

Generator Shorted Diode Protection System

The invention relates to a shorted diode protection system for a brushless alternating current generator.

5 The creation many years ago of brushless alternating current generators in which field excitation is supplied from an alternating current exciter and a rotating rectifier assembly have always faced the inherent problem of detecting a shorted diode in the rotating rectifier
10 assembly. The presence of a shorted diode in the rectifier assembly establishes an intermittent short-circuit across the exciter winding and if the exciter field excitation is maintained, heavy
15 short-circuit currents will flow in the exciter armature winding. These heavy short-circuit currents can result in extensive damage or destruction of the exciter and possible damage to the main generator and other system components.

20 Amongst the effective solutions to these shorted diode problems is that put forward in United States Patent Specification No. 3,210,603 wherein there is shown

rotating field generator in which the exciter field current is monitored and the field circuit interrupted upon failure of a rotating diode. A current transformer couples a signal representing the current to a diode bridge rectifier and RC filter. Upon failure of a diode, the AC ripple in the field circuit increases in amplitude and decreases in frequency. The rectified voltage from the diode bridge rectifier and RC filter increases in amplitude and actuates a relay to open the field circuit. The aforementioned is additionally effective to isolate the direct current component of the field current from the alternating current component. It is recognized that the design of the current transformer is critical since the transformer is biased with direct current. The direct current bias being equal to the average exciter field amperes. This direct bias requires a heavy and costly transformer. The invention to be described hereinafter requires no transformer and is free from any of the problems of isolation attendant with the detection of a current component.

Another solution to the shorted diode problem is that set forth in United States Patent Specification No. 3,534,228, which shows a sensing circuit including a series resistor in the exciter field circuit with a voltage transformer connected across the resistor through a DC blocking capacitor. The voltage output of the transformer is connected through an RC filter to a diode bridge rectifier and to a field current regulator. The Hyvarinen et al patent requires an AC conductive coupling circuit to the exciter field, to produce an AC error voltage proportional to the oscillation or ripple in the field current. Shorted diode protection is afforded by means for limiting the exciter field current when an AC error voltage exceeds a reference. The invention to be described hereinafter provides shorted diode protection without the need for the inclusion of heavy current

components in the field circuit lines thereby reducing the possibility, overall, of component failure as a factor in the reliability of the shorted diode detection.

The invention provides a shorted diode protection
5 system for a brushless alternating current generator of the type having an energizeable exciter field winding, the system including

means for sensing the voltage differential across the exciter field and multiplexing the voltage differential with
10 generator load current to provide a first output signal having a voltage differential component falling within a predictable range of values over a normal generator load current range and falling within a higher range of values upon the occurrence of a shorted diode and having a
15 generator load current component, and

means responsive to the first output signal such that whenever the voltage differential component thereof exceeds a present voltage differential value for the prevailing generator load current in the normal range, a second output
20 is generated to interrupt the energization of the exciter field.

The protect system according to the invention is particularly suitable for a generator including a stationary armature member and a rotatable member carrying
25 a field winding;

an exciter having a stationary member carrying a field winding and an armature member rotatable with said rotatable member of the generator,

rectifier means mounted for rotation with said
30 rotatable member and electrically connected between the exciter armature member and the generator field winding to supply direct current excitation thereto, and

means for supplying direct current to said exciter field winding.

35 Preferred embodiments of the invention will now be discussed.

The first circuit arrangement for sensing the voltage differential is electrically coupled across the exciter

field winding and includes a multiplexer electrically coupled to the exciter field winding. A microprocessor is part of the second circuit arrangement and is also electrically coupled to the multiplexer. The multiplexer is adapted to receive signals from either side of the exciter field winding as well as a control signal from the microprocessor.

A load current sensing circuit is coupled to an output of the generator and has an output coupled to the multiplexer.

The circuit arrangement for sensing the voltage differential further includes a digital to analog converter electrically coupled to an output from the multiplexer. The converter provides the aforementioned first output signal to the microprocessor, the voltage differential component of which is in either the predictable range of values or is in the higher ranges of values upon the occurrence of a shorted diode.

The second circuit arrangement further includes a generator control relay driver electrically coupled to a relay. The actuation of the relay controls the interruption of the energization of the exciter field.

The microprocessor has stored therein a range of present voltage differential values over the normal generator load current range, such that whenever the second output signal exceeds a preset value at any given load current in the normal range, the relay is activated to interrupt the exciter field. Finally, a resistance element is controllably electrically connected across the excitation field winding upon activation of the relay to thereby damp out any generator self excitation when a shorted diode is detected and the energisation of the exciter field winding interrupted.

The invention is illustrated by the drawings of which: Figure 1 is a schematic diagram of a generator system

embodying the invention;

Figure 2a to 2d are timing charts depicting the operational characteristics at various points in the generator system of Figure 1, with and without the occurrence of a shorted diode;

Figure 3 is a plot of the voltage differential across a generator exciter winding over a normal load current range, with and without a shorted diode present; and

Figure 4 is a graph illustrating the location of the preset values in the inventions microprocessor shown located between the shorted and non-shortcd operating characteristics of Figure 3.

Reference is now made to Figure 1, which is a schematic diagram of a brushless alternating current generator system embodying the invention. The generator is conventional in that it is provided with a rotatable assembly 10 which includes a rotatable shaft not shown, upon which there are mounted for rotation therewith a field winding 11, a three phase armature winding 12 and a rectifier assembly 13. The rectifier assembly 13 is electrically connected to the field winding 12 as shown and includes diodes 14, 15, 16, 17, 18 and 19. A three phase stator winding 20 is provided, which forms part of the stator structure not shown. Generator output conductors 21, 22 and 23 are depicted exiting the dotted outline of the three phase stator winding 20 and entering a current transformer arrangement designated by broken line box 26. The function of the current transformer arrangement 26 will be explained more fully hereinafter. A permanent magnet generator 30 of a conventional nature is employed in conjunction with a full wave rectifier bridge 31 along with conventional voltage regulator

components such as transistor Q_1 , capacitor C, resistor R_1 , as well as diodes CR1 and CR2, which are in turn electrically interconnected as shown to electrical leads 32, 33 to either side of an exciter field winding 36. The exciter field winding 36 is mounted on a stator, not shown, and is provided with direct current excitation from permanent magnet generator 30 via the full wave rectifier bridge 31 through the electrical connections and components hereinbefore shown and described. A permanent magnet field member, not shown, driven from the main generator shaft, also not shown, results in and through connections and components, an exciter voltage being delivered to exciter field winding 36 whenever the main generator shaft is rotated. Normally closed breaker contacts 37, 38 and 39 are shown in leads 41, 42 and 43, which leads interconnect the permanent magnet generator 30 with full wave rectifier bridge 31. The opening of these normally closed breaker contacts 37, 38 and 39 will be explained more fully hereinafter. At this point in the description it is sufficient to note that the opening of these breaker contacts 37, 38 and 39 will interrupt the DC power to the exciter field winding 36.

A pair of voltage divider networks generally designated by reference numerals 46 and 47 and associated forked arrows are electrically connected respectively to lead 33 at point 48 and lead 32 at point 49. The voltage divider networks 46, 47 provide on leads 50 and 51 to a multiplexer 52 reduced voltage signals dependent upon the values selected for voltage divider resistors R_2 , R_3 , R_4 , R_5 , and voltage divider capacitors C1, C2.

A circuit arrangement 55 or sensing means shown in dotted outline senses the voltage differential across the exciter field winding 36 and pairs the voltage differential with generator load current in the manner to be set forth hereinafter. The multiplexer as previously noted continuously receives voltage signals on leads 50,

51 which voltage signals are directly proportional to the voltage sensed on either side of exciter field winding 36 on the leads 32, 33.

5 The current transformer arrangement 26, shown schematically, continuously delivers on leads 27, 28 and 29 to a three phase load current averaging circuit 56 signals indicative of the load current the generator is being called upon to deliver. The load current averaging circuit 56 has a single output on lead 57 which is
10 delivered to the multiplexer 52. The multiplexer 52 is controlled by a signal from a microprocessor system 60 via lead 61. The multiplexer 52 has a single output provided on lead 58 to an analog to digital converter 59. The analog to digital converter 59 converts the signal
15 information on lead 58 to a digital form on lead 62 for use by the microprocessor system 60.

The microprocessor system 60 is programmed in a manner such that the multiplexer 52 under the control of the signal on lead 61 from the microprocessor sequentially
20 admits and passes to its output 58 the reduced voltage signals on leads 50, 51 and average load current signal on lead 57. The sequence in which the voltage and load current are sampled is a matter of design dependent upon the microprocessor system program. In any event, for
25 reasons that will become apparent hereinafter, the microprocessor requires a pair of conditions to be present to allow the microprocessor logic to determine if a differential voltage detected at a given average load current exceeds a preset value stored in the
30 microprocessor for the given average load current. Whenever a differential voltage is detected that exceeds the stored preset value at a given load current, a signal is generated on lead 68 to a generator control relay driver and relay 63 which is activated and causes the
35 interruption of the energization of exciter winding 36 by the opening of the normally closed breaker contacts 37,

38, 39 via the mechanical connection 64 shown in broken line form.

5 It will be observed that the mechanical connection 64 from generator control relay driver and relay 63 controls the closing of normally open breaker contact 66 via mechanical connection 64a. The closing of breaker contact 66 places resistor 67 across the leads 32, 33, to exciter field winding 36, thereby damping out any generator self-excitation whenever a shorted diode has
10 been detected and the energization of the exciter field winding interrupted.

15 The microprocessor system 60 and the generator control relay driver and relay 63 are shown and included within broken line box 65 and represent a means responsive to an output signal on lead 62, such that whenever the output signal exceeds a preset value over the normal load current range, an output is generated on connection 64 that interrupts the energization of the exciter field winding 36.

20 Before the detailed operation of the system of Figure 1 is described in conjunction with the signal timing charts of Figures 2a through Figure 2d, attention is directed to Figure 3 which graphically illustrates the phenomenon which the invention recognizes, detects and
25 acts upon. Accordingly Figure 3 is a plot of the voltage differential across a generator exciter winding such as the winding 36 in Figure 1, plotted over a normal load current range with and without a shorted diode present.

30 In Figure 1 the exciter field winding 36 has connected thereto at either end thereof, electrical leads 32 and 33. The reference character "A" and its associated arrow designate the point 48 on lead 33, while reference character "B" and its associated arrow designate the point 49 on lead 32.

35 When the diodes 14 through 19 of the rotating rectifier assembly 13 are in good operating condition, the

voltage at point "A" is represented by voltage curve 70 as shown in Figure 3 reduced by voltage divider network 46. Similarly, when the diodes 14 through 19 are in good operating condition, the voltage at point "B" is represented by voltage curve 71. At any given load current, the distance between the voltage curves 70, 71 represents the voltage differential across the exciter field winding 36.

It has been discovered that if one of the diodes 14 through 19 should become shorted, the rotating generator field 11 acts as a voltage energy source in respect of the exciter field winding 36. This voltage energy source influences the voltage at points "A" and "B" in respect of ground. When the generator field 11 acts as a voltage source as when there is a shorted diode present, the negative side of the exciter field winding 36 is limited only by the value of CR2 below ground. The positive end of the exciter field winding 36 pumps energy into capacitor C via electrical lead 32 thereby building up the voltage at point "B". This voltage build up at point B will increase to a level sufficient to back bias the permanent magnet full wave rectifier bridge 31. The voltage at point "B" is now reflected on capacitor C and will cause a field current to flow from point B through capacitor C and diode CR2 thereby influencing the voltage at point A.

Returning to Figure 3 it will be observed plotted therein is the point A shorted diode voltage curve 72 and point B shorted diode voltage curve 73. It can be seen that at all load currents the differential voltage between the good diode voltage curves 70 and 71 is always less than the differential voltage between shorted diode voltage curves 72 and 73.

Figure 4 is a plot of exciter field winding voltage differential curves plotted over the normal generator load current range. Solid "good diode" differential voltage

curves 74 and 75 are shown falling within a predictable range of values with the generator operating at the same frequency but at different temperatures. Broken line "shorted diode" differential voltage curves 76 and 77 are
5 seen to fall within a higher range of values.

A protection setting curve 78 represents preset values stored in the microprocessor 60. Whenever the absolute value of differential voltage across the exciter field winding 36 is above the protection setting curve 78,
10 the generator control relay driver and relay 63 is activated to interrupt the energization of the exciter field winding 36 by opening normally closed breaker contacts 37, 38, 39 via mechanical connection 64, as shown in Figure 1.

Reference is now made to Figures 2a through 2d inclusive, which are timing charts for a generator operating with no load at 400 Hz. Figures 2a through 2d are to be studied in conjunction with the generator system of Figure 1.

Figure 2a plots the voltage at point A versus time and illustrates the idealized full wave rectified square wave forms 80, 81, 82, and 83 delivered by full wave rectifier bridge 31. In time, at the end of square wave 83 a shorted diode occurs and it can be seen that while
20 peak voltage rises, the average voltage drops from 131.6 volts DC to 115 volts DC.

Figure 2b shows the plot of voltage at point "B" over the same time period as Figure 2a and illustrates during the shorted diode condition an increased voltage as
25 indicated by reference numeral 85.

In Figure 2c, the resistor divider output voltages representative of points A and B, and are plotted separately as indicated by the legend on the figure. The sudden increase in the $\Delta (V_B - V_A)$ at point in time 86
30 is recognized by the microprocessor 60 as being of a value greater than the preset value of protection setting curve

78 of Figure 4 and the microprocessor 60 provides the output shown in Figure 2d.

From the foregoing it can be readily appreciated that the invention described provides a brushless
5 alternating current generator with shorted diode protection free the need to detect and use field current or field current ripple to provide the shorted diode protection. All of this is advantageously accomplished by
10 the detection of a voltage differential across an exciter field winding that causes the energization of the exciter field to be interrupted whenever the voltage differential across the exciter field winding exceeds a preset value stored in a microprocessor system.

Although the invention has been illustrated and
15 described in connection with the particular embodiment illustrated, it should be apparent to those skilled in the art that various changes may be made without departing from the scope of the invention, such as the substitution of analogue circuits for the multiplexer, converter and
20 microprocessor combination shown.



CLAIMS:

1. A shorted diode protection system for a brushless
alternating current generator of the type having an
energizeable exciter field winding, the system including
5 means for sensing the voltage differential across the
exciter field and multiplexing the voltage differential
with generator load current to provide a first output
signal having a voltage differential component falling
within a predictable range of values over a normal
10 generator load current range and falling within a higher
range of values upon the occurrence of a shorted diode and
having a generator load current component, and
means responsive to the first output signal such that
whenever the voltage differential component thereof exceeds
15 a preset voltage differential value for the prevailing
generator load current in the normal range, a second output
is generated to interrupt the energization of the exciter
field.
2. A system according to claim 1 wherein the means for
20 sensing the voltage differential is electrically coupled
across the exciter field and includes multiplexer means
electrically coupled across the exciter winding and to a
microprocessor included in the means responsive to the
first output signal, the multiplexer means being adapted
25 to receive signals from either side of the exciter winding
and a control signal from the microprocessor.
3. A system according to claim 2 which includes in
combination a load current sensing circuit coupled to an
output of the generator, the load current sensing circuit
30 having an output coupled to the multiplexer means.
4. A system according to claim 3 wherein the first output
signal is provided by a converter electrically coupled
to an output from the multiplexer means.
5. A system according to any preceding claim wherein
35 the second output signal controls a relay driver



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electrically coupled to a relay for interrupting the energization of the exciter field.

6. A system according to claims 2 and 5 wherein the microprocessor has stored therein a range of present
5 voltage differential values over the normal generator load current range, such that whenever the voltage differential component of the first output signal exceeds the preset value voltage differential for the prevailing generator load current, in the normal range, the relay is
10 activated to interrupt the energization of the exciter field.

7. A system according to claim 5 or claim 6 wherein a resistance means is electrically connected across the excitation field winding upon activation of the relay to
15 damp out any generator self-excitation.

8. A brushless alternating current generator comprising a stationary armature member and a rotatable member carrying a field winding,

an exciter having a stationary member carrying a
20 field winding and an armature member rotatable with said rotatable member of the generator,

rectifier means mounted for rotation with said rotatable member and electrically connected between the exciter armature member and the generator field winding
25 to supply direct current excitation thereto,

means for supplying direct current to said exciter field winding,

and a shorted diode protection system according to any preceding claim.

30 9. A shorted diode protection system system for a brushless alternating current generator of the type having an energisable exciter field winding, the system being substantially as described herein with reference to the drawings.