AUTOMATIC CONTROL OF ALTERNATOR PARAMETERS IN A POWER STATION USING PLC

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Abstract—The objective of our dissertation is to control generator parameters using Programmable Logic Controllers (PLC) in thermal power stations. In most of the old power stations and captive power stations the control of alternator parameters is presently done by relay logics or controlled manually. In such cases , the control of generator parameters can be done by using PROGRAMMABLE LOGIC CONTROLLERS (PLC). GENERATOR PARAMETERS which are controlled under closed loop are 1)Stator current 2)Stator voltage 3)Rotor current 4)Rotor voltage 5)Rotor temperature 6)Stator Cu temperature 7)Cooling gas temperature 8)Seal oil drain temperature 9)Seal oil pressure 10)Active load 11)Reactive load 12)Power factor. The system which is in existence to control the generator parameters in Thermal power stations is Distributed Digital Control system (DDC) which houses microprocessors. However DDC cannot be used in captive power plants and other small power stations due to cost constraints.

1. INTRODUCTION

The alternators work on the principle of electromagnetic induction. When there is a relative motion between the conductors and the flux, emf gets induced in the conductors. Synchronous machines are principally used as alternating current (AC) generators.

The generators used in the Thermal Power Plant are synchronous generators. They supply the electric power used by all sectors of modern societies viz industrial, commercial, agricultural, and domestic. Synchronous generators usually operate together (or in parallel), forming a large power system supplying electrical energy to the loads or consumers. Synchronous generator converts mechanical power to ac electric power. The source of mechanical power, the prime mover here is a steam turbine.

The main generators used in the thermal power stations are separately excited generators. For this purpose another synchronous generator is installed on the same shaft of the turbine and the main generator which is called exciter.

The exciter is a self excited synchronous generator. In the initial start-up the DC supply is given to the field winding of the exciter by the DC batteries for 4 seconds. After that the DC batteries are cut-off and the DC supply is given to the field of the exciter by its own generator supply after the rectification.

The AC supply generated by the exciter is also given to the field winding for its excitation after the rectification. The AC produced by the exciter is sent to the rectifier room where it is converted into controlled DC supply by thyristor. The firing angles of thyristor are controlled by AVR(Automatic Voltage Regulator) and hence the excitation of the generator is controlled.

Table 1. Generator Particulars

S. NO	PARTICULARS	50 MW	100 MW
1.	Max continuous KVA rating	62500KVA	117500 KVA
2.	Max continuous KW	50000KW	100000 KW
3.	Rated terminal	10500+_5%V	10500+_5 %V
4.	Rated stator current	3440A	6475A
5.	Power factor	0.8	0.85
6.	Excitation current at MCR condition	640A	1600A
7.	Slip ring voltage at MCR condition	224V	240V
8.	Efficiency at MCR condition	98.4%	98.4%
9.	Rated speed	3000 rpm	3000 rpm
10.	Rated frequency	50Hz	50Hz

2. STATIC EXCITATION SYSTEM

The static excitation equipment is one which supplies the required excitation current to the generator rotor field and which regulates the generator voltage by direct influence on the excitation current controlled rectifiers replaces the old usual exciter machines.

The required excitation power is supplied by a 3.3 KV/ 380 V, 3-phase, star-delta transformer to the thyristor and from the thyristor, the rectified power is delivered to the generator slip rings through field breaker. The system is normally fed from the generator terminals, but in our station, it is fed from the 3.3KV unit section of the respective units.

DESIGN FEATURES

- The excitation system controls the field voltage the generator in such a way that the transient change in the voltage in the regulated voltage are effectively suppressed and sustained. Oscillations in the regulated voltage are not produced by the excitation system during steady state load condition.
- The generator terminal voltage is maintained constant within +/-0.5% of the present value over the entire load range of the machine.
- The excitation system is capable of providing field forcing for the maximum duration of 10seconds.
- The response of the excitation system is such that 90% of ceiling voltage emerges in 40milliseconds, at 5% drop in generator terminal voltage.
- The system incorporates a device for controlling volt/frequency ratio, which enables the regulation to be proportional to the frequency below a pre-determined cut-off frequency.
- The thyristor converter is based on (n-1) principle i.e. if one parallel bridge goes out; the remaining bridges are rated to meet the nominal excitation and field forcing excitation requirements of the generator without exceeding permissible operating temperature.
- The AVR measurement circuit suitable for 5A or 1A CT secondary and 110V PT secondary.

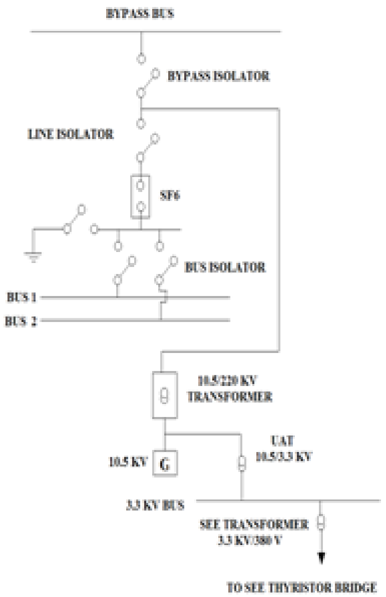

Fig. 1. Single line diagram of stator exciter control panel

AVR parameters

- ✓ Range of voltage level adjustment: +/-10% in all modes of operation of generator.
- ✓ Frequency range of operation: 48.5 to 51.5 Hz
- ✓ Accuracy with which generator voltage is held: better than +/-0.5%
- ✓ % of transformer drop compensation: 0 to 15%
- ✓ Maximum change in generator voltage: <0.5%
- ✓ When AVR is changed from 'Auto' to 'Manual' under all condition of excitation.
- ✓ Manual control range: 0-105% of generator terminal.
- ✓ Response time: <50milliseconds.

3. SIGNIFICANCE OF EACH PARAMETER

Generator Current:

Generator current (I_g) depends on the active load, the stator current should never be allowed to go beyond the full load current for a 50 MW alternator. At 10.5 KV GTV, the full load generator current is 3440 A and for 100 MW generator the full load stator current is 6500 A. There are chances in some instant that the generator current may go beyond this full load limit due to excessive steam input.

Generator Terminal Voltage (GTV):

As the turbine is spinning at 3000 rpm, the generator rotor coupled to the turbine will also spin at 3000 rpm. When DC voltage is injected into rotor circuit, voltage in induced across the stator terminals of the stator winding. For the alternator in thermal power station-1 of NLC, the GTV is 10.5 KV. The GTV may also be in range of 11 KV or 15 KV etc. The GTV depends on the rotor voltage.

When the machine is loaded, the GTV leads to fall and the excitation level has to be increased to maintain the GTV at constant level. Similarly when the load on the machine suddenly drops down, the GTV leads to rise and the excitation will be decreased and so maintain the GTV.

Rotor Voltage:

For a 50 MW machine the rotor voltage will be in the range of 140-160 V DC and for a 100 MW machine, the rotor voltage will be in the range of 220-240 V. When the rotor voltage is increased or decreased the active load on the machine increases or decreases. The static excitation system always maintains the GTV constant irrespective of the load condition by varying the rotor voltage or current.

Rotor Current

The rotor current is otherwise known as field current (I_f). The rotor current varies upon the active load on the machine. The rotor current is equally shared by the converter bridges in the SEE system. When there is any problem converter bridge will get overloaded. Action has to be taken to rectify the fault converter bridge. The exciter in the excitation system automatically takes action in the case of any abnormal rotor current.

Hydrogen Pressure

Another vital parameter controlled in the alternator is hydrogen pressure. Hydrogen is used for cooling purpose inside the alternator. Thermal conductivity of the hydrogen increases with increase in hydrogen pressure. Hydrogen is locked up inside the alternator in pressurized condition.

For a 50 MW machine, the hydrogen pressure inside the alternator is 1.0 KAC and for a 100 MW machine, the hydrogen pressure is 2.0 KAC. Hydrogen pressure low/high is acted upon manually by the engineer inside the control room.

Copper Temperature

When the load on the machine increases copper temperature tends to go high. The copper temperature should not be allowed to go beyond a preset limit. Alternators are provided with "class F" insulation and hence the maximum permissible temperature is 130 deg Celsius. In the stator side the temperature is restricted to 110 deg Celsius.

The copper temperature of a machine increases on the following occasions:

- When the active load on the machine increases.
- When the reactive load on the machine increases.
- When the cooling condensate pressure decreases.
- When the cooling condensate flow decreases.
- When the H_2 pressure decreases.
- When the H_2 purity decreases.

Iron Temperature

Iron temperature of the alternator should be maintained within prescribed limit. Iron temperature may also tend to rise when the load on the machine goes beyond the limit. The iron temperature is recorded at various points of the alternator and they are monitored continuously.

Cooling Gas Temperature

This is the temperature of the hydrogen gas at the inlet of the generator. The safe limit of the cold gas temperature is 45 deg Celsius. The cold gas temperature may rise when the cooling condensate water/pressure/flow decreases. The temperature low/high is monitored with an alarm system and is acted upon manually by the engineer inside the control room.

Hot Gas Temperature

This the temperature of the hydrogen gas at the outlet of the generator. The cold gas as it enters the generator it is made to circulate inside the alternator. The hydrogen gas takes away the heat from the winding and it gets heated up and its temperature rises. The maximum allowable hot gas temperature increases, it has to be ensured whether the cooling condensate flow is proper or not. Load reduction has to be done as a last measure.

Seal Oil Temperature

Another generator parameter of generator to be considered is seal oil temperature. The generator seals are provided at both ends of the generator in order to prevent hydrogen from escaping. The generator seals are provided with seal liners and the seal liners are made up of special alloy " Babbitt metal ". The Babbitt metal can withstand temperature up to 70 deg Celsius.

So the seal oil temperature has to be maintained well below this value. The seal oil temperature should be maintained in the range of 50 to 55 deg Celsius. When then seal oil temperature increases, steps have to be taken to increase the flow and pressure, to bring down the temperature. This can be done by adjusting automatic pressure regulator.

Seal Oil Pressure

As already discussed, the seals are provided for sealing the hydrogen gas in the generator. The seal oil pressure maintained depends on the hydrogen pressure inside the generator. Seal oil pressure maintained for a 50 MW generator is 1.5 KSC and for 100 MW it is 2.15 KSC. The seal oil pressure is adjusted automatically by the pressure regulator so as to maintain a constant pressure difference of 0.5 KSC.

When the seal oil pressure reduces below a certain limit, seal oil pressure low annunciation will come into control room. When the pressure rises, seal oil pressure annunciation will come, pressure intercool is provided for starting the reserve oil pumps when the seal oil pressure drops below normal limit.

When the seal oil pressure becomes very low, then the hydrogen will start escaping from the generator which is very dangerous. When the oil pressure becomes high, oil enters the generator which is also highly dangerous. Hence seal oil pressure has to be maintained always.

PRACTICAL DIFFERENCE BETWEEN PLC AND DCS:

PLC	DCS
1. Flexible: It is possible to use just one model of a PLC to run and control 'n' no. of machines.	1. 15 machines might require 15 different controllers.
2. When a PLC program circuit or sequence design change is made, the PLC program can be changed from the keyboard sequence in a matter of minutes.	2. With a wired relay panel, any program alternations require time for rewiring of panels and devices.
3. A PLC program change cannot be made unless the PLC is properly unlocked and programmed.	3. Relay panels tend to undergo undocumented changes.
4. The PLC is made of solid state components with very high reliable rates.	4. Mechanical system or relays are less reliable compared to PLC.
5. PLC control is a single-house type controller where in all the control is made available under one roof.	5. DCS deploys a wide spread control system, there is a threat of damage in communication system.

4. THE PRESENT SYSTEM OF PARAMETER CONTROL

A Distributed Digital Control Management Information System (DDC MIS) is a control system for a process or plant, wherein control elements are distributed throughout the system. This is in contrast to non-distributed systems, which use a single controller at a central location. In a DCS, a hierarchy of controllers is connected by communication networks for monitoring and controlling.

A DCS typically uses custom designed processors as controllers and uses both proprietary interconnections and standard communications protocol for communication. Input and output modules form component parts of the DCS. The processor receives information from input modules and sends information to output modules. The input modules receive information from input instruments in the process (or field) and the output modules transmit instructions to the output instruments in the field. The inputs and outputs can be either analog signal which are continuously changing or digital signals which are 2 state either on or off .

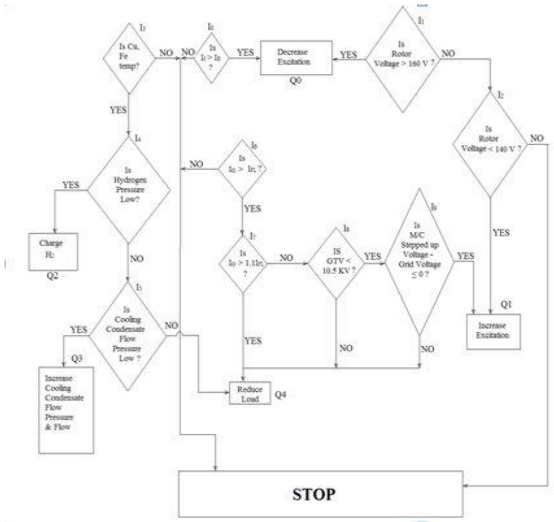

Fig. 2. Flow chart representation of various parameter control

In other words it acts as a Human Machine Interface (**HMI**).

The input/output devices (I/O) can be integral with the controller or located remotely via a field network. DCSs are usually designed with redundant processors to enhance the reliability of the control system. Most systems come with displays and configuration software that enable the end-user to configure the control system without the need for performing low-level programming, allowing the user also to better focus on the application rather than the equipment.

5. PARAMETER CONTROL USING PLC

Each different electronically controlled production machine required its own controller. 15 machines might require 15 different controllers. Now it is possible to use just one model of a PLC to run anyone of the 15 machine. Furthermore we probably need fewer than 15 controllers, because one PLC can easily run many machines. Each of the 15 machines under PLC control would have its own distinct program.

With a wired relay panel, any program alternations require time for rewiring of panels and devices. When a PLC program circuit or sequence design change is made, the PLC program can be changed from the keyboard sequence in a matter of minutes. No wiring is required for a PLC controlled system. Also if a programming error has to be corrected in a PLC control ladder diagram, a change can be typed in quickly.

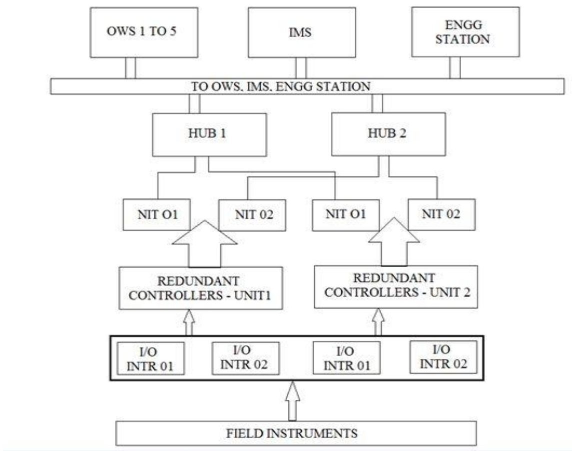

Fig. 3. Block diagram representation of DDC MIS in power plants

Relays can take an unacceptable amount of time to actuate. The operational speed for the PLC program is very fast. The speed for the PLC logic operation is determined by the scan time, which is a matter of milliseconds.

Below given figure (fig. 4) shows the ladder logic for PLC operation of parameter control.

1. I_0 – Rotor or Field current
2. I_1 – Rotor or Field voltage >160V
3. I_2 – Rotor voltage < 140V
4. I_3 – Copper and Iron temperature
5. I_4 – Hydrogen gas pressure
6. I_5 – Cooling condensate flow and pressure
7. I_6 – Generator current > Full load current
8. I_6 – Generator current > Full load current
9. I_7 – Generator current > Full load current + 10%
10. I_9 – [(Machine voltage) – (Grid voltage)] < or = 0
11. Q_0 – Decrease excitation
12. Q_1 – Increase excitation
13. Q_2 – Charge hydrogen
14. Q_3 – Unit tripped due to abnormal generator parameter
15. Q_4 – Reduce load
16. Q_5 – All parameters in normal condition
17. Q_6 – All parameters in abnormal condition

The hydrogen cooling system for instance, PLC has multiple inputs and multiple output arrangement. Hence, the inputs of PLC can be connected to sensors to keep track the value of hydrogen pressure, hydrogen purity and hydrogen temperature.

A brief explanation on how Rotor current I_0 control can be employed with this logic. Whenever the rotor current value goes below the specific reference value the switch I_0 closes and the memory M_0 picks up. Parallel operation takes place with respect to the reaction time set on the timer. As soon as the memory M_0 picks up after time delay T_0, Q_0 i.e. Excitation is reduce signal is generated. On the other hand if the Field current stays abnormal for too long timer T_2 trips the unit. The action sequence is as follows M_0-M_4-M_6-T_2.

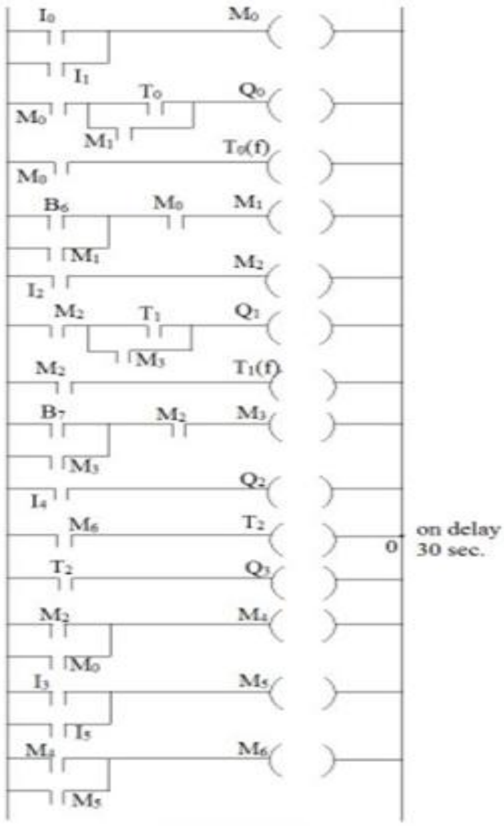

Fig. 4. PLC Ladder logic

6. CONCLUSION

In the project , effort has been made to demonstrate what are all the alternator parameters, how they are controlled in power stations by Distributed Digital Controls and Management Information System (DDCMIS) . The significance of each parameter is also dealt with. A few suggestive measures to improve the existing system by introducing a PLC is also discussed. Moreover the suggested model will be useful in captive power plants where distributed Digital Controls and Management Information System (DDCMIS) is not available.

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