Implementation of Programmable Logic Controller for Proposed New Instrumentation and Control System of RTP

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Abstract

Reactor Monitoring System is one of very important part of Reactor Instrumentation and Control system. Current monitoring system is using analogue system whereby all circuits are discrete circuit and all displays and indicators are not digitalized. The proposed new system will use using a Commercial Off-The-Shelf, state of the art, Supervisory Control and Data Acquisition system such as Programmable Logic Controller as well as Computer System. The implementations of Programmable Logic Controller are used for Data Acquisition System and as a sub-system for Computer System where all the activities involved are stored for operation record and report as well as use for research purposes. Programmable Logic Controller receives galvanised or optically isolated signal from Reactor Protection System. Programmable Logic Controller also receives signal from other parameters as a digital and analogue input related to reactor system.

Katakunci/keywords : Reactor Monitoring System, Programmable Logic Controller, Data Acquisition System

INTRODUCTION

The present analog console can be kept operational for next 3-4 years with the help of the present stock of the spare parts, but after that it would be very much difficult to keep it operational as a consequence of the shortage and unavailability of spare parts. The manufacturer and supplier of the 1MW TRIGA reactor informed that, it would not be possible for them to supply or provide any service relating to the old technology based analog control system in future. On the other hand, it is very much essential to ensure the nuclear radiation safety as far as the growing uses and especially repair and maintenance of the reactor are concerned. Needless to say that, Control and Instrumentation system is the key to manage nuclear safety of the reactor.

Considering the above mentioned points an ADP project on "Strengthening the Control System of RTP Research Reactor by installing Digital Control Console" has been taken for installation of a digital control console and instrumentations based on the state-of-the-art technology is being proposed by changing the analog based console and instrumentations. With the installation of PC based Digital Control Console including data acquisition and control unit, reactor protection system, wide range log power channel, multi range linear power channel, safety power channel, two fuel temperature channels, four control rod drives, three reactor pool water level float switches and Side Cabinet systems for monitoring and measuring different process parameters/variables like flow rate, pressure, temperature, electrical conductivity, pH of water, ventilations, cooling and other systems of the reactor will be developed under this project.

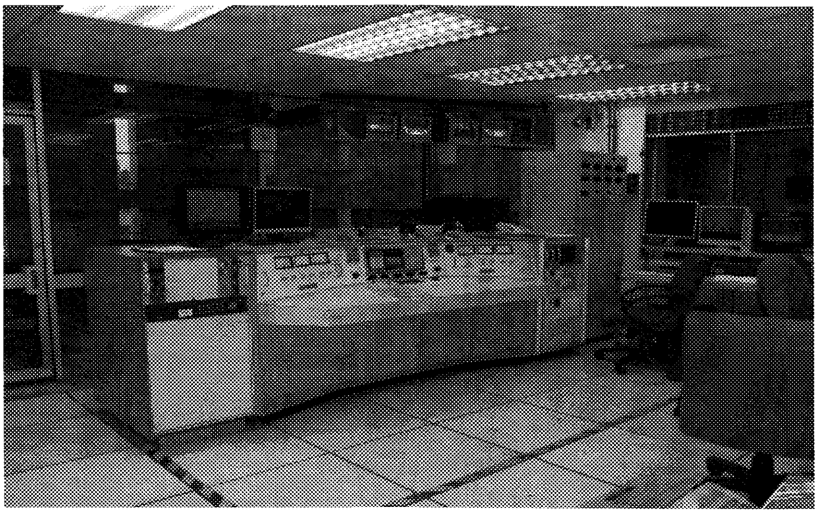

Figure 1: Analogue Control Console of RTP Research Reactor

Therefore as for this part of project proposed is the use of PLC (Programmable Logic Controller) as to replace analogue console control and upgrading the analogue display to digital display.

METHODOLOGY

As programmable logic controllers (PLCs) are widely used to implement safety critical systems such as nuclear reactor protection systems, testing of PLC programs is getting more important before running reactor into operation. Among the five standard PLC programming languages defined by the International Electrotechnical Commission (IEC) [1], **function block diagram** (FBD) is a commonly used implementation language. The goal is to develop a comprehensive suite of digital reactor protection systems, is an example in which PLC programs implementing safety critical systems were implemented in FBD. For such safety critical systems to be approved for operation, developers must demonstrate compliance to strict quality requirements including unit testing and test result evaluations.

Current FBD testing relies on mostly functional testing in which test cases are manually derived from natural language requirements. Although functional testing and structural testing are complementary each other and both are required to be applied to safety critical software, there have been little research and practices on structural testing for FBD programs. Another difficulty of current FBD testing is lack of test evaluation techniques. Regulation authorities such as U.S.NRC require that test results be documented and evaluated to ensure that test requirements have been satisfied. Although test results for FBD programs implementing safety critical software need to be evaluated thoroughly, there have been no other methods directly applicable to FBD programs except manually reviewing and analyzing test documents for assuring test quality. Domain experts have felt that manual reviews only were not adequate to assure test quality. More systematic and quantitative ways to evaluate the adequacy of the test cases have been strongly required.

In order to enable the structural testing for FBD programs, software engineers have defined structural test coverage criteria suitable to FBD programs in which the unique characteristics of the FBD language were fully reflected. An FBD program is interpreted as a directed data flow graph and three test coverage criteria have been defined using the notion of the data flow path (d-path) and the d-path condition (DPC) for each d-path. To work out a solution to lack of systematic test evaluation methods, an automated test coverage measurement tool called *FBDTestMeasurer*, which measures the coverage of a set of test cases on the FBD program with respect to the test coverage criteria proposed in. Given a unit FBD program, a set of test cases, and selected test coverage criteria, *FBDTestMeasurer* generates test requirements with respect to the selected test coverage criteria and measures the coverage of the test cases automatically. It provides coverage score and unsatisfied test requirements as a result. Uncovered d-paths can be visually presented on the graphical view of the FBD program.

The proposed technique has following contributions: 1) automated quantitative and systematic test evaluation for FBD programs gives concrete basis of quality assurance, 2) visual representation of uncovered d-paths on the FBD program helps testers analyze the uncovered test requirements intuitively, and 3) unsatisfied test requirements provided by *FBDTestMeasurer* reveal inadequately tested parts and help testers generate additional test cases.

FUTURE WORK

There have been no strong legal requirements to change the Instrumentation & Control systems of existing research reactors but the introduction of the symptom oriented philosophy has raised the importance of many safety or safety related information functions. These include function and status monitoring as well as parameter and procedure display functions. Other, indirect, requirements have arisen from licensing aspects of modernization by the use of digital Instrumentation & Control equipment. These include task specification, software design and qualification and life cycle management. There is now a need to ensure that licensing documentation is kept as formal and as tool based as possible. It is necessary to keep the documentation computer oriented and computer aided.

Digital Electronic

Digital electronics technology has rapidly taken over the bulk of new electronic applications because of its vastly increased functionality, lower cost, improved reliability and reduced maintenance requirements. Relay logic has been replaced almost completely by digital logic.

Control panel instruments (controllers, display meters, recorders, etc.) have essentially become digital devices. Transducer transmitters are also becoming digital and incorporating 'smart' features such as automatic zeroing and calibration, although there is continued preference for analog output signals (4–20 mA). The majority of diagnostic equipment and measuring instruments have become digital and provide more accurate and reliable readings than their analog counterparts.

Microprocessor Based Systems

Microprocessors have revolutionized Instrumentation & Control systems. With their capability for convenient programming of complex tasks, they have found applications in a phenomenally wide range of applications. Many applications which would, in the past, have used relays to implement logic are now largely built using microprocessor based programmable logic controllers (PLCs). PLCs provide a huge range of capabilities and functions that were not possible with relays.

Computer Based Monitoring and Control Systems

The extraordinary increase in computing power and the simultaneous dramatic reduction in cost of computing hardware have made it possible to develop high performance plant monitoring and control systems with a wide range of functions and features. Their most recognizable feature is user friendly human–machine interfaces (HMIs) with graphical displays. These monitoring and control systems are now being backfitted into existing NPPs as part of Instrumentation & Control upgrades and they have become essential features in the design of new NPPs. Favourable experience with integrated computer based monitoring and control systems has also led to their application in NPP protection and safety systems.

Personal Computers

Personal computers (PCs) have revolutionized the work environment and through them, the power of digital computers has been made available to the public at large. Their success has also made them popular for use in Instrumentation & Control systems and applications using PCs have been growing rapidly.

RECOMMENDATION

Therefore programmable logic controllers (PLC) are the main *brain* of the system where all the sensors, displays and actuators are linked as where the input and output are either in digital or analogue. There are a lot of types and brands of PLCs in the market and there are varies function that. As recommendation for this project in the future, *SIMATIC S7-300 MICRO PLC* by Siemens Industrial.

SIMATIC S7-300 MICRO PLC is a full-featured programmable logic control system that offering stand-alone CPUs, micro-modular expansion capability, and operator interface solutions. Almost any application that requires automation, from basic discrete or analog control, to intelligent networked solutions, can benefit by using the powerful *S7-300* family products. It's also easy programming and maintenance with STEP7-Micro/ WIN software where the development environment for all phases of the application including program development, documentation and machine startup.

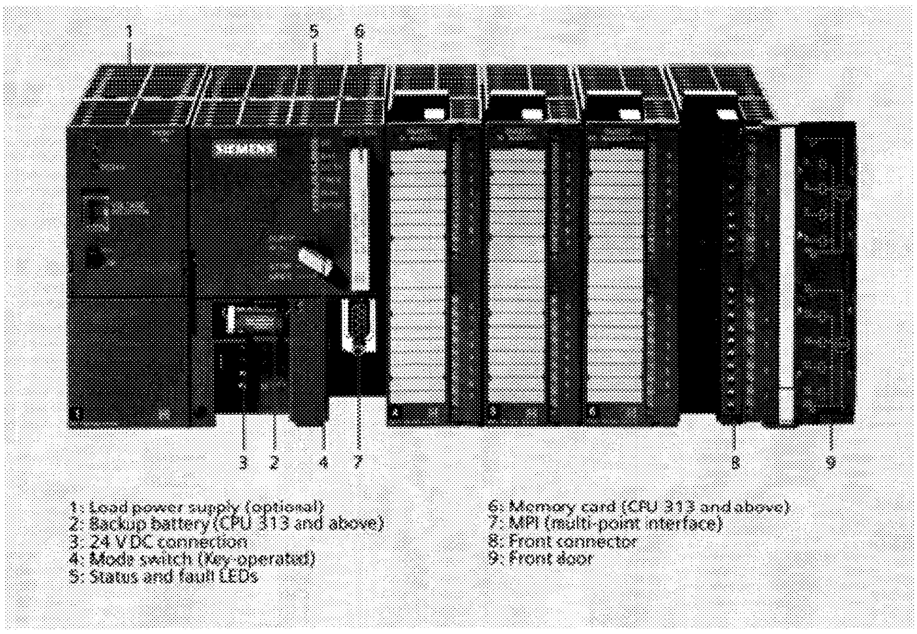

Figure2: *Automation system SIMATIC S7-300*

Technical specifications

General technical specifications S7-300, S7-300F

-Degree of protection IP 20 to IEC 529

-Ambient temperature

- At horizontal installation 0 to 60 °C
- At vertical installation 0 to 40 °C

-Relative humidity 5 to 95%, no condensation(RH degree of severity 2 to IEC 1131-2)

-Atmospheric pressure 795 to 1080 hPa

-Insulation

- 24 V DC circuit 500 V DC test voltage
- 230 V AC circuit 1460 V AC test voltage

-Electromagnetis compability Complies with EMC requirements;

Noise suppression to EN 50082-2, tested to: IEC 801-2, ENV 50140, IEC 801-4, ENV 50141, IEC 801-5; Noise emission to EN 50081-2, tested to EN 55011, Class A, Group 1

-Mechanical load

• Vibration, tests acc. to/tested with IEC 68, Part 2-6/10 to 58 Hz; constant amplitude 0.075 mm; 58 to 150 Hz; constant acceleration 1 g; period of vibration: 10 frequency sweeps per axis in each of the three mutually perpendicular axes

• Shock, tests acc. to/tested with IEC 68, Part 2-27/half-sine: Shock strength: 15 g (peak value), duration 11 ms

General technical specifications S7-300 Outdoor

Climatic operating conditions

-Temperature

Horizontal installation: -25°C to 60°C (70°C under development) Vertical installation: -25°C to 40°C

-Relative humidity

5 to 95%; short-term moisture condensation allowed, corresponds to relative humidity (RH) degree of severity 2 at IEC 1131-2 and IEC 721 3-3 Class 3K5

-Temporary icing

-25°C to 0°C

IEC 721 3-3 Class 3K5

-Atmospheric pressure

1080 to 795 hPa

Corresponds to a height of –1000 to 2000 m

-Pollutant concentrations

SO2: < 0.5 ppm; relative humidity

<60% Test: 10 ppm, 4 days

H2S: < 0.1 ppm; relative humidity

<60% Test: 1 ppm, 4 days

(to IEC 721 3-3; class 3C3)

Mechanical operating conditions

-Vibration

Type of vibration: frequency sweeps with a change rate of 1 octave per minute.2 Hz $\leq f \leq$ 9 Hz, constant amplitude 3.0 mm 9 Hz $\leq f \leq$ 150 Hz, constant acceleration 1 g period of vibration: 10 frequency sweeps per axis in each of the three mutually perpendicular axes;

Vibration tests according to IEC 68 part 2-6 (sinusoidal) and IEC 721 3-3, class 3M4

-Shock

Type of shock: half-sine Shock strength: 15 g peak value, 11 ms duration Shock direction: 3 shock each in +/- direction in each of the three mutually perpendicular axes.

Shock test according to IEC 68 part 2-27

CONCLUSION

Programmable Logic Controller (PLCs) is most sophisticated control microprocessor device that uses a programmable memory to store instructions and to implement specific functions such as logic, sequence, timing, counting, and arithmetic to control machines and processes. The implementation of these PLCs as control unit device in RTP Research Reactor are better way to overcome the most problem that occurred during operation using analogue control console. All operation data can be stored and analyze for better performance of operation and safety of RTP Research Reactor.

ACKNOWLEDGEMENT

The authors wish to thank to all BKN staff for their help for the information given that knowledgeable.

REFERENCE

M. M. Haque, M. A. M. Soner, P.K. Saha, M.A. Salam and M.A. Zulquarnain., *Operating Experiences and Utilization Programmes of the BAEC 3 MW TRIGA Mark-II Research Reactor of Bangladesh.*

IAEA (International Atomic Energy Agency), *Research Reactor Modernization and Refurbishment (August 2009).*

Eunkyoung Jee, Suin Kim, Sungdeok Cha, Insup Lee,. *Automated Test Coverage Measurement for Reactor Protection System Software implemented in Function Block Diagram*

Siemens Industrial Co., *Siemens ST 70 · 2003 Brochure*