HVAC AND LIGHTING CONTROL USING PLC AND SCADA FOR INTEGRATED BUILDING MANAGEMENT SYSTEM

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Abstract

Building Automation Systems (BAS) aims to improve efficiency, comfort, productivity, and the flexibility of buildings in the future. One of the major challenges in today's society concerns the reduction in energy use and CO2 footprint in existing public buildings without significant construction works. Building automation enhances protection and convenience. Benefits of using an advanced BAS includes Monitoring of several systems from one place, Interaction for more efficient control strategies, Remote service etc. Effective control of the heating, ventilation and air conditioning (HVAC) and lighting systems in a building is essential to provide a productive, healthy and safe working environment for the occupants. This paper presents effective control of HVAC and lighting systems in BMS by the use of Allen Bradley SLC 500 PLC along with wonder ware in touch SCADA for monitoring and management to control building conditions. Integration of two or more PLC's can be used to control and automate collaborative systems of building management system [1]. With reference to figures 3 to 4 different methods for identification and control of atmospheric air were studied as explained in [2]. Authors in [3] presented control strategies for HVAC and lighting systems to control air handling unit operations. PLC-SCADA functionality is explained in [4]. For effective lighting, standard luminance control is explained in [5].

Keywords: *BAS; BMS; PLC; SCADA; HVAC etc..*

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1. INTRODUCTION

The main aim of BAS system is to improve control and management of mechanical as well as electrical systems in buildings. The Purpose of this project is to provide comfort and energy savings in laboratories, cleanrooms, warehouses, offices, and manufacturing spaces, industries, houses for Integrated Building Management. The control variables are temperature, humidity, enthalpy and luminance. The basic functionality of system can be divided in three main parts as below.

1.1 Field level

The devices like temperature sensors, pressure sensors, humidity sensors, enthalpy sensors, actuators, motion sensors, smoke detectors, valves, dampers, fans, card readers, motors, light switches etc. are the field devices which physically controls and detect the building functions. They are located on field. Air temperature is the most common measure of comfort, and the one that is most widely used. The field network connects the actuators, sensors and other field level devices to controller in automation level. They are connected by means of hard wired, bus system, power line or wireless etc.

1.2 Automation level

The automation level includes the advanced controllers like PLC that controls and regulates the field level devices in real time. Programs are stored in RAM of PLC to initiate different control actions according to changes in building conditions.

1.3 Management level

All devices that manages and monitors the building automation system and that communicates with personnel and internet are included on management level. Examples of these devices are database which logs activities, web servers, operator panels, CCS (central control station), servers that translate messages into different protocols etc.

2. SYSTEM DESCRIPTION AND ARCHITECTURE

Fig. 1 represents the architectural block diagram of system integration. Computerized control will help to achieve more critical control tasks than conventional one. Use of PLC in co-ordination with SCADA will ensure more increased performance as compared to relay logic systems.

2.1 Relay Logic

Combinational logic implementation in electrical control circuits by using several electrical relays wired in a particular configuration is nothing but relay logic control. In this all system components are connected by means of hard wired connection hence the system flexibility is very low which means that if we want to change the connections in the system then whole system has to be redesigned.

2.2 PLC

The programmable logic controller (PLC) is nothing but the heart of system which controls the system operations in the form of ladder programming. Ladder programming is the most widely used programming language in PLC. This is more accurate and advance way of automation than relay logic control. Some of advantages of programmable logic control are:

1. Low cost for controlling complex systems.
2. Flexible and can be reprogrammed to control other systems quickly and easily.
3. Computational abilities allow more sophisticated control.
4. Easy programming and low downtime.
5. Long life and reliable operations.

2.3 SCADA

SCADA (Supervisory Control and Data Acquisition) is nothing but the combination of telemetry and data acquisition systems. It is used to collect information, to transfer it back to a central site, to carry out necessary analysis and control, and then to display this data on a number of operator screens. Hence this system helps to monitor and control a plant or equipment by means of either automatic control or can be initiated by operator commands.

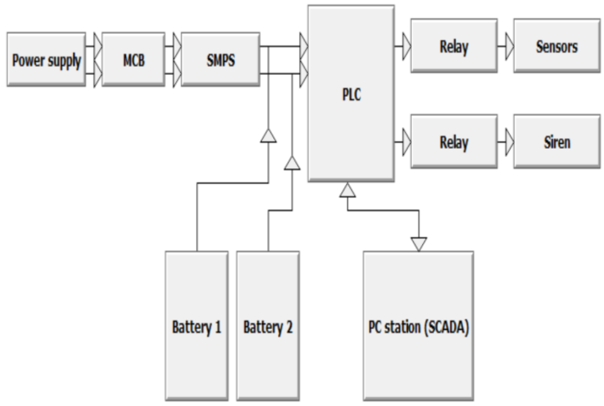

Fig-1: System architecture

3. HEATING, VENTILATION AND AIR CONDITIONING

Fig. 2 shows the schematic of central air conditioning plant. The main components of central air conditioning plant are compressor, shell and tube type condenser, shell and tube type chiller, motor, expansion valve, condenser water pump, cooling tower, air handling unit, fresh air duct, supply air, chilled water pump, expansion tank, supply air diffusers, return air diffusers etc. The process of central air conditioning plant is divided into four different cycles as refrigeration cycle, condenser water cycle, chilled water cycle, and air cycle. Air handling unit is the basic component in HVAC and hence optimization of air handling unit will result in substantial increase of HVAC performance.

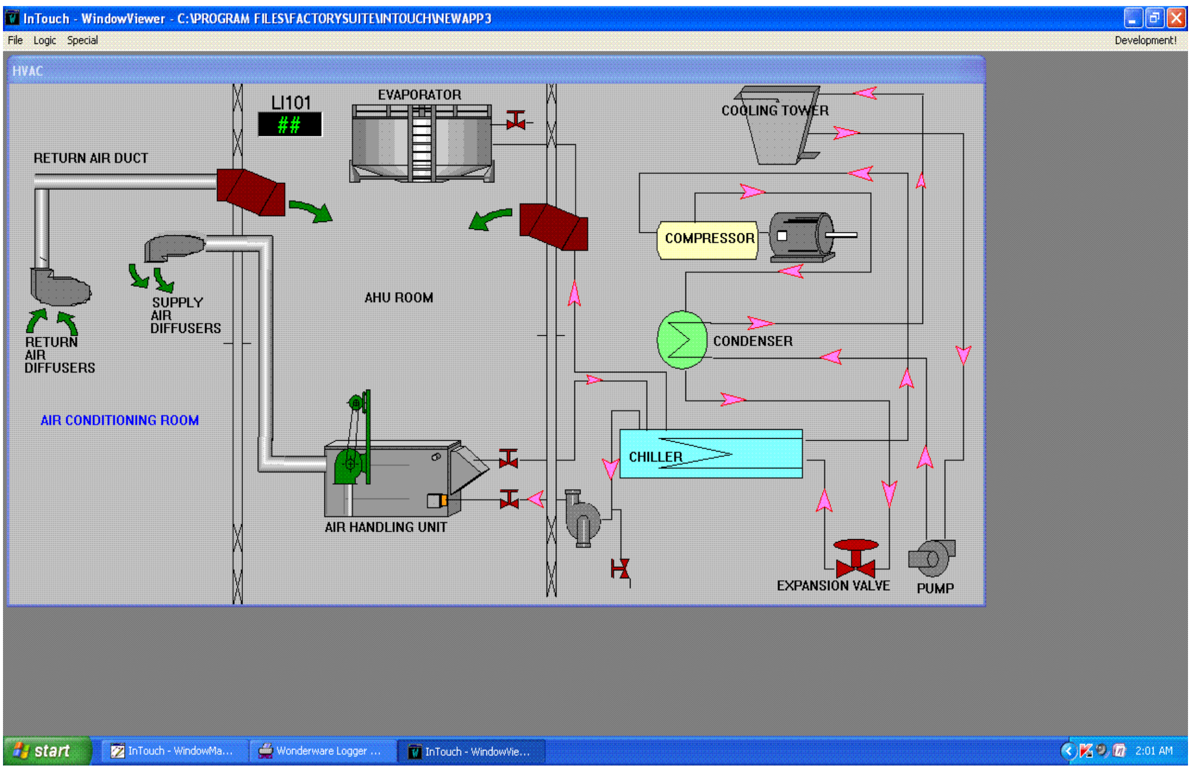

Fig-2: Process flow diagram of HVAC

3.1 Comfort zone

Fig. 3 defines conditions of comfort zone for specific values of variables. The corners of region drawn with dotted lines represents comfort zone. Thermal comfort is the concept which expresses satisfaction with the thermal environment and is assessed by personal evaluation. It is a behavioral condition within which a person operates in an anxiety neutral situation. One of the important goals of HVAC design engineer is to maintain this standard of thermal comfort for occupants of buildings or other enclosures.

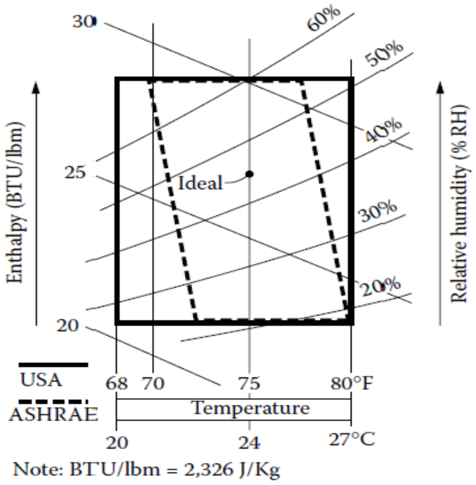

Fig-3: Comfort zones in terms of temperature, humidity and enthalpy

3.2 Air Handling Unit

An air handler consist of a motor, blower, heating or cooling elements, filter, sound attenuator, and dampers. These are usually connected to a ductwork ventilation system which distributes the conditioned air through the building and returns it to the AHU.

A typical air handler components are outside air damper (OAD), return air damper (RAD), filter (F), heating coil (HC), cooling coil (CC), humidifier (H), dehumidifier (CC), variable air volume damper (VAV), reheat coil (RHC), exhaust air damper (EAD).Normally the air handler operates with various types of mixed air. It is said to be in purge mode when it operates with full outside air. Optimization of air handling unit can be done by using methods like
1. Letting the building heat itself
2. Use of free cooling or free dying
3. Optimizing start up timing
4. Optimizing supply air temperature
5. Minimize fan energy use
6. Automating the selection of operating modes
7. Automating balancing of air distribution.

These above tasks can be done with the use of PLC in collaboration with SCADA software for automatic monitoring and control of air handler.

3.3 Operating Mode Selection

Fig. 4 shows the various operating modes which can be identified by observing status of the air handler components. Figure shows ON mode of operation. The basic operating modes are startup, occupied, night, and purge. Depending on the status of actuating devices and fans the various operating modes are identified and can be changed accordingly.

Operating Mode or Emergency Condition	*Supply Fan*	*Return Fan*	*Outside Air Damper*	*Exhaust Air Damper*	*Return Air Damper*	*Coil Control Valves*	*Alarm*
Off	—	—	C	C	O	C	—
On	On	On	← Modulating →				—
Warm-up	On	On	C	C	O	O(HC)	—
Cool-down	On	On	C	C	O	O(CC)	—
Night	← Cycled to maintain required nighttime temperature →						
Purge	On	On	O	O	C	Modulating	—
PSH-2	—	Off	—	C	—	—	Yes
PSL-3	—	Off	—	C	—	—	Yes
S/F-4	Off	Off	C	O	C	C	Yes
TSL-5	Off	—	C	—	O	C	Yes
PSL-6	Off	—	C	—	O	—	Yes
PSH-7	Off	—	C	—	O	—	Yes
S/F-8	Off	Off	C	O	C	C	Yes

Fig-4: Status of various actuated devices during various operating mode

3.4 Summer/Winter Mode Reevaluation

Fig.5 shows the strategy to calculate heat balance. Unlike conventional systems in computerized system summer or winter mode of operation is reevaluated by calculating heat balance equation. IN this Fc is cold deck flow, Ho is outside air enthalpy, Fe is exhaust air flow, Tc is cold deck temperature, Fh is hot deck flow, This hot deck temperature, He is exhaust air enthalpy, Tm is mixed air temperature.

$$\text{Net air handler load } Q0 = Q1 + Q2 + Q3 - Q4 + Q5 - Q6$$

When Q0 is negative then summer mode is required, and when Q0 is positive then winter mode is required.

3.5 Auto Balancing of Buildings

Fig. 6 represents auto balancing of area of the building, in this goal is to find the required optimum value for the set point of the supply air pressure controller (PIC). Supply air temperature (AT) and return air temperature (RT) are taken as input along with the zone temperatures.

After 4 min again the zone temperature is detected as ZT4 and zone temperature after 8 min of operation is detected as ZT8.
The above readings were compared with the values shown in fig.7 below which serves as the basis for determining the required startup openings of each of the VAV boxes (XSET-1, XSET-2, and so on). If the zone temperature after 8 minutes of operation is already within 5°F of reaching the comfort zone, the VAV box can be left at its minimum opening else a higher opening is needed.
Implementation of this logic will ensure that the VAV boxes on those zones that are furthest from comfort and that are moving most slowly toward comfort will be given the highest openings.

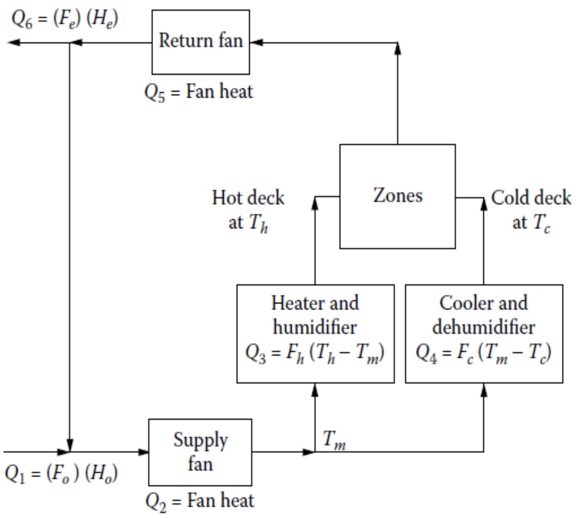

Fig-5: Summer or winter mode reevaluation

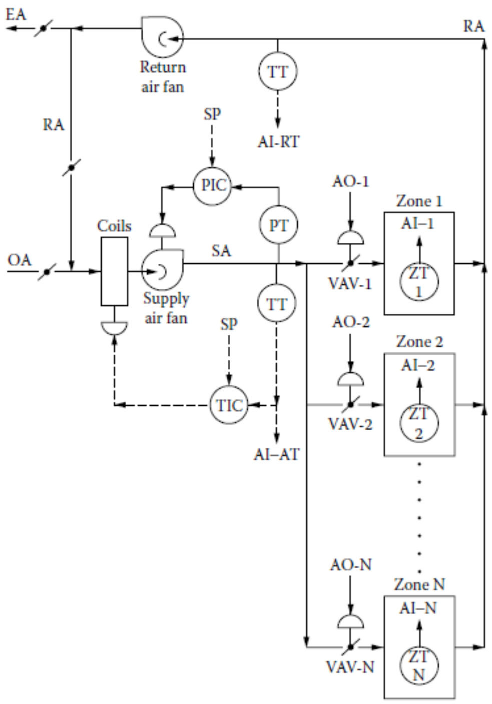

Fig-6: Air handler optimization and auto balancing can be handled efficiently by computer

4. LIGHTING CONTROL

The term lighting control deals with an intelligent networked system of different devices which maintain sufficient light inside that particular area. For optimum control of light energy lighting control strategies includes time switching, daylight Harvesting, occupancy control, time switching and manual control, daylight harvesting, occupancy detection and manual control etc.

Input Conditions			Output
Operating Mode	*Approach between Zone and Supply Temperatures*	*Amount of Temperature Change During Last 5 Minutes of Start-Up*	*Initial Value of XSET to be Used for AO-1 to AO-N (%)*
Heating (AT > RT)	(TL – ZT10) > 5°F	(ZT10 – ZT5) < 0.5°F	100
		(ZT10 – ZT5) 0.5–1°F	90
		(ZT10 – ZT5) 1–1.5°F	80
		(ZT10 – ZT5) 1.5–2°F	70
		(ZT10 – ZT5) 2–3°F	60
		(ZT10 – ZT5) 3–4°F	50
		(ZT10 – ZT5) 4–5°F	40
		(ZT10 – ZT5) > 5°F	30
	(TL – ZT10) < 5°F	Disregard	25
Cooling (AT < RT)	(ZT10 - TH) > 5°F	(ZT5 – ZT10) < 0.5°F	100
		(ZT5 – ZT10) 0.5–1°F	90
		(ZT5 – ZT10) 1–1.5°F	80
		(ZT5 – ZT10) 1.5–2°F	70
		(ZT5 – ZT10) 2–3°F	60
		(ZT5 – ZT10) 3–4°F	50
		(ZT5 – ZT10) 4–5°F	40
		(ZT5 – ZT10) > 5°F	30
	(ZT10 - TH) < 5°F	Disregard	25

Note: °C = (F – 32)/1.8.

Fig-7: Algorithm to determine start up openings of individual VAV boxes

4.1 Constant Illuminance Control

With respect to table1 particular values of luminance necessary for the specific areas can be selected. IN constant lighting control a light sensor is fixed which measures the luminance. This measured value which is actual value is compared with the predefined set point value and the control valve is adjusted so that the divergence between the set point and actual values is minimal. If it is brighter the artificial lighting is reduced. If it is darker the artificial lighting is increased.

Table-1: Standard values for lighting of residential buildings

Room	Place	Reference plane and its height	Standard value for illumination (Ix)
living room	general activities	horizontal plane 0.75m above the floor	100
living room	writing and reading	horizontal plane 0.75m above the floor	300
bedroom	general activities	horizontal plane 0.75m above floor	75
bedroom	bedside and reading	horizontal plane 0.75m above the floor	150
dining room	-	the top of a dining table 0.75m above the floor	150
kitchen	general activities	horizontal plane 0.75m above thefloor	100
kitchen	worktop	worktop	150

5. SIMULATION RESULTS

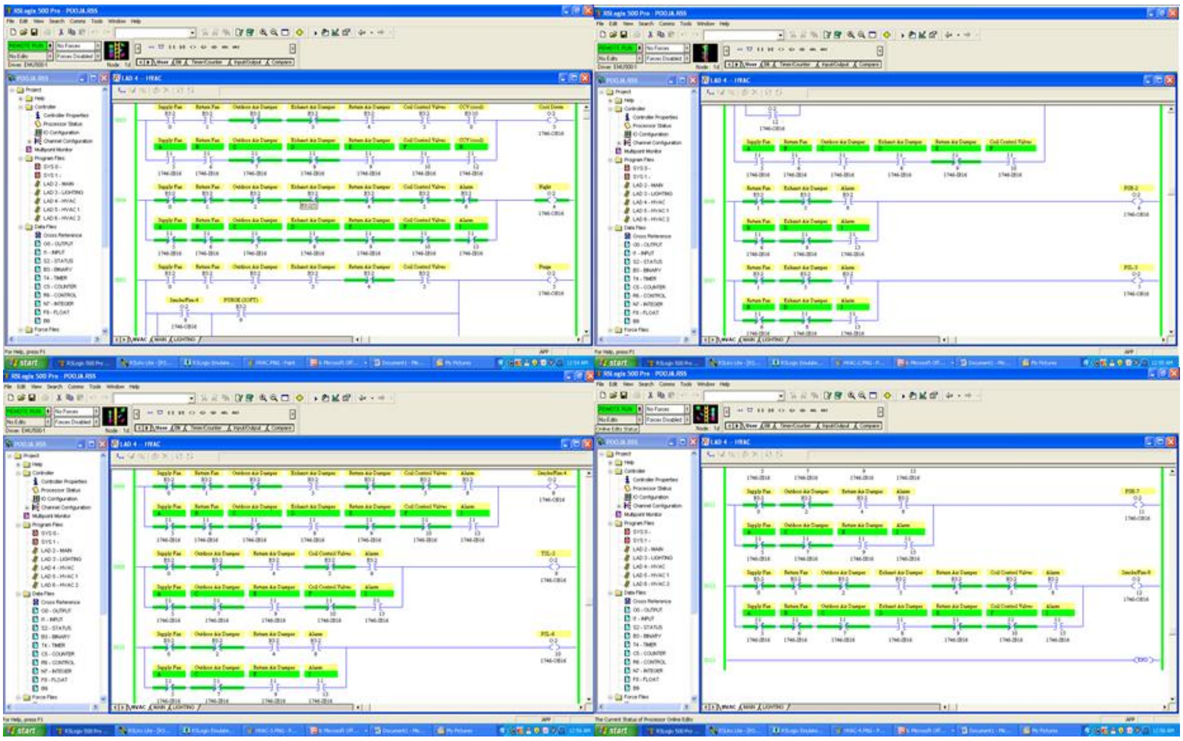

Fig-8: Status of various actuated devices during various operating modes programming for PLC

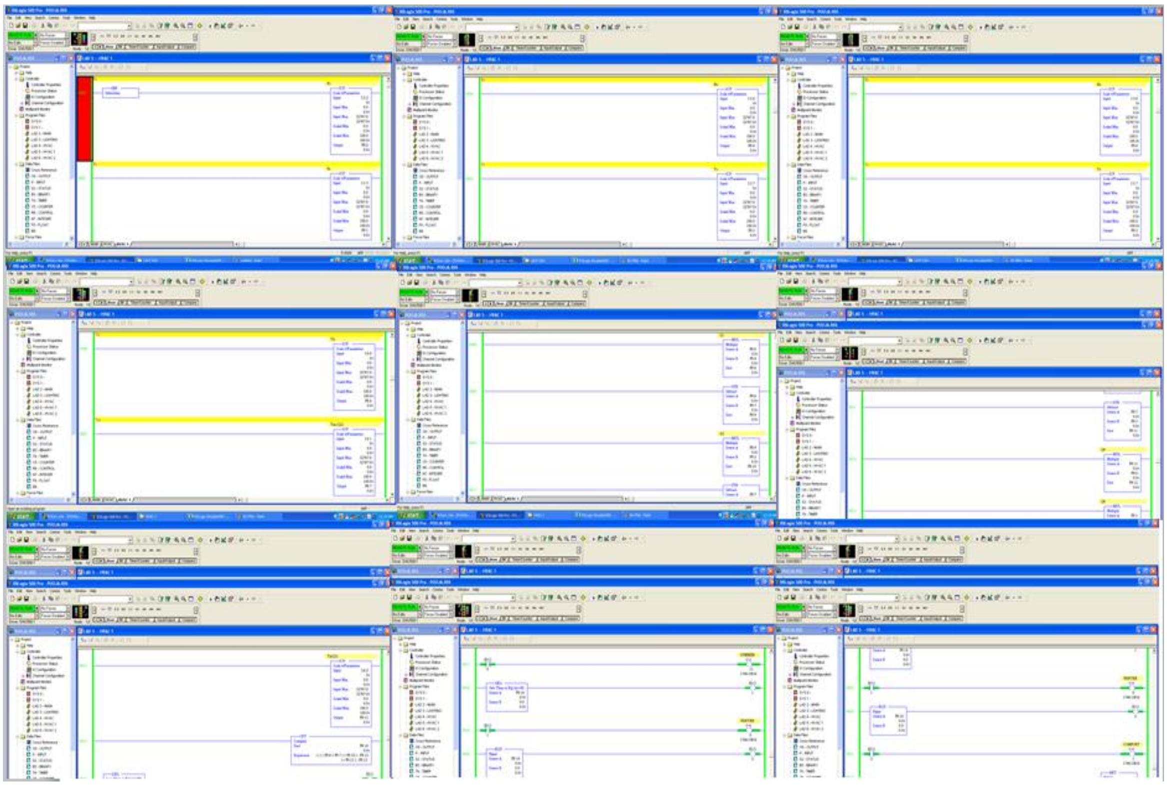

Fig-9: Summer or winter mode selection programming for PLC

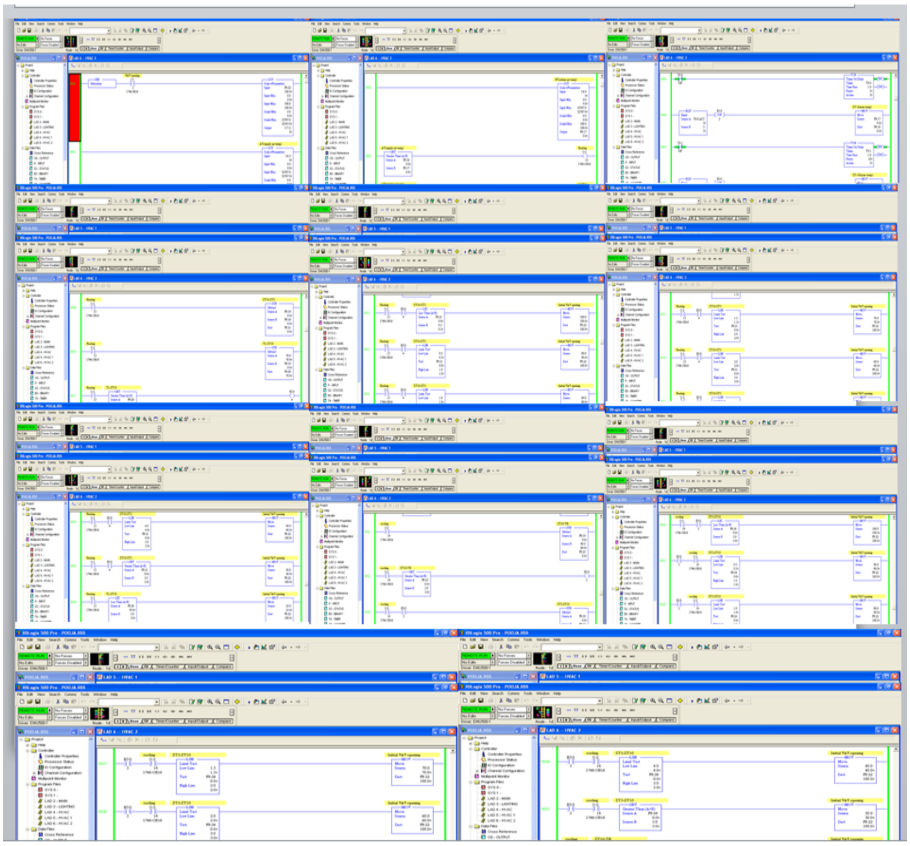

Fig-10: Programs in PLC to determine start up openings of individual VAV boxes (XSET)

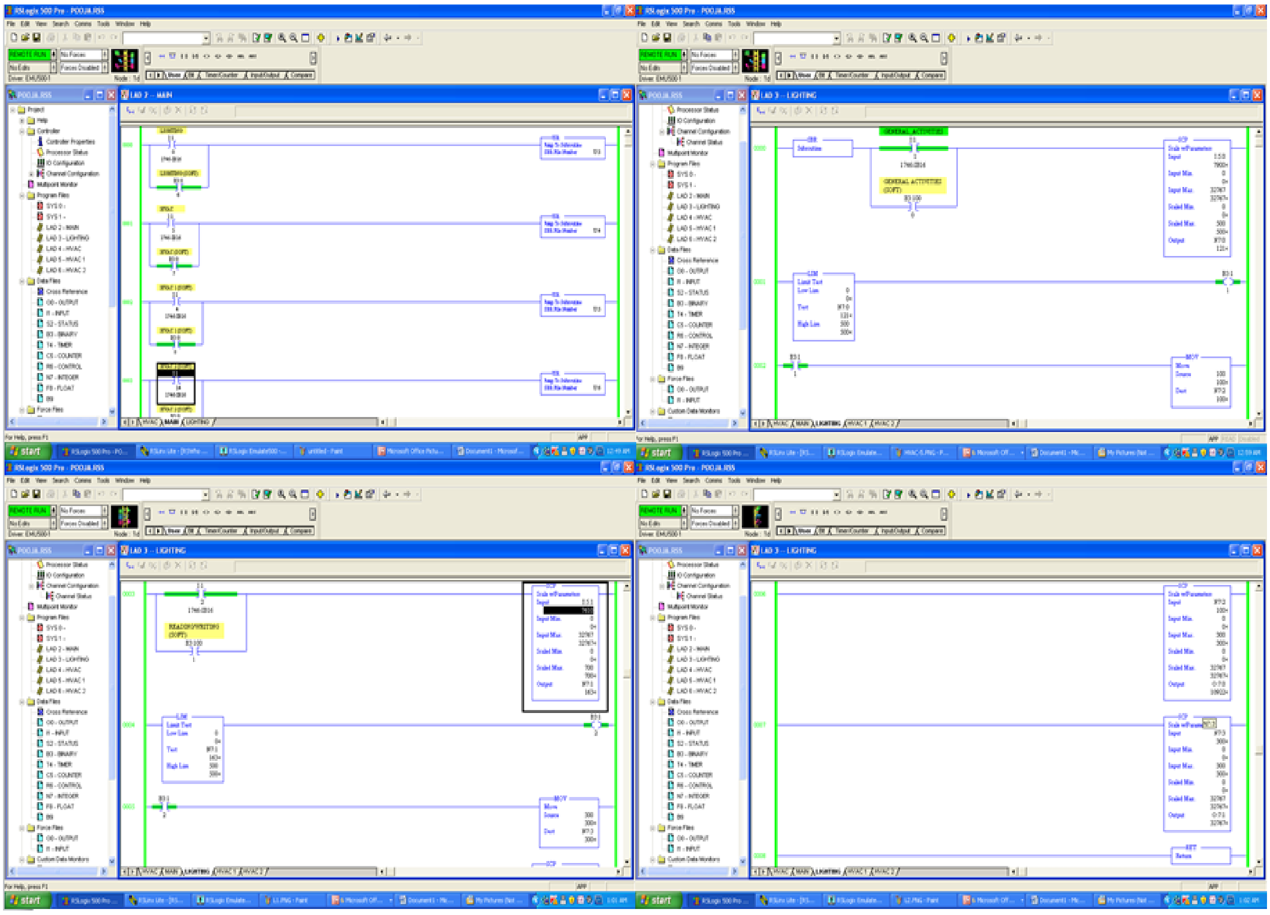

Fig-11: Constant Illuminance control programming for PLC

Fig-12: Representation for status of various actuated devices during operating mode ON in SCADA

Fig-13: Graphical representation in SCADA for summer or winter mode selection

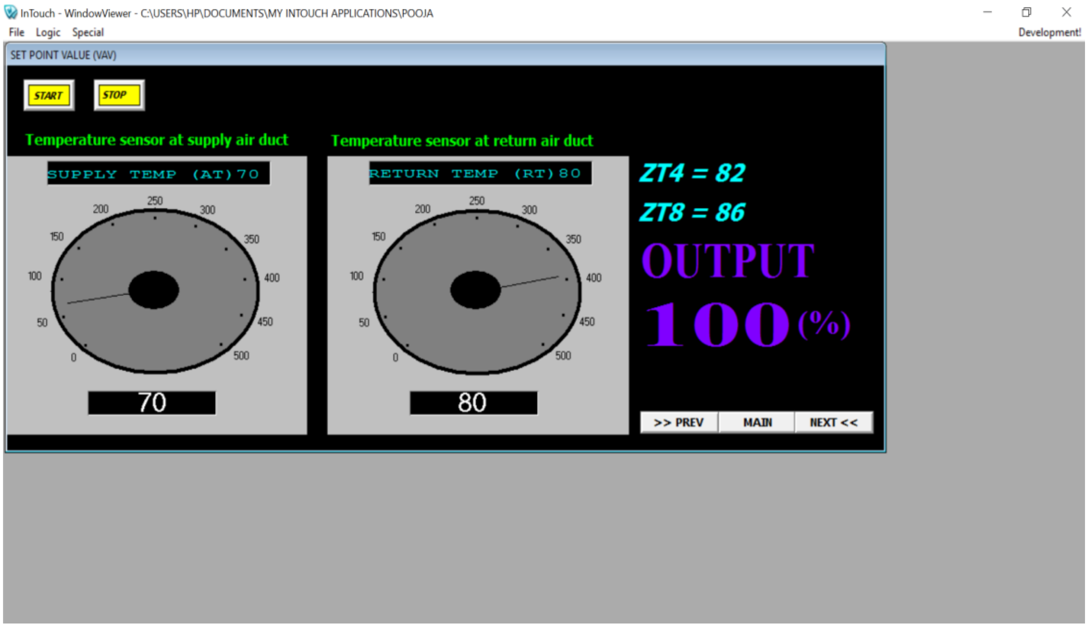

Fig-14: SCADA representation for set point selection of VAV

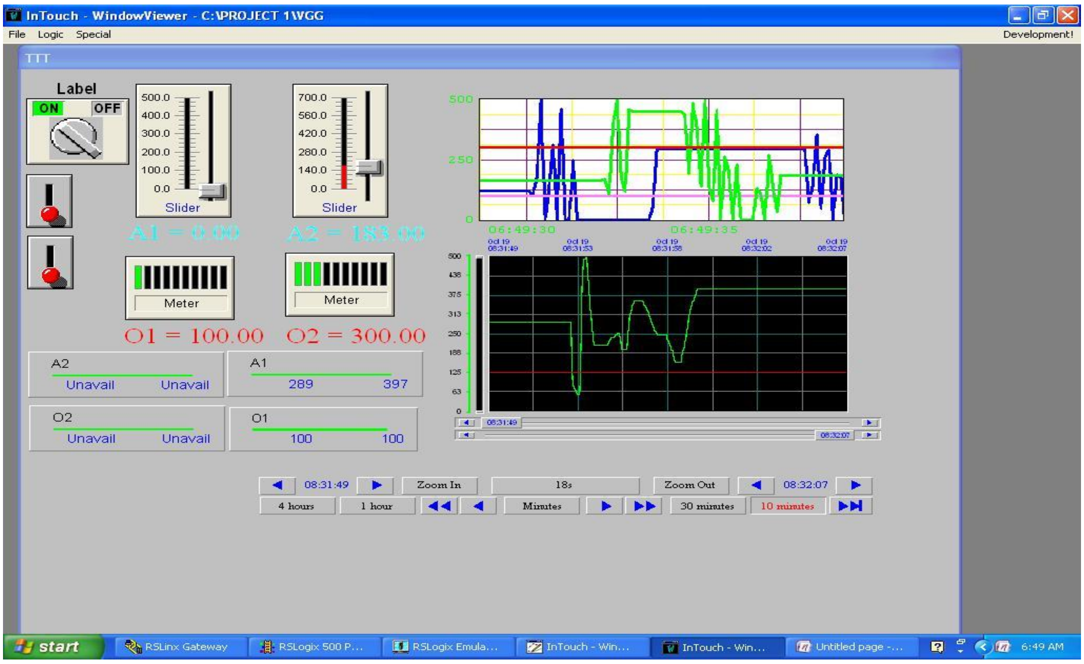

Fig-15: Constant Illuminance control using SCADA

6. CONCLUSION

In this paper, the results of HVAC and Lighting control have been worked out. It is found that Actions of retrofitting on building envelopes or services to reduce energy consumptions are not always possible or economically convenient in existing buildings and in particular for historical buildings where conservation is a matter of priority. Nevertheless savings can be achieved by designing computerized logic (PLC-SCADA)based service to monitor, control and manage air conditions, energy loads and plants operation.

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BIOGRAPHIES

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