the information-conversion.

[0045] The rolling-stock set-coupling device (1-05) is connected to the integrated rolling-stock set-connection device (1-04). Further, if a train includes a plurality of rolling-stock sets, the rolling-stock set-coupling device (1-05) is mechanically connected to a rolling-stock set-coupling device in the neighboring rolling-stock set, and performs communication with the other rolling-stock sets.

35 **[0046]** The individual rolling-stock set-control system (1-03) includes an individual rolling-stock set performance data-registering device (1-06), an individual rolling-stock set running state-detection device (1-07), an individual rolling-stock set-drive device (1-08), and the individual rolling-stock set device-wiring network (1-09). The respective devices in the individual rolling-stock set (1-03) are connected to each other, and exchange information with each other, via the individual rolling-stock set device-wiring network (1-09).

40 **[0047]** The individual rolling-stock set device-wiring network (1-09) is connected to the integrated rolling-stock set-connection device (1-04) in the integrated individual rolling-stock set-control system (1-102), the individual rolling-stock set performance data-registering device (1-06) in the individual rolling-stock set-control system (1-03), the individual rolling-stock set running state-detection device (1-07), and the individual rolling-stock set-drive device (1-08). Further, this device-wiring network (1-09) is used for communication among the above devices.

45 **[0048]** The individual rolling-stock set performance data-registering device (1-06) registers information (individual rolling-set performance information) representing a running-performance of each rolling-stock set (1-01), with the individual rolling-stock set-control system (1-03). The individual rolling-set performance information contains the length, weight, powering performance, braking performance, and the environmental resistance (the running resistance, grade resistance, and curve resistance acting on each rolling-stock set), of each rolling-stock set (1-01). Further, the individual rolling-stock set performance data-registering device (1-06) outputs the individual rolling-set performance information via the individual rolling-stock set device-wiring network (1-09).

50 **[0049]** The individual rolling-stock set running state-detection device (1-07) detects the running speed of the rolling-stock set (1-01) in which this individual rolling-stock set-control system (1-03) is mounted. Further, the individual rolling-stock set running state-detection device (1-07) sends the detected running-speed data (individual rolling-stock set running information) via the individual rolling-stock set device-wiring network (1-09).

55 **[0050]** The individual rolling-stock set-drive device (1-08) controls the running of the individual rolling-stock set (1-01) by accelerating or decelerating the individual rolling-stock set (1-01) with tractive or braking force, respectively. Further, the individual rolling-stock set-drive device (1-08) receives information which represents a control command (an

individual rolling-stock set-control command) for each individual rolling-stock set (1-01) via the individual rolling-stock set device-wiring network (1-09), and outputs the tractive or braking force corresponding to the individual rolling-stock set-control command.

[0051] Next, a train (1-300) is composed of two coupled rolling-stock sets A (1-01A) and B (1-01B).

[0052] A train-control system (1-301) for the train (1-300) includes train-control apparatuses A (1-02) and B (1-02B) for determining a control-command for the train (1-300), to control the running of the whole train (1-300); individual rolling-stock set-control systems A (1-03A) and B (1-03B); and an integrated rolling-stock set-control system (1-302) for mediating, provided between the train-control apparatuses A (1-02A) and B (1-02B), and the individual rolling-stock set-control systems A (1-03A) and B (1-03B), for mediating communication between the train-control apparatuses A (1-02A) and B (1-02B), and the individual rolling-stock set-control systems A (1-03A) and B (1-03B).

[0053] Here, the train-control apparatus A (1-02A) is connected to an integrated rolling-stock set-connection device A (1-04A) provided in an integrated rolling-stock set-control system (1-302), and performs the sending/receiving of information on running-control of the whole train (1-300) with the integrated rolling-stock set-connection device A (1-04A). Also, the train-control apparatus B (1-02B) is connected to an integrated rolling-stock set-connection device B (1-04B) provided in an integrated rolling-stock set-control system (1-302), and performs the sending/receiving of information on the running-control of the whole train (1-300), together with the integrated rolling-stock set-connection device B (1-04B).

[0054] Further, the individual rolling-stock set-control system A (1-03A) includes an individual rolling-stock set performance data-registering device A (1-06A), an individual rolling-stock set running state-detection device A (1-07A), an individual rolling-stock set-drive device A (1-08A), and an individual rolling-stock set device-wiring network A (1-09A). The respective devices in the individual rolling-stock set-control system A (1-03A) are connected to each other via the individual rolling-stock set device-wiring network A (1-09A), and exchange information with each other via the individual rolling-stock set device-wiring network A (1-09A).

[0055] Also, the individual rolling-stock set-control system B (1-03B) includes an individual rolling-stock set performance data-registering device B (1-06B), an individual rolling-stock set running state-detection device B (1-07B), an individual rolling-stock set-drive device B (1-08B), and an individual rolling-stock set device-wiring network B (1-09B). The respective devices in the individual rolling-stock set-control system B (1-03B) are connected to each other via the individual rolling-stock set device-wiring network B (1-09B), and exchange information with each other via the individual rolling-stock set device-wiring network B (1-09B). Meanwhile, the functions of the respective devices in each individual rolling-stock set-control system are the same as those of respective devices in the individual rolling-stock set-control system in the train (1-100) (consisting of a single rolling-stock set).

[0056] The integrated rolling-stock set-control system (1-302) includes the integrated rolling-stock set-connection device A (1-04A) in the rolling-stock sets A (1-01A), a rolling-stock set-coupling device A (1-05A), the integrated rolling-stock set-connection device B (1-04B) in the rolling-stock sets B (1-01B), and a rolling-stock set-coupling device B (1-05B). Further, by mechanically connecting both the rolling-stock set-coupling devices A (1-05A) and B (1-05B), the individual rolling-stock sets A (1-01A) and B (1-01B) are coupled, and communication between the individual rolling-stock sets is carried out via the devices A (1-05A) and B (1-05B). Thus, the integrated rolling-stock set-connection device A (1-04A) exchanges information with the integrated rolling-stock set-connection device B (1-04B) via the rolling-stock set-coupling devices A (1-05A) and B (1-05B).

[0057] Each integrated rolling-stock set-connection device is explained below. The integrated rolling-stock set-connection device A (1-04A) performs the sending/receiving of information on the running-control of the whole train (1-300), and of each individual rolling-stock set, with the train-control apparatus A (1-02A), and with each device in the individual rolling-stock set-control system A (1-03A) via the individual rolling-stock set device-wiring network A (1-09A), respectively. Further, the integrated rolling-stock set-connection device A (1-04A) also performs the sending/receiving of information on the running-control of each of the individual rolling-stock sets A (1-01A) and B (1-01B) with the integrated rolling-stock set-connection device B (1-04B) in the individual rolling-stock set B (1-01B) via the rolling-stock set-coupling device B (1-05B). Furthermore, the integrated rolling-stock set-connection device A (1-04A) mediates the communication between the train-control apparatus A (1-02A) and the integrated rolling-stock set-control system A (1-03A), and performs a predetermined conversion process of the information communicated between the train-control apparatus A (1-02A) and the integrated rolling-stock set-control system A (1-03A), corresponding to the train composition state of the train (1-300).

[0058] In the same manner as operations of the integrated rolling-stock set-connection device A (1-04A), the integrated rolling-stock set-connection device B (1-04B) performs the sending/receiving of information on the running-control of the whole train (1-300), and of each individual rolling-stock set, with the train-control apparatus B (1-02B), and with each device in the individual rolling-stock set-control system B (1-03B) via the individual rolling-stock set device-wiring network B (1-09B), respectively. Further, the integrated rolling-stock set-connection device B (1-04B) also performs the sending/receiving of information on the running-control of each of the individual rolling-stock sets A (1-01A) and B (1-01B) with the integrated rolling-stock set-connection device A (1-04A) in the individual rolling-stock set A (1-

01A) via the rolling-stock set-coupling device B (1-05B). Furthermore, the integrated rolling-stock set-connection device B (1-04B) mediates the communication between the train-control apparatus B (1-02B) and the integrated rolling-stock set-control system A (1-03B), and performs a predetermined conversion process of the information communicated between the train-control apparatus B (1-02B) and the integrated rolling-stock set-control system B (1-03B), corresponding to the train composition state of the train (1-300).

[0059] Fig. 2 shows an information flow in an integrated rolling-stock set-control system in this embodiment in the case when the rolling-stock sets are operated in the dividing operation mode.

[0060] The rolling-stock set A (2-01A) and the rolling-stock set B (2-01B) are independently operated as respective train 1 (2-100) and train 2 (2-200) in the dividing operation mode. In this operation, an integrated rolling-stock set-control system 1 (2-101) and an integrated rolling-stock set-control system 2 (2-201) in the respective trains 1 and 2 function separately. That is, an integrated rolling-stock set-connection device A (2-04A) and an integrated rolling-stock set-connection device B (2-04B) in the respective trains 1 and 2 do not perform communication with each other, and perform their information-processing separately in the respective trains 1 and 2. Therefore, in the following, only the respective train 1 (2-100) or the rolling-stock set A (2-01A) will be explained.

[0061] First, the integrated rolling-stock set-control system 1 (2-101) performs the sending/receiving of information (2-21A) on the running-control of the whole train 1 (2-100) with the train-control apparatus A (2-02A) by using the integrated rolling-stock set-control device A (2-04A). As per the information (2-21A) on the running-control of the whole train 1 (2-100); a control-command 1 for the train 1 (2-100), to control the running of the train 1 (2-100), is sent from the train-control apparatus A (2-02A), and the whole train running-performance information 1, which represents a running-performance of the whole train 1 (2-100), is sent to the train-control apparatus A (2-02A).

[0062] Further, the integrated rolling-stock set-control system 1 (2-101) performs the sending/receiving of information (2-22A) on the running-control of the individual rolling-stock set A (2-01A) with the individual rolling-stock set-control system A (2-03A) by using the integrated rolling-stock set-control device A (2-04A). As per the information (2-22A) on the running-control of the individual rolling-stock set A (2-01A); individual rolling-stock set performance information A, which represents a performance of the individual rolling-stock set A (2-01A), and individual rolling-stock set running-state information A, which represents the running speed of the individual rolling-stock set A (2-01A), are sent from an individual rolling-stock set performance information-registering device in the individual rolling-stock set A (2-01A) and an individual rolling-stock set running state-detection device A (2-07). Moreover, an individual rolling-stock set-control command A for the individual rolling-stock set A (2-01A) is output to an individual rolling-stock set-drive device A (2-08A).

[0063] Here, since the train 1 (2-100) includes only one individual rolling-stock set, the integrated rolling-stock set-connection device A (2-04A) in the integrated rolling-stock set-control system 1 (2-101) does not perform the sending/receiving of information with other individual rolling-stock sets via the rolling-stock set-coupling device A (2-05A).

[0064] In Fig. 2, the integrated individual rolling-stock set-connection device A (2-04A) in the integrated rolling-stock set-control system 1 (2-101) mediates the communication between the train-control apparatus A (2-02A) and the individual rolling-stock set-control system A (2-03A), and performs a predetermined information-converting process, corresponding to the train composition state of the train 1 (2-100). In this information-converting process, the information (2-21A) (a train-control command 1) on the running-control of the whole train 1 (2-100), which is output from the train-control apparatus A (2-02A), is converted to the information (2-22A) (an individual rolling-stock set-control command A) on the running-control of the individual rolling-stock set A (2-01A), and is further input to the individual rolling-stock set-control system A (2-03A). As per the information flow reverse to the above flow; the information (2-22A) (the individual rolling-stock set-control command A) on the running-control of the individual rolling-stock set A (2-01A) output from the individual rolling-stock set-control system A (2-03A) is converted to the information (2-21A) (a train-control command 1) on the running-control of the whole train 1 (2-100), and is input to the train-control apparatus A (2-02A).

[0065] Fig. 3 shows an information flow in an integrated rolling-stock set-control system in this embodiment in the case where the rolling-stock sets are operated in the coupling operation mode.

[0066] Meanwhile, in the case where a train consists of a plurality of rolling-stock sets as well as this embodiment, the role of outputting a control-command for the whole train is allocated to only one of the train-control apparatuses provided in the respective rolling-stock sets of the train. Here, the rolling-stock set to which the role of controlling the whole train is allocated is defined as a master rolling-stock set, and the other sets are defined as slave sets. Therefore, there is only one master rolling-stock set in one train. Frequently, the head rolling-stock set of a train is determined as the master set. However, in the train-control system, the method of determining the master rolling-stock set is not restricted to the above master set-determination method.

[0067] A rolling-stock set A (3-01A) and a rolling-stock set B (3-01B) are operated in a lot as one train 3 (3-300) in the coupling operation mode. In this operation, one integrated rolling-stock set-control system 3 (3-301) is composed so as to control the rolling-stock set A (3-01A) and a rolling-stock set B (3-01B) in a lump, and necessary information is communicated between an integrated rolling-stock set-connection device A (3-04A) and an integrated rolling-stock set-connection device B (3-04B).

[0068] In the train 3 (3-300) in this embodiment, the role of sending the control-command for the whole train 3 (3-300) is allocated to a train-control apparatus A (3-02A) provided in the rolling-stock set A (3-01A). Accordingly, the rolling-stock set A (3-01A) including the train-control apparatus A (3-02A) is the master set, and the rolling-stock set B (3-01B) other than the set A (3-01A) is a slave set.

[0069] First, the control performed in the rolling-stock set A (3-01A) is explained below. The integrated rolling-stock set-control system (3-301) performs the sending/receiving of information (3-21A) on the running-control of the whole train 3 (3-300) with the train-control apparatus A (3-02A) by using the individual rolling-stock set-connection device A (3-04A). The contents of the information (3-21A) on the running-control of the whole train 3 (3-300) are similar to those of the information on the running-control of the above-described train 1 (2-100).

[0070] Further, the integrated rolling-stock set-control system (3-301) performs the sending/receiving of information (3-22A) on the running-control of the individual rolling-stock set A (3-01A) with an individual rolling-stock set-control system A (3-03A) by using the individual rolling-stock set-connection device A (3-04A). Also, The contents of the information (3-22A) on the running-control of the individual rolling-stock set A (3-01A) are similar to those of the information on the running-control of the above-described train 1 (2-100).

[0071] Here, in the integrated rolling-stock set-control system (3-301), the individual rolling-stock set-connection device A (3-04A) performs the sending/receiving of information (3-22B) on the running-control of the individual rolling-stock set B (3-01B) with an individual rolling-stock set-connection device B (3-04B) in the individual rolling-stock set B (3-01B) via a rolling-stock set-coupling device A (3-05B). As per the information (3-22B) on the running-control of the individual rolling-stock set B (3-01B); individual rolling-stock set performance information B representing the running-performance of the rolling-stock set B (3-01B), which is one of attributions of the rolling-stock set B (3-01B), is input to the individual rolling-stock set-connection device A (3-04A), and individual rolling-stock set-control command B representing a running-control command for the rolling-stock set B (3-01B) is output from the individual rolling-stock set-connection device A (3-04A).

[0072] Further, the individual rolling-stock set-connection device A (3-04A) outputs the information (3-22A) on the running-control of the individual rolling-stock set A (3-01A) to the individual rolling-stock set-connection device B (3-04B) in the individual rolling-stock set B (3-01B) via the rolling-stock set-coupling device A (3-05A). The information (3-22A) on the running-control of the individual rolling-stock set A (3-01A) includes individual rolling-stock set performance information A representing the running-performance of the rolling-stock set A (3-01A), which is one of attributions of the rolling-stock set A (3-01A).

[0073] Next, the control performed in the rolling-stock set B (3-01B) is explained below. The integrated rolling-stock set-control system (3-301) performs the sending/receiving of information (3-21B) on the running-control of the whole train 3 (3-300) with the train-control apparatus B (3-02B) by using the individual rolling-stock set-connection device B (3-04B). The contents of the information (3-21B) on the running-control of the whole train 3 (3-300) is similar to those of the information on the running-control of the above-described train 1 (2-100).

[0074] Further, the integrated rolling-stock set-control system (3-301) performs the sending/receiving of information (3-22B) on the running-control of the individual rolling-stock set B (3-01B) with an individual rolling-stock set-control system B (3-03B) by using the individual rolling-stock set-connection device B (3-04B). Also, The contents of the information (3-22B) on the running-control of the individual rolling-stock set B (3-01B) is similar to those of the information on the running-control of the above-described train 1 (2-100).

[0075] Here, in the integrated rolling-stock set-control system (3-301), the individual rolling-stock set-connection device B (3-04B) receives the information (3-22A) on the running-control of the individual rolling-stock set A (3-01A) from an individual rolling-stock set-connection device A (3-04A) in the individual rolling-stock set A (3-01A) via a rolling-stock set-coupling device B (3-05B). The information (3-22A) on the running-control of the individual rolling-stock set A (3-01A) includes individual rolling-stock set performance information A representing the running-performance of the rolling-stock set A (3-01A), which is one of attributions of the rolling-stock set A (3-01A). Further, the individual rolling-stock set-connection device B (3-04B) performs the sending/receiving of information (3-22B) on the running-control of the individual rolling-stock set B (3-01B) with an individual rolling-stock set-connection device A (3-04A) in the individual rolling-stock set A (3-01A) via a rolling-stock set-coupling device A (3-05B). As per the information (3-22B) on the running-control of the individual rolling-stock set B (3-01B); individual rolling-stock set-control command B representing a running-control command for the rolling-stock set B (3-01B) is input to the individual rolling-stock set-connection device B (3-04B), and individual rolling-stock set performance information B representing the running-performance of the rolling-stock set B (3-01B), which is one of attributions of the rolling-stock set B (3-01B), and is output from the individual rolling-stock set-connection device B (3-04B).

[0076] In Fig. 3, the integrated individual rolling-stock set-connection device A (3-04A) in the integrated rolling-stock set-control system 3 (3-301) mediates the communication between the train-control apparatus A (3-02A) and the individual rolling-stock set-control system A (3-03A), and between the train-control apparatus A (3-02A) and the individual rolling-stock set-control system A (3-03B), and performs a predetermined information-converting process, corresponding to the composition state of the train 3 (3-300). In this information-converting process, the information (3-21A) (a

train-control command 3) on the running-control of the whole train 1 (3-300), which is output from the train-control apparatus A (3-02A), is converted to the information (3-22A) (an individual rolling-stock set-control command A) on the running-control of the individual rolling-stock set A (3-01A) and the information (3-22B) (an individual rolling-stock set-control command B) on the running-control of the individual rolling-stock set B (3-01B), and is further input to the individual rolling-stock set-control system A (2-03A) and the individual rolling-stock set-control system B (2-03B). As the information flow reverse to the above flow, the information (3-22A) (the individual rolling-stock set-control command A) on the running-control of the individual rolling-stock set A (3-01A) output from the individual rolling-stock set-control system A (3-03A) and the information (3-22B) (the individual rolling-stock set-control command B) on the running-control of the individual rolling-stock set B (3-01B) output from the individual rolling-stock set-control system A (3-03A) are converted to the information (3-21A) (a train-control command 3) on the running-control of the whole train 3 (3-300), and is input to the train-control apparatus A (3-02A).

[0077] Also, the integrated individual rolling-stock set-connection device B (3-04B) in the integrated rolling-stock set-control system 3 (3-301) mediates the communication between the train-control apparatus B (3-02B) and the individual rolling-stock set-control system A (3-03A), and between the train-control apparatus B (3-02B) and the individual rolling-stock set-control system B (3-03B), and performs a predetermined information-converting process, corresponding to the composition state of the train 3 (3-300). In this information-converting process, since the individual rolling-stock set B (3-01B) is a slave set, the outputting the information (3-22B) (a train-control command 3) on the running-control of the whole train 1 (3-300), which is output from the train-control apparatus B (3-02B), is stopped by the integrated individual rolling-stock set-connection device B (3-04B). Thus, the train-control apparatus B (3-02B) does not actually act on any individual rolling-stock set in the train 3 (3-300). However, the information (3-22A) (the individual rolling-stock set-control command A) on the running-control of the individual rolling-stock set A (3-01A) output from the individual rolling-stock set-control system A (3-03A) and the information (3-22B) (the individual rolling-stock set-control command B) on the running-control of the individual rolling-stock set B (3-01B) output from the individual rolling-stock set-control system A (3-03A) are converted to the information (3-21B) (a train-control command 3) on the running-control of the whole train 3 (3-300), and is input to the train-control apparatus B (3-02B).

[0078] The above-described train-control system with the integrated rolling-stock set-control systems of this embodiment possesses the following features.

[0079] The kinds of information which the integrated rolling-stock set-control system exchanges with the apparatus or devices are fixed, independent of whether each train including only one rolling-stock set is operated, in the dividing operation mode, or a train with different types of rolling-stock sets is operated, in the coupling operation mode. This is because measures handling effects of a train composition state on a train-control, are centered at only the integrated rolling-stock set-control system.

[0080] Further, the contents of the information which the integrated rolling-stock set-control system exchanges with the apparatus or devices, are ones common to usual rolling-stock sets, so as to exclude information particular to each of the dividing and coupling operation modes. This also means that the effects of a train composition state on a train-control, are handled only by the conversion of information, which is performed by the integrated rolling-stock set-control system.

[0081] As described above, in this embodiment, the train-control system for controlling the running of a train includes; the train-control apparatus for creating a control-command to control the whole train in a lot; each individual rolling-stock set-control system which is provided in each individual rolling-stock set, for controlling the running of each set; and the integrated rolling-stock set-control system which stands between the train-control system and the individual rolling-stock set-control systems, for mediating the communication between the train-control system and each individual rolling-stock set-control system.

[0082] Further, in this embodiment, the integrated rolling-stock set-control system includes each rolling-stock set-coupling device for mechanically coupling two neighboring rolling-stock sets, and performing the sending/receiving of information between the two neighboring rolling-stock sets, and each integrated rolling-stock set-connection device for exchanging the information on the running-control of each set with each individual rolling-stock set directly or via the rolling-stock set-coupling devices.

[0083] Furthermore, in this embodiment, each integrated rolling-stock set-connection device performs the converting of the information between the information received from and sent to the train-control apparatus, and the information received from and sent to each individual rolling-stock set. In this information-converting operation, the information received from and sent to the train-control apparatus and the information received from and sent to each individual rolling-stock set are converted to each other taking the train composition state into account. That is, when the information received from the train-control apparatus is converted to be sent to each individual rolling-stock set, the received information on the whole train, obtained by viewing all the sets of the train in a lump, is converted to be adapted to each rolling-stock set while the train composition state is considered. Also, when the information received from the individual rolling-stock sets is converted and sent to the train-control apparatus, the information received from the individual rolling-stock sets is integrated into the information on the whole train, obtained by viewing all the sets of the train in a lump

while the train composition state is considered.

[0084] As described above, the train-control system of this embodiment has the following effects on the running-control of a train.

[0085] In this embodiment, the train-control system is divided into the train-control apparatus, the individual rolling-stock set-control systems, and the integrated rolling-stock set-control system. According to this division of the train-control system, it is possible to unify the integrated information on the whole train, which the train-control apparatus processes, even if the composition of a train is from that consisting of a single rolling-stock set to that consisting of different rolling-stock sets. Therefore, since the train-control apparatus need not directly correspond to the change in the train composition state, it is not necessary for the train-control apparatus to implement processes particular to each train composition state. That is, the train-control apparatus has only to perform running-control for trains in general. This considerably reduces the processing load of the train-control apparatus which must handle controls corresponding to the respective dividing and coupling operation modes. Moreover, it is possible to use a general device for the train-control apparatus independent of the dividing or coupling operation mode, which in turn makes it easier to realize the switching operation mode between the dividing and coupling operation modes.

[0086] Further, according to the above train-control system, the information which each individual rolling-stock set-control system directly processes can always be restricted to that related only to each rolling-stock set, even if the train composition state changes. Therefore, each individual rolling-stock set-control system need not directly correspond with the change in the train composition state, and this in turn makes it unnecessary to implement processing particular to each train composition state. That is, each individual rolling-stock set-control system has only to perform the running-control common to the individual rolling-stock sets. This considerably reduces the processing load of each individual rolling-stock set-control system which must handle controls corresponding to the respective dividing and coupling operation modes. Moreover, it is possible to use a general device for each individual rolling-stock set control system, independent of the dividing or coupling operation mode, which in turn makes it easier to realize the switching operation mode between the dividing and coupling operation modes.

[0087] Furthermore, by composing the above-described train-control system, an information-converting operation between that sent from the train-control apparatus to each individual rolling-stock set-control system and that sent from the respective individual rolling-stock set-control systems to the train-control apparatus, can be carried out, while this converting operation is adapted to the train composition state. Also, each integrated rolling-stock set-control system converts information sent from the respective individual rolling-stock set-control systems to the information on the whole train, obtained by viewing all the sets of the train in a lump. For this information-converting operation, the optimal contents of the information obtained by viewing all the sets of the train in a lump, are defined in advance by taking the attributions (the running-performances) of the respective individual rolling-stock sets into account. By the above definition of the information on the whole train, it is possible to generate information adequate to cope with all the sets in the whole train in a lump, and send the generated information to the train-control apparatus. Also, each integrated rolling-stock set-control system converts the information on the whole train, sent from the train-control apparatus, and obtained by viewing all the sets of the train in a lump, to information for the respective individual rolling-stock set-control systems. For this information-converting operation, the optimal contents of the information for the respective individual rolling-stock set-control systems are defined in advance by taking the attributions (the running-performances) of the respective individual rolling-stock sets into account. By the above definition of the information on the whole train, it is possible to generate information adequate for the respective individual rolling-stock sets, and send the generated information to each of the individual rolling-stock sets. Thus, it becomes possible to optimize the running-control of a train, pursuant to the train composition state, by taking the performance of the whole train and that of each rolling-stock set in the train into account.

Embodiment 2:

[0088] In the above embodiment 1, in the train-control system for controlling the running of a train; the train-control apparatus for determining a control-command to control the whole train in a lot; each individual rolling-stock set-control system, which is provided in each individual rolling-stock set, for controlling the running of each set; and; the integrated rolling-stock set-control system which stands between the train-control system and the individual rolling-stock set-control systems, for mediating the communication between the train-control system and each individual rolling-stock set-control system; are provided. According to the above composition of the train-control system, even if the train composition state change pursuant to the dividing or coupling operation mode, since only the integrated rolling-stock set-control system copes with effects of the change on the running-control of the train, the train-control apparatus and each individual rolling-stock set need not consider the change in the train composition state. Further, it has been described above that it becomes possible to optimize the running-control of a train, corresponding to the train composition state, by taking the performance of the whole train and that of each rolling-stock set in the train into account, because the integrated rolling-stock set-control system adequately operates the communication between the train-control apparatus

and the respective individual rolling-stock set-control systems.

[0089] In this embodiment, the operations for the communication between the train-control apparatus and the respective individual rolling-stock set-control systems, performed by the integrated rolling-stock set-control system, are concretely set. Further, an communication means which takes the change in the running-performance of the whole train, corresponding with the change in the train composition state, into account, is incorporated into the integrated rolling-stock set-control system. That is, the integrated rolling-stock set-control system receives individual rolling-stock set performance information representing running-performances of the respective individual rolling-stock sets from the respective individual rolling-stock set-control systems, and outputs whole-train running-performance data representing a running-performance of the whole train, corresponding with the train composition state, to the train-control apparatus.

[0090] The integrated rolling-stock set-control system in this embodiment includes the integrated rolling-stock set-connection device and the rolling-stock set-coupling device. The rolling-stock set-coupling device mechanically couples two neighboring rolling-stock sets, and performs exchange between the two neighboring rolling-stock sets. The integrated rolling-stock set-connection device performs; the sending/receiving of information on the running-control of the whole train, with the train-control apparatus to which this integrated rolling-stock set-control system is connected, and; the sending/receiving of information on the running-control of each individual rolling-stock set with each individual rolling-stock set-control system directly or via the rolling-stock set-coupling device.

[0091] Also, The integrated rolling-stock set-connection device manages the information representing the running-performance of the whole train, (the whole-train running-performance), and outputs the whole-train running-performance data to the train-control apparatus to which this integrated rolling-stock set-control system is connected.

[0092] Fig. 4 shows the functional composition of the integrated rolling-stock set-connection device in this embodiment.

[0093] The integrated rolling-stock set-connection device (4-01) shown in Fig. 4 includes the following processing means.

[0094] First, a means (4-11) for inputting/outputting information on individual rolling-stock sets is provided. This means performs the sending/receiving of individual rolling-stock set performance information, which represents a running-performance of each individual rolling-stock set, (the running-performance information (4-21A) on own set, and running-performance information (4-21B) on the other set), with an individual rolling-stock set performance data registering device (4-03) in an individual rolling-stock set-control system (4-02) and a rolling-stock set-coupling device (4-04), respectively. Further, information (4-22) on performances of all individual rolling-stock sets is generated by accumulating the individual rolling-stock set performance information for all the individual rolling-stock sets in the train, and is output to a means (4-12) for registering information on performances of all individual rolling-stock sets.

[0095] Next, the means (4-12) for registering information on performances of all individual rolling-stock sets is included. This means receives the information (4-22) on performances of all individual rolling-stock sets from the means (4-11) for inputting/outputting information on individual rolling-stock sets, and registers the information (4-22) on performances of all individual rolling-stock sets, which is used for information-processing executed by the integrated rolling-stock set-connection device (4-01). Further, the means (4-12) sends the information (4-22) to a means (4-13) for generating information on performance of the whole train.

[0096] The integrated rolling-stock set-connection device (4-01) also includes the means (4-13) for generating information on the performance of the whole train. This means receives the information (4-22) on performances of all individual rolling-stock sets from the means (4-11) for inputting/outputting information on individual rolling-stock sets, and generates information (4-23) on the performance of the whole train, and sends the information (4-23) on the performance of the train as a whole to a means (4-14) for registering information on a performance of the whole train.

[0097] Further, the integrated rolling-stock set-connection device (4-01) includes the means (4-14) for registering information on the performance of the whole train. This means receives the information (4-23) on the performance of the whole train from the means (4-13) for generating information on the performance of the whole train, and registers the information (4-23) on a performance of the whole train, which is used for information-process executed by the train-control apparatus (4-05). Also, this means sends the information (4-23) on the performance of the whole train to the train-control apparatus (4-05).

[0098] Fig. 5 shows a flow chart of processing executed by the integrated rolling-stock set-connection device (4-01) in this embodiment.

[0099] In step (5-01), the information on the running-performance of each individual rolling-stock set is received from each individual rolling-stock set in the train. The process in step (5-01) is executed by the means (4-11) for inputting/outputting information on individual rolling-stock sets.

[0100] In step (5-02), it is determined whether or not there is any rolling-stock set (other set) other than the set (its own set), in which this integrated rolling-stock set-connection device is mounted, in the train. This integrated rolling-stock set-connection device performs the determination in step (5-02), by detecting the presence of an integrated rolling-stock set-connection device in another set, with communication via the rolling-stock set-coupling devices. If it is determined that there is another rolling-stock set, the process goes to step (5-03), otherwise it goes to step (5-04). The

process in step (5-02) is executed by the means for inputting/outputting information on individual rolling-stock sets.

[0101] In step (5-03), the information on the running-performance of its own set is sent to an integrated rolling-stock set-connection device of the other set. Also, the process in step (5-03) is executed by the means for inputting/outputting information on individual rolling-stock sets.

[0102] In step (5-04), the information on the running-performance of the whole train is generated based on the information on the running-performances of the individual rolling-stock sets, received from the respective individual rolling-stock sets. The process in step (5-04) is executed by the means for generating information on the running-performance of the whole train.

[0103] In step (5-05), the generated information on the running-performance of the whole train is sent to the train-control apparatus. The process in step (5-05) is executed by the means for registering information on a running-performance of the whole train.

[0104] The integrated rolling-stock set-connection device performs the information-converting operation, corresponding to the train composition state, by executing the information processing shown in Fig. 4 and Fig. 5.

[0105] Fig. 6 shows an information flow in the integrated rolling-stock set-control system in the case where the rolling-stock sets are operated as two trains in the dividing operation mode.

[0106] An individual rolling-stock set A (6-00A) and an individual rolling-stock set B (6-00B) are separately operated as a train 1 (6-100) and a train 2 (6-200), in the dividing operation mode. In these train compositions, an integrated rolling-stock set-control system 1 (6-101) and an integrated rolling-stock set-control system 2 (6-201) are independently provided in the two trains, respectively. That is, the information flow in an integrated rolling-stock set-connection device A (6-01A) and that in an integrated rolling-stock set-connection device B (6-01B) are independent of each other. Therefore, only the train 1 (6-100), or the individual rolling-stock set A (6-00A) is explained below.

[0107] First, in the integrated rolling-stock set-connection device A (6-01A) of the integrated rolling-stock set-control system 1 (6-101), a means (6-11A) for inputting/outputting information on an individual rolling-stock set receives information A (6-21A) on the running-performance of the individual rolling-stock set A (6-00A) from an individual rolling-stock set performance data-registering device A (6-03A) in an individual rolling-stock set-control system A (6-02A). The means (6-11A) for inputting/outputting information on an individual rolling-stock set generates information (6-22A) on all individual rolling-stock sets, based on the received information A (6-21A) on the running-performance of the individual rolling-stock set A (6-00A). In this example, since the train 1(6-100) includes only the individual rolling-stock set A (6-00A), the information A (6-21A) on the running-performance of the individual rolling-stock set A (6-00A) is used as the information (6-22A) on all individual rolling-stock sets.

[0108] Next, a means (6-12A) for registering information on all individual rolling-stock sets registers the information (6-22A) on all individual rolling-stock sets received from the means (6-11A) for inputting/outputting information on an individual rolling-stock set.

[0109] Further, a means (6-13A) for generating information on the performance of the whole train generates information 1 (6-23A) on the running-performance of the whole train1(6-100), based on the information (6-22A) on all individual rolling-stock sets, which is received from the means (6-12A) for registering information on all individual rolling-stock sets. In this example, since the train 1 (6-100) includes only the individual rolling-stock set A (6-00A), the contents of the information (6-22A) on all individual rolling-stock sets, that is: those of the information A (6-21A) on the running-performance of the individual rolling-stock set A (6-00A); are used as the information 1 (6-23A) on the running-performance of the whole train 1 (6-100).

[0110] Furthermore, a means (6-14A) for registering information on a performance of the whole train registers the information 1 (6-23A) on the running-performance of the whole train 1 (6-100), and the information 1 (6-23A) on the running-performance of the whole train 1 (6-100) is sent to a train-control apparatus A (6-05A) from the integrated rolling-stock set-connection device A (6-01A) by the means (6-14A) for registering information on the performance of the whole train.

[0111] Fig. 7 shows an information flow in an integrated rolling-stock set-control system in the case where the rolling-stock sets are operated in the coupling operation mode.

[0112] An individual rolling-stock set A (7-00A) and an individual rolling-stock set B (7-00B) are operated together as a train 3 (7-300), in the coupling operation mode. In this train composition, one integrated rolling-stock set-control system 3 (7-301) is composed so as to execute a supervisory control of an individual rolling-stock set A (7-00A) and an individual rolling-stock set B (7-00B), in the train 3 (7-300). Thus, the information flow in an integrated rolling-stock set-connection device A (7-01A) and that in an integrated rolling-stock set-connection device B (7-01B) interact with each other.

[0113] First, the information flow in the individual rolling-stock set A (7-00A) is explained below. In the integrated rolling-stock set-connection device A (7-01A) of the integrated rolling-stock set-control system 3 (7-301), a means (7-11A) for inputting/outputting information on an individual rolling-stock set receives information A (7-21A) on the running-performance of the individual rolling-stock set A (7-00A) from an individual rolling-stock set performance data-registering device A (7-03A) in an individual rolling-stock set-control system A (7-02A). Further, the means (7-11A) receives

information B (7-21B) on the running-performance of the individual rolling-stock set B (7-00B) from a rolling-stock set-coupling device A (7-04A). Furthermore, the information A (7-21A) on the running-performance of the individual rolling-stock set A (7-00A) is sent to the integrated rolling-stock set-connection device B (7-01B) in the individual rolling-stock set B (7-00B), via the rolling-stock set-coupling device A (7-04A). Moreover, information (7-22A) on the performance of all individual rolling-stock sets is generated by accumulating the information A (7-21A) and B (7-21B) on the running-performance of the individual rolling-stock sets A (7-00A) and B (7-00B).

[0114] Next, a means (7-12A) for registering information on all individual rolling-stock sets registers the information (7-22A) on all individual rolling-stock sets received from the means (7-11A) for inputting/outputting information on an individual rolling-stock set.

[0115] Further, a means (7-13A) for generating information on the performance of the whole train generates information 3 (7-23A) on the running-performance of the whole train 3 (7-300), based on the information (7-22A) on all individual rolling-stock sets, which is received from the means (7-12A) for registering information on all individual rolling-stock sets.

[0116] Furthermore, a means (7-14A) for registering information on the performance of the whole train registers the information 3 (7-23A) on the running-performance of the whole train 3 (7-300), and the information 3 (7-23A) on the running-performance of the whole train 3 (7-300), is sent to a train-control apparatus A (7-05A) from the integrated rolling-stock set-connection device A (7-01A) by the means (7-14A) for registering information on the performance of the whole train.

[0117] On the other hand, the information flow in the control of the individual rolling-stock set B (7-00B) is explained as follows. In the integrated rolling-stock set-connection device B (7-01B) of the integrated rolling-stock set-control system 3 (7-301), a means (7-11B) for inputting/outputting information on an individual rolling-stock set receives information B (7-21B) on the running-performance of the individual rolling-stock set B (7-00B) from an individual rolling-stock set performance data-registering device B (7-03B) in an individual rolling-stock set-control system B (7-02B). Further, the means (7-11B) receives the information A (7-21A) on the running-performance of the individual rolling-stock set A (7-00A) from a rolling-stock set-coupling device B (7-04B). Furthermore, the information B (7-21B) on the running-performance of the individual rolling-stock set B (7-00B) is sent to the integrated rolling-stock set-connection device A (7-01A) in the individual rolling-stock set A (7-00A), via the rolling-stock set-coupling device B (7-04B). Moreover, information (7-22B) on the performance of all individual rolling-stock sets is generated by accumulating the information A (7-21A) and B (7-21B) on the running-performance of the individual rolling-stock sets A (7-00A) and B (7-00B).

[0118] Next, a means (7-12B) for registering information on all individual rolling-stock sets registers the information (7-22B) on all individual rolling-stock sets received from the means (7-11B) for inputting/outputting information on an individual rolling-stock set.

[0119] Further, a means (7-13B) for generating information on the performance of the whole train generates information 3 (7-23B) on the running-performance of the whole train 3 (7-300), based on the information (7-22B) on all individual rolling-stock sets, which is received from the means (7-12B) for registering information on all individual rolling-stock sets.

[0120] Furthermore, a means (7-14B) for registering information on the performance of the whole train registers the information 3 (7-23B) on the running-performance of the whole train 3 (7-300), and the information 3 (7-23B) on the running-performance of the whole train 3 (7-300), is sent to a train-control apparatus B (7-05A) from the integrated rolling-stock set-connection device B (7-01B) by the means (7-14B) for registering information on the performance of the whole train.

[0121] Fig. 8 shows the functional composition of, and the information flow, in the means for generating information on the performance of the whole train in this embodiment.

[0122] First, in this embodiment, a means (8-01) for generating information on the performance of the whole train receives information (8-11) obtained by accumulating running-performances of all individual rolling-stock sets, from the means for registering information on the running-performances of all individual rolling-stock sets. The information (8-11) on the running-performances of all individual rolling-stock sets contains the length, weight, braking performance expressed with the braking force per unit weight, powering performance expressed with the tractive force per unit weight, the environmental resistance (the running resistance, grade resistance, and curve resistance acting on each rolling-stock set), of each individual rolling-stock set in the train.

[0123] Next, the means (8-01) for generating information on the performance of the whole train sends information (8-21) on the running-performance of the whole train to the means for registering the information on the performance of the whole train. The information (8-21) on the running-performance of the whole train contains the length, weight, braking performance expressed with the braking force per unit weight, powering performance expressed with the tractive force per unit weight, the environmental resistance (the running resistance, grade resistance, and curve resistance acting on each rolling-stock set), of the train as a whole.

[0124] Further, the means (8-01) for generating information on the performance of the whole train includes a train length-calculating means (8-02), a train weight-calculating means (8-03), a train braking performance-calculating

means (8-04), a train powering performance-calculating means (8-05), and a train environmental resistance-calculating means (8-06).

[0125] Furthermore, the train length-calculating means (8-02) obtains the train length (8-22) based on the information (8-11) on the running-performances of all individual rolling-stock sets.

[0126] Moreover, the train weight-calculating means (8-03) obtains the train weight (8-23) based on the information (8-11) on the running-performances of all individual rolling-stock sets.

[0127] Also, the train braking performance-calculating means (8-04) obtains the train braking performance (8-24) based on the information (8-11) on the running-performances of all individual rolling-stock sets.

[0128] Further, the train powering performance-calculating means (8-05) obtains the train powering performance (8-25) based on the information (8-11) on the running-performances of all individual rolling-stock sets.

[0129] In addition, the train environmental resistance-calculating means (8-06) obtains the train environmental resistance (8-26) based on the information (8-11) on the running-performances of all individual rolling-stock sets.

[0130] The information (8-21) on the running-performance of the whole train is output as a data set of the train length (8-22), the train weight (8-23), the train braking performance (8-24), the train powering performance (8-25), and the train environmental resistance (8-26).

[0131] Fig. 9 shows a flow chart of processing executed by the means for generating information on the performance of the whole train.

[0132] In step (9-01), this means receives the information on the running-performances of all individual rolling-stock sets containing the train length data, the train weight data, the train braking performance data, the train powering performance data, and the train environmental resistance data, from the means for registering information on all individual rolling-stock sets.

[0133] In step (9-02), the processes (step (9-03) - step (9-07)), of generating each data in the information on the performance of the whole train, are executed.

[0134] In step (9-03), the train length-calculating means generates the train length data, based on the length data of each individual rolling-stock set, contained in the information on the running-performances of all individual rolling-stock sets.

[0135] In step (9-04), the train weight-calculating means generates the train weight data, based on the weight data of each individual rolling-stock set, contained in the information on the running-performances of all individual rolling-stock sets.

[0136] In step (9-05), the train braking performance-calculating means generates the train braking performance data, based on the braking performance data of each individual rolling-stock set, contained in the information on the running-performances of all individual rolling-stock sets.

[0137] In step (9-06), the train powering performance-calculating means generates the train powering performance data, based on the powering performance data of each individual rolling-stock set, contained in the information on the running-performances of all individual rolling-stock sets.

[0138] In step (9-07), the train environmental resistance-calculating means generates the train environmental resistance data, based on the powering performance data of each individual rolling-stock set, contained in the information on the running-performances of all individual rolling-stock sets.

[0139] In step (9-08), on receiving the results of the processes in steps (9-03) - (9-07), the information on the performance of the whole train, composed of a set of the train length data, the train weight data, the train braking performance data, the train powering performance data, and the train environmental resistance data, is sent to the means for registering information on the performance of the whole train.

[0140] In the following, each processing means included in the means for generating information on the performance of the whole train will be explained in more detailed.

[0141] First, the train length-calculating means is explained.

[0142] The train length-calculating means obtains the train length L_{train} , based on the length L_i of each individual rolling-stock set i ($i = A, B, \dots$ (for all individual rolling-stock sets)), using the following equation.

$$L_{train} = \Sigma(L_i) \quad (1)$$

[0143] The symbol Σ in the right hand side of the above equation means that a value or an equation in the parenthesis is summed for all possible i . Accordingly, $\Sigma(L_i)$ indicates the summation with respect to i .

[0144] Here, even if a train includes a single individual rolling-stock set, the train length is set to the length of the single individual rolling-stock set by executing the above calculation.

[0145] As described above, in this embodiment, since the train length-calculating means obtains the train length, with reference to the performance data of all individual rolling-stock sets in a train, the train length-calculating means can generate the train length data for a train consisting of any types and any number of rolling-stock sets, corresponding to the composition state of the train.

[0146] Further, the train weight-calculating means is explained.

[0147] The train weight-calculating means obtains the train weight M_{train} , based on the length M_i of each individual rolling-stock set i ($i = A, B, \dots$ (for all individual rolling-stock sets)), using the following equation.

$$M_{train} = \Sigma(M_i) \quad (2)$$

[0148] The symbol Σ in the right hand side of the above equation means that a value or an equation in the parenthesis is summed for all possible i . Accordingly, $\Sigma(M_i)$ indicates the summation with respect to i .

[0149] Here, even if a train includes a single individual rolling-stock set, the train weight is set to the weight of the single individual rolling-stock set by executing the above calculation.

[0150] As described above, in this embodiment, since the train weight-calculating means obtains the train weight, with reference to the performance data of all individual rolling-stock sets in a train, the train weight-calculating means can generate the train weight data for a train consisting of any types and any number of rolling-stock sets, corresponding to the composition state of the train.

[0151] Further, the train braking performance-calculating means is explained.

[0152] In this embodiment, the train braking performance (braking force per unit weight of a train) is expressed as an average value of braking performance values of respective individual rolling-stock sets in the train, weighted with their weight values.

[0153] Fig. 10 conceptually shows a compound performance in the whole train in which rolling-stock sets with different running-performances are coupled.

[0154] Graph (10-01) in this figure shows the running-trajectory in the plane of train top position - running speed when the train 1 consisting of a single individual rolling-stock set A is decelerated with its maximal braking performance. Here, the braking performance of the train 1 is expressed as braking force per unit weight of the train 1, that is, a value β_1 obtained by dividing the whole braking force acting on the train 1 by its weight M_1 . The value β_1 indicates the deceleration in the motion of the train 1, and co-relates with the gradient of the running-trajectory shown in graph (10-01). Meanwhile, since the train 1 includes only the individual rolling-stock set A, β_1 is equal to a value β_A of the braking force per unit weight, that is, the braking performance of the individual rolling-stock set A.

[0155] In the same manner, graph (10-02) in this figure shows the running-trajectory in the plane of train top position - running speed when the train 2 consisting of a single individual rolling-stock set B is decelerated with its maximal braking performance. Here, the braking performance of the train 2 is expressed as braking force per unit weight of the train 2, that is, a value β_2 obtained by dividing the whole braking force acting on the train 2 by its weight M_2 . The value β_2 indicates the deceleration in the motion of the train 2, and relates with the gradient of the running-trajectory shown in graph (10-02). Meanwhile, since the train 2 includes only the individual rolling-stock set B, β_2 is equal to a value β_B of the braking force per unit weight, that is, the braking performance of the individual rolling-stock set B.

[0156] On the other hand, graph (10-03) in this figure shows the running-trajectory in the plane of train top position - running speed when the train 3 consisting of the individual rolling-stock set A coupled with the individual rolling-stock set B is decelerated with its maximal braking performance. Here, the braking performance of the train 3 is expressed as braking force per unit weight of the train 3, that is, a value β_3 obtained by dividing the whole braking force acting on the train 3 by its weight. The value β_3 indicates the deceleration in the motion of the train3, and relates with the gradient of the running-trajectory shown in graph (10-03). This value β_3 is equal to neither β_A nor β_B , different from the cases shown in graphs (10-01) and (10-02). By considering that the whole force acting on the train 3 is the sum of the braking force output by the respective rolling-stock sets A and B, the value β_3 is obtained by the following equation.

$$\beta_3 = \frac{\beta_A \times M_A + \beta_B \times M_B}{M_A + M_B} \quad (3)$$

[0157] Thus, the train braking performance generally depends on the braking performances of all individual rolling-stock sets in the train. Therefore, it follows that when the train composition state is changed, the train braking performance must be renewed by generating again information on the braking performance of the whole train whose composition state has been changed.

[0158] By taking the above analysis of the train braking performance into consideration, in this embodiment, the processing, executed by the means for generating information on the braking performance of the whole train, is prescribed as follows.

[0159] First, the processing executed by the means for generating information on the braking performance of the whole train is expressed by the following equation.

[0160] Let V denote the assumed running-speed of the train. In this embodiment, the train braking performance is expressed with a function of V , which represents braking force per unit weight of the train, that is: $\beta_{train}(V)$. Further, the

braking performance of each individual rolling-stock set i ($i = A, B \dots$ (for all individual rolling-stock sets)) in the train, is expressed with a function of V , which represents braking force per unit weight of the train, that is: $\beta_i(V)$. Furthermore, the weight of each individual rolling-stock set i is denoted by M_i .

[0161] The relationship between the train braking performance $\beta_{train}(V)$ and the braking performance $\beta_i(V)$ of each individual rolling-stock set i is expressed with the following equation.

$$\beta_{train}(V) = \frac{\sum(\beta_i(V) \times M_i)}{\sum(M_i)} \quad (4)$$

[0162] The symbol Σ in the right hand side of the above equation means that a value or an equation in the parenthesis is summed for all possible i .

[0163] The train braking performance-calculating means generates the train braking performance data, based on the braking performances of the respective individual rolling-stock sets in the train, by calculating the above equation.

[0164] Fig. 11 shows a flow chart of the process of generating the train braking performance $\beta_{train}(V)$ at the assumed speed V , which is executed by the train braking performance-calculating means.

[0165] In step (11-01), this means receives the braking performance $\beta_i(V)$ at the assumed running speed V , and the weight M_i , of each individual rolling-stock set i .

[0166] In step (11-02), a buffer 1 and a buffer 2, which are intermediately used, are initialized as 0.

[0167] In step (11-03), the following steps (11-04) - (11-05) are repeated for respective individual rolling-stock sets i .

[0168] In step (11-04), the value $\beta_i(V) \times M_i$ is added to the content of the buffer 1.

[0169] In step (11-05), the value M_i is added to the content of the buffer 2.

[0170] In step (11-06), the ratio of the content of the buffer 1 to the content of the buffer 2 is sent as the train braking performance $\beta_{train}(V)$.

[0171] Fig. 12 shows information input and output in the above-described processing shown in Fig. 11, which are expressed in Tables, in the case where the train is composed of rolling-stock sets A and B, with different running-performances.

[0172] Table (12-01) indicates input information expressing the relationship between running speed V and the braking performance $\beta_A(V)$ of the individual rolling-stock set A. For example, $\beta_A(V_0)$ indicates the braking performance of the set A, at the running speed V_0 .

[0173] Next, Table (12-02) indicates input information expressing the relationship between running speed V and the braking performance $\beta_B(V)$ of the individual rolling-stock set B. For example, $\beta_B(V_0)$ indicates the braking performance of the set B, at the running speed V_0 .

[0174] Last, Table (12-03) indicates input information expressing the relationship between running speed V and the train braking performance $\beta_{train}(V)$ of the whole train, composed of the individual rolling-stock set A and the individual rolling-stock set B. For example, $\beta_{train}(V_0)$ indicates the braking performance of the whole train, at the running speed V_0 . Also, the equation described in the parenthesis at the right side of $\beta_{train}(V_0)$, indicates that the train braking performance $\beta_{train}(V_0)$ is obtained based on the braking performance $\beta_A(V_0)$ of the set A and the braking performance $\beta_B(V_0)$ of the set B, at the running speed V_0 .

[0175] Fig. 13 conceptually shows the compounded train braking-performance with respect to its running speed, obtained by the processing shown in Fig. 12 in the case where the train is composed of rolling-stock sets A and B, with different running-performances.

[0176] Graph (13-01) indicates the braking-performance $\beta_A(V)$ with respect to its running speed V , of the individual rolling-stock set A, in the plane of the braking force per unit weight and the running speed.

[0177] Graph (13-02) indicates the braking-performance $\beta_B(V)$ with respect to its running speed V , of the individual rolling-stock set B, in the plane of the braking force per unit weight and the running speed.

[0178] Graph (13-03) indicates the compounded braking-performance $\beta_{train}(V)$ with respect to its running speed V , of the whole train consisting of the individual rolling-stock set A coupled with the individual rolling-stock set B, in the plane of the braking force per unit weight and the running speed.

[0179] The above train braking performance-calculating means of this embodiment generates the train braking performance (braking force per unit weight of the train) data, expressed as an average value, of braking performance (braking force per unit weight) data of respective individual rolling-stock sets in the train, weighted with their weight values.

[0180] Here, even if the train includes a single individual rolling-stock set, the train braking performance is set to the braking performance of the single individual rolling-stock set by the execution of the above calculation.

[0181] As described above, in this embodiment, since the train braking performance-calculating means obtains the train braking performance, with reference to the performance data of all individual rolling-stock sets in the train, the train braking performance-calculating means can generate the train braking performance data for a train consisting of any types and any number of rolling-stock sets, properly reflecting the composition state of the train.

[0182] Next, the train powering performance-calculating means is explained.

[0183] In this embodiment, the train powering performance (tractive force per unit weight of a train) is expressed as an average value of powering performance values of respective individual rolling-stock sets in the train, weighted with their weight values. Therefore, the train powering performance generally depends on the powering performances of all the independent rolling-stock sets in the train as well as the train braking performance explained with reference to Fig. 10. Thus, it follows that when the train composition state is changed, the train powering performance must be renewed by generating again information on the powering performance of the whole train whose composition state has been changed.

[0184] By taking the above investigation of the train powering performance into consideration, in this embodiment, the processing executed by the means for generating information on the powering performance of the whole train is prescribed as follows.

[0185] First, the processing executed by the means for generating information on the powering performance of the whole train is expressed by the following equation.

[0186] Let V denote the assumed running-speed of the train. In this embodiment, the train powering performance is expressed with a function of V , which represents powering force per unit weight of the train, that is: $\alpha_{\text{train}}(V)$. Further, the powering performance of each individual rolling-stock set i ($i = A, B \dots$ (for all individual rolling-stock sets)) in the train, is expressed with a function of V , which represents tractive force per unit weight of the train, that is: $\alpha_i(V)$. Furthermore, the weight of each individual rolling-stock set i is denoted by M_i .

[0187] The relationship between the train powering performance $\alpha_{\text{train}}(V)$ and the powering performance $\alpha_i(V)$ of each individual rolling-stock set i is expressed with the following equation.

$$\alpha_{\text{train}}(V) = \frac{\sum(\alpha_i(V) \times M_i)}{\sum(M_i)} \quad (5)$$

[0188] The symbol Σ in the right hand side of the above equation means that a value or an equation in the parenthesis is summed for all possible i .

[0189] The train powering performance-calculating means generates the train powering performance data, based on the powering performances of the respective individual rolling-stock sets in the train, by calculating the above equation.

[0190] Fig. 14 shows a flow chart of the process of generating a powering performance $\alpha_{\text{train}}(V)$ at an assumed speed V , which is executed by the means for generating the compounded powering-performance of the whole train.

[0191] In step (14-01), this means receives the powering performance $\alpha_i(V)$ at the assumed running speed V , and the weight M_i , of each individual rolling-stock set i .

[0192] In step (14-02), a buffer 1 and a buffer 2 intermediately used, are initialized as 0.

[0193] In step (14-03), the following steps (14-04) - (14-05) are repeated for respective individual rolling-stock sets i .

[0194] In step (14-04), the value $\alpha_i(V) \times M_i$ is added to the content of the buffer 1.

[0195] In step (14-05), the value M_i is added to the content of the buffer 2.

[0196] In step (14-06), the ratio of the content of the buffer 1 to the content of the buffer 2, is sent as the train powering performance $\alpha_{\text{train}}(V)$.

[0197] Fig. 15 shows information input and output in the above-described processing shown in Fig. 14, which are expressed in Tables, in the case where the train is composed of rolling-stock sets A and B, with different running-performances.

[0198] Table (15-01) indicates input information expressing $\alpha A(V)$ of the individual rolling-stock set A. For example, $\alpha A(V_0)$ indicates the powering performance of the set A, at the running speed V_0 .

[0199] Next, Table (15-02) indicate input information expressing the relationship between running speed V and the powering performance $\alpha B(V)$ of the individual rolling-stock set B. For example, $\alpha B(V_0)$ indicate the powering performance of the set B, at the running speed V_0 .

[0200] Last, Table (12-03) indicates input information expressing the relationship between running speed V and the train powering performance $\alpha_{\text{train}}(V)$ of the whole train, composed of the individual rolling-stock set A and the individual rolling-stock set B. For example, $\alpha_{\text{train}}(V_0)$ indicates the powering performance of the whole train, at the running speed V_0 . Also, the equation described in the parenthesis at the right side of $\alpha_{\text{train}}(V_0)$, indicates that the train powering performance $\alpha_{\text{train}}(V_0)$ is obtained based on the powering performance $\alpha A(V_0)$ of the set A and the powering performance $\alpha B(V_0)$ of the set B, at the running speed V_0 .

[0201] Fig. 16 conceptually shows the compounded train powering-performance with respect to its running speed, obtained by the processing shown in Fig. 14 in the case where the train is composed of rolling-stock sets A and B, with different running-performances.

[0202] Graph (16-01) indicates the powering-performance $\alpha A(V)$ with respect to its running speed V , of the individ-

ual rolling-stock set A, in the plane of the powering force per unit weight and the running speed.

[0203] Graph (16-02) indicates the powering-performance $\alpha_B(V)$ with respect to its running speed V , of the individual rolling-stock set B, in the plane of the powering force per unit weight and the running speed.

[0204] Graph (16-03) indicates the compounded powering-performance $\alpha_{train}(V)$ with respect to its running speed V , of the whole train consisting of the individual rolling-stock set A coupled with the individual rolling-stock set B, in the plane of the powering force per unit weight and the running speed.

[0205] The above train powering performance-calculating means of this embodiment generates the train powering performance (tractive force per unit weight of the train) data, expressed as an average value, of powering performance (tractive force per unit weight) data, of respective individual rolling-stock sets in the train, weighted with their weight values.

[0206] Here, even if the train includes a single individual rolling-stock set, the train powering performance is set to the powering performance of the single individual rolling-stock set by execution of the above calculation.

[0207] As described above, in this embodiment, since the train powering performance-calculating means obtains the train powering performance, with reference to the performance data of all individual rolling-stock sets in the train, the train powering performance-calculating means can generate the train powering performance data for a train consisting of any types and any number of rolling-stock sets, properly reflecting the composition state of the train.

[0208] Next, the train environmental resistance-calculating means is explained.

[0209] In this embodiment, the train environmental resistance (power of resistance per unit weight of a train) is expressed as an average value of environmental resistance values of respective individual rolling-stock sets in the train, weighted with their weight values. Therefore, the train environmental resistance generally depends on the environmental resistance of all the independent rolling-stock sets in the train as well as the train braking performance explained with reference to Fig. 10. Thus, it follows that when the train composition state is changed, the train environmental resistance must be renewed by generating again information on the environmental resistance of the whole train, whose composition state has been changed.

[0210] By taking the above analysis of the train environmental resistance into consideration, in this embodiment, the processing executed by the means for generating information on the environmental resistance of the whole train is prescribed as follows.

[0211] Let V denote the assumed running-speed of the train. In this embodiment, the train environmental resistance is expressed with a function of V , which represents power of resistance per unit weight of the train, that is: $R_{train}(V)$. Further, the environmental resistance of each individual rolling-stock set i ($i = A, B \dots$ (for all individual rolling-stock sets)) in the train, is expressed with a function of V , which represents power of resistance per unit weight of the train, that is: $R_i(V)$. Furthermore, the weight of each individual rolling-stock set i is denoted by M_i .

[0212] The relationship between the environmental resistance $R_{train}(V)$ and the environmental resistance $R_i(V)$ of each individual rolling-stock set i is expressed with the following equation.

$$R_{train}(V) = \frac{\sum(R_i(V) \times M_i)}{\sum(M_i)} \quad (6)$$

[0213] The symbol Σ in the right hand side of the above equation means that a value or an equation in the parenthesis is summed for all possible i .

[0214] The train environmental resistance-calculating means generates the train environmental resistance value, based on the environmental resistance values of the respective individual rolling-stock sets in the train, by calculating the above equation.

[0215] From the form of the above equation, it is seen that the process executed by the means for generating information on the train environmental resistance, is in the same manner as that executed by the means for generating information on the train braking performance, or that executed by the means for generating information on the train powering performance. Therefore, the flow chart of the process executed by the means for generating information on the train environmental resistance, is similar to that of the process executed by the means for generating information on the train braking performance or the train powering performance.

[0216] The above train environmental resistance-calculating means of this embodiment generates the train environmental resistance (power of resistance per unit weight of the train) value, expressed as an average value, of environmental resistance (power of resistance per unit weight) data, of respective individual rolling-stock sets in the train, weighted with their weight values.

[0217] Here, even if the train includes a single individual rolling-stock set, the train environmental resistance is set to the environmental resistance of the single individual rolling-stock set by execution of the above calculation.

[0218] As described above, in this embodiment, since the train environmental resistance-calculating means obtains the train environmental resistance, with reference to the resistance data of all individual rolling-stock sets in the train,

the train environmental resistance-calculating means can generate the train environmental resistance value for a train consisting of any types and any number of rolling-stock sets, properly reflecting the composition state of the train.

[0219] In the above description of this embodiment, as per the braking performance, powering performance, and environmental resistance, the means for generating information on the performance of the whole train deals with the braking force, tractive force, and power of resistance, per unit weight. However, it is possible to deal with the braking force, tractive force, and power of resistance on their own, without the equation of per unit weight. In the latter dealing, each sum in the numerator of each one of the equations (4), (5), and (6), used for; the processes of the train braking performance-calculating means; the train powering performance-calculating means; and the train environmental resistance-calculating means; in the means for generating information on the performance of the whole train, is replaced with a simple sum of; the braking performance values (the braking force values); the powering performance values (the tractive force values); and the environmental resistance values (the values of resistance power), of the respective individual rolling-stock sets, in order to obtain the train braking and tractive force, and the train's power of resistance.

[0220] The above explanation is summarized as follows.

[0221] As described above, in this embodiment, the train-control system for controlling the running of a train includes; the train-control apparatus for creating a control-command to control the whole train in a lot; each individual rolling-stock set-control system which is provided in each individual rolling-stock set, for controlling the running of each set; and the integrated rolling-stock set-control system which stands between the train-control system and the individual rolling-stock set-control systems, for mediating the communication between the train-control system and each individual rolling-stock set-control system.

[0222] Further, in this embodiment, the integrated rolling-stock set-control system includes each rolling-stock set-coupling device for mechanically coupling two neighboring rolling-stock sets, and performing the sending/receiving of information between the two neighboring rolling-stock sets, and each integrated rolling-stock set-connection device for exchanging the information on the running-control of each set with each individual rolling-stock set directly or via the rolling-stock set-coupling devices.

[0223] Furthermore, in this embodiment, the integrated rolling-stock set-connection device mediates the exchange of information between the train-control apparatus and the individual rolling-stock set-control system, and performs the bi-directional conversion of the exchanged information.

[0224] Also, in this embodiment, the integrated rolling-stock set-connection device includes the means for generating information on the performance of the whole train, which receives the information on the running-performances of the respective individual rolling-stock sets, and further generates the running-performance data of the whole train, corresponding with the train composition state.

[0225] Moreover, in this embodiment, the means for generating information on the performance of the whole train generates the individual performance information on the train length data, weight data, braking performance data, powering performance data, and environmental resistance data, with reference to the length data, weight data, braking performance data, powering performance data, and environmental resistance data of the respective individual rolling-stock sets, by taking the train composition state into account.

[0226] Still further, in this embodiment, the means for generating information on the performance of the whole train includes the train length-calculating means for generating the train length data, the train weight-calculating means for generating the train weight data, the train braking performance-calculating means for generating the train braking performance data, the train powering performance-calculating means for generating the train powering performance data, and the train environmental resistance-calculating means for generating the train environmental resistance data.

[0227] As described above, the train-control system of this embodiment has the following effects on the running-control of a train in addition to the effects of the train-control system of the embodiment 1.

[0228] According to this embodiment, since the above-described integral rolling-stock set-connection device including the means for generating information on the performance of the whole train is provided in the integrated rolling-stock set-control system, the train can be controlled as a whole, appropriately corresponding with the composition state of the train, even if the train is composed of any types and any number of rolling-stock sets. That is, since the integral rolling-stock set-connection device sends the information on the performance of the whole train, represented adequately from the view-point of the train as a whole, to the train-control apparatus, this train-control apparatus would be able to optimize the running-control of the train. Some optimization methods for the train running-control have been known, for example; as a single-step-braking train-protection disclosed in Japanese Patent Application Laid-Open Hei 3-295760, performing based on the appropriately recognized train weight and braking performance; and as a predetermined stop-position type control disclosed in Japanese Patent Application Laid-Open Hei 7-99708, devised to improve real-time control. Moreover, an optimized plan of train-operations in the respective intervals between stations, such as that reported in a paper titled "Generation method of energy saving running profiles for train operations by the optimization of running resistance and braking length", the proceedings for the Electronic and Information System Section in the Hei-sei-8 annual meeting of The Institute of Electrical Engineers of Japan. In this optimized pattern, a target operational pattern carried out between the originating and terminating stations of a train can realize both the on-time running and the

minimum consumption of energy, using the running-performance of the train, such as the train powering performance, the environmental resistance, etc. In not only an optimal control, but generally, in a control executed by a train-control apparatus, based on the prediction of a future running of a train, the information on the performance of the whole control is especially important, to ensure the propriety of the performed train running-control. Thus, the above-described integrated rolling-stock set-connection device can make the control executed by the train-control apparatus adequate, relative to the train composition state.

Embodiment 3:

[0229] In the above-described embodiment 2, by providing the integrated rolling-stock set-connection device, including the above-explained means for generating information on the performance of the whole train in the train-control system according to the present invention, it is possible to generate the performance information of the train as a whole, based on the running-performance information of the respective individual rolling-stock sets, while taking the differences in the running performances of the respective sets into consideration, for any train composition state. Thus, as mentioned above, even if the train composition state changes corresponding to the performed dividing or coupling operation mode, the above train-control system makes it possible to optimize the running control of a train, adequately corresponding with the train composition state.

[0230] In this embodiment, although the integrated rolling-stock set-control system is similar to that of the embodiment 2, as per the individual performance information of each rolling-stock set and the whole train performance information, there is a plurality of powering and braking performances with respect to the running speed, depending on the notch number. This embodiment handling the plurality of powering and braking performances with respect to the running speed is explained below.

[0231] Concerning the integrated rolling-stock set-control system included in-the train-control system of this embodiment according to the present invention, the apparatus or processing-means composition of this integrated rolling-stock set-control system, is the same as that in the embodiment 2.

[0232] In the following, the processes executed by the train powering performance-calculating means, and the train braking performance-calculating means, those means being provided in the means for generating information on the performance of the whole train, contained in the integrated rolling-stock set-connection device in the integrated rolling-stock set-control system, will be explained.

[0233] First, the process executed by the train powering performance-calculating means in this embodiment is explained below.

[0234] In this embodiment, the train powering performance (tractive force per unit weight of a train) is expressed as an average value of powering performance values of respective individual rolling-stock sets in the train, weighted with their weight values. Therefore, the train powering performance generally depends on the powering performances of all the independent rolling-stock sets in the train, as explained in the embodiment 2. In this embodiment, based on the above analysis of the train powering performance, the processing executed by the means for generating information on the powering performance of the whole train is prescribed as follows.

[0235] Let V denote the assumed running-speed of the train.

[0236] In this embodiment, the train powering performance is expressed with a function of V , which represents power of resistance per unit weight of the train, that is: $\alpha_{train, ntrain}(V)$. Further, the train powering notch number $ntrain$, related to the train powering performance, is denoted by the maximum powering notch number $Ntrain$.

[0237] Further, the powering performance of each individual rolling-stock set i ($i = A, B \dots$ (for all individual rolling-stock sets)) in the train, is expressed as a function of V , which represents power of resistance per unit weight of the train, that is: $\alpha_{i, ni}(V)$. Furthermore, the powering notch number ni , related to the powering performance of each individual rolling-stock set, is denoted by the maximum powering notch number Ni .

[0238] Moreover, the weight of each individual rolling-stock set i is denoted by M_i .

[0239] The relationship between the train powering performance $\alpha_{train, ntrain}(V)$ and the powering performance $\alpha_{i, ni}(V)$ of each individual rolling-stock set i is expressed with the following equation.

$$\alpha_{train, ntrain}(V) = \frac{\sum(\alpha_{i, ni}(V) \times M_i)}{\sum(M_i)} \quad (7)$$

[0240] The symbol Σ in the right hand side of the above equation means that a value or an equation in the parenthesis is summed for all possible i . Moreover, the relationship between $ntrain$ and ni in the above equation is described as follows.

[0241] As per ni in the right hand side of the equation:

If $n_{train} \leq N_i$, $n_i = n_{train}$ (n_{train} is directly used,) and (8)

if $n_{train} > N_i$, $n_i = N_i$ (the maximum value of n_i is used.)

5 [0242] As per n_{train} in the left hand side of the equation:

$$n_{train} = \max(n_i), \text{ and } N_{train} = \max(N_i)$$

[0243] Here, $\max(N_i)$ indicates the maximum value of N_i .

10 [0244] The train powering performance-calculating means generates the train powering performance data, based on the powering performances of the respective individual rolling-stock sets in the train, by calculating the above equation.

[0245] Although the contents of the above equation is similar to that of the equation used in the embodiment 2, the relationship between n_{train} and n_i is added. In implementing the above equation, $\alpha_{train, n_{train}}(V)$ is obtained based on each $\alpha_{i, n_i}(V)$, by setting each n_i to n_{train} as equally as the conditions permit. However, it sometimes happens that, since the maximum notch number N_j of a specific individual rolling-stock set j is lower than the maximum notch number of the other sets, n_j cannot be set to n_{train} . In such a situation, n_j is set to N_j , and while n_i for the remaining sets can be set to the same notch number n_{train} , the calculation of $\alpha_{train, n_{train}}(V)$ is continued according to the above equation. When all n_i reach N_i , the calculation of $\alpha_{train, n_{train}}(V)$ is completed. This results in the train maximum powering notch number N_{train} being set to the maximum value of all N_i in $\alpha_{train, n_{train}}(V)$.

[0246] If the combinations of n_{train} and respective n_i are fixed, the process of obtaining $\alpha_{train, n_{train}}(V)$ based on respective $\alpha_{i, n_i}(V)$ is the same as that executed by the train powering performance-calculation means in the embodiment 2. That is, if $\alpha_{train}(V)$ and $\alpha_i(V)$ in the flowchart shown in Fig. 14 are replaced with $\alpha_{train, n_{train}}(V)$ and $\alpha_{i, n_i}(V)$, respectively, the flow chart of the process executed by the train powering performance-calculation means in this embodiment can be obtained.

[0247] Fig. 17 conceptually shows the compounded powering-performance with respect to speed, obtained by the flow chart shown in Fig. 14, in the case where the train is composed of rolling-stock sets A and B, with different running performances.

[0248] Graph (17-01) indicates the powering-performance $\alpha_{A, n_A}(V)$ with respect to its running speed V , of the individual rolling-stock set A, in the plane of the tractive force per unit weight and the running speed. In the powering performance with respect to the speed, the maximum notch number (the total stage number in the powering) is N_A .

[0249] Graph (17-02) indicates the powering-performance $\beta_{B, n_B}(V)$ with respect to its running speed V , of the individual rolling-stock set B, in the plane of the powering force per unit weight and the running speed. In the powering performance with respect to the speed, the maximum notch number (the total stage number in the powering) is N_B .

35 [0250] Graph (17-03) indicates the compounded powering-performance $\alpha_{train, n_{train}}(V)$ with respect to its running speed V , of the whole train consisting of the individual rolling-stock set A coupled with the individual rolling-stock set B, in the plane of the tractive force per unit weight and the running speed.

[0251] In Fig. 17, the maximum notch numbers N_A and N_B are equal to N . Under this condition, the maximum powering notch number N_{train} related to the train powering performance is also equal to N . Further, the relationship between the train powering performance and that of each individual rolling-stock set is expressed by the following equation.

$$\alpha_{train, n}(V) = \frac{\alpha_{A, n}(V) \times M_A + \alpha_{B, n}(V) \times M_B}{M_A + M_B} \quad (9)$$

45 [0252] That is, the train powering performance $\alpha_{train, n}(V)$ is obtained based on the individual powering performances $\alpha_{A, n}(V)$ and $\alpha_{B, n}(V)$ corresponding to the same notch number n .

[0253] The above train powering performance-calculating means of this embodiment generates the train powering performance (tractive force per unit weight of the train) data expressed as an average value of powering performance (tractive force per unit weight) data of respective individual rolling-stock sets in the train, weighted with their weight values.

[0254] Further, in this embodiment, as per the compounded train powering performance also, a plurality of powering performances with respect to the running speed are obtained for all train notch numbers. In this point, this embodiment is extended from the embodiment 2.

[0255] Here, even if the train includes a single individual rolling-stock set, the train powering performance is set to the powering performance of the single individual rolling-stock set by executing the above calculation.

[0256] As described above, in this embodiment, since the train powering performance-calculating means obtains

the train powering performance, with reference to the performance data of all individual rolling-stock sets in the train, the train powering performance-calculating means can generate the train powering performance data for a train consisting of any types and any number of rolling-stock sets, properly reflecting of the composition state of the train.

[0257] Next, the train braking performance-calculating means is explained.

[0258] The process executed by the train braking performance-calculating means of this embodiment is similar to that executed by the above-described train powering performance-calculating means of this embodiment. Therefore, if all the contents related to the powering performance in the above description for the train powering performance-calculating means are replaced with those related to the braking performance, the description for the process executed by the train braking performance-calculating means can be obtained.

[0259] In the above description of this embodiment, as per the powering performance, and braking performance, the means for generating information on the performance of the whole train deals with the tractive force, and braking force, per unit weight. However, it is possible to deal with the tractive force, and braking force, per se, (not value per unit weight). In the later dealing, each weighted sum in the calculations of the train powering performance-calculating means, (expressed by the equation (7)), and the train braking performance-calculating means, included in the means for generating information on the performance of the whole train, is replaced with a simple sum of the powering performance values (the tractive force values), and the braking performance values (the braking force values), of the respective individual rolling-stock sets, in order to obtain the train tractive and braking force. Here, the method of setting the correspondence between the train notch number and the individual notch number, described in the equation (8), can be applied to the correspondence between the individual powering or braking performance to be summed and the powering or braking notch number.

[0260] As described above, the train-control system of this embodiment has the following effects on the running-control of a train in addition to the effects of the train-control system including the integrated rolling-stock set-control system, of the embodiment 2.

[0261] That is, according to this embodiment, the effects of the embodiment 2 can be obtained in the running-control of the train composed of individual rolling-stock sets each of which is equipped with a notch-operation device.

Embodiment 4:

[0262] In the above embodiment 1, in the train-control system for controlling the running of a train; the train-control apparatus for determining a control-command to control the whole train in a lot; each individual rolling-stock set-control system, which is provided in each individual rolling-stock set, for controlling the running of each set; and; the integrated rolling-stock set-control system which stands between the train-control system and the individual rolling-stock set-control systems, for mediating the communication between the train-control system and each individual rolling-stock set-control system; are provided. According to the above composition of the train-control system, even if the train composition state changes pursuant to the dividing or coupling operation mode, since it is only the integrated rolling-stock set-control system which copes with effects of the change on the running-control of the train, the train-control apparatus and each individual rolling-stock set need not consider the change in the train composition state. Further, it has been described above that it becomes possible to optimize the running-control of a train, corresponding to the train composition state, by taking the performance of the whole train and that of each rolling-stock set in the train into account, because the integrated rolling-stock set-control system adequately operates the communication between the train-control apparatus and the respective individual rolling-stock set-control systems.

[0263] In this embodiment, the operations for the communication between the train-control apparatus and the respective individual rolling-stock set-control systems, performed by the integrated rolling-stock set-control system, are concretely set. Further, a communication means which takes it into account that the individual rolling-stock sets composing the train have different running-performances, is incorporated into the integrated rolling-stock set-control system. That is, the integrated rolling-stock set-control system receives a train-control command to control the running of the train as a whole from the train-control apparatus, and then converts the train-control command to control commands for the respective individual rolling-stock sets. Further, it sends the converted control commands for the respective individual rolling-stock sets. The control commands that control the running of the respective individual rolling-stock sets are created so as to optimize the driving-state of each individual rolling-stock set by taking differences in the running-performances of the respective individual rolling-stock sets into consideration, while corresponding with the composition state of the train.

[0264] The integrated rolling-stock set-control system of this embodiment includes the integrated rolling-stock set-connection device and the rolling-stock set-coupling device. The rolling-stock set-coupling device mechanically couples the two neighboring sets in the individual rolling-stock sets of the train, and mediates the communication between the neighboring sets. The integrated rolling-stock set-connection device performs the sending/receiving of information on the running-control of the whole train, with the train-control apparatus to which the integrated rolling-stock set-connection device is connected, and the sending/receiving of information on the running-control of each individual rolling-stock

set, with the respective individual rolling-stock sets, directly or via the rolling-stock set-coupling device.

[0265] The integrated rolling-stock set-connection device of this embodiment receives the train-control command that controls the running of the whole train, from the train-control apparatus connected to the integrated rolling-stock set-connection device, and sends a control command that controls each individual rolling-stock set to each individual rolling-stock set-control system, directly, or via the rolling-stock set-coupling device.

[0266] Fig. 18 shows the functional composition of the integrated rolling-stock set-connection device in this embodiment.

[0267] The integrated rolling-stock set-connection device (18-01) shown in Fig. 18 includes the following processing means.

[0268] First, this device has a means (18-11) for registering a train-control command. This means receives the train-control command (18-21) to control the train as a whole, from a train-control apparatus (18-02), and registers the received train-control command (18-21) to be used for the information-processing performed in the integrated rolling-stock set-connection device (18-01). Further, this means sends the train-control command (18-21) to a means (18-15) for generating a control-command for each individual rolling-stock set, which will be explained later.

[0269] Next, this device has a means (18-12) for inputting/outputting information on individual rolling-stock sets. This means receives information (18-22) on the running-state of its own individual rolling-stock set (18-03), indicating the running speed of its own set, in which an individual rolling-stock set-control system (18-03) is provided, from an individual rolling-stock set running state-detection device (18-04) located in the individual rolling-stock set (18-03).

[0270] Further, the means (18-12) for inputting/outputting information on individual rolling-stock sets sends a control-command (18-26A) for its own individual rolling-stock set (18-03) to an individual rolling-stock set-drive (18-05) provided in the individual rolling-stock set (18-03). Moreover, if the train is composed of a plurality of rolling-stock sets, this means sends control-commands (18-26B) for other individual rolling-stock sets to those sets via a rolling-stock set-coupling device (18-06). Furthermore, if the train is composed of a plurality of rolling-stock sets, and its own individual rolling-stock set is a slave set, this means receives the control-command (18-26A) for its own individual rolling-stock set, sent from the other individual rolling-stock set (a master set), via the rolling-stock set-coupling device (18-06).

[0271] Also, the means (18-12) for inputting/outputting information on individual rolling-stock sets receives control-commands (18-25) for all individual rolling-stock sets, obtained by collecting control-commands for the respective individual rolling-stock sets, that control the respective sets, from a means (18-16) for registering control-commands for all individual rolling-stock sets, which will be explained later, provided in the integrated rolling-stock set-connection device (18-01). Further, this means sends information (18-22) on the running-state of its own individual rolling-stock set (18-03), indicating the running speed of its own set, to a means (18-13) for registering the running-states of individual rolling-stock sets, provided in the integrated rolling-stock set-connection device (18-01).

[0272] Moreover, the integrated rolling-stock set-connection device (18-01) has the means (18-13) for registering the running-states of individual rolling-stock sets. This means receives the information (18-22) on the running-state of its own individual rolling-stock set from the means (18-12) for inputting/outputting information on individual rolling-stock sets. The means (18-13) for registering the running-states of individual rolling-stock sets regards the running speed of its own set, indicated by the information (18-22) on the running-state of its own individual rolling-stock set, as the running speed of the train, and generates running-speed information (18-23) indicating the train speed. Also, the means (18-13) registers the running-speed information (18-23) to be used for the information-processing performed in the integrated rolling-stock set-connection device (18-01). Further, the running-speed information (18-23) is sent to a means (18-15) for generating control-commands for respective individual rolling-stock sets, which will be explained later, situated in the integrated rolling-stock set-connection device (18-01).

[0273] Further, the integrated rolling-stock set-connection device (18-01) has a means (18-14) for registering information (18-24) designating a master individual rolling-stock set. Also, this device sends that information (18-24) to the later-explained means (18-15) for generating control-commands for respective individual rolling-stock sets.

[0274] Here, the information (18-24) designating a master individual rolling-stock set is created based on the train composition state, preceding the start of the train. The information (18-24) always designates its own set if the train consists of a single rolling-stock set. On the other hand, if the train consists of a plurality of rolling-stock sets, the information (18-24) designates one of the plurality of rolling-stock sets in the train. Meanwhile, concerning which set is determined as a master set, although an example is described in the embodiment 1, a master set-determining method or a method of designating a master set, used in the train-control system according to the present invention, is not restricted to the above example, and is not an essential inventive matter.

[0275] Still further, the integrated rolling-stock set-connection device (18-01) has the means (18-15) for generating control-commands for respective individual rolling-stock sets. This means receives the train-control command (18-21), the running-speed information (18-23), and the information (18-24) designating a master set, from the means (18-11) for registering a train-control command, the means (18-13) for registering the running-states of individual rolling-stock sets, and the means (18-14) for registering information (18-24) designating a master, respectively. This means further generates control-commands (18-26A) and (18-26B) for the respective individual rolling-stock sets composing the train,

based on the above received information. Also, this means creates a set of control-commands (18-25) by accumulating the control-commands for the respective individual rolling-stock sets, and sends the set to the below-described means (18-16) for registering control-commands for all individual rolling-stock sets.

[0276] In addition, the integrated rolling-stock set-connection device (18-01) has the means (18-16) for registering control-commands for all individual rolling-stock sets. This means receives the set of control-commands (18-25) from the means (18-15) for generating control-commands for respective individual rolling-stock sets, and registers the set of control-commands (18-25) to be used for the information-processing performed in the integrated rolling-stock set-connection device (18-01). Also, this means sends the set of control-commands (18-25) to the means (18-12) for inputting/outputting information on individual rolling-stock sets.

[0277] Fig. 19 shows a flow chart of the processing executed in one control-cycle by the integrated rolling-stock set-connection device in this embodiment.

[0278] In step (19-01), one of the input processes executed in steps (19-02) - (19-04) is selected, corresponding to the information to be received by the integrated rolling-stock set-connection device.

[0279] In step (19-02), the train-control command is received from the train-control apparatus. The process executed in step (19-02) is implemented by the means for registering a train-control command.

[0280] In step (19-03), the control-command for an individual rolling-stock set, which sent from another set, is received from the integrated rolling-stock set-connection device of another set via the rolling-stock set-coupling devices. The process executed in step (19-03) is implemented by the means for inputting/outputting information on individual rolling-stock sets.

[0281] In step (19-04), the information on the running-state of its own individual rolling-stock set is received from the individual rolling-stock set running state-detection device. The process executed in step (19-04) is implemented by the means for inputting/outputting information on individual rolling-stock sets.

[0282] In step (19-05), the running-speed information indicating the train speed is generated based on the information, obtained in step (19-04), on the running-state of its own individual rolling-stock set. Meanwhile, in this embodiment, the running-speed information indicating the train speed is set to the running speed indicated by the information on the running-state of each individual rolling-stock set. The process executed in step (19-05) is implemented by the means for registering the running-states of rolling-stock sets.

[0283] In step (19-06), it is determined whether or not the information designating a master set, handled in the integrated rolling-stock set-connection device, does designate its own set. If the information designating a master set designates its own set, the process goes to step (19-07), otherwise, it goes to step (19-08). The process executed in step (19-06) is implemented by the means for generating a control-command for each individual rolling-stock set.

[0284] In step (19-07), the control-commands for controlling the respective individual rolling-stock sets are generated based on the train-control command and the running-speed information. The process executed in step (19-07) is implemented by the means for generating a control-command for each individual rolling-stock set. After this step, the process goes to step (19-09). In step (19-08), it is determined whether or not the control-command for its own set has been received from another set via the rolling-stock set-coupling device. If the control-command for its own set has been received from another set, the process goes to step (19-09), otherwise, it goes to step (19-10). The process executed in step (19-08) is implemented by the means for inputting/outputting information on individual rolling-stock sets.

[0285] In step (19-09), the control-command for its own set is sent to the individual rolling-stock set-drive device of its own set. The process executed in step (19-09) is implemented by the means for inputting/outputting information on individual rolling-stock sets.

[0286] In step (19-10), it is determined whether or not there is another set. As per this step, the integrated rolling-stock set-connection device implements this determination by detecting the presence of an integrated rolling-stock set-connection device of another set based on the communication with another set via the rolling-stock set-coupling devices. If there is another set, the process goes to step (19-11), otherwise, it goes to the end. The process executed in step (19-10) is implemented by the means for inputting/outputting information on individual rolling-stock sets.

[0287] In step (19-11), the control-command for another set is sent to the integrated rolling-stock set-connection device of another set via the rolling-stock set-coupling devices. The process executed in step (19-11) is implemented by the means for inputting/outputting information on individual rolling-stock sets.

[0288] The integrated rolling-stock set-connection device performs the information-converting operation which can reflect the train composition state, by executing the information processing shown in Fig. 18 and Fig. 19.

[0289] Fig. 20 shows an information flow in one control-cycle executed in an integrated rolling-stock set-control system of this embodiment in the case where the rolling-stock sets are operated in the dividing operation mode.

[0290] An individual rolling-stock set A (20-00A) and an individual rolling-stock set B (20-00B) are separately operated as a train 1 (20-100) and a train 2 (20-200), in the dividing operation mode. In these train compositions, an integrated rolling-stock set-control system 1 (20-101) and an integrated rolling-stock set-control system 2 (20-201) are independently provided in the two trains, respectively. That is, the information flow in an integrated rolling-stock set-connection device A (20-01A) and that in an integrated rolling-stock set-connection device B (20-01B) are independent of

each other. Therefore, only the train 1 (20-100), or the individual rolling-stock set A (20-00A) is explained below.

[0291] First, in the integrated rolling-stock set-connection device A (20-01A) of the integrated rolling-stock set-control system 1 (20-101), a means (20-12A) for inputting/outputting information on individual rolling-stock sets receives information A (20-22A) on the running-performance of the individual rolling-stock set A (20-00A) from an individual rolling-stock set running state-detection device A (20-04A) in an individual rolling-stock set-control system A (20-03A). The means (20-12A) for inputting/outputting information on individual rolling-stock sets sends the received information A (20-22A) to a means (20-13A) for registering the running states of individual rolling-stock sets.

[0292] Next, the means (20-13A) for registering the running states of individual rolling-stock sets receives the information A (20-22A) on the running-performance of the individual rolling-stock set A (20-00A) from the means (20-12A) for inputting/outputting information on individual rolling-stock sets, and sets the content of running-speed information (20-23A) to the running speed indicated by the information A (20-22A). Further, the running-speed information (20-23A) is registered in a running-speed information-registering table managed by the means (20-13A) for registering the running states of individual rolling-stock sets.

[0293] Further, before the start of the train 1 (20-100), a means (20-14A) for registering information designating a master individual rolling-stock set registers information (20-24A) designating a master set in the train 1 (20-100), in a master set-designating information-registering table managed by the means (20-14A) for registering the information (20-24A) designating a master individual rolling-stock set.

[0294] Furthermore, a means (20-11A) for registering a train-control command receives a train-control command (20-21A) from a train-control apparatus (20-02A), and registers the train-control command (20-21A) in a train-control command registering table managed by the means (20-11A) for registering a train-control command.

[0295] Further, a means (20-15A) for generating control-commands for respective individual rolling-stock sets receives the train-control command (20-21A), the running-speed information (20-23A), and the information (20-24A) designating a master individual rolling-stock set, from the means (20-11A) for registering a train-control command, the means (20-13A) for registering the running states of individual rolling-stock sets, and the means (20-14A) for registering information designating a master, respectively.

[0296] The means (20-15A) for generating control-commands for respective individual rolling-stock sets generates control-commands for respective sets in the train 1 (20-100), based on the running-speed information (20-23A) and the information (20-24A) designating a master individual rolling-stock set; and sends a control-command set (20-25A) for all rolling-stock sets, created by accumulating the control-commands for respective individual rolling-stock sets. In this example, since the train 1 (20-100) includes only the set A (20-00A), a control-command A (20-26A) is set to the train-control command (20-21A) for the set A (20-00A). Thus, there is only the control-command A (20-26A) in the control-command set (20-25A) for all rolling-stock sets.

[0297] Next, a means (20-16A) for registering control-commands for all individual rolling-stock sets receives the control-command set (20-25A) for all rolling-stock sets from The means (20-15A) for generating control-commands for respective individual rolling-stock sets, and registers the control-command set (20-25A) for all rolling-stock sets in a table for describing a control-command set for all rolling-stock sets, managed by the a means (20-16A).

[0298] Further, the means (20-12A) for inputting/outputting information on individual rolling-stock sets receives the control-command set (20-25A) for all rolling-stock sets from the means (20-16A) for registering control-commands for all individual rolling-stock sets. Also, the means (20-11A) sends a control-command for each individual rolling-stock set, indicated by the control-command set (20-25A), to the corresponding rolling-stock set. In this example, the control-command A (20-26A) for the set A (20-00A) is sent to an individual rolling-stock set-drive device A (20-05A) in the individual rolling-stock set-control system A (20-03A).

[0299] Fig. 21 shows an information flow in one control-cycle executed in an integrated rolling-stock set-control system in this embodiment in the case where the rolling-stock sets are operated in the coupling operation mode.

[0300] An individual rolling-stock set A (21-00A) and an individual rolling-stock set B (21-00B) are operated together as a train 3 (21-300), in the coupling operation mode. In the example shown in Fig. 21, the individual rolling-stock set A (21-00A) is a master set, and the individual rolling-stock set B (21-00B) is a slave set. In this train composition, one integrated rolling-stock set-control system 3 (21-301) is composed so as to execute a supervisory control of the individual rolling-stock set A (21-00A) and the individual rolling-stock set B (21-00B), in the train 3 (21-300). Thus, the information flow in the integrated rolling-stock set-connection device A (21-01A) and that in the integrated rolling-stock set-connection device B (21-01B) interact with each other.

[0301] First, the information flow in the individual rolling-stock set A (21-00A) is explained below. In the integrated rolling-stock set-connection device A (21-01A) provided in the integrated rolling-stock set-control system 3 (21-301), a means (21-11A) for registering a train-control command receives a train-control command 3 (21-21A) from a train-control apparatus A (21-02A), and registers the train-control command 3 (21-21A) in a train-control command registering table managed by the means (21-11A) for registering a train-control command.

[0302] Next, a means (21-12A) for inputting/outputting information on individual rolling-stock sets receives information A (21-22A) on the running-performance of the individual rolling-stock set A (21-00A) from an individual rolling-stock

set running state-detection device A (21-04A) in an individual rolling-stock set-control system A (21-03A). The means (20-12A) for inputting/outputting information on individual rolling-stock sets sends the received information A (21-22A) to a means (21-13A) for registering the running states of individual rolling-stock sets.

[0303] Further, the means (21-13A) for registering the running states of individual rolling-stock sets receives the information A (21-22A) on the running-performance of the individual rolling-stock set A (20-00A) from the means (21-12A) for inputting/outputting information on individual rolling-stock sets, and sets the content of running-speed information (21-23A), used as the running speed of the train 3 (21-300), to the running speed of the set A (21-00A), indicated by the information A (20-22A). Furthermore, the running-speed information (21-23A) is registered in a running-speed information-registering table managed by the means (21-13A) for registering the running states of individual rolling-stock sets.

[0304] Also, before the start of the train 3 (21-300), a means (21-14A) for registering information designating a master individual rolling-stock set registers information (20-24A) designating a master set in the train 3 (21-300), in a master set-designating information-registering table managed by the means (21-14A) for registering the information (21-24A) designating a master individual rolling-stock set.

[0305] Further, a means (21-15A) for generating control-commands for respective individual rolling-stock sets receives the train-control command (21-21A), the running-speed information (21-23A), and the information (21-24A) designating a master individual rolling-stock set, from the means (21-11A) for registering a train-control command, the means (21-13A) for registering the running states of individual rolling-stock sets, and the means (21-14A) for registering information designating a master, respectively.

[0306] In the example shown in Fig. 21, since a master set of the train 3 (21-300) is the set A (21-00A), the information (21-24A) designating a master individual rolling-stock set indicates the set A (21-00A). Therefore, the means (21-15A) for generating control-commands for respective individual rolling-stock sets provided in the set A (21-00A) generates a control-command for each set, to control each set in the train3 (21-300), based on the train-control command (21-21A), the running-speed information (21-23A), and the information (21-24A) designating a master individual rolling-stock set; and sends a set (21-25A) of control-commands for all sets, created by accumulating the above generated control-commands for the respective sets, to a means (20-16A) for registering control-commands for all individual rolling-stock sets. In this example, since there are two sets of the individual rolling-stock sets A (21-00A) and B (21-00B) in the train 3 (21-300), the set (21-25A) of control-commands includes two control-commands for the sets A (21-00A) and B (21-00B).

[0307] The means (20-16A) for registering control-commands for all individual rolling-stock sets receives the set (21-25A) of control-commands for all sets from the means (21-15A) for generating control-commands for respective individual rolling-stock sets, and registers the set (21-25A) of control-commands in the table for describing a control-command set for all rolling-stock sets, managed by the a means (20-16A).

[0308] Next, the means (21-12A) for inputting/outputting information on individual rolling-stock sets receives the set (21-25A) of control-commands for all rolling-stock sets from the means (21-16A) for registering control-commands for all individual rolling-stock sets. Also, the means (21-12A) sends a control-command for each individual rolling-stock set, indicated by the control-command set (21-25A), to the corresponding rolling-stock set. In this example, the control-command A (21-26A) for the set A (21-00A) is sent to an individual rolling-stock set-drive device A (21-05A) in the individual rolling-stock set-control system A (21-03A). Further, the control-command B (21-26B) for the set B (21-00B) is sent to the integrated rolling-stock set-connection device B (21-01B) in the set B via the rolling-stock set-coupling device A (21-06A) and the rolling-stock set-coupling device B (21-06B) in the set B.

[0309] On the other hand, the information flow in the individual rolling-stock set A (21-00A) is explained below. In the integrated rolling-stock set-connection device B (21-01B) provided in the integrated rolling-stock set-control system 3 (21-301), a means (21-11B) for registering a train-control command receives a train-control command 3 (21-21B) from a train-control apparatus B (21-02B), and registers the train-control command 3 (21-21B) in a train-control command registering table managed by the means (21-11B) for registering a train-control command.

[0310] Next, a means (21-12B) for inputting/outputting information on individual rolling-stock sets receives information B (21-22B) on the running-performance of the individual rolling-stock set B (21-00B) from an individual rolling-stock set running state-detection device B (21-04B) in an individual rolling-stock set-control system A (21-03B). The means (20-12B) for inputting/outputting information on individual rolling-stock sets sends the received information B (21-22B) to a means (21-13B) for registering the running states of individual rolling-stock sets.

[0311] Further, the means (21-13B) for registering the running states of individual rolling-stock sets receives the information B (21-22B) on the running-performance of the individual rolling-stock set B (20-00B) from the means (21-12B) for inputting/outputting information on individual rolling-stock sets, and sets the content of running-speed information (21-23B), used as the running speed of the train 3 (21-300), to the running speed of the set B (21-00B), indicated by the information B (20-22B). Furthermore, the running-speed information (21-23B) is registered in a running-speed information-registering table managed by the means (21-13B) for registering the running states of individual rolling-stock sets.

[0312] Also, before the start of the train 3 (21-300), a means (21-14B) for registering information designating a master individual rolling-stock set registers information (20-24B) designating a master set in the train 3 (21-300), in a master set-designating information-registering table managed by the means (21-14B) for registering the information (21-24B) designating a master individual rolling-stock set.

[0313] Further, a means (21-15B) for generating control-commands for respective individual rolling-stock sets receives the train-control command (21-21B), the running-speed information (21-23B), and the information (21-24B) designating a master individual rolling-stock set, from the means (21-11B) for registering a train-control command, the means (21-13B) for registering the running states of individual rolling-stock sets, and the means (21-14B) for registering information designating a master, respectively.

[0314] In the example shown in Fig. 21, since a master set of the train 3 (21-300) is the set A (21-00A), the information (21-24A) designating a master individual rolling-stock set indicates the set A (21-00A). Therefore, the means (21-15B) for generating control-commands for respective individual rolling-stock sets provided in the set B (21-00B) does not generate control-commands to control of the running of each set in that train, in response to a train-control command 3 (21-21B). Thus, the means (21-15B) sends no information to a means (21-16B) for registering control-commands for all individual rolling-stock sets.

[0315] The means (20-16B) for registering control-commands for all individual rolling-stock sets does not receive any information from the means (21-15B) for generating control-commands for respective individual rolling-stock sets, and no information is registered in the table for describing a control-command set for all rolling-stock sets, managed by the means (20-16B).

[0316] Also, the means (21-12B) for inputting/outputting information on individual rolling-stock sets receives no information from the means (20-16B) for registering control-commands for all individual rolling-stock sets.

[0317] On the other hand, the means (21-12B) for inputting/outputting information on individual rolling-stock sets receives the control-command B (21-26B) for the slave set B (21-00B) from the integrated rolling-stock set-connection device A (21-01A) in the set A (21-00A) via the rolling-stock set-coupling device B (21-06B) and the rolling-stock set-coupling device A (21-06A) in the set A. Further, the means (21-12B) sends the received control-commands for respective individual rolling-stock sets to the corresponding sets. In this example, the means (21-12B) sends the control-command B (21-26B) for the slave set B (21-00B) to an individual rolling-stock set-drive device B (21-05B) in the set B.

[0318] Fig. 22 shows the functional composition of a means (22-01) for generating control-commands for individual rolling-stock sets, in this embodiment.

[0319] The means (22-01) for generating control-commands for individual rolling-stock sets includes a means (22-02) for determining a master rolling-stock set, a means (22-03) for registering information on the relationship between a control-command for a train and control-commands for respective individual rolling-stock sets, and a means (22-04) for converting a control-command for a train to control-commands for respective individual rolling-stock sets.

[0320] The means (22-02) for determining a master rolling-stock set, receives a train-control command (22-11) to control the train as a whole, and information (22-12) designating a master set of the train, which are sent from the outside of the means (22-01) for generating control-commands for individual rolling-stock sets. The individual rolling-stock set including the integrated rolling-stock set-connection device in which the means (22-01) for generating control-commands for individual rolling-stock sets is provided, determines whether or not the set designated by the information (22-12) designating a master set of the train is its own set, that is, whether or not its own set is a master set. If its own set is a master set, this set sends the train-control command (22-11) to the means (22-04) for converting a control-command for a train to control-commands for respective individual rolling-stock sets, otherwise, it does not send any control information to the outside.

[0321] The means (22-03) for registering information on the relationship between a control-command for a train and control-commands for respective individual rolling-stock sets, registers a table (22-14) describing information on the relationship between each of various contents contained in a control-command for a train, and control-commands corresponding to each content of the train-control command, for respective individual rolling-stock sets; and this table (22-14) is referred to by the means (22-04) for converting a control-command for a train to control-commands for respective individual rolling-stock sets.

[0322] This conversion means (22-04) receives the train-control command sent from the means (22-02) for determining a master rolling-stock set, running-speed information (22-13) input from the outside of the means (22-01) for generating control-commands for individual rolling-stock sets, and the table (22-14) describing information on the relationship between a control-command for a train and control-commands for respective individual rolling-stock sets, sent from the means (22-03) for registering information on the relationship between a control-command for a train and control-commands for respective individual rolling-stock sets. Further, the conversion means (22-04) determines whether or not this means receives a train-control command (22-11) output from the means (22-02) for determining a master rolling-stock set. If the conversion means (22-04) has received a train-control command (22-11), this conversion means (22-04) searches the table (22-14) describing information on the relationship between a control-command for a train and control-commands for respective individual rolling-stock sets in order to obtain control-commands for the respective

individual rolling-stock sets, and sends a set (22-21) of control-commands for all individual rolling-stock sets to the external means for registering control-commands for respective individual rolling-stock sets. Conversely, if the conversion means (22-04) has not received a train-control command (22-11), the conversion means (22-04) sends no control information to its outside.

[0323] In the following, each of the processes executed by the processing means included in the means (22-01) for generating control-commands for individual rolling-stock sets will be explained.

[0324] First, the process executed by the means (22-02) for determining a master rolling-stock set corresponds to step (19-06) of the conditional jump in the flow chart, shown in Fig. 19, of the processing executed by the integrated rolling-stock set-connection device.

[0325] Next, the process executed by the means (22-04) for converting a control-command for a train to control-commands for respective individual rolling-stock sets, is explained below.

[0326] Figs. 23, 24, and 25 conceptually show examples of respective force acting between rolling-stock sets in different coupling operation modes, in each of which two rolling-stock sets with different running-performances are coupled as a train. Here, it is assumed that each train shown in Fig. 23, 24, or 25 is in a powering operation state, and the acceleration of each train is the same.

[0327] In Fig. 23, the weight values of rolling-stock sets A (23-01) and B (23-01) are MA and MB, (unit: t), respectively. Further, the respective tractive force TA (23-11) and TB (23-21), (unit: kN), are acting on the sets A (23-01) and B (23-01). The sets A (23-01) and B (23-01) are connected to each other by a rolling-stock set-coupling device (23-03), and an interactive force (unit: kN) is acting between the two sets A (23-01) and B (23-01). As per the interactive force, the force TAB (23-12) and the force TBA (23-22) are acting on the sets A (23-01) and B (23-01), respectively, and their absolute values are equal, and their directions are opposite to each other. Thus, the acceleration of the whole train is $(TA + TB)/(MA + MB)$, (unit: m/s).

[0328] Also, in Fig. 24, in the same manner as shown in Fig. 23, the weight values of rolling-stock sets A (24-01) and B (24-01) are MA and MB, respectively. Further, the respective tractive force TA (24-11) and TB (24-21), are acting on the sets A (24-01) and B (24-01). The force TAB (24-12) and the force TBA (24-22) are loaded on a rolling-stock set-coupling device (24-03) as an interactive force. The weight values MA and MB are the same as those in Fig. 23. On the other hand, the values of TA (24-11) and TB (24-21), and TAB and TBA, are different from those in Fig. 23. That is, the force TA (24-11) in Fig. 24 is weaker than the force TA (23-11) in Fig. 23, and the force TB (24-11) in Fig. 24 is stronger than the force TB (23-11) in Fig. 23. Further, the respective directions of TAB (24-12) and TBA (24-22) are opposite to those in Fig. 23. However, the acceleration $(TA + TB)/(MA + MB)$ of the whole train is equal to that in Fig. 23.

[0329] Moreover, in Fig. 25 also, in the same manner as shown in Fig. 23 and Fig. 24, the weight values of rolling-stock sets A (25-01) and B (25-01) are MA and MB, respectively. Further, the respective tractive force TA (25-11) and TB (25-21), are acting on the sets A (25-01) and B (25-01). The force TAB (25-12) and the force TBA (25-22) are loaded on a rolling-stock set-coupling device (25-03) as an interactive force. The weight values MA and MB are the same as those in Fig. 23 and Fig. 24. On the other hand, the values of TA (25-11) and TB (25-21), and TAB and TBA, are different from those in Fig. 23 and Fig. 24. That is, the values of TA (25-11) and TB (25-21) in Fig. 25 are intermediate values between the value of TA (23-11) in Fig. 23 and the value of TA (24-11) in Fig. 24, and the value between the value of TB (23-21) in Fig. 23 and the value of TB (24-21) in Fig. 24, respectively. Further, the values of TAB (24-12) and TBA (24-22) are zero. However, the acceleration $(TA + TB)/(MA + MB)$ of the whole train is equal to that in Fig. 23 and Fig. 24.

[0330] Furthermore, in Fig. 23, it is assumed that the tractive force per unit weight, TA/MA , obtained by dividing the tractive force TA acting on the set A (23-01) by the weight MA of the set A (23-01), is stronger than the similarly obtained tractive force per unit weight, TB/MB , obtained by dividing the tractive force TB acting on the set B (23-02) by the weight MB of the set B (23-02). TA/MA and TB/MB are the acceleration of the set A (23-01) and the set B (23-02), respectively, when each of these sets runs independently. However, in the coupling operation mode shown in Fig. 23, since the interactive force acts on the sets A and B so that the sets A and B in the train run at the same acceleration, the set A (23-01) runs while this set is pulling the set B (23-02), and conversely, the set B (23-02) runs while this set is being pulled by the set A (23-01). Thus, this interactive force is loaded on the rolling-stock set-coupling device (23-03), which in turn may cause the strength degradation, due to fatigue, and defacement of this device.

[0331] Also, in Fig. 24, it is assumed that the tractive force per unit weight, TA/MA , of the set A(23-01), is weaker than the tractive force per unit weight, TB/MB , of the set B (23-02). This means that, in the coupling operation mode shown in Fig. 24, the set A (23-01) runs while this set is being pushed by the set B (23-02), and conversely, the set B (23-02) runs while this set is pushing the set A (23-01), which in turn badly affects on the rolling-stock set-coupling device (24-03).

[0332] On the other hand, in Fig. 25, it is assumed that the tractive force per unit weight, TA/MA , of the set A(23-01), is equal to the tractive force per unit weight, TB/MB , of the set B (23-02). This means that, in the coupling operation mode shown in Fig. 25, it is possible to realize the same acceleration in the set A (23-01) and the set B (23-02) in the whole train, without generation of an interactive force between these two sets. Thus, the bad effects of an interactive

force can be removed.

[0333] Although the case where the drive force output by the individual rolling-stock set-drive device is the tractive force carrying out the powering of the train in the above explanations of Figs. 23, 24, and 25, as per the braking force carrying out the braking of the train also, the similar dynamical phenomena appear. Even if the deceleration in all rolling-stock sets in the train is the same, the load on each rolling-stock set-coupling device, due to the force interacting between neighboring rolling-stock sets, and its bad effects, can be reduced by adjusting the distribution of the braking force output by the respective rolling-stock set-drive devices in the train.

[0334] As mentioned above, by adjusting the distribution of the drive force output by the respective rolling-stock set-drive devices in the train, it is possible to optimize the train-drive, in which while all the rolling-stock sets in the train are run at the same acceleration (in the powering-control), or the same deceleration (in the braking-control), the load on each rolling-stock set-coupling device for coupling neighboring sets can be reduced.

[0335] In this embodiment, based on the above analysis of the force acting among the sets in the train, the processes executed by the means for converting a control-command for a train to control-commands for respective individual rolling-stock sets, are prescribed as follows.

[0336] First, the conception of the processing executed by the means for converting a control-command for a train to control-commands for respective individual rolling-stock sets, is explained by the following equation.

[0337] In this embodiment, the control-command for a train in the powering-control is expressed by the tractive force per unit weight, $C_{\alpha\text{train}}$. Also, the control-command for a train in the braking-control is expressed by the braking force per unit weight, $C_{\beta\text{train}}$. Further, the control-command for each rolling-stock set i , ($i = A, B, \dots$ (for all sets in the train)), in the powering-control, is expressed by the tractive force per unit weight, $C_{\alpha i}$. Furthermore, the control-command for each rolling-stock set i in the braking-control is expressed by the tractive force per unit weight, $C_{\beta i}$.

[0338] Here, the weight of each rolling-stock set is denoted by M_i .

[0339] The relationships between the respective train-control commands and the control-commands for the respective set i , are expressed by the following equations.

$$C_{\alpha\text{train}} = \frac{\Sigma(C_{\alpha i} \times M_i)}{\Sigma(M_i)} \text{ (for the powering-control),} \quad (10)$$

$$C_{\beta\text{train}} = \frac{\Sigma(C_{\beta i} \times M_i)}{\Sigma(M_i)} \text{ (for the braking-control),} \quad (11)$$

[0340] The symbol Σ in the right hand side of the above equation means that a value or an equation in the parenthesis is summed for all possible i .

[0341] Each of the above equations is only one of the constraint conditions which obtain each control-control command $C_{\alpha i}$ or $C_{\beta i}$, prescribing the relationships between the train-control command $C_{\alpha\text{train}}$ or $C_{\beta\text{train}}$, and the control-commands $C_{\alpha i}$ or $C_{\beta i}$, for the respective set i , with the condition that $C_{\alpha\text{train}}$ or $C_{\beta\text{train}}$, is a weighted average value of the control-commands $C_{\alpha i}$ or $C_{\beta i}$, weighted by the weight values M_i for the respective set i . Therefore, the respective powering abilities (individual powering abilities) and braking abilities (individual braking abilities) for the respective individual rolling-stock sets i , are introduced as follows. In this embodiment, the maximum tractive and braking force per unit weight, $[\alpha_i]_{\max}(V)$ and $[\beta_i]_{\max}(V)$ which are functions of the running speed V , are used as the individual powering and braking abilities, respectively. Using those individual powering and braking abilities, other constraint conditions are given by the following inequalities.

$$C_{\alpha i} \leq [\alpha_i]_{\max}(V) \text{ (for the powering-control),} \quad (12)$$

$$C_{\beta i} \leq [\beta_i]_{\max}(V) \text{ (for the braking-control)}$$

[0342] The processing executed by the means for converting a control-command for a train to control-commands for respective individual rolling-stock sets, is given by the following propositions under the above constraint conditions.

$$\text{Minimize } \{\max(C_{\alpha i}) - \min(C_{\alpha i})\} \text{ (for the powering-control),} \quad (13)$$

$$\text{Minimize } \{\max(C_{\beta i}) - \min(C_{\beta i})\} \text{ (for the braking-control)}$$

[0343] The above $\max()$ and $\min()$ indicate the maximum and minimum values of values or equations in the parentheses for all i , respectively. The first proposition means that the distribution of $C_{\alpha i}$ should be determined so as to min-

imize the difference between the maximum and minimum values of $C_{\alpha i}$ for all i . Similarly, the second proposition means that the distribution of $C_{\beta i}$ should be determined so as to minimize the difference between the maximum and minimum values of $C_{\beta i}$ for all i .

[0344] Fig. 26 shows a flow chart of the powering-control executed by the means for converting a control-command for the whole train to control-commands for respective individual rolling-stock sets.

[0345] In the step (26-01), the train-control command $C_{\alpha \text{train}}$ is received.

[0346] In the step (26-02), the current running-speed V is received.

[0347] In the step (26-03), the table for describing information on the relationship between a train-control command and control-commands for respective individual rolling-stock sets is received.

[0348] In the step (26-04), the control-commands $C_{\alpha i}$ ($i = A, B$, (for all the sets in the train)) for the respective rolling-stock sets are obtained, corresponding to $C_{\alpha \text{train}}$ and V , by searching the table for describing information on the relationship between a train-control command and control-commands for respective individual rolling-stock sets.

[0349] In the step (26-05), the set of control-commands for all the rolling-stock sets obtained by accumulating the control-commands $C_{\alpha i}$ for the sets i is output.

[0350] Although the processing flow for the powering-control is shown in Fig. 26, only by replacing $C_{\alpha \text{train}}$ and $C_{\alpha i}$ with $C_{\beta \text{train}}$ and $C_{\beta i}$, respectively, the processing flow for the braking-control can be obtained.

[0351] Fig. 27 shows an example of the table describing information on the relationship between a control-command for a train and corresponding control-commands for respective individual rolling-stock sets, which is used in the processing shown in Fig. 26. The table shown in Fig. 27 relates to the powering-control, and describes a control-command $C_{\alpha i}$ for each set, corresponding to the argument of a pair of; the train-control command $C_{\alpha \text{train}}$ and the current running-speed V . Here, the table describing information on the relationship between a control-command for a train and corresponding control-commands for respective individual rolling-stock sets, relating to the braking-control, has the same data-structure as that of the table shown in Fig. 27.

[0352] Here, it is assumed that the processing shown in Fig. 26 is executed on real time during the running of the train. As known from Fig. 27, the basic element which implements the above means for converting a control-command for the whole train to control-commands for respective individual rolling-stock sets, is the information described in the table describing information on the relationship between a control-command for a train and corresponding control-commands for respective individual rolling-stock sets. In this embodiment, by generating the information in advance before the starting of the train, the means for converting a train-control command to a control-command for each set, has only to refer to the table in order to implement its function, and this can reduce the load on the means in real-time control.

[0353] Fig. 28 shows a flow chart of the process of generating the information described in the Table which is used in the processing shown in Fig. 26. In this embodiment, the above-explained process executed by the means for converting a control-command for the whole train to control-commands for respective individual rolling-stock sets is carried out to generate this information described in the table. Here, in this embodiment, the apparatus or device in which the function for executing the above information-generation for the table is not specified.

[0354] In step (28-01), the train-control command $C_{\alpha \text{train}}$ is set.

[0355] In step (28-02), the running speed V of the train is set.

[0356] In step (28-03), for all the individual rolling-stock sets i in the train, the maximum powering performance $[\alpha_i]_{\max}(V)$, representing the maximum tractive force per unit weight, with respect to V , and the weight values of the respective sets i , are gathered.

[0357] In step (28-04), the variables $C_{\alpha i}$ are set to $[\alpha_i]_{\max}(V)$ for all i .

[0358] In step (28-05), the sum total of $[\alpha_i]_{\max}(V) \times M_i$, and that of M_i , calculated for all i , are registered in intermediately used buffers 1 and 2, respectively.

[0359] In step (28-06), the following steps (28-07) - (28-09) are repeated while the inequality: the content of the buffer 1/ the content of the buffer 2 $> C_{\alpha \text{train}}$, is valid.

[0360] In step (28-07), the maximum $C_{\alpha i}$ is searched for all sets i , and the maximum value of $C_{\alpha i}$, and the number i , are registered.

[0361] In step (28-08), $\Delta\alpha \times M$ is subtracted from the content of the buffer 1. Here, $\Delta\alpha$ is a predetermined small quantity for changing α , related to $C_{\alpha i}$.

[0362] In step (28-09), $\Delta\alpha$ is subtracted from $C_{\alpha i}$.

[0363] In step (28-10), as the results of the above processes, the train-control command and control-commands for the respective sets i , with respect to the current running-speed V , are set to the obtained values of $C_{\alpha \text{train}}$ and $C_{\alpha i}$, respectively.

[0364] Although the processing flow for the powering-control is shown in Fig. 28, only by replacing $C_{\alpha \text{train}}$, $C_{\alpha i}$, $[\alpha_i]_{\max}(V)$, and $\Delta\alpha$, with $C_{\beta \text{train}}$, $C_{\beta i}$, $[\beta_i]_{\max}(V)$, and $\Delta\beta$, respectively, the processing flow for the braking-control can be obtained.

[0365] Figs. 29A and 29B conceptually show examples of the relationship between a train-control command and control commands for respective individual rolling-stock sets, which are obtained by the processing executed by the

above means for converting a train control-command to control commands for respective individual rolling-stock sets. Here, the train consist of the coupled sets A and B.

[0366] In Fig. 29A, bar graph (29-01) shows that the train-control command $C_{\alpha train}$ is set to the tractive force per unit weight, $\alpha 1$.

[0367] Bar graph (29-02) shows that the control-command for the set A is generated as $C_{\alpha A}$, corresponding to $C_{\alpha train}$. The value of $C_{\alpha A}$ is equal to the tractive force per unit weight $\alpha 1$, that is, the value of $C_{\alpha train}$.

[0368] Bar graph (29-03) shows that the control-command for the set A is generated as $C_{\alpha B}$, corresponding to $C_{\alpha train}$. The value of $C_{\alpha B}$ is equal to the tractive force per unit weight $\alpha 1$, that is, the value of $C_{\alpha train}$.

[0369] Since $C_{\alpha A}$ and $C_{\alpha B}$ are set to the same value as $C_{\alpha train}$, for the input $C_{\alpha train}$, as shown in bar graphs (29-01) - (29-03), the acceleration of the train composed of the sets A and B is equal to the acceleration at which the respective sets A and B are running when each set is operated separately. This means that there is no interactive force between the two sets A and B, and that the optimal train-driving state is realized.

[0370] On the other hand, in Fig. 29B, bar graph (29-01) shows that the train-control command $C_{\alpha train}$ is set to the tractive force per unit weight, $\alpha 2$.

[0371] Bar graph (29-05) shows that the control-command for the set A is generated as $C_{\alpha A}$, corresponding to $C_{\alpha train}$ shown by bar graph (29-04). In this example, since $C_{\alpha A}$ cannot attain $\alpha 2$, $C_{\alpha A}$ is set to the maximum tractive force per unit weight of the set A, that is, the maximum individual powering performance $[\alpha_A]_{max}(V)$. The reason is that the powering performance of the set A is comparatively lower among the sets in the train, and the value of $\alpha 2$ exceeds $[\alpha_A]_{max}(V)$. That is, this means that $C_{\alpha A}$ is output without subtracting any quantity from the value of $[\alpha_A]_{max}(V)$ set in step (28-04) in the processes of generating the table describing information on the relationship between respective control-commands for a train and corresponding control-commands for respective individual rolling-stock sets, shown in Fig. 28.

[0372] Bar graph (29-04) shows that the control-command for the set A is generated as $C_{\alpha B}$, corresponding to $C_{\alpha train}$ shown by bar graph (29-04). In this example, the value of $C_{\alpha B}$ exceeds $\alpha 2$. The reason is that since $C_{\alpha A}$ cannot attain $\alpha 2$, the value $C_{\alpha B}$ is set to a value, higher by an amount necessary to assure the required powering-performance $C_{\alpha train}$ ($= \alpha 2$) of the train as a whole, than $\alpha 2$. That is, the value $C_{\alpha B}$ is determined as a value such as that which optimally compensates the shortage of $C_{\alpha A}$, in steps (29-07) - (29-09), and the determined value $C_{\alpha B}$ is output. Here, the difference between $C_{\alpha A}$ and $C_{\alpha B}$ is expressed by the following equation, by taking the weight M_i of the respective sets i , based on the equation (10).

$$C_{\alpha B} - C_{\alpha A} = \frac{M_A + M_B}{M_B} (C_{\alpha train} - C_{\alpha A}) \quad (14)$$

[0373] The respective values of $C_{\alpha A}$ and $C_{\alpha B}$ are set to values different from $C_{\alpha train}$. This means that there exists an interactive force between the sets A and B when the train is operated in the coupling operation mode. However, since the difference between $C_{\alpha A}$ and $C_{\alpha B}$ is minimized, the optimal operation of the train can be realized under the given constraint conditions.

[0374] Although the processing flow for the powering-control is shown in Fig. 29, only by replacing $C_{\alpha train}$, $C_{\alpha A}$, and $[\alpha_A]_{max}(V)$, with $C_{\beta train}$, $C_{\beta B}$, and $[\beta_B]_{max}(V)$, respectively, can the processing flow for the braking-control be obtained.

[0375] As described above, according to the means for generating control commands for respective individual rolling-stock sets, of this embodiment, the control-commands $C_{\alpha A}$ and $C_{\alpha B}$, or $C_{\beta A}$ and $C_{\beta B}$, for the individual rolling-stock sets A and B, can be set to respective optimal values, corresponding to the train-control command $C_{\alpha train}$ or $C_{\beta train}$, by taking the difference between the powering performances of the sets A and B into account. That is, although the required control-command for the whole train is maintained, the dynamical load on each set can be minimized by the running-control executed by the means for generating control commands for respective individual rolling-stock sets, in which the powering performance proper to each set is considered.

[0376] Here, even if the train includes a single individual rolling-stock set, the control-command for the single rolling-stock set is set to the train-control command by the above calculation executed by the means for generating control-commands for respective individual rolling-stock sets of this embodiment.

[0377] As described above, the means for converting a train control-command to control commands for respective individual rolling-stock sets, of this embodiment, can generate the control-commands for the respective individual rolling-stock sets, adapted to the train composition state.

[0378] In the above description of this embodiment, as per the control-commands of the powering and braking controls, the powering performance, and braking performance, the means for generating control-commands for the respective individual rolling-stock sets, deals with the tractive force, and braking force, per unit weight. However, it is possible to deal with the tractive force, and braking force, per se, (not value per unit weight), concerning the control-commands of the powering control and the braking control, the powering performance, and braking performance. In the later deal-

ing, in this embodiment, the processes executed by the means for generating control-commands for the respective sets, which are represented by expressing the terms related to the control-commands of the powering control and the braking control, the powering performance, and braking performance with the tractive force, and braking force, per unit weight; are represented by expressing the above terms with the tractive force, and braking force, per se, (not value per unit weight). For example, as per the process of generating the table for describing information on the relationship between a train-control command and control-commands for respective sets, shown in Fig. 28, the process corresponding with the tractive force, per se, can be realized by carrying out the following variable-replacements, that is: the train-control command $C_{\alpha train}$ (the tractive force per unit weight) used in step (28-01) is replaced with the train-control command T_{train} (the tractive force, per se); the powering performances $[\alpha_A]_{max}(V)$ for the respective sets i (the tractive force per unit weight) used in step (28-03) is replaced with the powering ability (the maximum tractive force) $[T_{il}]_{max}(V)$; the powering performances $[\alpha_A]_{max}(V)$ for the respective sets i (the tractive force per unit weight) used in step (28-04) is replaced with $[T_{il}]_{max}(V) / M_i$; $[\alpha_i]_{max}(V) \times M_i$ used in step (28-05) is replaced with $[T_{il}]_{max}(V)$; $C_{\alpha train}$ used in step (28-06) is replaced with T_{train} /the content of the buffer 2; and $C_{\alpha i}$ used in step (28-10) is replaced with $C_{\alpha i} \times M_i$.

[0379] As described above, in this embodiment, the train-control system for controlling the running of a train includes; the train-control apparatus for creating a control-command to control the whole train in a lot; each individual rolling-stock set-control system which is provided in each individual rolling-stock set, for controlling the running of each set; and the integrated rolling-stock set-control system which stands between the train-control system and the individual rolling-stock set-control systems, for mediating the communication between the train-control system and each individual rolling-stock set-control system.

[0380] Further, in this embodiment, the integrated rolling-stock set-control system includes each rolling-stock set-coupling device for mechanically coupling two neighboring rolling-stock sets, and performing the sending/receiving of information between the two neighboring rolling-stock sets, and each integrated rolling-stock set-connection device for exchanging the information on the running-control of each set with each individual rolling-stock set directly or via the rolling-stock set-coupling devices.

[0381] Furthermore, in this embodiment, the integrated rolling-stock set-connection device mediates the exchange of information between the train-control apparatus and the individual rolling-stock set-control system, and performs the bi-directional conversion of the exchanged information.

[0382] Moreover, in this embodiment, the integrated rolling-stock set-connection device has the means for generating control-commands for respective individual rolling-stock sets, which receives the train-control command for controlling the train as a whole, and outputs the control-commands for the respective individual rolling-stock sets, corresponding to the train-control command

[0383] Also, in this embodiment, the means for generating control-commands for respective individual rolling-stock sets generates and outputs the control-commands for the respective sets, corresponding to the train-control command, by taking the different running-performances of the respective sets into consideration, such that the driving states of the respective sets, which are controlled by these control-commands, can reduce an interactive force between neighboring sets to as low as possible.

[0384] Thus, this embodiment can bring the following effects in addition to those obtained by the embodiment 1.

[0385] As shown in the explanation of this embodiment, since the integrated rolling-stock set-control system includes the integrated rolling-stock set-connection device which also includes the means for generating control-commands for respective individual rolling-stock sets, the train control for controlling the train as a whole, realized by integrating the controls of the respective sets, can be implemented while taking the different running-performances of the respective sets into account. In this way, it is possible to realize the optimal driving-state of each set, responding to the running-state of the whole train, instructed by the train-control command, while reflecting the train composition state.

[0386] In an example of the optimal driving-state, the control-commands for the respective sets, responding to the train-control command, can be created so as to minimize the interactive force between the sets in the train. This reduces the load on the rolling-stock set-coupling devices, which mechanically couple the neighboring sets, which in turn can extend a life time of the rolling-stock set-coupling devices, and contribute to the reduction of man power for maintenance work on the train.

Embodiment 5:

[0387] In the above embodiment 4, in the integrated rolling-stock set-control system situated in the train-control system according to the present invention, by providing the integrated rolling-stock set-connection device, which includes the means for generating control-commands for the respective individual rolling-stock sets, such as that described in the above embodiment 4, it is possible to create the control-commands for the respective sets, responding to the running-state of the whole train, instructed by the train-control command, while reflecting the train composition state, so as to minimize the interactive force between neighboring sets in the train. Thus, the running control of the train can be optimized, while reflecting the train composition state, even if the operation mode changes between the dividing

and coupling operation modes.

[0388] In the embodiment 5, although an integrated rolling-stock set-connection device is similar to the integrated rolling-stock set-connection device of the embodiment 4, the train-control command and the control-commands for the respective sets are executed by a notch control command.

[0389] In an integrated rolling-stock set-control system situated in the train-control system according to the present invention, its composition concerning apparatus and devices, or processing means, is the same as that in the embodiment 4.

[0390] A means for converting a train-control command to control-commands for respective individual rolling-stock sets, provided in a means for generating control-commands for respective sets situated in the integrated rolling-stock set-control system of this embodiment, will be explained in the following.

[0391] First, the means for converting a train-control command to control-commands for respective sets of this embodiment is explained below.

[0392] In the embodiment 5 as well as the embodiment 4, by adjusting the distribution of the drive force, output by the respective rolling-stock set-drive devices in the train, it is possible to optimize the train-drive, in which, while all the rolling-stock sets in the train are run at the same acceleration (in the powering-control), or the same deceleration (in the braking-control), the load on each rolling-stock set-coupling device for coupling neighboring sets can be reduced.

[0393] In this embodiment, based on the above analysis of the force acting among the sets in the train, the processes executed by the means for converting a control-command for a train to control-commands for respective individual rolling-stock sets, are prescribed as follows.

[0394] First, the conception of the processes related to the powering control, executed by the means for converting a control-command for a train to control-commands for respective individual rolling-stock sets, is explained by the following equation. Meanwhile, the processes related to the braking control can be described simply by replacing the variables used in the powering control with the variables used in the braking control. Therefore, the detailed explanation concerning the braking control is omitted.

[0395] Here, as per the powering control, the train-control command is indicated with the notch number n_{train} which indicates the number instructed in the notch control command for the powering control. Further, the control-commands for the respective sets i ($i = A, B, \dots$ (for all the sets in the train)) are indicated with n_i .

[0396] In this embodiment, the running performance (the train running-performance) of the train in the powering control is represented by the tractive force per unit weight, $\alpha_{train, n_{train}}(V)$, of the whole train, with respect to the assumed running-speed V and the train-control notch command, n_{train} . Also, the running performances (the individual set running-performance) of the respective sets are represented by the tractive force per unit weight, $\alpha_{i, n_i}(V)$, of each set i , with respect to the assumed running-speed V and the individual set-control notch command, n_i . Further, the weight of each set i is denoted by M_i .

[0397] The relationship between the train-control command n_{train} and the control-command n_i of each individual rolling-stock set i is expressed with the following equation.

$$\alpha_{train, n_{train}}(V) = \frac{\sum(\alpha_{i, n_i}(V) \times M_i)}{\sum(M_i)} \text{ (for the powering -control)} \quad (15)$$

[0398] The symbol Σ in the right hand side of the above equation means that a value or an equation in the parenthesis is summed for all possible i .

[0399] The group of the above equations is only one of the constraint conditions to obtain respective control-commands $\alpha_{i, n_i}(V)$, prescribing the relationships between the train-control command n_{train} , and the individual set running-performances $\alpha_{i, n_i}(V)$, for the respective set i , with the condition that the train powering-performance $\alpha_{train, n_{train}}(V)$ is a weighted average value of the individual set running-performances $\alpha_{i, n_i}(V)$, weighted by the weight values M_i for the respective set i . Therefore, the relationship between the individual set control-commands n_i and the maximum number (corresponding to the maximum notch) of n_i , expressed with the following equation, is set as another constraint condition.

$$n_i \leq N_i \text{ (for the powering-control)} \quad (16)$$

[0400] The processing executed by the means for converting a control-command for a train to control-commands for respective individual rolling-stock sets, is given by the following propositions under the above constraint conditions.

$$\text{Minimize } \{\max(\alpha_{i, n_i}(V)) - \min(\alpha_{i, n_i}(V))\} \text{ (for the powering-control)} \quad (17)$$

[0401] The above $\max()$ and $\min()$ indicate the maximum and minimum values of values or equations in the paren-

theses for all i , respectively. The proposition means that the distribution of $\alpha_{i, n_i}(V)$ corresponding to n_i , should be determined so as to minimize the difference between the maximum and minimum values of $\alpha_{i, n_i}(V)$ for all i .

[0402] Fig. 30 shows a flow chart of the powering-control executed by the means for converting a control-command for the whole train to control-commands for respective individual rolling-stock sets.

[0403] In step (30-01), the train-control command n_{train} is received.

[0404] In step (30-02), the current value of the running speed V is received.

[0405] In the step (30-03), the table for describing information on the relationship between a train-control command and control-commands for respective individual rolling-stock sets is received.

[0406] In the step (30-04), the control-commands n_i ($i = A, B$, (for all the sets in the train)) for the respective rolling-stock sets are obtained, corresponding to n_{train} and V , by searching the received table.

[0407] In the step (30-05), the set of control-commands for all the rolling-stock sets obtained by accumulating the control-commands n_i for the sets i is output.

[0408] Fig. 31 shows an example of the table describing information on the relationship between a control-command for a train and corresponding control-commands for respective individual rolling-stock sets, which is used in the processing shown in Fig. 30. The table shown in Fig. 30 relates to the powering-control, and describes a control-command n_i for each set, corresponding to the argument of a pair of the train-control command n_{train} and the current running-speed V . Here, the table describing information on the relationship between a control-command for a train and corresponding control-commands for respective individual rolling-stock sets, relating to the braking-control, has the same data-structure as that of the table shown in Fig 31.

[0409] Here, it is assumed that the processing shown in Fig. 30 is executed in real time during the running of the train. As known from Fig. 30, the basic element which implements the above means for converting a control-command for the whole train to control-commands for respective individual rolling-stock sets, is the information described in the table describing information on the relationship between a control-command for a train and corresponding control-commands for respective individual rolling-stock sets. In this embodiment, by generating the information in advance before the starting of the train, the means for converting a train-control command to a control-command for each set has only to refer to the table in order to implement its function, and this can reduce the load on the means in the real-time control.

[0410] Fig. 32 shows a flow chart of the process of generating the information described in the Table which is used in the processing shown in Fig. 30. In this embodiment, the above-explained process executed by the means for converting a control-command for the whole train to control-commands for respective individual rolling-stock sets is carried out to generate this information described in the table. Here, in this embodiment, the apparatus or device in which the function for executing the above information-generation for the table is not specified.

[0411] In step (32-01), the train-control command is set to n_{train} .

[0412] In step (32-02), the running speed is set to the current value V .

[0413] In step (32-03), the train powering-performance $\alpha_{train, n_{train}}(V)$ with respect to n_{train} and V is taken in.

[0414] In step (32-04), the powering-performances (the tractive force per unit weight) $\alpha_{i, n_i}(V)$ for all sets with respect to all combinations of the control commands n_i for the respective sets i and V , and the weight of each set, are taken in.

[0415] In step (32-05), the maximum value N_i in the control commands for the respective sets is taken in.

[0416] In step (32-06), the variables n_i for all i is set to N_i .

[0417] In step (32-07), the sum total of $\alpha_{i, n_i}(V) \times M_i$ for all i is registered in the intermediately used buffer 1, and the sum total of M_i for all i is registered in the intermediately used buffer 2.

[0418] In step (32-08), the following steps (32-09) - (32-11) are repeated while the inequality: the content of the buffer 1/ the content of the buffer 2 $> \alpha_{train, n_{train}}(V)$, is valid.

[0419] In step (32-09), the maximum $\alpha_{i, n_i}(V)$ is searched for all sets i , and the maximum value of $\alpha_{i, n_i}(V)$, and the number i , are registered.

[0420] In step (32-10), $\alpha_{i, n_i}(V) \times M$ is subtracted from the content of the buffer 1, and $\alpha_{i-1, n_i}(V) \times M$ is further added to the content of the buffer 1.

[0421] In step (32-11), 1 is subtracted from n_i .

[0422] In step (32-12), as the results of the above processes, the train-control command and control-commands for the respective sets i , with respect to the current running-speed V , are set to the obtained values of n_{train} and n_i , respectively.

[0423] Figs. 33A and 33B conceptually show examples of the relationship between the train-control command and the control commands for the respective individual rolling-stock sets, which are obtained by the processing executed by the above means for converting a train control-command to control commands for respective individual rolling-stock sets. Here, the train consist of the coupled sets A and B.

[0424] In Figs. 33A and 33B, the notch number n_{train} of the train-control command is set to 9, and the current running-speed is denoted by V .

[0425] In Fig. 33A, the curves (33-11), (33-12), and (33-13) indicate the individual set powering-performances corresponding to the notch number nA of 8, 9, and 10, respectively, in the plane of tractive force per unit weight - running speed.

[0426] Also, the curves (33-21), (33-22), and (33-23) indicate the individual set powering-performances corresponding to the notch number nB of 8, 9, and 10, respectively, in the plane of tractive force per unit weight - running speed.

[0427] When the notch numbers nA and nB are set to the ntrain of 9, based on the curves (33-11) - (33-13), and the curves (33-21) - (33-23), the tractive force per unit weight of the sets A and B are indicated by the solid-line curves (33-12) and (33-22). If the value of $\alpha_{A, 9}(V)$ at the point of the speed V in the curve (33-12) is compared with the value of $\alpha_{B, 9}(V)$ at the point of the speed V in the curve (33-22), there is the difference (33-31) of scores of percentage points between both the values. This large difference means the generation of an interactive force between the sets A and B, which in turn will cause a damage to the rolling-stock set-coupling devices.

[0428] Moreover, in Fig. 33B, the curves (33-14), (33-15), and (33-16) indicate the individual set powering-performances corresponding to the notch number nA of 8, 9, and 10, respectively, in the plane of tractive force per unit weight - running speed.

[0429] Also, the curves (33-24), (33-25), and (33-26) indicate the individual set powering-performances corresponding to the notch number nB of 8, 9, and 10, respectively, in the plane of tractive force per unit weight - running speed.

[0430] In this embodiment, the notch numbers nA and nB are set to 10 and 9, respectively, by the means for generating control-commands for each set, based on the curves (33-14) - (33-16), and the curves (33-24) - (33-26). The tractive force per unit weight, of the sets A and B, are indicated by the solid-line curves (33-16) and (33-24). If the value of $\alpha_{A, 10}(V)$ at the point of the speed V in the curve (33-16) is compared with the value of $\alpha_{B, 9}(V)$ at the point of the speed V in the curve (33-24), the difference (33-32) between both the values is almost zero. In this control, there is no interactive force between the sets A and B, that is, no load is applied on the rolling-stock set-coupling devices.

[0431] The above control in which the control-commands for the respective sets A and B are set to the train-control command ntrain of 9 without any modification is generally performed for the coupling operation mode by the conventional techniques.

[0432] On the other hand, in the control in which the control-commands for the respective sets A and B are set to 10 and 8, converted from the train-control command ntrain of 9 by the means for generating control-commands for each set of this embodiment, the same control-command as that in the conventional techniques is given for the running-control of the train as a whole, and the acceleration of the whole train is also the same as that in the conventional techniques.

[0433] However, as per the respective rolling-stock sets in the train, there is the difference in the distribution of force acting on the respective sets, between the case where the control-commands for the respective sets with different running-performances are always set to the same notch and the case where the control-commands for the respective sets are set to proper different notches, respectively, by taking their different running-performances into consideration. That is, the dynamic load on the respective sets greatly changes depending on whether or not the running control is implemented by taking their different running-performances into consideration.

[0434] The means for generating control-commands for the respective individual rolling-stock sets can create the control-commands for the respective sets in the train, corresponding to one notch number given as the train-control command, and by performing the processes of determining the notches for the respective sets in the manner such as that shown in Fig. 32, the distribution of the dynamic loads on the respective sets can be optimized, adapted to the train composition state. Here, even if the train includes a single individual rolling-stock set, the control-command for the single rolling-stock set is set to the train-control command by the above calculation executed by the means for generating control-commands for respective individual rolling-stock sets of this embodiment.

[0435] As described above, the means converting a train control-command to control commands for respective individual rolling-stock sets, of this embodiment, can generate the control-commands for the respective individual rolling-stock sets, adapted to the train composition state.

[0436] In the above description of this embodiment, as per the powering performance, and braking performance, the means for generating control-commands for the respective individual rolling-stock sets, deals with the tractive force, and braking force, per unit weight. However, it is possible to deal with the tractive force, and braking force, per se, (not value per unit weight), concerning the powering performance, and braking performance. In the later dealing, in this embodiment, the processes executed by the means for generating control-commands for the respective sets, which are represented by expressing the terms related to the powering performance, and braking performance with the tractive force, and braking force, per unit weight; are represented by expressing the above terms with the tractive force, and braking force, per se, (not value per unit weight). For example, as per the process of generating the table for describing information on the relationship between a train-control command and control-commands for respective sets, shown in Fig. 32, the process corresponding with the tractive force, per se, can be realized by carrying out the following variable-

replacements, that is: the train powering performance $\alpha_{\text{train}, \text{ntrain}}(V)$ (the tractive force per unit weight) used in step (32-03) is replaced with the train-control command $T_{\text{train}, \text{ntrain}}(V)$ (the tractive force, per se); the powering performances $\alpha_{i, \text{ni}}(V)$ for the respective sets i (the tractive force per unit weight) used in step (32-04) is replaced with the powering ability $T_{i, \text{ni}}(V)$ for the respective sets i ; $\alpha_{i, \text{Ni}}(V) \times M_i$ used in step (32-07) is replaced with $T_{i, \text{Ni}}(V)$; $\alpha_{\text{train}, \text{ntrain}}(V)$ used in step (32-08) is replaced with $T_{\text{train}, \text{ntrain}}(V)$ /the content of the buffer 2; $\alpha_{i, \text{ni}}(V)$ used in step (32-09) is replaced with $T_{i, \text{ni}}(V)/M_i$; and $\alpha_{i, \text{ni}}(V) \times M_i$ and $\alpha_{i, \text{ni}-1}(V) \times M_i$ used in step (32-10) are replaced with $T_{i, \text{ni}}(V)$ and $T_{i, \text{ni}-1}(V)$, respectively.

[0437] As described above, the train-control system of this embodiment has the following effects on the running-control of a train in addition to the effects of the train-control system including the integrated rolling-stock set-control system, of the embodiment 4.

[0438] That is, according to this embodiment, the effects of the embodiment 4 can be obtained in the running-control of the train composed of individual rolling-stock sets each of which is equipped with a notch-operation device, by the means for generating control-commands for each set of this embodiment.

Embodiment 6:

[0439] In the above embodiment 4 or embodiment 5, in the integrated rolling-stock set-control system situated in the train-control system according to the present invention, by providing the integrated rolling-stock set-connection device including the means for generating control-commands for the respective individual rolling-stock sets, such as that described in the above embodiment 4 or embodiment 5, it is possible to create the control-commands for the respective sets, responding to the running-state of the whole train, instructed by the train-control command, while reflecting the train composition state, so as to minimize the interactive force between neighboring sets in the train. Thus, the running control of the train can be optimized, while reflecting the train composition state, even if the operation mode changes between the dividing and coupling operation modes.

[0440] The integrated rolling-stock set-control system of the embodiment 6 is similar to those of the embodiments 4 and 5. However, the means for generating control-commands for each set of this embodiment includes a means for generating the table describing information on the relationship between a train-control command and control-commands for respective individual rolling-stock sets, different from the means for generating control-commands for each set of the embodiments 4 and 5. This means for generating the table is explained below.

[0441] In accordance with the addition of the above processing means, the means for generating control-commands for each set situated in the integrated rolling-stock set-connection device of this embodiment, receives a train-control command, running-speed information, information designating a master set, train-performance information, and a set of performance information of all the individual sets, from the means for registering a train-control command, the means for registering information on the running state of a train, the means for registering information designating a master set, the means for registering information on the performance of the whole train, and the means for registering a set of information on the performance of the whole train, respectively. Further, the means for generating control-commands for each set generates control-commands that control the running-operations of the respective individual rolling-stock sets composing the train. Furthermore, a set of control-commands for all sets is generated by accumulating the control-commands for the respective sets in the train, and is sent to the means for registering information on the performance of the whole train.

[0442] The composition of processing means provided in the means for generating control-commands for the respective sets, situated in the integrated rolling-stock set-connection device in the integrated rolling-stock set-control system; and the processes executed by those processing means, which is provided in the device; are explained below.

[0443] Fig. 34 shows the functional composition of the means for generating information on the performance of the whole train in this embodiment.

[0444] The means (34-01) for generating control-commands for individual rolling-stock sets includes a means (34-02) for determining a master rolling-stock set, a means (34-03) for generating information on the relationship between a control-command for a train and control-commands for respective individual rolling-stock sets, a means (34-04) for registering information on the relationship between a train-control command and control-commands for respective individual rolling-stock sets, and a means (34-05) for converting a train-control-command to control-commands for respective individual rolling-stock sets.

[0445] The function and detailed processes of the means (34-02) for determining a master rolling-stock set is the same as those of the corresponding means in the embodiments 4 and 5.

[0446] The means (34-03) for generating information on the relationship between a control-command for a train and control-commands for respective individual rolling-stock sets, receives information (34-14) on the running-performance of the whole train, and a set of information (34-15) on running-performances of all the sets, obtained by accumulating the running-performances of the respective rolling-stock sets in the train, the information (34-14) and the information (34-15) being generated outside the means (34-01) for generating control-commands for individual rolling-stock sets. The means (34-03) for generating information on the relationship between a train-control command and control-com-

mands for respective individual rolling-stock sets, generates information (34-16) on the relationship between each of the various contents contained in the train control-command, and control-commands corresponding to each content of the train-control command, for respective individual rolling-stock sets, based on the information (34-14) and the information (34-15). Further, the generated information (34-16) is sent to the means (34-05) for converting a control-command for a train to control-commands for respective individual rolling-stock sets.

[0447] The means (34-04) for registering information on the relationship between a train-control command and control-commands for respective individual rolling-stock sets, receives the information (34-16) from the means (34-03) for generating information on the relationship between a train-control command and control-commands for respective individual rolling-stock sets, and registers it in a table (34-17) for describing information on the relationship between the train control-command and control-commands for respective individual rolling-stock sets, which is managed by the means (34-04). This table (34-17) is referred to by the means (34-05) for converting a control-command for a train to control-commands for respective individual rolling-stock sets.

[0448] The function and detailed processes of the means (34-05) for converting a control-command for a train is the same as those of the corresponding means in the embodiments 4 and 5.

[0449] Further, the processes executed by the means (34-03) for generating information on the relationship between a control-command for a train and control-commands for respective individual rolling-stock sets, situated in the means (34-01) for generating control-commands for individual rolling-stock sets, is explained below.

[0450] The processes executed by the means (34-03) are the same as those executed by the means for generating the contents described in the table for describing information on the relationship between a train-control command and control-commands for the respective sets, which are explained for the embodiments 4 and 5. That is, the processes executed by the means (34-03) can be explained in the same manner as the processes shown in Fig. 28 for the embodiment 4, or those shown in Fig. 32 for the embodiment 5. Meanwhile, the maximum notch number N_i of the control-commands, the powering performances $\alpha_{i, ni}(V)$, information on performances of all sets, and the weight M_i , for the respective sets i , which are used in step (28-03) in Fig. 28 for the embodiment 4, or steps (32-04) and (32-05) for the embodiment 5, are acquired by referring to the set of information on performances of all sets, received from the means for registering a set of information on performances of all sets. Further, the powering performance $\alpha_{train, ntrain}(V)$, used in step (32-03) in Fig. 28 for the embodiment 5, is acquired by referring to the train-performance information, received from the means for registering information on the performance of the whole train.

[0451] As per the braking control, simply by replacing the variables used in the powering control with those used in the braking control, a similar explanation of the control processes is available.

[0452] Here, even if the train includes a single individual rolling-stock set, the control-command for the single rolling-stock set is set to the train-control command by the above calculation executed by the means for generating control-commands for respective individual rolling-stock sets of this embodiment.

[0453] As described above, the means converting a train control-command to control commands for respective individual rolling-stock sets, of this embodiment, can generate the control-commands for the respective individual rolling-stock sets, adapted to the train composition state.

[0454] Further, the means for generating control-commands for the respective sets of this embodiment performs its information-processing by always referring to both the information on running-performances of all the individual rolling-stock sets in a train, and the information on the running-performance of the whole train. Accordingly, for a train in which the information on the running-performance of the train as a whole, and the information on running-performances of all individual sets composing the train, can be acquired, even if the train is composed of any types or any numbers of rolling-stock sets, the means for generating control-commands for the respective sets of this embodiment can generate control-commands for the respective sets, properly adapted to the train composition state. Here, by incorporating the features of the train-control system of the embodiment 1 or 2 into the train-control system of this embodiment, a more effective train-control system can be created.

[0455] The integrated rolling-stock set-control system in the train-control system, of this embodiment, can bring about the following effects in addition to those of the embodiment 4 or 5.

[0456] This embodiment can bring about the same effects as those of the embodiment 4 or 5, onto the running-control of a train composed of more extensive types of rolling-stock sets. That is, according to this embodiment, the co-operative control, which has been implemented only for a predetermined combination of rolling-stock sets by the conventional control techniques, can be applied to a train composed of any types or any numbers of rolling-stock sets. This is because it has become possible in accordance with this embodiment to generate the information on the relationship between a train-control command and control-commands for the respective sets, suited to the occasion, in the train-control system, by performing the information-processing while always referring to both the information on running-performances of all the individual rolling-stock sets in a train, and the information on the running-performance of the whole train. Thus, for example, even if a combination of rolling-stock sets, which has not been assumed in the operational plan, is used for the coupling operation mode of the train, the running-control of the train with such a combination of sets, properly reflecting the renewed train-composition state, becomes possible by immediately recognizing the new

relationship between a train-control command and control-commands for the respective sets, just after the renewed combination of the sets has been implemented.

Embodiment 7:

[0457] The integrated rolling-stock set-control system of the embodiment 7 is similar to those of the embodiments 4, 5, and 6. However, the means, which is explained for the embodiment 6, for generating a table describing information on the relationship between a train-control command and control-commands for respective sets, the table being used in the means for generating control-commands for respective set of the embodiments 4 and 5, is situated in the outside of the means for generating control-commands for the respective sets of this embodiment. This embodiment is explained below.

[0458] In accordance with the addition of the above processing means, the means for generating control-commands for each set situated in the integrated rolling-stock set-connection device of this embodiment, receives a train-control command, running-speed information, information designating a master set, and information on the relationship between a train-control command and control-commands for the respective sets, from the means for registering a train-control command, the means for registering information on the running state of a train, the means for registering information designating a master set, and the means for generating information on the relationship between a train-control command and control-commands for the respective sets, respectively. Further, the means for generating control-commands for each set generates control-commands that control the running-operations of the respective individual rolling-stock sets composing the train, based on the received information. Furthermore, a set of control-commands for all sets is generated by accumulating the control-commands for the respective sets in the train, and is sent to the means for registering information on the performance of the whole train.

[0459] The composition of processing means related to the means for generating control-commands for the respective sets, situated in the integrated rolling-stock set-connection device in the integrated rolling-stock set-control system; and the processes executed by those processing means; are explained below.

[0460] Fig. 35 shows the functional composition of the means for generating information on the performance of the whole train in this embodiment.

[0461] The means (35-01) for generating control-commands for individual rolling-stock sets includes a means (35-02) for determining a master rolling-stock set, a means (35-04) for registering information on the relationship between a train-control command and control-commands for respective individual rolling-stock sets, and a means (35-05) for converting a train-control-command to control-commands for respective individual rolling-stock sets.

[0462] The function and detailed processes of the means (35-02) for determining a master rolling-stock set is the same as those of the corresponding means in the embodiments 4 and 5.

[0463] The means (35-04) for registering information on the relationship between a train-control command and control-commands for respective individual rolling-stock sets, receives information (35-16) on the relationship between a train-control command and control-commands for respective individual rolling-stock sets, from a means (35-03) for generating information on the relationship between a train-control command and control-commands for respective individual rolling-stock sets; and registers in a table (35-17) for describing information on the relationship between a train control-command and control-commands for respective individual rolling-stock sets, which is managed by the means (35-04). This table (35-17) is referred to by the means (35-05) for converting a control-command for a train to control-commands for respective individual rolling-stock sets.

[0464] The function and detailed processes of the means (35-05) for converting a control-command for a train to control-commands is the same as those of the corresponding means in the embodiments 4 and 5.

[0465] Next, the processes executed by the means for generating information on the relationship between a train-control command and control-commands for the respective sets of this embodiment are explained below.

[0466] The processes executed by this means are the same as those executed by the processes executed by the means for generating information on the relationship between a train-control command and control-commands for the respective sets of this embodiment, explained for the embodiment 6.

[0467] Further, the explanation for the processes of the braking control can be done in the same manner as that of the powering control simply by replacing the variables used in the powering control with the variables used in the braking control.

[0468] Here, even if the train includes a single individual rolling-stock set, the control-command for the single rolling-stock set is set to the train-control command without any processing of it, by the above calculation executed by the means for generating information on the relationship between a train-control command and control-commands for the respective sets, and the means for generating control-commands for respective sets, which refers to the information on the relationship between a train-control command and control-commands for the respective sets, sent from the former means, of this embodiment.

[0469] As described above, the means for generating control-commands for respective sets, of this embodiment,

can generate the control-commands for the respective individual rolling-stock sets, corresponding the given train-control command, adapted to the train composition state.

[0470] Further, the means for generating control-commands for the respective sets of this embodiment performs its information-processing by always referring to both the information on running-performances of all-the individual rolling-stock sets in a train, and the information on the running-performance of the whole train. Accordingly, for a train in which the information on the running-performance of the train as a whole, and the information on running-performances of all individual sets composing the train, can be acquired, even if the train is composed of any types or any numbers of rolling-stock sets, the means for generating control-commands for the respective sets of this embodiment can generate control-commands for the respective sets, properly adapted to the train composition state. Here, by incorporating the features of the train-control system of the embodiment 1 or 2 into the train-control system of this embodiment, a more effective train-control system can be created.

[0471] The integrated rolling-stock set-control system in the train-control system, of this embodiment, can bring about the same effects as those of the embodiment in addition to those of the embodiment 4 or 5, by using the different means.

Embodiment 8:

[0472] The integrated rolling-stock set-control system of the embodiment 7 is similar to those of the embodiments 4, 5, 6, and 7. However, in the embodiment 8, the means for generating control-commands for respective sets, which is explained for the embodiments 4 and 5, does not use the table describing information on the relationship between a train-control command and control-commands for respective set, and directly generates control-commands for the respective sets in response to a train-control command every control cycle. This embodiment is explained below.

[0473] In accordance with the addition of the above processing means, the means for generating control-commands for each set situated in the integrated rolling-stock set-connection device of this embodiment, receives a train-control command, running-speed information, information designating a master set, train-performance information, and a set of information on performances of all sets, from the means for registering a train-control command, the means for registering information on the running state of a train, the means for registering information designating a master set, the means for registering information on the performance of the whole train, and the means for registering a set of information on performances of all sets, respectively. Further, the means for generating control-commands for each set generates control-commands that control the running-operations of the respective individual rolling-stock sets composing the train, based on the received information. Furthermore, a set of control-commands for all sets is generated by accumulating the control-commands for the respective sets in the train, and is sent to the means for registering information on the performance of the whole train.

[0474] Also, the composition of processing means related to the means for generating control-commands for the respective sets, situated in the integrated rolling-stock set-connection device in the integrated rolling-stock set-control system; and the processes executed by those processing means; are explained below.

[0475] Fig. 36 shows the functional composition of the means for generating information on the performance of the whole train in this embodiment.

[0476] The means (36-01) for generating control-commands for individual rolling-stock sets includes a means (36-02) for determining a master rolling-stock set, and a means (36-05) for converting a train-control-command to control-commands for respective individual rolling-stock sets.

[0477] The function and detailed processes of the means (36-02) for determining a master rolling-stock set is the same as those of the corresponding means in the embodiments 4 and 5.

[0478] A means (36-04) for converting a train-control command to control-commands for respective sets receives a train-control command (36-11) output from the means (36-02) determining a master rolling-stock set; and running-speed information (36-13), information (36-14) on the performance of the whole train, and a set of information (36-15) on performances of all sets, generated outside the means (36-01) for generating control-commands for individual rolling-stock sets. Further, the means (36-04) determines whether or not the train-control command (36-11) output from the means (36-02) determining a master rolling-stock set is received. Furthermore, if the train-control command (36-11) is received, the means (36-04) generates control-commands for the respective sets corresponding to the train-control command (36-11), and sends a set (36-21) of control-commands for all the sets, obtained by accumulating the generated control-commands for the respective sets. Conversely, if no train-control command (36-11) has been received, the means (36-04) sends no information to its outside.

[0479] Next, the processes executed by the means for converting a train-control command to control-commands for respective sets situated in the means for generating control-commands for the respective sets of this embodiment is explained below.

[0480] The processes executed by the means for converting a train-control command to control-commands for respective sets of this embodiment, are the same as those used for generating the contents of the table for describing

information on the relationship between a train-control command and control-commands for the respective sets, which are explained for the embodiments 4 and 5. That is, Fig. 28 and its explanation in the embodiment 4, or Fig. 32 and its explanation in the embodiment 5, can be applied to the explanation of the processes executed by the means for converting a train-control command to control-commands for respective sets of this embodiment. Meanwhile, the maximum value N_i of the control-commands $\alpha_{i, n_i}(V)$ for the respective sets, the powering performances, and the weight M_i of each set, which are obtained in step (28-03) shown in Fig. 28 for the embodiment 4, or in steps (32-04) and (32-05) shown in Fig. 32 for the embodiment 5, is acquired by referring to the set of information on performances of all the sets received from the means for registering a set of information on performances of all sets; and the train powering-performance $\alpha_{\text{train}, n_{\text{train}}}(V)$ is acquired by referring to the information on the performance of the whole train.

[0481] Further, the explanation for the processes of the braking control can be done in the same manner as that of the powering control simply by replacing the variables used in the powering control with the variables used in the braking control.

[0482] Here, even if the train includes a single individual rolling-stock set, the control-command for the single rolling-stock set is set to the train-control command without any processing of it, by the above means for generating control-commands for respective sets of this embodiment.

[0483] As described above, the means for generating control-commands for respective sets of this embodiment, can generate the control-commands for the respective individual rolling-stock sets, corresponding to the given train-control command, adapted to the train composition state.

[0484] Further, the means for generating control-commands for the respective sets of this embodiment performs its information-processing by always referring to both the information on the running-performances of all the individual rolling-stock sets in a train, and the information on the running-performance of the whole train. Accordingly, for a train in which the information on the running-performance of the train as a whole, and the information on running-performances of all individual sets composing the train, can be acquired, even if the train is composed of any types or any numbers of rolling-stock sets, the means for generating control-commands for the respective sets of this embodiment can generate control-commands for the respective sets, properly adapted to the train composition state. Here, by incorporating the features of the train-control system of the embodiment 1 or 2 into the train-control system of this embodiment, a more effective train-control system can be created.

[0485] The integrated rolling-stock set-control system in the train-control system, of this embodiment, can bring about the same effects as those of the embodiment in addition to those of the embodiment 4 or 5, by using the different means.

[0486] Further, this embodiment can bring about the following effects in addition to the above effects.

[0487] That is, the above-explained processes for generating the control-commands for the respective sets can create finely-adjusted control-commands for the respective sets even if the train-control command is continuously given. In the conventional train-control methods, a stepwise control command such as a notch control-command is generally given. Therefore, a table for describing the relationship between a train-control command, which takes discrete values, and control-commands for respective sets, is useful for the embodiment 4 and 5. On the other hand, in a train-control method to be adopted in the future, it is predicted that the control of a train will advance to a finer running-control which instructs a continuously-valued control-command, in addition to an instruction of a torque value or an acceleration value. To cope with the above-predicted advance in the train-control, by implementing the processes of directly generating control-commands for respective individual rolling-stock sets in each control cycle during the running of a train, this embodiment, according to the present invention, can provide a train-control system which can also correspond with a train-control command with continuous values, and flexibly with the switching between the dividing and coupling operation modes.

Embodiment 9:

[0488] In this embodiment, the train-control system includes a train-control apparatus for creating a train-control command that controls the running of a train as a whole, and an integrated rolling-stock set-control system that receives the train-control command, and controls rolling-stock sets in the train, respectively, adapted to the train composition state.

[0489] The integrated rolling-stock set-control system of this embodiment receives the train-control command from the train-control apparatus, and performs the running-control of each set in the train, based on the received train-control command. The above running-control of each set is performed corresponding with the set-composition of the train, by using the method of generating control-commands for respective sets, provided in the integrated rolling-stock set-control system in any one of the embodiments 4 - 8.

[0490] Further, the integrated rolling-stock set-control system of this embodiment generates information on the whole train, representing the running-performance of the train as a whole, from information on running-performances of respective individual rolling-stock sets in the train, and sends the generated information to the train-control apparatus.

tus. The generation of the above information is performed according with the set-composition of the train, by using the method of generating information on the whole train, provided in the integrated rolling-stock set-control system in either the embodiment 2 or 3.

[0491] The above integrated rolling-stock set-control system can also be composed by integrating the integrated rolling-stock set-control system in any one of the embodiments 1 - 8, with the individual rolling-stock set-control system, situated in each set, that controls the running of each set. That is, the above integrated rolling-stock set-control system includes the integrated rolling-stock set-connection devices and the rolling-stock set-coupling devices in any one of the embodiments 1 - 8, and the devices included in each individual rolling-stock set-control system, in the train. The running-control of all the rolling-stock sets, which corresponds with the train composition state, executed by the integrated rolling-stock set-control system, is implemented by the means for generating train control-commands for the respective sets, provided in the rolling-stock set-connection device in any one of the embodiments 4 - 8, or by the means for generating information on the performance of the whole train, described for either the embodiment 2 or 3.

[0492] Fig. 37 shows an example of a schematic composition of a train-control system of this embodiment. The train-control apparatus (37-01) is directly connected to the rolling-stock set-connection device (37-03) in the integrated rolling-stock set-control system (37-02). Also, the rolling-stock set-connection device (37-03) is directly connected to a rolling-stock set-coupling device (37-04), and further to devices in the set via a rolling-stock set device-wiring network (37-05). In Fig. 37, the combination of the rolling-stock set-connection device (37-03) and the rolling-stock set-coupling device (37-04), composed in the integrated rolling-stock set-control system (37-02), is equal to the integrated rolling-stock set-control system in any one of the embodiments 1 - 8.

[0493] Fig. 38 shows another example of a schematic composition of a train-control system of this embodiment. The train-control apparatus (38-01) is directly connected to the rolling-stock set-connection device (38-03) in the integrated rolling-stock set-control system (38-02). Also, the rolling-stock set-connection device (38-03) is connected to a rolling-stock set-coupling device (38-04) via a rolling-stock set device-wiring network (38-05), and further to devices in the set via the rolling-stock set device-wiring network (38-05). In Fig. 38, the combination of the rolling-stock set-connection device (38-03), and the rolling-stock set-coupling device (38-04) via the rolling-stock set device-wiring network (38-05), composed in the integrated rolling-stock set-control system (38-02), is equal to the integrated rolling-stock set-control system in any one of the embodiments 1 - 8.

[0494] Fig. 39 also shows another example of a schematic composition of a train-control system of this embodiment. The train-control apparatus (39-01) is connected to the rolling-stock set-connection device (39-03) in the integrated rolling-stock set-control system (39-02) via a rolling-stock set device-wiring network (39-05). Also, the rolling-stock set-connection device (39-03) is directly connected to a rolling-stock set-coupling device (39-04), and further to devices in the set via the rolling-stock set device-wiring network (39-05). In Fig. 39, the combination of the rolling-stock set-connection device (39-03) and the rolling-stock set-coupling device (39-04), composed in the integrated rolling-stock set-control system (39-02), is equal to the integrated rolling-stock set-control system in any one of the embodiments 1 - 8.

[0495] Fig. 40 also shows another example of a schematic composition of a train-control system of this embodiment. The train-control apparatus (40-01) is connected to the rolling-stock set-connection device (40-03) in the integrated rolling-stock set-control system (40-02) via a rolling-stock set device-wiring network (40-05). Also, the rolling-stock set-connection device (40-03) is connected to a rolling-stock set-coupling device (40-04) via the rolling-stock set device-wiring network (40-05), and further to devices in the set via the rolling-stock set device-wiring network (40-05). In Fig. 40, the combination of the rolling-stock set-connection device (40-03), and the rolling-stock set-coupling device (40-04) via the rolling-stock set device-wiring network (40-05), composed in the integrated rolling-stock set-control system (40-02), is equal to the integrated rolling-stock set-control system in any one of the embodiments 1 - 8.

[0496] The above-described train-control system of this embodiment can bring about the same effects of any one of the embodiments 1 - 8, with the different system composition.

Embodiment 10:

[0497] In this embodiment, the train-control system includes an integrated train-control apparatus to control the running of the whole train, for generating control-commands for respective rolling-stock sets, and sending the generated control-commands to the respective sets; and an individual rolling-stock set-control system situated in each set, for controlling each set.

[0498] The integrated train-control apparatus of this embodiment performs the running-control of each set in the train, corresponding with the set-composition of the train, by using the method of generating control-commands for respective sets, provided in the integrated rolling-stock set-control system in any one of the embodiments 4 - 8.

[0499] Further, the integrated train-control apparatus receives information on running-performances of the respective sets from the individual rolling-stock set-control system of each set, and generates information on the running-performance of the whole train, based on the received information. Furthermore, the integrated train-control system uses

the generated information on the running-performance of the whole train, to control the running of the whole train. The generation of the information on the running-performance of the whole train is performed by using the method of generating information on the running-performance of the whole train, provided in the rolling-stock set-control system of either the embodiment 2 or 3.

[0500] The above integrated train-control apparatus can also be composed by integrating the integrated rolling-stock set-control system in any one of the embodiments 1 - 8, and the train-control apparatus, that controls the running of the whole train. That is, the above integrated train-control apparatus includes the integrated rolling-stock set-connection device and the rolling-stock set-coupling device in any one of the embodiments 1 - 8, and the train-control apparatus. The running-control of all the rolling-stock sets, which corresponds with the train composition state, executed by the integrated rolling-stock set-control system, is implemented by the means for generating control-commands for respective sets, provided in the rolling-stock set-connection device in any one of the embodiments 4 - 8, or by the means for generating information on the performance of the whole train, described for either the embodiment 2 or 3.

[0501] Fig. 41 shows an example of a schematic composition of a train-control system of this embodiment. The integrated train-control apparatus (41-01) includes the function of the train-control apparatus for generating a train-control command that controls the running of the whole train, and an integrated rolling-stock set-connection device (41-03). Also, the integrated rolling-stock set-connection device (41-03) is directly connected to a rolling-stock set-coupling device (41-04) in the integrated train-control apparatus (41-01), and further to devices in the set via the rolling-stock set device-wiring network (41-05). In Fig. 41, the train-control system includes the integrated train-control apparatus (41-01), and the combination of the rolling-stock set-connection device (41-03) and the rolling-stock set-coupling device (41-04), composed in the integrated train-control apparatus (41-01), is equal to the integrated rolling-stock set-control system in any one of the embodiments 1 - 8.

[0502] The above-described train-control system of this embodiment can bring about the same effects of any one of the embodiments 1 - 8, with different system compositions.

Embodiment 11:

[0503] In this embodiment, the train-control system includes an integrated train-control apparatus which controls the running of a train as a whole, for generating control-commands for controlling the running of respective individual rolling-stock sets in the train, an individual rolling-stock set-control system situated in each set of the train, for controlling each set, and a rolling-stock set-coupling device for mechanically coupling two neighboring sets, and performing communication between the two neighboring sets.

[0504] The integrated train-control apparatus of this embodiment is the same as that of the embodiment 10 except that the rolling-stock set-coupling device is situated separately from the integrated train-control apparatus. Therefore, the train-control system functions in the same manner as that of the embodiment 10.

[0505] Fig. 42 shows an example of a schematic composition of a train-control system of this embodiment. The integrated train-control apparatus (42-01) includes the function of the train-control apparatus for generating a train-control command that controls the running of the whole train, and the integrated rolling-stock set-connection device (42-03). Also, the integrated rolling-stock set-connection device (42-03) is directly connected to the rolling-stock set-coupling device (42-04), and further to devices in the set via the rolling-stock set device-wiring network (42-05) in the individual rolling-stock set-control system (42-02). In Fig. 42, the combination of the integrated train-control apparatus (42-01) and the rolling-stock set-coupling device (42-04) composes the same system as the integrated train-control apparatus of the embodiment 10. Further, the combination of the rolling-stock set-connection device (42-03) and the rolling-stock set-coupling device (42-04) is equal to the integrated rolling-stock set-control system in any one of the embodiments 1 - 8.

[0506] Fig. 43 shows an example of a schematic composition of a train-control system of this embodiment. An integrated train-control apparatus (43-01) includes the function of a train-control apparatus for generating a train-control command that controls the running of the whole train, and an integrated rolling-stock set-connection device (43-03). Also, the integrated rolling-stock set-connection device (43-03) is connected to a rolling-stock set-coupling device (43-04) via a rolling-stock set device-wiring network (43-05) in an individual rolling-stock set-control system (43-02), and further to devices in the set via the rolling-stock set device-wiring network (43-05). In Fig. 43, the combination of the integrated train-control apparatus (43-01) and the rolling-stock set-coupling device (43-04) composes the same system as the integrated train-control apparatus of the embodiment 10. Further, the combination of the rolling-stock set-connection device (43-03) and the rolling-stock set-coupling device (43-04) is equal to the integrated rolling-stock set-control system in any one of the embodiments 1 - 8.

[0507] The above-described train-control system of this embodiment can bring about the same effects of any one of the embodiments 1 - 8, with different system compositions.

Embodiment 12:

[0508] In this embodiment, the train-control system includes an train-control apparatus for generating a train-control command that controls the running of a train as a whole, an individual rolling-stock set-control system situated in each set of the train, an integrated rolling-stock set-control apparatus, mechanically coupling two neighboring sets, which receives the train-control command, generates control-commands that control the sets in the train, respectively, corresponding with the train composition state, and performs communication between the two neighboring sets.

[0509] The integrated rolling-stock set-connection device of this embodiment receives the train-control command from the train-control apparatus, and generates the control-commands for the respective sets in the train, based on the received train-control command. The above generation of the control-commands for the respective sets is performed corresponding with the set-composition of the train, by using the method of generating control-commands for respective sets, provided in the integrated rolling-stock set-control system in any one of the embodiments 4 - 8.

[0510] Further, the integrated rolling-stock set-control apparatus of this embodiment generates information on the whole train, representing the running-performance of the train as a whole, from information on running-performances of respective individual rolling-stock sets in the train, and sends the generated information to the train-control apparatus. The generation of the above information is performed according with the set-composition of the train, by using the method of generating information on the whole train, provided in the integrated rolling-stock set-control system in either the embodiment 2 or 3.

[0511] The above integrated rolling-stock set-control apparatus can also be realized by integrating the integrated rolling-stock set-control system situated in any one of the embodiments 1 - 8 into one apparatus. That is, the above integrated rolling-stock set-control apparatus is composed by combining the integrated rolling-stock set-connection devices and the rolling-stock set-coupling devices in any one of the embodiments 1 - 8. The running-control of all the rolling-stock sets, which corresponds with the train composition state, executed by the integrated rolling-stock set-control apparatus, is implemented by the means for generating control-commands for the respective sets, provided in the rolling-stock set-connection device in any one of the embodiments 4 - 8, or by the means for generating information on the performance of the whole train, described for either the embodiment 2 or 3.

[0512] Fig. 44 shows an example of a schematic composition of a train-control system of this embodiment. The train-control apparatus (44-01) is directly connected to the rolling-stock set-connection device (44-03) in the integrated rolling-stock set-control apparatus (44-04). Also, the rolling-stock set-connection device (44-03) is connected to devices in the set via a rolling-stock set device-wiring network (44-05) situated in an individual rolling-stock set-control system (45-02). In Fig. 44, the combination of the rolling-stock set-connection device (44-03) and a rolling-stock set-coupling device, composed in the integrated rolling-stock set-control apparatus (44-04), is equal to the integrated rolling-stock set-control system in any one of the embodiments 1 - 8. for either the embodiment 2 or 3.

[0513] Fig. 45 shows another example of a schematic composition of a train-control system of this embodiment. The train-control apparatus (45-01) is connected to the rolling-stock set-connection device (45-03) in the integrated rolling-stock set-control apparatus (45-04) via a rolling-stock set device-wiring network (45-05) situated in an individual rolling-stock set-control system (45-02). Also, the rolling-stock set-connection device (45-03) is connected to devices in the set via a rolling-stock set device-wiring network (45-05) situated in an integrated rolling-stock set-control system. In Fig. 45, the combination of the rolling-stock set-connection device (45-03) and a rolling-stock set-coupling device, composed in the integrated rolling-stock set-control apparatus (45-04), is equal to the integrated rolling-stock set-control system in any one of the embodiments 1 - 8.

[0514] The above-described train-control system of this embodiment can bring about the same effects of any one of the embodiments 1 - 8, with different system compositions.

[0515] As described above, in accordance with the present invention, the train-control system performs a train, properly adapted to the train composition state even if the composition state of the train variously changes according to switching between the dividing and coupling operation modes.

[0516] That is, since the train-control system includes the train-control apparatus for controlling a train as a whole, the individual rolling-stock set-control system for each set in the train, and the integrated rolling-stock set-control system for mediating the communication between the train-control apparatus and the individual rolling-stock set-control system, it has become possible to implement easily the running-control of the train, corresponding with various composition states of the train, and further optimize the running-control, corresponding with the designated composition state of the train.

[0517] Further, by generating the running-performance of the whole train, based on the information on the running of each rolling-stock set in the train, it has become possible to perform the suitable running-control, corresponding with any composition state of the train, by taking the running-performance of the whole train into account, which in turn contributes to the optimization of the running-control, corresponding to the train composition state.

[0518] Furthermore, by generating control-commands for the respective rolling-stock sets in the train in response to the designated control-command for controlling the running of the train as a whole, it has become possible to realize

the optimal driving-state of each set, according to the train running-state indicated by the train-control command.

[0519] Thus, in accordance with the train-control system of the present invention, it is possible to realize more effective performances in the running-control of both the train as a whole, and the respective rolling-stock sets in the train, in comparison with the conventional train-control techniques.

Claims

1. A train-control system for controlling the running of a train including one or more rolling-stock sets, said train-control system comprising:
 - a train-control apparatus for generating control-commands for controlling the running of said train as a whole; and
 - an integrated rolling-stock set-control unit for controlling the running of said respective rolling-stock sets, corresponding with a set-composition state of said train.
2. A train-control system according to claim 1, wherein said integrated rolling-stock set-control apparatus includes an individual rolling-stock set-control unit, which is situated in each rolling-stock set in said train, for controlling the running of its own rolling-stock set; and an integrated rolling-stock set-control unit, which is situated between said train-control apparatus and said individual rolling-stock set-control unit, for mediating the communication between said train-control apparatus and said individual rolling-stock set-control unit.
3. A train-control system according to claim 1, wherein said integrated rolling-stock set-control unit includes an integrated rolling-stock set-connection device for inputting/outputting information on the running-control of said train as a whole, to and from said train-control apparatus, and information on the running-control of each rolling-stock set, to and from each individual rolling-stock set-control unit; and a rolling-stock set-coupling device for performing information-transmission between neighboring rolling-stock sets.
4. A train-control system according to claim 3, wherein said integrated rolling-stock set-control unit includes said integrated rolling-stock set-connection device which receives information on running-performances of said respective rolling-stock sets from said respective individual rolling-stock set-control units, and sends information on the running-performance of said train as a whole to said train-control apparatus.
5. A train-control system according to claim 3, wherein said integrated rolling-stock set-connection device included in said integrated rolling-stock set-control unit includes means for generating information on the running-performance of said train as a whole from information on the running-performances of said respective rolling-stock sets in said train, adapted to a set-composition state of said train.
6. A train-control system according to claim 3, wherein said integrated rolling-stock set-control unit includes said integrated rolling-stock set-connection device which receives a train-control command for controlling the running of said train as a whole, and sends control-commands for controlling the running of said respective rolling-stock sets to said respective individual rolling-stock set-control units.
7. A train-control system according to claim 3, wherein said integrated rolling-stock set-connection device included in said integrated rolling-stock set-control unit includes means for generating control-commands for controlling the running of said respective rolling-stock sets in said train from a train-control command for controlling the running of said train as a whole, adapted to a set-composition state of said train.
8. A train-control system according to claim 3, wherein means for generating control-commands for controlling the running of said respective rolling-stock sets, generates said control-commands for said respective rolling-stock sets from said train-control command, such that an interactive load force acting on each rolling-stock set can be reduced in the driving state, caused by said control-commands, of said train.

FIG. 1

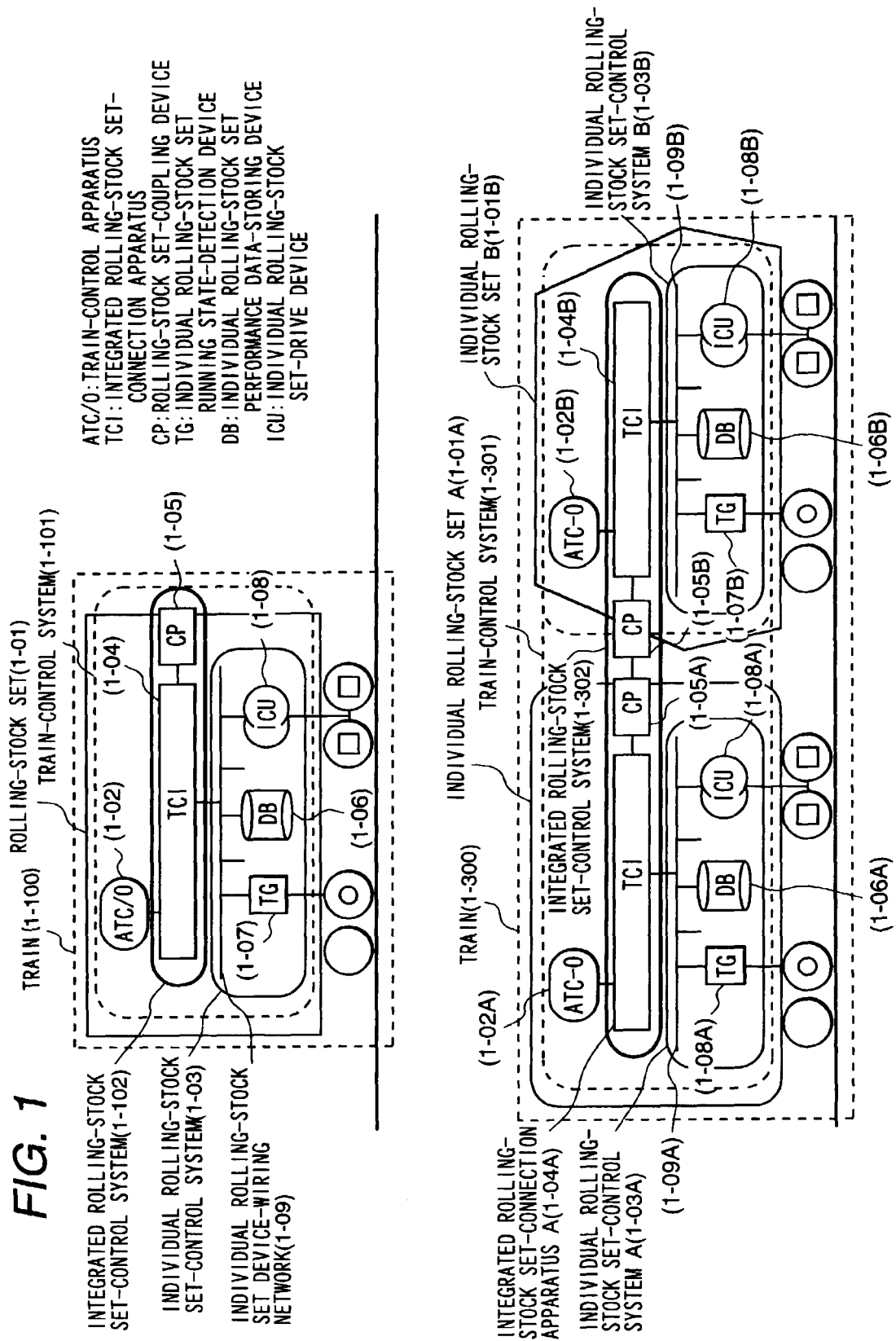


FIG. 2

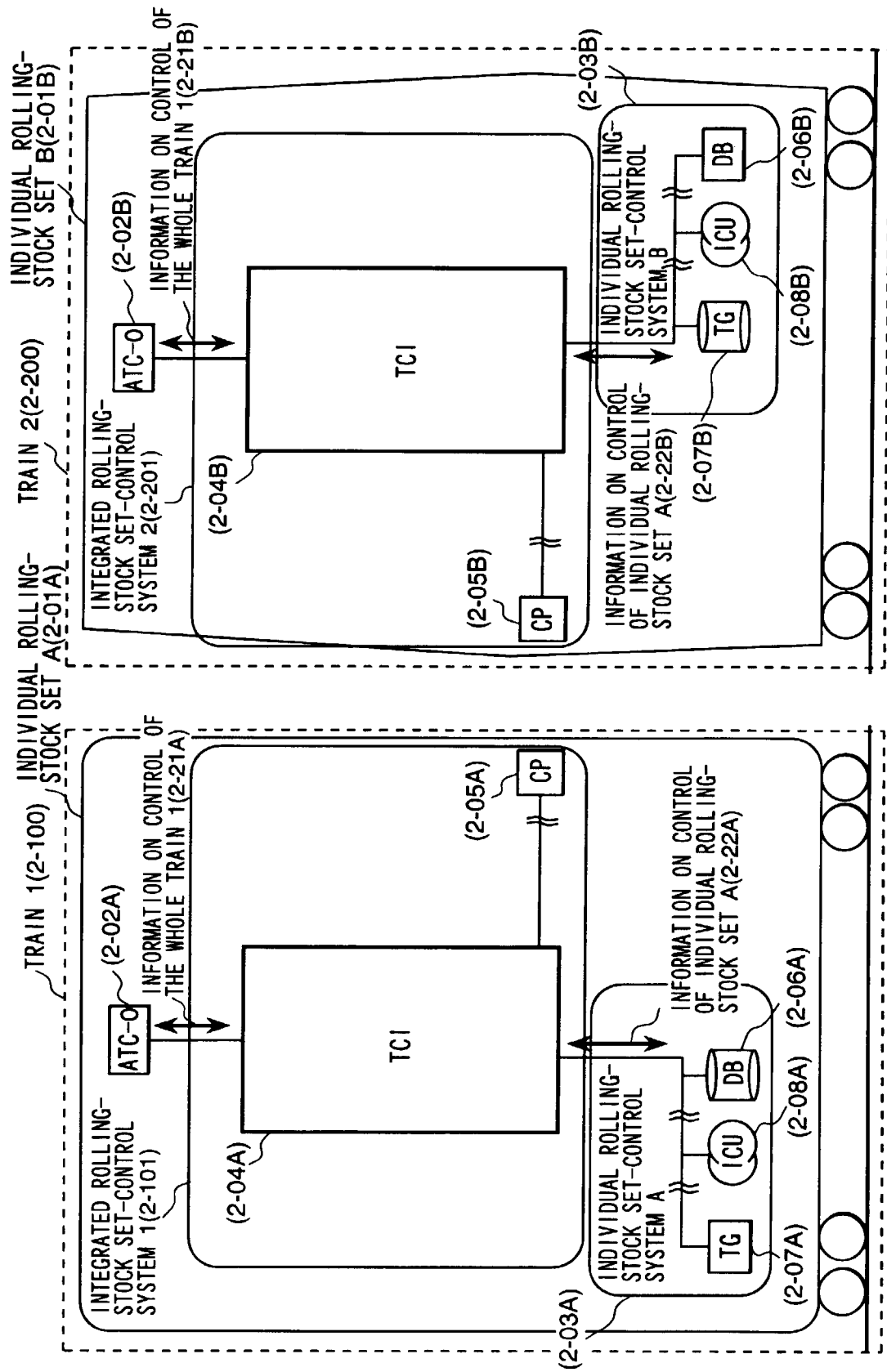


FIG. 3

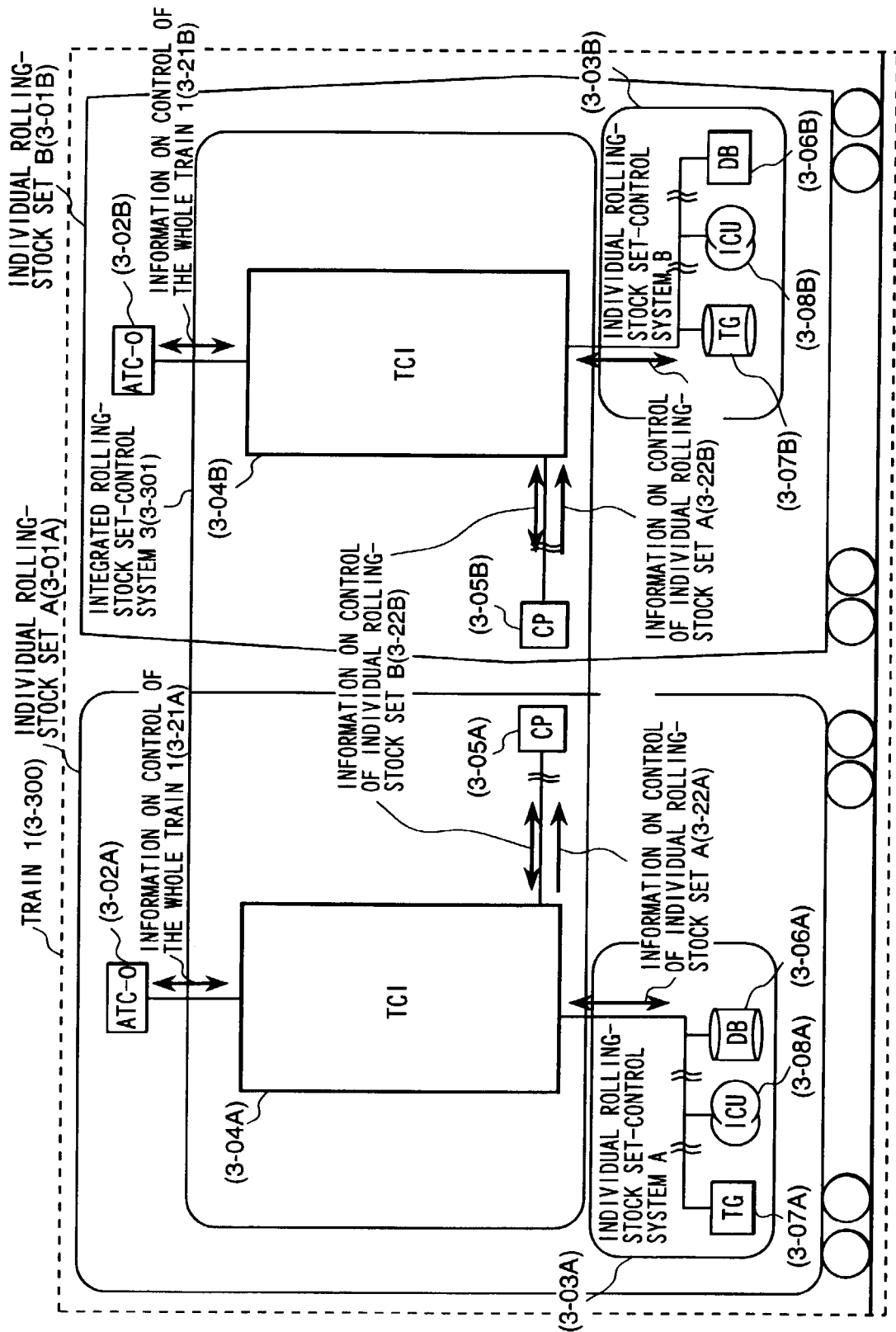


FIG. 4

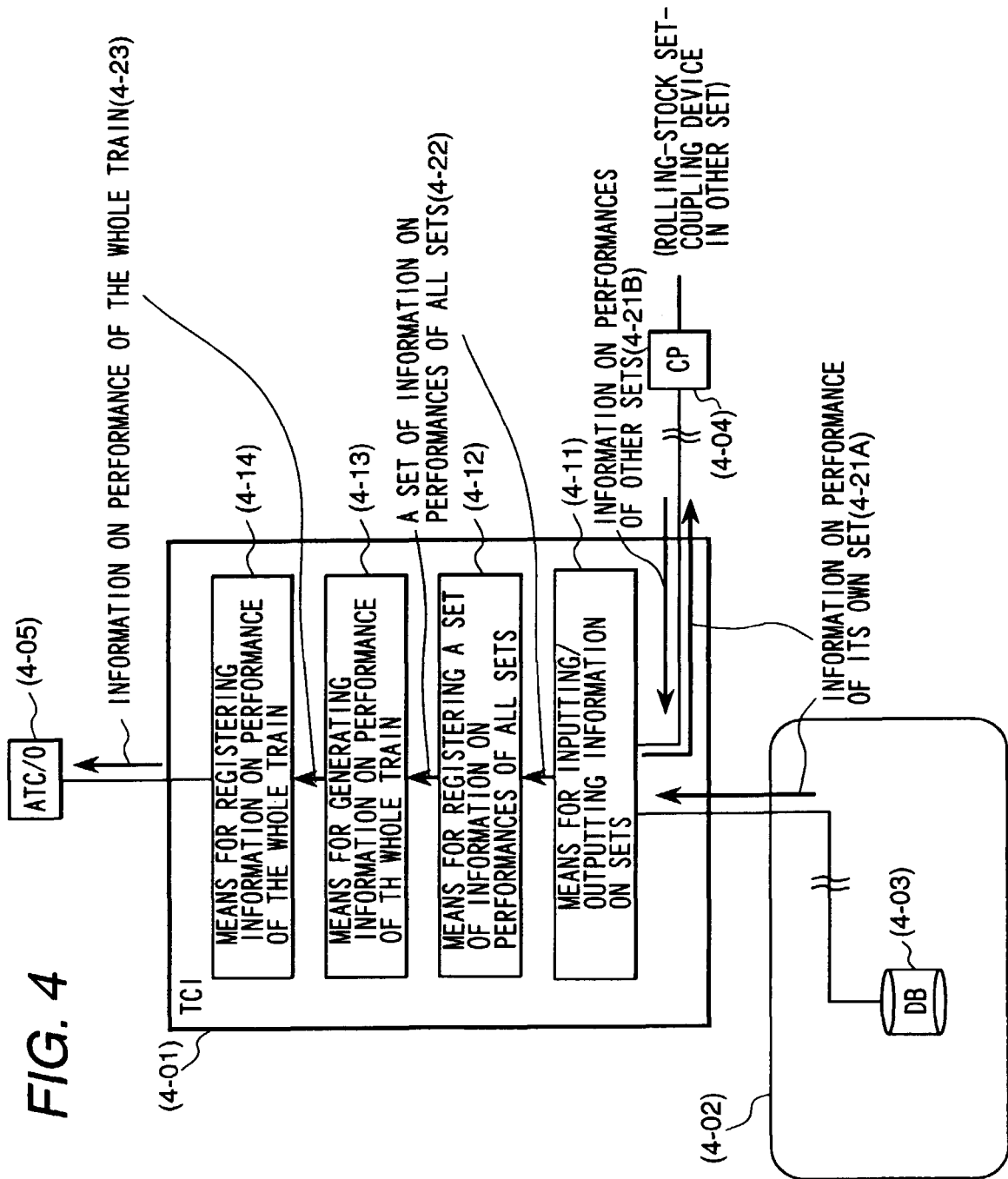


FIG. 5

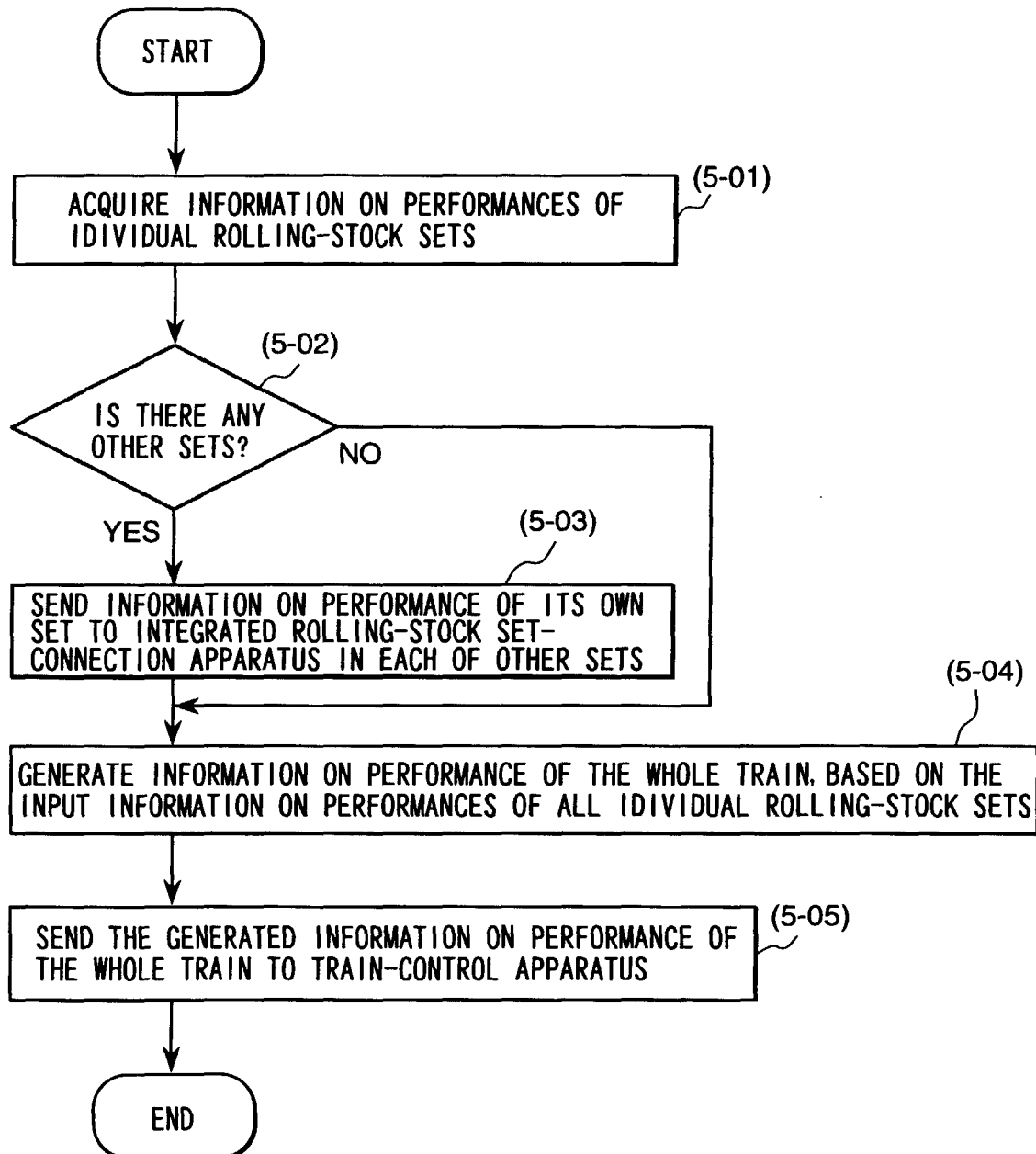


FIG. 6

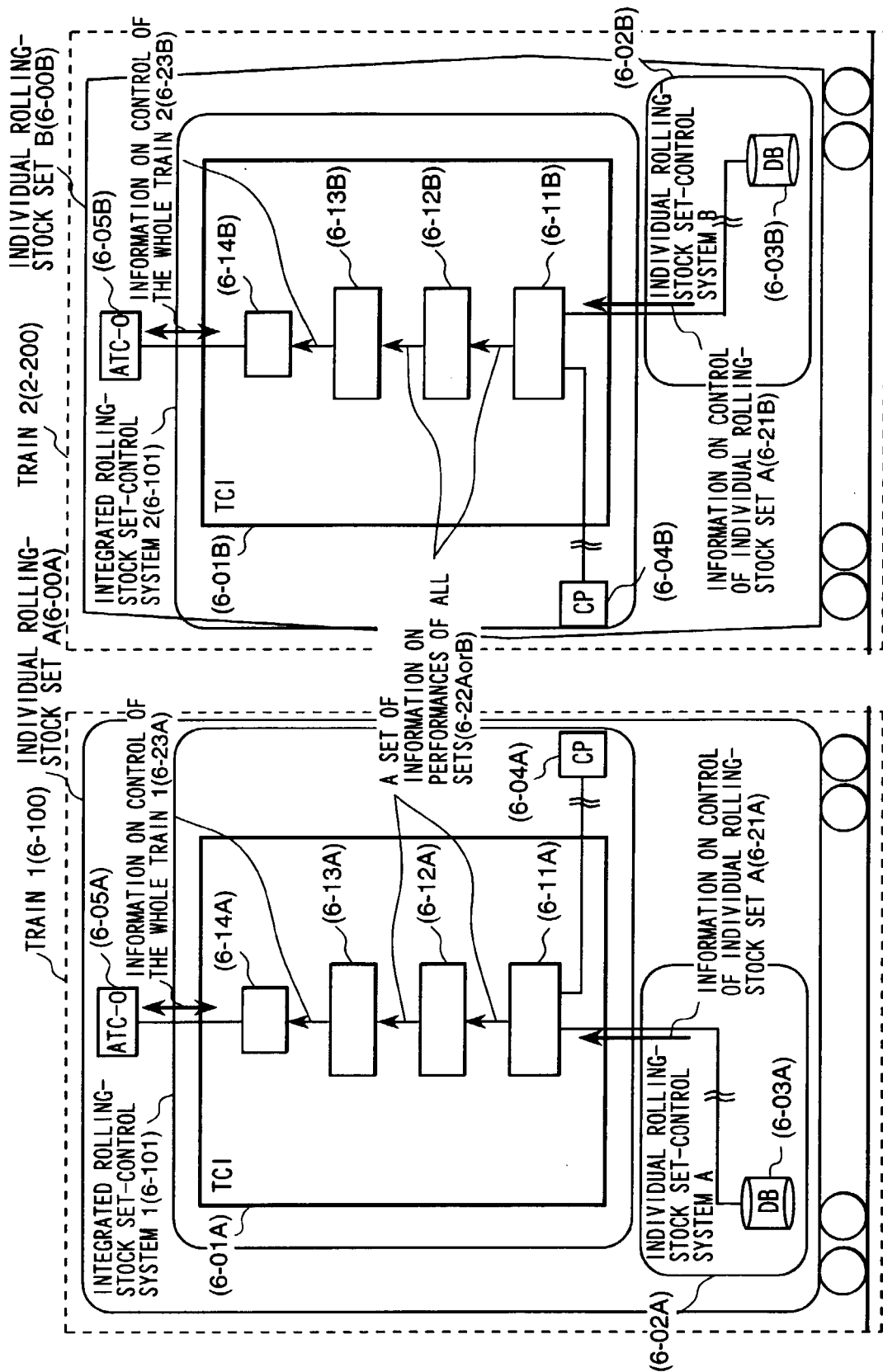


FIG. 7

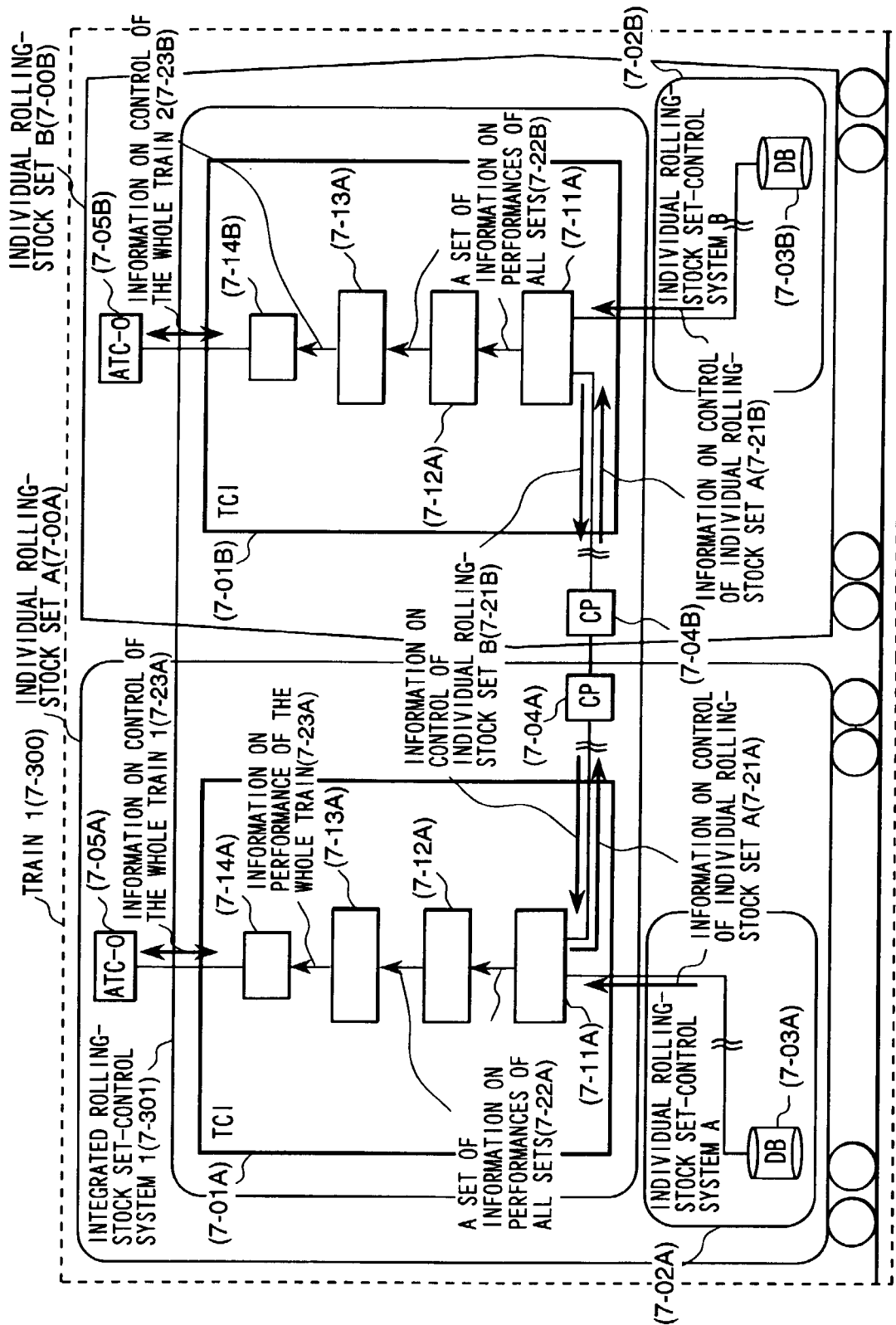


FIG. 8

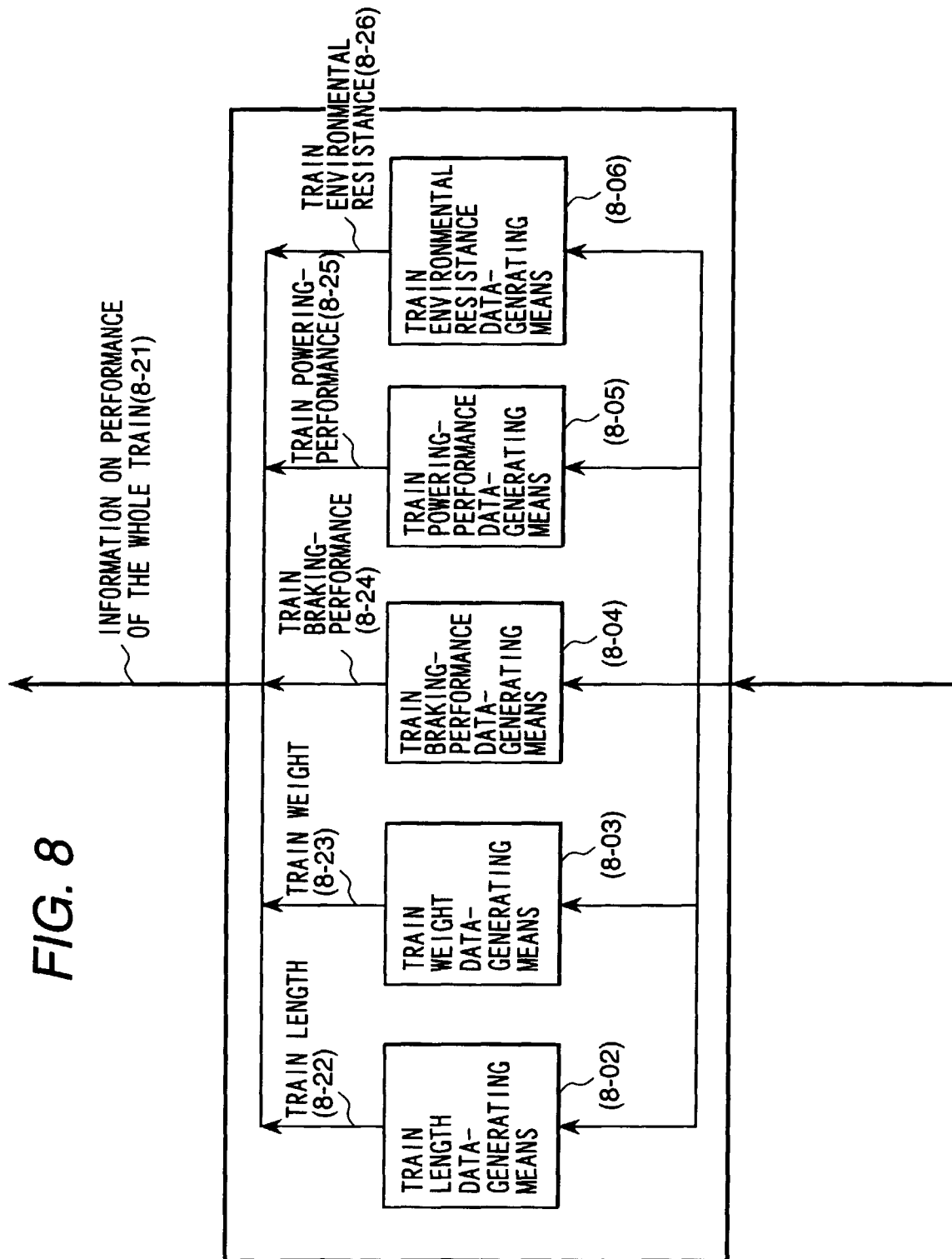


FIG. 9

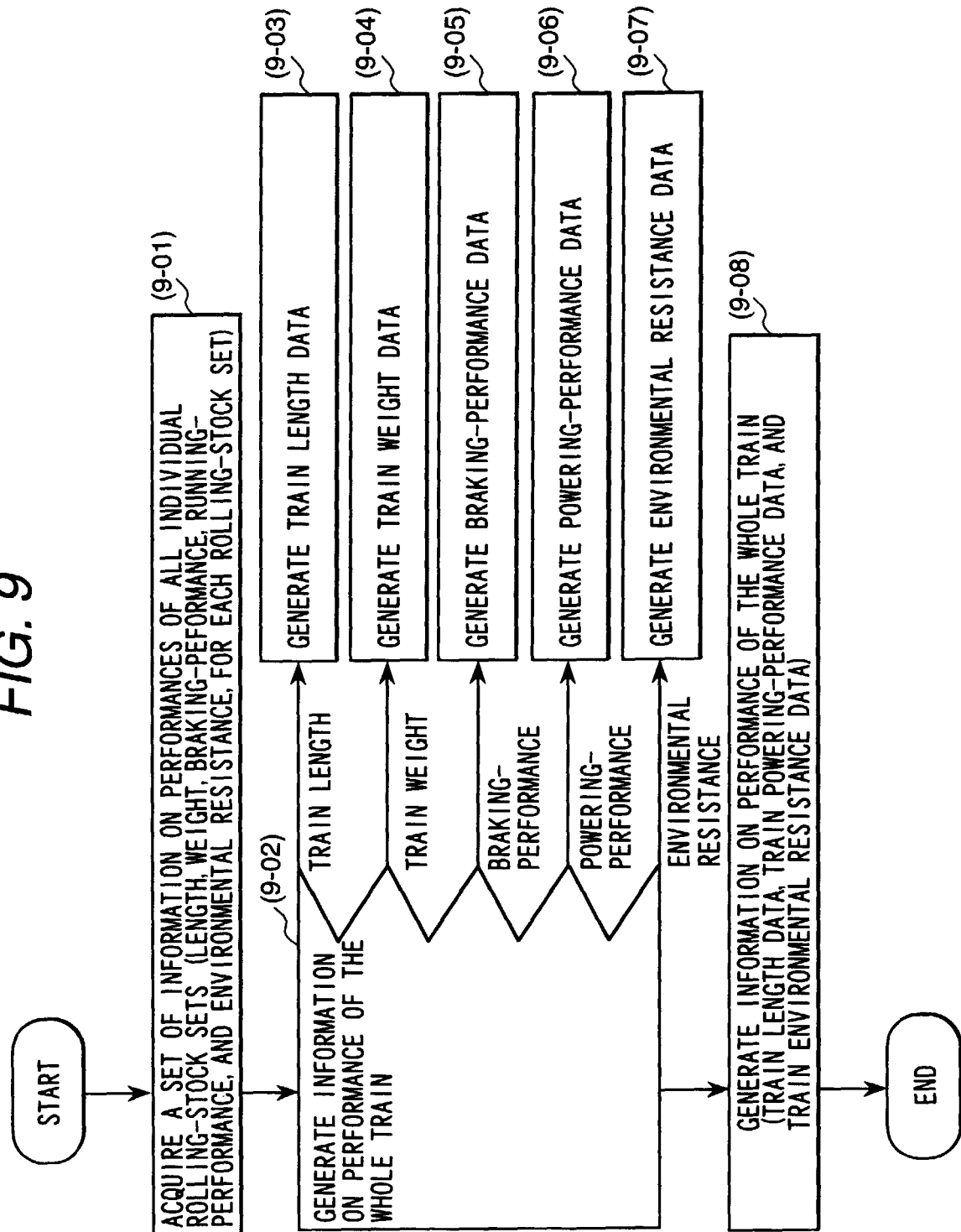


FIG. 10

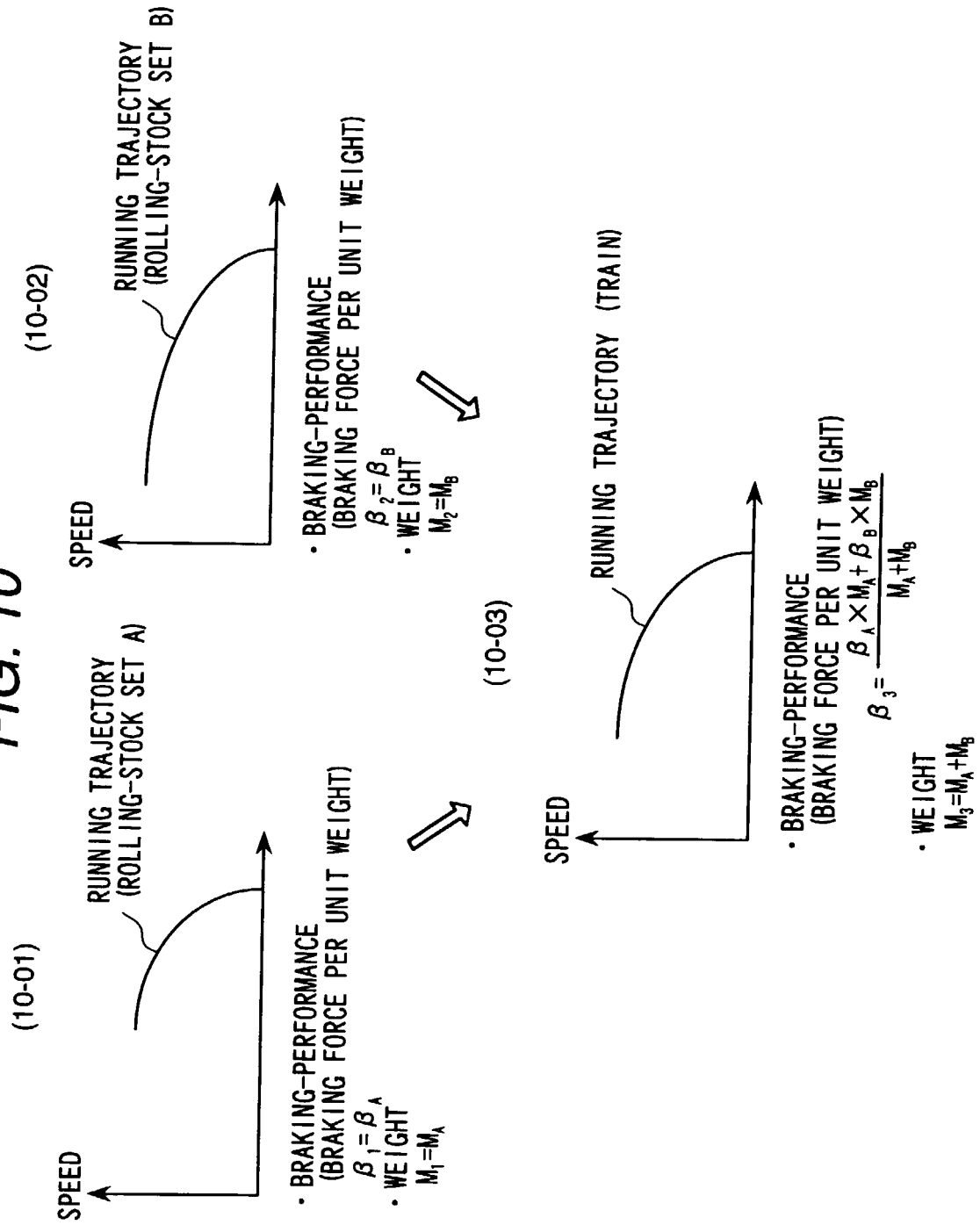


FIG. 11

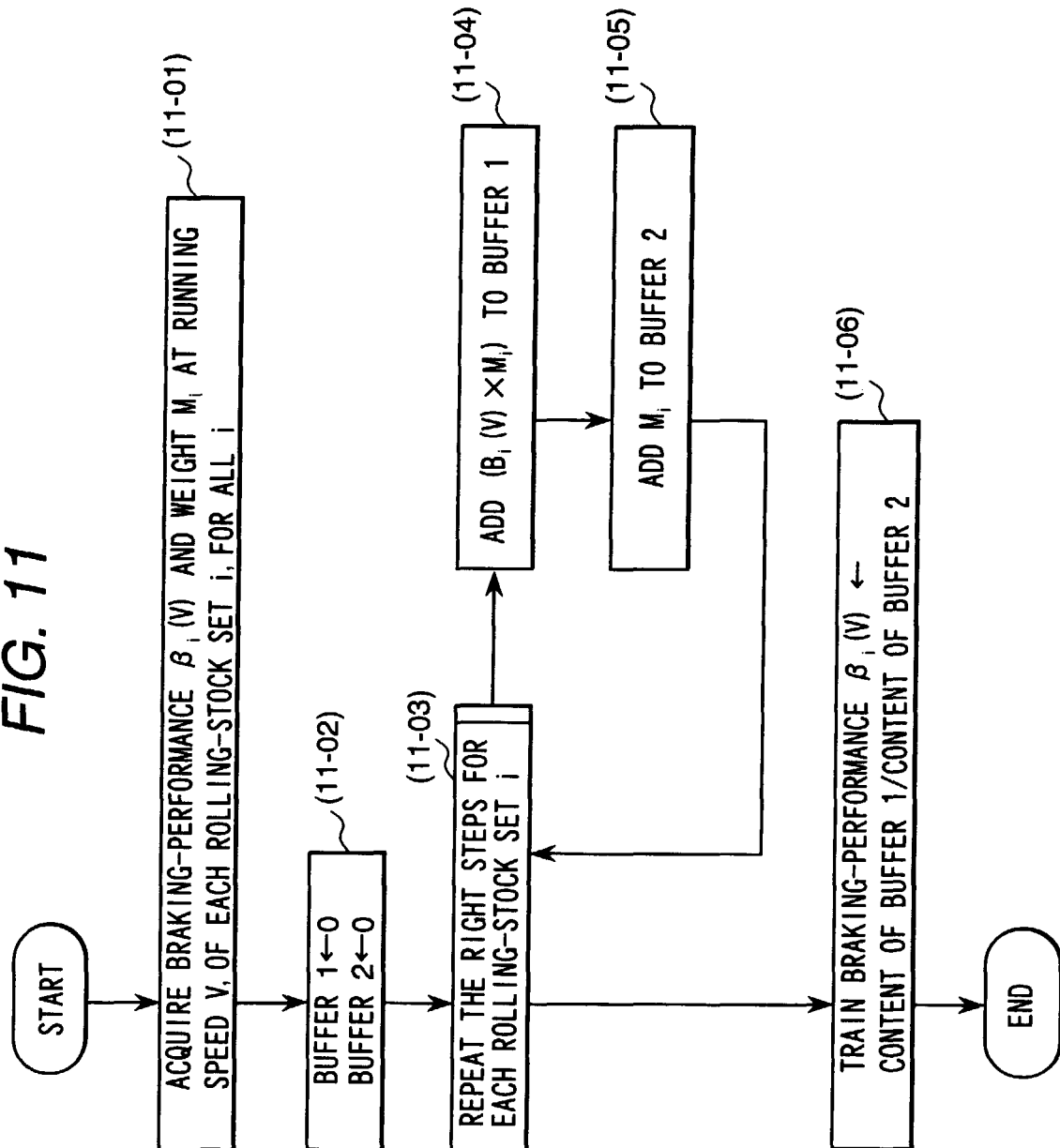


FIG. 12

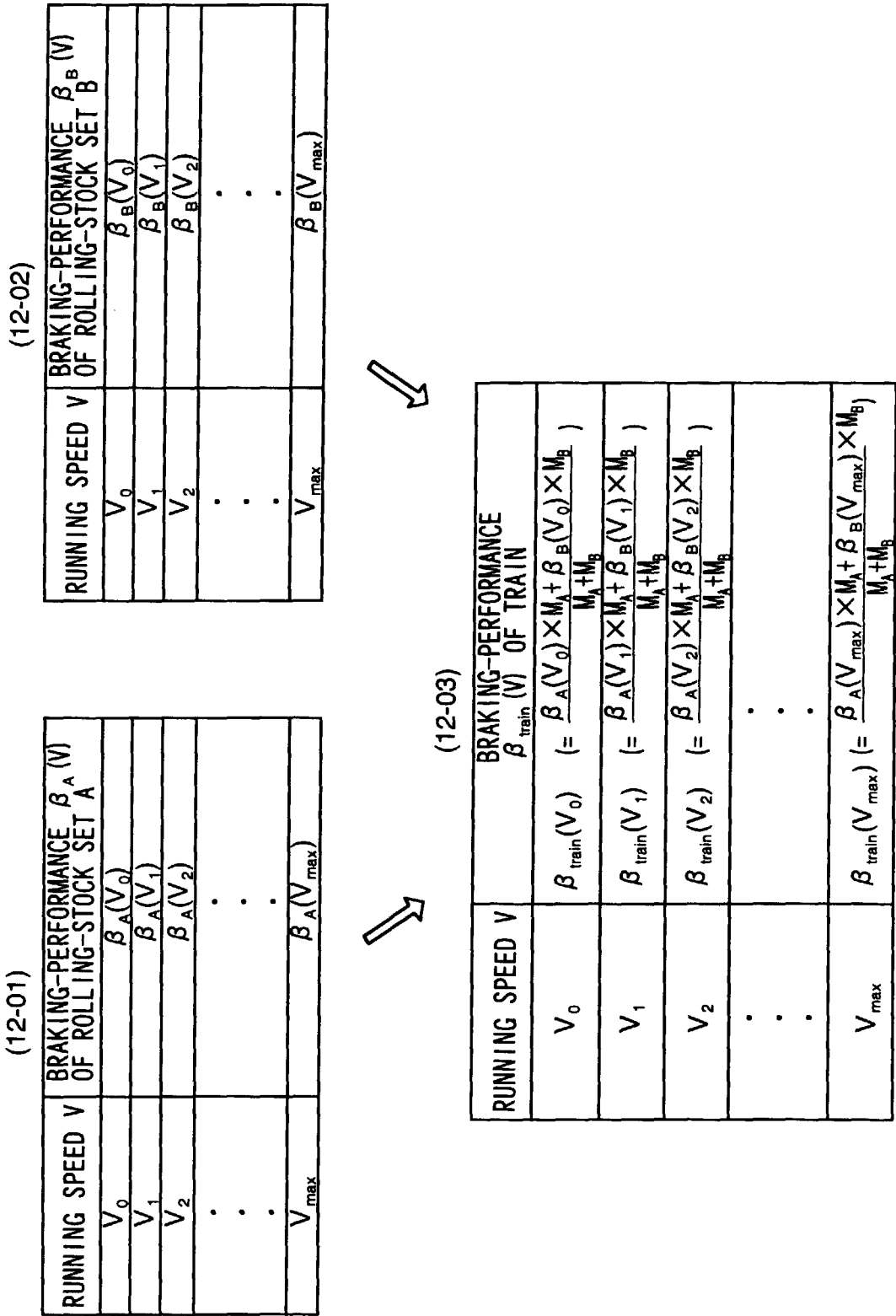


FIG. 13

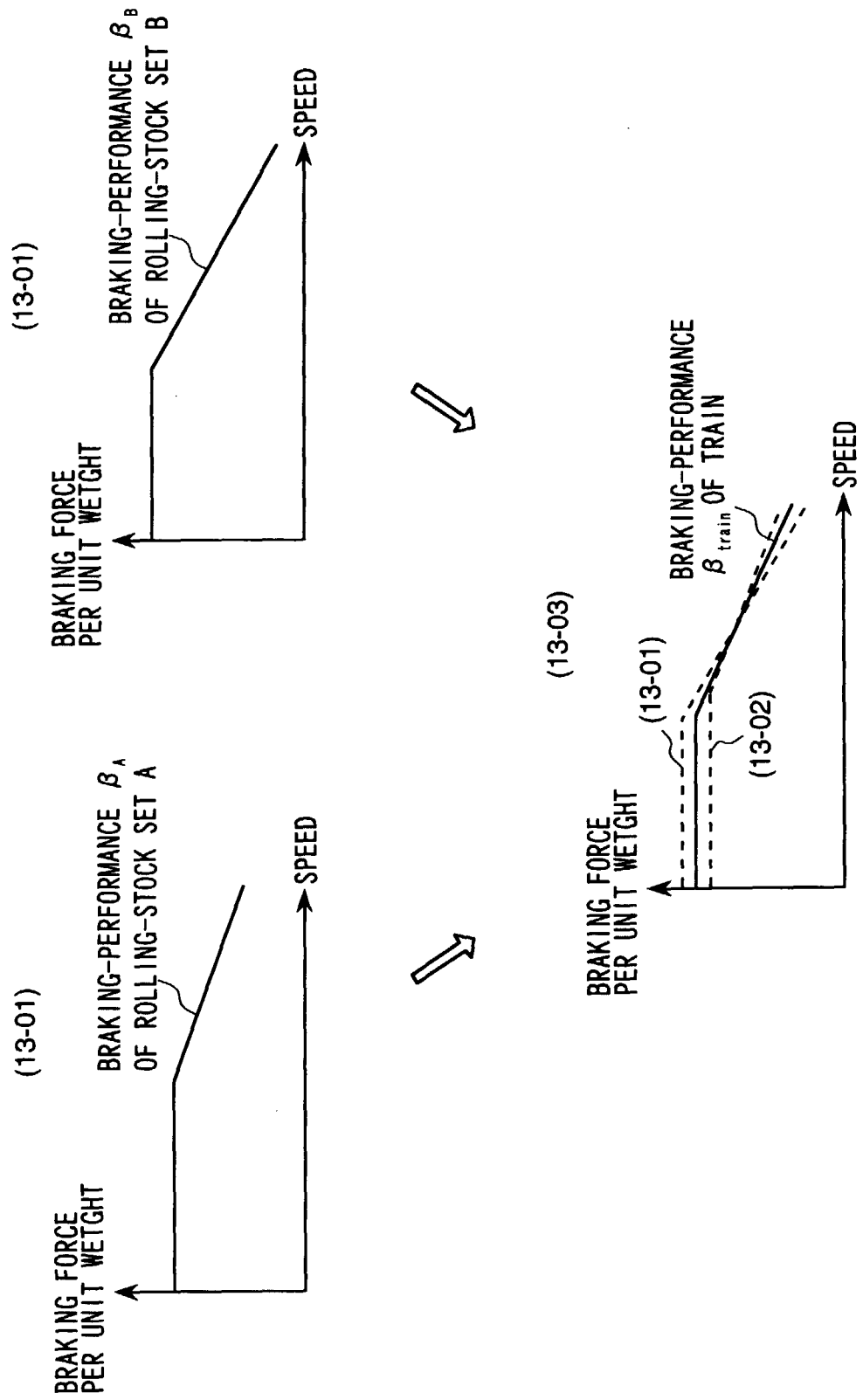


FIG. 14

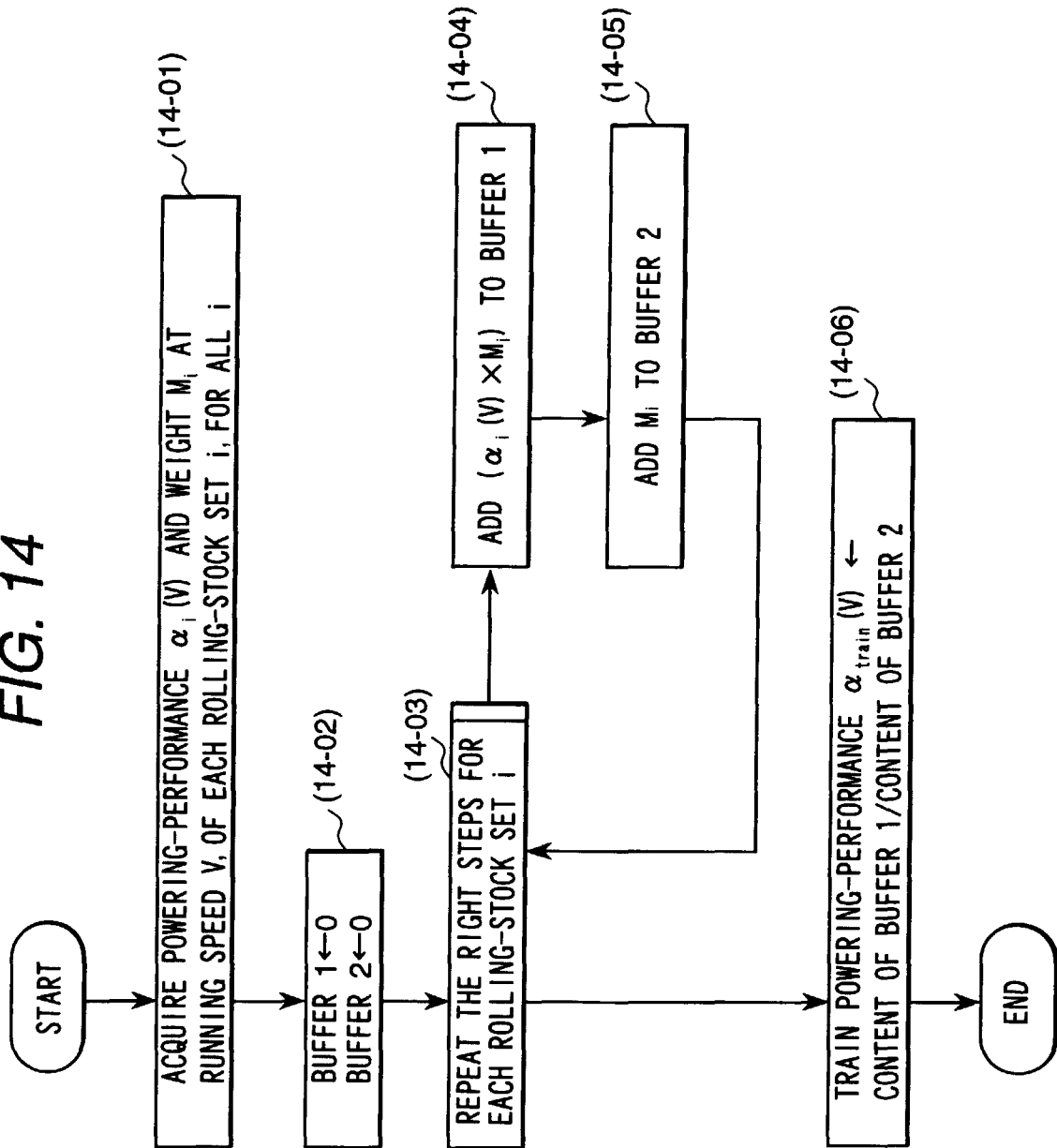


FIG. 15

(15-01)

RUNNING SPEED V	BRAKING-PERFORMANCE α_A (V) OF ROLLING-STOCK SET A
V_0	$\alpha_A(V_0)$
V_1	$\alpha_A(V_1)$
V_2	$\alpha_A(V_2)$
$\vdots$	$\vdots$
$\vdots$	$\vdots$
$\vdots$	$\vdots$
$V_{\max}$	$\alpha_A(V_{\max})$

(15-02)

RUNNING SPEED V	BRAKING-PERFORMANCE α_B (V) OF ROLLING-STOCK SET B
V_0	$\alpha_B(V_0)$
V_1	$\alpha_B(V_1)$
V_2	$\alpha_B(V_2)$
$\vdots$	$\vdots$
$\vdots$	$\vdots$
$\vdots$	$\vdots$
$V_{\max}$	$\alpha_B(V_{\max})$



(15-03)

(15-03)

RUNNING SPEED V	BRAKING-PERFORMANCE α_{train} (V) OF TRAIN
V_0	$\alpha_{\text{train}}(V_0) \quad (= \frac{\alpha_A(V_0) \times M_A + \alpha_B(V_0) \times M_B}{M_A + M_B})$
V_1	$\alpha_{\text{train}}(V_1) \quad (= \frac{\alpha_A(V_1) \times M_A + \alpha_B(V_1) \times M_B}{M_A + M_B})$
V_2	$\alpha_{\text{train}}(V_2) \quad (= \frac{\alpha_A(V_2) \times M_A + \alpha_B(V_2) \times M_B}{M_A + M_B})$
$\vdots$	$\vdots$
$\vdots$	$\vdots$
$\vdots$	$\vdots$
$V_{\max}$	$\alpha_{\text{train}}(V_{\max}) \quad (= \frac{\alpha_A(V_{\max}) \times M_A + \alpha_B(V_{\max}) \times M_B}{M_A + M_B})$



FIG. 16

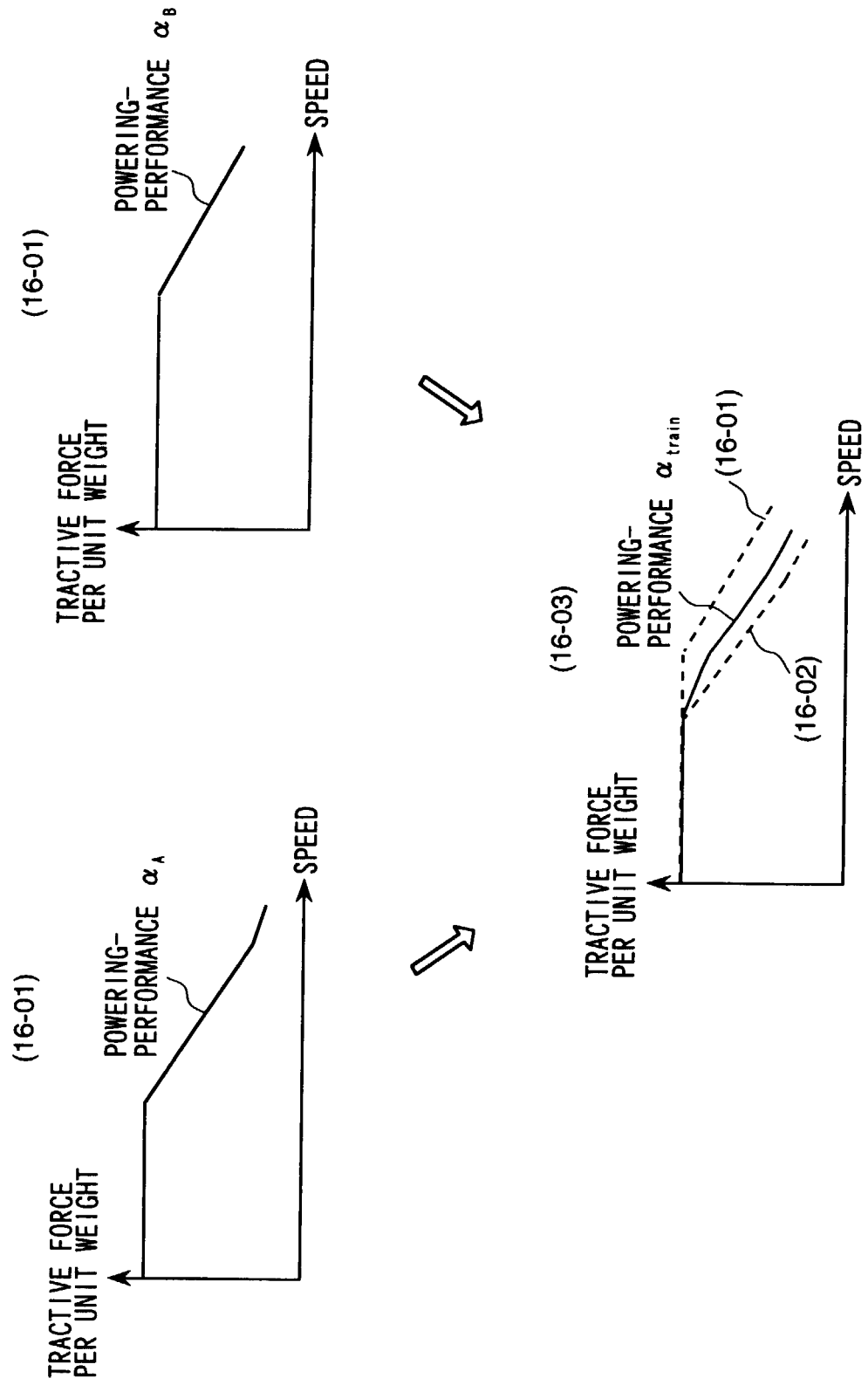
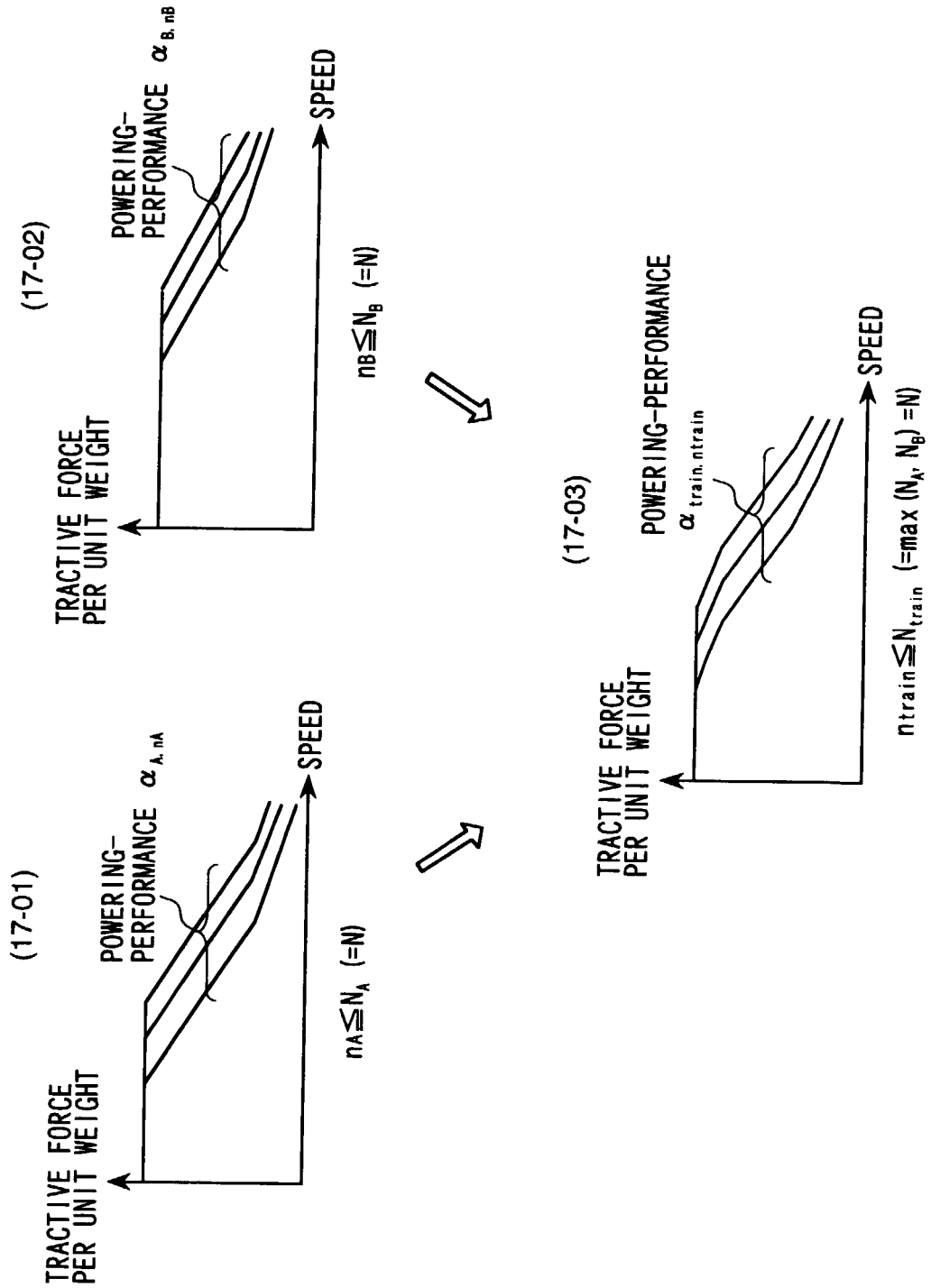


FIG. 17



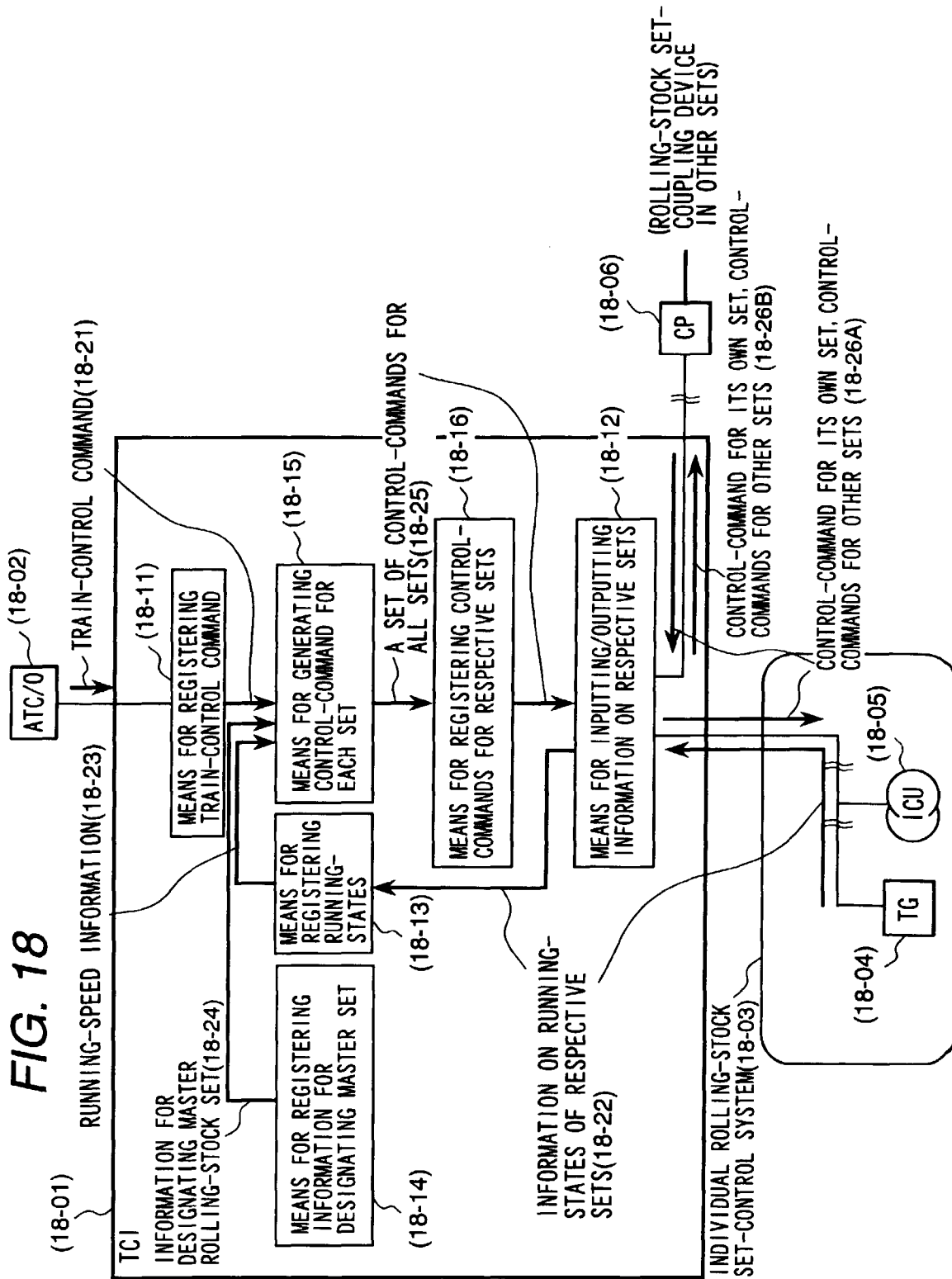


FIG. 19

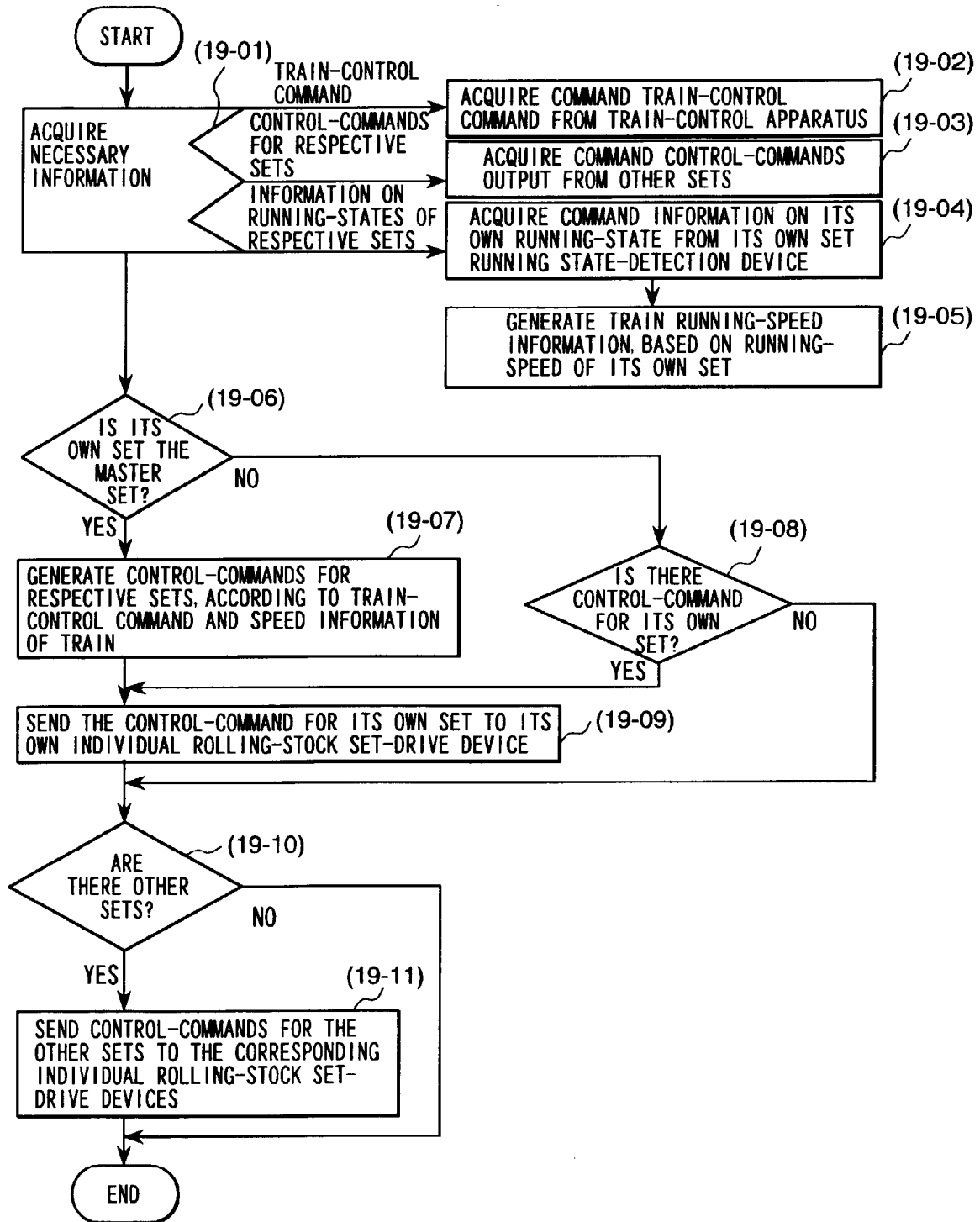


FIG. 20

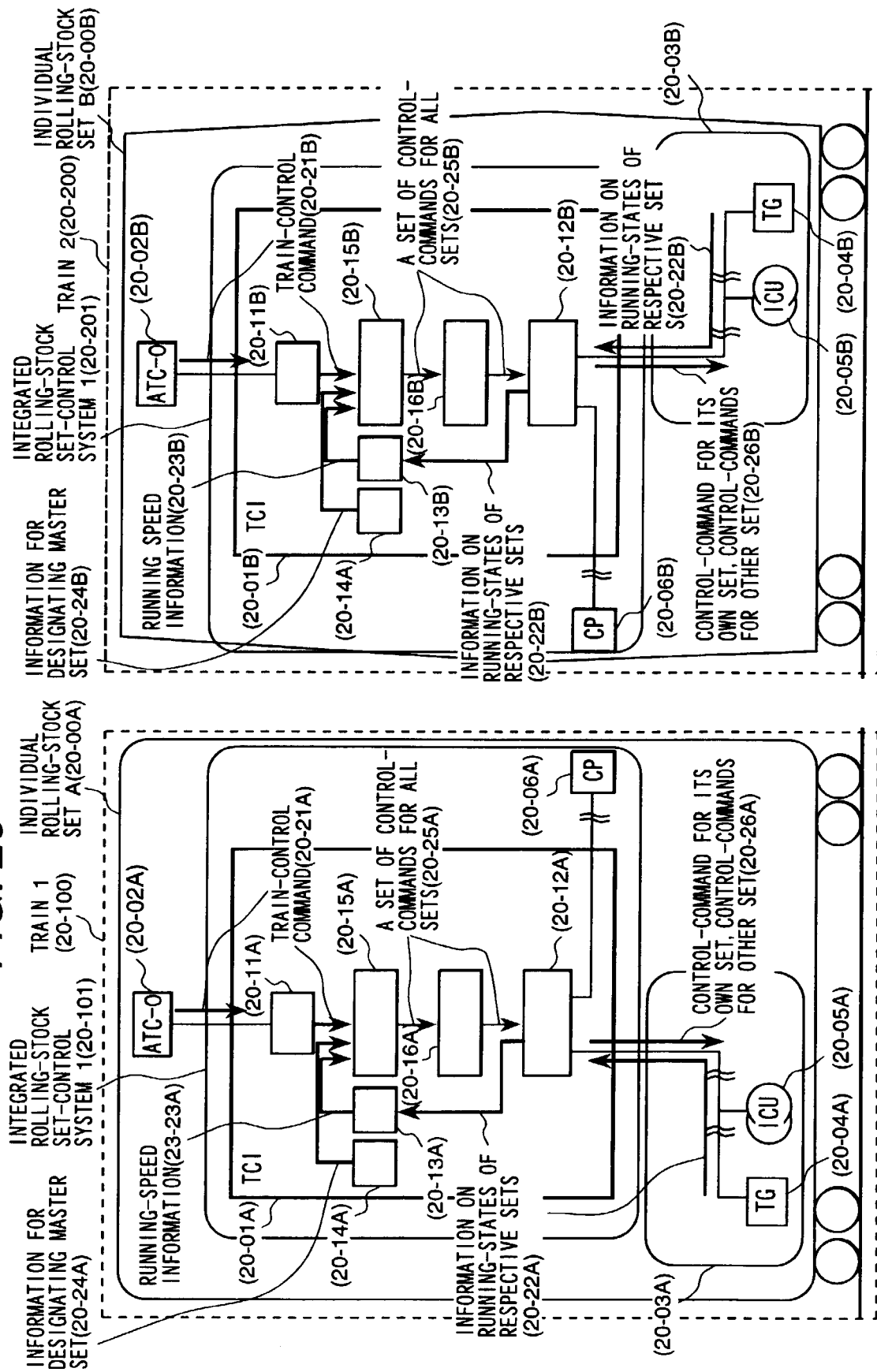


FIG. 21

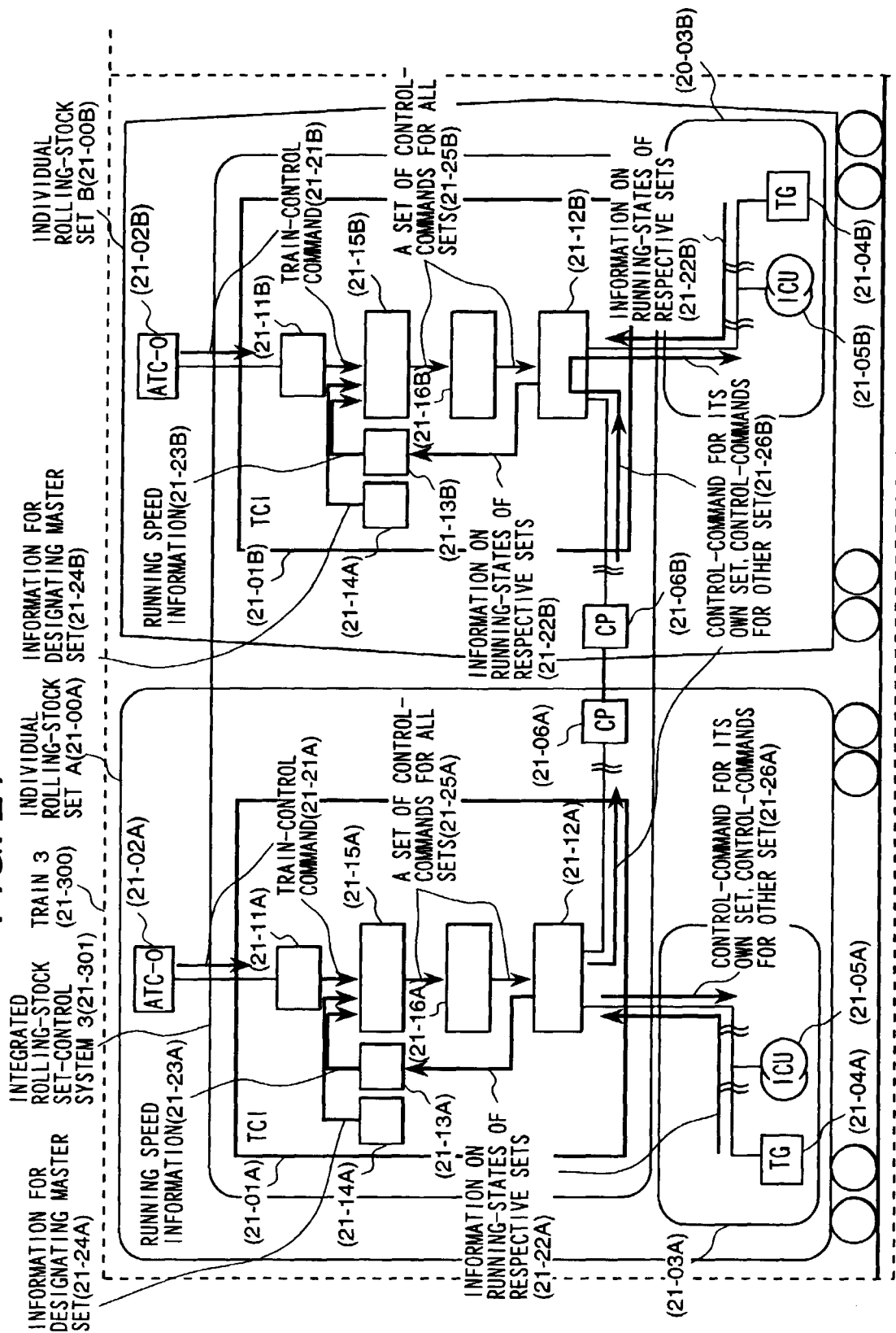


FIG. 22

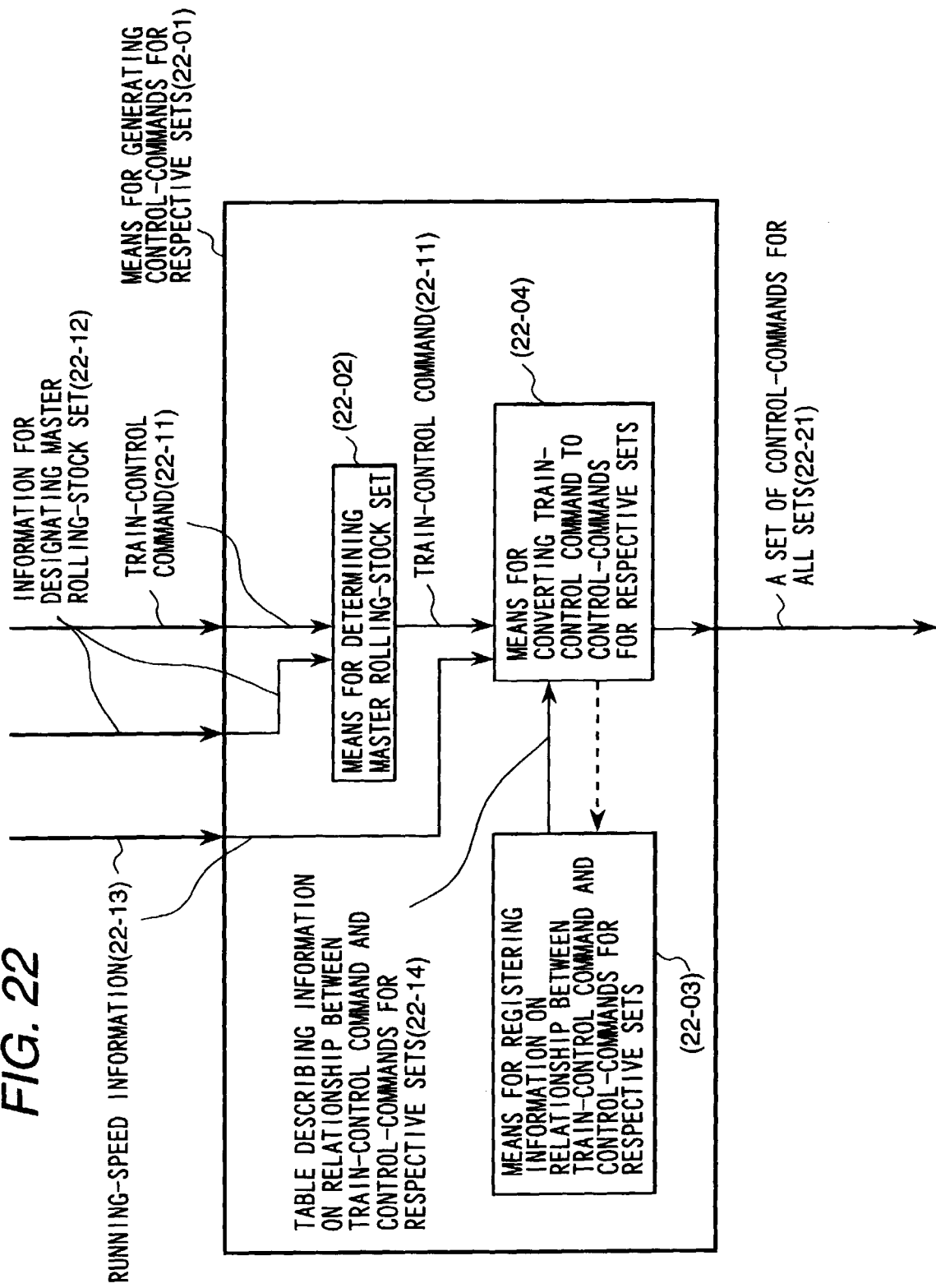


FIG. 23

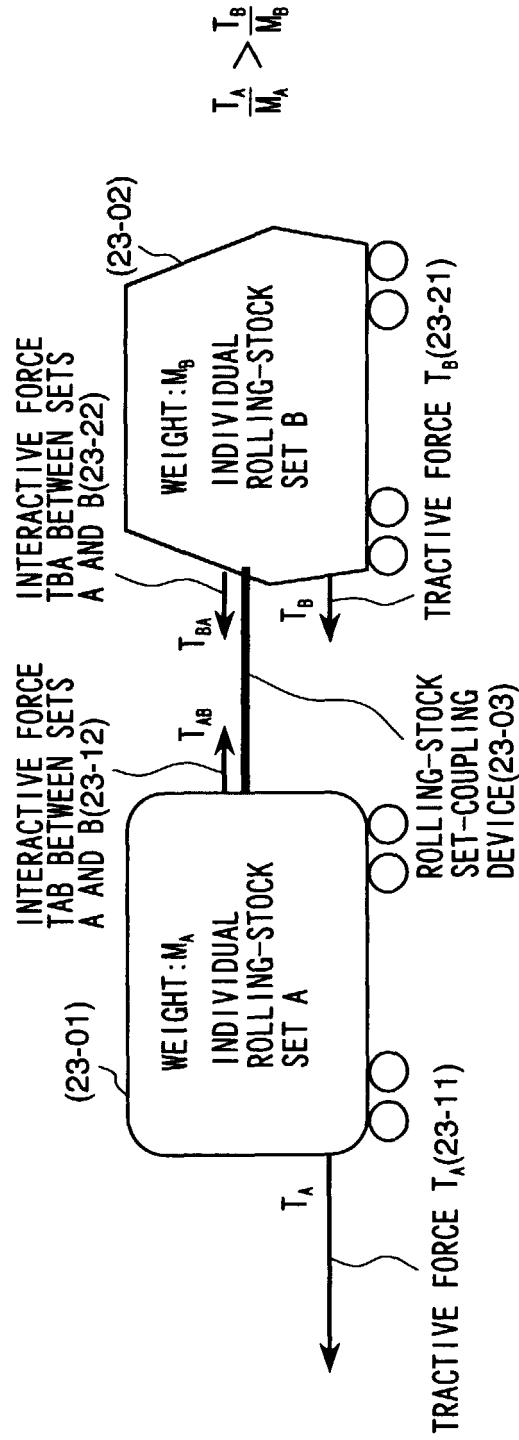


FIG. 24

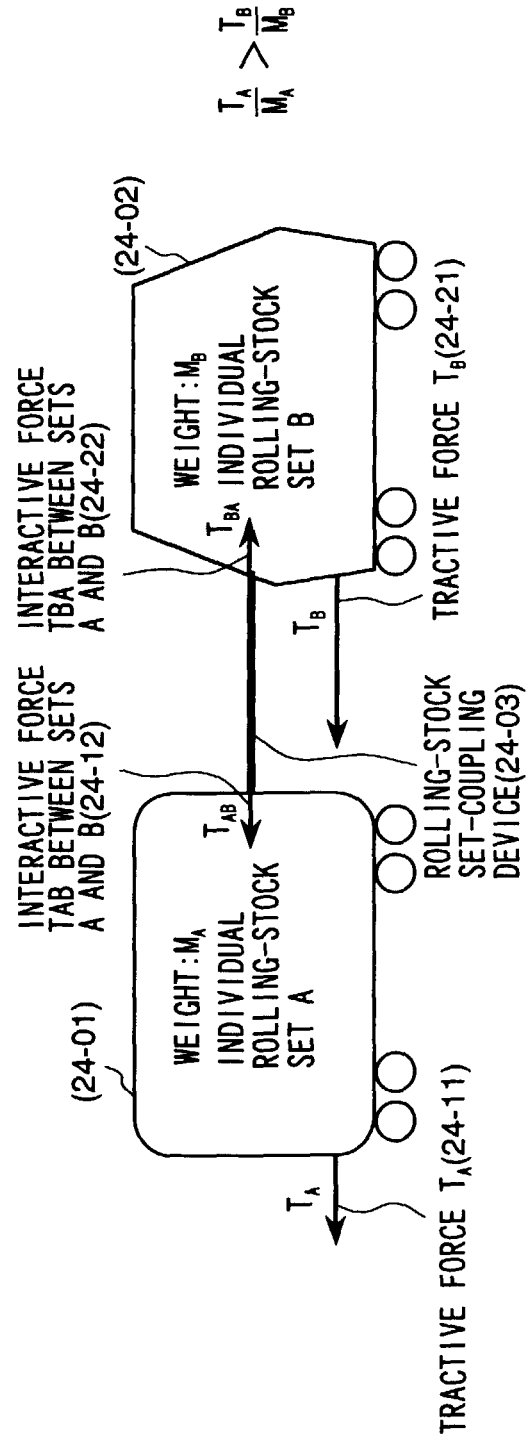


FIG. 26

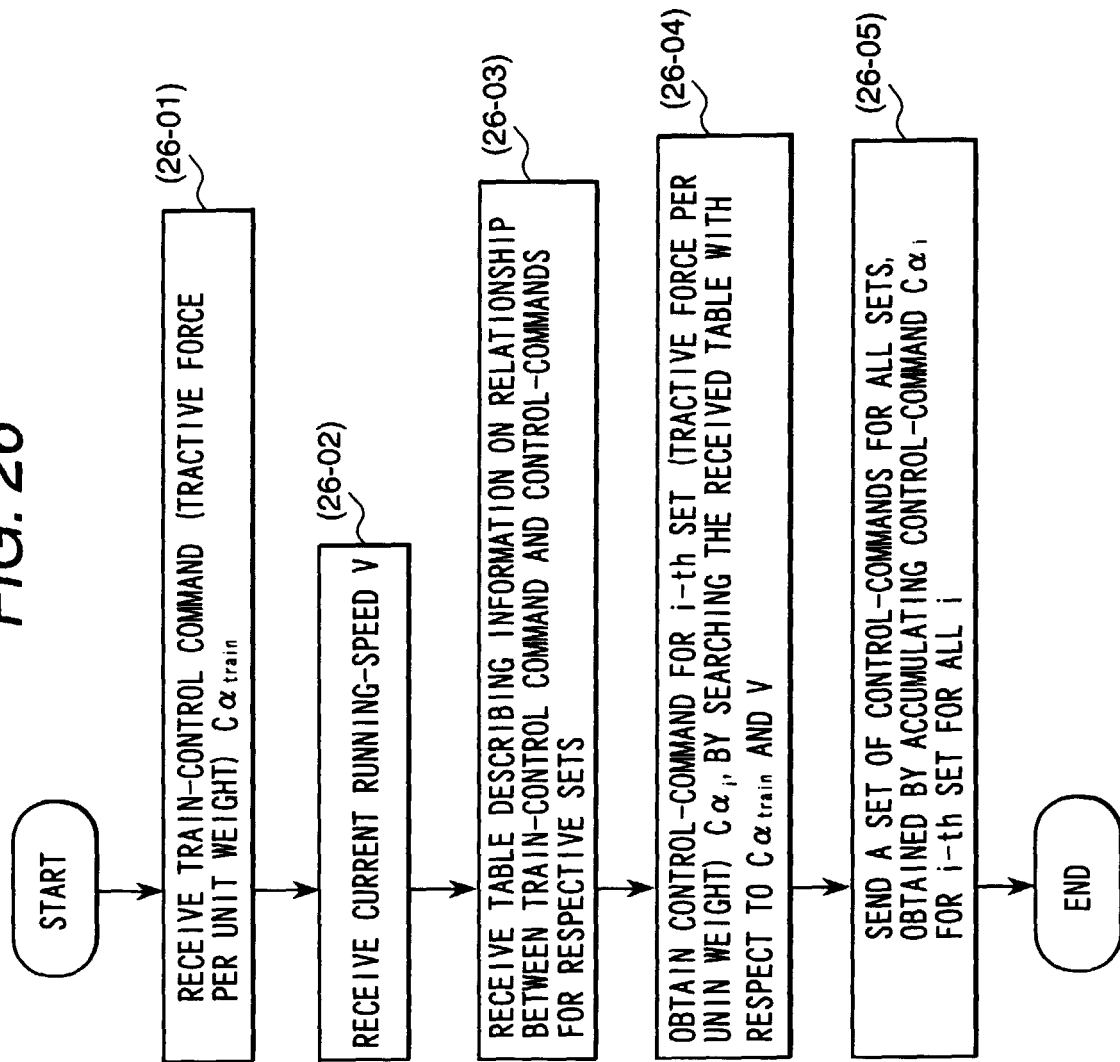


FIG. 27

TRAIN-CONTROL COMMAND (TRACTION FORCE PER UNIT WEIGHT) $C \propto \alpha_{train}$	RUNNING SPEED V	CONTROL-COMMAND FOR ROLLING-STOCK SET A: $C \propto \alpha_A$	CONTROL-COMMAND FOR ROLLING-STOCK SET B: $C \propto \alpha_B$
0.1	V_0	0.1	0.1
	V_1	0.1	0.1
	V_2	0.1	0.1
	.	.	.
	.	.	.
0.2	V_{max}	0.1	0.1
	V_0	0.2	0.2
	V_1	0.2	0.2
	V_2	0.2	0.2
	.	.	.
0.9	.	.	.
	.	.	.
	.	.	.
	V_{max}	0.2	0.2
	.	.	.
1.0	V_0	0.9	0.9
	V_1	0.9	0.9
	V_2	0.8 (MAXIMUM OUTPUT VALUE AT V_2)	1.0
	.	.	.
	.	.	.
1.0	V_{max}	0.8 (MAXIMUM OUTPUT VALUE AT V_{max})	1.0
	V_0	1.0	1.0
	V_1	0.9 (MAXIMUM OUTPUT VALUE AT V_1)	1.1
	V_2	0.8 (MAXIMUM OUTPUT VALUE AT V_2)	1.2 (MAXIMUM OUTPUT VALUE AT V_2)
	.	.	.
	V_{max}	0.8 (MAXIMUM OUTPUT VALUE AT V_{max})	1.2 (MAXIMUM OUTPUT VALUE AT V_{max})

FIG. 28

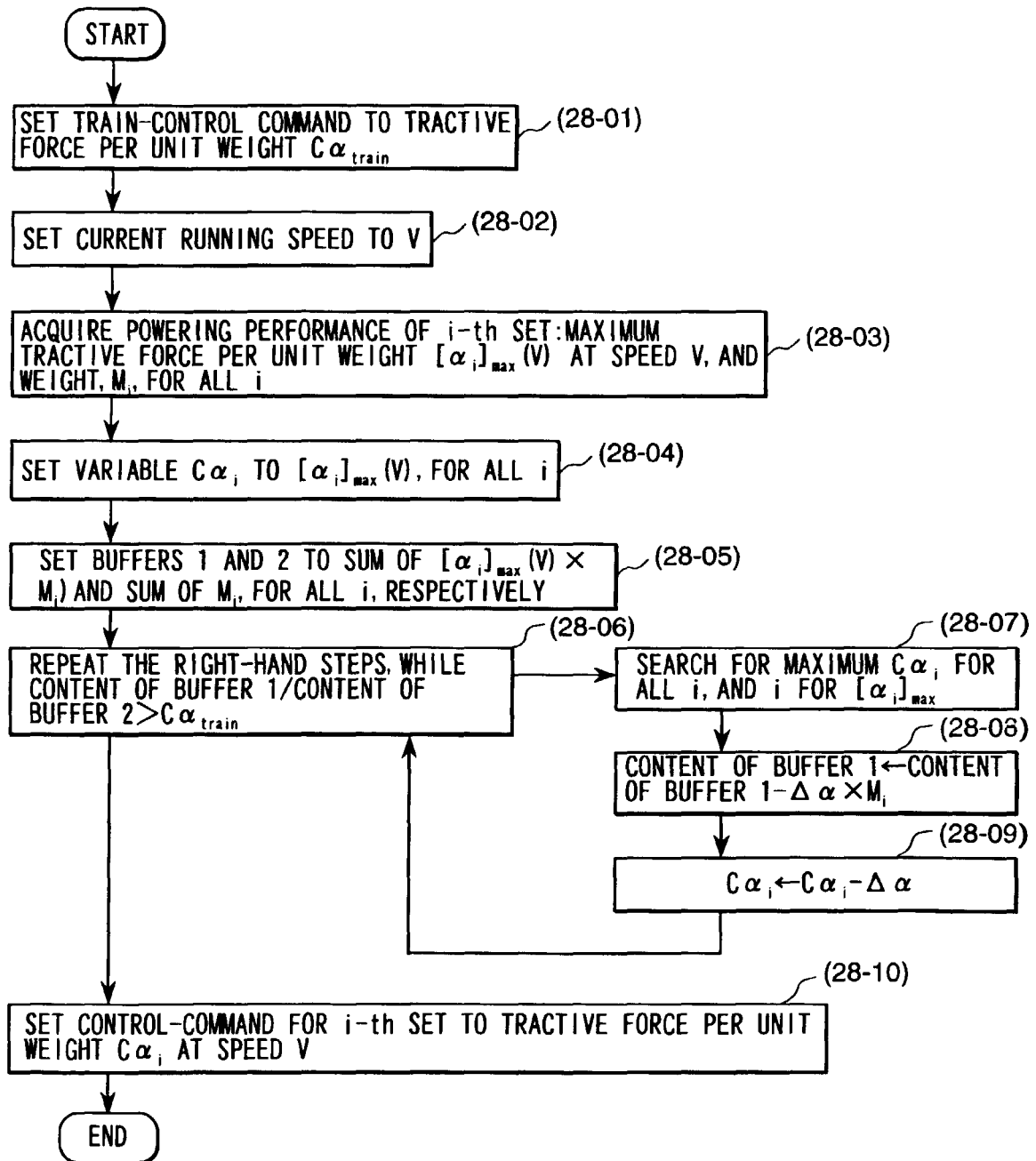


FIG. 29A

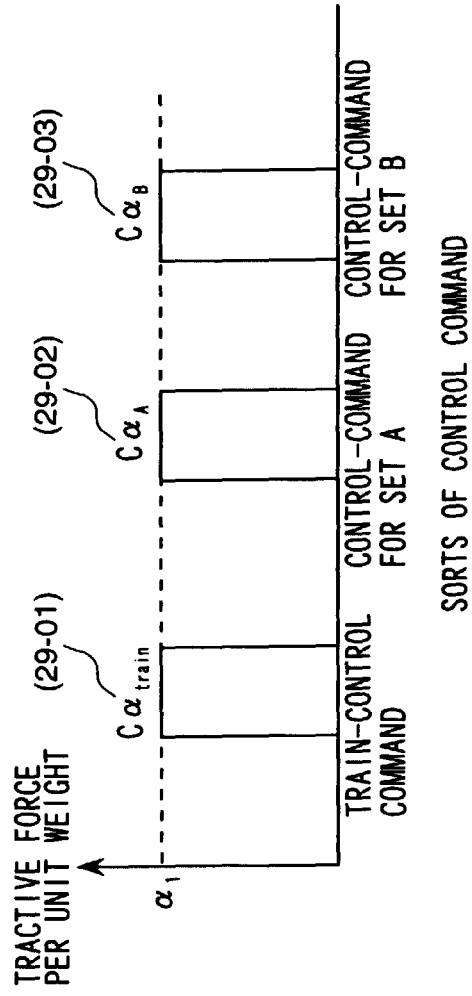


FIG. 29B

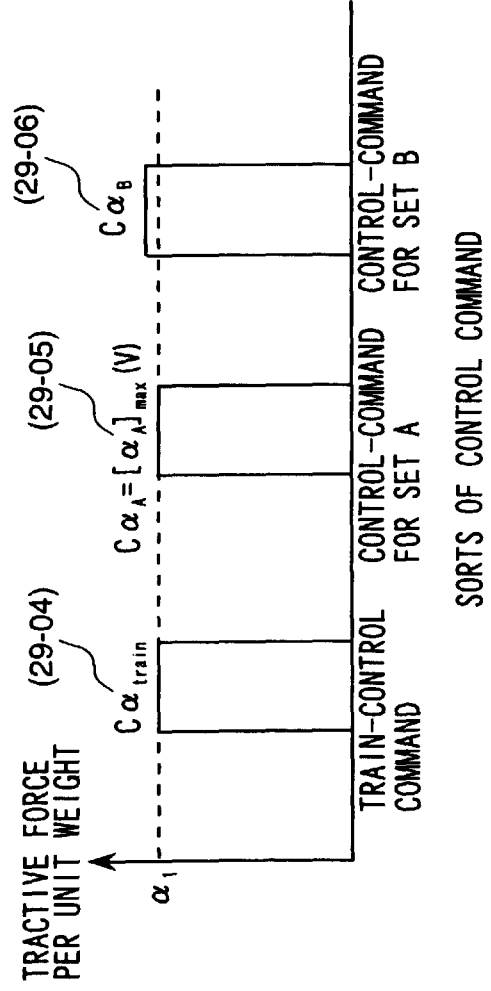


FIG. 30

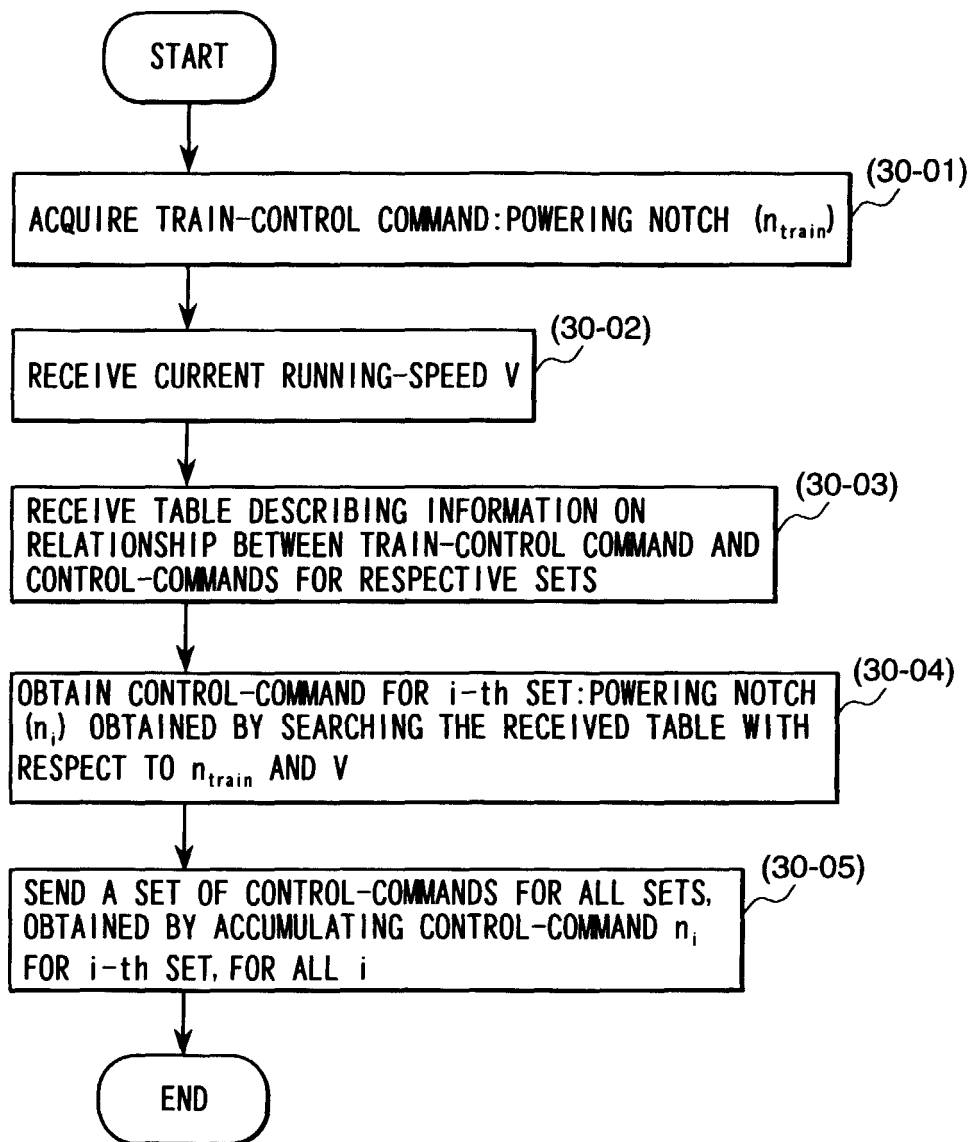


FIG. 31

TRAIN-CONTROL COMMAND: TRACTIVE FORCE PER UNIT WEIGHT (n_{train})	RUNNING SPEED V	CONTROL-COMMAND FOR ROLLING-STOCK SET A : n_A	CONTROL-COMMAND FOR ROLLING-STOCK SET B : n_B
1	V_0	1	1
	V_1	1	1
	V_2	2	1
	.	.	.
	.	.	.
	V_{max}	2	1
2	V_0	2	2
	V_1	2	2
	V_2	3	2
	.	.	.
	.	.	.
	V_{max}	3	2
.	.	.	.
	.	.	.
	.	.	.
	.	.	.
	.	.	.
	V_{max}	.	.
9	V_0	9	9
	V_1	9	9
	V_2	10 (MAXIMUM NOTCH)	8
	.	.	.
	.	.	.
	V_{max}	.	.
10	V_0	10 (MAXIMUM NOTCH)	8
	V_1	10 (MAXIMUM NOTCH)	
	V_2	10 (MAXIMUM NOTCH)	
	.	.	.
	.	.	.
	V_{max}	10 (MAXIMUM NOTCH)	.

FIG. 32

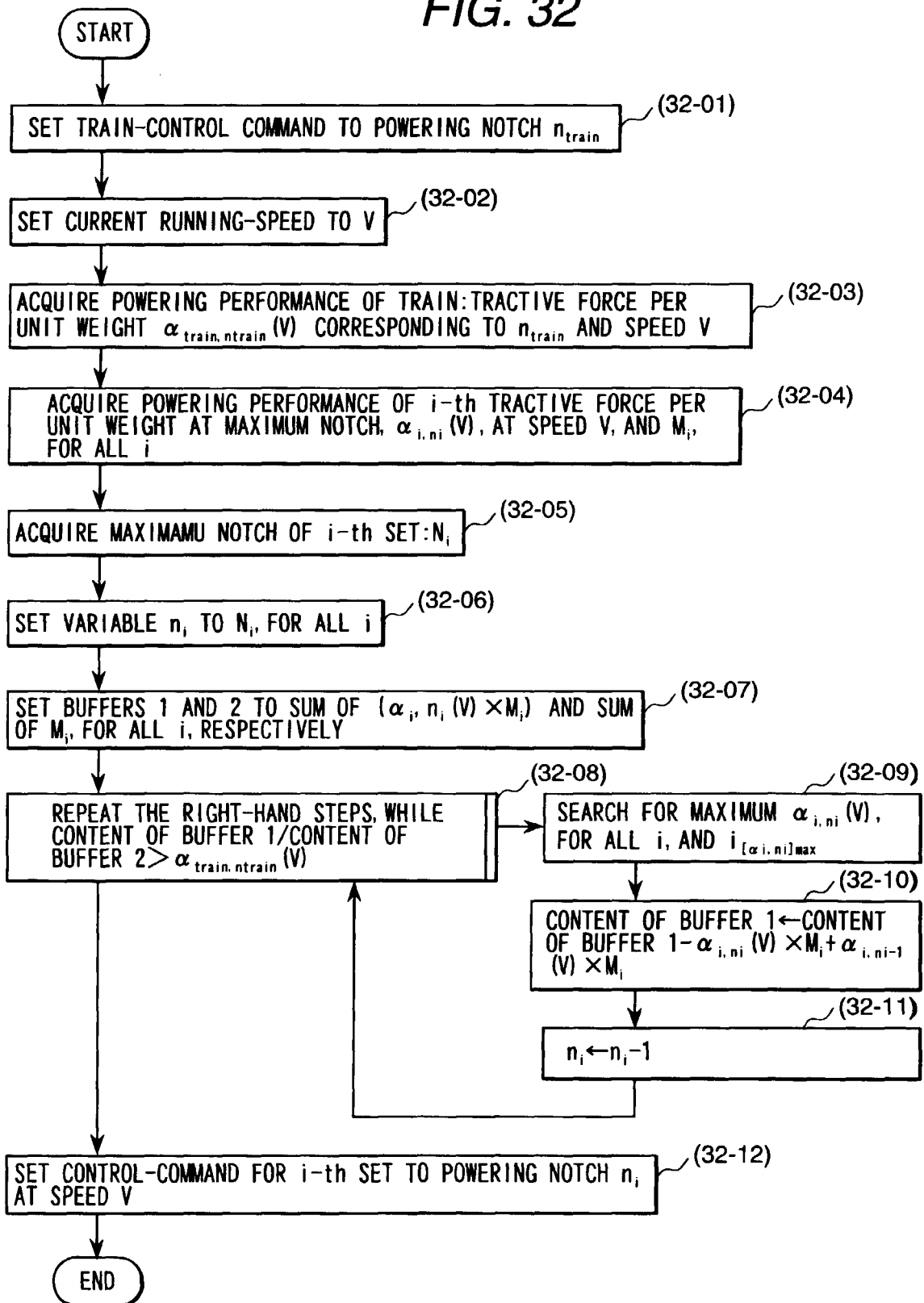
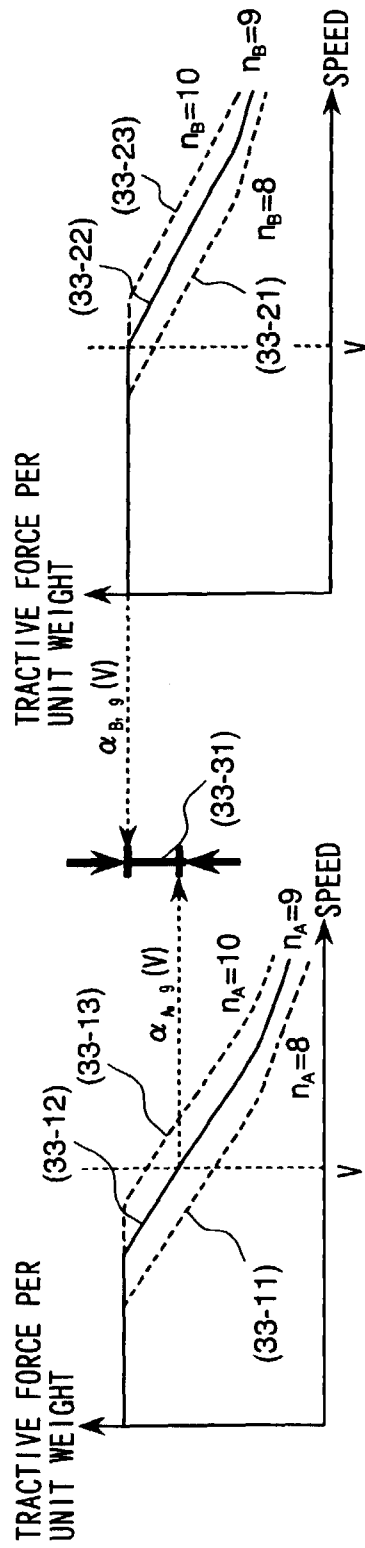


FIG. 33A

• IN THE CASE WHERE CONTROL-COMMAND FOR EACH ROLLING-STOCK SET=TRAIN CONTROL-COMMAND

**FIG. 33B**

• IN THE CASE WHERE CONTROL-COMMAND FOR RESPECTIVE ROLLING-STOCK SETS ARE ADJUSTED

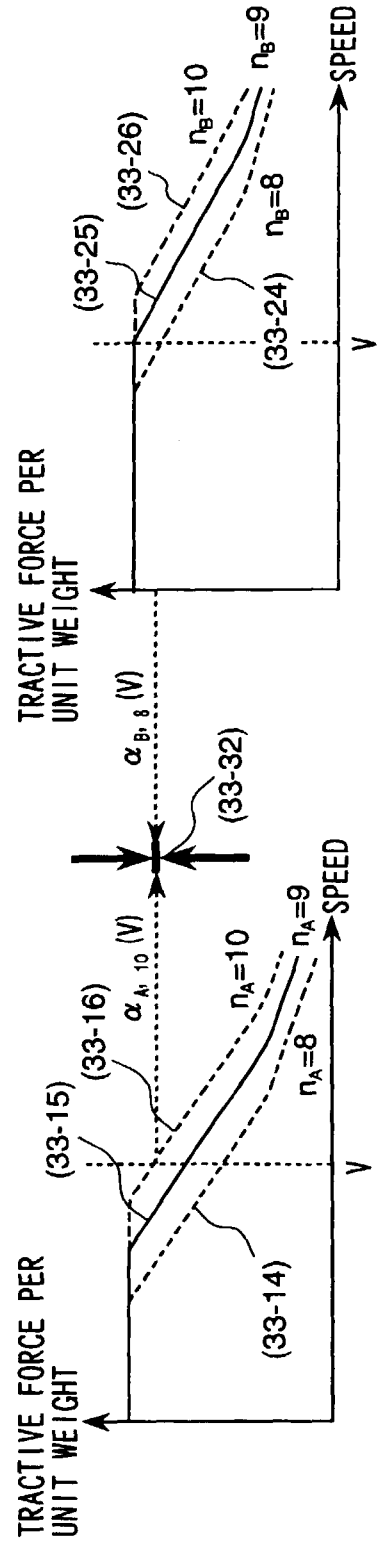


FIG. 34

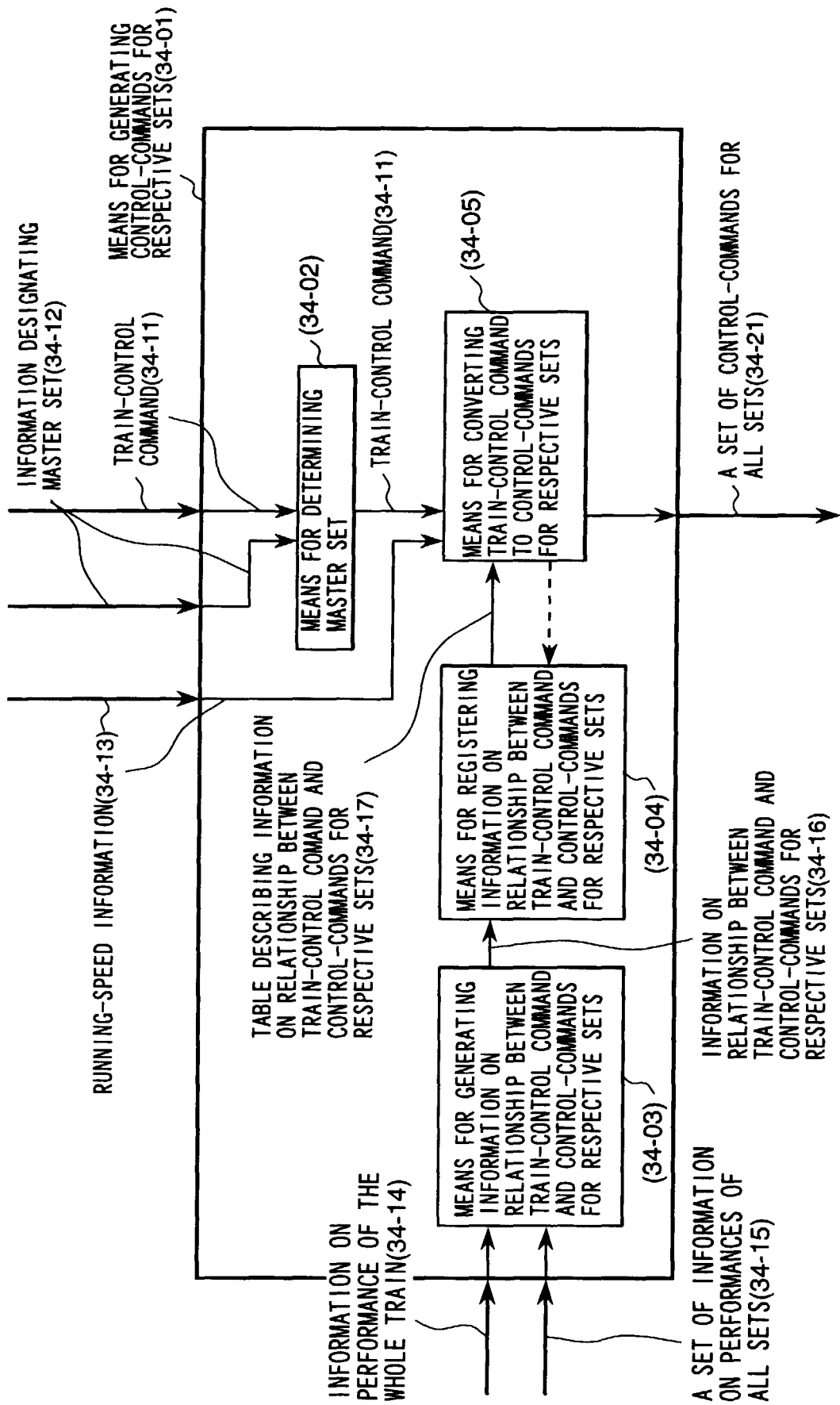


FIG. 35

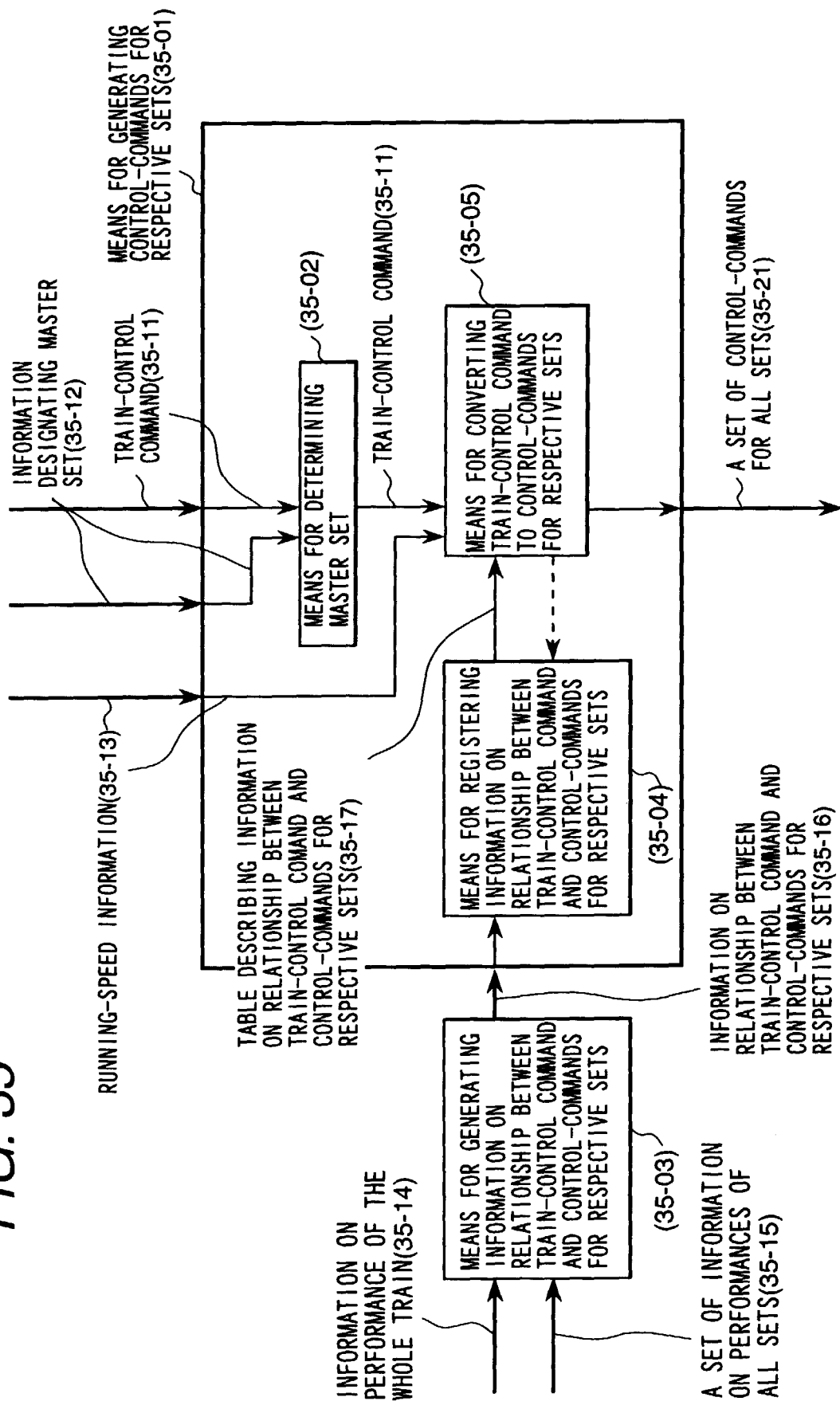


FIG. 36

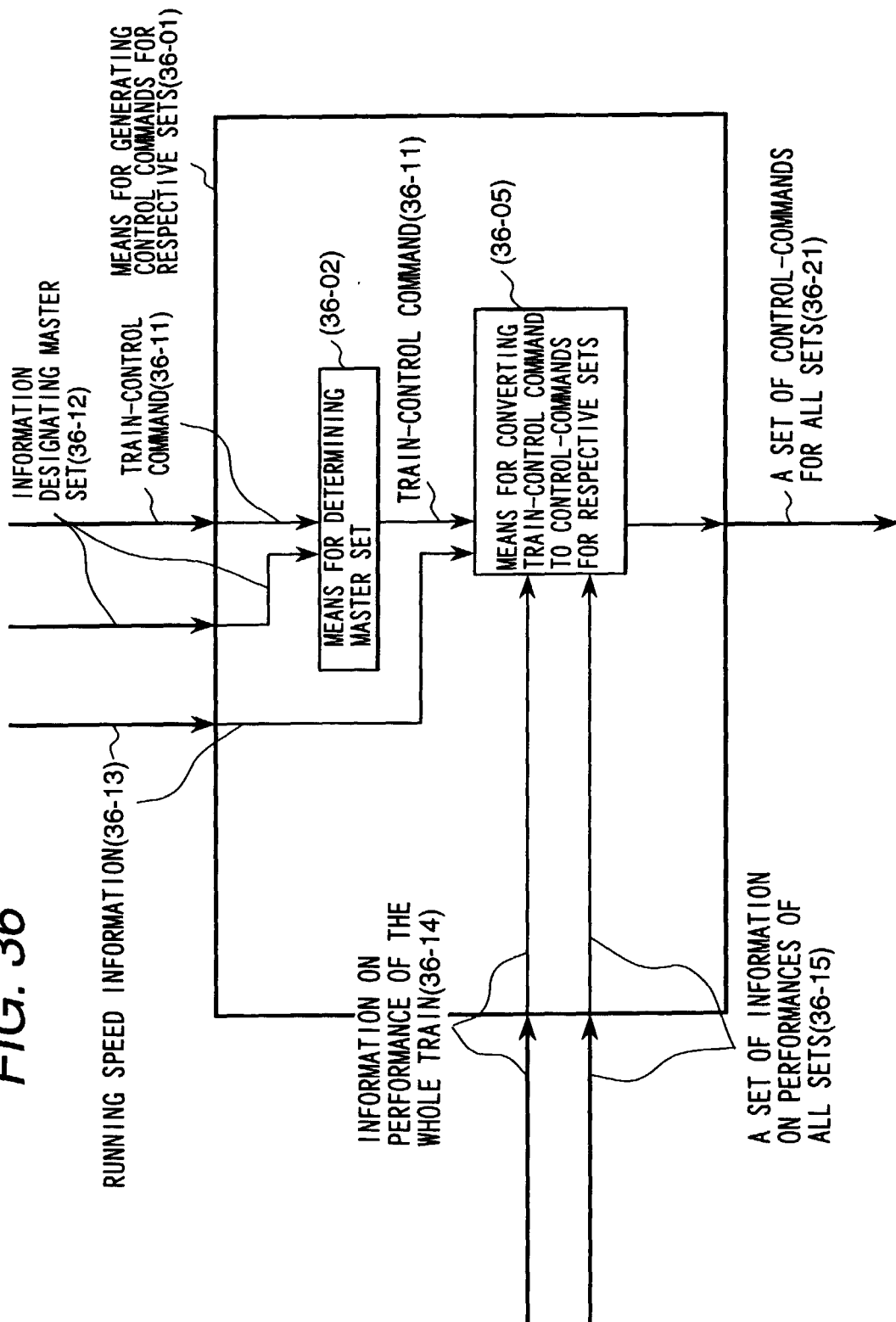


FIG. 37

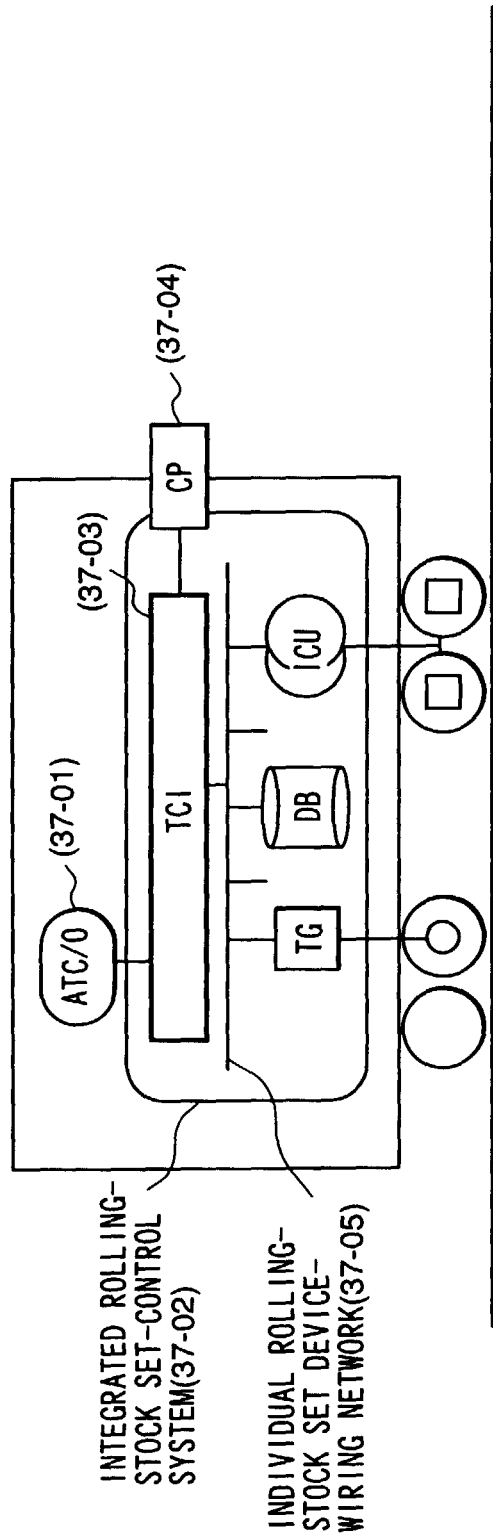


FIG. 38

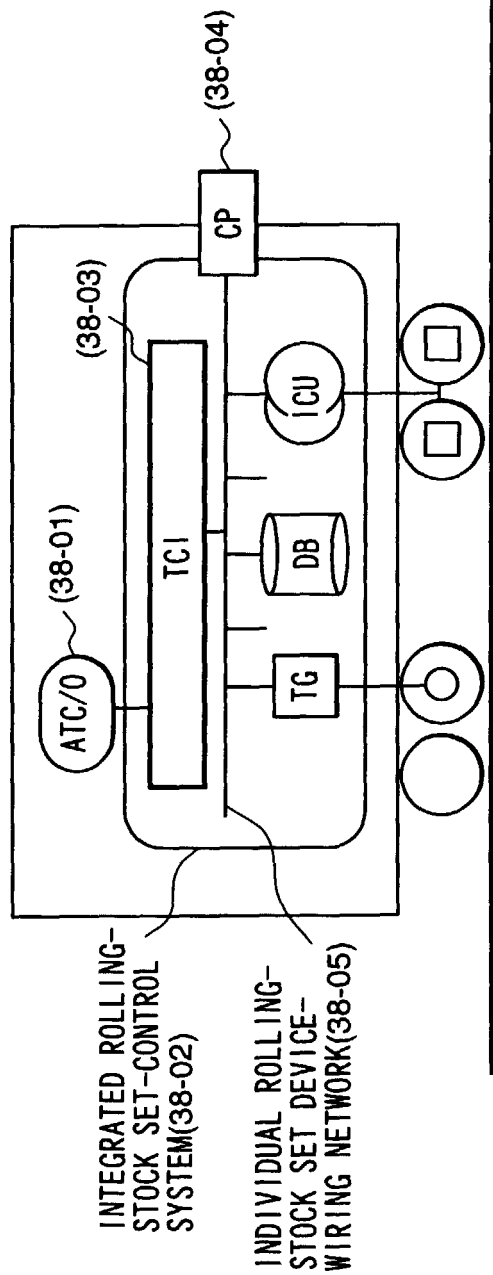


FIG. 39

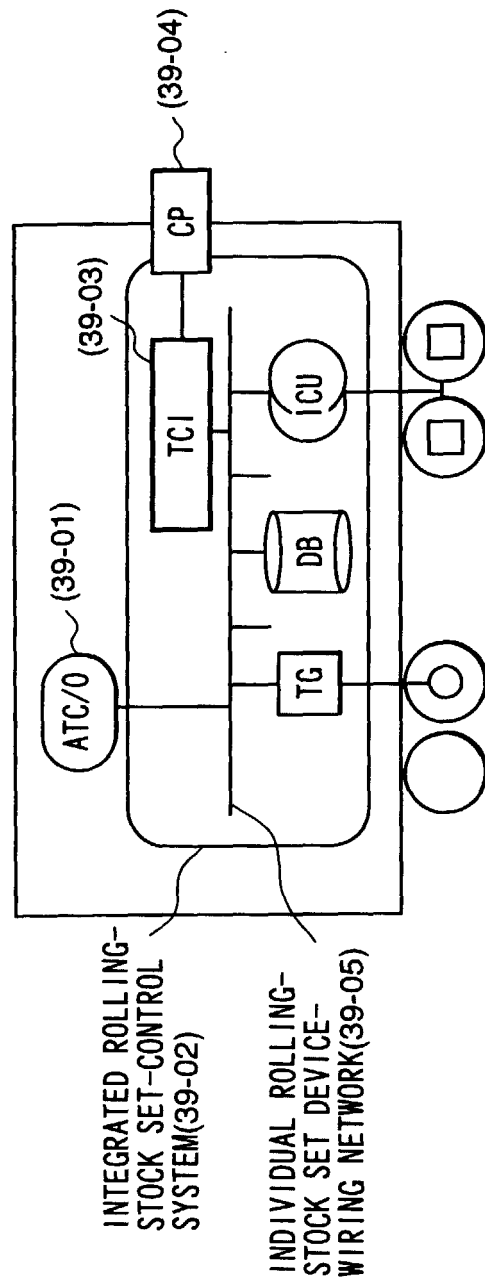


FIG. 40

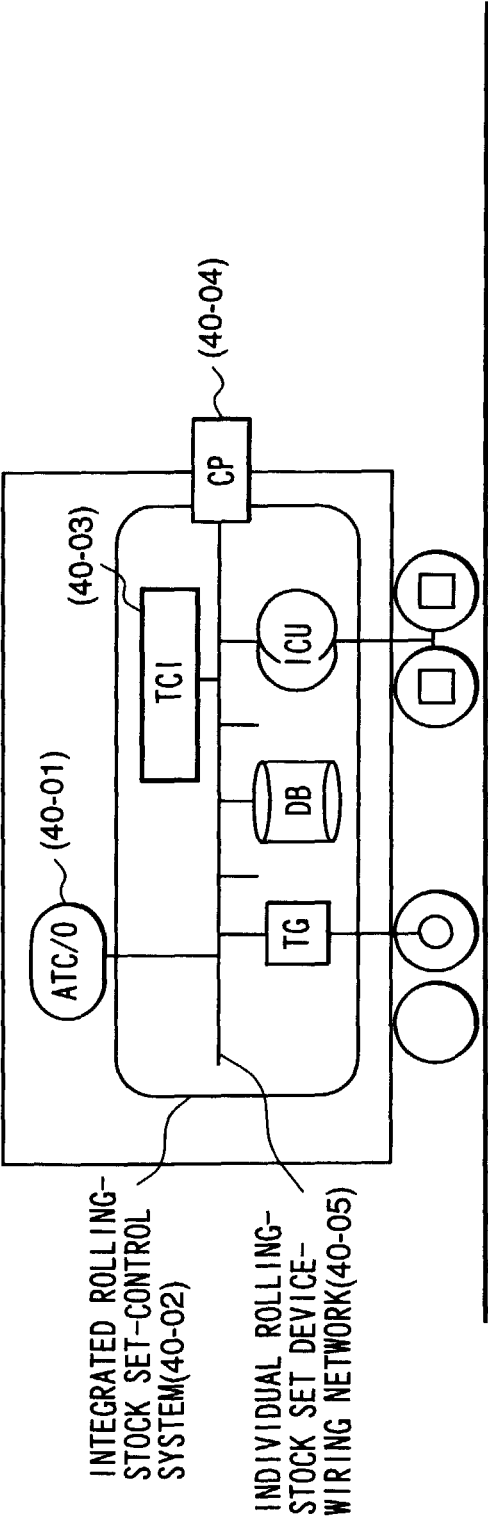


FIG. 41

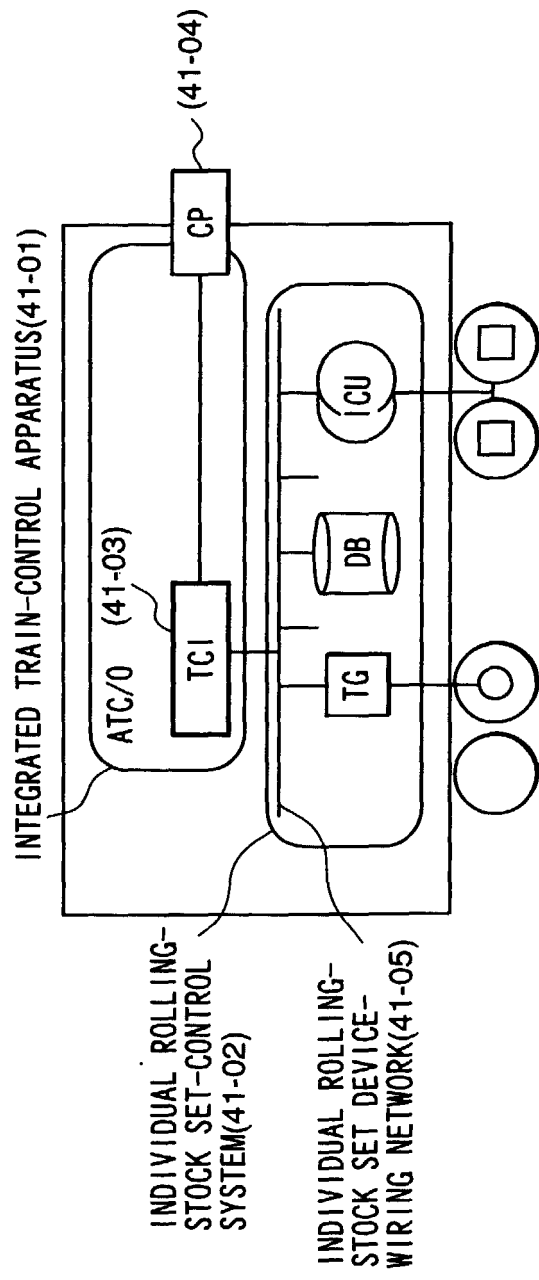


FIG. 42

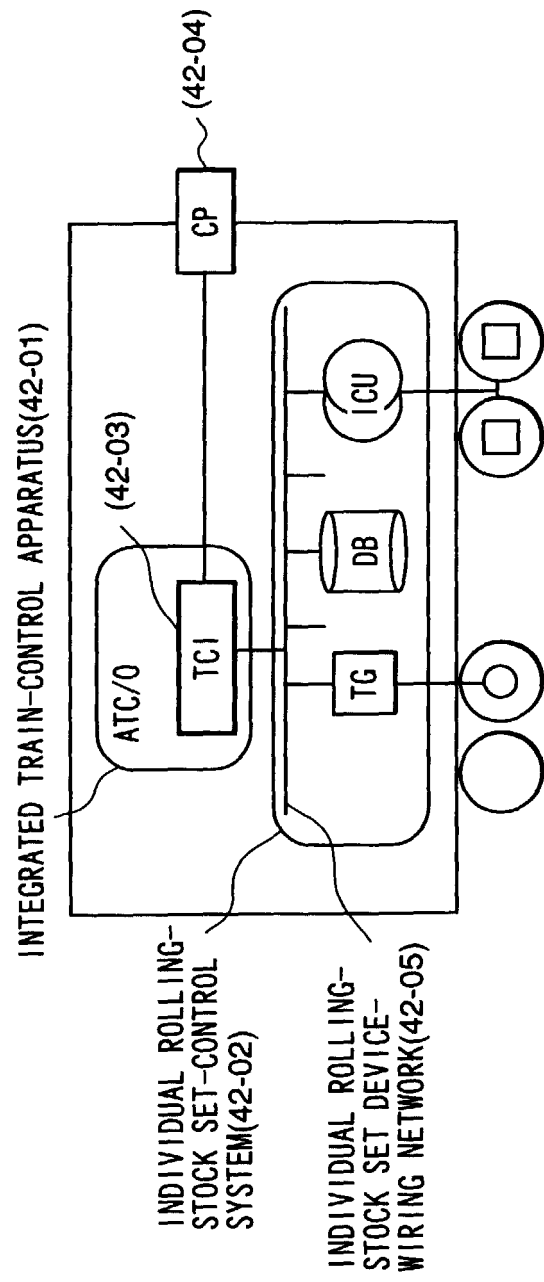


FIG. 43

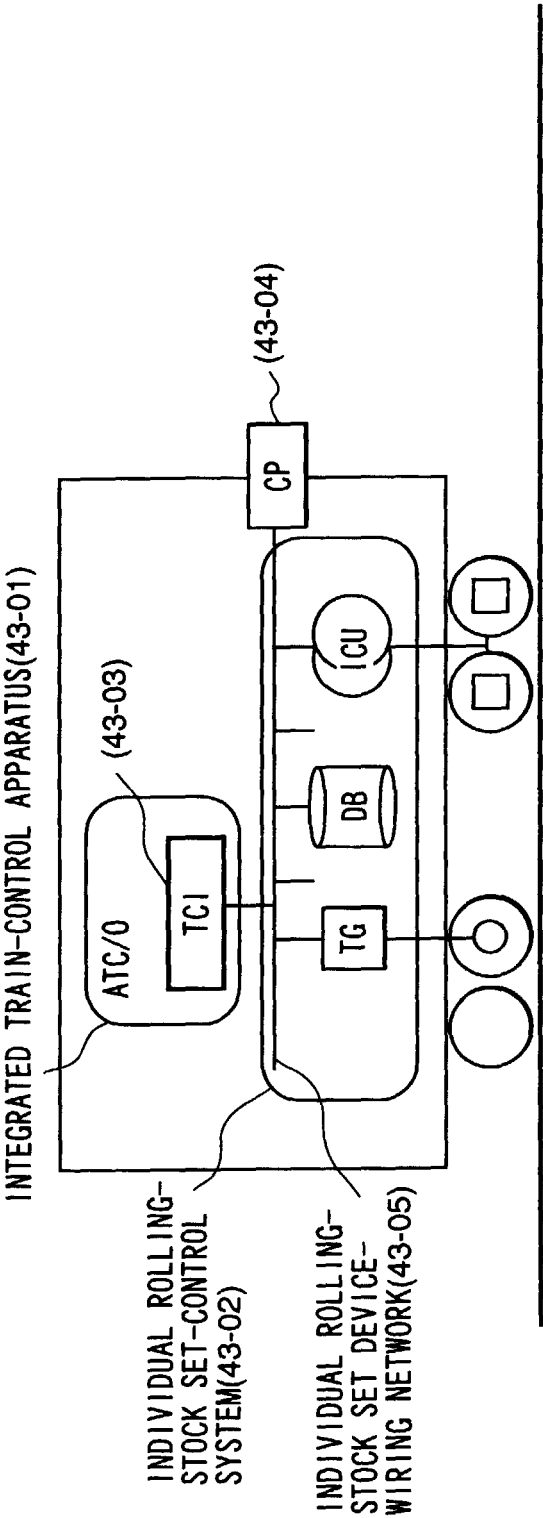


FIG. 44

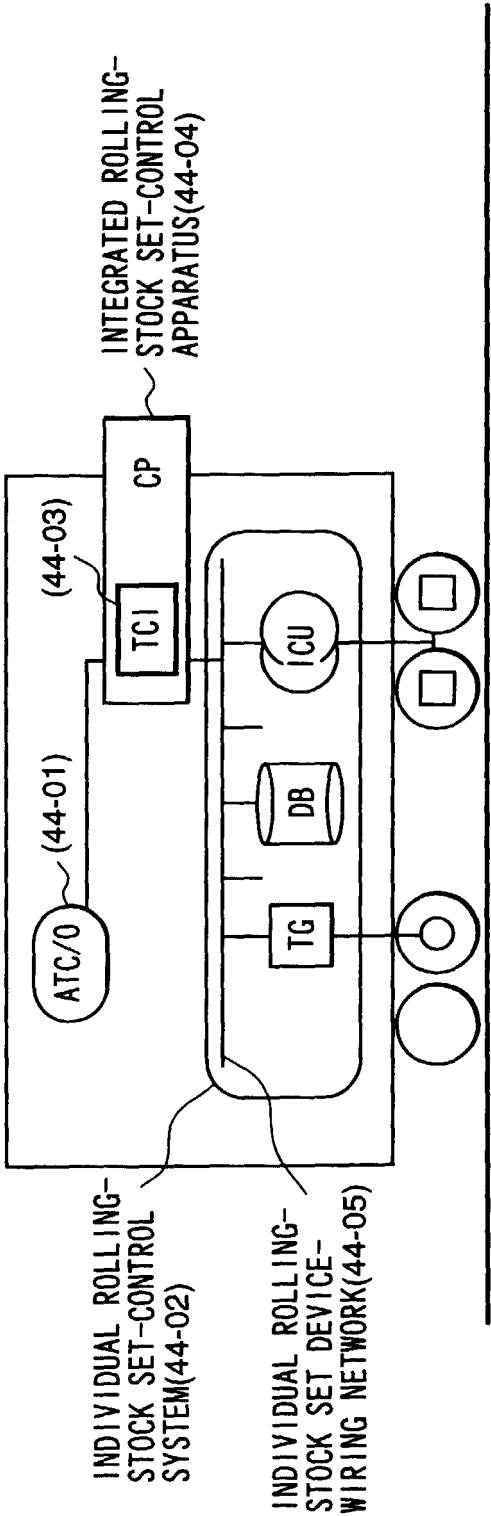


FIG. 45

