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[54] **CONTROL SYSTEM FOR DIESEL LOCOMOTIVE**

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[51] **Int. Cl.** **H02p 9/04**

[58] **Field of Search**.................290/3, 14, 17, 40, 51; 318/140–143, 147, 157, 158; 322/14, 15, 17, 38

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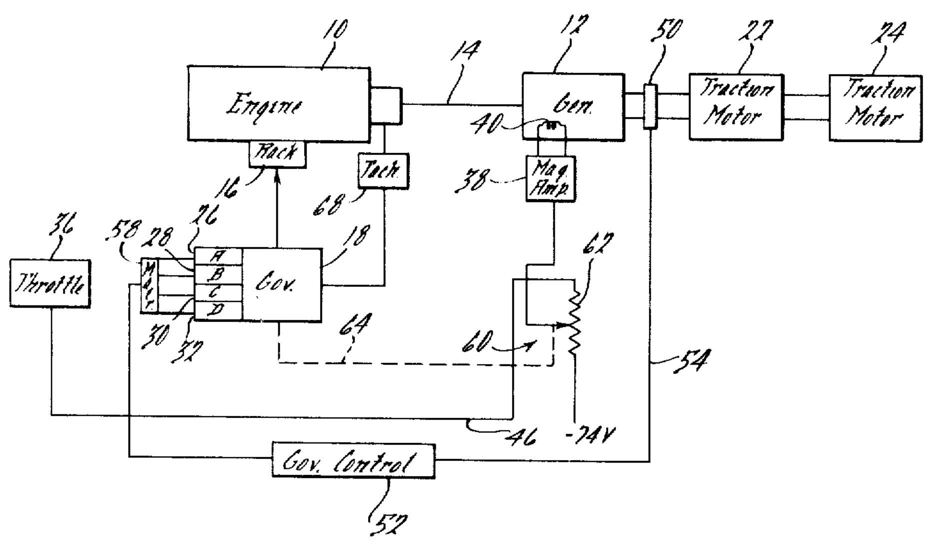
[57] **ABSTRACT**

A control system for a diesel locomotive wherein the locomotive is controlled on a power basis, the engineer selecting the power to be supplied the traction motors from the electrical generator, the power selection being sensed and used to control the diesel engine. The system includes means for selecting an infinite number of power settings. Thus, the engineer selects a particular desired power setting or successively selects power settings and the control system automatically controls the engine to achieve that power setting.

30 Claims, 4 Drawing Figures



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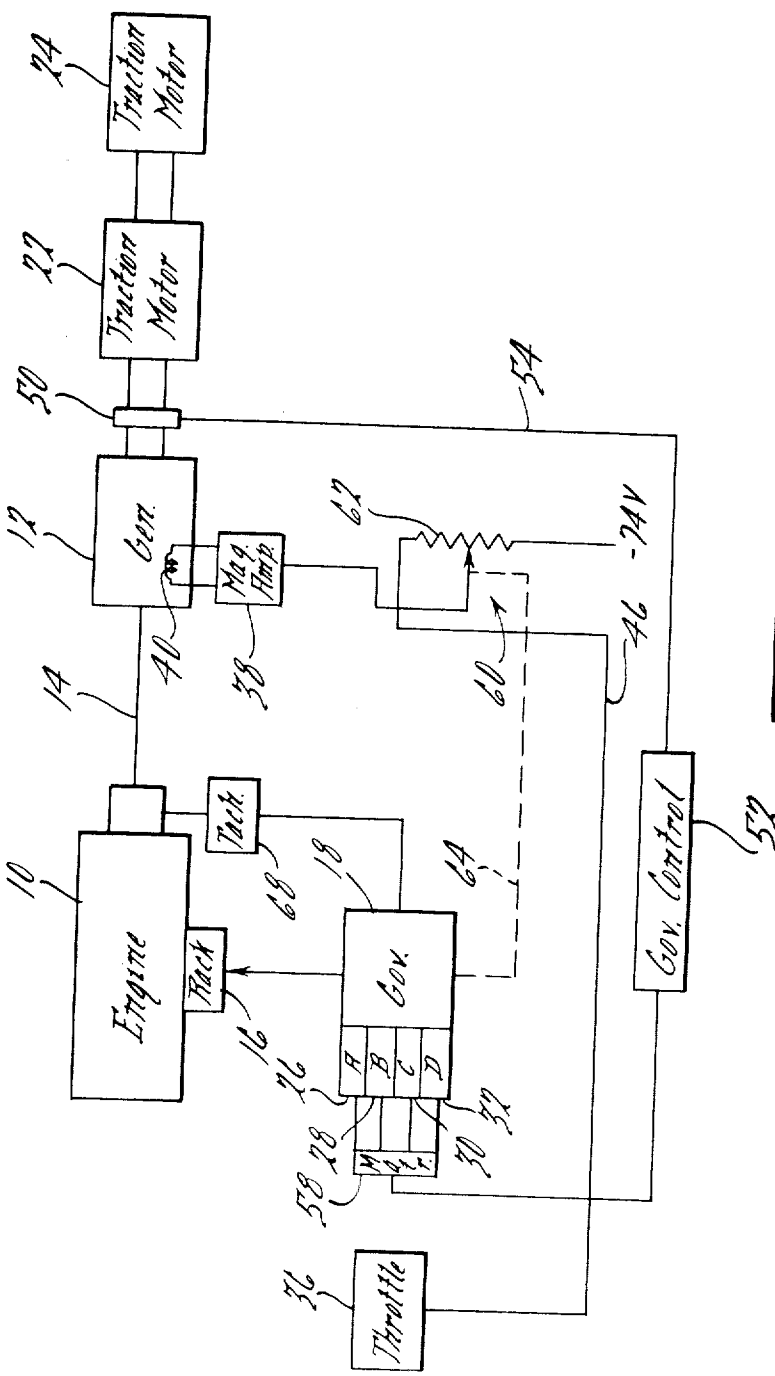

FIG. 1

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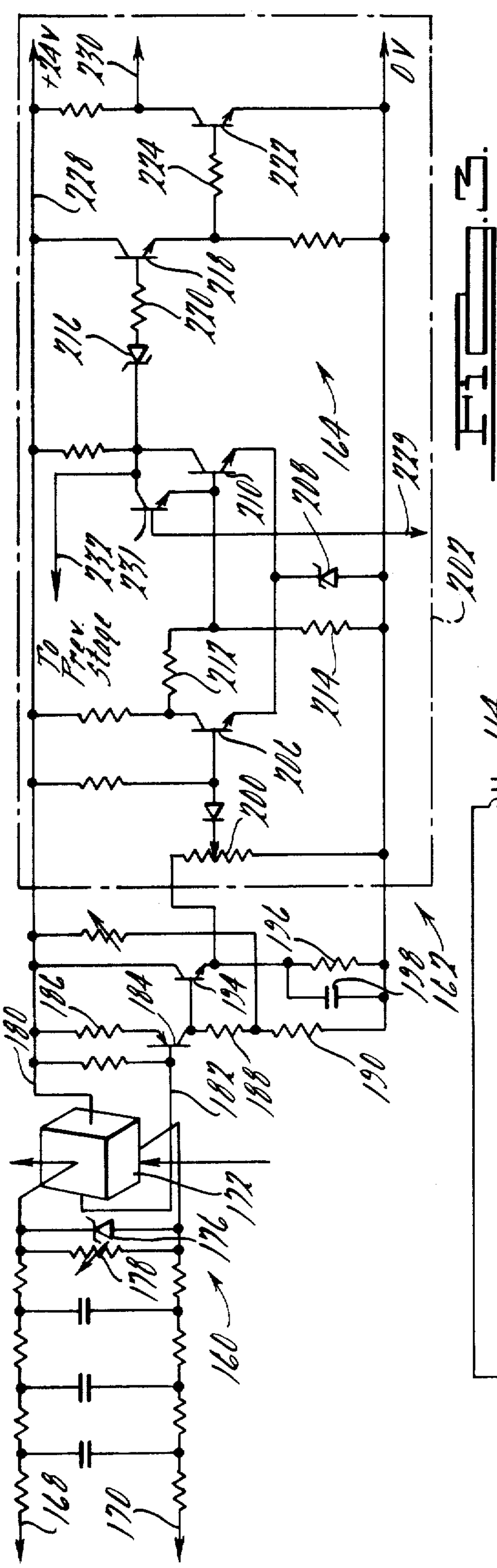

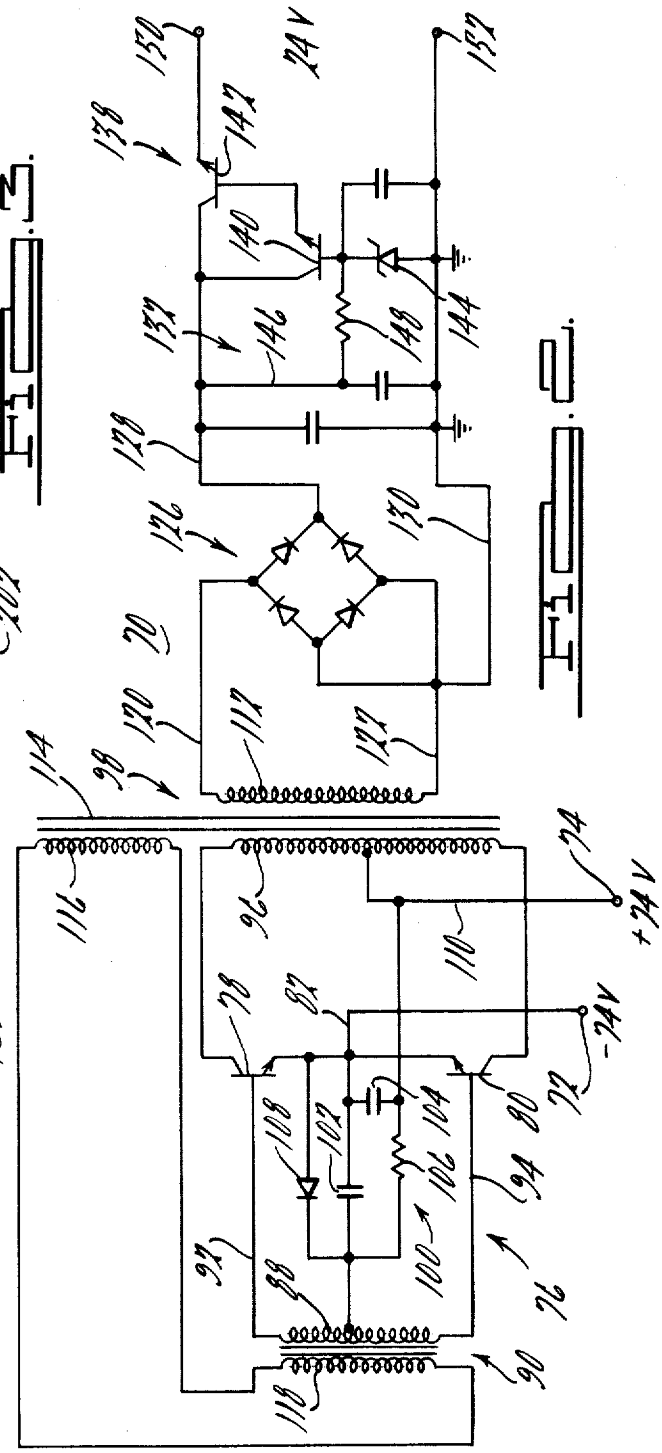

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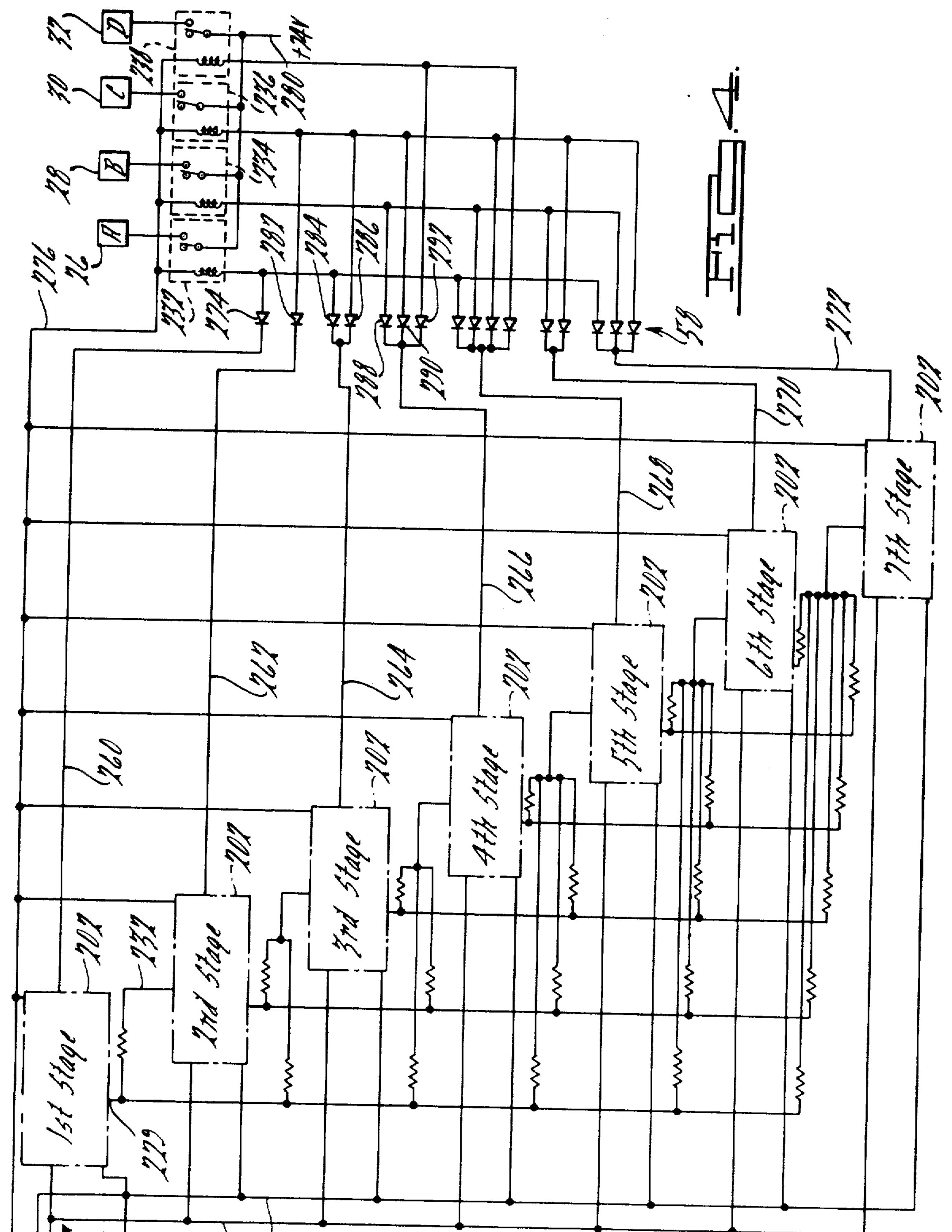

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CONTROL SYSTEM FOR DIESEL LOCOMOTIVE

BACKGROUND AND SUMMARY OF THE DISCLOSURE

This invention relates generally to a control system for a diesel locomotive and more particularly to an automatic control system which is adapted to control the operation of a diesel engine in accordance with the power requirements selected by the engineer.

In typical diesel locomotives presently in use, the engineer is provided with a throttle which typically has eight positions, each position of the switch selecting a particular operating characteristic, i.e. RPM, of the diesel engine. Particularly, the power switch operates to select a combination of governor solenoids, these solenoids normally being designated the A, B, C and D governor solenoids. The selection of a particular combination of solenoids ultimately positions a fuel rack, which in turn, controls the amount of fuel being fed to the diesel engine and thus the speed of the diesel engine.

The shaft from the diesel engine drives a power generator which is utilized to supply electrical energy to a plurality of traction motors, the traction motors being utilized to drive the diesel locomotive. As the traction motors require more power to pull the load, as for example in ascending a grade, the load on the diesel is increased, the increased load attempting to cause a decrease in the rotary speed of the diesel engine. However, before the engine slows down, the governor increases the rack setting to maintain the engine speed. If the load increases to the point that the rack is moved to the maximum setting, the load regulator takes over to decrease the excitation of the generator to decrease the output capability of the generator. As this phenomena occurs in prior art systems, the engineer selects a different combination of governor solenoids to increase the speed of the diesel engine and thus increasing the energy being supplied from the power generator. As the train reaches the peak of the hill and starts to descend, the traction motors then act as a generator, in certain instances causing dynamic breaking, but ultimately causing the diesel engine to reverse the process described above due to the decreased load on the engine. When an increase in speed occurs, the engineer reduces the position of the throttle and thus selects a different combination of governor solenoids to decrease the speed of the diesel engine.

As is readily apparent, the prior art system creates a problem in that the engineer must constantly make a judgment as to the proper throttle setting and continually change the setting to meet the conditions encountered as the train moves down the track. The proper selection of the throttle requires a great deal of skill on the part of the engineer and requires years of training to enable the engineer to achieve constant speed over a particular run.

The prior art system has additional defects to those enumerated above, namely, the engineer must constantly change the power setting to accommodate changing conditions along the particular run being made. These additional problems include the requirements that the engineer estimate initial power setting as the train is brought up to speed to avoid the possibility that the locomotive wheels will spin, while maintaining optimum acceleration of the train to the ultimate speed. This estimating process is necessary due to the fact that the engineer does not have an accurate measure of the load required to be accelerated by the diesel engine, this load only exhibiting itself upon attempting to accelerate the load.

Further, it is a well-known phenomena that fuel consumption at, for example, the eighth setting of power is dramatically different than the fuel consumption exhibited at the seventh setting of power. However, the horse power produced at the eighth setting of power is not dramatically different from that produced at the seventh, and either setting will produce approximately the same speed of the train under certain conditions. Thus, if the engineer selects the eighth setting when only the seventh is required, a great deal of fuel is consumed unnecessarily. Accordingly, an accurate power setting would result in a large saving in operating cost due to a saving in fuel consumption.

Further, with the prior art system, the engineer cannot select intermediate steps of power due to the system of selecting certain combinations of governor solenoids. Thus, for the conventional engine, the engineer usually has only eight power settings available. Certain other engines may have as many as sixteen settings. In the typical locomotive, the zero power setting is in fact merely an idle setting and no electrical energy is supplied to the traction motors due to the fact that the zero power setting does not interconnect the electrical system with the generator. Thus, the engineer only has discrete power settings available.

With the system of the present invention, the engineer need merely bring the throttle control slowly up to a desired position while accelerating the train to the ultimate speed. The system of the present invention will then automatically control the speed of the engine to achieve the power setting determined by the engineer. In the particular embodiment of the present invention, the throttle takes the form of a potentiometer which controls the energization of the field winding of the generator. Thus the excitation of the generator is controlled by the operator to achieve the desired speed.

The system further includes a power sensing device which senses the power being derived from the generator and utilizes this power signal to automatically control the selection of the governor solenoids through a governor control circuit. The selection of a combination of governor solenoids thus controls the position of the fuel rack to in turn control the injection of fuel to the diesel engine. As the traction motors require a greater amount of power from the generator in order to maintain a constant speed of the load, the engineer has an infinite number of power settings to slowly increase power and to select intermediate settings of power which may require switching back and forth between two governor solenoid combinations. With the automatic system of this invention, the governor control will automatically select the next higher combination of governor solenoids corresponding to the next higher throttle position of the prior art systems to bring the engine up to a speed corresponding to the solenoid combinations above the throttle setting and then select the solenoid combinations for the engine speed below the throttle setting so that the average engine speed, and thus train speed, corresponds to the intermediate throttle setting. In this way, the engine is run at optimum speed for the particular power setting required by the load. On the other hand, if the load requirement goes down, the opposite conditions will occur wherein the traction motors will require less power from the generator and thus cause the engineer to select a lower combination of governor solenoids.

In general, diesel electric traction locomotives are equipped with interconnected direct current traction motors which are fed from generators, the generators being either direct current generators or they may be alternating current generators with a rectified output. The phrase fuel injection rate denotes the quantity of fuel injected into the engine per operating cycle thereof. The function of the control system of the present invention is to manipulate the variables of the system so as to obtain rapidly and precisely the traction output desired by the engineer, particularly to select the proper engines RPM's to meet the power demand for a particular speed over selected terrain.

In the system of the present invention, the preferred modification takes the form of a magneto diode which is utilized to sense the output of the main generator. However, it is to be understood that other horsepower sensing devices or systems could be used. The output of the magneto diode takes the form of a direct current voltage which is proportional to the power output of the main generator. This variable voltage is fed to the input circuits of a plurality of stages, in the preferred system seven stages, each stage of which includes a level detector for sensing when the level of the voltage output from the magneto diode achieves a preselected level for each of the control stages. In the particular system to be described, each stage is preset to respond to a particular voltage level. If the preselected voltage level is achieved, the particular stage is energized to provide an output signal from the level detector through a driver circuit, this latter circuit being utilized to boost the current level of the output signal. When a particular stage is energized, a feedback signal is also generated, characterized a turn-off signal, which is fed back to all of the previous stages preceding the selected stage to turn off each of the preceding stages. In this way the system insures that only a single stage is selected.

The output of the selected stage is fed to a solenoid control circuit, in this case a diode matrix, the output of the diode matrix being interconnected with the A, B, C and D governor solenoids. The energization of a particular stage, as described above, thus energizes a preselected combination of governor solenoids to control the rate of fuel injection to the diesel engine in accordance with the load demand of the electric generator to achieve the proper engine speed. Thus, if the load demand goes up due to the increase load on the engine because of a rising terrain, a different set of governor solenoids will be selected by the governor control in accordance with the increased load being sensed at the output of the electric generator. On the other hand, the opposite condition occurs when the load is decreased due to dropping terrain.

The mechanical control of the speed by the engineer in the present system is accomplished by means of an infinitely variable resistance element which is interconnected with the field excitation circuit of the generator. It is to be understood that the resistance element is shown purely for illustrative purposes and that any type of voltage or current control may be utilized to control the operation of the generator.

Accordingly, when the engineer increases the excitation to the field windings, the output of the generator will increase in accordance with the increased excitation. This increased output is sensed by the generator output sensor and fed back through the governor control to select the particular combination of governor solenoids which is required to achieve the sensed power requirements to maintain a constant speed or to accelerate to a selected speed. As stated above, the control device manipulated by the engineer is infinitely variable. Accordingly, the engineer could select a position intermediate to power settings created by the combination of governor solenoids. For example, the engineer could select a speed which would fall between the sixth and seventh power setting in the conventional control system when the train is being operated at a constant load requirement. With the present system, the governor control would select the governor solenoid corresponding to the higher number until such time that the diesel engine was rotating at such a speed as to lower the output from the generator to a point where the next lower power setting, for example, power setting six, is required. The system would automatically select the lower power setting at this point.

Thus, the control system will alternately select the higher and lower power settings to achieve the speed set by the engineer on the throttle assembly. The ratio that the higher power setting is energized relative to the time of energization of the lower power setting will be determined, for the most part, by the position of the throttle or speed setting selected by the engineer relative to the speed achieved by the higher setting or the speed achieved by the lower setting.

The system of the present invention is adapted to be utilized in conjunction with the conventional Woodward governor normally found in diesel engines of this type. Thus, the system includes the normal RPM sensor for the diesel engine and the speed of the diesel engine, for a particular throttle setting or for a particular combination of governor solenoids energized, will maintain that preselected speed. In this way the system closely regulates the speed of the engine in accordance with the selected combination of governor solenoids, it being remembered that the governor solenoid combination is automatically selected by the governor control system, this latter control system operating in accordance with the selected horsepower setting introduced by the engineer with the throttle. The system further includes a load regulator for the electric generator, the load regulator actually being a part of the Woodward governor. In the system of the present invention, the conventional load regulator is interconnected with the generator excitation circuit and the throttle to control the magnitude of voltage being fed to the load regulator in a manner different from the interconnection of previous load regulators.

Basically the governor senses when the diesel engine is being overloaded and automatically controls, through the load regulator, the excitation to the generator in accordance with the overload condition to maintain constant diesel speed for the throttle chosen. This auxiliary control of the excitation of the generator is independent from the throttle controlled excitation and is automatically selected in accordance with the sensed overload condition of the diesel engine. The particular details of the load regulator are illustrated and include a potentiometer having a slidable arm, the position of the slidable arm being controlled by the governor in response to the overload condition. The potentiometer is interconnected with the supply voltage for the generator field circuit and reduces the amount of voltage being fed to the field excitation circuit by the throttle control, the slowing of the excitation having a capability of reducing the excitation to substantially zero. Normally, the load regulator would be at maximum voltage output and reacts only under emergency conditions of overloading the diesel in the case where the rack cannot increase the fuel any further in spite of the fact that the RPM's of the diesel engine are reducing. Accordingly, under an overload condition, the diesel RPM's are reducing and cannot be brought back up because the rack can't increase the amount of fuel being fed to the engine. In order to reduce the load, the load regulator starts down to cause the excitation to the main generator to be reduced. This will reduce the output of the main generator to the traction motors thereby reducing the load on the generator and, as a result, on the diesel. This permits the diesel to increase speed to a point wherein the speed is normal for the particular solenoid governors which are energized.

Accordingly, it is one object of the present invention to provide an improved control system for a diesel engine.

It is another object of the present invention to provide an improved method of controlling a diesel locomotive.

It is still a further object of the present invention to provide an improved control system for a diesel locomotive which is an automatic horsepower output control system.

It is a further object of the present invention to provide an improved system for selecting the speed of a diesel locomotive.

It is another object of the present invention to provide an improved system for controlling the energization of the governor solenoids in a diesel engine.

It is still a further object of the present invention to provide an improved control system for a diesel locomotive which eliminates guessing at the initial power settings heretofore inherent in control systems of this type.

It is still another object of the present invention to provide an improved control system for a diesel locomotive which eliminates the guesswork as to changes in power settings heretofore present in control systems of this type.

It is still a further object of the present invention to provide an improved control system for a diesel locomotive which minimizes fuel consumption in the diesel engine for any selected speed of operation.

It is still a further object of the present invention to provide an improved control system for a diesel locomotive which has infinitely variable power settings.

It is still a further object of the present invention to provide an improved control system for a diesel locomotive which is simple to incorporate into present control systems and which is reliable in operation.

Further objects, features and advantages of this invention will become apparent from a consideration of the following description, the appended claims and the accompanying drawings in which:

FIG. 1 is a schematic block diagram of a preferred form of control system for a diesel locomotive incorporating features of the present invention;

FIG. 2 is a schematic diagram illustrating a preferred form of power supply for the system of the present invention;

FIG. 3 is a schematic diagram illustrating the horsepower sensing circuit, including a magneto diode, and further including a schematic diagram of a preferred form of level detector circuit; and

FIG. 4 is a schematic diagram illustrating the seven stages of level detector circuits and the diode matrix utilized to control the energization of selected combinations of governor solenoids.

Referring now to FIG. 1, there is illustrated a preferred form of generator control system as incorporated into the conventional diesel, electric-generator type locomotive. The description of this invention will incorporate many elements and subsystems which could be replaced by other elements and subsystems performing substantially the same function and leading to the identical result. It is to be understood that it is contemplated within the scope of this invention that such substitutions and modifications could be made to the system.

The locomotive includes a diesel engine **10** which could be of any type commonly used in powering a train. The output of the engine is fed to an electrical generator **12**, which may be of the direct current or alternating current type, by means of an output shaft **14** from the engine **10**. In the absence of other control features, the output from the generator **12** will be a direct function of the speed of the diesel engine **10**. The speed of the diesel engine is controlled by a fuel injection system, normally called a fuel rack **16**, which controls the rate of injection of fuel to the engine **10**. The control of the rack operation will be described hereinafter in conjunction with the control of the engine governor **18**.

In the absence of any other control functions, particularly in control of the generator **12**, the output of the generator **12** will be a certain maximum level for a particular engine speed. If the power requirements from the generator **12** are increased beyond that point, the load regulator will decrease the available power from the generator while maintaining constant engine speed. The output of the generator **12** is fed to a plurality of traction motors **22, 24**, the number in size of traction motors **22, 24** being a function of the load to be driven and the speed at which it is driven. The system thus far described is a conventional diesel locomotive system.

As is common in the art, the governor **18** is normally selected to be a conventional Woodward governor, the control of the governor being accomplished by means of a plurality of governor solenoids **26, 28, 30** and **32**, these governor solenoids being designated the A, B, C and D governor solenoids respectively. Referring to a conventional prior art governor system, the engineer controls a throttle having eight distinct settings in a typical system. The idle setting normally would permit the engine to rotate at idle speed but the electrical system is not interconnected to provide an output from the generator. This position is normally referred to as the idle position and zero volts are produced at the output of the generator **12**. The following description will proceed with selected representative speeds and voltages but it is to be understood that these numbers are selected for illustration only.

When the engineer moves the throttle to the first position, the engine will rotate at 225 RPM and the electrical system is interconnected with the generator **12** and the engine-generator combination will put out a relatively low voltage, for example 33 volts. As the throttle settings are increased from three through eight, the speed of the engine is increased from some value greater than 225 RPM to approximately 875 RPM in one engine tested in conjunction with this invention. It is to be understood that the speeds are selected purely for illustrative purposes and are not to be considered representative.

As the throttle settings are increased from two to eight, the governor solenoids are interconnected into the system to control the rate of fuel injection to the engine. For example, at the second setting the A governor solenoid is energized. At the third setting, the A governor solenoid is deenergized and the C governor solenoid is energized. In the fourth setting the A and C governor solenoids are energized. The remaining power settings from five through eight energize the following combinations of governor solenoids; the B, C and D governor solenoids for position five, the A, B, C and D governor solenoids for position six, the B and C governor solenoids for position seven and the A, B, and C governor solenoids for position eight. Again, these combinations of governor solenoids are selected purely for illustrative purposes.

In the conventional system heretofore used on diesel locomotives of this type, the throttle is used to select the combinations of governor solenoids. In the system of the present invention, a throttle **36** is provided, the throttle being utilized to change the field excitation of the generator **12** by means of, for example, controlling the operation of a magnetic amplifier **38** which in turn controls the excitation of the field winding **40** for the generator **12**. The control of the magnetic amplifier is accomplished by a potentiometer **44**, the supply voltage to which in turn is controlled by the throttle **36**, this voltage appearing on a conductor **46**. Thus, as the throttle setting is increased in the throttle **36**, the voltage being fed to a load regulator circuit **60** is changed to change the operation of the magnetic amplifier **38** to increase the excitation of the field winding. It is to be understood that the magnetic amplifier **38** is again purely illustrative and it is to be understood that any type of control system may be utilized as for example controlling the firing angle of silicon controlled rectifiers, etc.

The output of the generator **12** is sensed by means of a power sensing device **50** which, in the selected system, is a magneto diode. The output signal from the magneto diode system **50** is fed back to a governor control **52** by means of conductors **54**. The governor control **52**, in the system of the present invention, is utilized to control the energizations of combinations of the governor solenoids **26–32**.

This control is accomplished through a diode matrix circuit **58**, the matrix in turn being controlled by the governor control circuit **52**. The matrix circuit, in the preferred system, operates to control the energization of the combination of governor solenoids as outlined above. It is to be understood that if an intermediate setting is selected by the engineer which would normally be between certain throttle setting positions in prior art systems, this system will alternately select the higher combination and the lower combination to provide a speed which is between the speeds which would normally be achieved by the two settings.

The system also includes, as a part of the Woodward governor assembly, a load regulator circuit **60** which incorporates a potentiometer **62**, the slider arm of which is controlled by the Woodward governor through a mechanical linkage **64**. The load regulator is of the type commonly associated with the Woodward governor and is utilized to control the maximum energy, for a particular throttle setting, being fed to the magnetic amplifier circuit **38** in accordance with the position of the slider arm of the potentiometer circuit **62**. Under normal operating conditions, the slider arm would be at a position to provide the full voltage from the throttle to the magnetic amplifier and the voltage to the magnetic amplifier would then be controlled by the position of the throttle **36**. However, if the load requirements of the traction motors **22, 24** exceed the energy which is capable of being supplied by the generator **12** at a particular throttle setting, the engine will then start to lose speed as described above and could ultimately slow to a stop.

The governor **18** also senses which combination of governor solenoids **26–32** are energized and regulates the speed of the engine **10** such that the speed is a function of which governor solenoids **26–32** are energized. However, if the rack assembly **16** is positioned to the maximum for a particular set of governor solenoids, the governor can no longer control the speed of the engine **10**. In this situation, the governor **18** will reduce the voltage fed to the magnetic amplifier circuit **38** by moving the slider arm of the potentiometer **62**. As described above, this will decrease the load on the engine to permit it to maintain proper RPM's of the engine for the throttle setting.

In operation, the engineer will slowly increase the throttle setting **36**, thereby increasing the excitation of the field winding **14**. As this occurs, the power sensing device **50** will sense the power requirements for the traction motors **22, 24** and provide a signal to the governor control **52**. This signal will be of a varying magnitude as the load on the generator increases and decreases. As the load varies, the governor control **52** will select different combinations of governor solenoids **26–32** through the diode matrix **58**. As the engineer wishes to increase the power output of locomotives, thus possibly increase the speed of the train, he increases the excitation of the generator **12** through increasing the excitation of the field winding **40**. This will provide a larger output to the traction motors **22, 24** which will, in turn, increase the output signal to the governor control circuit **52**. This increase in signal to the governor control circuit **52** will increase the setting of the combinations of governor solenoids **26–32**. This operation will be more apparent from a description of the details of the system to be described in conjunction with FIGS. 2–4.

Referring now to FIG. 2, there is illustrated a power supply circuit **70** which is utilized to supply a regulated voltage level to the remaining system from a plus and minus 74 volts which is relatively unregulated. The particular power supply system has been selected to isolate the control from the electric generator and the power signal generated at the output thereof. In this way noise is eliminated from the power supply and the other control circuits of the present invention.

Particularly, the power supply circuit **70** includes a negative 74 volt input at input terminal **72** and a positive 74 volt input at input terminal **74**. The 74 volt positive and negative potential is fed to a conventional chopper circuit **76** which includes a pair of NPN transistors **78** and **80**, the emitter electrodes of which are connected to the negative 74 volt potential at terminal **72** by means of a conductor **82**. The base electrodes of the transistor **78, 80** are connected to opposite ends of the primary winding **88** of a driver transformer **90** by means of conductors **92, 94**. The collector electrodes of transistor **78, 80** are connected to opposite ends of the primary winding **96** of a transformer **98**. The circuit includes a filter network **100** which includes a pair of capacitors **102, 104**, a resistor **106** and a diode **108**. The positive potential at input terminal **74** is fed to a center tap of primary winding **96** by means of a conductor **110**. The primary winding **96** is coupled to a secondary winding **112** through a core **114**, the core also including a third winding **116** which is electrically connected to a secondary winding **118** of the driver transformer **90**.

With the above described circuit, an alternating current square wave is generated across conductors **120, 122**, this wave being fed to a full wave rectifier circuit **126**. The output of the full wave rectifier circuit is impressed across output conductors **120, 130**, this signal being filtered by a filter circuit **132**.

The output of the filter circuit is fed to a series voltage regulator circuit **138** which includes a driver transistor **140** connected in a Darlington configuration with a second transistor **142**. The base electrode of the transistor **140** is held at a particular voltage level, for example, 24 volts, by means of a zener diode **144**, the zener diode being supplied with the voltage at conductors **128, 130** by means of a conductor **146** and a resistor **148**. Thus, the conduction of transistor **140** is held at a particular level by means of the diode **144**, the transistor **140** in turn controlling the conduction of transistor **142**. The result is an extremely smooth, highly regulated output DC potential at output terminals **150, 152**.

Referring now to FIG. 3, there is illustrated a current sensing circuit **160** and an amplifier circuit **161**, the output of which is fed to the input circuit of a level detector circuit **162**, the output of which is fed to a driver circuit **164**. Specifically, the output of the generator is fed to the input circuit of the voltage sensing circuit **160**, specifically to input conductors **168, 170**, the signal being fed through a filter circuit, including resistor-capacitor combinations, to a magneto-diode device **172**. The magneto-diode device is a device typically sold by the Sony Corporation and also includes a current sensing capability which is sensed by the magnetic field created in the direction of the arrows. The input to the magneto-diode device **172** is fed across a zener diode **176** to limit the maximum voltage which may be developed across a magneto diode.

The magneto-diode device **172** transforms the combination of the voltage and current signals into a voltage signal representative of horsepower the output of which is fed across a pair of conductors **180, 182** forming the input to the amplifier circuit **161**. The conductor **180** is connected to the base electrode of a normally nonconductive transistor **184** and the conductor **180** is fed to the emitter electrode thereof by means of a resistor **186**. The emitter collector circuit of transistor **184** feeds current through a pair of resistors **188, 190** to develop a voltage across resistors **188, 190** during the time that the transistor **184** is conductive. This voltage is fed to the base electrode of a second normally non-conductive transistor **194**, the collector of which is connected to the conductor **180** and the emitter of which is connected to a filter circuit including a resistor **196** and a capacitor **198**. When the transistor **194** conducts, a voltage developed across resistor **196** which voltage is fed to a variable voltage divider circuit including a slider tapped resistor **200**.

The slider tap **200** is adapted to be variable so that the output thereof may be preset at a certain level depending on the input current and voltage representative of horsepower as sensed by the diode **172**. The voltage divider **200** is set to provide increments of voltage at the slider thereof which are approximately 1 volt for each stage in the representative example. Thus, if FIG. 3 were the first stage of a plurality of seven stages, the plurality of stages to be more fully described in conjunction with the description of FIG. 4, the output at the slider of voltage divider **200** will be approximately 9/10 of a volt as an example. On the other hand, if the circuit enclosed within dotted line **202** is the second stage, the voltage at the slider of voltage divider **200** will be 1.9 volts at full current at input conductors **168, 170**. A similar condition exists for the third through seventh stages. The above voltages have been selected in accordance with a ratio of 1 volt per thousand horsepower and the voltage has been selected to anticipate the switch to the subsequent combination of governor solenoids.

If the potential at the slider of voltage divider **200** reaches sufficient magnitude, the voltage will turn on a normally nonconductive transistor **206** which will break down a zener diode **208** and thus shortcircuit the bias voltage being fed to a normally conductive transistor **210** by means of a voltage divider including resistors **212, 214**. The transistor **210** is connected to a zener diode **208** at the emitter electrode thereof the zener diode **208** providing a constant voltage at the emitters of transistors **206, 210** to reduce the hysteresis of the circuit **162**. The removal of this bias will cause transistor **210** to become nonconductive, thereby raising the potential at the collector electrode thereof. The rise in potential at the collector electrode of transistor **210** will break down a zener diode **216** to feed a bias voltage to a normally nonconductive transistor **218** through a resistor **220**. This bias voltage will cause transistor **218** to conduct to raise the voltage at the base electrode of a second normally nonconductive transistor **222**, this voltage being fed through a resistor

224, to lower the potential at the collector electrode thereof to approximately 0 volts.

Prior to the conduction of transistor 222, the voltage at the collector electrode of transistor 222 was at a high level, very near the 24 volts present at a conductor 228. The output of transistor 222 is sensed by means of a conductor 230, the voltage at the conductor 230 being at a high level prior to the conduction of transistor 222, that is, when the voltage generated at the voltage divider 200 was below the critical level. When the voltage at the voltage divider 200 reaches the critical level, the transistor 222 will commence conduction to lower the potential at the output conductor 230.

The detector circuit 202 also includes a reset circuit having an input conductor 229 and a reset transistor 231, the conductor 229 receiving an input signal from any subsequent stage which has been energized as a result of the input voltage level due to the energization of the magneto diode 172 reaching a level which is sufficiently great to energize the next stage. A signal at input conductor 229 will cause transistor 231 to turn on thereby lowering the voltage at the collector of transistor 210, thereby turning off transistor 210. Simultaneously, the turning on of transistor 231 provides an output signal at an output conductor 232 to cause any previous stage to turn off. Thus, the turn off operation is connected in cascade such that subsequent stage will turn off its immediately preceeding stage. The same operation is true for each stage.

Referring now to FIG. 4, there is illustrated the overall system described in conjunction with FIG. 1, and particularly illustrating the details of the seven stages, one of which was described in connection with the block 202 described in FIG. 3, and further illustrates the cut-off circuit for previous stages as was described above. The circuit of FIG. 4 also illustrates the diode matrix circuit 58 which is utilized to control the A solenoid 26, the B solenoid 28, the C solenoid 30 and the D solenoid 32 through a plurality of relays 232, 234, 236, 238 respectively. From the output circuit, it is seen that the solenoids, by means of the switches contained therein, control a plurality of fuel injectors representatively illustrated as blocks 26, 28, 30 and 32, respectively.

Referring now particularly to the details of FIG. 4, the power supply for the various stages 202 are supplied by a pair of input conductors 246, 248 supplying a positive and negative 24 volts respectively. The input from the magneto-diode circuit is fed to the input terminals 250, 252, the signal being fed to each of the input stages by means of conductors 254, 256, respectively.

As each successive stage 202 is energized by the, for example, steadily increased voltage input at input terminals 250, 252, each successive stage will be energized to provide an output signal at the output terminals of each successive stage to provide the positive to zero signal at output terminals 260 to 272 corresponding to the first through seventh stages, respectively. As stated above, each of the stages controls a portion of the diode matrix circuit 58 in accordance with the particular governor solenoid combination to be energized.

For example, if the first stage is energized and no subsequent stages are energized, the signal level on conductor 260 will drop to approximately 0 volts to forward bias a diode 274, thus permitting current to flow from the positive 24 volt potential at input terminal 246 through a conductor 276, the coil in relay 232, the diode 274 and conductor 260 through the now conducting output transistor 222 of the particular stage. The energization of the relay coil 232 will close the set of normally open contacts thereof to permit current to flow from the positive 74 volt potential at input terminal 280 to the device to be controlled, in this case the governor solenoid 26. Thus, the A solenoid is energized in response to the first stage being energized.

When the second stage 202 is energized, the 0 volt signal is impressed on conductor 262 to forward bias a diode 282 and thus energize the C governor solenoid. Similarly, the third stage energizes the A and C governor solenoids through diodes 284, 286 and the energization of the fourth stage energizes governor solenoids B, C and D by forward biasing diodes 288, 290 and 292. A similar situation occurs with the fifth, sixth and seventh stages which energize the governor solenoid connected to the respective diodes of the diode matrix 58 as indicated in the lower right-hand portion of FIG. 4.

While it will be apparent that the preferred embodiments of the invention disclosed are well calculated to fulfill the objects above stated, it will be appreciated that the invention is susceptible to modification, variation and change without departing from the proper scope or fair meaning of the subjoined claims.

What is claimed is:

1. A throttle control system for selecting a large number of power settings in excess of sixteen for controlling the operation of a diesel locomotive, the locomotive including a diesel engine, an electrical generator driven thereby, and a plurality of govenor solenoids, the energization of a combination of the solenoids controlling the amount of fuel being fed the engine, the improvement comprising infinitely variable throttle control means for controlling the amount of energy being fed from the engine to the output of the generator, means connected to the generator for sensing the power output of the generator, and circuit means connected to the govenor solenoids for selecting an appropriate solenoid combination in response to the sensed power of the generator output.

2. The improvement of claim 1 wherein said circuit means includes a govenor control circuit having a means responsive to the sensed power of the output of the generator, said govenor control circuit selecting preselected combinations of govenor solenoids in response to the sensed power.

3. The improvement of claim 2 wherein said generator power sensor generates an output analog signal having a characteristic which varies in accordance with variations in output power from said generator.

4. The improvement of claim 3 wherein said generator govenor control circuit includes a signal characteristic magnitude sensitive circuit, said circuit being energized in response to the magnitude of sensed output power.

5. The improvement of claim 4 wherein said magnitude sensitive circuit includes a plurality of circuit modules, said circuit modules being connected in cascade so that successively connected circuit modules

are energized in response to increases in magnitude of sensed generator power.

6. The improvement of claim 5 wherein said circuit means further includes a plurality of feedback circuits, each feedback circuit being connected between successive stages of said circuit modules, said feedback circuit being connected to turn off previously turned on modules in response to the turning on of the next successive module.

7. The improvement of claim 6 wherein said power sensing means includes means responsive to both the current and voltage output of said generator and conversion means for generating a voltage signal in response to sensed power.

8. The improvement of claim 7 wherein each said module includes a voltage responsive circuit having a set voltage level at which the voltage responsive circuit means is energized, each said voltage responsive circuit being responsive to successively higher voltage magnitudes.

9. The improvement of claim 8 wherein said voltage responsive module includes monostable circuit means connected to said voltage responsive means for energizing a selected module in response to the sensed power voltage signal exceeding the set voltage magnitude of said voltage responsive circuit.

10. The improvement of claim 9 wherein said power sensing means includes a magnetostrictive diode connected to respond to the output voltage and current from said generator.

11. The improvement of claim 8 wherein said selecting circuit means includes a matrix circuit having a plurality of input conductors at least equal to in number to said voltage responsive modules.

12. The improvement of claim 11 wherein said govenor solenoids are four in number, said matrix circuit being connected to each of said govenor solenoids such that the energization of a particular matrix input conductor energizes a preselected combination of govenor solenoids in accordance with the sensed generator power.

13. The improvement of claim 12 wherein said module circuit selectively energizes one of a single govenor solenoid, two govenor solenoids, three govenor solenoids and four govenor solenoids in response to the sensed power from said generator.

14. The improvement of claim 4 wherein said circuit means generates an output signal for selecting two combinations of govenor solenoids on a time basis such that the duty cycle of the energization of one combination of govenor solenoids is selected to feed fuel to said engine to respond to the sensed power output of said generator.

15. The improvement of claim 14 wherein the sensed power causes the energization of the second combination of govenor solenoids until such time that the power output of said generator drops below that required to maintain energization of said second combination of govenor solenoids, said circuit means thereafter selecting first combination of govenor solenoids, until such time as said power output of said generator exceeds that required by said first combination of govenor solenoids.

16. The improvement of claim 15 wherein said selection of the time said first and second combinations of govenor solenoids are energized is responsive to the ratio of said power requirement of said generator relative to the power generator in response to the selection of said second combination of govenor solenoids.

17. The improvement of claim 13 wherein said circuit means generates an output signal for selecting two combinations of govenor solenoids on a time basis such that the duty cycle of the energization of one combination of govenor solenoids is selected to feed fuel to said engine to respond to the sensed power output of said generator.

18. The improvement of claim 17 wherein the sensed power causes the energization of the second combination of govenor solenoids until such time that the power output of said generator drops below that required to maintain energization of said second combination of govenor solenoids, said circuit means thereafter selecting first combination of govenor solenoids, until such time as said power output of said generator exceeds that required by said first combination of govenor solenoids.

19. The improvement of claim 18 wherein said selection of the time said first and second combinations of govenor solenoids are energized is responsive to the ratio of said power requirement of said generator relative to the power generator in response to the selection of said second combination of govenor solenoids.

20. A method of selecting a large number of power settings in excess of sixteen for controlling the operation of diesel locomotive, the locomotive including a diesel engine, an electrical generator driven thereby, and a plurality of govenor solenoids, the energization of a combination of the solenoids controlling the amount of fuel being fed the engine, the improvement comprising infinitely, variably controlling the amount of energy being fed from the engine to the output of the generator, sensing the power output of the generator, and selecting an appropriate govenor solenoid combination in response to the sensed power of the generator output.

21. The improvement of claim 20 wherein said method includes selecting preselected combinations of govenor solenoids in response to the sensed power.

22. The improvement of claim 21 wherein said method includes generating an output analog signal having a characteristic which varies in accordance with variations in output power from said generator.

23. The improvement of claim 22 wherein said power sensing steps includes sensing both the current and voltage output of said generator and generating a voltage signal in response to sensed power.

24. The improvement of claim 23 wherein each method includes controlling the selection of said govenor solenoids in response to successively higher voltage magnitudes.

25. The improvement of claim 22 wherein said method includes generating an output signal for selecting two combinations of govenor solenoids on a time basis such that the duty cycle of the energization of one combination of govenor solenoids is selected to feed fuel to said engine to respond to the sensed power output of said generator.

26. The improvement of claim 25 wherein the sensed power causes the energization of the second combination of govenor solenoids until such time that the power

output of said generator drops below that required to maintain energization of said second combination of govenor solenoids, and thereafter selecting first combination of govenor solenoids, until such time as said power output of said generator exceeds that required by said first combination of govenor solenoids.

27. The improvement of claim **26** wherein said selection of the time said first and second combinations of govenor solenoids are energized is responsive to the ratio of said power requirement of said generator relative to the power generator in response to the selection of said second combination of govenor solenoids.

28. The improvement of claim **24** wherein said method includes generating an output signal for selecting two combinations of govenor solenoids on a time basis such that the duty cycle of the energization of one combination of govenor solenoids is selected to feed fuel to said engine to respond to the sensed power output of said generator.

29. The improvement of claim **28** wherein the sensed power causes the energization of the second combination of govenor solenoids until such time that the power output of said generator drops below that required to maintain energization of said second combination of govenor solenoids, and thereafter selecting first combination of govenor solenoids, until such time as said power output of said generator exceeds that required by said first combination of govenor solenoids.

30. The improvement of claim **29** wherein said selection of the time said first and second combinations of govenor solenoids are energized is responsive to the ratio of said power requirement of said generator relative to the power generator in response to the selection of said second combination of govenor solenoids.

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