

SPECIFICATION

Multi-channel generating systems

DESCRIPTION

The invention relates to multi-channel generating systems and particularly to such systems having circuitry for detecting an underspeed condition.

Generators may be coupled in parallel for multi-channel operation to provide current to a load, for example, in a four-engine aircraft, four-channel operation is provided, each engine being a prime mover for one channel. When a prime mover for one channel is shut down, the rotor of the generator tends to motor the prime mover. This is undesirable and results from a voltage impressed on the stator of the shut-down channel by the other operating channels. An overrunning clutch has been coupled between the output of the constant speed drive and the rotor of the generator portion of a generator. United States Patent Specification No. 3,576,143 shows an integrated constant speed drive generator having an overrunning clutch which slips as the speed of the prime mover decreases below minimum speed. Simultaneously, the drive charge pressure between the constant speed drive section of the system and the rotor of the generator section decreases, until an underspeed pressure switch is actuated. The switch provides a signal to the generator control unit to remove the excitation voltage from the exciter of the generator and to open the line contactor, thereby electrically disconnecting that channel from the multi-channel system. The generator control unit receives power from a permanent magnet generator (PMG) mounted on the rotor of the generator.

It is desirable to eliminate the underspeed pressure switch from the constant speed drive. One reason for this is that usually the underspeed switch is physically located near the prime mover and the generator control is in a remote location. Elimination of the switches thus eliminates a significant amount of copper conductor. In a four-engine commercial aircraft, for example, approximately 1,000 feet of interconnecting wire is eliminated.

We have developed an improved integrated constant speed drive generator for use in a multi-channel generating system which does not require the use of an underspeed pressure switch thereby reducing the use of interconnecting wire within the system and the number of parts in the system.

The invention provides a generating system having a plurality of channels, each channel comprising a constant speed drive unit coupled to a generator, the output of the generator being coupled through a line contactor switch in parallel with the output(s) of the generator(s) of the or each other channel to provide current to a load, a permanent magnet generator connected to the constant speed drive for generating a sinusoidal signal having a frequency which is proportional to the angular velocity of the output of the constant speed drive,

a shaping circuit for converting the sinusoidal signal to a square wave pulse signal of the same frequency,

a one-shot circuit having as an input the square wave pulse signal, the one shot circuit providing a pulsed output signal, and an inverted pulse output signal each time a square wave pulse is received from the shaping circuit,

the pulsed output signal being equal to or smaller than the width of the square pulse wave signal received from the shaping circuit and being proportional to the frequency of the output speed of the constant speed drive,

the inverted pulses becoming shorter in length as the frequency is increased, a set point of the system representing operation at a desired frequency existing when the pulse length of the pulsed output signal equals the pulse length of the inverted pulse output signal,

a low pass summing active filter for receiving the pulsed output signal and the inverted pulse output signal from the one-shot circuit and having a voltage output, the amplitude of which is directly proportional to a frequency error from the set point,

a comparator having as inputs a reference voltage representative of a desired minimum speed and the voltage output of the low pass summing active filter, whereby an underspeed condition exists when the low pass summing active filter voltage output is less than the reference voltage,

the comparator being coupled to a time delay circuit providing an output to control the line contactor switch if an underspeed condition from the comparator has lasted for a preset period of time,

and an overrunning clutch coupled between the constant speed drive unit and the generator for mechanically disconnecting the constant speed drive unit from the generator if the output speed of the constant speed drive unit drops below the speed of the generator.

The multi-channel generating system of the invention supplies current to a load. The channels are electrically connected in parallel and are of similar construction. Each channel has a prime mover which drives a constant speed drive unit which, in turn, drives a generator, during shutdown, the overrunning clutch, interposed between the output of the constant speed drive unit and the generator, slips mechanically to disconnect the rotor of the generator from the constant speed drive unit. A permanent magnet generator coupled directly to the output of the constant speed drive unit provides a signal having a frequency proportional to the output speed of the constant speed drive unit. The signal from the permanent magnet generator is provided to a generator control unit and there it is compared to a signal representative of a speed equal to a minimum desirable speed. When the speed of the constant speed drive unit decreases to less than minimum desired speed, the generator control unit electrically disconnects the shut-down

channel from the multi-channel system. The circuit is unaffected by false signals, as short transient disturbances.

The multi-channel generating system of the invention in each channel has a constant speed drive unit not having an underspeed pressure switch, yet capable of providing underspeed information.

The invention is illustrated with reference to the drawings of which:

Figure 1 is a block diagram of a single channel of a prior art multi-channel generating system;

Figure 2 is a block diagram of a single channel of a multi-channel generating system according to the invention;

Figure 3 is a block diagram of the circuit in the channel of Figure 2 which circuit provides underspeed information;

Figure 4 is a wiring diagram of the circuit shown in Figure 3; and

Figure 5 is a cross-sectional view of the permanent magnet generator of Figure 2 mounted on the constant speed drive unit of Figure 2, a rotor of the generator of Figure 2 and the overrunning clutch of Figure 2 therebetween.

Referring to Figure 1, a single channel 12 of a prior art multi-channel generating system 10 is shown. The single channel 12 provides power to a load 14, and additional similarly constructed channels (not shown) are connected to a bus 16. Since all the channels of the multi-channel system 10 are similar, only the channel 12 will be described. A prime mover 18 is mechanically coupled to the input of a constant speed drive as, for example, constant speed drive section 20 of an integrated drive generator 22. The integrated drive generator 22 may be of the type disclosed in United States Patent Specification No. 3,576,143. The constant speed drive 20 is coupled through an overrunning clutch 24 to a generator 26. An underspeed pressure switch 28, responsive to the output speed of the constant speed drive 20, provides a signal to a generator control unit 30. The generator control unit 30 receives its power from a permanent magnet generator (PMG) 36. The underspeed pressure switch is an ON/OFF switch which responds to the pressure in the constant speed drive. During start-up of the prime mover 18, the output speed of the constant speed drive increases, and the pressure in the constant speed drive increases in proportion to the increase in speed. When minimum sufficient speed is reached, a flyball governor stem moves, generating a hydraulic signal which causes the underspeed pressure switch 28 to close, providing information to the generator control unit 30. The generator control unit 30 controls the voltage to an exciter 32 of the generator 26, as well as the open/closed position of a line contactor 34 when the output speed of the constant speed drive is greater than the minimum sufficient speed.

The generator control unit 30, responsive to the underspeed pressure switch 28, opens the line contactor 34 if the output of the constant speed drive fails or decreases in angular velocity to a

point lower than the minimum angular velocity necessary for proper generator operation. During shutdown of the prime mover 18, the generator control unit 30 maintains line contactor 34 closed and power to the exciter 32 until the output speed of the constant speed drive 20 has dropped below minimum speed, as detected by the underspeed pressure switch 28.

The PMG 36 is coupled to the shaft of the generator 26 (see United States Patent Specification No. 3,576,143, Figure 1, where the PMG, not labelled, is on the left end of the rotor 54 adjacent the bearing 56). Frequency information from the PMG has been used to detect a speed condition of generator 26.

Referring to Figure 2, a single channel 38 of a multi-channel generating system 40 according to the invention will now be described, it being understood that the other channels are of similar construction and connected to a load bus 39, providing power to a load 41.

A prime mover 42 is mechanically coupled to a constant speed drive as, for example, a constant speed drive 44 of integrated drive generator 46. A PMG 48 is coupled directly to the output of the constant speed drive 44. The signal from the PMG 48 provides speed information of the output of the constant speed drive. The frequency of the signal from the PMG 48 is directly proportional to the speed of the constant speed drive 44. An overrunning clutch 50 is coupled between the PMG 48 and the shaft of a generator 52 and exciter 58.

During start-up, the constant speed drive 44 exceeds a level greater than minimum sufficient speed, and this condition is detected by PMG 48. A circuit in a generator control unit 56 detects the sufficient speed condition and provides a voltage to the exciter 58 and closes a line contactor 60.

When the prime mover 42 shuts down and the speed from the constant speed drive 44 drops below minimum sufficient speed, the overrunning clutch 50 slips. The generator control unit 56 comprises the frequency of the signal with a signal representing a reference frequency and when the signal from the PMG 48 indicates an underspeed condition, the generator control unit 56 causes the exciter 58 to become de-excited and the line contactor 60 to open, thereby disconnecting the channel from the system.

Referring to Figure 3, a block diagram of the circuit within the generator control unit 56, which circuit detects an underspeed condition, is shown. The output from the PMG 48 is a sinusoidal waveform, the frequency of which is proportional to the angular velocity of the output of the constant speed drive 44. The signal from the PMG 48 is provided to a shaper 62 to square up and make more uniform the sinusoidal input signal. The output of the shaper 62 is applied to a one-shot circuit 64. The one-shot circuit 64 provides a pulse on output Q and an inverted pulse on output $\bar{Q}$ each time a pulse is received from shaper 62. The width of pulses on output Q must be equal to or smaller than the width of the pulses received

from shaper 62. Therefore, the repetition rate of the pulses from the one-shot circuit 64 is proportional to the frequency of the output speed of the constant speed drive 44. As the repetition rate increases, the length of the pulses on output $\bar{Q}$ become shorter, and when the length of the pulses on output Q equals that of the pulses on output $\bar{Q}$, the system operates at what hereinafter is referred to as the set point. The set point represents operation at a desired frequency (e.g. 400 Hz), and may be changed by adjusting the width of the pulses on output Q of the one-shot circuit 64. The outputs Q and $\bar{Q}$ from one-shot 64 are applied to the differential inputs of a low pass summing active filter 66. The output of the low pass summing active filter 66 is a voltage, the amplitude being directly proportional to the frequency error from the set point.

A reference voltage, representing the desired minimum speed, for example a speed equal to 95% of the synchronous speed, is compared to the voltage from the summing active filter 66 by a comparator 68. An underspeed condition exists when the voltage from the summing active filter 66 is less than the reference signal. An output is provided from a time delay circuit 70 if the signal from the comparator 68 indicating an underspeed condition has lasted for a preset period of time. The time delay circuit 70 permits the system to be unaffected by short transient disturbances. The length of the time delay is operator-selectable and must accommodate the longest duration the speed will be outside the trip range. This length of time is typically 0.5 to 2 seconds.

Referring to Figure 4, a detailed description of the block diagram shown in Figure 3 will now be provided. The signal from the PMG 48 is applied to the shaper 62 through resistors 72 and 74. The negative input terminal of an operational amplifier 76 is connected between resistors 72 and 74 and the voltage applied thereto is proportional to the input voltage from the PMG 48. The positive input terminal of the operational amplifier 76 is connected to grounded resistor 78 and to the output of the operational amplifier 76 through resistor 80. The hysteresis of the operational amplifier 76 is determined by the selection of appropriate values for the resistors 78 and 80. The output of the operational amplifier 76 is provided to a voltage divider consisting of resistors 82 and 84.

The input of the one-shot 64 is connected between the resistors 82 and 84. The output of the one-shot 64 is a pulse, the length of which is determined by the selection of appropriate values for a resistor 86 and a capacitor 88. The pulse repetition rate on the outputs Q and $\bar{Q}$ of the one-shot 64 is the same as the frequency of the signal from the pulse shaper 62.

The signals Q and $\bar{Q}$ are provided to the active low pass filter 66. The differential transmission of the Q and $\bar{Q}$ signals assures the elimination of common mode noise and reduces the effect of the power supply at the set point. A resistor 90 and a capacitor 92 form a simple lag network to filter the

pulses from Q output of the one-shot 64 to provide a voltage across resistor 94. Similarly, a resistor 96 and a capacitor 98 form a lag network to filter the signal from $\bar{Q}$ of the one-shot 64.

providing a voltage across resistor 100. The resistor 94 is coupled to the negative input of an operational amplifier 102 and the resistor 100 is coupled to the positive input of the operational amplifier 102. The difference between the voltage at the negative and positive inputs to the operational amplifier 102 is amplified to provide an output on line 104. The amplitude of the voltage on line 104 is proportional to the error from the set point. Matched resistor and capacitor networks 106 and 108 filter the signals at the negative and positive input terminals, respectively, of the operational amplifier 102.

The voltage from the active low pass filter 66 is provided to the negative input of an operational amplifier 110 through a resistor 112 of the comparator 68. Resistors 114, 116 and 118, coupled to a positive voltage V , from a voltage divider which establishes the reference signal to which the voltage from the active low pass filter 66 is compared. When the operation of the system is not indicative of an underspeed condition, the voltage at the positive input terminal of the operational amplifier 110 exceeds the voltage at its negative input terminal. Under this condition, an output voltage is provided from the operational amplifier 110. An underspeed condition is detected when the voltage at the negative input terminal of the operational amplifier 110 exceeds the voltage at the positive input terminal, there being no output voltage from the operational amplifier 110 in this condition.

The time delay circuit 70 assures that the system will be unaffected by short transient disturbances resulting from the output of the operational amplifier 110 being low or off for a short period of time. Specifically, the output of the operational amplifier 110 is coupled to a transistor 120 through biasing resistors 122 and 124. As stated previously, during normal operation, the output of operational amplifier 110 will be positive. A positive voltage to the base of the transistor 120 keeps it on, shorting capacitor 126 and the positive input of an operational amplifier 128 to ground. Resistors 130 and 132, coupled to a voltage V , from a voltage divider network to provide a reference voltage at the negative input terminal of the operational amplifier 128. When the voltage at the positive input terminal of the operational amplifier 128 exceeds that established by the voltage dividers 130 and 132, voltage is provided from the output of the operational amplifier 128. This occurs when transistor 120 is off for a sufficient amount of time to permit the voltage across capacitor 126 to charge to $+V$ through a resistor 134, overcoming the voltage applied to the negative input of the operational amplifier 128. The output from the time delay circuit 70 is coupled to well-known circuitry within the generator control unit 56 to control the ON/OFF condition of the exciter 58 and the line

contactor 52.

Referring to Figure 5, a brief description of the placement of the overrunning clutch 24 between the constant speed drive 44 and the generator 52 will now be described.

The output of the constant speed drive 44 drives a gear 136 which is secured to a sleeve 138. The main field winding 140 of the PMG 36 is also secured to the sleeve 138. A shaft 142 of the generator 26 is mounted at its left (as shown in the drawing) end by bearings 144 which are supported by a housing 146. An overrunning clutch 148 couples the sleeve 138 to the shaft 142, and sleeve bearings 150, 152 and 154 are mounted to the shaft of the overrunning clutch 148. The output from the PMG 36 is taken from windings 156.

CLAIMS

1. A generating system having a plurality of channels, each channel comprising a constant speed drive unit coupled to a generator, the output of the generator being coupled through a line contactor switch in parallel with the output(s) of the generator(s) of the or each other channel to provide current to a load, a permanent magnet generator connected to the constant speed drive for generating a sinusoidal signal having a frequency which is proportional to the angular velocity of the output of the constant speed drive,

a shaping circuit for converting the sinusoidal signal to a square wave pulse signal of the same frequency,

a one-shot circuit having as an input the square wave pulse signal, the one shot circuit providing a pulsed output signal, and an inverted pulse output signal each time a square wave pulse is received from the shaping circuit,

the pulsed output signal being equal to or

40 smaller than the width of the square pulse wave signal received from the shaping circuit and being proportional to the frequency of the output speed of the constant speed drive,

the inverted pulses becoming shorter in length as the frequency is increased, a set point of the system representing operation at a desired frequency existing when the pulse length of the pulsed output signal equals the pulse length of the inverted pulse output signal,

50 a low pass summing active filter for receiving the pulsed output signal and the inverted pulse output signal from the one-shot circuit and having a voltage output, the amplitude of which is directly proportional to a frequency error from the set point,

55 a comparator having as inputs a reference voltage representative of a desired minimum speed and the voltage output of the low pass summing active filter, whereby an underspeed condition exists when the low pass summing active filter voltage output is less than the reference voltage,

60 the comparator being coupled to a time delay circuit providing an output to control the line contactor switch if an underspeed condition from the comparator has lasted for a preset period of time,

65 and an overrunning clutch coupled between the constant speed drive unit and the generator for mechanically disconnecting the constant speed drive unit from the generator if the output speed of the constant speed drive unit drops below the speed of the generator.

2. A generating system having a plurality of channels, each channel being substantially as described herein with reference to Figures 2 to 5
75 of the drawings.

contact 52.

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60 the comparator being coupled to a time delay circuit providing an output to control the line contactor switch if an underspeed condition from the comparator has lasted for a preset period of time,

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70 2. A generating system having a plurality of channels, each channel being substantially as described herein with reference to Figures 2 to 5
75 of the drawings.

