The Initiation of Programmable Control Unit Developments for Proactive Maintenance Approach: Pilot Project in Case Study of High Bay Lighting System of Extension Area in Experimental Hall.

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***Abstract*—Proactive maintenance is a maintenance strategy that aims to correct root cause of failure and breakdown caused by underlying equipment conditions. Breakdown can be avoided by monitoring equipment deterioration, and root cause of failure can be found by using empirical evidence of condition monitoring and data-driven engineering approach. Proactive maintenance corresponds to sustainable development goals set up by the United Nation (UN). To achieve this goal, resources is utilized efficiently. This manuscript reports the case study of resource utilization within Synchrotron Light Research Institute (SLRI) laboratory. In role of international central laboratory, the SLRI organization highly uses resource consumptions to produce synchrotron light to service scientist and researcher. There is novel project aimed to support proactive maintenance approach by developing the Programmable Control Unit (PCU) to harvest insight data from target equipment. The harvested data can be used as patterns for learning and analysis process of proactive maintenance. The high bay lighting system is target equipment which operation within experimental hall of the SLRI laboratory. This manuscript is the first study of PCU implementation into the high bay lighting system in a part of extension area. Unique details of design and implementation method are explained in this document. All findings, pros and cons are reported. Finally, suggestions for further step of proactive maintenance approach are made.**

Keywords-Programmable Control Unit; Data-driven Engineering; Proactive maintenence; Synchrotron;

I. INTRODUCTION

Synchrotron light [1] is an electron radiation generated by human skill which brighter than sunlight over a million times. These lights are emitted from electrons when they are moving at velocities close to the speed of light and suddenly forced with a magnetic field to change direction. As a result, electrons lose energy and discharge in the form of electromagnetic waves called by scientist as "synchrotron light". This light has a sharp beam and high intensity and it covers 4 wavelengths ranged from infrared to X-Rays. These characteristics make it suitable for research in many areas such as fundamental science, biological and medical science, and industry product research.

Synchrotron Light Research Institute (SLRI) is the only one synchrotron light facility of Thailand. As public organization, SLRI serves the produced synchrotron light for international scientist and researcher. Two main parts of the facility are particle accelerator machine and experimental hall which can be further divided into hall area and extension area.

The extension area is in a large experimental hall installed with high bay lighting system like that like any arena and factory. However, there is a challenge in maintenance of the high bay lighting system because the extension area is a controlled area and sensitive to radiation condition. The SLRI has applied preventive maintenance approach by replacing new high bay lamp, one by one, based on time schedule before damage occurs. Time to replace was roughly approximated by using record of installation date. Alternatively, operating time of each high bay lamp can be used for exactly time scheduling.

To record operating time of the high bay lighting system, it needs some tools that can collect data around the extension area and send data to a center processing unit. Furthermore, the SLRI can employ proactive maintenance [2] based on other collected data for finding root cause of failure and preventing breaking condition of the equipment.

This manuscript presents a pilot project of proactive maintenance for high bay lighting system of the extension area in the experimental hall. This project develops a new device called the programmable control unit (PCU) to collect data from the remote terminal unit (RTU) [3] and send to the central processing unit on the microcomputer. The PCU takes response as data acquisition of the data-driven engineering [4] which supports predictive maintenance approach. Main result of this project is log data of operating time and other electrical signals which can be used to create predicting model and time scheduling in the future.

II. HIGH BAY LIGHTING MAINTENANCE IN RADIATION AND CONTROLLED AREA

High bay lamp is one type of lighting lamps. Normally, it is installed far from over head and fixed tightening with roof and ceiling structure of any arena, factory and facility etc.

In early days of power circuits design, high bay lighting system was designed as a group of lamps. Therefore, it cannot separate out one by one. For a large hall such at the extension area at SLRI, the high bay lighting system contains 90 high bay lamps. According to traditional preventive maintenance approach, all of the lamps will be replaced together in the same time.

Normally, there is a difficulty of replacing operation of the high bay lamp because of the installed position of the component that is very high. In addition, there is a challenge to operate in radiation and controlled area. Since machines' SLRI produce many types of radiation, it cannot replace during on radiation states. Usually, SLRI uses the preventive maintenance approach by replacing new ones based on time schedule before they practically damage. The time schedule is a rough approximation based on records of installation date.

Due to the fact that a large number of high bay lighting lamps, it is not efficient to take out the good lamps amount near one hundred to trash at once. In practical, there are other electrical characteristics that can be used to schedule the replacing time. These data are corresponding to data-driven engineering of proactive maintenance approach. Therefore, it would be better to replace only bad lamps based on their operating time.

III. Data-Driven Engineering for Proactive Maintenance Approach in Electrical System

A. *Empirical evidence of electrical data*

Predictive maintenance approach employs data-driven engineering by recording data from many parts. Then uses the data analysis to predict the possibility of failure. This approach is only forecasting the future but cannot find root cause of failures. There are many factors that are cause of failures of the high bay lamp such as transient behavior while switching, loading effects, contact life time or run out. Therefore, these electrical data should be concerned as used as empirical evidence for finding the root cause of failure. Furthermore, they can be used to make decision for root cause eliminations later.

B. *Measuring point of high bay lighting lamp*

To define measuring point, it needs to understand the key parameters. In the case of high bay lighting lamp, the key parameters are voltage and current signals. Because they can provide many data such as power consumption, exactly operating time and they relate to other electrical parameters such as electrical harmonics and noise etc.

C. *Data pattern learning and analysis*

Raw data recorded from electrical equipment must be processed into information that human can understand. Pattern of data can be learned and analyzed on the computer with a specific program. When the engineers have the insight about their data, they can indicate the abnormal points efficiently.

IV. Programmable Control Unit (PCU)

Programmable control unit (PCU) is new device built as the center of data that acquired from far range devices and remote terminal units and co-ordinates with a microcomputer that runs more sophisticated programs. It consists of three unit sections that are central processing unit, DC power supply unit, and input and output units. The diagram of PCU is shown at the center of figure 1 and detail of these sections are described below.

A. *Central processing unit*

This part is a microcomputer that programmed to process input data from remote terminal units (RTU) [4] via LoRa gateway [5] and interface with other units. Because RTU is installed for each high bay lamp at the ceiling of the hall which high and far from the workstation computer. It is inconvenience to use wired-based connection thus wireless-based communication is preferable.

B. *DC power supply unit*

Direct current power supply unit is used to supply voltage to electronic devices. There are two voltage levels according to energy concerns of related devices. DC power supply unit supplies +5VDC to central processing unit and input and output units and supplies +12VDC to relay modules.

C. *Input and output units*

Input part of this unit was received signal from another sensing unit. RTUs are equipment installed over head of each high bay lighting lamp which far from base station and used as input units of this project. Input data are then converted and sent to processing unit via TCP/IP protocol [6]. On the other hand, output part receives command from processing unit and then takes action to actuators.

D. *LoRa communication*

RTUs interface to base station and actuator via LoRa communication. LoRa [5] is long-range, low power and low bitrate wireless communication. It is a popular technology used to construct low power wide area network (LPWAN). Command data from Lora gateway at base station is Java script object notation (JSON) format [7].

*RTU has protections by fused.

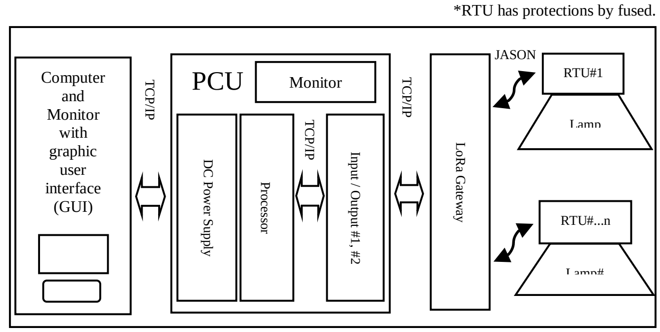

Figure 1. Conceptual design for PCU implementations to high bay lighting system.

V. CONCEPTUAL DESIGN OF PROGRAMMABLE CONTROL UNIT (PCU) IN SYNCHROTRON RADIATIONS FACILITY

In conceptual design for synchrotron radiations facility, safety is must be first priority because SLRI produces various radiations [1] such as X-ray, Gamma, Neutral and etc. In addition, there are many laboratory apparatuses and measuring devices below RTU installation places. These devices are sensitive, complex and very expensive. Therefore, these concerned topics can be corrected by following design methods.

A. Maintenance prevention design

Remote terminal unit and central processing unit are designed by preventing to often maintenance as follows:

1) Robusness design

a) Industrial grade devices are selected.

b) Embedded devices and program are available and ready to work automatically after specific conditions.

c) System can be operated eventhough cooling fans are broken by air flow direction design.

d) Thermal accumulation inside modules from low power consumptions devices is low.

B. Parallel operation design

SLRI cannot be interrupted and reliability must be hold. Remote terminal units and central processing unit are designed by parallel operating concept. The old systems are not changed in local mode. PCU becomes the best choice for selection in remote mode.

C. Worst case protection design

1) Many cases of failure that can be eliminated are shown in table I.

TABLE I. FAILURE CASE VS WORST CASE PROTECTION DESIGN

No.	**Failure case vs Worst case protection design**	
	Failure Case	***Protection Design***
1	RTU Communications has error.	RTU back to Local (Old systems)
2	Proceesing unit has error.	RTU back to Local (Old systems)
3	Electrical system has unstable.	RTU back to Local (Old systems)
4	RTU has short circuit occur.*	Other lamp in same power circuit are still on.

VI. RESULTS

This project develops graphic user interface (GUI) as shown in figure 2. It is used for sending commands to the PCU and display the simulation of PCU implementation in the extension area. It reports current status of RTUs and related data. Log data as shown in figure 3 are resulted acquisition data of this pilot project. These log data describe electrical current and name of a corresponding RTU. The result data is recorded in computer as comma-separated value (CSV) [8] file. This project installs PCU and RTUs in the extension area of experimental hall at SLRI as shown in figure 4.

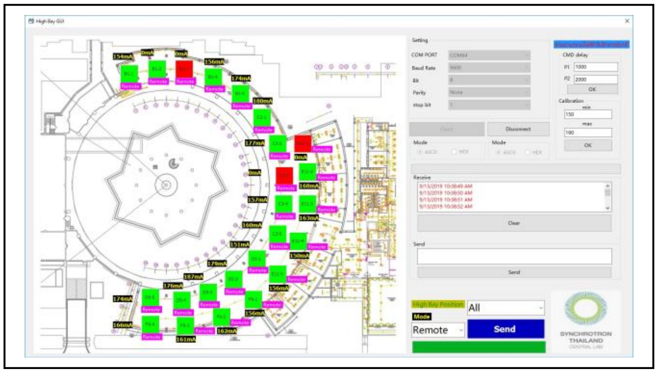

Figure 2. Graphic user interface and current data from RTU.

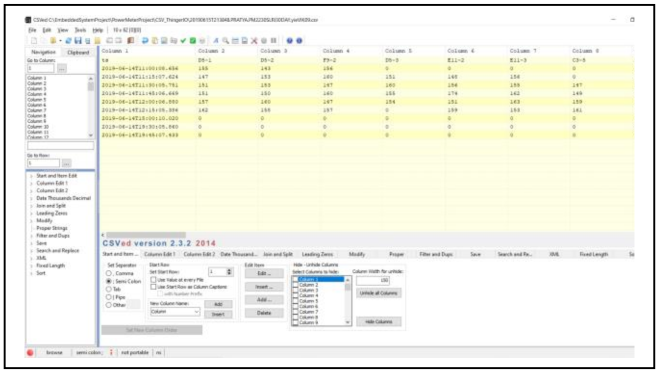

Figure 3. Log data results from RTU with CSV file.

VII. SUMMARY

There are many contributions of this project. This summary section reports both pros and cons sides of the PCU implementation in high bay lighting system in experimental hall at SLRI.

Pros, PCU can operate as data center and coordinate commands between computer and LoRa systems very well. It can transmit exactly data of operating electrical current to computer to be recorded and analysis later. The PCU implementation is good at management data traffic among LoRa master and RTUs. Computer can be used as user interface for sending commands to the PCU. According to data-driven engineering for proactive maintenance approach, this project supports data acquisition effectively.

Cons, due to the fact that in this state, RTUs has using low cost microcontroller. It cannot bring the real shape of current signal from RTUs to more analysis.

Discussions, in further steps should be changing to RTU's microcontroller and current sensor with the higher performance which will able to harvest more insight data from current signal.

Suggestions, SLRI can apply this electrical current data to energy conservation management system for using data efficiently.

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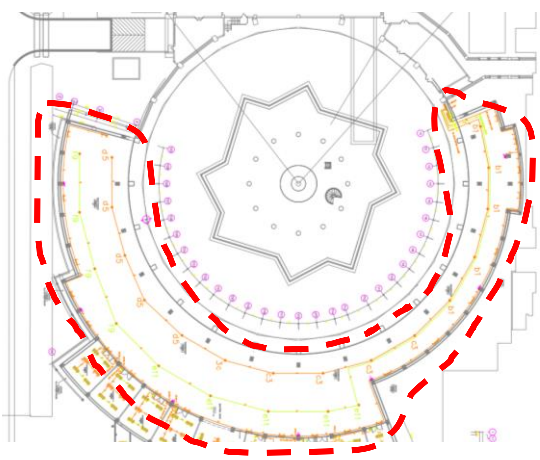

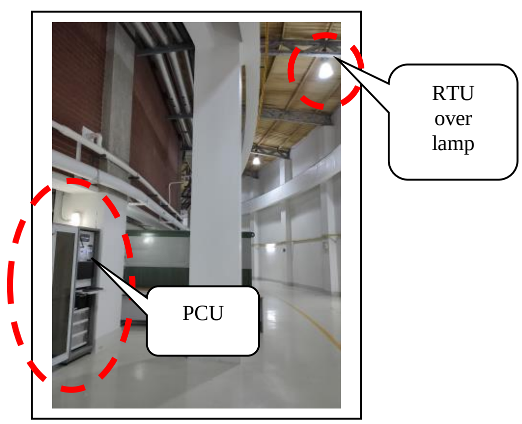

Figure 4. (a) shown extension area of experimental hall and (b) shown PCU and RTUs installations.