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3,368,073

TRAIN SPEED CONTROL SYSTEM

Filed Oct. 1, 1965

3 Sheets-Sheet 1

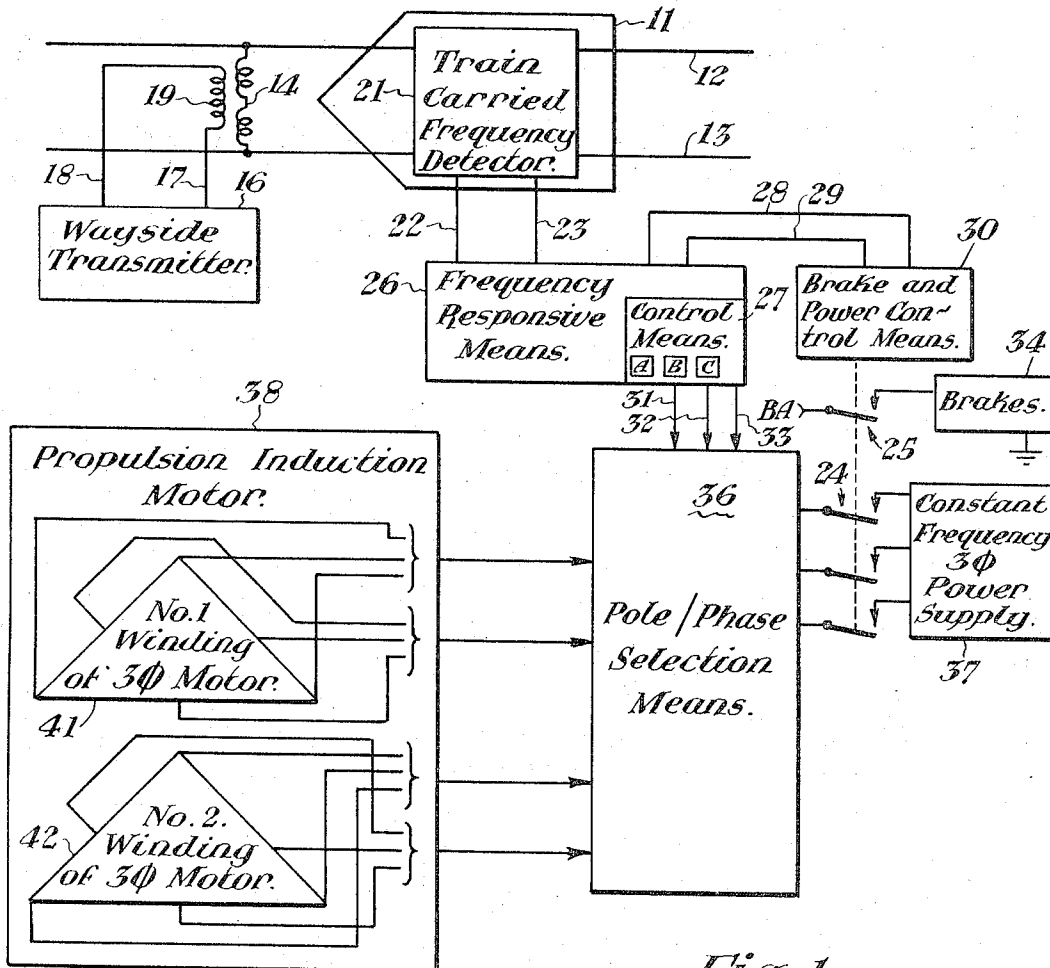


Fig. 1.

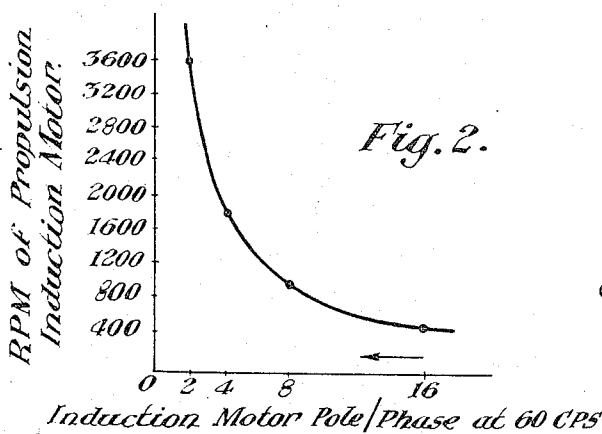


Fig. 2.

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3 Sheets-Sheet 2

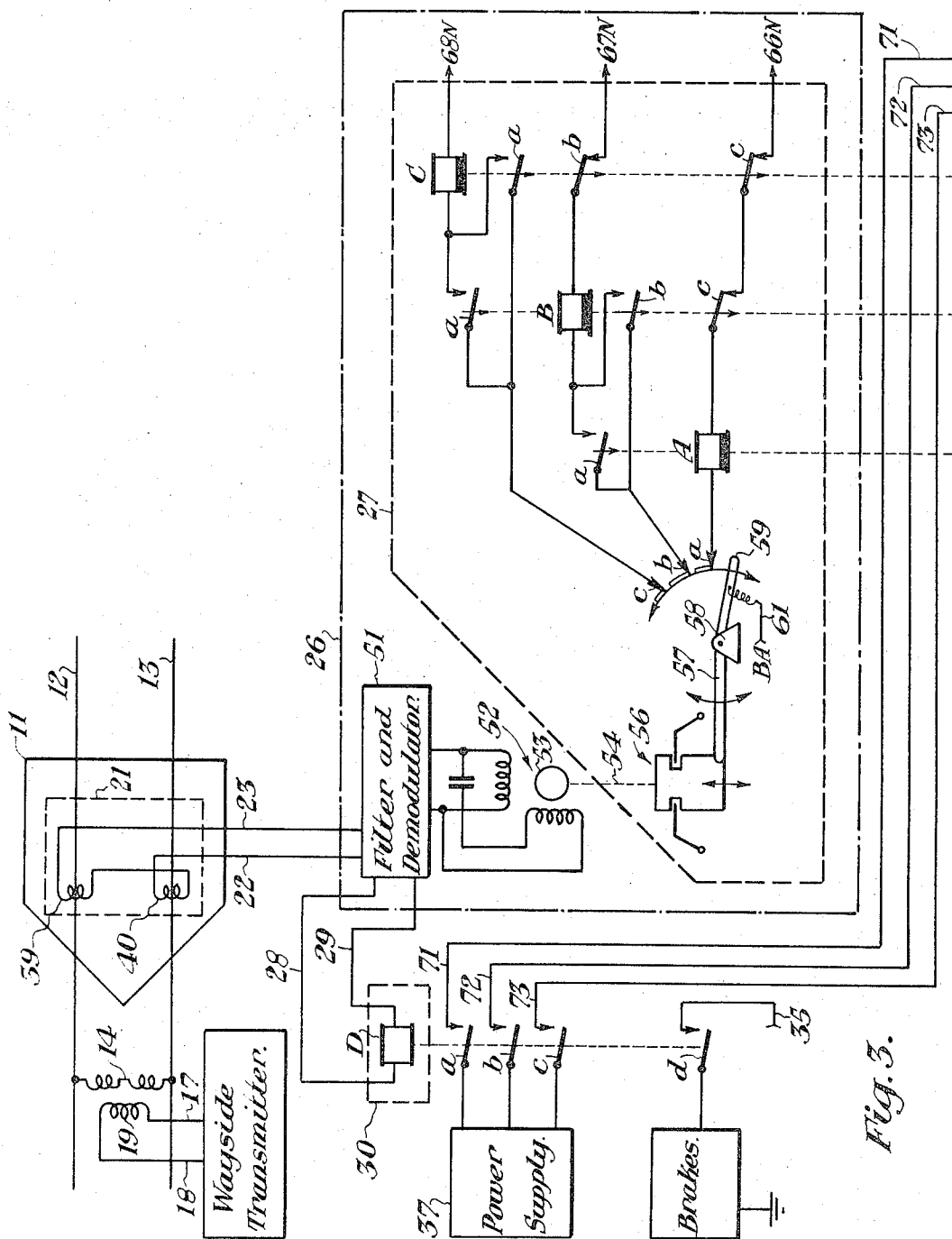


Fig. 3.

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3 Sheets-Sheet 3

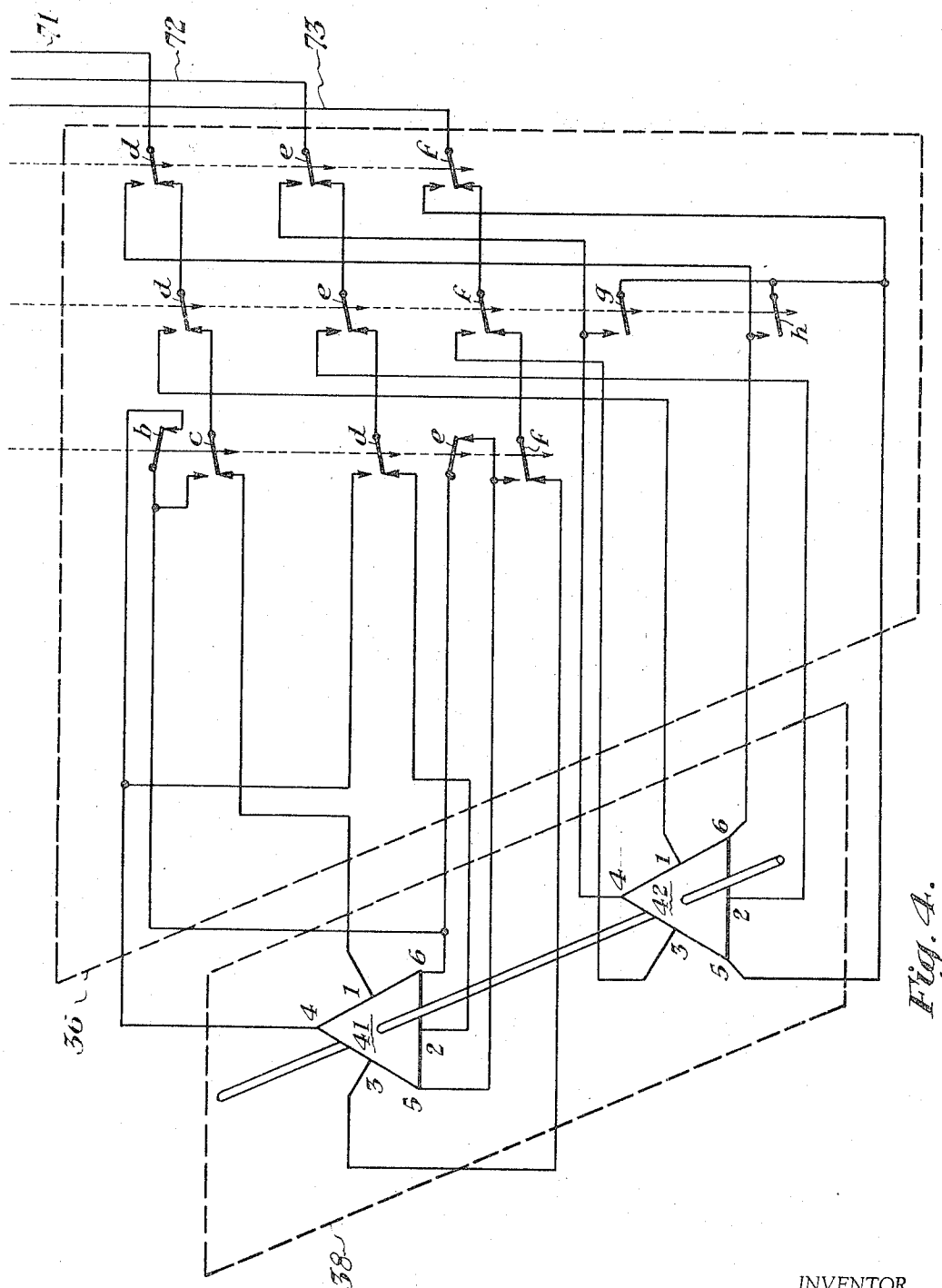


Fig. 4.

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3,368,073

TRAIN SPEED CONTROL SYSTEM

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13 Claims. (Cl. 246-187)

ABSTRACT OF THE DISCLOSURE

This invention relates to a train speed control system in which the propulsion motor is an induction motor, the output speed of which is mutually dependent upon a variable frequency delivered to the train from the wayside and the number of poles per phase utilized in the propulsion induction motor. The propulsion induction motor is driven by a constant frequency signal source.

This invention relates to a train speed control system, and particularly to a train speed control system in which the propulsion motor is an induction motor, the output speed of which is mutually dependent upon a variable frequency delivered to the train from the wayside and the number of poles per phase utilized in the propulsion induction motor.

It has been generally recognized in the prior art that a basic and difficult problem in any train speed control system resides in the safe operation of a speed measuring device on the train. This problem arises due to the fact that the prior art speed measuring devices carried by the train operate on the open circuit principle. Accordingly, a defect in the system may cause the speed indication to be zero when the train is operating at a high speed. Therefore, an unsafe condition could occur where the automatic equipment permitted more propulsion power to be applied to the train's propulsion motors when the actual conditions in fact required the shutting off of power and the application of the brakes.

The invention to be described hereafter obviates this problem just noted and in doing so establishes a new and unique advance in the art which greatly enhances the attainment of efficient, fail-safe automatic train speed control.

It is therefore an object of this invention to provide automatic train speed control by the utilization of a constant frequency power supply and a selectable pole per phase induction motor.

Another object of this invention is to provide a train speed control system that is mutually dependent upon a variable frequency signal from the wayside and the controlled selection of a number of different poles per phase in the train's propulsion induction motor.

Yet another object of this invention is to provide a fail-safe train speed control system that inherently operates in a speed restrictive manner in the event of a failure in any portion of the control system.

Another object of this invention is to provide a train speed control system that makes use of conventional induction propulsion motors that may be easily modified to incorporate the speed control circuitry of the invention.

Another object of this invention is to provide a train speed control system that may be utilized in trains operating in electrified territory as well as diesel electric trains in non-electrified territory.

In the attainment of the foregoing objects there is utilized a train speed control system which includes the running rails upon which the train travels and a constant frequency power supply for the train's induction propulsion motor or motors. An integral part of the system is a train motor speed control signal source which is a signal

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of variable frequency energy. In the preferred embodiment this source of variable frequency energy includes a wayside variable frequency transmitter and a transmission link to the train which includes the rails.

The remaining apparatus of the system is carried by the train and includes a frequency detector electrically coupled to the rails to detect the motor speed control signal of variable frequency being delivered from the wayside. A frequency responsive unit which is comprised of an induction motor is connected to and controlled by the frequency detector. The speed of the frequency responsive unit's motor is a direct function of the frequency received by the frequency detector from the wayside.

The train propulsion motor that is to be controlled from the wayside is a multiphase, multiwinding induction motor that has a number of connections to provide a plurality of different pole per phase connections. The induction motor of the frequency responsive unit in turn drives a speed responsive mechanism which actuates a relay control device to control a pole per phase selection apparatus.

The pole per phase selection apparatus is selectably electrically connected to the multiphase propulsion induction motor. The pole per phase selection apparatus is controlled by the relay control device to connect the constant frequency power supply to a selected pole per phase connection of the propulsion motor, which connection is determined by the signal frequency received by the frequency detector. From the foregoing it is apparent that the system that embodies the invention establishes a unique speed control for the train's propulsion motor or motors, which speed control is mutually dependent on the presence and the variable frequency rate of the signal from the wayside and the number of poles per phase utilized in the propulsion induction motor or motors.

Other objects and advantages of the present invention will become apparent from the ensuing description of illustrative embodiments thereof, in the course of which reference is had to the accompanying drawings in which:

FIG. 1 illustrates in block diagram form the train speed control system embodying the invention.

FIG. 2 is a graph of propulsion motor r.p.m. at constant frequency versus different pole per phase connections.

FIG. 3 is a portion of a circuit diagram illustrating the invention.

FIG. 4, when positioned immediately below Fig. 3, depicts the completed circuit diagram illustrating the invention.

A description of one embodiment of the invention will follow and then the novel features of the invention will be presented in the appended claims.

Reference is now made to FIG. 1 in which there is depicted a functional block diagram of the invention to be described more fully hereinafter. The basic principle, upon which the system is based, is related to an induction motor and its inherent speed characteristic with respect to frequency. The following formula represents the basic parameters involved:

$$\text{Induction motor r.p.m.} = (f)(120)/P$$

where

f = the frequency of the motor power source in cycles per second,

P = poles per phase.

In the system to be described in conjunction with this invention, the frequency remains constant and the number of poles per phase of the propulsion induction motor is varied in a manner directly dependent upon the frequency received from a wayside transmitting station.

Referring now again to FIG. 1 where there is illustrated

the functional block diagram before mentioned, a pair of track rails 12 and 13 are depicted with a train 11 traveling thereon. Mounted on the train is a frequency detector 21. Across the rails 12 and 13 is an impedance bond 14 of the type described in the copending application for Letters Patent of the United States, Ser. No. 382,551, filed July 14, 1964, by Ralph Popp, for Electric Induction Apparatus. This bond is explained in detail in the Popp patent application, and includes a primary coil 19 which serves as a means of impressing upon the bond and the rails 12 and 13 a signal from the wayside transmitter 16 via the leads 17 and 18 from the wayside transmitter 16. These signals appear on a carrier frequency that is modulated at a frequency dependent upon the traffic conditions in advance of the train 11. A system by means of which these variable frequency signals may be delivered to the rails is fully described in the copending application for Letters Patent of the United States, Ser. No. 382,620, filed July 14, 1964, by Crawford E. Staples, for Rapid Transit Speed Control System.

The train frequency detector 21 picks up the signals impressed upon the rails 12 and 13 by the wayside transmitter 16. These signals are, in turn, delivered from the frequency detector 21 via the leads 22 and 23 to a frequency responsive means 26. The frequency responsive means 26 has incorporated therein a means which filters and demodulates the signals received from the frequency detector 21. This filter and demodulator means forms an integral portion of the frequency responsive means 26. The control means 27, which will be described in detail more fully hereinafter, is comprised of a plurality of relay units which provide a control function via the control leads 31, 32 and 33 to select a pole per phase connection in the pole per phase selection means 36. The pole per phase selection means 36, in turn, controls the connection of a constant frequency three-phase power supply 37 to the appropriate pole per phase connection of the propulsion induction motor 38. While the power supply 37 is designated as a block, it should be understood that the invention being described contemplates the use of train-carried diesel electric power to drive the train's propulsion, as will three-phase power from the wayside.

The propulsion induction motor 38 in the embodiment to be described more fully hereafter includes a first winding and a second winding. The first winding 41 has a set of connections which will permit a 16-pole per phase configuration and an 8-pole per phase configuration. By the same token, the second winding 42 of the propulsion induction motor 38 contains two sets of connections to provide two different pole per phase configurations, the first of which is four poles per phase and the second of which is two poles per phase.

It can, therefore, be seen from a study of FIG. 1 that when a signal is generated by the wayside transmitter 16 and is delivered via the leads 17 and 18 to the primary coil 19 of the impedance bond 14, and thence inductively coupled to the other or secondary winding of the impedance bond 14 which connects the rails 12 and 13, there is impressed upon the rails 12 and 13 a signal from the wayside which is indicative of the train speed desired. This signal is received or picked up from the rails by a train-carried frequency detector 21. As soon as a signal appears in the frequency detector unit and is transferred via the leads 22 and 23 to the frequency responsive means 26, there appears in the leads 28 and 29, connected to the frequency responsive means 26, a signal which indicates the presence of a train speed control signal. The appearance of a signal on leads 28 and 29 actuates a brake and power control means 30 which, in turn, actuates the power control switches 24 to connect the constant frequency three-phase power supply 37 to the pole per phase selection means 36. Simultaneously, with the actuation of the power control switches 24, the brake control switch 25, which is normally opened, is closed and the closing of the

brake control switch 25 deenergizes the mechanisms that actuate the brakes 34. This arrangement just described provides a fail-safe arrangement in which, upon the cessation of any signal from the wayside transmitter, the brake and power control means 30 will cease to function and the brake switch 25 will open, thereby actuating the brakes 34.

From this broad description, taken in conjunction with FIG. 2, it may be seen that when the basic formula initially noted is applied to the system just described there arises a number of permissible speeds which the propulsion induction motor 38 may experience dependent upon the pole per phase connection that has been selected in the pole per phase selection means 36 by the related control means 27 of the frequency responsive means 26. The manner in which the control means 27 is connected to and controlled by the frequency responsive means 26 will be set forth in detail in the description of FIGS. 3 and 4 which follows.

Specific reference is made to FIG. 2 which shows a speed curve as the number of poles per phase is selected in accordance with the frequency delivered from the wayside transmitter 16 to the train-carried frequency detector 21. In the first instance, when the pole per phase selection is 16 poles per phase and the frequency is constant, for example, 60 cycles per second, the output r.p.m. of the propulsion induction motor 38 will be 450 r.p.m. As the signal changes from the wayside increasing in frequency, the next pole per phase selection would be 8 poles per phase and the resultant speed of the induction motor would be 900 r.p.m. When the second winding of the propulsion induction motor 38 is utilized at an even higher frequency delivered from the wayside transmitter 16, a 4-pole per phase selection is then made and a resulting r.p.m. of the propulsion induction motor 38 is 1800 r.p.m. Finally, when a higher frequency is received by the train-carried frequency detector 21 from the wayside transmitter 16, there is a 2-pole per phase selection which results in the maximum speed being delivered from the propulsion induction motor 38, namely, 3600 r.p.m. This maximum frequency being received is indicative of a full speed ahead operation of the train and will occur only when the traffic conditions and rail conditions permit full speed operation.

Reference is now made to FIGS. 3 and 4 which taken together illustrate the preferred embodiment of the invention. Similar reference numerals to those set forth in FIG. 1 have been used where applicable, since their use is intended to designate the same elements set forth in FIG. 1.

Accordingly, FIG. 3 sets forth a train 11 which travels on the rails 12 and 13. The rails 12 and 13 are electrically connected by an impedance bond 14 which has a dual function of balancing the propulsion return current between the rails 12 and 13 when the system is being utilized in electrified territory, as well as providing a means for impressing a speed control signal on the rails. To accomplish this impressing of a speed control signal on the rails 12 and 13 by the impedance bond 14, a primary coil 19 is located in the bond and is electrically connected to the wayside transmitter 16 via the leads 17 and 18. This wayside transmitter 16 produces a signal indicative of the traffic conditions which, in turn, will impress upon the bond 14 a signal whose frequency indicates the maximum permissible speed which the train 11 may travel. It should be understood that the impedance bond 14 between rails 12 and 13 along with the wheels of the train, not shown, complete a track circuit, which track circuit will have the frequency sought to be delivered to the train impressed thereon. The rails 12 and 13 in that portion of track between the train and the bond 14 are designated as a transmission link between the wayside transmitter 16 and the train 11.

Mounted on the train 11 there is a pair of coils 39 and 40 which form a portion of the frequency detector. These coils 39 and 40 are located in front of the wheels of the

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train, which wheels are not shown in FIG. 3. The coils 39 and 40 inductively receive the signals being impressed upon the track circuit which includes the rails 12 and 13. These signals are picked up and delivered from the frequency detector 21 via the leads 22 and 23 to the filter and demodulator 51 which, in turn, has a pair of outputs which drive a split phase induction motor 52. It is well known in the art that a split phase induction motor of this type generally illustrated in FIG. 3 will drive the rotor 53 of the split phase inductor motor 52 at a speed proportional to the frequency delivered to the split phase induction motor 52. Accordingly, the split phase induction motor 52 will have a rotor output which is proportional to the frequency of the signal being delivered from the wayside transmitter 16 via the bond 14, the rails 12 and 13, and the coils 39 and 40. As soon as the train speed control signal appears in the rails 12 and 13 and is picked up by the coils 39 and 40 of the frequency detector 21, there will instantly appear in the leads 28 and 29, which leads are connected directly to the filter and demodulator 51, a signal indicative of the fact that a speed control signal has been delivered to the train. Upon the appearance of this signal, there will appear in the leads 28 and 29 an electrical voltage sufficient to actuate the brake and power control means 30 and its related relay D. With the relay D picked up the power supply 37 is connected over the front contacts *a*, *b* and *c* with the electrical leads 71, 72 and 73 to thereby cause the flow of power from the power supply 37 to the pole per phase selection means 36 shown outlined in dashes in FIG. 4. As has been pointed out earlier, the frequency responsive means 26 shown in dotted lines in FIG. 3 includes a control means 27 also shown in dotted outline in this figure. This control means 27 includes a centrifugal speed responsive mechanism 56 which is connected to the rotor 53 of the split phase induction motor 52, the connection between the rotor 53 and the centrifugal speed responsive mechanism being made via the schematically shown drive 54. Accordingly, the centrifugal speed responsive mechanism 56 will move in an up and down movement dependent upon the speed of the rotor 53, which rotor speed, in turn, depends upon the frequency being received by the frequency detector 21 and the filter and demodulator 51 for the motor 52. When the centrifugal speed responsive mechanism 56 moves, it in turn will cause the oscillation of the mechanical link 57 which is shown schematically in this FIG. 3. The link 57 is, in turn, connected to the contact arm 59, and both the mechanical link 57 and the contact arm 59 are pivotally connected to a fulcrum point 58 in such a manner that the movement of the mechanical link 57 in an up or down movement as designated by the arrow crossing link 57 will bring about the movement of the contact arm 59 in an accurate manner as is designated by the arrow which crosses this contact arm 59. Therefore, as the speed control signal of variable frequency delivered from the wayside transmitter 16 increases, this increase in frequency will be detected by the frequency detector 21 and the split phase induction motor 52 will respond by increasing its rotary speed, thereby increasing the speed at which the centrifugal speed responsive mechanism is driven. This increase in speed will provide a downward movement of the mechanical link 57 and this downward movement will result in an upward movement of the contact arm 59 from the position shown in FIG. 3 to a point at which the contact arm 59 makes connection with the contact *a* shown immediately above the contact arm 59.

When a speed control signal of predetermined frequency is present which is indicative of a range of safe speed for the train to travel, the contact arm 59 will have moved into contact with the contact *a* and in so doing the battery terminal BA and lead 61 will be electrically connected via the contact arm 59, the contact *a*, the winding of relay A, back contact *c* of relay B, and back contact *c* of relay C to the battery terminal 66N to complete a circuit. Upon the completion of a circuit as the speed of the split phase

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induction motor 52 increases in response to the frequency of the signal being delivered by the wayside transmitter 16, the contact arm 59 will move from its position of contact with contact *a* to a position in which the contact arm 59 rests on the contact *b*. When this occurs, the relay A which is a slow-to-release relay will have maintained itself in its picked-up condition until the contact arm 59 comes in contact with the contact *b* and a circuit will then be completed between the battery terminal BA over lead 61, the contact arm 59, contact *b*, the front contact *a* of relay A, the winding of relay B, and the back contact *b* of relay C to the battery terminal 67N. Upon the completion of this circuit, the relay B will pick up and in so doing the front contacts *a* and *b* of relay B will be closed, and the back contact *c* of relay C will be opened, thereby insuring that the circuit containing relay A will not be energized. The relay A at this time will have released, thereby opening the front contact *a* of relay A, but a circuit remains completed from the battery terminal BA, through lead 61, the contact arm 59, contact *b* of the contact arm 59, front contact *b* of relay B, the winding of relay B, and back contact *b* of relay C to the battery terminal 67N.

The relay B as was the relay A is a slow-to-release relay and it will be evident that its front contact *a* when the relay B has been energized becomes closed and in so doing completes a circuit connection between the contact *c* of the contact arm 59 through the winding of relay C to its related battery terminal 68N. Upon an additional increase in frequency delivered by the wayside transmitter 16 there is a further increase in speed of the motor 52 which produces a further downward movement of the centrifugal speed responsive mechanism 56 causing the contact arm 59 to come into electrical connection with the contact *c*. This will then complete a circuit from the battery terminal BA through the lead 61, the contact arm 59, the associated terminal C, front contact *a* of relay B, and the winding of relay C to the battery terminal lead 68N. When this occurs, the relay C will pick up and in picking up will close the front contact *a* of relay C and open the back contacts *b* and *c* of relay C. The manner in which the energization of relays *a*, *b* and *c* control the pole per phase selection means 36 will be explained in more detail hereinafter.

It should be understood that while this embodiment sets forth an arrangement in which there are three relays A, B and C to provide three distinctive control actions to select the appropriate number of poles per phase this system may be expanded to include more relays should the ultimate desire be to include additional pole per phase selection capacity. This event may well occur when there is a desire to have an increase in the number of speed range selections which can be made by the control means 27 in response to different variations in the frequency being delivered from the wayside transmitter 16. It will be obvious as the description of the invention proceeds that the incorporation of additional speed ranges will necessitate the inclusion of additional windings and pole per phase connections for the propulsion induction motor. As has been earlier noted, the appearance of the signals upon the rails which in turn is detected by the frequency detector 21, immediately energizes the relay D via the leads 28 and 29 from the filter and demodulator 51, and in so doing connects the three-phase power supply 37 over the front contacts *a*, *b* and *c* of relay D, through the leads 71, 72 and 73 to the pole per phase selection means 36 shown outlined in dashes in FIG. 4.

Referring to FIG. 4, there is designated a propulsion induction motor 38, having a first winding 41 and a second winding 42. For purposes of explanation only, the first winding has been designated as having a first set of 16 poles per phase connections and a second set of 8 poles per phase connections to provide two different speeds. This winding configuration illustrated in FIG. 4 is the same as the standard configuration for a multiphase multipole induction motor described in the seventh edition of

the Standard Handbook for Electrical Engineers on page 706, FIG. 90.

The second winding 42, for purposes only of giving a typical example, contains a first set of four pole per phase connections and a second set of two pole per phase connections to provide two additional speed ranges.

It will be evident from a study of the pole per phase selection means 36 that when the relay A is in a deenergized condition the three-phase power being delivered from the power supply 37 will enter the pole per phase selection means 36 via the leads 71, 72 and 73, and this three-phase power will be delivered over the back contacts *d*, *e* and *f* of relay C, the back contacts *d*, *e* and *f* of relay B, the back contacts *c*, *d* and *f* of relay A, and thence to the connections 1, 2 and 3, respectively, of the first winding designated 41 in this figure. Pursuant to the arrangement set forth in the Electrical Engineers' Handbook noted above, the connections 4, 5 and 6 of the first winding must be electrically interconnected during the use of the first group of pole per phase connections made by the use of points 1, 2 and 3 of the winding 41. The point 4 of the winding 41 is connected to the terminal 6 via the electrical lead which emanates from the point 4 of the winding 41, thence over the back contact *b* of relay A and thence to the terminal 6 and the lead which emanates therefrom. The terminal 5 of the winding 41 in a similar manner is connected to the terminal 6 over the back contact *e* of relay A, so that it may be seen that the winding terminals 4, 5 and 6 are mutually interconnected during the time at which the points 1, 2 and 3 are connected to provide a first speed range.

When relay A has been picked up, the second speed range results when the following circuit connections are made between the power supply 37 and the propulsion induction motor 38. The description of the circuitry that follows will be presented on the basis that the power supply 37 delivers three-phase power. A first, second and third phase of the power is delivered to the propulsion induction motor 38 over the leads 71, 72 and 73, respectively.

The first phase of power delivered over electrical lead 71 completes a circuit over the back contact *d* of relay C, the back contact *d* of relay B, the front contact *c* of relay A, and thence to the terminal 6 of the first winding of the induction motor here designated 41. It should be recognized that simultaneously with the completion of this electrical connection via the lead 71 to the terminal 6 of the winding 41, the back contact *b* of relay A has been opened as has the back contact *e* of relay A to thereby break the afore-noted mutual connection between the terminal points 4, 5 and 6 of the winding 41.

The second phase of power that is delivered by the line 72 completes a circuit from the power supply 37, over the back contact *e* of relay C, the back contact *e* of relay B, and thence over the front contact *d* of relay A to the terminal 4 of the winding 41.

Finally, the third phase of the power being delivered via the line 73 from the power supply 37 completes a circuit over the back contact *f* of relay C, thence over the back contact *f* of the relay B, and finally over the front contact *f* of the relay A to complete an electrical connection. Accordingly, it will be seen that with relay A picked up, the output of the propulsion motor 38 has changed in a direct dependence upon the desired increase in speed commanded by wayside transmitter 16 and received by the frequency detector 21 of the train which, in turn, delivered this increased frequency to the split phase induction motor 52 which converted this increase in frequency to a rotational speed of the rotor 53 proportional to the frequency delivered from the wayside transmitter 16. This increase in frequency is reflected by a movement in the contact arm 59 from a position not in contact with the contact *a* of the switching arm 59 into contact with the contact *a* of the switching arm 59 which com-

pletes the circuit energizing the relay A to bring about the second stage of the speed control for the system.

As the speed command signal from the wayside increases, a third range of speed control is provided. This third range of speed control is provided when the contact arm 59 of the centrifugal speed responsive device 56 has moved from contact with contact *a* to contact with contact *b*. This new position of the contact arm 59 will produce a completed circuit from battery terminal BA, through the electrical lead 61, the contact arm 59 in contact with contact *b*, front contact *a* of relay A, which has remained closed due to the slow release characteristics of relay A, thence through the winding of relay B, and the back contact *b* of relay C to the battery terminal 67N as described earlier. This will bring about the energization of the relay B and the closing of the front contact *b* of relay B will provide a completed stick circuit to hold the relay B in a picked-up position once the relay A has finally dropped away in a manner typical of a slow-to-release relay of the type utilized here. The ultimate effect of relay B being picked up brings about a third speed range to be selected by the pole per phase selection means 36. A third speed is now possible with the relay B in a picked-up condition. The third speed control circuit is completed in the following manner. A circuit for one phase of the three-phase power supply 37 is completed over the front contact *a* of relay D, the line 71, the back contact *d* of relay C and the front contact *d* of relay B to the terminal 1 of the winding 42. A circuit for the second phase of the power supply 37 completes a circuit over the front contact *b* of the relay D, the line 72, the back contact *e* of the relay C, and the front contact *e* of the relay B to the terminal 2 of the winding 42. The last or third phase of the power supply is connected over the front contact *c* of the relay D, the line 73, the back contact *f* of the relay C, and the front contact *f* of the relay B to the terminal 3 of the motor winding 42. We now see that with the relay B picked up as occurs when the contact arm 59 has moved upward into a position of contact with its contact *b* there will result a third range of speed control which has occurred due to the selection of the pole per phase selection means 36 connecting the appropriate terminals of the winding 42 to give in this exemplary situation a four-pole per phase connection.

Finally, with reference to this third range of speed control it should be recognized that the terminals 4, 5 and 6 of the winding 42 in a manner similar to the windings 4, 5 and 6 of winding 41 must also be mutually electrically interconnected while the terminals 1, 2 and 3 of winding 42 are being utilized to drive the induction motor. These terminals 4, 5 and 6 of winding 42 are electrically interconnected when the relay B picks up, thereby closing the front contacts *g* and *h* of relay B which, therefore, electrically connects terminal 5 via the front contact *h* of relay B to the terminal 6 of winding 42 and the terminal 5 is also connected over the front contact *g* of relay B to the terminal 4 to provide the mutual interconnection to permit the winding 42 to act as a four-pole per phase motor.

Accordingly, when the frequency from the wayside is indicative of the maximum speed permissible by the train the frequency delivered from the wayside transmitter 16 will be such that when delivered via the frequency detector 21, which frequency is then converted by the split phase induction motor 52 into a rotary speed sufficient to drive the centrifugally speed responsive mechanism 56 to its maximum down position, there will occur a movement of the contact arm 59 to its maximum upward position in which the contact arm 59 comes into contact with contact *c*. This then completes the circuit between the battery terminal BA, the lead 61, the contact arm 59 and its related contact *c*, over the front contact *a* of relay B which has not yet released and through the winding of the relay C to the battery terminal 68N. This, in turn, brings about the energization of the relay C which, in

turn, picks up and the circuit is sustained by the closing of the circuit which includes the front contact *a* of relay C, the battery terminal BA, lead 61, contact arm 59 and its contact *c*, the relay C and terminal 68N. This final speed range completes the supply of power from the power supply 37 to propulsion motor 38 in the following manner. With the relay C picked up, the power supply 37 is electrically connected in the following manner to the winding 42 of the propulsion induction motor 38. The first phase of the power supply 37 is delivered over the front contact *a* of the relay D, the lead 71, thence over the front contact *d* of relay C to the terminal 6 of the motor winding 42. The second phase of power passes over the front contact *b* of relay D, the lead 72, the front contact *e* of the relay C to the terminal 4 of the motor winding 42. The third phase of the power passes over the front contact *c* of relay D, the lead 73, the front contact *f* of relay C to the terminal 5.

It should be appreciated that, while this invention has been shown in an embodiment which includes only four ranges of speed, this system may be readily adapted to provide any multiple of speed ranges dependent upon the number of motor windings and the selection of poles per phase of the windings employed. It can be seen that this system provides a basic fail-safe situation in which, should for any reason the frequency being delivered from the wayside be interrupted due to any malfunction of the circuitry, the speed responsive mechanism 56 will cease to drive the contact arm 59, and therefore bring the train via its induction motor 38 to a restrictive speed operation. In the event that no signal whatsoever is delivered to the train, no signal, in turn, will appear on the leads 28 and 29 which are fed to the brake and power control means from the filter and demodulator 51 which, therefore, will render the power supply 37 disconnected from the pole per phase selection means 36 and the motor 38. Furthermore, the opening of the contact *d* of the relay D will cause the brakes 34 to be applied, thereby bringing the train to a halt.

While the present invention has been illustrated and disclosed in connection with the details of the illustrative embodiments thereof, it should be understood that those are not intended to be limitative of the invention as set forth in the accompanying claims.

Having thus described my invention, what I claim is:

1. A train propulsion motor speed control system having a constant frequency power supply for said propulsion motor comprising in combination:

- (a) a train-carried frequency detector means,
- (b) a source of variable frequency energy to control the speed of said train,
- (c) a frequency responsive means electrically connected to and controlled by said train-carried frequency detector means,
- (d) a multi-phase propulsion induction motor having a number of connections to provide a plurality of different poles per phase,
- (e) a pole per phase selection means electrically connected to said frequency responsive means and said multi-phase propulsion induction motor, said pole per phase selection means being controlled by said frequency responsive means to connect said constant frequency power supply to a selected pole per phase connection of said propulsion motor to thereby establish a propulsion speed control for said train's propulsion motor.

2. The train propulsion motor speed control system of claim 1 wherein said train-carried frequency detector is a pair of coils mounted on said train.

3. The train propulsion motor speed control system of claim 1 wherein said source of variable frequency includes a wayside variable frequency transmitter and a transmission link to said train which includes the rails upon which said train travels.

4. The train propulsion motor speed control system of

claim 1 wherein said frequency responsive means is comprised of an induction motor, said induction motor's speed being controlled by the frequency received by said frequency detector and delivered to said induction motor.

5. The train propulsion motor speed control system of claim 4 wherein said induction motor of said frequency responsive means drives a speed responsive unit to actuate a control means connected to said pole per phase selection means.

6. The train propulsion motor speed control system of claim 1 in which said constant frequency power supply is a three-phase power supply and said multi-phase propulsion motor is a three-phase induction motor with a plurality of different poles per phase.

7. A train propulsion motor speed control system having a constant frequency power supply to said propulsion motor comprising in combination:

- (a) a signal source of variable frequency energy to control the train propulsion motor speed,
- (b) a train-carried frequency detector means to detect said signal of variable frequency,
- (c) a frequency responsive means electrically connected to and controlled by said frequency detector means,
- (d) a multi-phase propulsion induction motor having a number of connections to provide a plurality of different poles per phase,
- (e) a pole per phase selection means connected to said frequency responsive means and electrically connected to said multi-phase propulsion induction motor, said pole per phase selection means being controlled by said frequency responsive means to connect said constant frequency power supply to a selected pole per phase connection of said propulsion motor determined by the signal frequency received by said frequency detector means to thereby establish a speed control for said train's propulsion motor.

8. The train propulsion motor speed control system of claim 7 wherein said train-carried frequency detector is a pair of coils mounted on said train.

9. The train propulsion motor speed control system of claim 7 wherein said source of variable frequency includes a wayside variable frequency transmitter and a transmission link to said train which includes the rails upon which said train travels.

10. The train propulsion motor speed control system of claim 7 wherein said frequency responsive means is comprised of an induction motor, said induction motor's speed being controlled by the frequency received by said frequency detector and delivered to said induction motor.

11. The train propulsion motor speed control system of claim 10 wherein said induction motor of said frequency responsive means drives a speed responsive unit to actuate a control means connected to said pole per phase selection means.

12. The train propulsion motor speed control system of claim 7 in which said constant frequency power supply is a three-phase power supply and said multi-phase propulsion motor is a three-phase induction motor with a plurality of different poles per phase.

13. A train propulsion motor speed control system for a rail running train having constant frequency power supply to said propulsion motor comprising:

- (a) a signal source of variable frequency energy to control the train's propulsion motor speed, said source of variable frequency including a wayside variable frequency transmitter and a transmission link to said train which includes said rails,
- (b) a train-carried frequency detector means electrically coupled to said rails to detect said signal of variable frequency,
- (c) a frequency responsive means electrically connected to and controlled by said frequency detector means, said frequency responsive means comprised of an induction motor, said induction motor's output

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- speed being controlled by the frequency received by said frequency detector and delivered to said frequency responsive means induction motor,
- (d) a multi-phase propulsion induction motor having a number of connections to provide a plurality of different poles per phase, 5
- (e) a pole per phase selection means,
- (f) a speed responsive unit driven by said frequency responsive means induction motor,
- (g) a control means connected to and controlled by said frequency responsive means induction motor, said control means controlling said pole per phase selection means, 10
- (h) said pole per phase selection means selectably electrically connected to said multi-phase propulsion induction motor, said pole per phase selection means being controlled by said control means to connect 15

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said constant frequency power supply to a selected pole per phase connection of said propulsion motor determined by the signal frequency received by said frequency detector means to thereby establish a speed control for said train's propulsion motor which speed control is mutually dependent on said variable signal frequency and the number of poles per phase utilized in said propulsion induction motor.

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