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Automation of ac system employing plc and Scada

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ABSTRACT

Air conditioners have become an important need in industrial and domestic places. On the other hand industrial automation tools provide a wide range of applications in control and monitoring of mechanical, power, automobile, telecommunication systems etc. Programmable Logic Controller (PLC) and Supervisory Control and Data Acquisition (SCADA) can be easily used as automation tool in HVAC industries. In this work we present the monitoring and controlling of AC system employed for more prominent work space using PLC and SCADA. PLC is used at the remote end as hardware to supervise and control the required air conditioning space. The ladder logic developed for programming PLC is provided which can also be implemented in monitoring and controlling of multiple AC systems in remote and local mode to operate either automatically or manually. SCADA is used to operate remotely by developing Graphical User Interface (GUI) using CIMPLICITY software. With all the features, this designed system is capable of efficient handling of the resources such as the compressor, blower, condenser etc. With all the levels of safety and durability, it maintains the temperature and control humidity levels within the official work place and also looks after the health of the compressor.

1. INTRODUCTION

Automation involves numerous technologies like robotics, telemetry, process measurement, sensors, control systems, expert systems, wireless applications etc. Automation employs control systems to operate a huge number of equipment's with least/ reduced intervention of human beings [1,2]. Many control systems are used to monitor and control the operation of Heating, Ventilation and Air Conditioning (HVAC) systems from distance employing different communication methods [3–5].

There are various industrial automation tools available which include Human Machine Interface, Manufacturing Execution System, Factory Automation Test, Programmable Logic Controller (PLC), Supervisory Control and Data Acquisition (SCADA) etc., [6,7]. SCADA systems are employed in many applications to supervise and control of remote instruments and processes [8,9]. In SCADA system the PLC can be employed as a process controller to communicate with it via networks. Air Conditioning (AC) System nowadays has become a need in industrial and domestic fields. Package AC employs huge blower and is used to cool larger area either at office or home [10–12], [13–16]. The Package AC system works in remote mode and local mode in which the compressor, blower and heater are controlled remotely or manually accordingly.

Inspite of various advantages of PLC and SCADA, no work is reported on remote monitoring of AC system using PLC and SCADA except [17-19], in which a very few brief results were discussed. The results presented in this paper are in detail and give in-depth idea of working of AC system in remote and local mode. Hence, in this study we present the design and working of Package AC system employing SCADA as a software and PLC as hardware. SCADA is used at the operator end (which is at some distance from the working field) and PLC is used as a process controller at the required AC system.

2. DESIGN OF THE AUTOMATION SYSTEM

Table 1. Devices and components used

Part	Specification	Part	Specification
PLC-CPU	Versamax micronano 28 point plc IC200UDR005	Switches	Emergency push button, start push button, stops push button, toggle switch, selector switch
SCADA software	CIMPLICITY	Contactors	MNX Type TP CS94980
Communication module	RTU modbus SNP protocol	Thermostat	Honeywell T6360A5013 (two numbers)
Power supply	24 VDC	Humidistat	Honeywell H600A
Digital inputs	16 inputs	Indicators	24 VDC (5)
Digital outputs	12 inputs (relay contacts)	Timer	ETR 650
Relays	24 VDC		

In the current package air conditioner considered for study, uses different devices and switches and the same are mentioned in below Table 1. To measure the conditioning parameters like temperature and humidity the current package AC system consists of thermostat and humidistat. The various digital input/ output devices and switches used to operate the system are mentioned in the below table. The ladder logic created in PLC for operation of AC system using Proficy machine edition 6.0 programming tool in described in the following section. The communication between the AC system and PLC is established employing using RTU modbus SNP protocol as communication module. The conditioning parameters are stored in the PLC register using SCADA software. GUI screen is created in SCADA which facilitates the operator to switch the blower/ compressor/ heater ON or OFF.

3. LADDER LOGIC AND FLOW DIAGRAM

The programming method adopted for PLCs are Ladder Logic. The logic is developed in PLCs software Proficy Machine Edition V.6.0. The flow chart for developing the ladder logic for working of AC system is as follows For PLCs, the main programming technique adopted is Ladder logic. It is developed to mimic relay logic. Since the control operation is carried in PLC, logic is created in PLC's software Proficy Machine Edition V.6.0 and simulated by enabling run mode in PLC. The flow chart for creating the ladder logic for operation of AC system and the design and development of ladder logic is explained as follows.

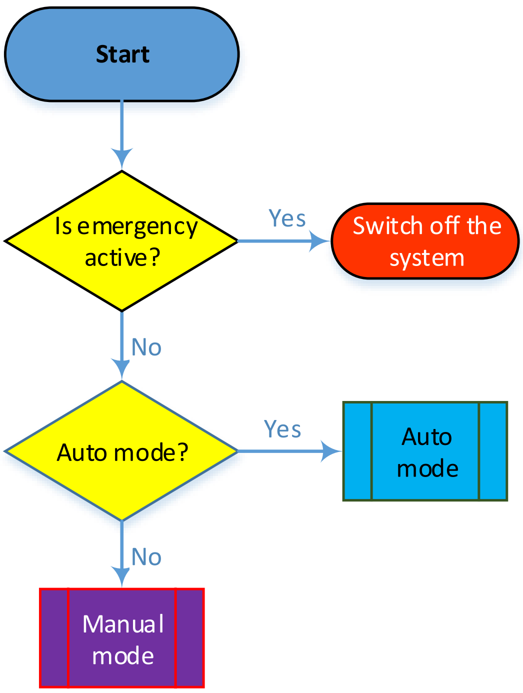

Figure 1. Flow chart for selecting mode

The flow chart in Figure 1 discusses ladder logic formed for AC system operation in different modes. The control has inputs and outputs. The system is developed to work in two modes i.e., manual mode or automatic mode of operation. The system initiates with manual operation by the operator. The operator selects `start', 'switch' or `emergency switch' if system is healthy or faulty, respectively. If the system encounters any fault and needs to be shut down, the control panel is provided with the `emergency switch' functioned manually by the operator. If emergency switch' status is `OFF', it enters in the program flow, else entire system is shut down. The next step is mode selection, the control panel is provided with `auto/manual toggle switch', if required `AUTO' mode is selected else `MANUAL' mode.

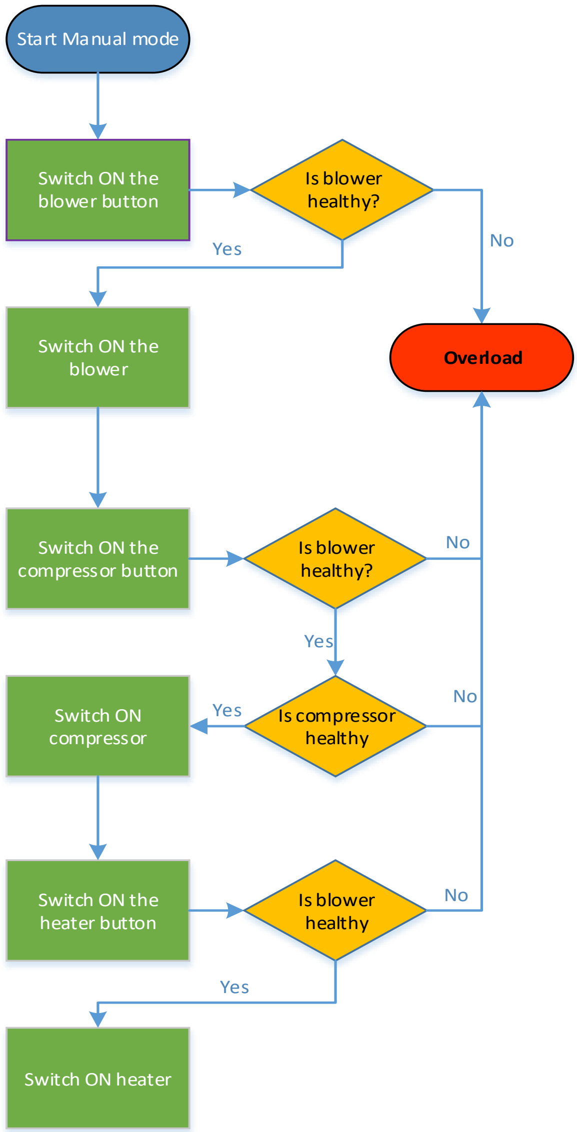

Figure 2. Flow chart for manual mode

In manual mode (Figure 2) of operation inputs are operated by operator physically. The operator first switches `ON' the blower by blower switch control, if the blower is in healthy condition without any fault then next step is taken else an overload state occurs and system waits till the fault is rectified. If blower is healthy, operator switches the compressor `ON', and then checks for healthy status of compressor, if fault is detected, overload state occurs or conditioning of air continues. If humidity is beyond the threshold value (Normal range from 45%to 55%) operator uses heater to reduce the humidity level. The prerequisite for heater to be `ON' is that the blower status should be `ON' else heater switch remains inactive. The Auto mode of operation (Figure 3) is selected by the operator by toggling auto/manual switch to low state. After the selection of auto mode, the system is working without human or operator intervention.

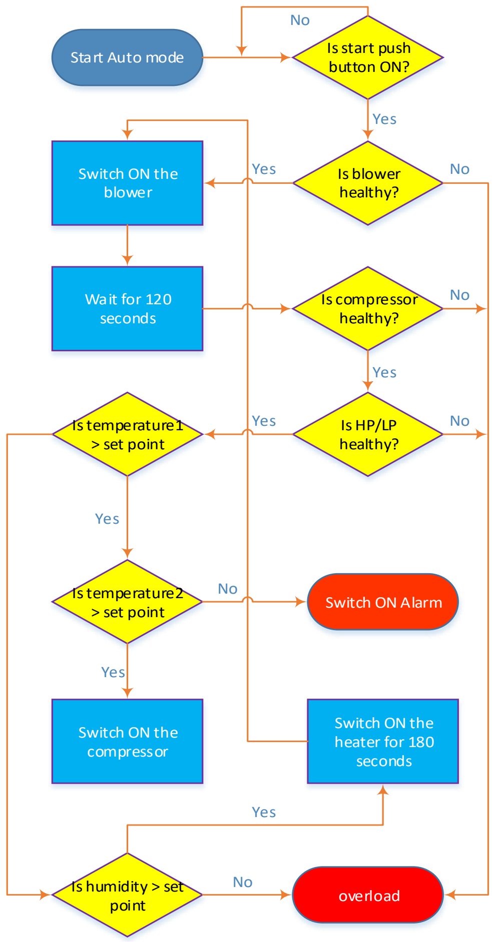

Figure 3. Flow chart for auto mode

In `AUTO' mode, the operation starts with status check of blower, if blower is found healthy without any fault then output is put onto PLC output coil to switch on the blower. If blower is `ON' then second step is to switch `ON' the compressor, but the compressor is switched `ON' by the output compressor coil with a delay of 120 seconds for healthy operation of compressor and the overall system. The other condition met before the compressor to be `ON' is checking the overload status of compressor, if found faulty it goes to step 1 and waits for fault correction (overload). In the `AUTO' mode operation, the system executes in response to temperature and humidity sensors (thermostat and humidistat). The system uses two thermostats to set two threshold set points, first thermostat is used by the system to control and second is used to indicate system condition beyond control, and system needs to be modified. If the blower is `ON' system checks for temperature set point 1, if it is greater than the threshold value, compressor is switched `ON' for conditioning. When the compressor is switched `ON' the continuous monitoring of temperature is in loop, if temperature drops below the threshold value after conditioning, the compressor is automatically switched OFF. In faulty system or system limits exceed the control conditions i.e. if in the air condition system temperature exceeds second threshold point (2nd set point), the operator has to be informed about system malfunction or system overload condition to rectify or modify the system functionalities. The buzzer output alarms the operator if thermostat 2exceeds second set point. The operator switches the system down and in case of manual mode after overload conditions entire system is shut down automatically by PLC. The other condition that system encounters is increase in humidity of the plant environment. The prerequisite for the controlling heater for humidity control is the temperature of environment is to be less than threshold value (set point 1). If the temperature is less than first set point, humidity set point status is checked by humidistat, if greater than threshold value (55%) heater is switched `ON' else it goes to initial temperature status (set point 1) check. The `AUTO' mode is continuous monitoring and control process in infinite loop till status operator decides to switch in different mode.

4. WORKING AND IMPLEMENTATION OF THE DESIGNED SYSTEM

The Figure 4 shows the proposed SCADA system with selection of remote mode selected by the operator. The operator can have a selection on control panel using a toggle switch or on GUI screen by using remote/local mode status dialog box which is programmed in control mode i.e. the ON click of status bar the command is propagate to PLC to actuate the respective outputs of the PLC. The initial conditions show that the blower, compressor, heater is in OFF state since operator has not issued any command from the GUI screen. The Figure 5 also describes in remote mode by default the auto mode is selected or can be operated in manually on click of particular status bar. The continuation of the process is upon selection of Remote mode, the system in auto mode is programmed to switch on Blower on system start. On dialog Box “operate only in Remote mode” operator can select compressor on/off command to switch ON or OFF the compressor on click of this status bar for confirmation a popup window appears with a message as shown in Figure 6 “do you wish to change value from 0(OFF) to 1(ON)”. On confirmation command is issued from GUI screen to PLC output for switching on the compressor via Contactor. The Figure 7 shows the system in remote mode, upon auto mode selection and command issued by operator console, the compressor status has switched ON with shifting its color from Red to Green. The operator has this selection because its decision is based on status bar indicates Temp 1> set. The other status bar indicates such as Blower Olr, HP/LP trip as healthy condition as appears in green color. The Figure 8 shows the system is operated in Local mode on operator selection on operator console as Local mode status bar as indicated as Local mode in Yellow colored dialog box. The initial conditions show the blower, compressor and heater in OFF condition. In local mode the operator has a choice to opt manual/auto mode with manual or auto status/command bar. The Figure 9 shows the operator has selected manual mode indicating the system will be controlled from the control panel with switch button rather than GUI Screen console bars. The control no longer exists at screen on switching ON/OFF the blower, compressor or heater.

The Figure 10 displays the GUI screen with blower ON status, the screen displays the monitoring status of respective outputs on the screen but controlled manually from the control panel. The Figure 11 shows the compressor status has changed to green from red status upon operator switching ON the compressor with some delay as blower is already in ON condition. The temperature1 is greater than set point, the compressor is switched on until the conditioned space reaches the normal temperature level. The operator can manually know the status on screen to take the decision or observe the control panel indicators. The Figure 12 demonstrates the GUI screen of proposed system in Local mode. After the selection of local mode on operator console in screen the user has to select whether to operate in manual mode or auto mode. The auto mode selections give the capability to the system to take its decision based on the program in PLC. On auto selection its takes its decision based on sensory inputs and outputs are actuated accordingly. The Figure shows the Temp1 > set points indicating the first thermostat has exceed the first threshold, the output is actuated to switch On the Blower, the blower will be switched on if the overload conditions are fulfilled if the blower Olr status is healthy it switches the blower ON.

The Figure 13 shows the continued process after the blower is ON in auto mode the compressor is switched ON after a delay of 120 seconds with pre requisites of Blower On and compressor olr healthy. The compressor remains in this state till the temperature 1 status fall below the set point in conditioned space named as Hoysala. The Figure 14 shows the system working in auto mode in local mode selection. The status bar indicates the temperature2 exceeds the second set point indicating High temperature, indicating single compressor is insufficient to condition the work space area, this condition rarely exist and alarms the operator to shift on back up or extra compressor or second package unit. The system can be modified for this condition by the operator. The Figure 15 is illustrations of Compressor getting overloaded with compressor olr status bar turning it Red. It prevents the compressor to turn it on or switches it OFF if the compressors overload trips. The Figure 16 is illustrations of blower getting overloaded with blower olr status bar spinning it Red. It prevents the blower to turn it ON or switches it OFF if the blower overload trips. The Figure 17 indicates the emergency switch is switched ON. The emergency status bar on the screen is programmed as status and command bar that indicates the emergency status also on click of this bar the status of the system changes. The emergency switch can be operated from the GUI screen or from control panel at the control area. On selection of this switch by the operator the status bar turns RED and command is issued by the PLC via relay and contactors to switch OFF or shut down the whole system.

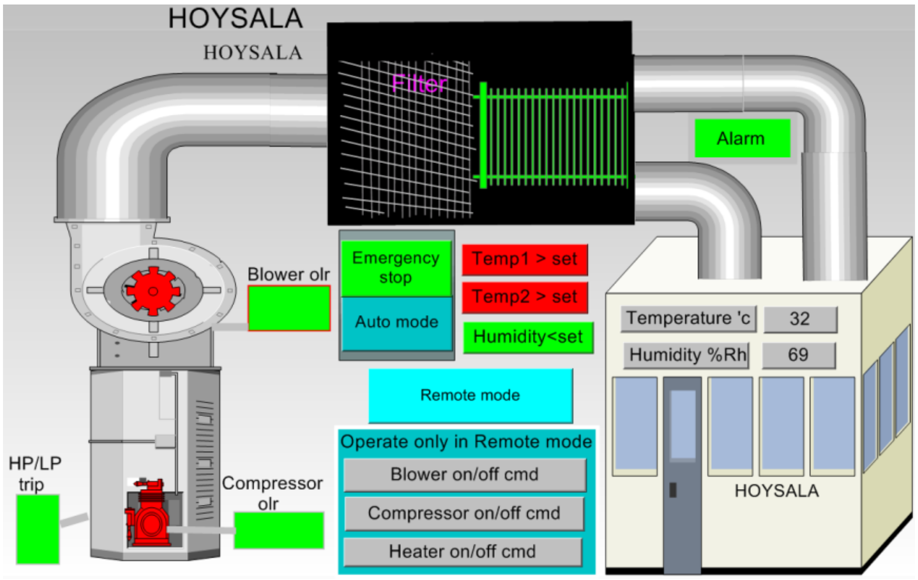

Figure 4. Proposed SCADA system (GUI screen)

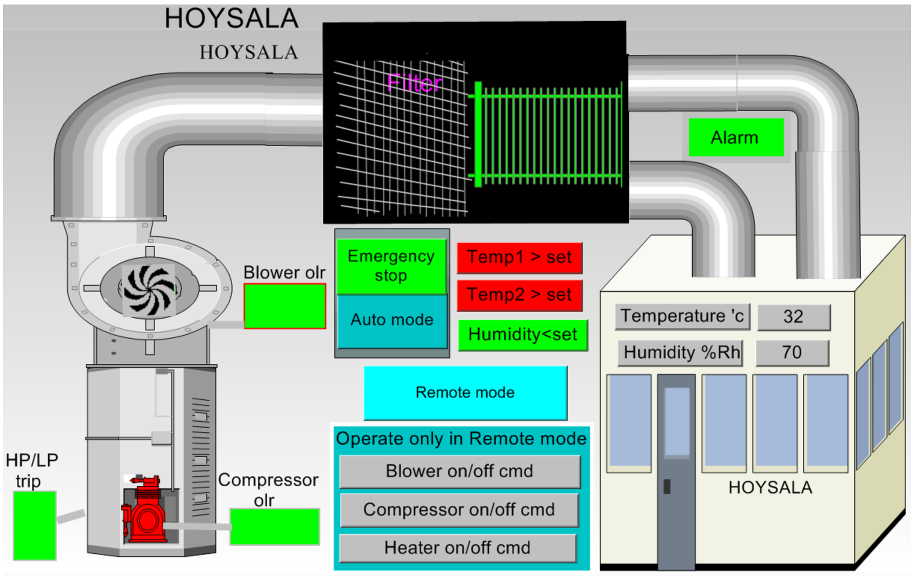

Figure 5. GUI screen in remote mode with auto mode selection

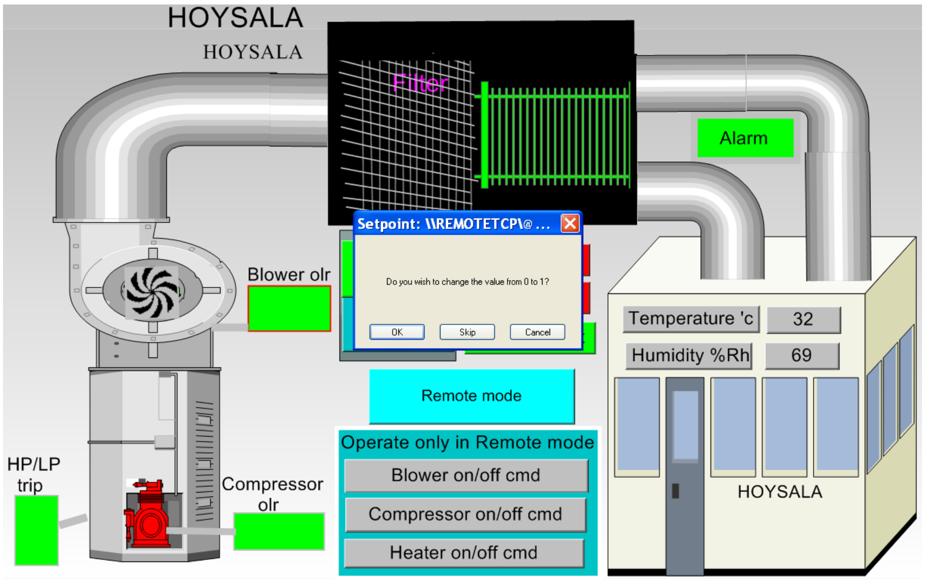

Figure 6. GUI screen in remote mode with dialog box to control individual components

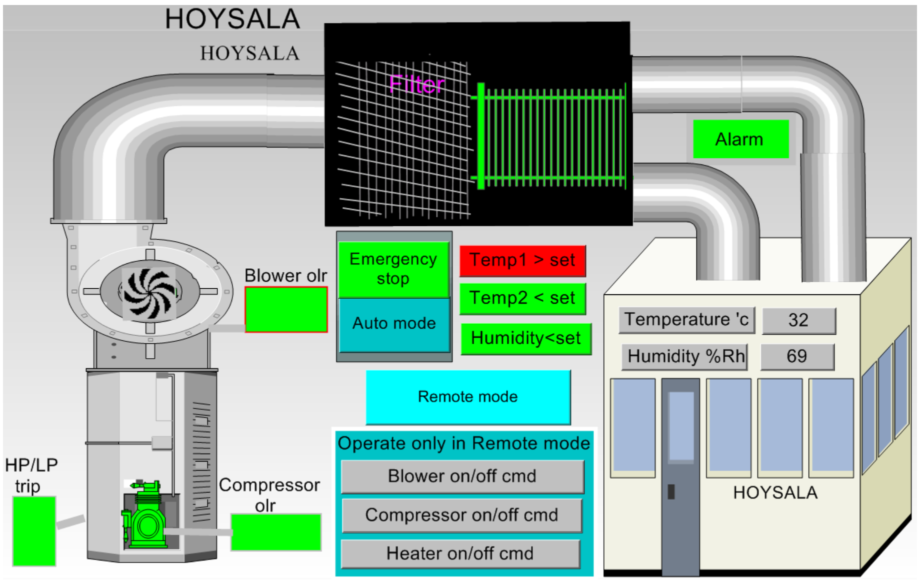

Figure 7. GUI screen in auto mode with blower and compressor ON

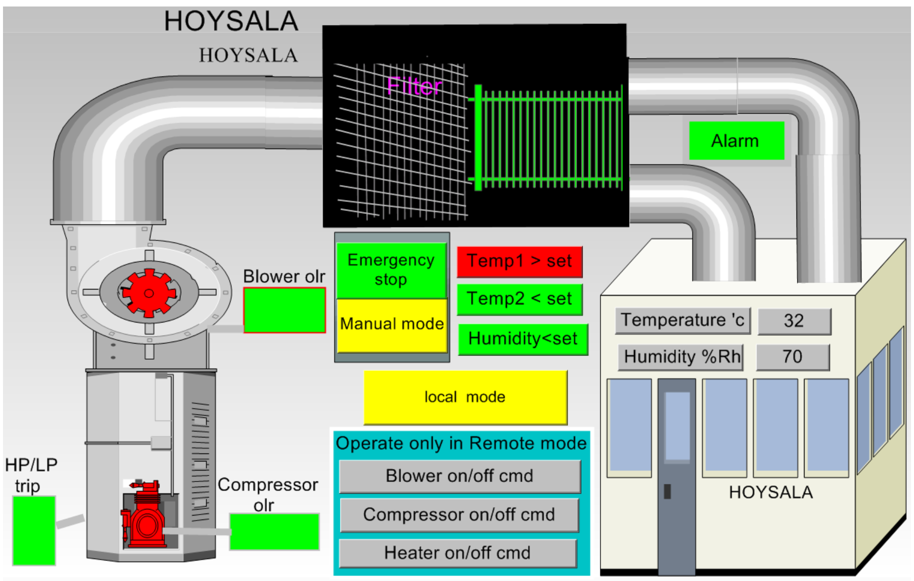

Figure 8. GUI screen in remote mode with manual mode selection

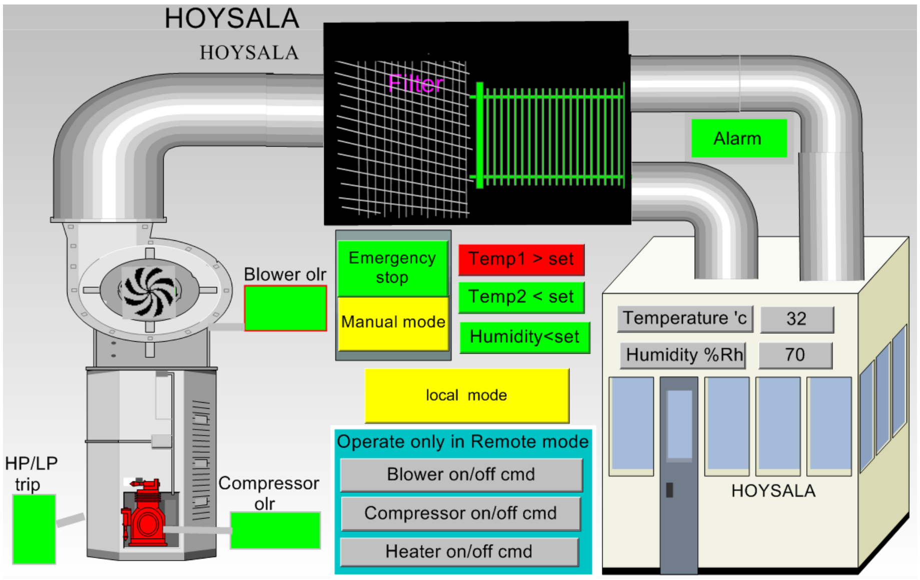

Figure 9. GUI screen in local mode with auto mode selection with blower ON status

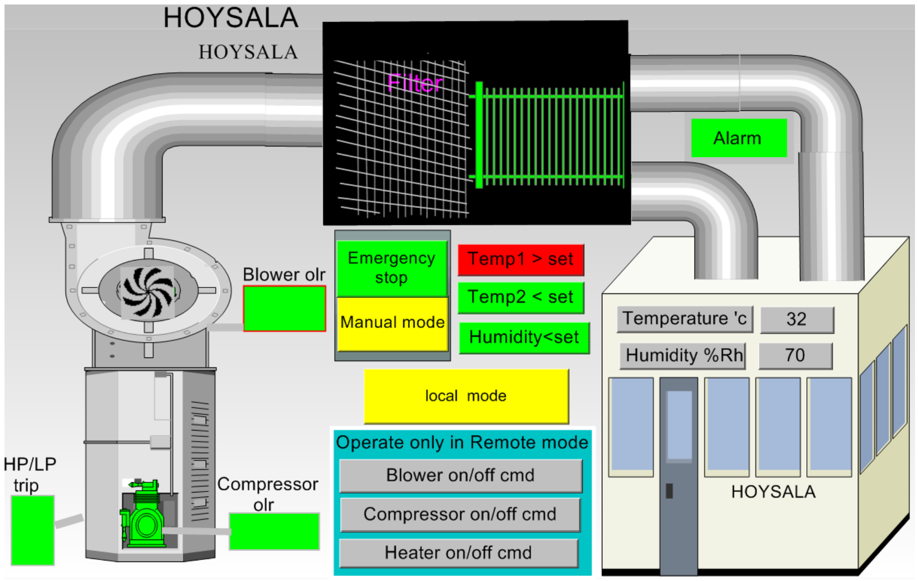

Figure 10. GUI screen in local mode with auto mode selection with blower and compressor ON status

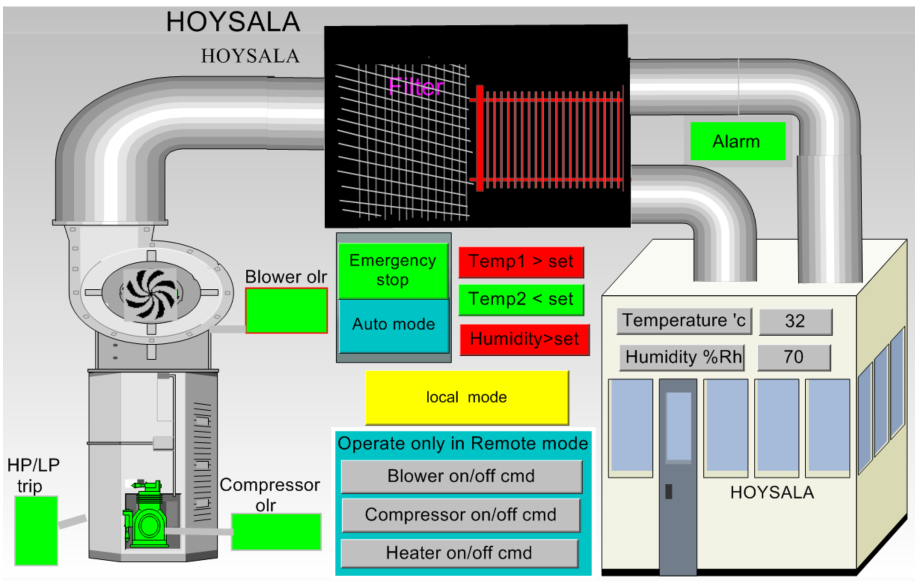

Figure 11. GUI screen in remote mode with auto mode selection with heater ON status

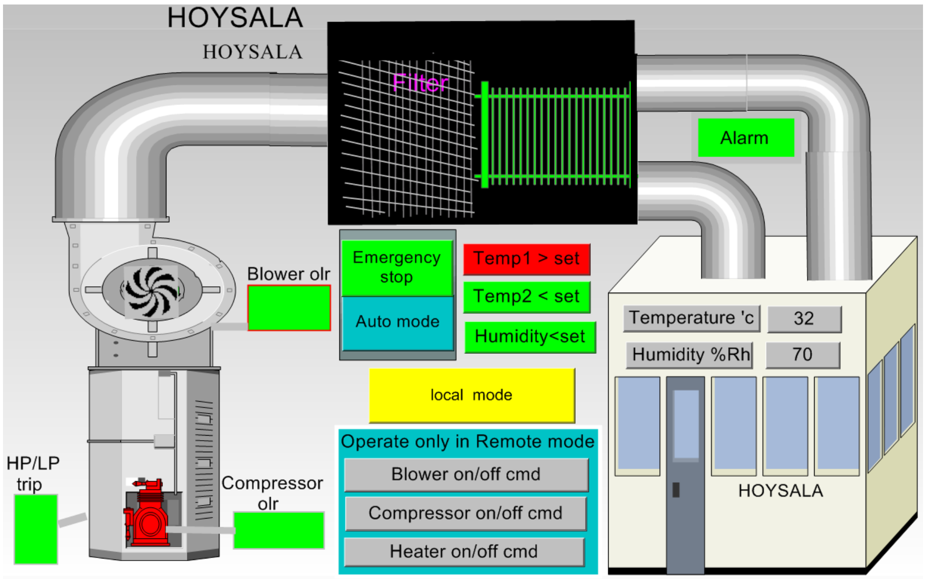

Figure 12. GUI screen in local mode with auto mode selection with blower ON status

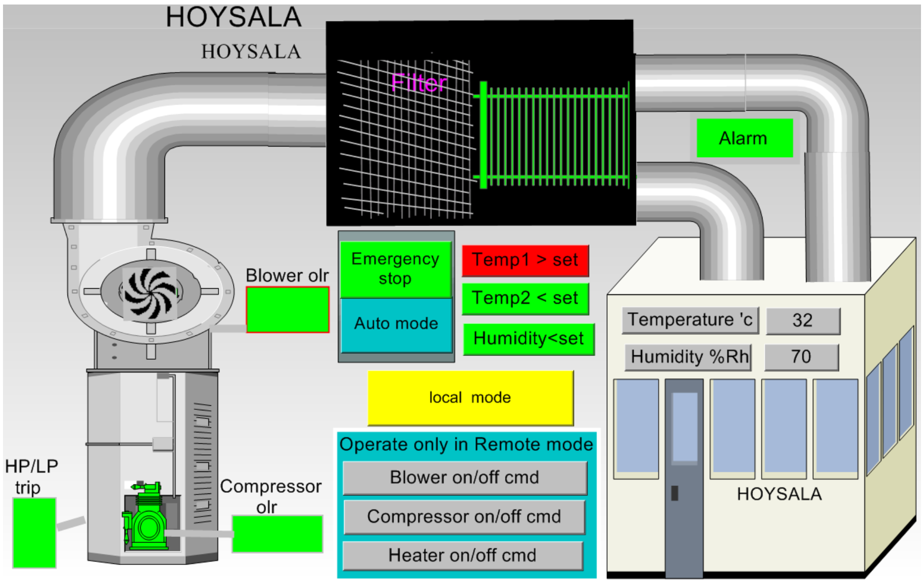

Figure 13. GUI screen in local mode with auto mode selection with blower and compressor ON

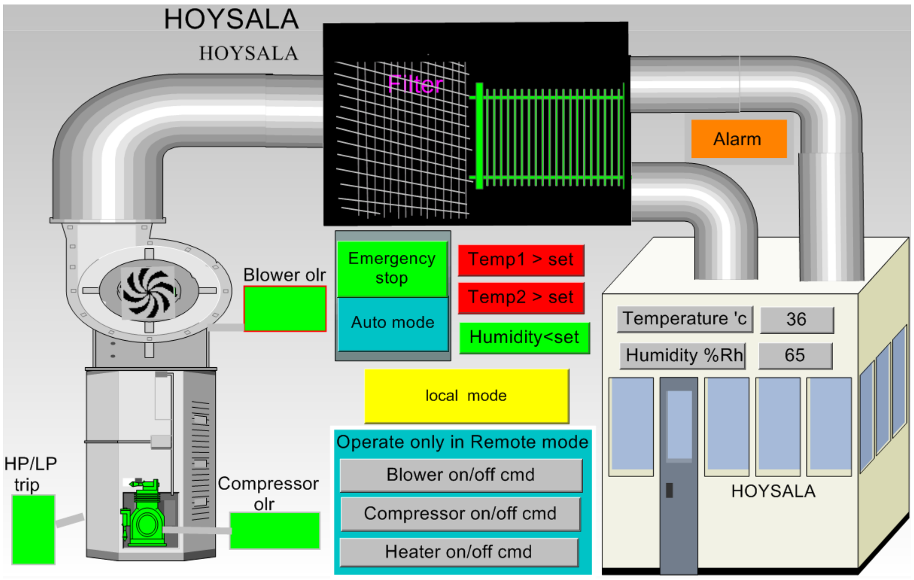

Figure 14. GUI screen in local mode with auto mode selection with Alarm ON status

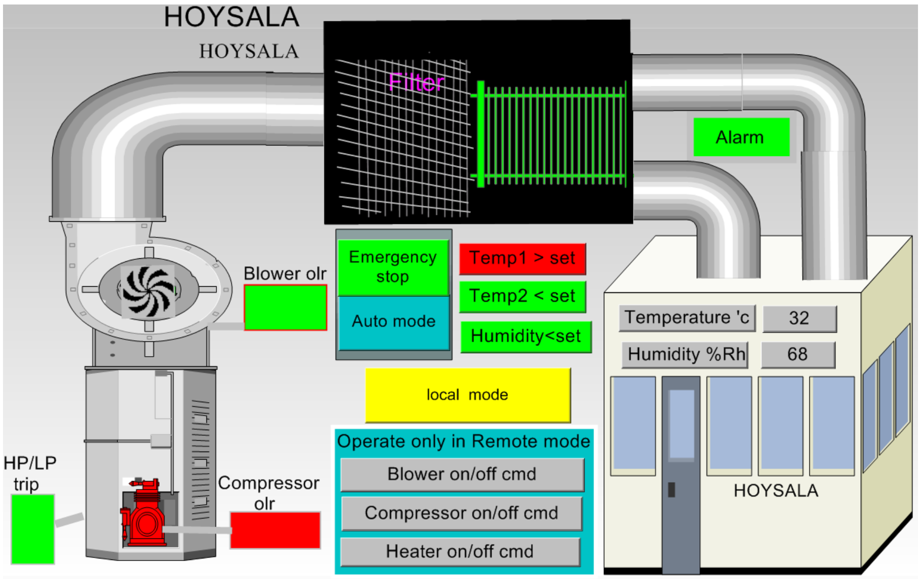

Figure 15. GUI screen in local mode with auto mode selection with compressor overload status

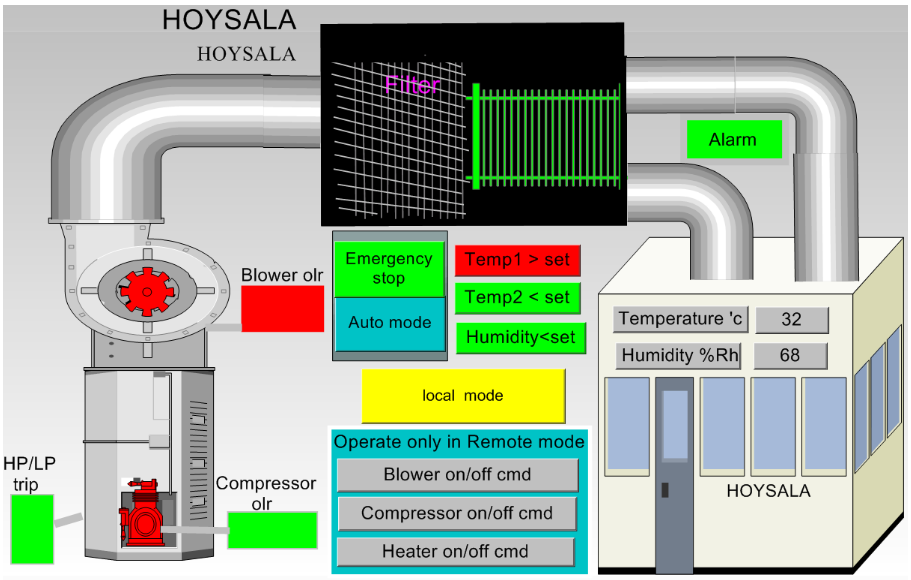

Figure 16. GUI screen in local mode with auto mode selection with blower overload status

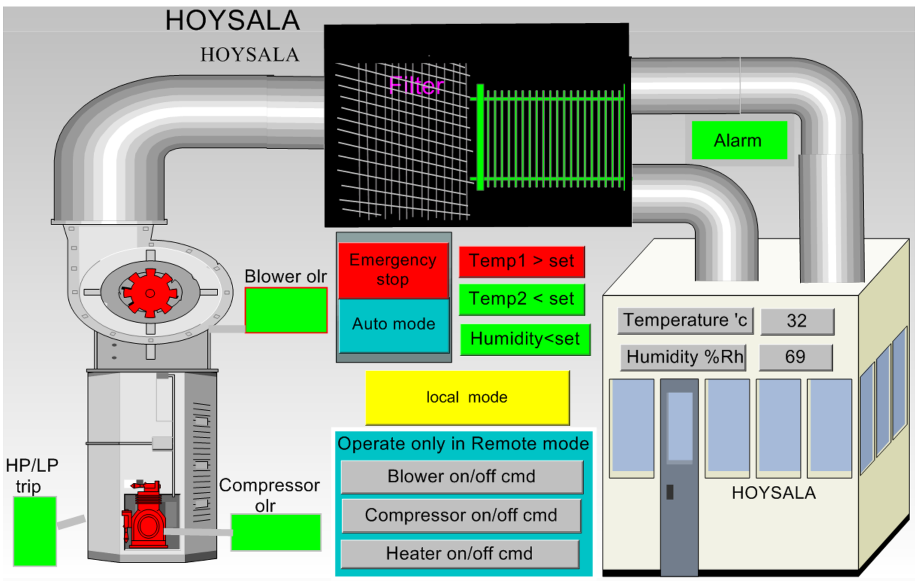

Figure 17. GUI screen in local mode with auto mode selection with emergency switch ON manually/automatically

5. CONCLUSION

In the present work we have designed an automation system to control and monitor AC system in remote mode and local mode. These modes can be operated automatically or manually using PLC and SCADA. The following are designed and implemented in the automation AC systems:

- Parameters like temperature, humidity, pressure etc., are determined for setting the set points for AC system.
- Created the ladder logic in PLC for operation of AC system using Proficy machine edition 6.0 programming tool.
- Established the communication between AC system and PLC using RTU modbus SNP protocol as communication module.
- Created GUI screen in SCADA for control and monitoring for operation of AC system.
- Stored the required AC system parameter in the PLC register for control and monitoring purpose using CIMPLICITY HMI/SCADA software.

The designed system for package AC system offers a programmable and cost effective control for wide range of package ACs. The designed system verifies safety interlock conditions before starting the sequence of operations. With all the features, this designed system is capable of efficient handling of the resources such as the compressor, blower, condenser etc. With all the levels of safety and durability, it maintains the temperature and control humidity levels within the official work place and also looks after the health of the compressor. Therefore this design can be implemented, modified, duplicated and optimized to use for multiple packages Air Conditioning systems to supervise and control remotely. In this type of AC system, to increase the comfort conditions more parameters can be considered like CO_2 monitoring, ambient temperature monitoring, blower speed control, power optimization of compressor etc. The system can be precisely controlled and monitored with analog values of parameters: PLC with analog inputs and outputs enhances the system accuracy and efficiency.

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