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Industrial Energy Monitoring System Using PLC and SCADA

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Abstract: Proposed system monitors the energy consumption by the different sections of the plant during different time and during different process steps. This data gives us energy requirement of the plant with respect to various parameters. It enables to understand sudden changes in energy requirement with different aspects like at particular time, at particular section of the plant or during certain process. Using this data corrective/preventive maintenance or improvement can be done to particular section of the plant. The aim is achieved by using systems used in industry PLC and SCADA. PLC collects all information from the plant with different sensors and energy meters, Flow meters etc. Also it can gets data on communications from DCS of the plant. And finally all this data i.e. electric power consumption, steam flow, instrument air pressure etc. is compiled and represented in the SCADA in different format. This data plays vital role in understanding and managing energy requirement of the industry.
Keywords: ***PLC, SCADA, DCS, Energy Monitoring System, Modbus TCP/IP***

I. INTRODUCTION

Energy monitoring System is an energy efficiency technique based on the standard management axiom stating that “you cannot manage what you cannot measure”. Energy monitoring techniques provide energy managers with feedback on operating practices, results of energy management projects, and guidance on the level of energy use that is expected in a certain period. Importantly, they also give early warning of unexpected excess consumption caused by equipment malfunctions, operator error, unwanted user behaviours, lack of effective maintenance and the like.

The Energy monitoring System lies in determining the normal relationships of energy consumptions to relevant driving factors HVAC equipment, production though puts, weather, occupancy available daylight, etc.) and the goal is to help business managers:

Identify and explain excessive energy use

Detect instances when consumption is unexpectedly higher or lower than would usually have been the case

Visualize energy consumption trends (daily, weekly, seasonal, operational…)

Determine future energy use and costs when planning changes in the business

Diagnose specific areas of wasted energy

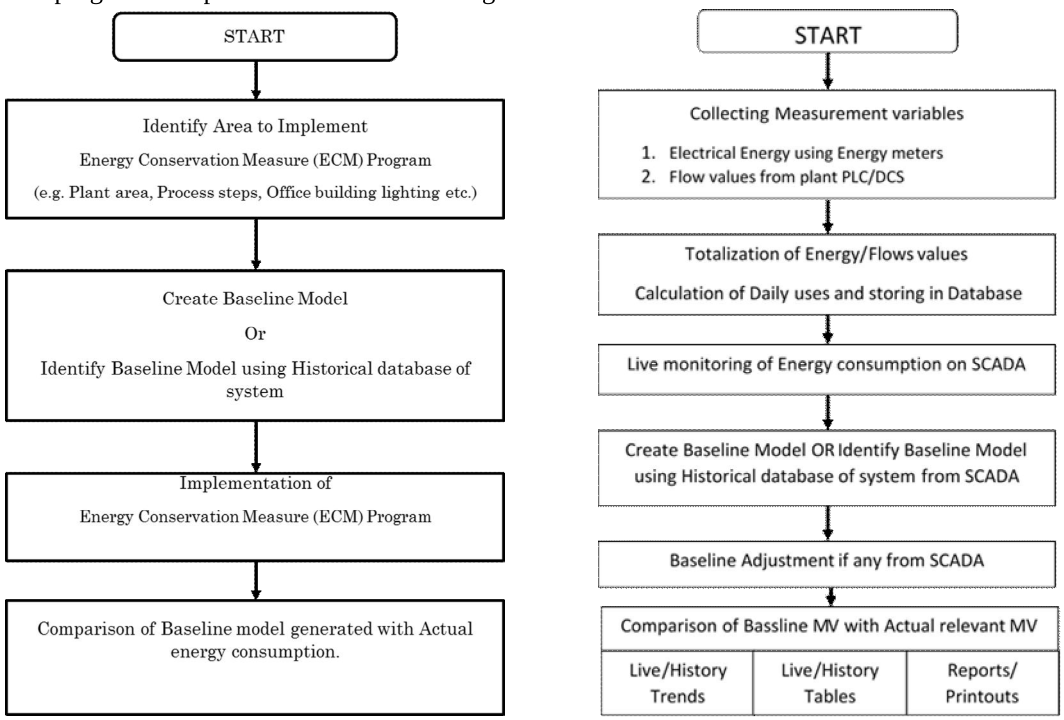
Observe how changes to relevant driving factors impact energy efficiency

Develop performance targets for energy management programs

Manage energy consumption, rather than accept it as a fixed cost

Energy management is a continuous process and our energy monitoring system is a part of this process. Fig.1 shows flow diagrams for EMS. Flow diagram (a) shows how EMS is working. The first of the thing is we have to identify the area for which energy conservation measure (ECM) and create bassline model for that area. Here area can be plant area, office building, process steps etc. We can consider particular process steps also as area for ECM to optimize the energy used in that particular step of the process. Next roll is for energy measurement in existing situation which results in to baseline model creation. This baseline model can be modelled using historian logs of energy consumption data or can be modelled using standardized data from manufacturers. Once the baseline model is ready we are ready to implement ECM program. Under ECM program we are going to improve our energy efficiency of the system with main ace, replacements of high energy consuming devices with low energy consumption devices etc. after ECM we get actual comparisons between baseline model and our energy uses. Reports are generated to know how efficiently ECM program is implemented.

In proposed Energy monitoring system flow graph first we will make measurements. Measurements are done using readings from energy meters and flow meters. Also data is received from process PLC on communication like process steps and flow meters readings. All data is compiled and stored in database also can be monitored live on SCADA. These data in important in creating baseline modelling for ECM program. If there is any changes for baseline data with historical data that can be adjusted from SCADA. Then ECM program is implemented and results are generated.



(a) (b)

Fig. 1 (a) Energy management flow. (a) Energy monitoring system working.

II. RELATED WORK

In order to start the thesis, the first step is to study the previous work performed by researchers. For this purpose various papers have been studied.

TABLE I
RELATED WORK

SR. NO.	PAPER TITLE	AUTHOR	WORK
1.	Smart Energy Monitoring and Management System for Industrial Applications 2012 IEEE Electrical Power and Energy Conference	K. Collins, M. Mallick, G. Volpe and W.G. Morsi	An industrial facility was used to demonstrate the importance of managing the energy consumption. To address this issue, an energy monitoring and management system is developed[1]
2.	Systems Approach to Corporate Sustainability in Energy Management of Industrial Units IEEE SYSTEMS JOURNAL, VOL. 2, NO. 4, DECEMBER 2008	Theodora C. Kouloura, Panagiotis D. Panagiotakopoulos, Anastasia S. Safigianni	The cybernetic viable system model (VSM) of Beer is used to consider an industrial unit as a viable organization and through this consideration to diagnose the technical and managerial gaps identifying the Best Interventions Plan according to principles of sustainability[2]

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3.	Automation Project Framework for Energy Management 2014 IEEE	Renato Ely Castro, Carlos E. Pereira, Fausto B.Líbano, Luciano F. Chaves, Hermes J. G	a supervisory framework for monitoring and verification of energy resources compatible with a standardized energy management system, including energy use and consumption requirements, documentation, communication[3]
4.	Implementation of Modbus RTU and Modbus TCP Communication using Siemens S7-1200 PLC 2015 (ICSTM),	Sadik Tamboli, Mallikarjun Rawale, Rupesh Thoraiet, Sudhir Agashe	Modbus RTU and Modbus TCP configuration using Siemens S7-1200 PLC. [4]

III. SYSTEM ARCHITECTURE

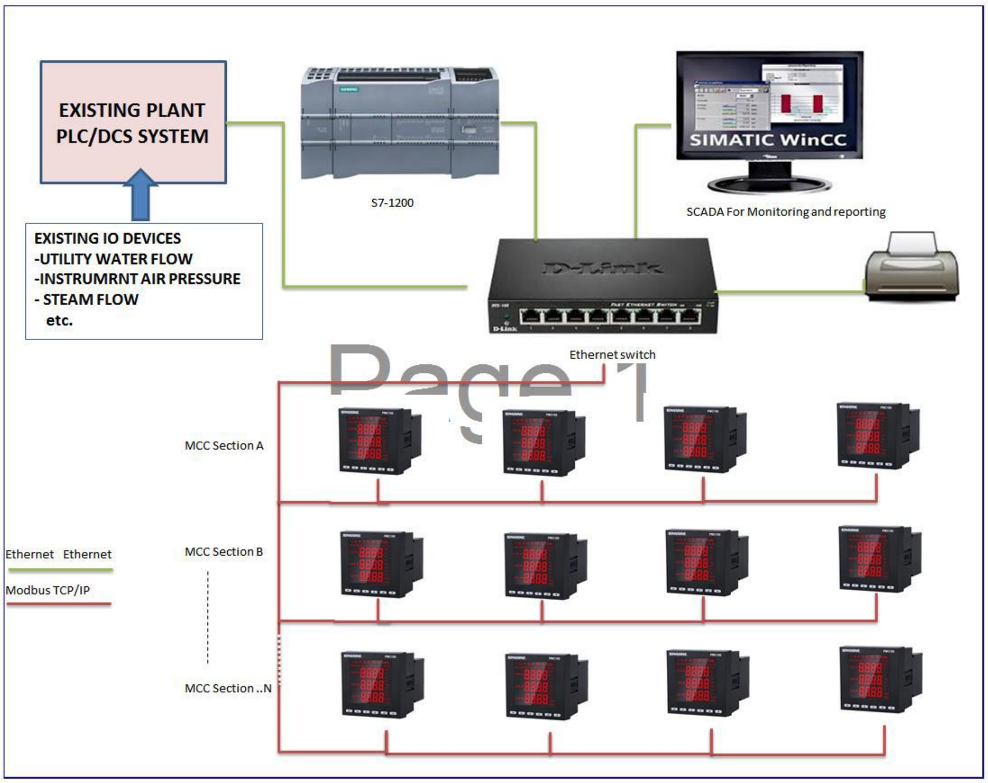

Fig. 2 Proposed System Architecture

The proposed system i.e. industrial energy monitoring system using PLC and SCADA architecture is as shown in above Fig-1. In this system, S7-1200 PLC with WinCC SCADA software is used. Data is collected from different energy meters from MCC building using Modbus communication. WinCC software is used to monitor and logging of the data. Data analysis in different formats is done in SCADA station. Also reports are generated which are printed automatically and on demand using printer. WinCC used SQL server to store the data.

It also include the other forms of energies like steam, compressed air, and water in this system. These are connected to the system by using Analog inputs to EMS PLC or from the existing PLC on communication. The system can have communication with the existing plant DCS system over Modbus and collect process data. Using this process data energy used in specific part of the process can be monitored. Also it gives us more no's of data points to estimate energy uses. The more number of data points more accurate will be the system. Totalizers in the PLC take record of all energy uses.

To collect data from smart energy meters and plant DCS/PLC system Modbus protocol is used. Most commonly used Modbus protocols are Modbus RTU, Modbus ASCII and Modbus TCP. Modbus RTU is the point to point serial communication between

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multi-masters and slaves. In this RS-232, RS422, RS485 are used as physical layer. It can have simplex and duplex mode.

IV. SYSTEM COMPONENTS

A. Hardware Introducing the S7-1200 PLC

The S7-1200 programmable logic controller (PLC) provides the flexibility and power to control a wide variety of devices in support of our automation needs. The compact design, flexible configuration and powerful instruction set combine to make the S7-1200 a perfect solution for controlling a wide variety of applications.

The CPU combines a microprocessor, an integrated power supply, input circuits and output circuits in a compact housing to create a powerful PLC. After you download your program, the CPU contains the logic required to monitor and control the devices in your application. The CPU monitors the inputs and changes the outputs according to the logic of your user program, which can include Boolean logic, counting, timing, complex math operations and communications with other intelligent devices.

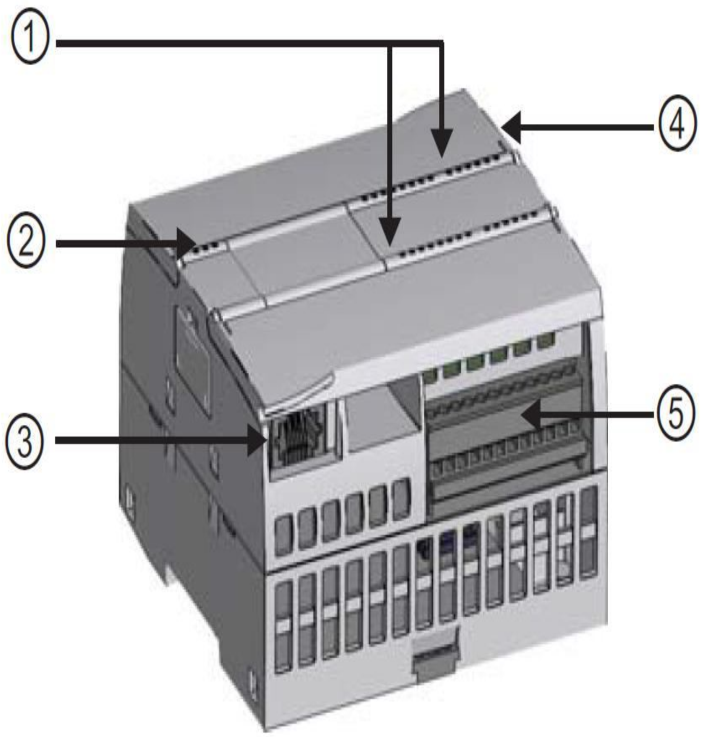

Fig.3 S7-1200 PLC

The S7-1200 PLC is as shown in below Fig.3. It has different LED indications that are as given below,

Status LEDs for the on-board I/O Status LEDs for the operational state of the CPU

PROFINET connector, Memory card slot (under door), Removable user wiring connector

The CPU provides a PROFINET port for communication over a PROFINET network. Communication modules are available for communicating over RS485 or RS232 networks.

B. Introducing the energy meter sentron pac

The SENTRON PAC is a Power Monitoring Device for displaying all the relevant system parameters in low-voltage power distribution. It is capable of single-phase, two-phase or three-phase measurement and can be used in two-wire, three-wire, and four-wire, TN, TT and IT systems. It also has a multifunctional digital input and digital output. The parameters can be set either direct on the device or via the communications interface. Password protection is integrated via the front of the device to guard against unauthorized access.

PAC meters are available as PAC3100 is a basic device for digital measurement, PAC3200 is for specialist precise energy measurement and PAC4200 is for experts for communication and monitoring.

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Fig.4 SENTRON PAC3200 power meter front panel

C. Software

1) TIA Portal software: The Totally Integrated Automation (TIA) Portal software provides a user-friendly environment to develop, edit, and monitor the logic needed to control your application. The TIA Portal provides the tools for managing and configuring all of the devices in your project, such as PLCs and HMI devices. As a component of the TIA Portal, STEP 7 Basic provides two programming languages (LAD and FBD) for convenience and efficiency in developing the control program for your application. The TIA Portal also provides the tools for creating and configuring the HMI devices in your project [5].

2) SIMATIC wincc: SIMATIC WinCC is a supervisory control and data acquisition (SCADA) and human-machine interface (HMI) system from Siemens. SCADA systems are used to monitor and control physical processes involved in industry and infrastructure on a large scale and over long distances.

IV. IMPLEMENTATION AND RESULTS

Experimental setup for the energy monitoring system is as in fig.6. SCADA software on laptop makes human interface with the Energy monitoring system. Both S7 1200 PLCs are used for demonstration one as EMS PLC and another is Plant PLC. Communication between both PLC is established with TCP/IP Modbus. Used PAC 3200 Energy meter to demonstrate energy consumption data communication to the EMS PLC over TCP/IP Modbus protocol. As in second figure of experimental setup a PIR sensor is used to detect man movement in storage area and control it lighting. PIR sensor is a motion sensor which detects any motion in its area of sensation and generate signal. Also two speed motor is used to demonstrate automatic speed adjustment in case of more energy consumption. Which will result in reducing load for load sharing.

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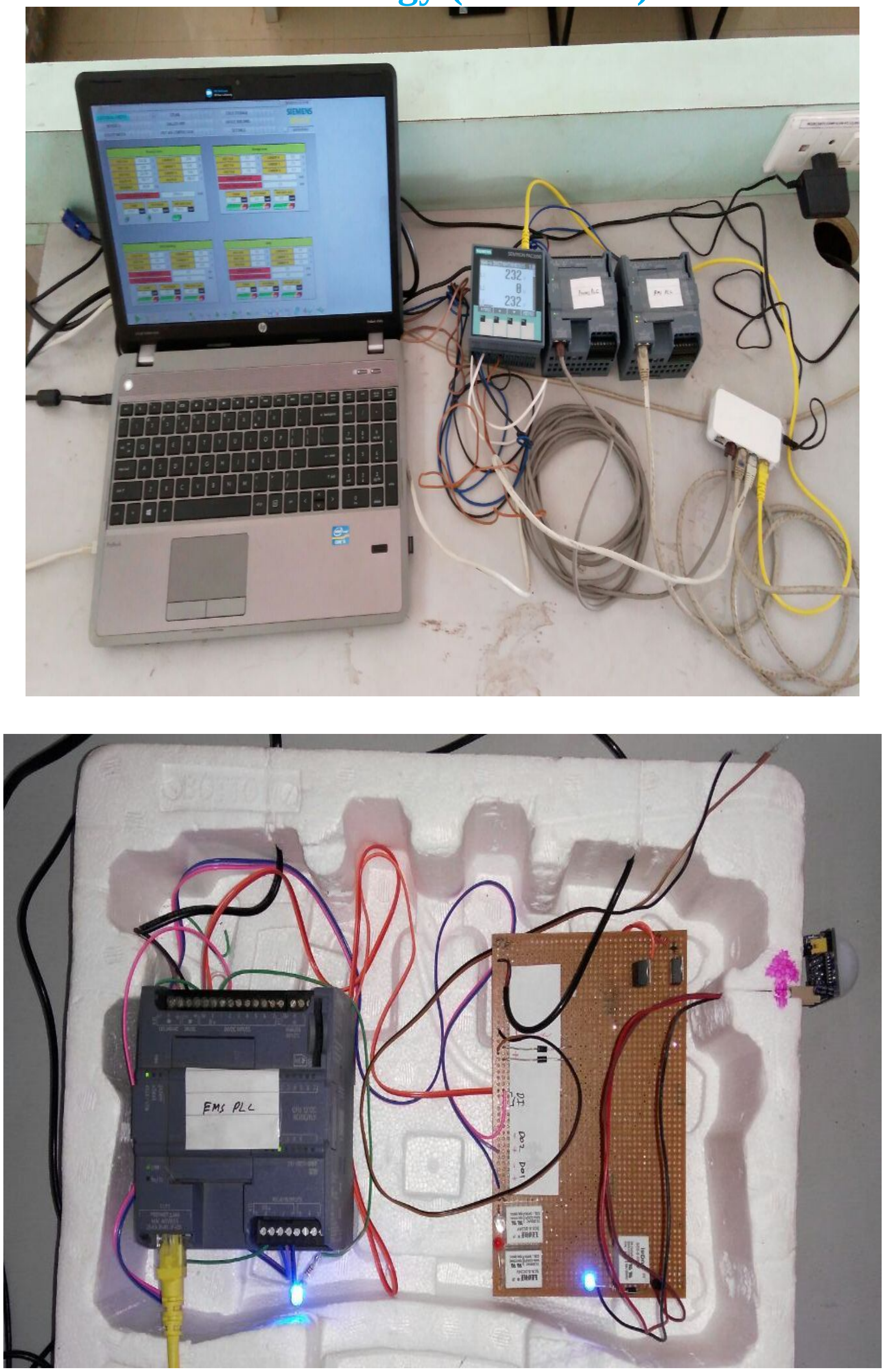

Fig.5 Experimental Setup

As result we can monitor online energy consumptions in different sections of the plant. Also live comparison with yesterday's energy consumption and today's ongoing consumption is displayed as shown in figure 6. Live data from energy meter is monitored using faceplates in WinCC. Receives alarms and warnings on excess or less energy consumption to alert operators there is some process upset.
In the screen shown in fig. 7 we monitor the air compressor cycle day wise. Any changes in the normal cycle is alerted to the operator. Also we can compare it with old data in the form of trends and tables. In second screen in fig 8 while implementing

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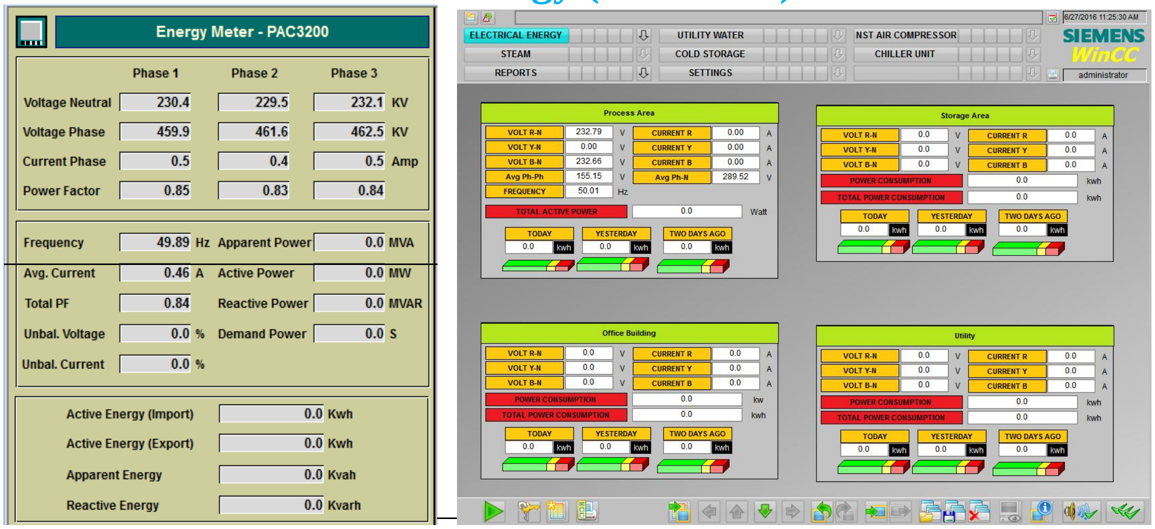

Fig.6 Live monitoring of Energy consumption in SCADA Screen

ECM program we can model our baseline model for it. And after implementing ECM program we can compare it with new energy consumption data with baseline model. This gives us how effective is ECM program and how much energy is saved from it.

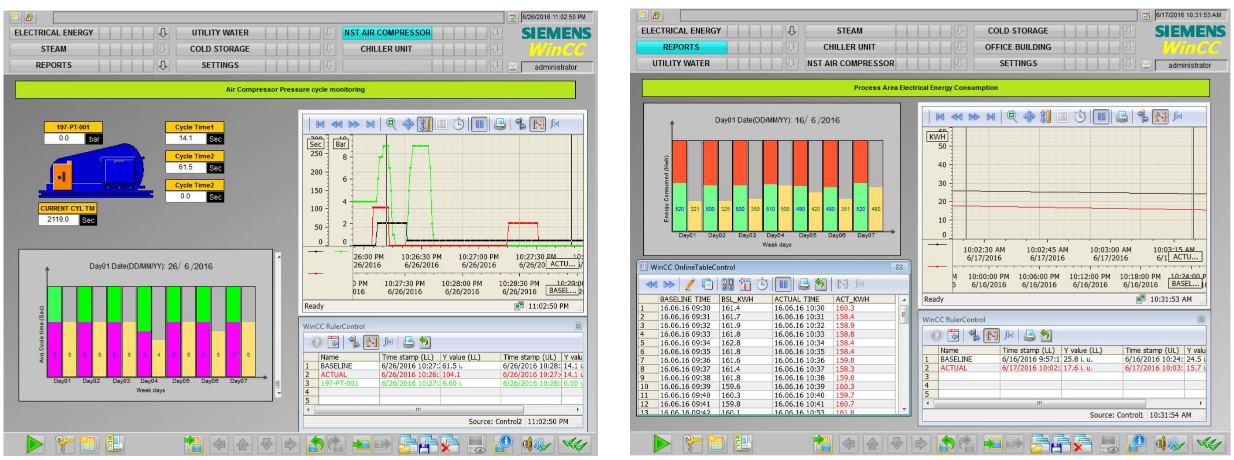

Fig.7 Instrument Air Monitoring and baseline data comparison

As experiment implanted ECM program for the closed storage area. As in industry it was used always to access the storage area so it was a difficult to switch on lights and switch of for each time. Also if there is multiple persons working it was difficult to identify where to switch on and off the lights. So as an ECM program closed storage area is chosen. Creating baseline model before implementing ECM baseline model is developed in which it is found that out of 24 hours 17 hours all lights are in ON. Consider 60 W light bulbs total numbers 10 running for 17 hours a day will make 17 kWh a day. After implementing ECM program with PIR sensors lights are on only when there is any movement in storage area. Also unnecessary lights are OFF where no person is present. With this implementation 17 hours are reduced to 11 hours per day which reduced energy consumption for same numbers of bulbs to 11 kWh. It makes 6 kWh of energy saving which is about 35.29% of energy use before implementing ECM program. With considering large area with large numbers of bulbs huge amount of energy can be saved. Also with different ECM programs we can get different results and EMS system helps to track our work in energy saving process.

V. CONCLUSION

The proposed system is used to monitor the energy uses in different sections of the plant. Live comparison of energy used is monitored on SCADA screens. System also make help in improving the existing system by analyzing the changes in the energy

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consumptions of the plant sections. It highlight the wastages of the energy uses by comparing with the standard requirements of energy consumption. Any accident or the Emergency situations is the result of excessive energy release in different forms like electricity, heat, pressure etc. Proposed system also help to alert the unwanted emergency situations or accidents in the plant and improves safety. In experiment for storage area lighting 35.29 % of energy saved by implementing ECM program.

VI. ACKNOWLEDGMENT

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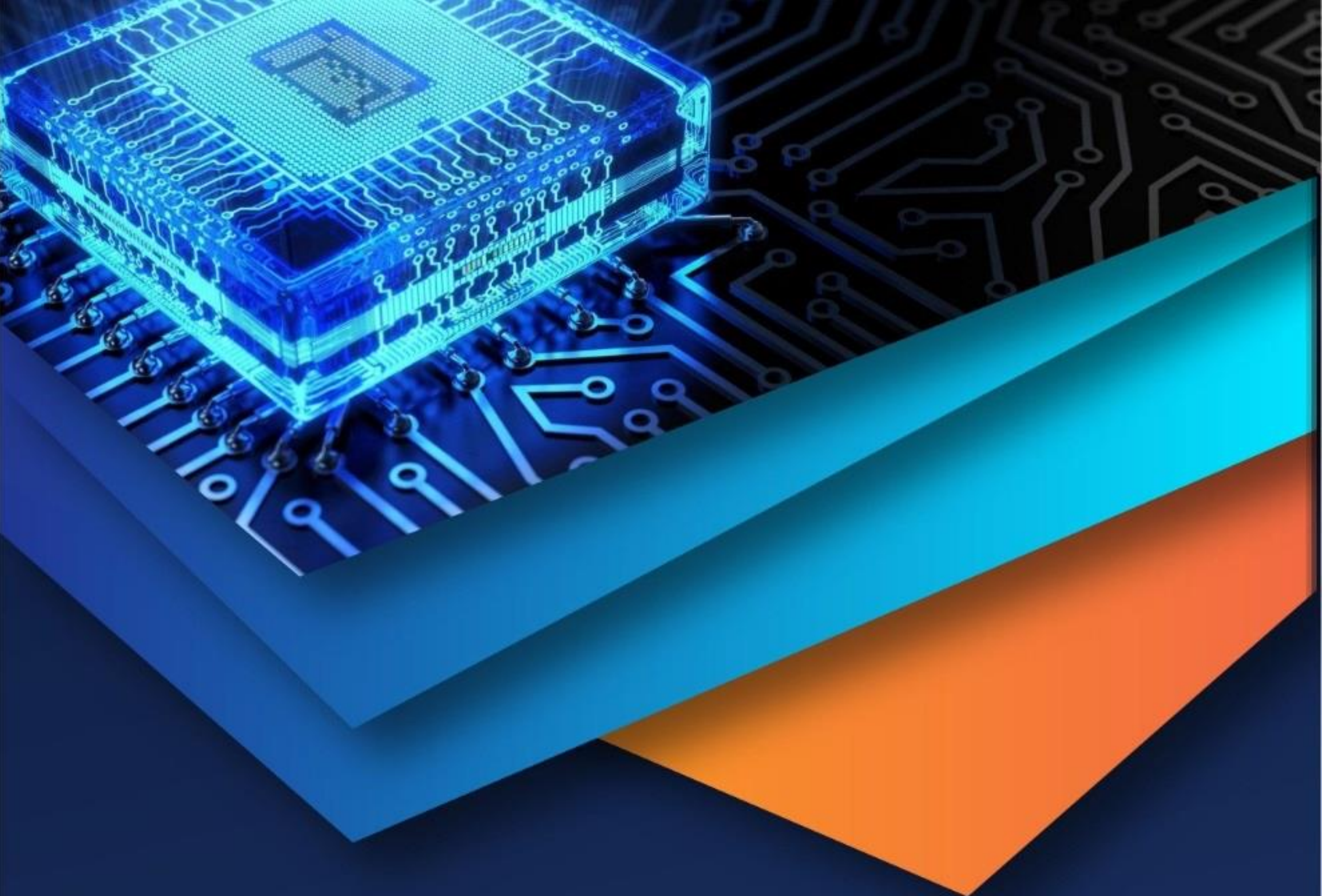

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