MONITORING AND CONTROL OF GAS TURBINE INLET GUIDE VANE SYSTEM

MYA YEE MON WIN[1], SOE WIN[2], ZARCHI LINN[3]

[1]Ph.D. Research Student (Electrical Power Engineering)Yangon Technological University, Yangon, Myanmar.

[2]Associate Professor (Electrical Power Engineering) Yangon Technological University, Yangon, Myanmar.

[3]Lecturer (Electrical Power Engineering) Yangon Technological University, Yangon, Myanmar.

Email - m.yeemonwin@gmail.com, soewin1982@gmail.com, zclinn@gmail.com

Abstract: In recent years, much attention has been given to the application of the Programmable Logic Controllers (PLC) and Supervisory Control and Data Acquisition (SCADA) in power plant automation and control system. Many researchers and engineers have been actively seeking new applications for PLC and SCADA in power plants. The manufacturers of PLCs have been responded by developing new products that meet the unique requirement of power plant automation and SCADA application. PLCs are very cost competitive with traditional Remote Terminal Units (RTU) and have many benefits in power plant automation and control applications. PLCs have an important position in power plant automation and control in power plant automation and their usage in power plant applications is still growing. This research aims to propose the applications of PLC-SCADA system in Gas Turbine Inlet Guide Vane Control System. Monitoring and control of a Gas Turbine Inlet Guide Vane Control System by a PLC-SCADA system is executed for application and the detailed study is carried out at Hlawga CCGT power plant. The automation is enhanced by constant monitoring using SCADA screen which is connected to the PLC by means of communication cable. The different steps of the application of a PLC-SCADA system is mentioned by Unity Pro PLC, Version 8.0, Modicon, Schneider Electric, Vijeo Citect SCADA, Version 7.2, Schneider Electric, RJ 45 for communication cable and Modbus (TCP/IP) as a driver.

Key Words: Gas Turbine, Inlet Guide Vane, Programmable Logic Controller, Supervisory Control and Data Acquisition.

INTRODUCTION:

This research is taken an attempt for PLC and SCADA system application of controlling gas turbine inlet guide vane. Power plants require continuous monitoring and inspection at frequent intervals. To control a gas turbine inlet guide vane, there is a need to develop a PLC system that is used for the internal storage of instruction for the implementing function such as logic, sequencing, timing, counting and arithmetic to control through digital or analogue input/output modules in various types of machines processes. For supervisory control and data acquisition of a gas turbine inlet guide vane, the supervisory system of a process must collect, supervise and record important data linked to the process, to detect the possible loss of function and alert the human operator. The essential parts of a gas turbine PLC control system, Unity Pro Function Block Diagram (FBD) is used as PLC language in this research. For monitoring of a gas turbine system, Vijeo Citect SCADA control system is used.

Overview of Hlawga CCGT Power Plant:

Hlawga CCGT power plant is one of thermal power plant in Myanmar. It is located in Mingalardon township, Yangon. This power plant is mainly provided the electricity to Yangon. There are three gas turbines and one steam turbine. The power rating of each gas turbine generator is 33.3 MW (47.3 MVA) and of steam turbine generator is 54.3 MW (67.875 MVA). For the operation of Hlawga power plant, the natural gas is supplied from Yadana offshore gas production. The single line diagram for Hlawga CCGT power plant is shown in the Figure.1.

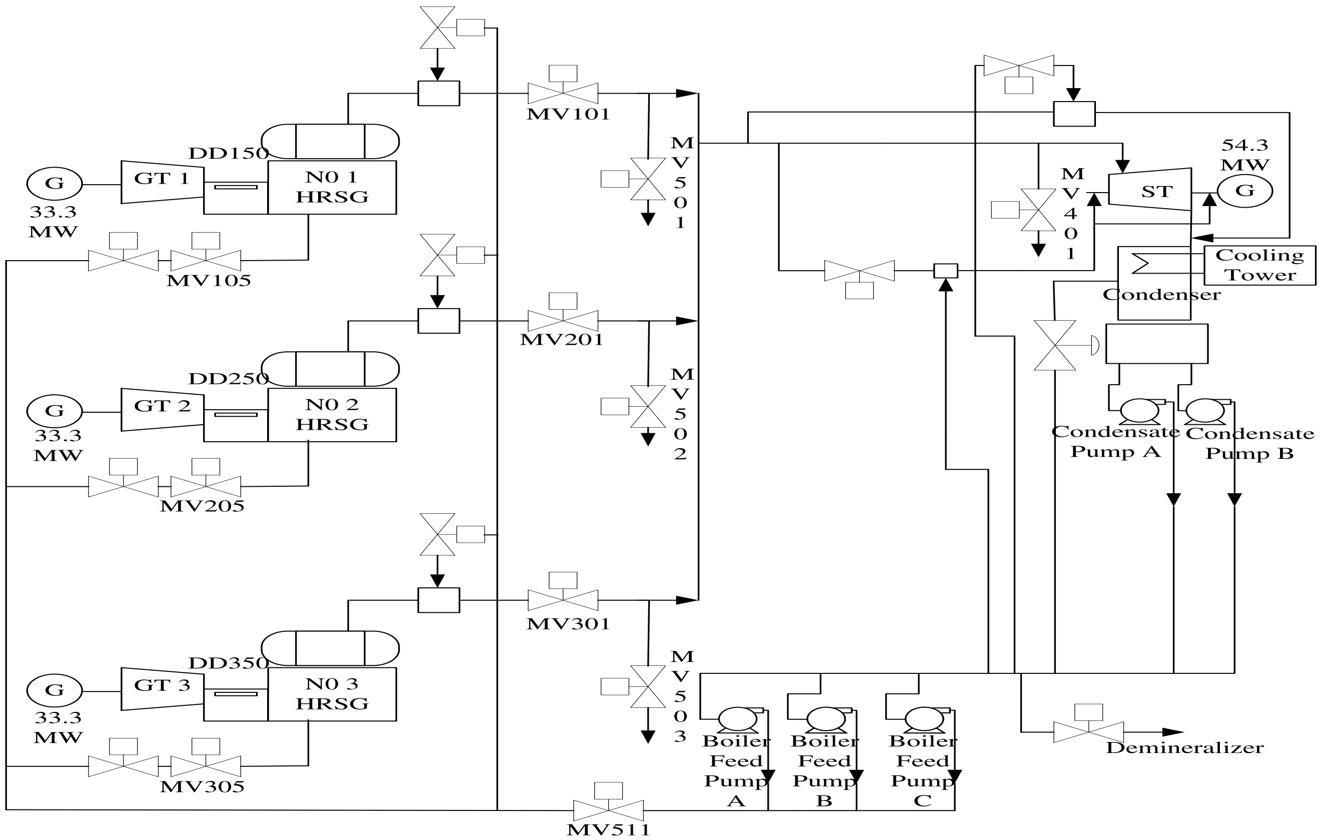

Figure 1. Overview of Hlawga CCGT Power Plant

Gas Turbine Control System:

There are six parts in gas turbine control system. Gas turbine control system is described in Figure.2. Overall control scheme of gas turbine control system is also presented in Figure.3. Inlet guide vane control system is focused on this research.

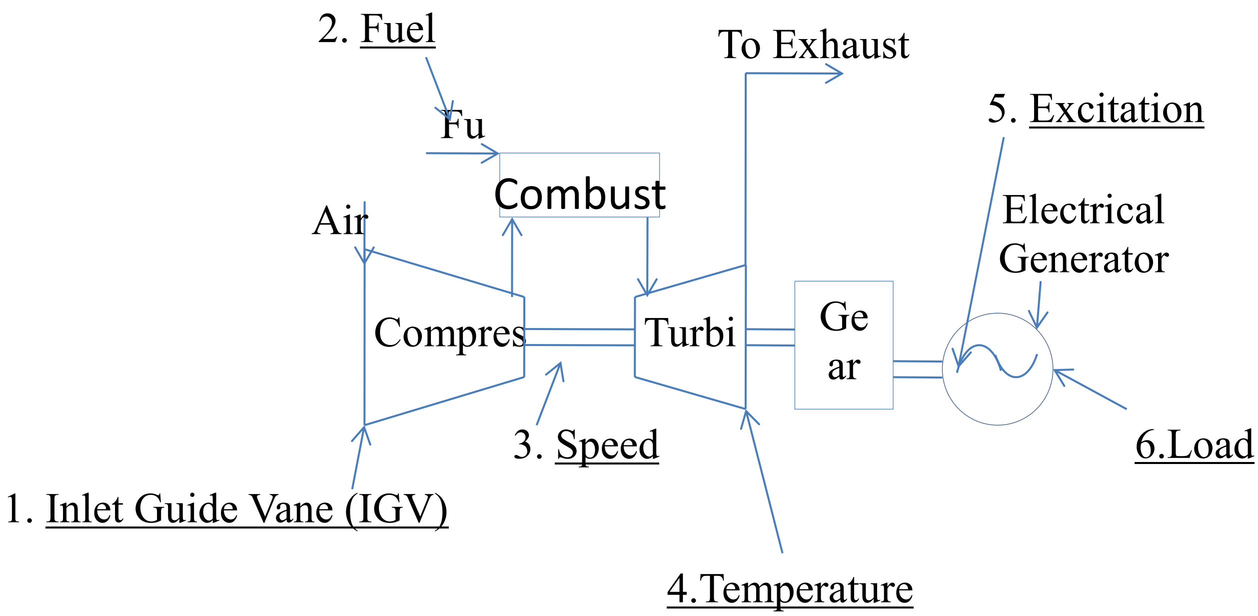

Figure 2. Gas Turbine Control System

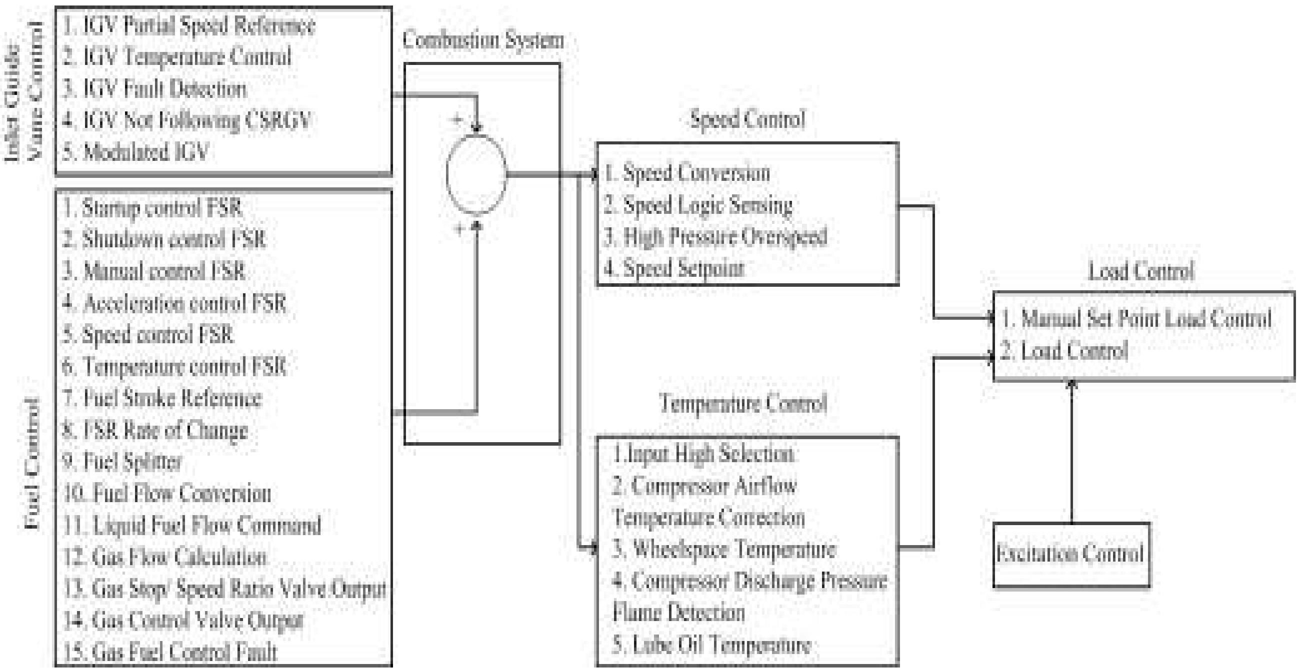

Figure 3. Gas Turbine Control System

Inlet Guide Vane System:

Variable compressor inlet guide vanes are installed on the turbine to provide compressor pulsation protection during start-up and shut-down and also to be used during operation under partial load conditions. The variable inlet guide vane actuator is a hydraulically actuated assembly having a closed feedback control loop to control the guide vanes angle. The vanes are automatically positioned within their operating range in response either to the control system exhaust temperature limits for normal loaded operation, or to the control system pulsation protection limits during the start-up and shut-down sequences. Inlet guide vanes are modulated in order to maintain various stresses, pressures and flows within required limits. Their corrected speed control system is a portion of their control system, to accomplish this function.

For normal shutdown, inlet guide vane actuation is the reverse of the startup sequence when the generator breaker is opened. In the event of a turbine trip, the inlet guide vanes will ramp to the closed position as a function of temperature corrected speed.

Variable Inlet Guide Vanes (VIGV) regulate airflow into the Compressor to optimize turbine efficiency at part loads. Normally, they are closed during engine starting and low RPM, but they open progressively as the RPM is increased. Fixed or variable vanes, also known as stators, located in front of the first stage of the compressor of a gas turbine. These guide vanes direct the air onto the compressor at the correct angle. So, IGV is also called intake guide vanes.

Method and Control Parameters:

There are five parts in gas turbine inlet guide vane control system. They are:

1. IGV Partial Speed Reference,
2. IGV Temperature Control,
3. IGV Fault Detection,
4. IGV Not Following CSRGV and
5. Modulated IGV Control.

The flow charts, PLC implementation and SCADA simulation of each control system is presented in the Figure.4. There are many control variables (sensors and actuators) in those control systems.

1. IGV Partial Speed Reference:

According to the study of this control system, the operation is represented by the flowchart as shown in Figure 4. There are many stages prior to the operation of this system. PLC program, as shown in Figure.5 and SCADA program, as shown in Figure.6 are executed based on the operation shown in this flowchart.

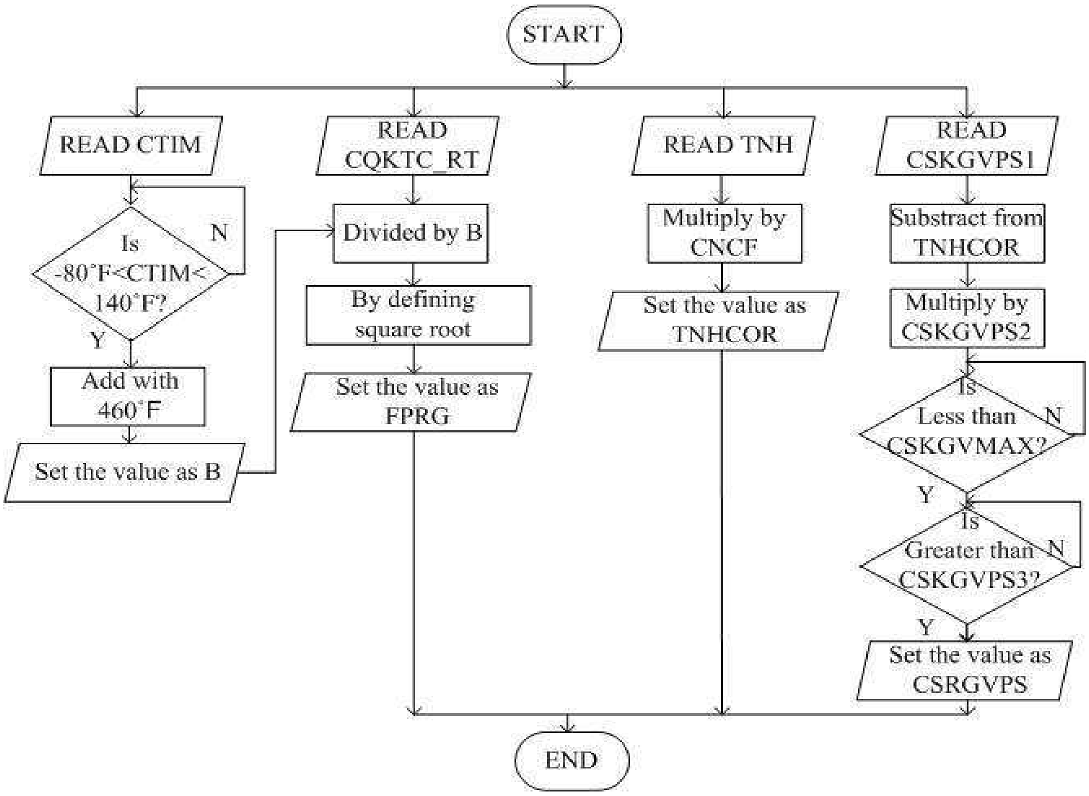

Figure 4. Flow Chart of IGV Partial Speed Reference

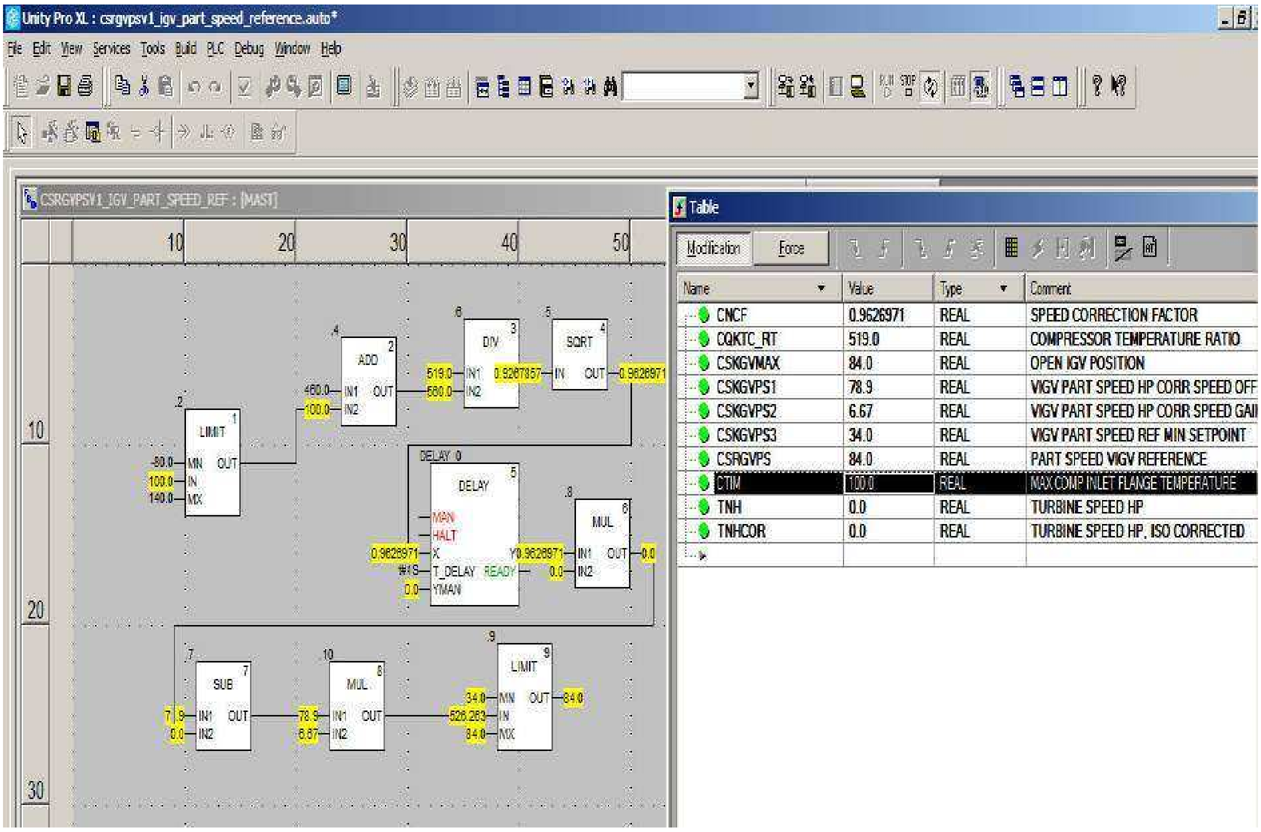

Figure 5. PLC Implementation of IGV Partial Speed Reference

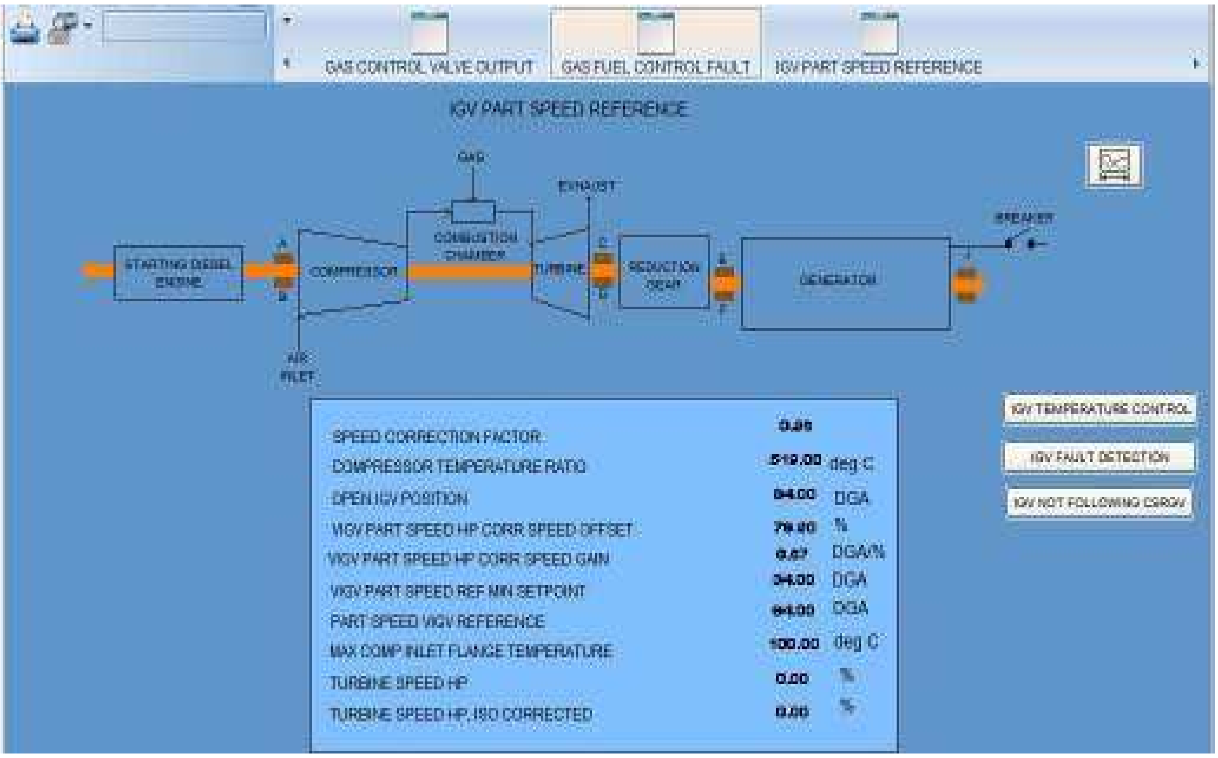

Figure 6. SCADA Simulation of IGV Partial Speed Reference

2. IGV Temperature Control:

There are many control schemes in operation of this control system. The main control input variables are Compressor Discharge Pressure (CPD), Ambient Temperature Reference (TEMP_AMB_REF), Alternate Temperature Control Minimum Limit (TTR_LIMIT), IGV Temperature Control TX Ref Isothermal (TTKGVI) and Deadband IGV Temperature Constant Maximum Position (CSKGVDB). The output variable is IGV Temperature Control Reference (TTRXGV). PLC program, as shown in Figrure.8 and SCADA program, as shown in Figure.9 are executed based on the operation shown in this flowchart.

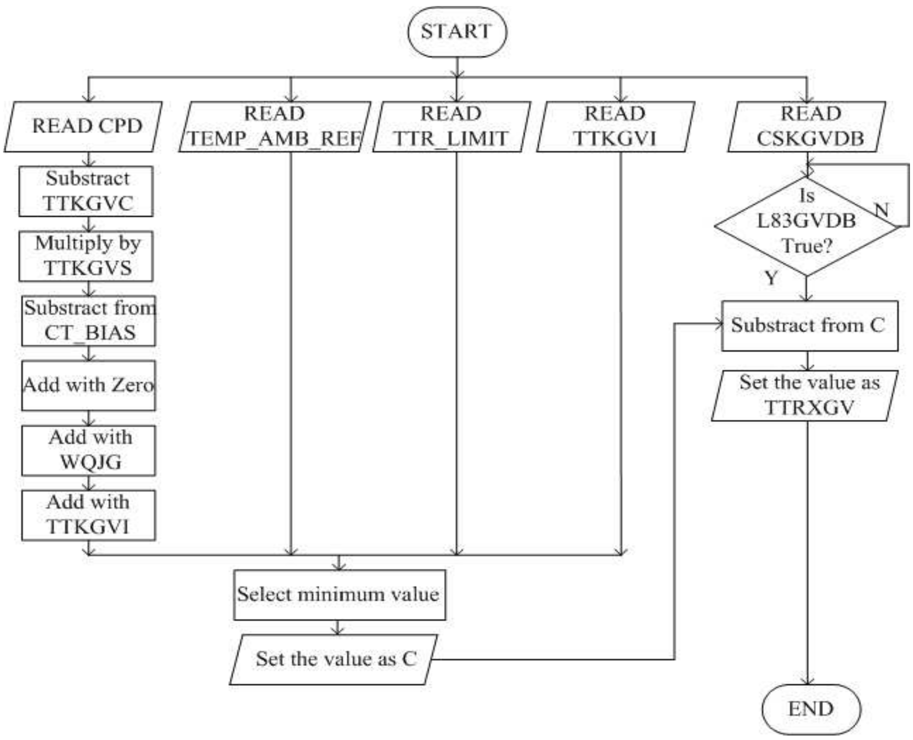

Figure 7. Flow Chart of IGV Temperature Control

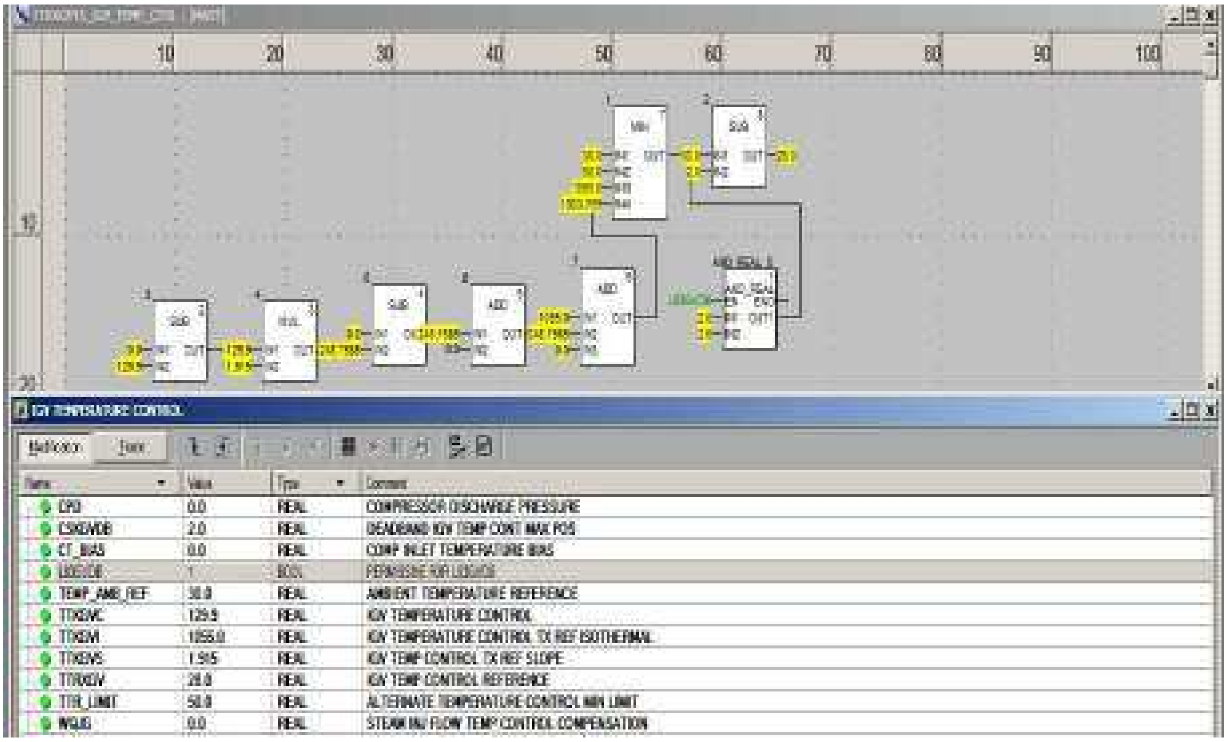

Figure 8. PLC Implementation of IGV Temperature Control

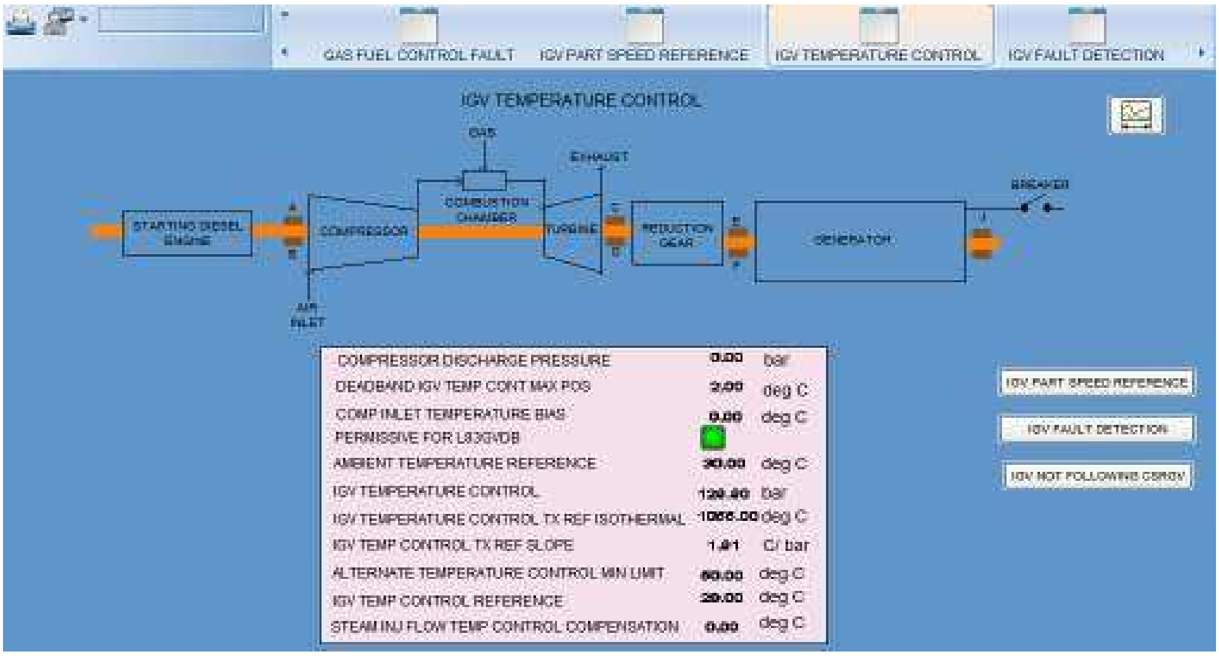

Figure 9. SCADA Simulation of IGV Temperature Control

3. IGV Fault Detection:

According to the study of this control system, the operation is described by the flowchart as shown in Figure 10. The input variables are IGV Angle Input (CSGV), IGV Control Servo Current (CAGV) and the output variables are IGV- Loss of Feedback Alarm (L3IGVF1), IGV- Vanes Open Alarm (L3IGVF2) and IGV- Servo Current Alarm (L3IGVF3). PLC program, as shown in Figure.11 and SCADA program, as shown in Figure.12 are executed based on the operation shown in this flowchart.

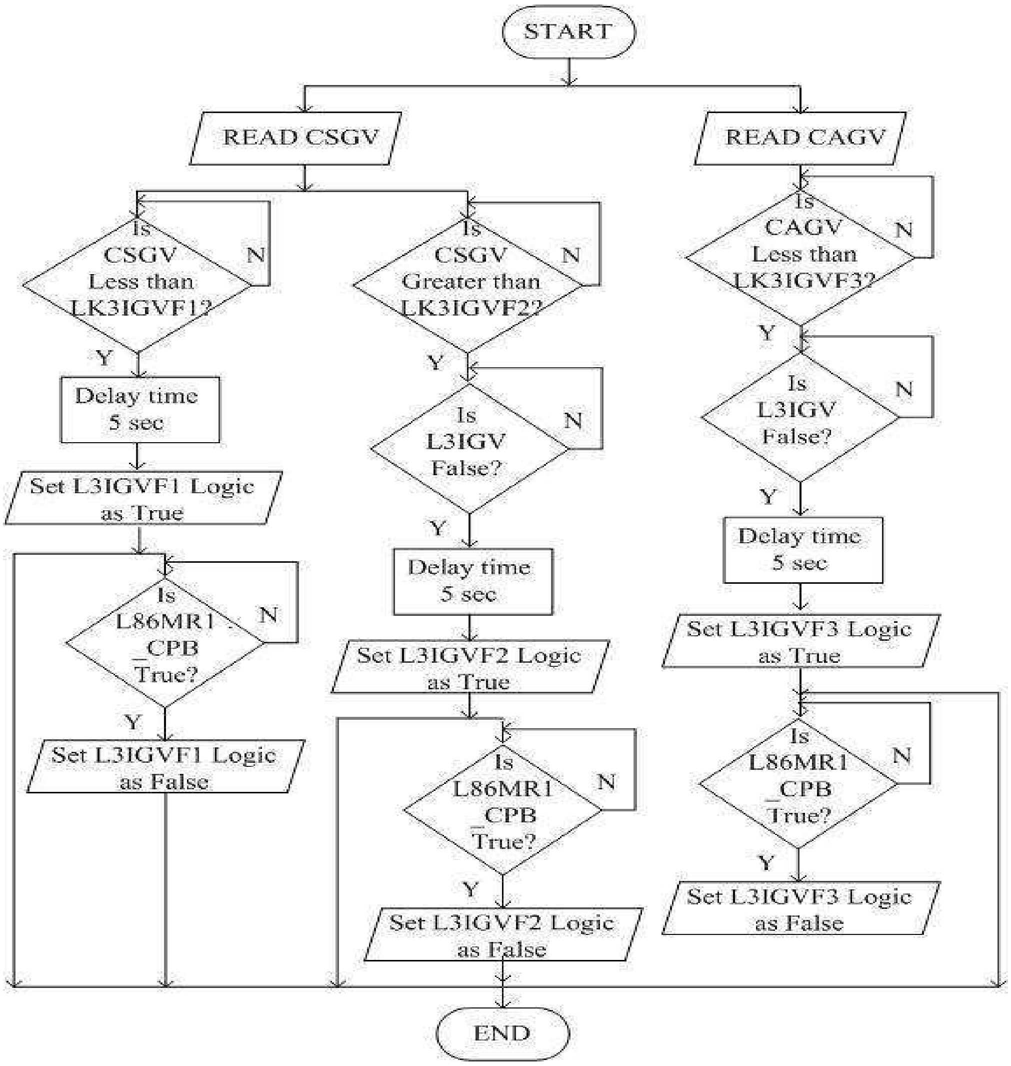

Figure 10. Flow Chart of IGV Fault Detection

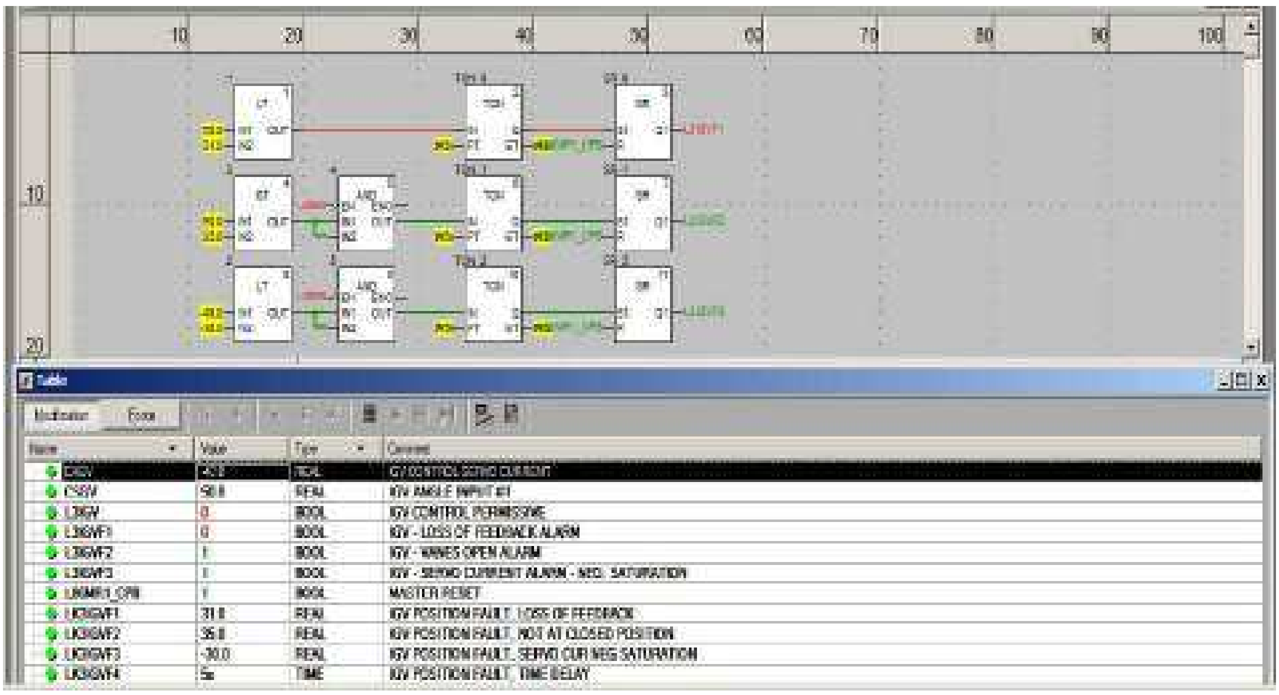

Figure 11. PLC Implementation of IGV Fault Detection

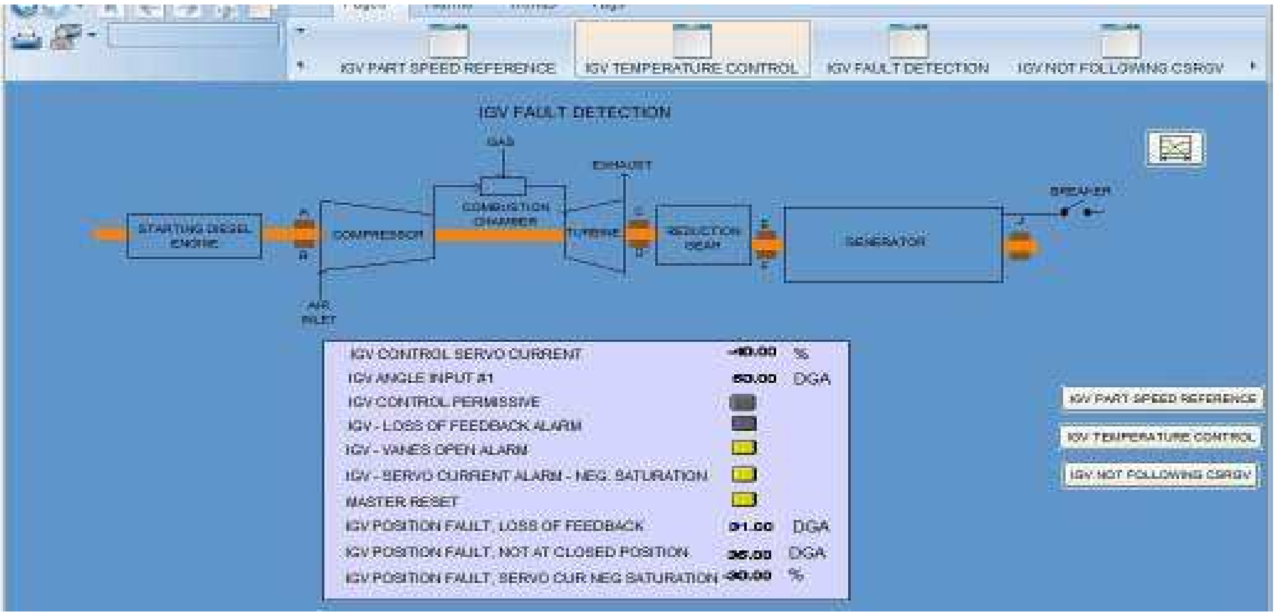

Figure 12. SCADA Simulation of IGV Fault Detection

4. IGV Not Following CSRGV:

According to the study of this control system, the operation is described by the flowchart as shown in Figure 13. The input variable is Inlet Guide Vane Angle Input (CSGV). First, Variable IGV reference angle (CSRGV) is substracted from CSGV and the output is set as D. Then, D is absoluted. Next, the output, IGV Control Trouble Alarm (L86GVA) is set as a True after absolute D was greater than IGV Not Following Reference Alarm (LK86GVA1) and delayed 5 sec. Then, the output, IGV Not Following CSRGV Trip (L86GVT) is set as a True after D was greater than IGV Not Following Reference Trip (LK86GVT1) and delayed 5 sec. PLC program, as shown in Figure. 14 and SCADA program, as shown in Figure.15 are executed based on the operation shown in this flowchart.

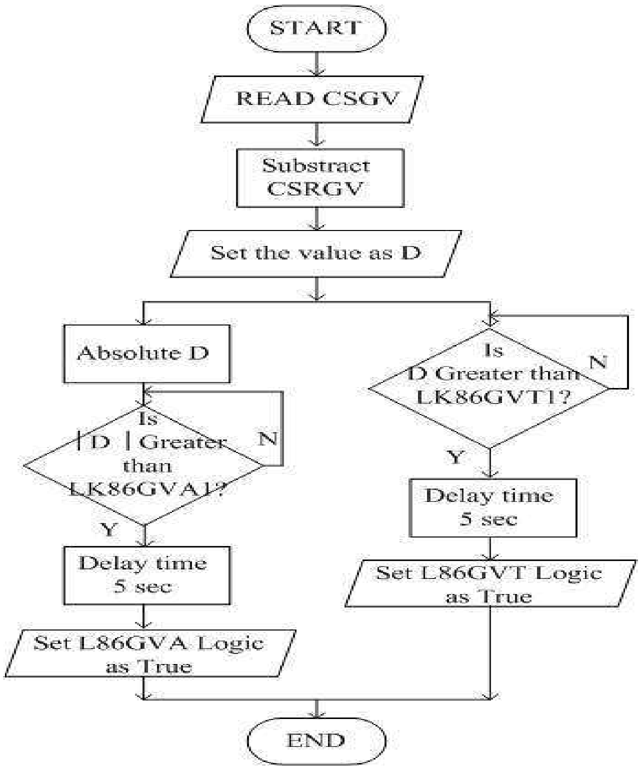

Figure 13. Flow Chart of IGV Not Following CSRGV

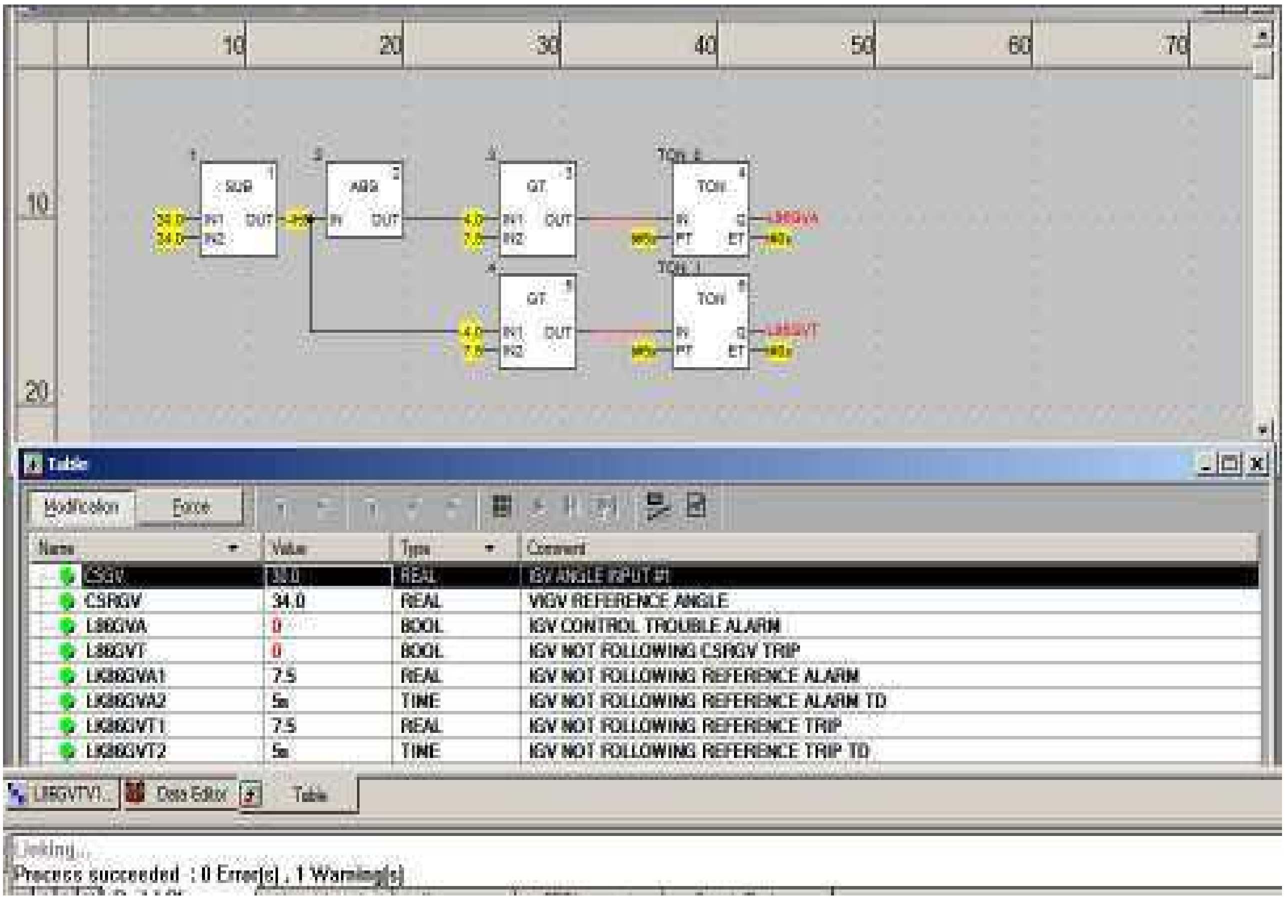

Figure 14. PLC Implementation of IGV Not Following CSRGV

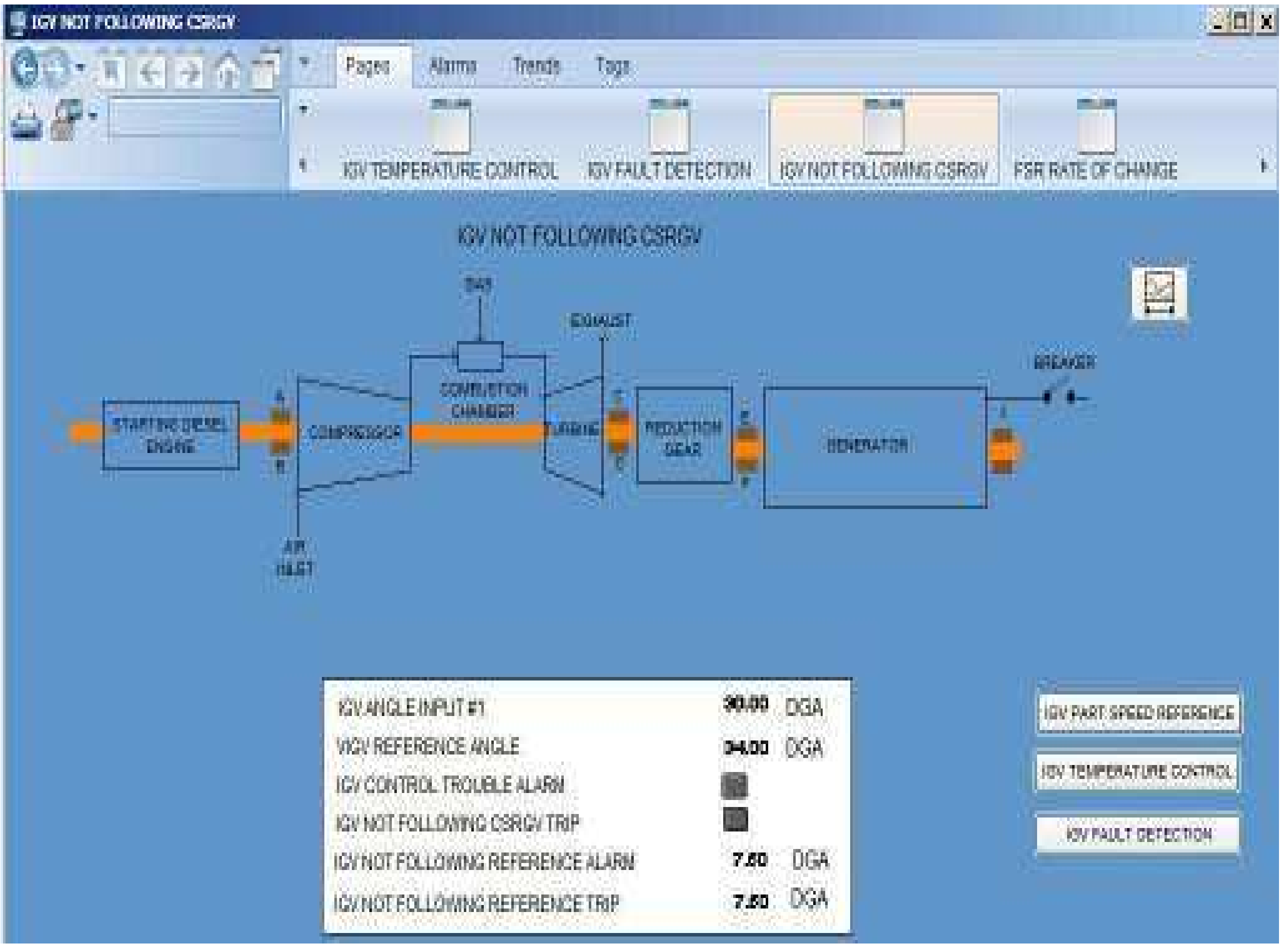

Figure 15. SCADA Simulation of IGV Not Following CSRGV

5. Modulated IGV Control:

Modulated IGV protects compressor pulsation by modulating during the acceleration of gas turbine to rated speed. IGV modulation maintains proper flow and pressure to combustion.

According to the study of this control system, the operation is represented by the flowchart as shown in Figure 16. There are many stages prior to the operation of this system. PLC program, as shown in Figure.17 and SCADA program, as shown in Figure.18 are executed based on the operation shown in this flowchart.

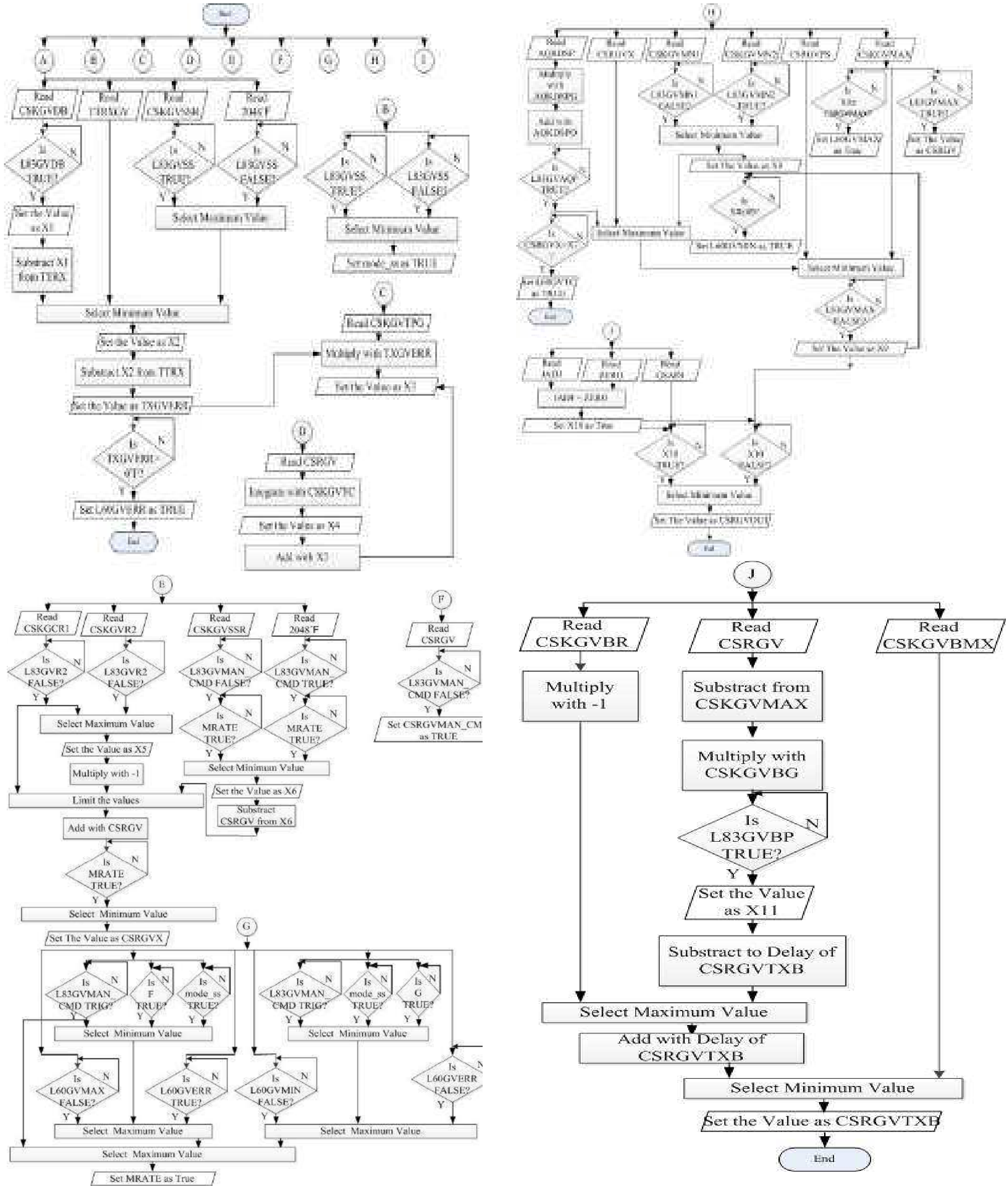

Figure 16. Flow Chart of Modulated IGV Control

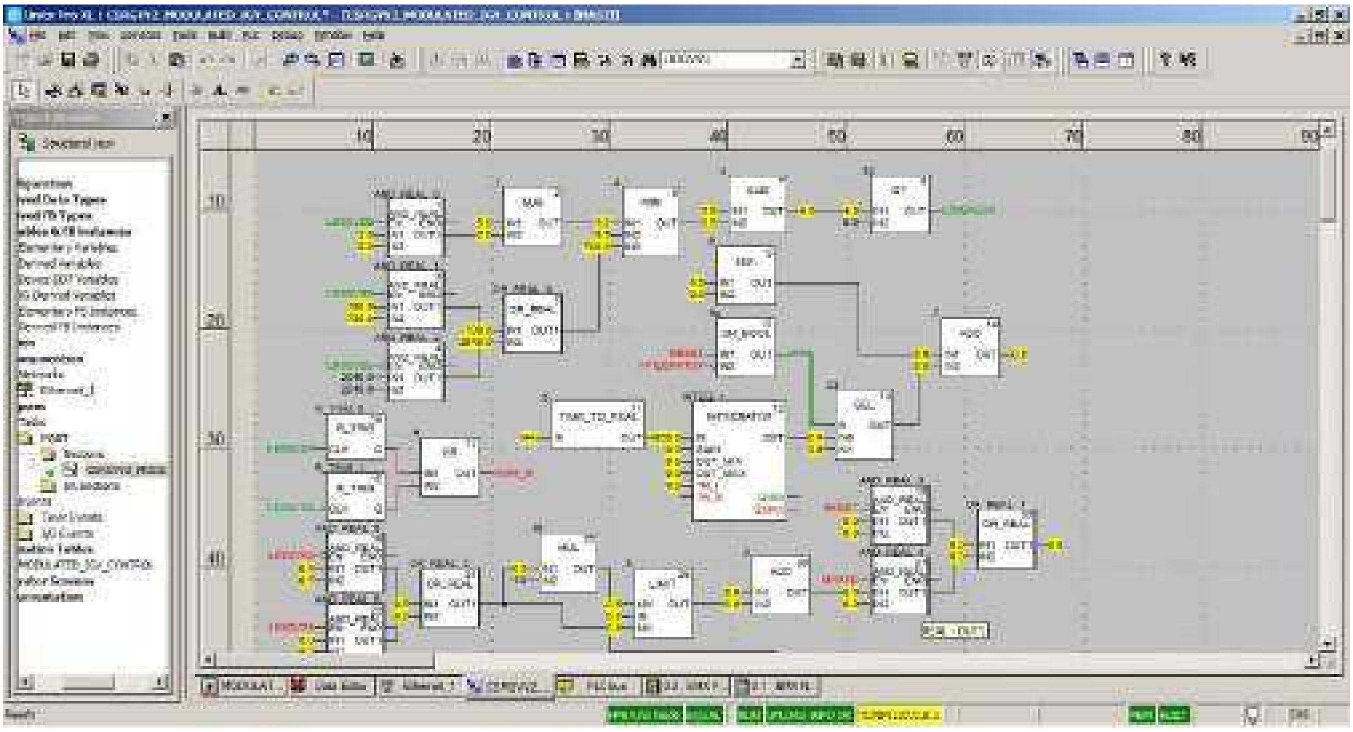

Figure 17. PLC Simulation of Modulated IGV Control

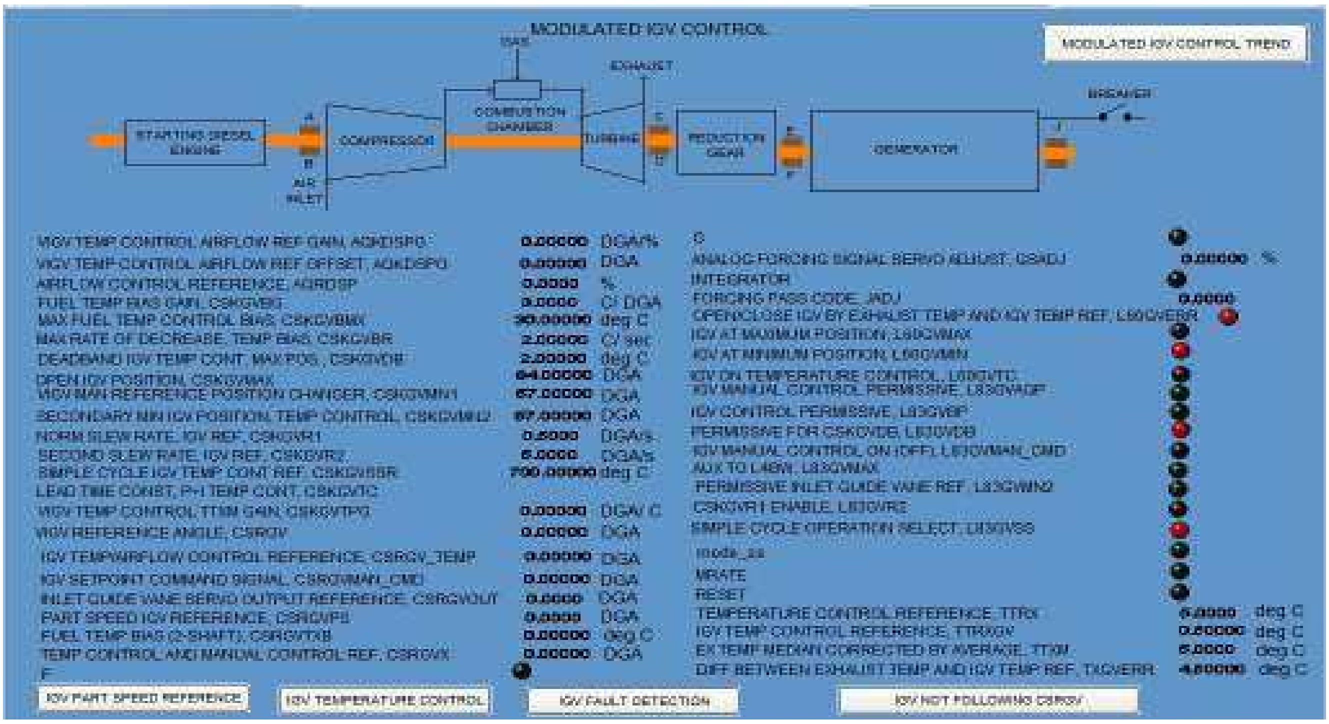

Figure 18. SCADA Simulation of Modulated IGV Control

CONCLUSION:

In this research, Hlawga gas turbine inlet guide vane control system is upgraded by PLC based SCADA system. The flow charts, functional block diagrams, data assignment tables, PLC FBDs and SCADA monitoring systems for each component of gas turbine inlet guide vane control system are done. By using PLC control system in place of the speedtronic control system, operators can do troubleshooting and calibration easily. By using PLC modules instead of the old cards, the maintenance engineers can easily chase the spare modules and remove and install the modules fastly.

REFERENCES:

1. T.R. Chávez and V.M.A. Delgadillo, *Modernization of a Computer Control System in a Combined Cycle Power Plant.*ISA. 1990.
2. R. Chavez and Y.R. Díaz. Upgrading of a Computer Control System in a Combined Cycle Power Plant. ProceedingsPower-Gen Americas 93. Vol. 12-13:56-62, 1993.
3. S.A. Boyer. SCADA: Supervisory Control and Data Acquisition, Instrument Society of America, Research Triangle, NC, 1993.
4. Barry. Ezell. Supervisory Control and Data Acquisition Systems for Water Supply and Its Vulnerability to Cyber Risks. May 2015.
5. GE Industrial Control Systems, Technical Publications, Room 191, 1501 Roanoke Blvd. Salem, VA 24153-6492, U.S.A.
6. N. LAKHOUA. Mohamed. Analysis and Command of Systems (ACS), ENIT. ISSAT, Route de Tabarka 7030, Mateur, Tunisia.
7. D.L. Chase and P.T. Kehoe. GE Power Systems, Schenectady, NY: GE Combined-Cycle Product Line and Performance. GE Power Systems.
8. Gordon Clarke, Deon Reynders. Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems. Newnes. 2004.
9. GEH-6195F. Speedtronic Mark V Turbine Control. June 2014.
10. David Lucier. GT Control and Protection System. Pal Engineering. July 2015.
11. W.I. Rowen. Operating Characteristics of Heavy-Duty Gas Turbines in Utility Service. ASME Paper No. 88-GT-150, presented at the Gas Turbine and Aeroengine Congress, Amsterdam, Netherlands, June 6-9, 1988.
12. D. Johnson and R.W. Miller. GE Drive Systems and Ashley, T., GE Power Systems, W.I., Speedtronic™ Mark V Gas Turbine Control System. Salem, VA and Schenectady, NW, June 6-9, 1988.
13. J.E. Jamison, B.G. Liptak and A. Rohr. Power Plant Controls: Cogeneration and Combined Cycle. 2005.

BIOGRAPHY:

Mrs. Mya Yee Mon Win is a Ph.D Research Student from Department of Electrical Power Engineering, Yangon Technological University, Yangon, Myanmar. She is also a Sub-assistant Engineer at Hlawga Combined Cycle Gas Turbine Power Plant, Yangon, Myanmar since 2010. She received Master Degree in Electrical Power Engineering from Pyay Technological University in 2007. She has participated in the fifth International Conference on Science and Engineering (ICSE) 2014.

Mr.Soe Win is an Associate Professor from Department of Electrical Power Engineering, Yangon Technological University, Mandalay, Myanmar. He received Ph.D in Electrical Power Engineering from Mandalay Technological University, Myanmar since 2011. His interest fields are Power Electronics and motor drives.

Mrs. Zarchi Linn is a Lecturer from Department of Electrical Power Engineering, Yangon Technological University, Yangon, Myanmar. She received Ph.D in Electrical, Electronic and Information Technology Engineering from Osaka University, Japan since 2012. Her interest fields are power electronics and smart grid.