Design of Safety Instrumented System for Gas Turbine Power Plant using PLC and SCADA

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ABSTRACT

Accidents in gas power plants are rarely happened due to some faults and failures in plants as well as it made a history by leaving a large damage to lives and machines. To avoid such a unpredictable accidents in gas turbine power plant we are implementing a safety prevention measures by testing a fuel tank level, maintaining the lube oil and cooling air pressure and other measurements. Generally in a gas turbine power plant the air is compressed by the compressor and it is passed into the combustion chamber where the combustion takes place and the hot gas is passed into the turbine to generate a power from the generator. During this process the control issues of the equipment (air filter, compressor, combustion chamber, turbine and generator) should be controlled and monitored by using PLC and SCADA. This logic controller is used to detecting and rectifying the issues and they are visually treated through SCADA.

KEY WORDS: Lube oil pressure, Cooling air pressure, Fuel tank level, PLC, SCADA.

1. INTRODUCTION

Process operations are be managed by the industrial management, if they don't, then the following problems will arrive such as production loss, facilities damage and serious injury or loss of life. To avoid these criteria the safety department should install the safety instrumented system over the plant and it should maintain properly.

Gas turbine plays an important role to provide power for industries, during the peak load a single gas turbine can't work efficiently and it can be rectified by the combined cycle system. Some mechanisms are also involved to prevent the sudden breakdown in the plant.

In early period the gas turbine power plants are functioned by using relay logics but it has some demerits while performing the operation and then later 1990's the relays are replaced by the PLC's. They are used to controlling the entire power plant through control room but still there is a problem in monitoring and it overcome by SCADA.

Every power plant should have individual or new logics than the existing one to overcome the drawbacks of the existing plant. Here we designed a new PLC (Programming logic controllers) logic for controlling some major components in gas turbine power plant and it can be monitored through the SCADA (Supervisory Control And Data Acquisition).

This article is related to real time gas turbine safety mechanism and which is demonstrated by the simple miniature model related to gas turbine operation.

Components of Gas Turbine: The gas turbine is separated into three sections. They are:

Compressor Section: Compressor is the initial part of the gas turbine which is used to compress the atmospheric air and allow to pass the compressed air into the combustion chamber. According to Brayton cycle, increase in pressure of the air will increase the temperature and so the high pressure-temperature is used in the combustion chamber for the combustion process. Fig.1, shows the inner casing of the compressor which used in gas turbine.

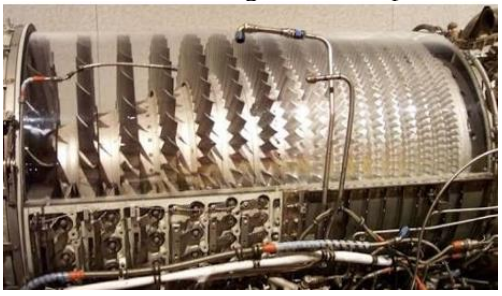

Fig.1. Stage compressor

Combustion Chamber: Discharged air from the compressor is charged into combustion chamber which contains 5kV igniter to ignite the fuel-air mixture. On the surface of the combustion chamber flame sensors are placed to detect the fire accident. In order to measure the pressure inside the chamber pressure gauge is used. Generally, the combustion chamber is placed at the middle part of the gas turbine which is shown in Fig.2.

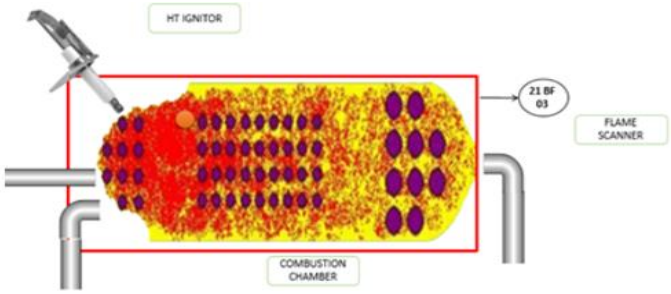

Fig.2. Combustion chamber

The ten combustion chamber casings are identical with the exception of those fitted with spark plugs and flame detectors.

Turbine Section: The turbine is placed at tail part of the gas turbine which is used to generate power by connecting the turbine blades to the generator with the help of shaft. Turbine provides the power required to drive the load package as well as the compressor which is shown in Fig.3.

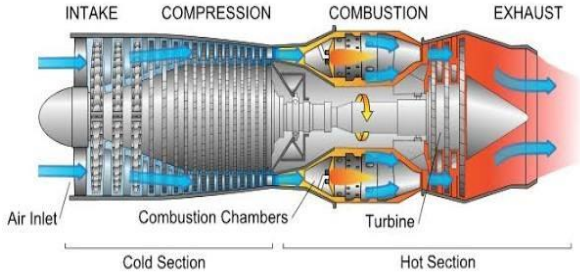

Fig.3. Gas turbine operation

The turbine has two stages. The first stage and second stage rotor bolted together to form a single unit and it is contained within the shell. The turbine section components include the turbine shaft, shell, outlet frame, and diffuser, nozzles. The exhaust hot air from the combustion chamber is release through turbine section which sends that air to the atmosphere through chimney. In CCPP the hot gas is passed into the boiler to generate another power production source and it is called as Heat Recovery Steam Generator (HRGS).

Installing the Safety equipment: Some equipment breakdown or disaster can be occurred due to improper maintenance and poor monitoring in the gas turbine power plant which can be prevented by the following:

Proper fuel tank level monitoring: In gas turbine power plant, fuel such as naphtha, high speed diesel or diesel is used for the combustion purpose. Initially the fuel tank is filled with the process fuel and that could be levelled by using the level sensors. The dimension of the cylindrical tank is 1:0.95 and the volume should satisfy the mathematical conditions.

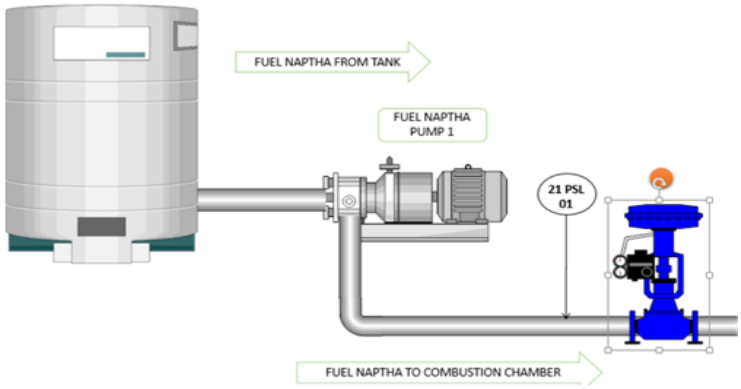

Fig.4. Naphtha flows into combustion chamber

These are also includes the safety measurement to construct a good tank as shown in Fig.4. Also the proper level of the tank should be maintained else the gas turbine should be tripped.

Fuel filters: Before passing the naphtha or diesel into the combustion chamber the fuel must be filtered through 6, 10 and 25 micron filter. Only the limited amount of fuel is allowed to pass through the pipelines and the fuel tank/pipe ratio is 14.6:0.1. These filters are used to remove unwanted particles from the fuel and indicate them in the control panel to improve the combustion capacity of the fuel and this is related to Fig.4.

Fuel separator: The delivery of naphtha and diesel from the pipeline to the gas turbine should be separated by using "three way motor". This motor is used to switch between two various liquids, here we use naphtha and diesel. Initially diesel is used as a start-up fuel for the combustion after that the naphtha is used. Without using this motor we can supply these fuels into combustion chamber but it may cause some sudden fire accident. To avoid such incident here

we implement this motor. The moderate fuel pressure is also maintained here which can satisfied by using the orifice plate.

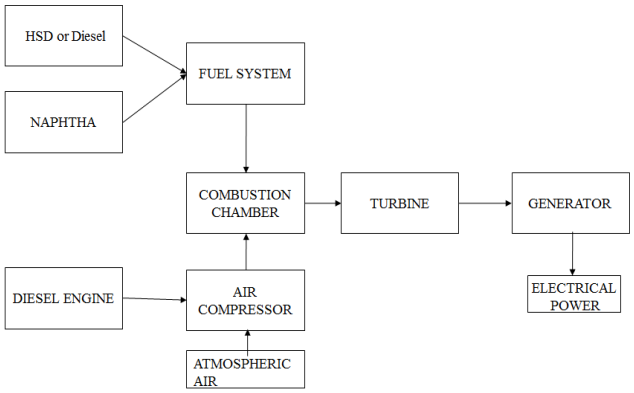

Fig.5. Basic block representation for the operation of gas turbine

Lubrication: The purpose of Lubrication is to avoid the friction and high temperature caused inside the bearing and roator and it can be avoiding by using the lubrication. The lube oil is commonly used for lubrication purpose which shown in Fig.6, and in case of emergency the auxiliary oil pump is used. Maintaining the constant lube oil pressure will avoid the mechanical disability of the machines.

Temperature sensor: During the continuous process the enormous amount of heat is produced, it will make serious damage to the gas turbine. So to prevent the plant we should install the temperature measurement devices. They are varied with their uses, for example, turbine supervisory thermocouple is used for turbine safety.

Flame detector: The flame detector is a device commonly placed around the gas turbine or in heat generation process which is used to detect flame or fire and raise the alarm corresponding to the flame indication. Due to the proper (PLC) installation, the response of the flame can be detected by raising the alarms to deactivate the fuel line (such as naphtha or diesel). Proper installation of this sensor will be easier to identify and solve the fire accidents in the plant.

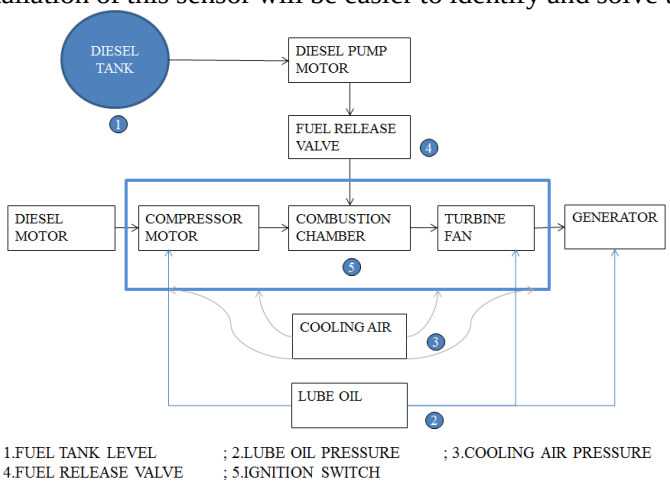

Fig.6. Miniature model representation

Ignition: An ignition system generates a spark or heats an electrode to a high temperature to ignite a fuel-air mixture in spark ignition internal combustion engines oil-fired. Diesel engines ignite the fuel-air mixture by the compression in combustion chamber. Other engines may use a flame, or a heated tube, for ignition. The certain duration of time is allocated for this process as in Fig.6, and the process will be tripped when the time exceeds.

Coolant: A coolant is a fluid or air which flows through or around the machines used in the power plant. Here we used a cooling air and maintaining the constant air pressure make the plant in a constant temperature. So here also the cooling air pressure is maintained and it is detailed in Fig.6.

Control and Monitoring:

PLC as a control device: A programmable logic controller (PLC) is a digital computer used for electromechanical process such as industrial machinery control, robotic controls, packaging or used in some commercial operations. PLC is a special type of controller contains with multiple input-output arrangements and used for some other environmental parameter measurement and control. Programs (ladder logic diagram) can be stored in the PLC for certain operation due to its non-volatile nature or memory which is also called as battery-backed memory. A PLC is an example of a real time system which generates the output signal with in the period of time, otherwise unintended operation will result.

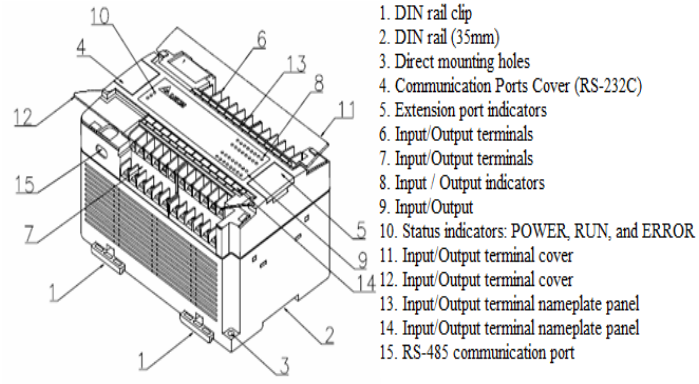

Fig.7. PLC Pin diagram

The safety operation method require logical ladder diagrams for control and monitoring where the programs are fed into the PLC through "WPLSoft2.38" software and then the plant can be accessed. The PLC used in our model is "Delta PLC_ES2" (Fig.7), which is suitable for the above software.

SCADA as a display device: SCADA (Supervisory Control And Data Acquistion) is a software application program for process control which is used to visualise the PLC operation held in plant. The functions of gas turbine can be visualised through SCADA and defects can be easily identified by the monitor which is placed in the control room. Our prototype model was designed with simple equipment to describe the project and the "Astra Run" software is used to visualise the operation i.e., SCADA.

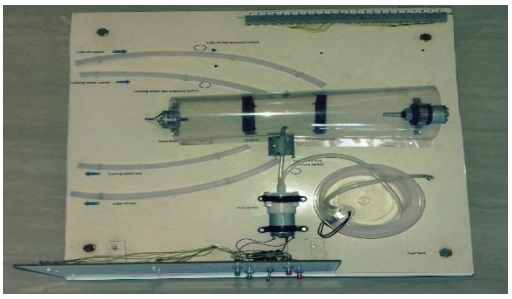

Fig.8. Overall view of proposed system

2. CONCLUSIONS

This paper has focused on gas turbine power plant consists of a various safety instruments in the system. To avoid accidents in gas turbine, the above methods should be taken. Thereby utilizing PLC effectively we were able to ensure safety in the working conditions of gas turbine and henceforth ensuring safety to the industry, mankind and vicinity environment. The SCADA is used to monitor and control the equipment from a remote place.

3. ACKNOWLEDGMENT

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REFERENCES

Amir Firoozshahi and Seyeon Kim, Intelligent and innovative monitoring of water treatment plant in large Gas Refinery, IEEE International Conference on Control Application, 2010.

Hardy Kliemke and Thomas Johnke, Gas Turbine Modernization – Fuel Conversion and Special Fuel Applications for the Asian Market, POWER-GEN Asia 2012, Bangkok, Thailand, 2012.

Laihua Fang and Zongzhi Wu, Design and development of safety instrumented system, IEEE International Conference on Automation and Logistics, 2008.

Mamoon Alyah and Jeff Ashman, Combined Cycle Power Plants, IMIA Working Group Paper 91 (15) IMIA Annual Conference 2015, Mexico, 2015.

Marcantonio Catelani and Lorenzo Ciani, Safety analysis in oil & gas industry in compliance with standards IEC61508 and IEC61511:Methods and applications, IEEE International Instrumentation and Measurement Technology Conference (I2MTC), 2013.