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(54) STATE DETERMINATION DEVICE FOR DOOR LOCK DEVICE, STATE DETERMINATION METHOD FOR DOOR LOCK DEVICE, AND STATE DETERMINATION PROGRAM FOR DOOR LOCK DEVICE

(57) A state determination device for a door lock device (30) includes: a calculation section (61) for calculating an elapsed unlock time H from the time when a drive signal for driving a door lock device (30) is output to the time when unlock operation of the door lock device (30) is completed (steps S10, S20, S40, S50); and a determination section (62) for determining whether or not a malfunction is present in the door lock device (30) based on the elapsed unlock time H (steps S70, S80, S110).

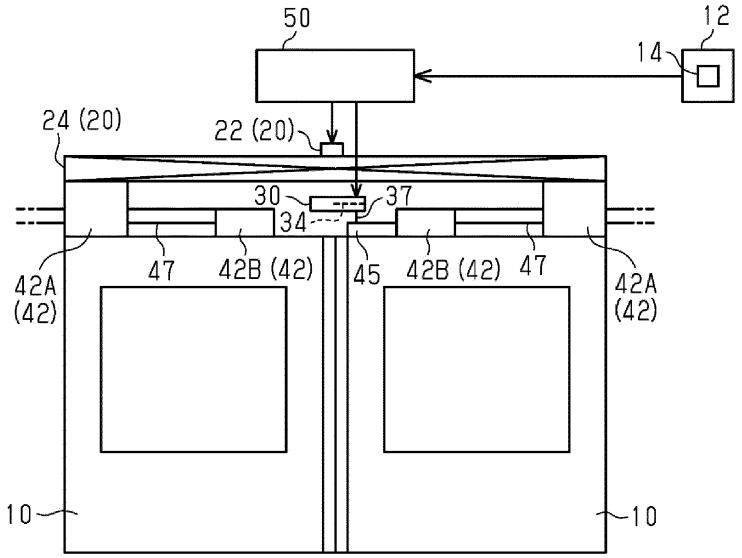

Fig. 1

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Description

[0001] The present invention relates to a state determination device for a door lock device, a state determination method for a door lock device, and a state determination program for a door lock device.

[0002] Japanese Utility Model Application Publication No. Hei 7-21777 (the "'777 Publication") discloses a door lock device for locking a door of a railway vehicle. The door lock device includes a lock pin that reciprocates. The lock pin is driven by a solenoid. The door is locked or unlocked in accordance with the movement of the lock pin.

[0003] The door lock device as disclosed in the '777 Publication sometimes experiences malfunctions such as delayed operation. Therefore, it is preferable to detect the malfunctions of the door lock device. However, in the technique disclosed in the '777 Publication, no consideration is given to determination of whether or not a malfunction is present in the door lock device. In this respect, the above technique is susceptible of improvement.

[0004] The present invention addresses such a drawback, and one object thereof is to determine whether or not a malfunction is present in the door lock device.

[0005] A state determination device for a door lock device according to one aspect of the present disclosure comprises: a calculation section for calculating an elapsed time from a time when a drive signal for driving a door lock device is output to a time when lock operation or unlock operation of the door lock device is completed; and a determination section for determining whether or not a malfunction is present in the door lock device based on the elapsed time. In the above configuration, when the door lock device experiences a malfunction such as delayed operation, the elapsed time is prolonged. Therefore, it is possible to determine whether or not a malfunction is present in the door lock device based on the elapsed time.

[0006] In the state determination device for a door lock device, the calculation section may calculate the elapsed time with a timing at which operation of the door lock device is completed defined as a timing at which, after the drive signal is output, an output signal of a door lock switch is switched between a state in which the door lock device locks a door leaf and a state in which the door lock device unlocks the door leaf.

[0007] In the above configuration, the completion of operation of the door lock device is determined using a door lock device, which is a conventional feature installed on a railway vehicle. Accordingly, no additional peculiar component is needed for determining the completion of the door lock device, and thus increase of the number of components can be avoided.

[0008] In the state determination device for a door lock device, the calculation section may calculate the elapsed time for the unlock operation of the door lock device.

[0009] In unlocking a door leaf, when the drive signal for driving the door lock device is output, the door lock device operates without the medium of the operation of the door leaf. As a result, it is possible to accurately obtain the elapsed time from the time when the drive signal for driving the door lock device is output to the time when unlock operation of the door lock device is completed. This is favorable for grasping the state of the door lock device.

[0010] In the state determination device for a door lock device, when the elapsed time is longer than a prescribed time, the determination section may determine that a malfunction is present in the door lock device. In the above configuration, since it is determined that a malfunction is present in the door lock device when the elapsed time is longer than the prescribed time, the malfunction in the door lock device can be readily detected.

[0011] In the state determination device for a door lock device, a railway vehicle may have a plurality of door lock devices installed thereon, and the determination section may calculate the prescribed time based on values of the elapsed time related to the plurality of door lock devices installed on the same railway vehicle.

[0012] It can be presumed that the plurality of door lock devices installed on the same vehicle have deteriorated to similar degrees since they were new. Since the prescribed time is calculated based on the door lock devices having deteriorated to similar degrees so as to be used for comparison between them, it is possible to determine whether or not a malfunction is present in the door lock device irrespective of its degree of deterioration. Further, since the prescribed time is calculated from the door lock devices on the same vehicle, it is not necessary to previously perform an experiment or simulation for calculating the prescribed time.

[0013] A state determination method for a door lock device according to one aspect of the present disclosure comprises: a calculation step of calculating an elapsed time from a time when a drive signal for driving a door lock device is output to a time when operation of the door lock device is completed; and a determination step of determining whether or not a malfunction is present in the door lock device based on the elapsed time. In the above configuration, when the door lock device experiences a malfunction such as delayed operation, the elapsed time is prolonged. Therefore, it is possible to determine whether or not a malfunction is present in the door lock device based on the elapsed time.

[0014] A state determination program for a door lock device according to one aspect of the present disclosure causes a computer to perform: a calculation process for calculating an elapsed time from a time when a drive signal for driving a door lock device is output to a time when operation of the door lock device is completed; and a determination process for determining whether or not a malfunction is present in the door lock device based on the elapsed time. In the above configuration, when the door lock device experiences a malfunction such as delayed operation, the elapsed time is prolonged. Therefore, it is possible to determine whether or not a malfunc-

tion is present in the door lock device based on the elapsed time.

[0015] A computer-readable storage medium according to one aspect of the present disclosure stores a state determination program for a door lock device. When executed by a computer, the state determination program for a door lock device causes the computer to perform: a calculation process for calculating an elapsed time from a time when a drive signal for driving a door lock device is output to a time when operation of the door lock device is completed; and a determination process for determining whether or not a malfunction is present in the door lock device based on the elapsed time. In the above configuration, when the door lock device experiences a malfunction such as delayed operation, the elapsed time is prolonged. Therefore, it is possible to determine whether or not a malfunction is present in the door lock device based on the elapsed time.

Fig. 1 is a schematic view of a mechanism related to opening and closing of a door of a railway vehicle.
Fig. 2 is a block diagram of a door lock device.
Fig. 3 is a flowchart of a state determination process.

[0016] With reference to Figs. 1 to 3, a description is hereinafter given of one embodiment in which a state determination device for a door lock device is formed in a door control unit.

[0017] A schematic configuration will be first described as to a door, a door opening-closing device, and a door lock device of a railway vehicle.

[0018] As shown in Fig. 1, the railway vehicle includes a door with door leaves 10 that operate to open and close an opening, or a doorway of the railway vehicle. The door leaves 10 form a bi-parting door. The paired door leaves 10 are suspended with door suspending members 42 positioned above. Each of the door leaves 10 is provided with two door suspending members 42. The door suspending members 42 slide along rails 47 extending in the front-rear direction of the vehicle. The paired door leaves 10 constitute a sliding door with two leaves sliding in the front-rear direction of the vehicle. The paired door leaves 10 slide in directions away from each other and enter an open state to open the doorway, and slide in directions coming close to each other and enter a closed state to close the doorway. The railway vehicle includes a plurality of doorways each provided with a corresponding pair of door leaves 10. Fig. 1 shows only one pair of door leaves 10 among a plurality of such pairs.

[0019] A door opening-closing device 20 for driving the door leaves 10 is provided around, or more specifically, above the doorway of the railway vehicle. The door opening-closing device 20 includes an electric motor 22 as a drive source. The electric motor 22 is coupled to the two door leaves 10 via a door drive mechanism 24 that includes a rack and a pinion, for example. Specifically, the door drive mechanism 24 is coupled to outer door suspending members 42A among the two door suspending members 42 provided for each of the door leaves 10. The outer door suspending members 42A are positioned outside the doorway in the sliding direction of the door leaves 10. The door leaves 10 enter the open state when an output shaft of the electric motor 22 rotates in one direction, and the door leaves 10 enter the closed state when the output shaft of the electric motor 22 rotates in the other direction.

[0020] Above the doorway of the railway vehicle, there is provided a door lock device 30 for locking the paired door leaves 10 in the fully closed state. Only one door lock device 30 is provided for each pair of the door leaves 10. The door lock device 30 is positioned around the middle of the doorway in the sliding direction of the door leaves 10.

[0021] As shown in Fig. 2, the door lock device 30 includes a solenoid 32 as a drive source. The solenoid 32 includes a coil 33 having a cylindrical shape. A voltage from a power source 31 is applied to the coil 33. A lock pin 34 shaped like a rod projects from inside the coil 33. The lock pin 34 is biased by a compression spring 36 in such a direction as to project from the coil 33. The solenoid 32 includes a built-in ammeter 39A for measuring an electric current A flowing through the coil 33. A voltmeter 39B for measuring a voltage V of the power source 31 is installed on the wire connecting between the power source 31 and the coil 33.

[0022] In the door lock device 30, when a voltage is applied from the power source 31 to the coil 33 of the solenoid 32 to excite the coil 33, the lock pin 34 is withdrawn into the coil 33 against the elastic force of the compression spring 36. On the other hand, when no voltage is applied from the power source 31 to the coil 33 and the coil 33 is demagnetized, the lock pin 34 is projected from the coil 33 by the elastic force of the compression spring 36.

[0023] As shown in Fig. 1, in the door lock device 30, the lock pin 34 is coupled to a projecting rod 37 via a coupling mechanism (not shown). The projecting rod 37 moves in accordance with the movement of the lock pin 34. The door suspending members 42 provided for one of the paired door leaves 10 have a fixing member 45 attached thereto. The fixing member 45 is configured to engage with the projecting rod 37 when the door leaves 10 are in the fully closed state. The fixing member 45 is attached to a middle door suspending member 42B of one of the door leaves 10, which is one of the two door suspending members 42 provided for this door leaf 10 and is positioned closer to the middle of the doorway in the sliding direction of the door leaves 10.

[0024] When the door leaves 10 are in the fully closed state, the lock pin 34 projects from the coil 33 in response to the demagnetization of the coil 33 of the solenoid 32, and thus the projecting rod 37 moves to engage with the fixing member 45. As a result, the above one of the door leaves 10 enters a locked state in which this door leaf 10 is prohibited from sliding. As one door leaf 10 is prohibited from sliding, the other door leaf 10 is also prohibited from

sliding by the door drive mechanism 24. When the lock pin 34 is withdrawn into the coil 33 in response to excitation of the coil 33 of the solenoid 32, the projecting rod 37 is disengaged from the fixing member 45. The door leaves 10 then enter an unlocked state.

[0025] The movement of the lock pin 34 is transmitted to a door lock switch (DLS) 38 via a transmission mechanism (not shown). As shown in Fig. 2, the door lock switch 38 outputs a lock signal LS as an output signal when the lock pin 34 is in a lock position where it projects from the coil 33. The door lock switch 38 stops outputting the lock signal LS as an output signal when the lock pin 34 moves into an unlock position where it is withdrawn into the coil 33. In this way, the door lock switch 38 switches the output of the lock signal LS between On and Off depending on whether the door lock device 30 locks or unlocks the door leaves 10.

[0026] Next, an electrical configuration of the door opening-closing device 20 and the door lock device 30 will be described.

[0027] As shown in Fig. 1, the door opening-closing device 20 and the door lock device 30 are controlled by a door control unit 50. The door control unit 50 is provided for each pair of the door leaves 10 and installed in the vicinity of the doorway of the railway vehicle. The door control unit 50 may be formed of one or more processors that perform various processes in accordance with computer programs (software). Alternatively, the door control unit 50 may be formed of one or more dedicated hardware circuits such as microcomputers that perform at least a part of the various processes, or it may be formed of circuitry including a combination of such circuits. The processors include a CPU and a memory such as a RAM or ROM. The memory stores therein program codes or instructions configured to cause the CPU to perform processes. The memory, or a computer-readable medium, encompasses any kind of available media accessible by a general-purpose or dedicated computer. The door control unit 50 also includes a non-volatile storage section. The door control unit 50 receives the lock signal LS from the door lock switch 38. The door control unit 50 also receives the values of the electric current A and the voltage V from the ammeter 39A and the voltmeter 39B, respectively.

[0028] The door control unit 50 is connected with a vehicle control device 12 that serves as an upper-level device to control traveling of the railway vehicle and opening and closing of the door 10. As shown in Fig. 2, the door control unit 50 operates based on an instruction signal W from the vehicle control device 12. The vehicle control device 12 may be formed of one or more processors that perform various processes in accordance with computer programs (software). Alternatively, the vehicle control device 12 may be formed of one or more dedicated hardware circuits such as microcomputers that perform at least a part of the various processes, or it may be formed of circuitry including a combination of such circuits. The processors include a CPU and a memory such as a RAM or ROM. The memory stores therein program codes or instructions configured to cause the CPU to perform processes. The memory, or a computer-readable medium, encompasses any kind of available media accessible by a general-purpose or dedicated computer. The vehicle control device 12 also includes a non-volatile database 14. The database 14 intensively stores information input from the door control unit 50.

[0029] As shown in Fig. 2, the door control unit 50 includes a drive control section 52 for driving the door opening-closing device 20 and the door lock device 30 in accordance with the instruction signal W from the vehicle control device 12. The drive control section 52 outputs a drive signal for driving the door opening-closing device 20 and the door lock device 30. As a drive signal for driving unlock operation of the door lock device 30, the drive control section 52 outputs to the power source 31 an excitation signal EM1 for exciting the solenoid 32. When the excitation signal EM1 is output, the power source 31 applies a voltage to the solenoid 32 to excite the solenoid 32. As a drive signal for driving lock operation of the door lock device 30, the drive control section 52 outputs to the power source 31 a demagnetization signal EM2 for demagnetizing the solenoid 32. When the demagnetization signal EM2 is output, the power source 31 stops applying a voltage to the solenoid 32 to demagnetize the solenoid 32.

[0030] In the door lock device 30, the movement of the lock pin 34 may undergo a large slide resistance due to clogging by foreign substances or partial wear. The slide resistance may also be enlarged in accordance with deformation of the vehicle body to which the door lock device 30 is attached. When the movement of the lock pin 34 undergoes a large slide resistance, the lock pin 34 may start moving at a delayed timing or move at a low speed after it starts moving, in response to the excitation signal EM1 or the demagnetization signal EM2 output to the solenoid 32. To address this problem, the door control unit 50 includes a state determination device 60 for determining whether or not a malfunction is present in the door lock device 30.

[0031] In addition to the enlarged slide resistance mentioned above, the door lock device 30 may undergo a fault such as a disconnection or a short circuit occurring in the solenoid 32 or the electrical system connected thereto, resulting in a reduced electric current flowing through the solenoid 32. This also causes the lock pin 34 to start moving at a delayed timing or move at a low speed after it starts moving. The state determination device 60 also determines whether or not such a malfunction is present.

[0032] The state determination device 60 of the door control unit 50 includes a calculation section 61 for calculating the elapsed time from the time when a drive signal for driving the door lock device 30 is output to the time when the operation of the door lock device 30 in response to the drive signal is completed. The calculation section 61 calculates the elapsed time related to the un-

lock operation of the door lock device 30. Specifically, the calculation section 61 calculates the elapsed unlock time H elapsed from the time when the excitation signal EM1 is output to the solenoid 32 to the time when the withdrawal of the lock pin 34 into the coil 33 is completed and the projecting rod 37 is disengaged from the fixing member 45. In calculating the elapsed unlock time H, the calculation section 61 regards the timing at which the lock signal LS output from the door lock switch 38 switches from On to Off as the time at which the withdrawal of the lock pin 34 into the coil 33 is completed.

[0033] The state determination device 60 of the door control unit 50 includes a determination section 62 for determining whether or not a malfunction is present in the door lock device 30 based on the elapsed unlock time H. When the elapsed unlock time H is longer than a prescribed time H1 set previously, the determination section 62 determines that the movement of the lock pin 34 is delayed, that is, a malfunction is present in the door lock device 30. Further, when the resistance R obtained by dividing the voltage V of the power source 31 by the electric current A flowing through the coil 33 is different from a prescribed resistance RQ set previously, the determination section 62 determines that a fault has occurred in the solenoid 32 or the electrical system connected thereto, that is, a malfunction is present in the door lock device 30. In this way, the determination section 62 determines whether a fault has occurred, based on the relationship between the electric current A and the voltage V. The prescribed resistance RQ mentioned above is calculated by previously investigating through an experiment or simulation the relationship between the voltage and the electric current occurring when the voltage is applied to the solenoid 32.

[0034] The determination section 62 calculates the prescribed time H1 as a reference value for determining whether or not a malfunction is present in the door lock device 30. The determination section 62 calculates the prescribed time H1 based on values of the elapsed unlock time H related to a plurality of door lock devices 30 installed on the same vehicle among a plurality of vehicles constituting a train. The calculation section 61, which has calculated the elapsed unlock time H, transmits the elapsed unlock time H to the vehicle control device 12. The vehicle control device 12 stores the elapsed unlock time H on the database 14. The vehicle control device 12 receives the values of the elapsed unlock time H from the plurality of door control units 50 installed on the railway vehicle. The database 14 stores data on the elapsed unlock time H related to the plurality of door lock devices 30 installed on the railway vehicle. This data covers a previous predetermined period. In calculating the prescribed time H1, the determination section 62 accesses the database 14 of the vehicle control device 12 to obtain data on the elapsed unlock time H related to the plurality of door lock devices 30 installed on the same vehicle, covering the previous predetermined period. The determination section 62 then calculates the average time from the obtained data and calculates the prescribed time H1 such that it is longer than the average time.

[0035] Next, a state determination process performed by the door control unit 50 will be described. Upon receiving from the vehicle control device 12 the instruction signal W for opening the door leaves 10, the door control unit 50 starts the state determination process including a series of steps. At the time when the door control unit 50 receives from the vehicle control device 12 the instruction signal W for opening the door leaves 10, the door leaves 10 are in the fully closed state, and the lock pin 34 is in the lock position where it projects from the coil 33. In addition, the door lock switch 38 is outputting the lock signal LS.

[0036] As shown in Fig. 3, the door control unit 50 starts the state determination process in step S10. In step S10, the calculation section 61 of the door control unit 50 determines whether or not the excitation signal EM1 has been output from the drive control section 52 to the solenoid 32. When the excitation signal EM1 has not been output (NO in step S10), the calculation section 61 executes step S10 again. The calculation section 61 repeats step S10 until the excitation signal EM1 is output. When the excitation signal EM1 has been output (YES in step S10), the calculation section 61 proceeds to step S20.

[0037] In step S20, the calculation section 61 starts counting the lock time H. The calculation section 61 proceeds to step S30. In step S30, the determination section 62 refers to the measurement results of the ammeter 39A and the voltmeter 39B. The determination section 62 then determines whether or not the resistance R obtained by dividing the voltage V by the electric current A is equal to the prescribed resistance RQ. When the resistance R is different from the prescribed resistance RQ ($R \neq RQ$) (NO in step S30), the determination section 62 proceeds to step S100.

[0038] In step S100, the determination section 62 determines that a fault has occurred in the electrical system related to the solenoid 32. The determination section 62 then outputs to the vehicle control device 12 first information J1 indicating that a fault has occurred in the electrical system related to the solenoid 32. Upon receiving the first information J1, the vehicle control device 12 stores on the database 14 the information indicating that a fault has occurred in the electrical system related to the solenoid 32. After executing step S100, the determination section 62 temporarily ends execution of the series of steps of the state determination process.

[0039] In step S30, when the resistance R is equal to the prescribed resistance RQ ($R = RQ$) (YES in step S30), the determination section 62 proceeds to step S40. In step S40, the calculation section 61 determines whether or not the output of the lock signal LS has been switched to Off. When the lock signal LS is being continuously output (NO in step S40), the calculation section 61 returns to step S30. The determination section 62 then executes step S30. The calculation section 61 and the determination section 62 repeat step S30 and step S40 until the

output of the lock signal LS is switched to Off. When the output of the lock signal LS has been switched to Off (YES in step S40), the calculation section 61 proceeds to step S50.

[0040] In step S50, the calculation section 61 ends the count of the lock time H that was started in step S20. The calculation section 61 then calculates the final elapsed unlock time H at the elapsed unlock time H as of the time when step S50 is reached. The calculation section 61 transmits the calculated elapsed unlock time H to the vehicle control device 12. Subsequently, the calculation section 61 proceeds to step S60.

[0041] In step S60, the determination section 62 of the door control unit 50 calculates the prescribed time H1. As already described, the determination section 62 calculates the prescribed time H1 based on the values of the elapsed unlock time H related to a plurality of door lock devices 30 installed on the same vehicle. Subsequently, the determination section 62 proceeds to step S70. Step S60 corresponds to the calculation step and the calculation process.

[0042] In step S70, the determination section 62 determines whether the elapsed unlock time H is equal to or shorter than the prescribed time H1. When the elapsed unlock time H is longer than the prescribed time H1 (H>H1) (NO in step S70), the determination section 62 proceeds to step S110.

[0043] In step S110, the determination section 62 determines that the movement of the lock pin 34 is delayed. The determination section 62 then outputs to the vehicle control device 12 second information J2 indicating that the movement of the lock pin 34 is delayed. Upon receiving the second information J2, the vehicle control device 12 stores on the database 14 the information indicating that the movement of the lock pin 34 is delayed. After executing step S110, the determination section 62 temporarily ends execution of the series of steps of the state determination process.

[0044] On the other hand, in step S70, when the elapsed unlock time H is equal to or shorter than the prescribed time H1 (H≤H1), the determination section 62 proceeds to step S80. In step S80, the determination section 62 determines that the door lock device 30 is operating normally. After executing step S80, the determination section 62 temporarily ends execution of the series of steps of the state determination process. Steps S70, S80, and S110 correspond to the determination process and the determination step.

[0045] The information related to the fault in the electrical system and the delay in movement of the lock pin 34 that is stored on the database 14 of the vehicle control device 12 is read out, for example, by a worker inspecting the railway vehicle and is utilized for replacement or repair of the door lock device 30.

[0046] Operation in the embodiment will be now described. While the door leaves 10 are locked, the lock pin 34 projects from the coil 33 and the projecting rod 37 engages with the fixing member 45. In addition, the output of the lock signal LS from the door lock switch 38 remains On. In this state, the door control unit 50 receives an instruction signal W for opening the door, and then the drive control section 52 of the door control unit 50 outputs the excitation signal EM1 to the solenoid 32. In response to the excitation signal EM1, the solenoid 32 is excited and the lock pin 34 is withdrawn into the coil 33. As the lock pin 34 is withdrawn, the output of the lock signal LS from the door lock switch 38 is switched to Off.

[0047] Advantageous effects of the embodiment will be now described. (1) In the state determination process, it is determined whether or not the elapsed unlock time H required for the unlock operation of the door lock device 30 is within the prescribed time H1. When the elapsed unlock time H is longer than the prescribed time H1, it is determined that the movement of the lock pin 34 is delayed. This determination makes it possible to detect a malfunction of the door lock device 30.

(2) A malfunction of the door lock device 30 may be caused by a fault in the electrical system, in addition to an enlarged slide resistance. With this taken into account, the state determination process employs two-stage determination. The first stage is to determine whether or not the relationship between the voltage V of the power source 31 and the electric current A flowing through the coil 33 is appropriate. It is thus confirmed whether or not a fault has occurred in the electrical system related to the solenoid 32. When no fault has occurred in the electrical system, then it is determined whether or not the elapsed unlock time H required for the unlock operation of the door lock device 30 is within the prescribed time H1. Confirming that no fault has occurred in the electrical system, it is thus determined whether or not the movement of the lock pin 34 is delayed. Accordingly, when it is determined that the movement of the lock pin 34 is delayed, it can be presumed that such a delay is caused by an enlarged slide resistance. In this way, the state determination process makes it possible not only to detect a malfunction of the door lock device 30, but also to distinguish the causes of the malfunction of the door lock device 30.

(3) The door lock switch 38, which is an existing component, is used to confirm completion of the unlock operation of the lock pin 34, and therefore, it is not necessary to add a new peculiar component such as a camera for monitoring the movement of the lock pin 34 to confirm completion of the unlock operation of the lock pin 34. It is thus possible to avoid increase of the number of components for detecting a malfunction of the door lock device 30.

(4) A fault in the solenoid 32 and the electrical system connected thereto may cause delayed movement of the lock pin 34. Therefore, it is important to grasp the state of the electrical system in order to grasp

the state of the door lock device 30. Since the solenoid 32 is excited for the unlock operation of the lock pin 34, it is possible to obtain information related to the electric current A flowing through the coil 33 of the solenoid 32. Accordingly, it is possible to detect a fault in the solenoid 32 and the electrical system connected thereto.

(5) The determination section 62 calculates the prescribed time H1 based on the values of the elapsed unlock time H related to a plurality of door lock devices 30 installed on the same vehicle. Although the plurality of door lock devices 30 installed on the same vehicle deteriorate to slightly different degrees in accordance with the loads imparted thereto, it can be presumed that these door lock devices 30 as a whole have deteriorated to similar degrees since they were new. Since the prescribed time H1 is calculated based on the door lock devices 30 having deteriorated to similar degrees so as to be used for comparison between them, it is possible to determine whether or not a malfunction is present in the door lock device 30 irrespective of its degree of deterioration. Further, since the prescribed time H1 is calculated from the door lock devices 30 on the same vehicle, it is not necessary to previously perform an experiment or simulation for calculating the prescribed time H1, and therefore, the effort of performing such an experiment or simulation can be eliminated.

[0048] The above embodiment can be modified as described below. The above embodiment and the following modifications can be implemented in combination to the extent where they are technically consistent with each other.

[0049] The method of calculating the prescribed time H1 is not limited to the example in the above embodiment. The prescribed time H1 has a length with which to determine a delay in movement of the lock pin 34, and specifically a length with which to determine a relatively slight delay in movement that does not affect the safe operation of the railway vehicle.

[0050] The prescribed time H1 may be calculated based on the elapsed unlock time H of the door lock devices on a plurality or all of the vehicles included in a train.

[0051] The prescribed time H1 may be calculated based on the elapsed unlock time H of only the door lock devices that satisfy a condition, not based on the elapsed unlock time H of all the door lock devices, among the door lock devices installed on the same vehicle or a plurality of vehicles included in a train. For example, with values of the elapsed unlock time H of a plurality of door lock devices sorted from the shortest one, the prescribed time H1 may be calculated as an average of a plurality of top-sorted values of the elapsed unlock time H.

[0052] When the difference between the loads imparted to the doors is previously known, the prescribed time H1 may be calculated based on the elapsed unlock time H of the door lock devices of the doors subjected to a load of the same degree.

[0053] A fixed prescribed time H1 may be previously calculated by an experiment or simulation.

[0054] The determination of a fault in the electrical system related to the solenoid 32 may be based on only one of the voltage V of the power source 31 and the electric current A flowing through the solenoid 32. For example, it is possible to monitor the time series of the electric current A flowing through the solenoid 32 while a voltage is applied to the solenoid 32, and determine that a fault has occurred in the electrical system related to the solenoid 32 when the variation of the electric current A is excessively large, or when the electric current A is instable.

[0055] It is not necessary to determine a fault in the electrical system related to the solenoid 32 at the timing of the unlock operation of the door lock device 30. Only a delay in movement of the lock pin 34 may be determined at the timing of the unlock operation of the door lock device 30.

[0056] It is possible to determine whether or not a malfunction is present in the door lock device 30 at the timing of the lock operation of the door lock device 30. In the lock operation of the door lock device 30, the solenoid 32 is demagnetized, unlike the unlock operation of the door lock device 30. In other words, no voltage is applied to the solenoid 32 in the lock operation of the door lock device 30, and therefore, information related to the electrical system such as the voltage V cannot be obtained in the lock operation of the door lock device 30. Accordingly, a fault in the electrical system related to the solenoid 32 cannot be detected at the timing of the lock operation of the door lock device 30. However, a delay in movement of the lock pin 34 can be detected in the lock operation of the door lock device 30. Specifically, while the door leaves 10 operate from the open state to the closed state prior to the lock operation of the door lock device 30, the solenoid 32 is excited and the lock pin 34 is withdrawn in the coil 33. When the door leaves 10 are in the fully closed state, the solenoid 32 is demagnetized, such that the lock pin 34 projects from the coil 33 by the elastic force of the compression spring 36, and the projecting rod 37 engages with the fixing member 45.

[0057] To determine whether or not a malfunction is present in the door lock device 30 using the above lock operation, an elapsed lock time is compared with a prescribed time for the lock operation. The elapsed lock time is counted from the time when the demagnetization signal EM2 is output to the solenoid 32 to the time when the lock pin 34 completes projecting from the coil 33 and the door lock switch 38 switches to On. This makes it possible to determine whether or not the movement of the lock pin 34 is delayed. For example, it is possible to make determination related to an elapsed time in both the lock operation and the unlock operation of the door lock device 30, so as to doubly monitor at least a delay in movement

of the lock pin 34.

[0058] The configuration of the door lock device 30 is not limited to the example in the above embodiment. For example, the movement of the lock pin 34 may be transmitted directly to the door lock switch 38 without a medium of a transmission mechanism. Further, the lock pin 34 may engage directly with the door leaves 10 to lock the door leaves 10.

[0059] The door lock device 30 may be modified such that the lock pin 34 is withdrawn by a tension spring into the solenoid 32 upon demagnetization of the solenoid 32, and the lock pin 34 projects from the solenoid 32 upon excitation of the solenoid 32. It is also possible that the solenoid 32 alone drives the reciprocation of the lock pin 34 without use of a spring for return.

[0060] The door lock device may be configured such that the unlocked state and the locked state of the door leaves 10 are controlled in accordance with the electric motor 22 for driving the opening and closing of the door leaves 10. In such configuration, the unlock operation of the door lock device and the opening operation of the door leaves 10 are performed as a series of operations in response to a drive signal for rotating the output shaft of the electric motor 22 in one direction. Specifically, when the door leaves 10 are in the fully closed state, the output shaft of the electric motor 22 rotates in one direction. At this time, the door lock device first operates such that the door leaves 10 enter the unlocked state, and then the door leaves 10 enter the open state. On the other hand, the closing operation of the door leaves 10 and the lock operation of the door lock device are performed as a series of operations in response to a drive signal for rotating the output shaft of the electric motor 22 in the other direction. Specifically, when the door leaves 10 are in the open state, the output shaft of the electric motor 22 rotates in the other direction. At this time, the door leaves 10 first enter the closed state, and then the door lock device operates such that the door leaves 10 enter the locked state. In this door lock device, the drive signal for rotating the output shaft of the electric motor 22 in one direction serves as both the drive signal for driving the unlock operation of the door lock device and the drive signal for opening the door leaves 10. Also, the drive signal for rotating the output shaft of the electric motor 22 in the other direction serves as both the drive signal for closing the door leaves 10 and the drive signal for driving the lock operation of the door lock device.

[0061] In the lock operation of the above door lock device, when the drive signal for rotating the output shaft of the electric motor 22 in the other direction is output, the door leaves 10 are first closed. Therefore, the elapsed time from the time when the above drive signal is output to the electric motor 22 to the time when the lock operation of the door lock device is completed includes the elapsed time for the closing operation of the door leaves 10. To confirm whether or not a malfunction related to the lock operation of the door lock device is present, it is possible to use a detection signal from the door closing switch (DCS) for detecting closing of the door leaves 10. Specifically, an elapsed door closing time from the time when the drive signal is output to the time when the door closing switch detects closing of the door leaves 10 is calculated separately from the elapsed time from the time when the drive signal is output to the time when the lock operation of the door lock device is completed. The elapsed door closing time is added to a prescribed lock time determined previously by an experiment or the like as a prescribed time related to the lock operation of the door lock device, thereby to obtain the prescribed time. The elapsed time from the time when the drive signal is output to the time when the lock operation of the door lock device is completed is compared with the prescribed time. When the elapsed time is longer than the prescribed time, it is determined that the operation of the door lock device is delayed. It is also possible to determine that the operation of the door lock device is delayed when the above elapsed time subtracted by the elapsed door closing time is longer than the prescribed lock time.

[0062] In the unlock operation of the above door lock device, when the drive signal is output to the electric motor 22, the door lock device first operates without the medium of the operation of the door leaves 10. Accordingly, the elapsed time related to the unlock operation of the door lock device can be obtained accurately by calculating the elapsed time from the time when the drive signal is output to the electric motor 22 to the time when the door lock switch is switched to Off. As a result, it is possible to determine whether or not the operation of the door lock switch is delayed based on the above elapsed time. Further, it is also possible to detect a fault in the electric motor and the electrical system connected thereto by sensing the voltage applied to the electric motor 22 and the electric current flowing through the electric motor 22 during the lock operation and the unlock operation of the door lock device.

[0063] The method of determining the timing of completion of the lock operation or the unlock operation of the door lock device does not necessarily use the door lock switch. For example, a camera for monitoring the movement of the lock pin may be used to determine the timing of completion of the lock operation or the unlock operation of the door lock device.

[0064] A notification lamp or a buzzer for notifying a malfunction in the door lock device 30 may be provided on the driver's cab, for example. When a delay in the operation of the lock pin 34 or a fault in the electrical system is detected, the notification lamp or the buzzer may be actuated.

[0065] A dedicated server may be provided outside the railway vehicle, and the dedicated server may serve as a database that intensively stores information input from the door control unit 50. The door control unit 50 may be connected to the server via an external communication network, and the door control unit 50 may transmit to the server various information such as related to whether or not a malfunction is present in the door lock device 30 or

related to the elapsed unlock time H.

[0066] The storage section of the door control unit 50 may store information such as related to whether or not a malfunction is present in the door lock device 30 controlled by the door control unit 50 or related to the elapsed unlock time H. For example, a plurality of door control units 50 may be connected with each other to exchange information, such that it is no longer necessary to read information from the database 14 for calculation of the prescribed time H1.

[0067] A computer that serves as the state determination device for the door lock device is not limited to the door control unit 50. For example, the vehicle control device 12 or a server outside the railway vehicle may serve as the state determination device for the door lock device. The computer serving as the state determination device may obtain information related to the timing at which the drive signal for driving the door lock device is output and the timing at which the operation of the door lock device is completed, such that the computer can calculate the elapsed unlock time and the elapsed lock time. When the elapsed unlock time or the elapsed lock time calculated is longer than the respective prescribed time, the computer serving as the state determination device may determine that a malfunction is present in the door lock device. In this configuration, the computer serving as the state determination device includes the calculation section and the determination section.

[0068] For example, when the vehicle control device 12 is used as the state determination device, the instruction signal W output from the vehicle control device 12 may be handled as the drive signal for driving the door lock device. Suppose that the door lock device uses the solenoid described for the above embodiment. In this case, when the door leaves 10 are in the fully closed state, the vehicle control device 12 outputs the instruction signal W for opening the door leaves 10. The door control unit 50 receives the instruction signal W and outputs the excitation signal EM1 for the unlock operation of the door lock device 30. The output of the lock signal LS from the door lock switch 38 is then switched to Off, and information indicating this switching is output to the vehicle control device 12. In this process, the vehicle control device 12 calculates the elapsed time from the time when it output the instruction signal Wto the time when it received the information indicating that the lock signal LS has been switched to Off, and it compares the elapsed time with the prescribed time to determine whether or not a malfunction is present in the door lock device 30. The prescribed time used in this case is set taking account of the elapsed time from the time when the vehicle control device 12 output the instruction signal W to the time when the signal is received by the door control unit 50, and the elapsed time until the information indicating that the lock signal LS has been switched to Off is input to the vehicle control device 12.

[0069] In the above case where the instruction signal W output from the vehicle control device 12 is handled as the drive signal for driving the door lock device, it is determined at the timing of the lock operation of the door lock device whether or not a malfunction is present in the door lock device. When the door leaves 10 are in the open state, the vehicle control device 12 outputs the instruction signal W for closing the door leaves 10. The door control unit 50 receives the instruction signal W and first drives the door leaves 10 for the closing operation. After the door leaves 10 are fully closed, the door control unit 50 drives the door lock device 30 for the lock operation. The output of the lock signal LS from the door lock switch 38 is then switched to On, and information indicating this switching is output to the vehicle control device 12. The elapsed time from the time when the vehicle control device 12 outputs the instruction signal Wto the time when the vehicle control device 12 receives the information indicating that the lock signal LS has been switched to On includes the elapsed time during the closing operation of the door leaves 10. Therefore, in the case where the instruction signal W output from the vehicle control device 12 is handled as the drive signal for driving the door lock device, the detection signal of the door closing switch described above can be used. Specifically, the detection signal of the door closing switch can be used to calculate the elapsed door closing time from the time when the instruction signal W is output to the time when the door leaves are closed, such that it can be confirmed whether or not the lock operation of the door lock device is delayed, as with the modification in which the rotation of the electric motor 22 drives the door leaves 10 for closing operation and also drives the door lock device for the lock operation.

[0070] In the case where, as with the above modification, it is determined whether or not a malfunction is present in the door lock device based on the elapsed time from the time when the vehicle control device 12 outputs the instruction signal Wto the time when the operation of the door lock device is completed, the above elapsed time may be calculated on a server outside the railway vehicle to determine whether or not a malfunction is present in the door lock device.

[0071] The door may be a single sliding door. That is, it is possible to determine whether or not a malfunction is present in a door lock device for locking a single sliding door.

[0072] The method of determining a malfunction in the door lock device is based on the elapsed time from the time when the drive signal is output to the time when the lock operation or the unlock operation of the door lock device is completed, but this method dot not necessarily include comparison between the elapsed time and the prescribed time. For example, values of the elapsed time obtained each time the door is opened or closed are sorted to monitor the change (the trend of change) of the length of the elapsed time. When, for example, the trend of change exceeds a predetermined increase rate, it may be determined that a malfunction is present in the door lock device. Alternatively, when the rate of change be-

tween values of the elapsed time obtained at two sequential timings exceeds a reference value, it may be determined that a malfunction is present in the door lock device.

LIST OF REFERENCE NUMBERS

[0073]

12	vehicle control device
30	door lock device
32	solenoid
34	lock pin
38	door lock switch
50	door control unit
60	state determination device
61	calculation section
62	determination section

Claims

1. A state determination device (60) for a door lock device (30), comprising:

a calculation section (61) for calculating an elapsed time from a time when a drive signal for driving a door lock device (30) is output to a time when lock operation or unlock operation of the door lock device (30) is completed; and
a determination section (62) for determining whether or not a malfunction is present in the door lock device (30) based on the elapsed time.

2. The state determination device (60) for a door lock device (30) according to claim 1, wherein the calculation section (61) calculates the elapsed time with a timing at which operation of the door lock device (30) is completed defined as a timing at which, after the drive signal is output, an output signal of a door lock switch (38) is switched between a state in which the door lock device (30) locks a door leaf (10) and a state in which the door lock device (30) unlocks the door leaf (10).

3. The state determination device (60) for a door lock device (30) according to claim 1 or 2, wherein the calculation section (61) calculates the elapsed time for the unlock operation of the door lock device (30).

4. The state determination device (60) for a door lock device (30) according to any one of claims 1 to 3, wherein when the elapsed time is longer than a prescribed time, the determination section (62) determines that a malfunction is present in the door lock device (30).

5. The state determination device (60) for a door lock device (30) according to claim 4, wherein a railway vehicle has a plurality of door lock devices (30) installed thereon, and wherein the determination section (62) calculates the prescribed time based on values of the elapsed time related to the plurality of door lock devices (30) installed on the same railway vehicle.

6. A state determination method for a door lock device (30), comprising:

a calculation step (S10, S20, S40, S50) of calculating an elapsed time from a time when a drive signal for driving a door lock device (30) is output to a time when operation of the door lock device (30) is completed; and
a determination step (S70, S80, S110) of determining whether or not a malfunction is present in the door lock device (30) based on the elapsed time.

7. A state determination program for a door lock device (30), the state determination program causing a computer to perform:

a calculation process for calculating an elapsed time from a time when a drive signal for driving a door lock device (30) is output to a time when operation of the door lock device (30) is completed; and
a determination process for determining whether or not a malfunction is present in the door lock device (30) based on the elapsed time.

8. A computer-readable storage medium storing a state determination program for a door lock device, wherein when executed by a computer, the state determination program causes the computer to perform:

a calculation process for calculating an elapsed time from a time when a drive signal for driving a door lock device (30) is output to a time when operation of the door lock device (30) is completed; and
a determination process for determining whether or not a malfunction is present in the door lock device (30) based on the elapsed time.

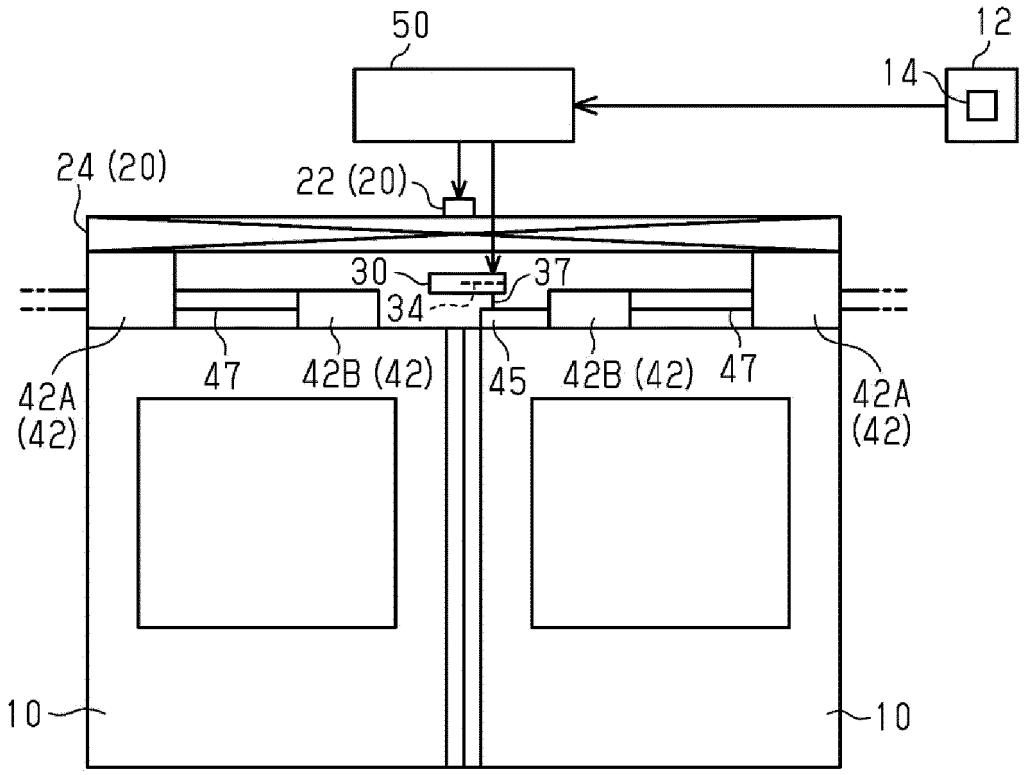
50
12
14
24 (20)
22 (20)
30
37
34
42A
(42)
47
42B (42)
45
42B (42)
47
42A
(42)
10
10

Fig. 1

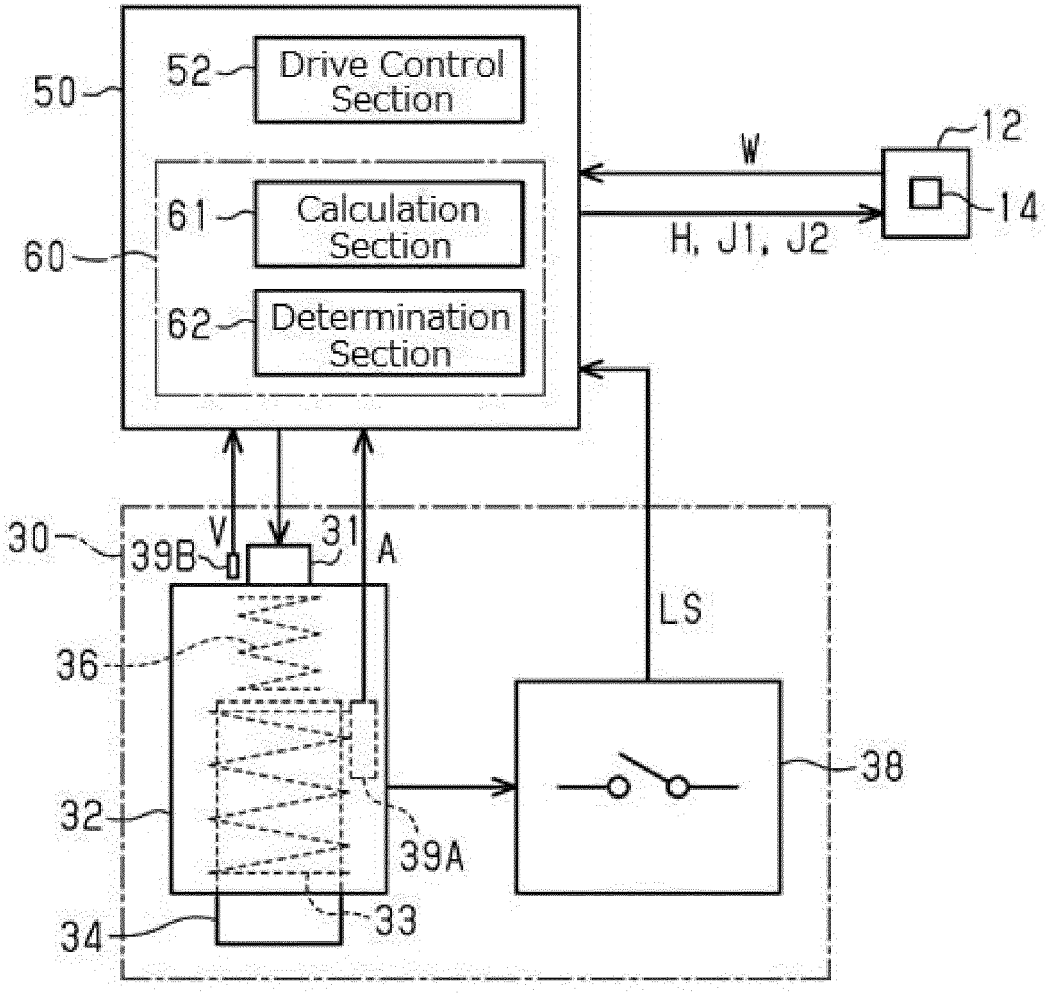
50
52
Drive Control Section
60
61
Calculation Section
62
Determination Section
W
H, J1, J2
12
14
30
39B
V
31
A
LS
36
32
39A
34
33
38

Fig. 2

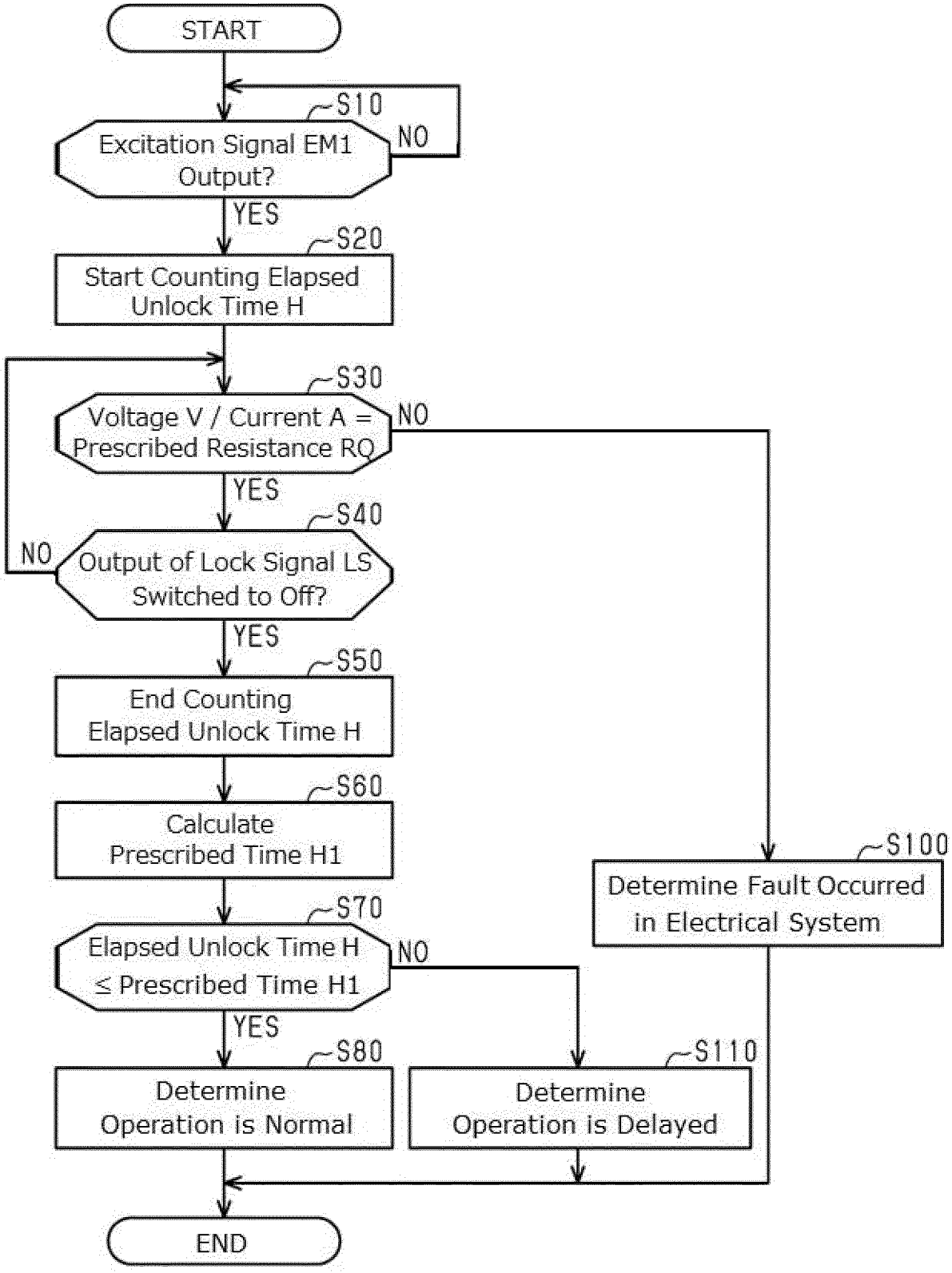
START
S10
Excitation Signal EM1 Output?
NO
YES
S20
Start Counting Elapsed Unlock Time H
S30
Voltage V / Current A = Prescribed Resistance RQ
NO
YES
S40
NO
Output of Lock Signal LS Switched to Off?
YES
S50
End Counting Elapsed Unlock Time H
S60
Calculate Prescribed Time H1
S70
Elapsed Unlock Time H ≤ Prescribed Time H1
NO
YES
S80
Determine Operation is Normal
S100
Determine Fault Occurred in Electrical System
S110
Determine Operation is Delayed
END

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 20 20 2278

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B61L
E05B
G07C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	26 March 2021	Robelin, Fabrice

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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