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Development of PLC Logic and SCADA System for Chiller Plant Automation

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Abstract : Today, PLC applications are having a major impact on process engineering. PLC has entered this field with software and hardware for fail-safe, intrinsically safe, and process language-speaking solutions. Controls the entire system. The installation cost is not low, but it is possible to operate efficiently for a long period of time. Reduce operating costs and energy consumption. Chiller Units have become an essential requirement in industrial and domestic environments. On the other hand, industrial automation tools provide many applications to control and monitor equipment, power etc. By initiating an automation process, it improves the benefits of managing and controlling chiller plants. PLC and SCADA are easiest automation tool in HVAC industries. The Simatic S7-400H controller is used to automate the process with the rated supply of 24V DC, achieved by implementation of SMPS for the input voltage of 230V.

***Index Terms* - PLC, Chillers, Automation, SCADA, HVAC, Simatic, SMPS**

I. INTRODUCTION

Heating, Ventilation, and Air Conditioning (HVAC) systems frequently consume the most energy in commercial buildings. More than 60% of the energy used in a typical office building is produced by the HVAC system [1].

In both commercial and home settings, chiller units have become a necessity. A typical chiller plant consists of a number of coolers, cooling towers, water pumps, and other related components. It is a sizable, intricate, and interconnected system [2]. Compressors, pumps, and fans are only a few of the chillers' motor-driven HVAC system components. Therefore, it is crucial to increase the energy efficiency of the fans, compressors, and pumps in the HVAC system, this is possible to achieve by a variety of methods [3].

However, there are numerous applications for industrial automation tools to control and monitor equipment, power, vehicle, telecommunications systems etc. By initiating an automation process, it improves the benefits compared to managing and controlling those plants manually [4]. PLC and SCADA are easy to use for automation in HVAC industries. The IEC standard, enables the programmer to use multiple programming languages in the same PLC, it is the main benefit of using PLC-based automation because it eliminates the need for proprietary implementation and allows different tasks to be implemented effectively using the most appropriate language. Hence for recommissioning, troubleshooting and rescheduling is no challenge [5].

In the past and even now, chiller plant operations have been frequently governed by rules. For instance, the coolant supply temperature is constant, and there are only as many active chillers as necessary to provide the cooling requirements. The relationship between the chiller cooling load and the chiller/condenser supply temperature is nonlinear. Due to the chillers' poor effectiveness at maintaining a steady supply temperature, energy is squandered, and occasionally two chillers use less energy than one. Therefore, chiller plant optimization is required for energy savings [6].

The optimization and control of chiller plant requires adjustments of multiple set points, primarily temperatures, and flow rates. In this work, PLC and SCADA have been used to monitor and operate the Chiller Plant for a building's more noticeable operation.

PLC has been utilized as hardware at the remote end to monitor and read field instruments for the predefined temperatures, pressures, and other parameters as well as to control the Chiller equipment in accordance with predetermined instructions. The many chiller units in the plant have been monitored and controlled remotely using the ladder logic created for programming PLC S7 400H. By creating Graphical User Interfaces (GUI) utilizing TIA portal software, SCADA/HMI are operated remotely.

II. CONTROL AND OPERATION USING PLC

2.1 Programmable Logic Controller (PLC)

A Programmable Logic Controller, or PLC, is a ruggedized computer used in industrial automation. PLCs are devices that allow control logic and instructions to be stored as programmes and executed by running the PLC with power that is supplied [4]. The programme, for instance, uses logical justifications such "if button is pressed, open valve," etc. Depending on the inputs and outputs, a PLC monitor and records run-time data such as machine productivity or operating temperature, initiate and terminate processes automatically, generate alarms in the event of a machine failure, and do much more [7]. The input interface, CPU, memory unit, and output interface are the four fundamental parts that make up a PLC's structure, Fig. 1.

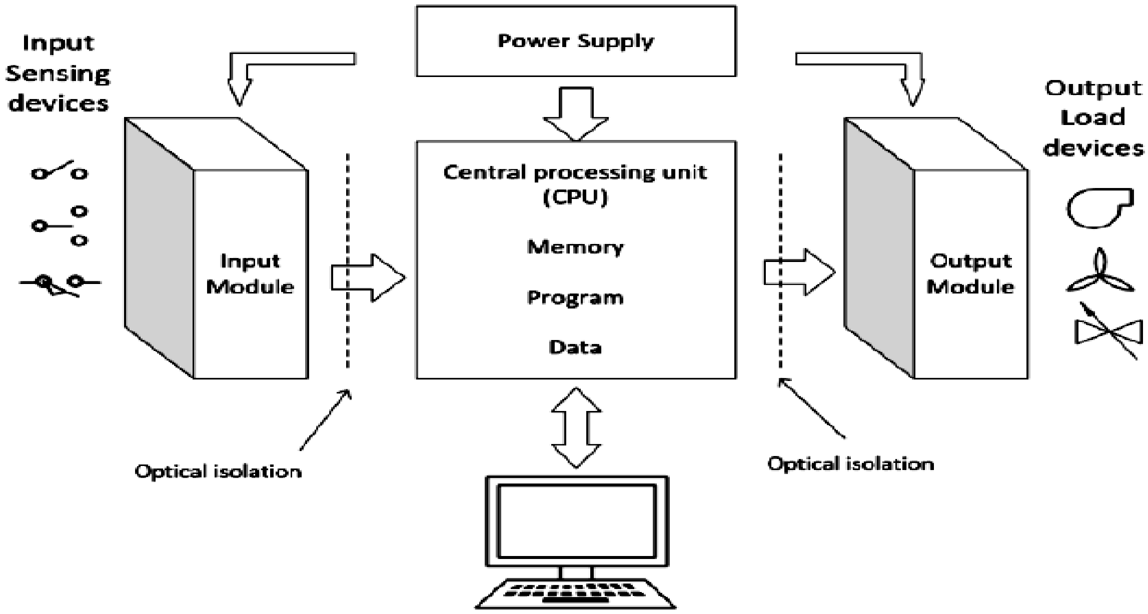

Fig.1. Components of PLC

Typically, PLC programs are created on a computer before being downloaded to the controller. Ladder Logic or "C" programming is supported by the majority of PLC programming software [6]. A classic programming language often used is called Ladder Logic.

2.2 SCADA & HMI Overview

Supervisory Control and Data Acquisition, or SCADA. In sectors like telecommunications, water and waste management, power, oil and gas refining, and transportation, SCADA systems are used to monitor and manage equipment or plants. These systems cover the data transfer between a SCADA central host computer and several Remote Terminal Units (RTUs) or PLCs, as well as between the central host and the operator terminals[8]. A SCADA system collects data (such as a pipeline starts to leak), sends the data back to a central location, and then notifies the control station that a leak has occurred. At this point, the control station starts the necessary analysis and control, such as by determining whether the leak is critical and presenting the data logically and efficiently.

By creating Graphical User Interface (GUI) for the selection of equipment like chillers and pumps as well as for monitoring, SCADA is utilised to operate remotely. HMIs are made specifically to act as a user-machine interface. An HMI, on the other hand, is a lot more tailored to industrial and process control systems. An HMI delivers real-time data of the site's instruments and equipment as well as a visual depiction of a control system.

2.3 Block Diagram

Figure 2 shows a conceptual block diagram that describes the structure and behavior of multiple components and network devices, hardware of a control system. It shows the connection between PLC, HMI, IO racks and field equipment and control instruments.

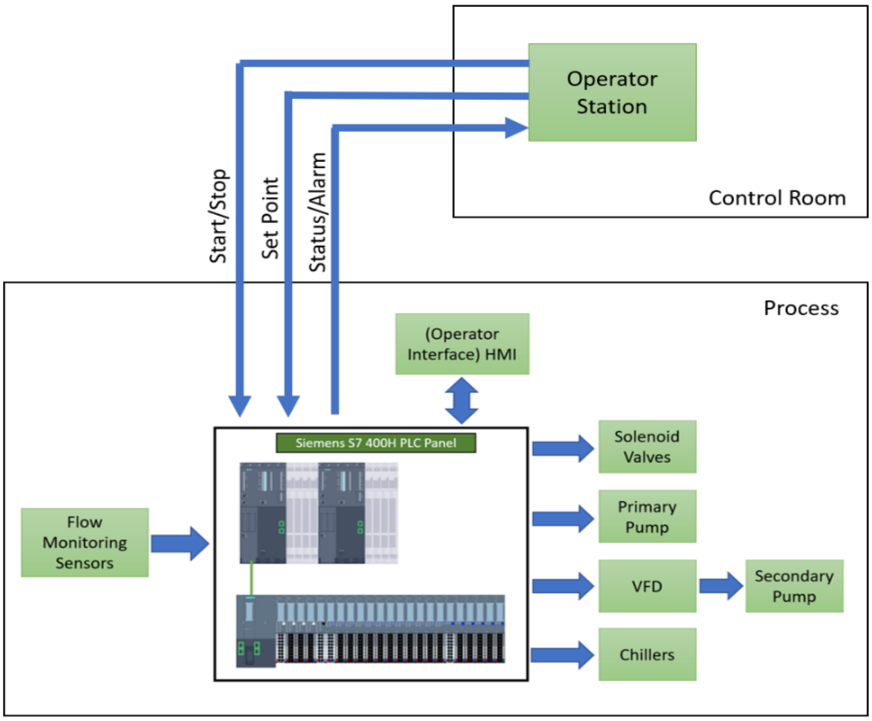

Fig.2. Control Block Diagram

III. Hardware Structure And Network Establishment

All of the hardware that has been used in the system is described in this section. The network diagram in Fig. 3 displays the components.

- Siemens PLC S7-400H
- HMI TP 1500 Comfort
- IO Racks.
- Ethernet Switch
- Field equipment like chiller, pumps and valves
- Control Instruments like temperature sensors, pressure transmitter etc.

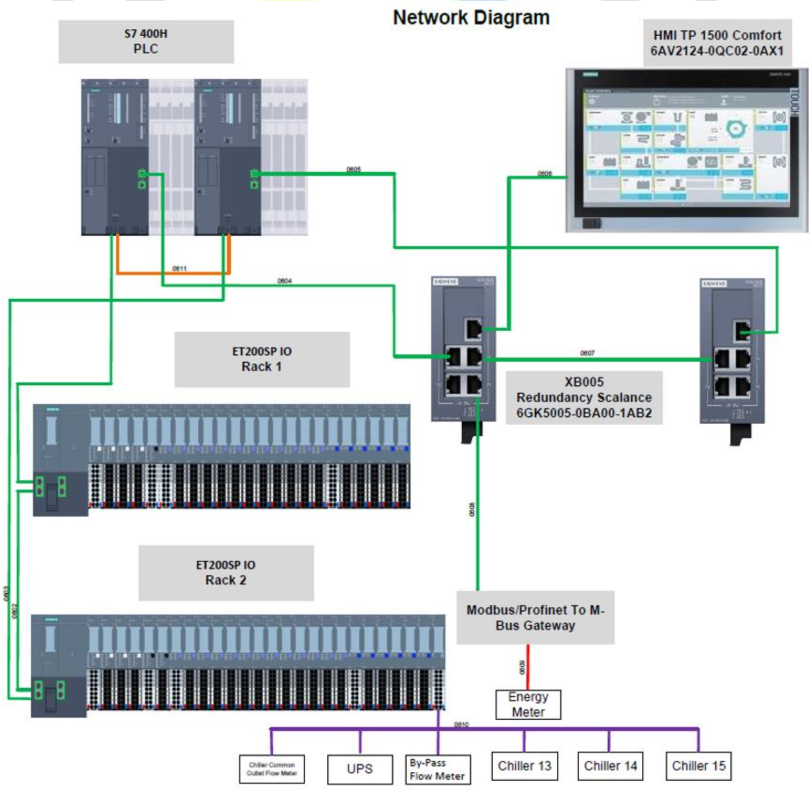

Fig.3. Network Diagram

3.1 IO Point Scheduling

I/O Point Scheduling is the important factor in the selection of controller, Simatic controllers are chosen depending on the inputs and outputs. Based on the load calculation and equipment scheduling, the input output configuration pins available are 140 AI, 101 DI, 37 AO, and 31 DO. The IO points is connected to the controller through additional remote IO modules.

3.2 Control Panel Design

Electrical control panel is a combination of electrical devices and switchgears used to power the PLC module and communication network to control the various equipment at the chiller plant.

Power Supply Unit (PSU) has been selected based on the connected load that is PLC, IO modules, Field Instruments if required. Based on Simatic PLC a 24V DC and about 5A PSU is suitable for the design. Rating of MCB is 2 times the rating of module to be protected i.e., For 16 Digital inputs module with 0.5A rating, I= 0.5*2*3= 3A. In similar manner MCB, terminals and relays are calculate based on number of DI, AO, AI and DO module.

IV. SOFTWARE STRUCTURE

The Ladder Logic Program for the automation of Chiller Plant has been developed using Totally Integrated Automation Portal. The ladder logic program is written for the controller selected i.e., 412-5 H CPU in the Siemens TIA Portal.

4.1 The Algorithm

The overall algorithm is depicted in the Fig. 4 ,5 and 6. The algorithm demonstrates the behavior of the controller it consists of the following:

- Check the mode of operation selected by operator
- Checking the temperature difference of the inlet and outlet pipe
- ON and OFF of the modulating Valve
- Start and Stop of the pumps and chillers
- Maintaining the process for the run cycle

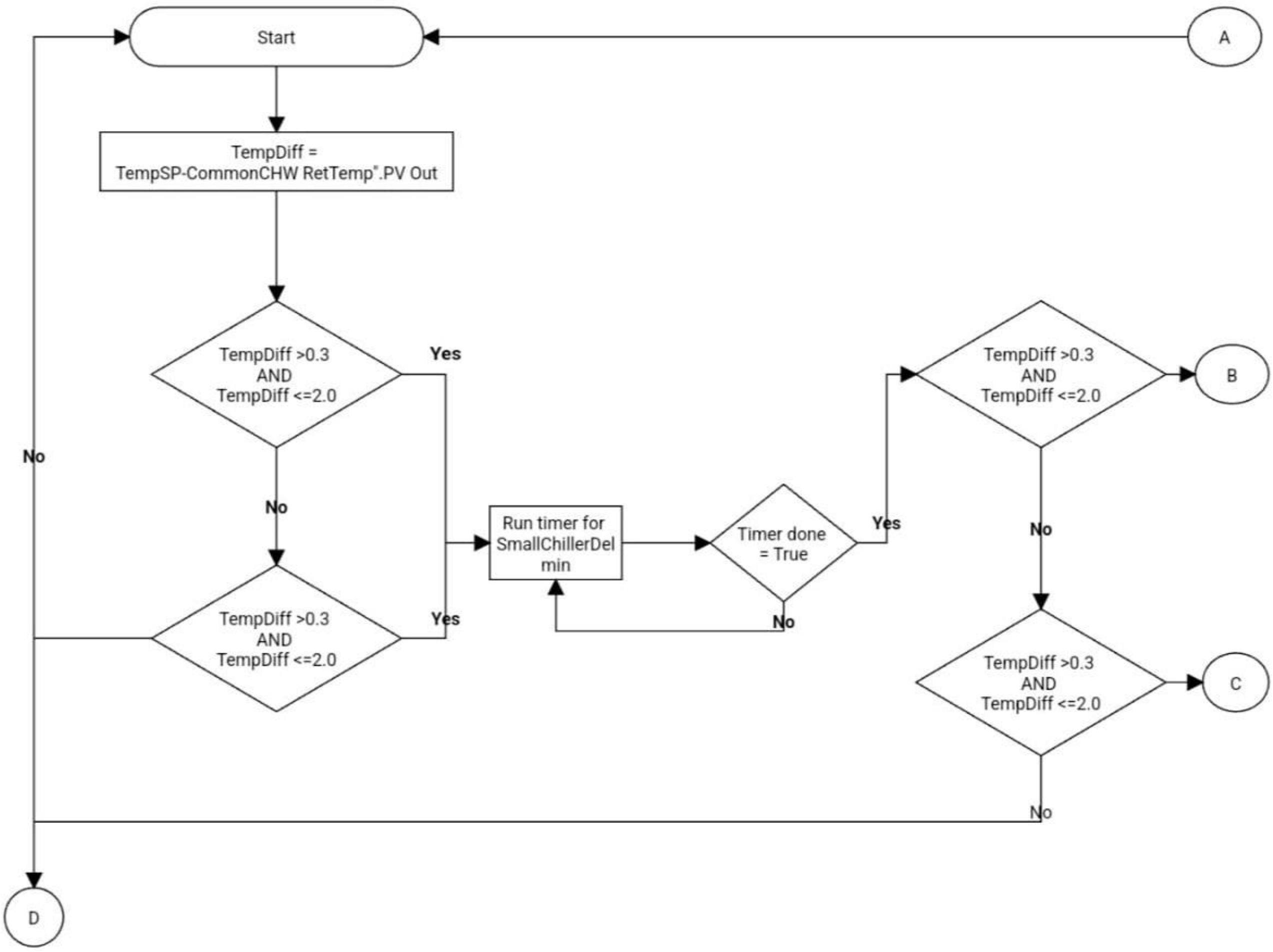

Fig.4. Comparison of Temperature Difference

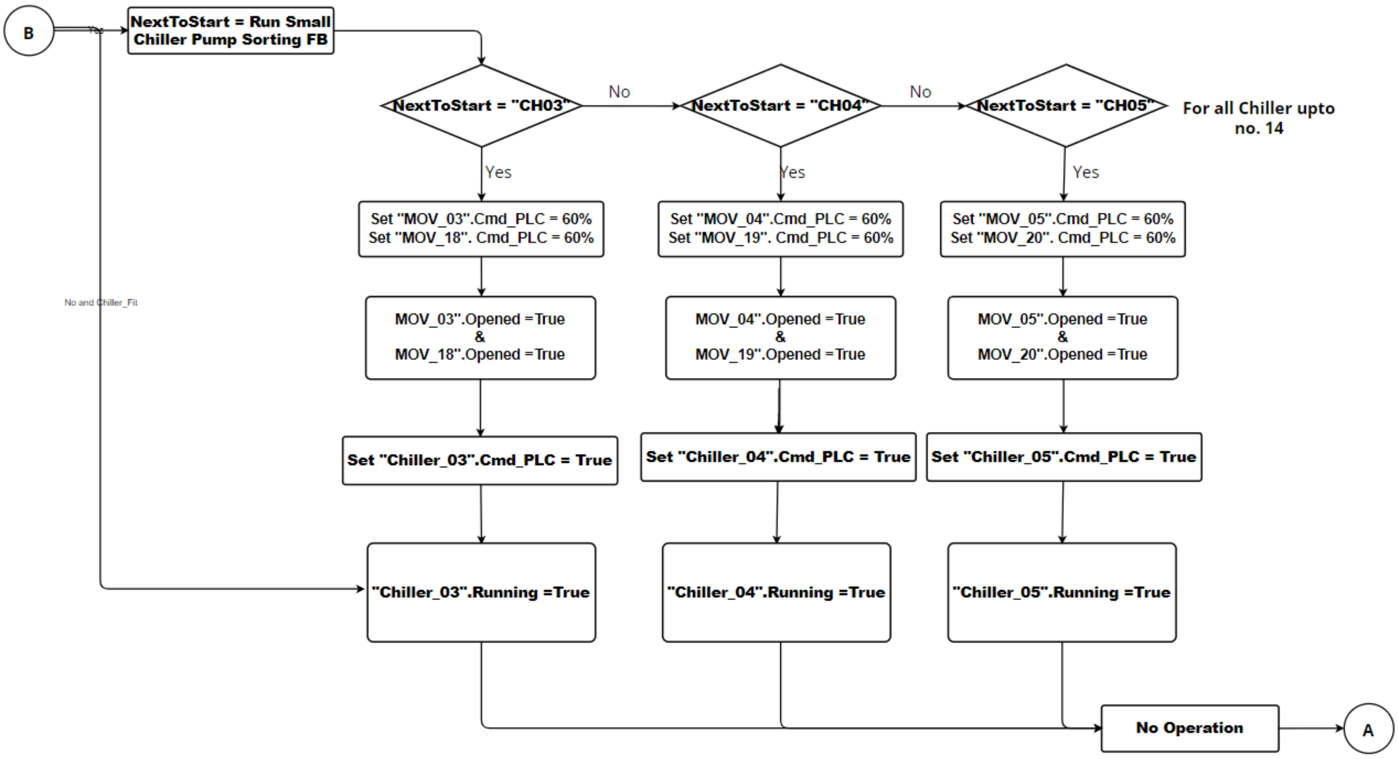

Fig. 5. Starting of a Chiller

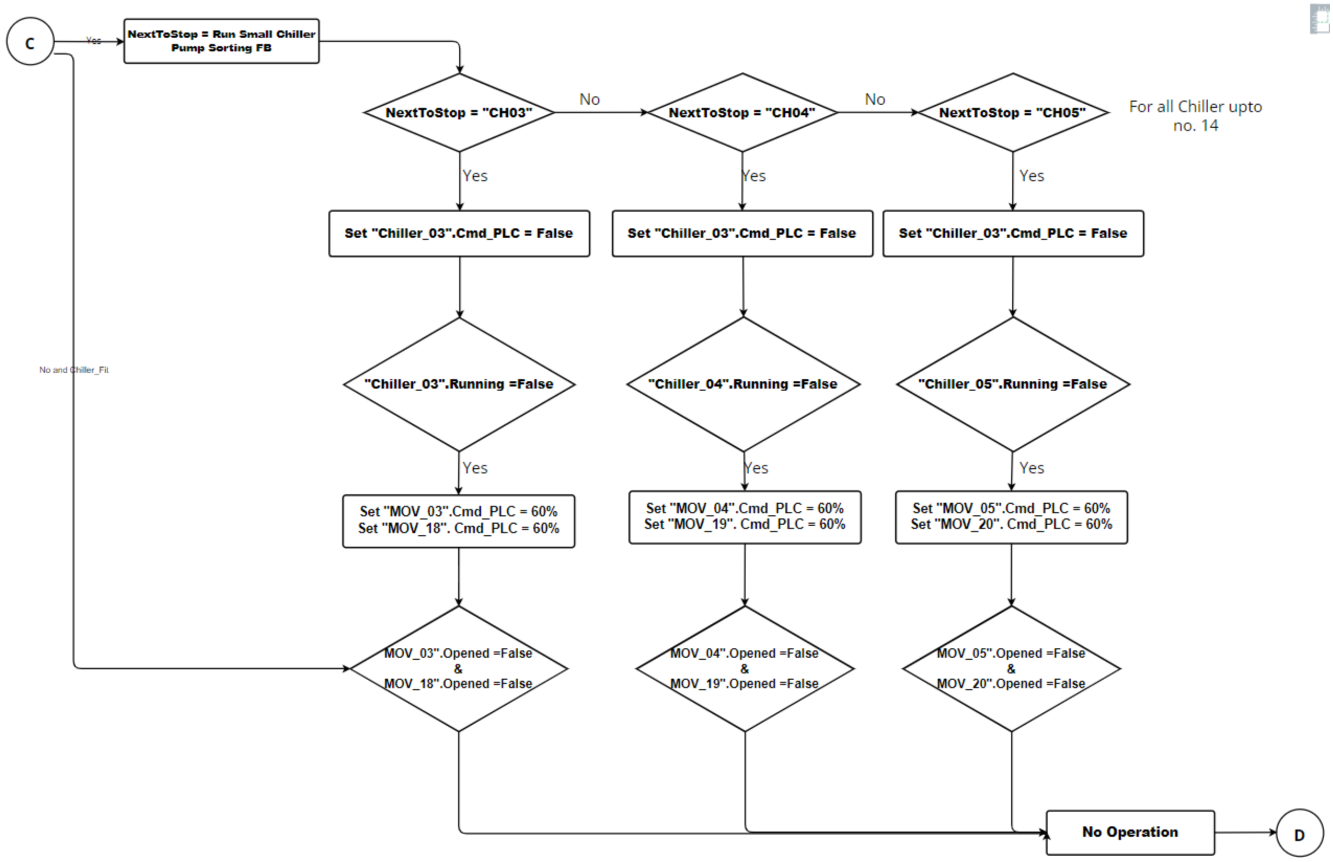

Fig. 6. Stopping of a Chiller

4.2 PLC Program

The controller selected i.e., S7-400H has been simulated in TIA portal with the IO modules configured as per the requirement of the project, here Inputs are 241 and Outputs are 68. The steps involved in selection of controller is as shown in Fig. 7 and Fig. 8.

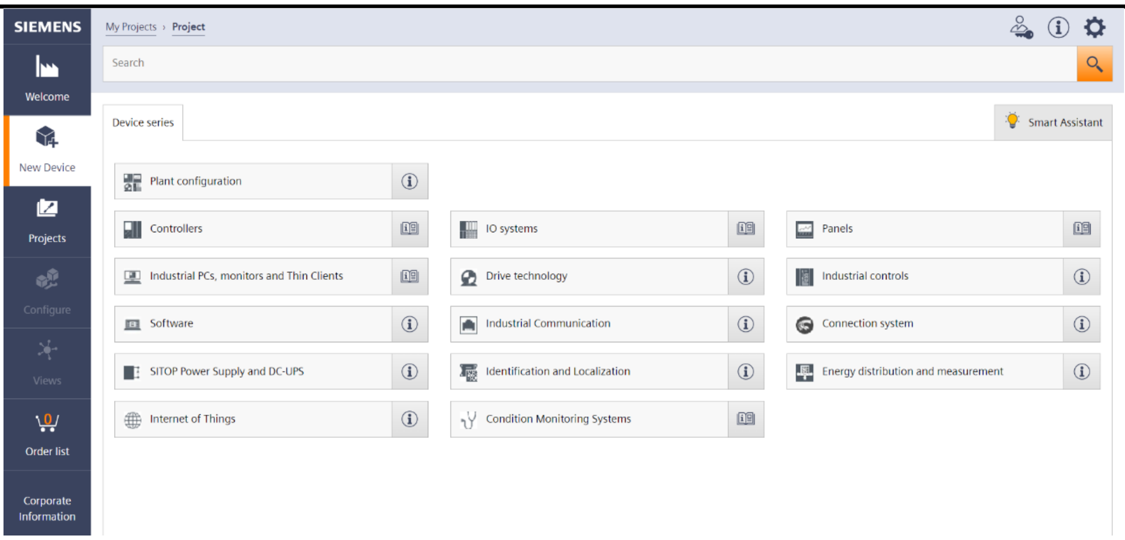

Fig. 7. Controller Configuration

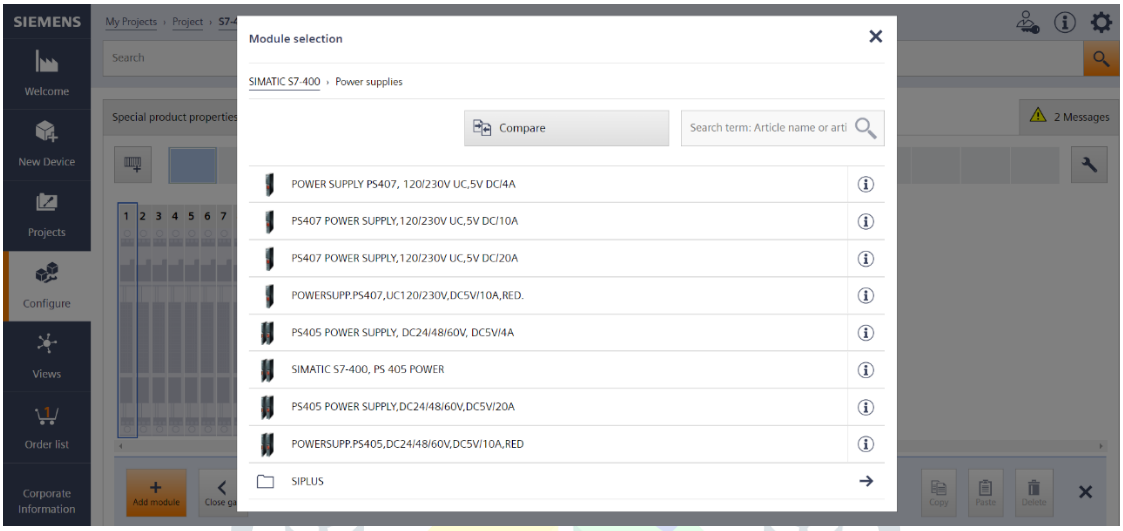

Fig. 8. Component Selection

The S7-400H PLC has been used and programmed to carry out all automation activities, including automated mode operation, as illustrated in Fig. 9, and manual control mode is also depicted. TIA Portal V15 is used for programming purposes.

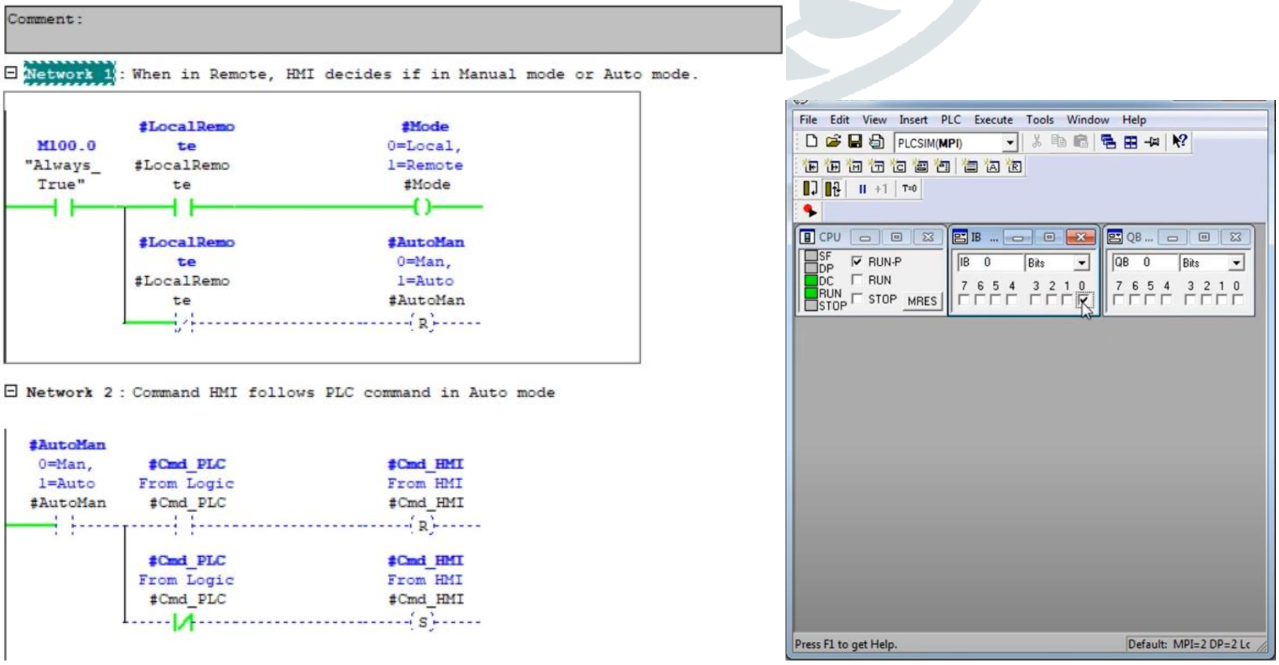

Fig. 9. Simulation for Mode Selection

4.2 HMI Implementation

The input selection and output command monitoring is carried through the HMI screen as shown in Fig. 10 to give manual and automatic command for equipment mode selection. For the equipment used in the displayed ladder logic, there are two operating modes: remote mode and local mode. Depending on whether Manual mode or Auto mode is selected by the HMI input as the Remote mode is high, the HMI has to execute PLC commands.

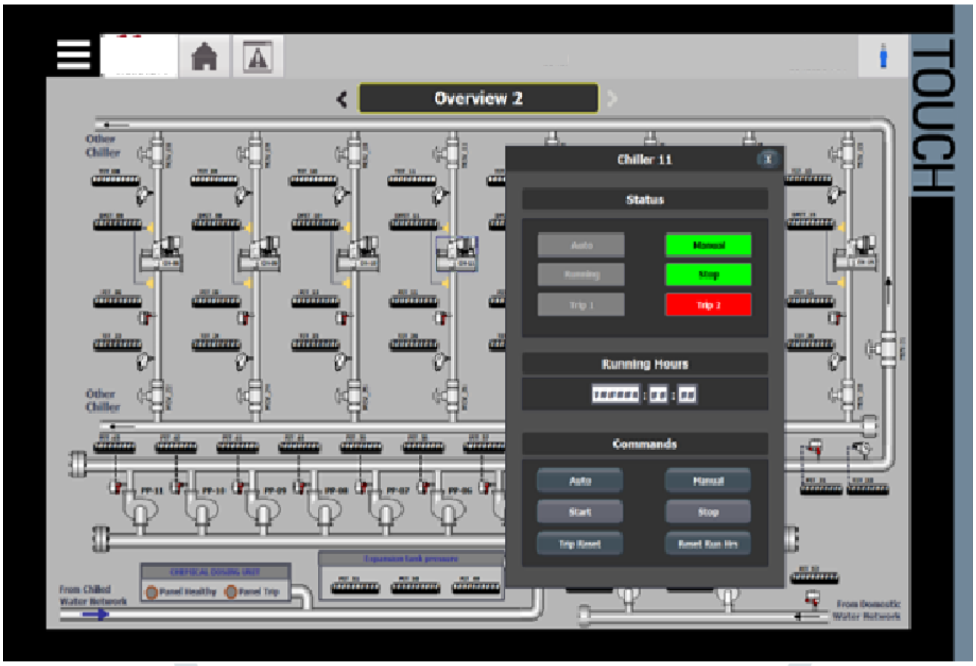

Fig. 10. HMI Screen

V. Results

The Simatic S7-400H controller has been used to automate the process with the input output configuration pins available are 140 AI, 101 DI, 37 AO, and 31 DO. Based on the plant state 0 (i.e., Idle) or 1 (i.e., Start) and simultaneously the input selected from HMI screen for Mode selection sets the rung energized (0=Manual mode, 1=Auto mode). Variable Set temperature is at 12℃, based on it the temperature difference is found.

For variable Temp Diff between 0.3℃ and 2℃, Start Trigger is set to 1 (high) for a preset delay of 1min and following respective pump, MOVs and chillers commands were set to 1 (high). Similar to the simulation for mode selection all other section of the program is simulated and tested by configuring it to the HMI. Similarly for variable TempDiff between -0.3℃ and -2℃, Stop Trigger is set to 1 (high) for a preset delay of 1min and following respective Chiller, Pump and MOVs were set to 0.

VI. Conclusion

In this work, PLC and SCADA have been used to monitor and manage the Chiller Plant for a building's more noticeable operation. PLC is utilized as hardware at the remote end to monitor and read field instruments for the predetermined temperatures, pressures, and other parameters as well as to regulate the chiller equipment in accordance with predetermined instructions.

The Simatic S7-400H controller is used to automate the process with the rated supply of 24V DC, achieved by implementation of SMPS for the input voltage of 230V. The input output configuration pins available are 140 AI, 101 DI, 37 AO, and 31 DO. The IO points is connected to the controller through additional remote IO modules. The communication is established between electrical panel with controller and the local SCADA i.e., HMI using 2 Ethernet switch. The PLC program that has been developed for the control philosophy, it observed that automation helps optimize the process as well as helps reduce energy consumption.

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