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Programmable Logic Controller for HVAC Application

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ABSTRACT: Heating, Ventilation and Air Conditioning system (HVAC) is a system design that provides heating and cooling service to building or industry. The design of control system for HVAC system is to introduce automation in the HVAC process. This paper describes idea about design of control panel for HVAC application. In every industry there is focus on achieving energy efficient environment, hence during designing any HVAC system for industrial application, engineer have to propose control philosophy. Based on control philosophy, PLC panel specifications and load calculations can be done.

In accordance with current methodology used by industry, in the paper procedure for PLC panel design is introduced. This procedure will help engineers to understand design flow of PLC Panel in HVAC automation. The process starts from preparation of documents like Control Philosophy, Logic Flow Chart, IO list, specification, and layout. The Process of PLC manufacturing starts, in accordance with mentioned documents. After that testing and commissioning starts to check the functional correctness of controller and to ensure its safety requirements. After reviewing current industrial automation, additional concept of advanced alarm and notification system is introduced here can be future work for safety purpose.

KEYWORDS: HVAC, PLC, P&ID, IO List, LFC, control philosophy, block diagram, layout, commissioning.

I. INTRODUCTION

Programmable Logic Controller can be used in automation of industry as well building. This paper discuss about industrial automation in HVAC application. System on chip concept is evolving. [1] shows research on conversion of PLC language in to VHDL language which shows advancement in the PLC design. This paper is an informative article which describes procedure of PLC design in HVAC area. Starting with customer specifications, design engineer have to do work on accurate load calculation and energy modeling with use of guidelines given in the ASHRAE90.1 handbook to achieve energy efficient system. Electrical and automation engineer works on that to achieve final requirement of HVAC design. This paper describes whole process from proposing control philosophy of PLC Panel to actual implementation of PLC panel in the industry.

Need of HVAC systems for industrial applications are increasing exponentially. Manufacturing industries have their own heat exhausting machineries, hence it becomes essential to remove that hot air and maintain ventilation in the plant. HVAC plays important role to provide cooling service in the industry. HVAC system designed by engineer completely depends upon temperature or humidity requirement in the plant and customer's requirement. Programmable Logic Controller (PLC) used to maintain automation in the system. Temperature and Humidity maintained in the plant using some plant instruments like Temperature Sensors, Humidity sensors, which provides process humidity and temperature input to PLC. Depending on that input PLC provides output signals as digital or analog depends on control philosophy. PLC contains IO modules with interfaces, programming ports, memory.

ES 61131/3 control system programming standard states 5 languages for PLC system design[2] -1.Ladder diagram(Ld), Structured Text(ST), Instruction List(IL), Sequential Flow Chart (SFC), Function Block Diagram (FBD).Ladder language is one of the PLC language which is simple one and widely used for PLC programming. Details of PLC referred from books[3] and internet browser[4] Manufacturing of PLC starts after finalization of panel Specification. In accordance this specification design engineer starts control philosophy document.

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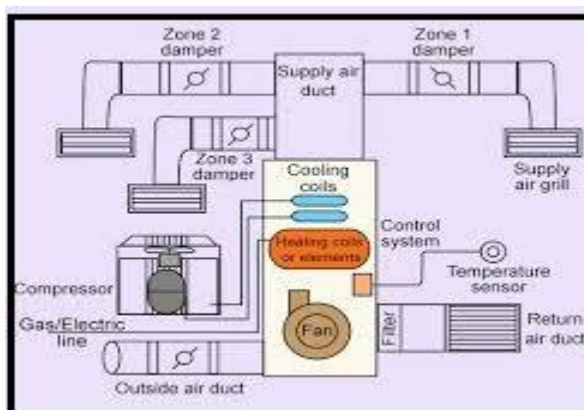
In general HVAC system contains number of equipments like Cooling Tower, Air Handling Units, and Exhausting Units, Connecting ducts etc. HVAC automation works on air flow control. PLC gives command to regulate air flow of Fresh and exhausted Air through duct. This regulating action achieved by using Variable Frequency Drive (VFD) and actuating dampers or valve. VFD's are present at motor side on equipment while instruments such as actuated dampers and valves present on duct. Number of instruments associated with plant gives informative data about current temperature and humidity. This information used as data log on PLC and used as feedback from plant to take necessary action.

II. RELATED WORK

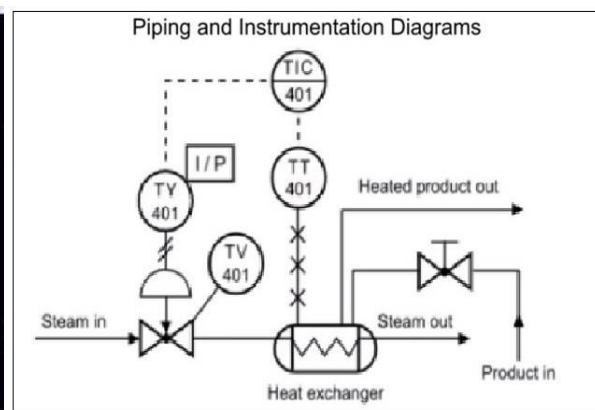
This paper describes general flow of PLC design in HVAC application and its sequence starting from documentation to implementation.

1. GENERAL CONTROL SYSTEM IN HVAC:

Control system in HVAC have number of instruments and sensors which gathers information such as temperature and humidity from plant and gives this as an input to the controller and output digital or analog signal generated by PLC depends on predefined control logic. There are temperature sensors in plant and actuated dampers on duct for modulating incoming and outgoing airflow. Supply air duct provides fresh air inside plant area, return air duct collects hot air from the plant area and outside air duct removes hot air by exhausting it to outside environment. Air cooling system contains number of mechanical equipments such as Air Handling Unit, cooling tower, exhaust fan etc. PLC provides control on air flow through duct to achieve required temperature and humidity in the plant area. Sensors allocated in area wise manner will take process parameter reading for monitoring purpose.



a) Fig.1 HVAC Automation system in HVAC



b) Fig.2 Piping and Instrumentation diagram [5]

2. DOCUMENTATION FOR PLC DESIGN:

The process of PLC design starts from documents like writing of Control Philosophy, Logic Flow Chart, IO list, specification, and layout. The Process of PLC manufacturing starts, in accordance with mentioned documents. After that testing and commissioning is to check functional correctness and to ensure safety requirements.

2.1 Control Philosophy:

Control philosophy becomes helpful document to decide PLC specifications. HVAC engineer uses Piping and Instrumentation Diagram P&ID to derive control philosophy. Fig.2 shows sample P&ID is AutoCAD generated plant layout which briefly describes about location, label and total number of instruments. P&ID gives idea about Panel location and cable route. by referring P&ID and HVAC design goal, engineer proposes control philosophy document.

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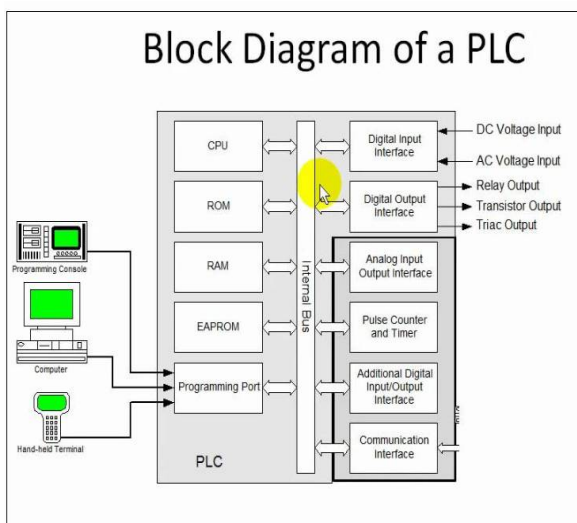
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Vol. 6, Issue 10, October 2017

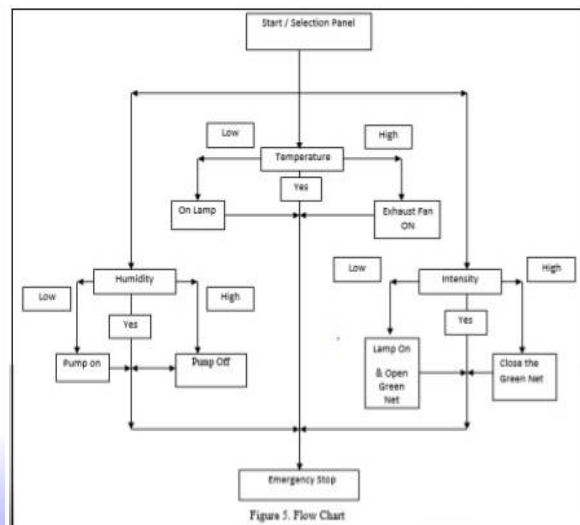
Based on control philosophy Input Output (IO) list finalized. After completion of control philosophy engineers start to work on Logic Flow Chart.

2.2 PLC Block Diagram:

PLC is programmable controller having on-chip memory and IO modules. Ladder programming used accordingly PLC gives modulating analog signal or digital on-off type signal in the system. PLC is a automation part which can only understand form of signal whether it is analog or digital and depends on processor requirement it converts analog to digital for at input module. Fig.3 PLC Panel block diagram [6] shows basic block diagram of PLC Panel in which there is Input analog and digital module for interfacing PLC with outside instruments. Through input module field signal will come to PLC. There is output module for interfacing PLC with valves and actuators. Memory is used to store data, CPU is central processing unit which generated integrated, proportional or differential output depends on programmed Ladder logic. There is communication and programming port for interfacing PLC with server or computer, RS232, Ethernet etc used for communication. PLC has memory section which stores data log for monitoring purpose



c) Fig.3 PLC Panel block diagram [6]



d) Fig.4 Logic Flow Chart [7]

2.3 Logic Flow Chart and IO List:

Logic Flow Chart is a document depends on which ladder logic can be built. Here we have taken HVAC application hence monitoring and setting temperature and humidity is goal of system design. Fig.4 Logic Flow Chart [7] shows an example how Logic Flow Chart describes flow of PLC work. LFC begins with Start condition after starting control logic controller will monitor temperature, RH and intensity. There are different condition blocks given. 1st for Temperature monitoring and controlling – if process temperature is less than required temperature then give on command to lamp else if it is higher than required one then just start blower of exhaust fan. 2nd for RH monitoring and controlling – if process humidity measured by RH sensor seems to be low than required humidity then give on command to pump else if it found to be higher than required then give off command to pumps. 3rd to measure intensity. This 3rd one logic generally not required for manufacturing industry application where as for home or building automation it becomes beneficial to maintain intensity Accordingly PLC design engineers can design different control logic depend on Logic Flow Chart.

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 10, October 2017

IO-Input and Output Module:

PLC can understand only analog and digital signals and depends on number of analog and digital, input and output engineer have to select supporting IO modules. For future use generally extra spare IO's considered at the time of designing. There are four IO modules provides input / output interface with controller. 1st Analog Input Modules-AI- Input signal is in the analog form. Example process temperature, RH measured by sensor gives input signal to AI since measured quantity is in analog form i.e. 4 to 20 mA. Any analog input from the field interfaced with PLC through AI modules. Table1 is describing AI list and type of signal, direction of flow of signal, range and unit. Since it takes analog signal as a input range of signal varies from 4-20mA or 0-10v depends on application requirement. It is called as modulating signal. Table2^[7] describes about digital signal input, generally this signals are describing status of equipment whether it is On or Off hence it also called as potential free signal type. Feedback signals are of DI type.

From	To	IO Type	signal	Min Ind. Range	Max Ind. Range	Unit	From	To	IO Type	signal	Min Ind. Range	Max Ind. Range	Unit
Field	PLC	AI	4-20 mA,2 wire	0	100	Deg C	EX FAN Z1 VFD PANEL	PLC	DI	Potential Free	-	-	-
Field	PLC	AI	4-20 mA,2 wire	0	100	Deg C	AHU1 BLR VFD PANEL	PLC	DI	Potential Free	-	-	-
Field	PLC	AI	4-20 mA,2 wire	0	100	%	AHU1 BLR VFD PANEL	PLC	DI	Potential Free	-	-	-
Field	PLC	AI	4-20 mA,2 wire	0	100	%	AHU1 BLR VFD PANEL	PLC	DI	Potential Free	-	-	-
Field	PLC	AI	4-20 mA,2 wire	0	100	Deg C	EX FAN Z1 FILTER	PLC	DI	Potential Free	-	-	-
Field	PLC	AI	4-20 mA,2 wire	0	100	Deg C	EX FAN Z1 FILTER	PLC	DI	Potential Free	-	-	-
Field	PLC	AI	4-20 mA,2 wire	0	100	%	EX FAN Z2 VFD PANEL	PLC	DI	Potential Free	-	-	-
Field	PLC	AI	4-20 mA,2 wire	0	100	%	AHU2 BLR VFD PANEL	PLC	DI	Potential Free	-	-	-
Field	PLC	AI	4-20 mA,2 wire	0	100	Deg C	AHU2 BLR VFD PANEL	PLC	DI	Potential Free	-	-	-
Field	PLC	AI	4-20 mA,2 wire	0	100	%	AHU2 BLR VFD PANEL	PLC	DI	Potential Free	-	-	-
Field	PLC	AI	4-20 mA,2 wire	0	100	%	EX FAN Z2 FILTER	PLC	DI	Potential Free	-	-	-
Field	PLC	AI	4-20 mA,2 wire	0	100	Deg C	EX FAN Z2 FILTER	PLC	DI	Potential Free	-	-	-
Field	PLC	AI	4-20 mA,2 wire	0	100	%	EX FAN Z3 VFD PANEL	PLC	DI	Potential Free	-	-	-
Field	PLC	AI	4-20 mA,2 wire	0	100	%	AHU3 BLR VFD PANEL	PLC	DI	Potential Free	-	-	-
Field	PLC	AI	4-20 mA,2 wire	0	100	Deg C	AHU3 BLR VFD PANEL	PLC	DI	Potential Free	-	-	-
Field	PLC	AI	4-20 mA,2 wire	0	100	Deg C	AHU3 BLR VFD PANEL	PLC	DI	Potential Free	-	-	-

a) Table1. Format for Analog input list

b) Table2. Format for Digital Input list

Same as input signal list, Output signal can be listed, which describes about direction of signal flow (always from PLC to field), type of signal either modulating 4-20mA or on-off depends on requirement. From this tables total number of AI,AO,DI and DO calculated and according to this count one can select suitable controller model as well IO modules.

2.4 System Architecture and Panel layout view:

Architecture for PLC panel describes selected controller type, HMI type and type of communication link. For example drawing of system architecture given in Fig. 5 shows architecture of panel that selected controller model of compact logix type ,HMI-Human Machine Interface model PVP6 compact type and selected model number .Ethernet switch and link. This selection of PLC components depends on number of input and outputs also depend on customer requirements.PLC described in more detail in one of the paper [8].

PLC panel box and components manufacturing started by considering requirements like area, size, functionality, length of cable. This selection to be done by remembering needs of safety requirements and standards.

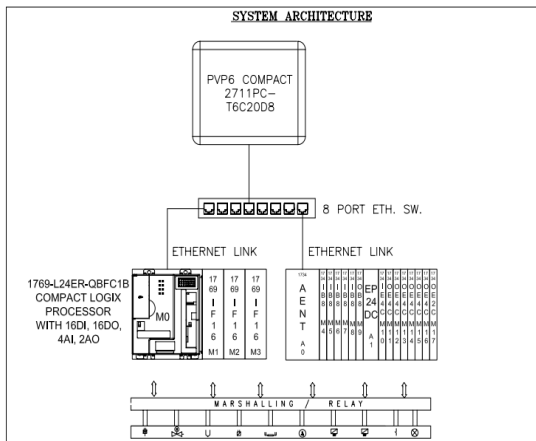
After Manufacturing panel and placement of internal components in the panel Fig.6 shows Panel's physical diagram.PLC panel layout is used to decide overall dimensions of panel on site and size in respect of height, width and length is decided accordingly standards. There are vertical racks in which input and output relays are placed for external control cable connections these are relay contacts and cabling done at the time of commissioning by checking continuity

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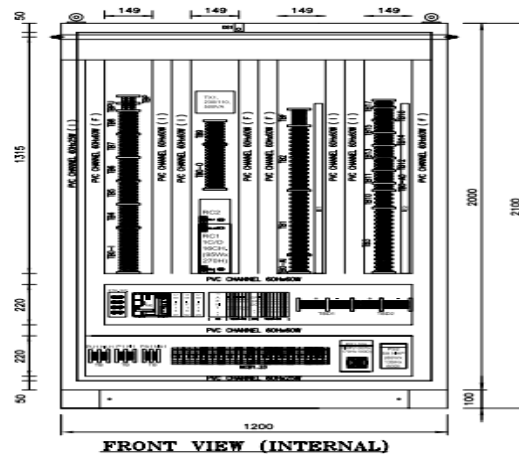
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Vol. 6, Issue 10, October 2017



e) Fig.5 PLC system Architecture



f) Fig.6 Panel View

3. MANUFACTURING AND TESTING:

PLC panel manufacturing starts after approval of each document described in section-2. In accordance with all documents, components of panel selected. This components are controller model, input and output module, bus bar type, power supply, panel box size, number of partitions in (rack) in panel box, type of switchgear in supply section, size of control cable, Human Machine Interface (HMI) type etc. Generally panel box height should be reachable; hence as per standard it should not exceed 2 meter.

Ref [9] mentioned some of the manufacturers, UL-listed.

- Enclosures - Hoffman, Saginaw, Hammond
- Auxiliary 24VDC Power Supplies - Automation Direct, Sola or Allen-Bradley Din-Rail mounted, Regulated
- Circuit Breakers - Square D, Allen-Bradley, ABB, or Siemens
- Programmable Controllers - Based on Customer selection
- Receptacle - Automation Direct, Din-Rail mounted
- Terminal blocks and accessories - Automation Direct, DN-T, Screw-Terminal
- Fuse blocks - Automation Direct DN-F series, Screw-Terminal
- Din-Rail - Weidmuller, Kleinhaus
- Wire way - Panduit, IBOCO

After successfully placement and assembly of all components in the cabinet of PLC box, it goes for next stage called testing and simulation in which at first verification engineers check safety related parameters and then they will check functional working of PLC panel. Actual simulation result and accepted result from control philosophy cross comparison carried out and accordingly modifications in the logic to be done if any. Manufacturer of PLC panel reports one document on Testing and verification of PLC panel to assure about its functional correctness, reliability, robustness and safe design.

4. COMMISSIONING:

After successful report from testing and verification stage, HVAC site engineer starts implementation of PLC panel in the process plant. Fig.7 and fig.8 shows panel and HMI look respectively. This process covers under Commissioning stage. It can take more than 1 month to completely achieve automation in the plant. Site engineer takes help from worker to complete network of wiring and cabling between panel and process equipment as well process instruments to establish connection. After that to ensure proper connection connectivity checking takes place. Next step is running PLC panel in the process plant for actual checking of functionality in which involvement of Design Engineer,

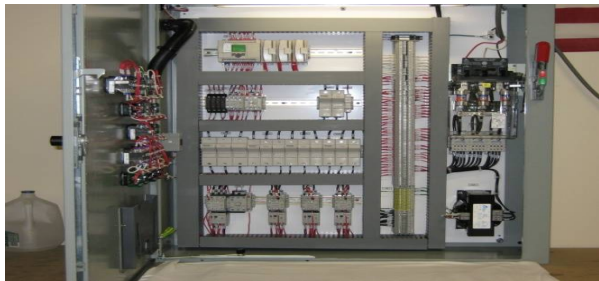
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Vol. 6, Issue 10, October 2017

Automation Engineer, Safety Engineer, and Site Engineer etc becomes mandatory. One by one each equipment and instrument needs to be checked for its functional correctness. At last parameters like temperature and humidity monitored through HMI. Alarm and notification checking is also one of the important stages in the commissioning in which manually some error signal generated and checked about status of alarm and its notification. Each panel is associated with a guide document to describe Standard Operation Process, which becomes a lifetime manual for PLC panel and covers all about its functionality.



g) Fig.7 PLC Panel [10]



h) Fig.8 HMI Screen

III. SUMMARY

This informative paper describes about procedure for PLC panel design in HVAC application. This is a typical process and not a standard one, hence it may differ from one to another application and requirement. Paper covers design stages from overview of general HVAC process, documentation for PLC design, actual manufacturing and testing, implementation and commissioning. Fig.9 shows about flow of PLC design part of this figure is described with proper diagram and description in the proposed informative article.

IV. FUTURE WORK

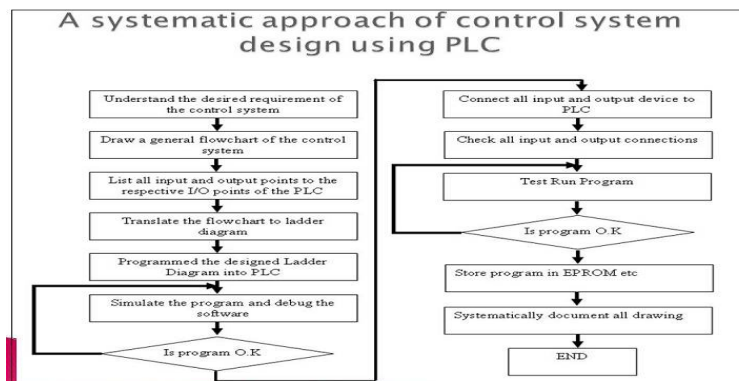
Instead of giving a single hooter with constant frequency we can use a hooter based on multi-frequency. Need of such advanced alarm and notification arises, since in the actual process plant there are non-technical persons which are actually working as operators. If PLC gives the same kind of alarm in normal failure as well in a dangerous situation, then a single delay by operator can take the whole plant on risk, because operator is also a person; he can ignore repeated alarm of constant frequency or can take it lightly. To avoid such a scenario we can implement the concept of priority scheduling in the alarm which can separate dangerous failure from normal errors by assigning priority to each and every alarm. Depending on this, a multi-frequency generator can give signal to hooter with different frequency such that non-technical workers can easily understand the strength of error in the panel by only listening to the alarm. We can also implement red-colored lamps as mentioned in *fig.10* for visualization of dangerous situations to avoid any disaster and manual harm in the plant.

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Vol. 6, Issue 10, October 2017



i) Fig.9 Systematic Approach of control system using PLC[10]



j) Fig.10 Hooter system for alarm[11]

V. CONCLUSION

The Procedure for PLC Panel in HVAC automation briefly explained in this paper. Purpose of this informative paper is to give an idea about current methodology in PLC automation in HVAC. By reviewing existing system and with safety concern, an advanced alarm and notification system needs to be integrated in the plant. Here concept of the same is explained in short under the name of future work. Actual implementation of the same is not yet done and can be future work as open to design engineer.

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