

Design of Emergency Shutdown System for Steam Turbo Generator

P. Abiranjana, K. Vinoth, R. Natarajan, B. A. Abhijith
Electronics and Instrumentation Engineering,
Sri Sairam Engineering College
Anna University, Chennai – 600025

Guided by
T. Sathies Kumar

Abstract: The general purpose of a generator is to generate electrical power at higher voltages which for industrial applications. It involves large values of voltage and current controls and must be maintained within the prescribed limits to enable safe and profitable running process. In recent years all the controlling processes are carried out by Programmable Logic Controller (PLC) which is programmed to the customer's requirements. In order to increase the reliability of the plant solid state logic is overcome by automating the power plant using Programmable Logic Controller (PLC). In addition to it a mathematical model of the steam turbo generator has been developed and its non-linear response has been obtained using MATLAB simulation. The voltage and current control can be done very efficiently by the Programmable Logic Controller (PLC) without the requirement of much man power and at reduced costs.

Keywords: Turbine, generator, PLC, MATLAB.

I. INTRODUCTION

In India, most of the plants are using solid state logic for all its working purposes. It has been an expensive one mainly for the ones in large scales and a simple discontinuity of a wire could mean the failure of the whole system. This paper gives a detailed view about how to change the solid state logic to a much better one, in this case, a PLC controller. PLC has been growing much in industrial part because of its higher reliability and cost effective property. The PLC software used here is "i-Trilogi 6". In addition to it a MATLAB simulation has been simulated to compare the various controllers and find out the best one for the system. The system taken here is a Turbo-Generator and the shutdown of that system under emergency purposes.

II. ARCHITECTURE OF A TURBO GENERATOR

A. Turbine

A turbine generator, which is sometimes called a turbo-generator, is usually a synchronous generator that is directly connected to the turbine of a steam power plant. Since the turbines at steam power plants that use fossil fuels operate best and most economically at high rotational speeds, turbine generators driven directly by a turbine shaft must also operate at high rotational speeds. The rotational speed n of a turbine generator is given by the equation $f = p \times n$, where f is the AC frequency and p is the number of pole pairs present in the inner part of the steam turbine generator.

A turbine generator is an electrical machine of the horizontal type. Its excitation winding is embedded in a rotor with non-salient poles; a three-phase armature winding is located in a stator. The rotor experiences the highest mechanical stress and is therefore manufactured as a solid high-quality steel forging. Because of strength considerations, the linear velocity v of any point of the rotor must not exceed 170–190 m/sec. This requirement limits the diameter of the rotor to $D = v/\pi n = 1.2-1.3$ m for $n = 50$ sec-1.



The relatively small rotor diameter results in a relatively large rotor length. The rotor length, however, is limited by the permissible bending of the turbine shaft and does not exceed 7.5–8.5 m. The surface of the rotor contains longitudinal milled slots, in which the coils of the excitation winding are embedded. The coils are held in place by wedges, which enclose the slots, and by large bindings made of nonmagnetic steel, which cover the ends of the winding. The excitation winding is energized by an electrical machine exciter.

B. Energy Absorption from fluid - Role of Rotor Blades

When high energy fluid (high pressure and high temperature) passes through series of rotor blades, it absorbs energy from fluid and starts rotating, thus it transforms thermal energy in fluid to mechanical energy. So series of such blades which eventually transform thermal energy, are the most vital part of a steam turbine.



If you take a close look at one of the blade, it would be clear that a blade is a collection of airfoil cross sections from bottom to top. When flow passes through such airfoils it induces a low pressure on bottom surface and high pressure on top surface of airfoil. This pressure difference will induce a resultant force in upward direction, thus making the blade rotate. So some part of fluid energy will get transformed to mechanical energy of blade. Before analyzing energy transfer from fluid to blade, we will have a close look at energy associated with a fluid.

C. Energy Associated with a Fluid

A flowing fluid can have 3 components of energy components

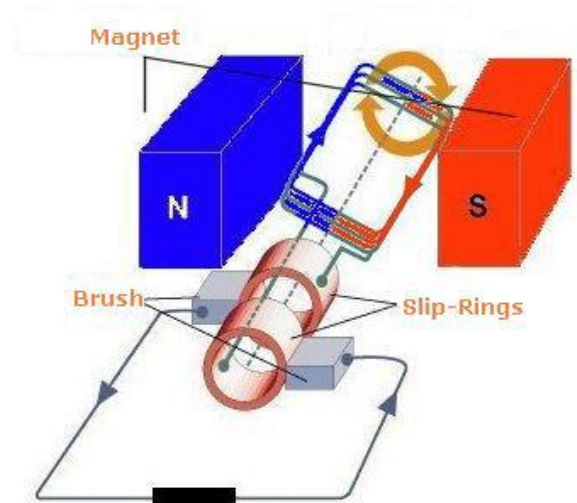
- Kinetic energy - Virtue of its velocity
- Pressure Energy - Virtue of its pressure
- Internal Energy - Virtue of its temperature

D. Generator

A.C. generators or alternators (as they are usually called) operate on the same fundamental principles of electromagnetic induction as D.C. generators.

Alternating voltage may be generated by rotating a coil in the magnetic field or by rotating a magnetic field within a stationary coil. The value of the voltage generated depends on the number of turns in the coil, strength of the field, the speed at which the coil or magnetic field rotates.

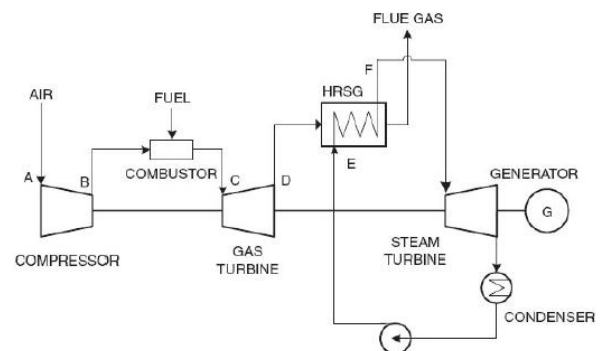
According to Faraday's law of electromagnetic induction, when a conductor moves in a magnetic field (thereby cutting the magnetic flux lines), a dynamically induced emf is produced in the conductor. The magnitude of generated emf can be given by emf equation of a DC generator. If a closed path is provided to the moving conductor then generated emf causes a current to flow in the circuit.



E. Interlock

An interlock is a device used to prevent undesired states in a state machine, which in a general sense can include any electrical, electronic, or mechanical device or system. In most applications an interlock is used to help prevent a machine from harming its operator or damaging itself by stopping the machine when tripped. Household microwave ovens are equipped with interlock switches which disable the magnetron if the door is opened. Similarly washing machines will interrupt the spin cycle when the lid is open. Interlocks also serve as important safety devices in industrial settings, where they protect employees from devices such as robots, presses, and hammers. While interlocks can be something as sophisticated as curtains of infrared beams and photodetectors, they are often just switches.

F. Interlock in Turbine



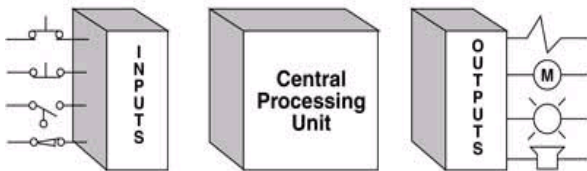
Interlocked equipment, like motors or valves, is an equipment that has a protection circuit (real or logic) that interdicts the activation of the equipment if at least one danger condition is met.

III.PLC

A. Description

A Programmable Logic Controller (PLC) is an industrial computer control system that continuously monitors the state of input devices and makes decisions based upon a custom program to control the state of output devices. Almost any production line, machine function, or process can be greatly enhanced using this type of control system. However, the biggest benefit in using a PLC is the ability to change and replicate the operation or process while collecting and communicating vital information. Another advantage of a PLC system is that it is modular. That is, you can mix and match the types of Input and Output devices to best suit your application.

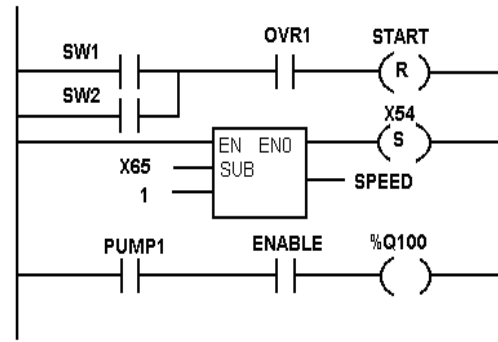
The first Programmable Logic Controllers were designed and developed by Modicon as a relay re-placer for GM and Landis. These controllers eliminated the need for rewiring and adding additional hardware for each new configuration of logic. The new system drastically increased the functionality of the controls while reducing the cabinet space that housed the logic. The first PLC, model 084, was invented by Dick Morley in 1969. The first commercial successful PLC, the 184, was introduced in 1973 and was designed by Michael Greenberg.



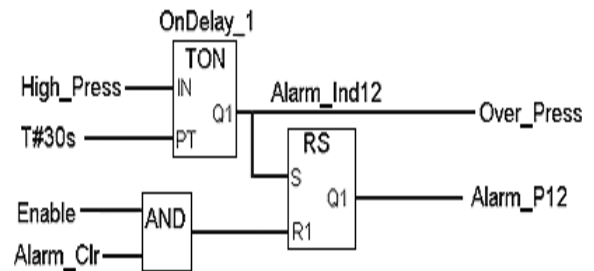
There are four basic steps in the operation of all PLCs; Input Scan, Program Scan, Output Scan, and Housekeeping. These steps continually take place in a repeating loop. While Ladder Logic is the most commonly used PLC programming language, it is not the only one. The following table lists of some of languages that are used to program a PLC.

B. Ladder Logic

Ladder Diagram (LD) Traditional ladder logic is graphical programming language. Initially programmed with simple contacts that simulated the opening and closing of relays, Ladder Logic programming has been expanded to include such functions as counters, timers, shift registers, and math operations. A simple example is shown in the below diagram:



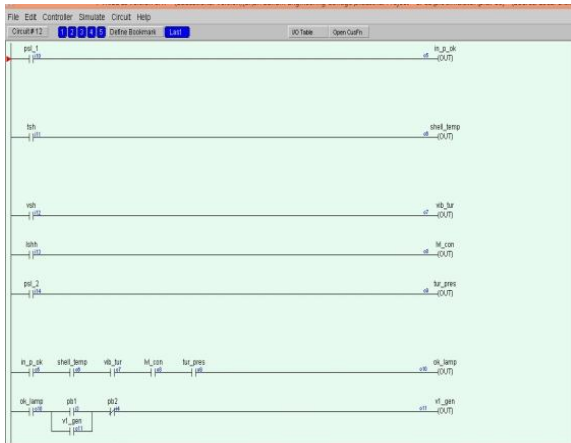
Functional Block Diagram (FBD) - A graphical language for depicting signal and data flows through re-usable function blocks. FBD is very useful for expressing the interconnection of control system algorithms and logic.



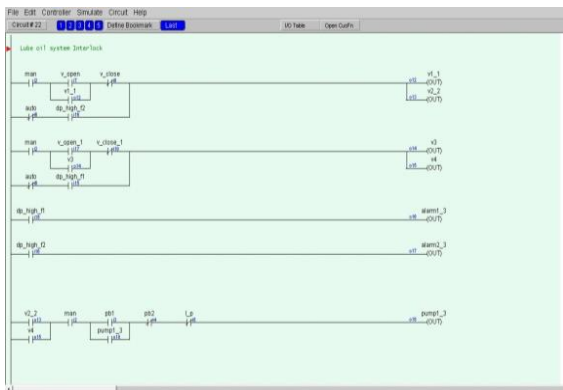
A simple functional block diagram is shown above. Here a delay is given with the help of an ON-timer and the enable switch is a AND gate. The output of the timer and AND gate is given as input to the alarm which turns on if the value exceeds the value given in the timer (30seconds). According to the delay, the AND gate will modify the input to the flip flop and thus the output will appear at the over press or an alarm will be initiated by the circuit if something goes wrong or if the time base value is exceeded by the counter. A preset value will be maintained to make comparison with the value of the counter at every cycle.

C. Implementation

The PLC ladder logic for the interlocks present in the steam turbine is developed using the PLC software i-Trilogi 6. Each rungs are well placed with the normally open and normally closed circuit types in which, even if any of the condition fails for a turbine, the system will shut down safely not enabling the generator to be turned ON.



Similarly for the lube oil system also, special care is taken to ensure that pressure of the oil is maintained within the set point level. If it exceeds the set point value, then an alarm buzzer will be initiated which causes the first pump to be turned OFF and subsequently the second pump will be turned ON.



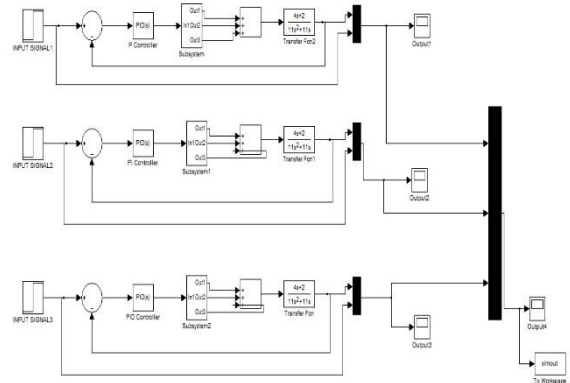
IV. MATLAB

A. Description

MATrixLABoratory (MATLAB) is a high-level language and interactive environment for numerical computation, visualization, and programming. Using MATLAB, you can analyze data, develop algorithms, and create models and applications. The language, tools, and built-in math functions enable you to explore multiple approaches and reach a solution faster than with spreadsheets or traditional programming languages, such as C/C++ or Java. You can use MATLAB for a range of applications, including signal processing and communications, image and video processing, control systems, test and measurement, computational finance, and computational biology.

B. Simulink model

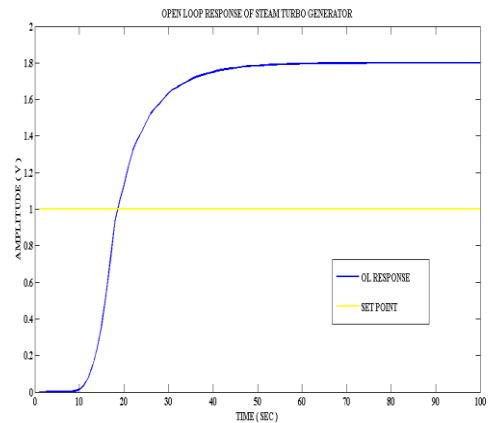
The below figure shows the Simulink model of P,PI,PID controllers in MATLAB. The step signal is given as the input and the response is seen in the scope.



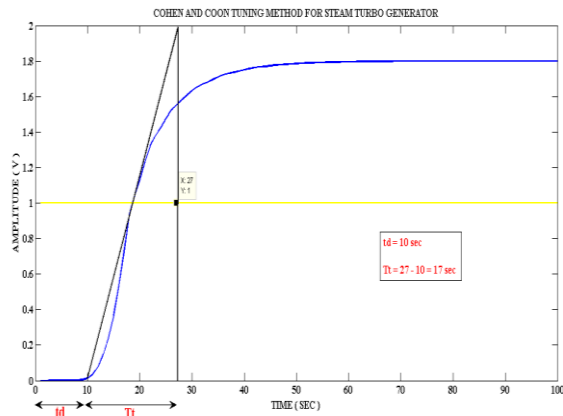
It offers tight integration with the rest of the MATLAB environment and can either drive MATLAB or be scripted from it. Simulink is widely used in control theory and digital signal processing for multidomain simulation and Model-Based Design.

C. Implementation

The open loop response curve for the steam turbo generator is shown below. For a step input, the output shoots up and hence to bring back the process curve to the set point, special tuning method such as ‘‘Cohen and Coon’’ method is employed.

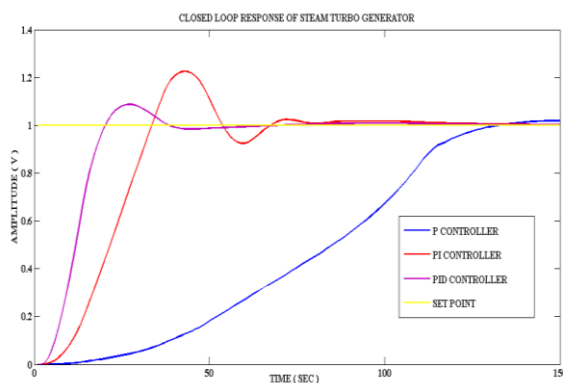


The tuning method for the steam turbine is shown below in which a line tangent to the process curve is drawn such that, the line hitting the top of the axis will be brought down to the horizontal axis. Measuring from the origin to the point where the tangent started, gives us the value of delay time (td) and tau can be calculated from the graph below.



V. RESULT

The step signal is given as input and after a small time another step signal is added and the set point is tracked. It is observed that the P controller will not settle to the desired set point. PI controller will settle at the desired set point but it will take a long time. PID controller will settle at the desired set point and the settling time will be small when compared to PI controller.



When the controllers become stable, after a small time delay, a step input is added with the input signal and the set point is varied. Now the system will track the setpoint and become stabilized. Here the P, PI, PID Controllers will track the change in step input, the P controller will not settle, PI controller will settle and the PID controller will settle in a short time much before the PI controller settles. Thus by giving a step change, the set point varies and the new set point is tracked by the controller and hence set point tracking is achieved.

VI. CONCLUSION

The control system developed replaces actual control systems for steam turbo generators as the operating and design philosophies are kept similar to the original ones, but it incorporates those characteristics that modern systems can offer. With little effort, the control system can be easily implanted in other PLC's. The software modular structure has been prepared to accept the changes of the control strategies. Thus efficiency of a process is improved by providing necessary interlocks using PLC.

VII. ACKNOWLEDGMENT

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VIII. REFERENCES

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