Transformer Cooler Control Automation And Condition Monitoring System Using PLC And HMI Modules

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ABSTRACT –

Transformer plays a vital role in transmission and distribution system. There are many problems associated with power loss in transformer but this paper mainly focuses on efficient cooling system design. We have proposed an intelligent cooling system based on Programmable Logic Controller (PLC) which eliminates the problem of manual transformer cooling control system by automatically switching ON and OFF. This switching is PLC controlled and thus minimizes the errors caused by human intervention. PLC logic is used for controlling all the components which are involved in the cooling system control cubical of transformer and it also uses the component only when needed, this reduces the wastage of power and unnecessary operations. We have also focused upon proper utilization of standby bank by means of periodic switching. Human Machine Interface (HMI) can also be used for complete visualization of the process in the control room. Along with this, continuous monitoring and data recording is simultaneously done.

I. INTRODUCTION

In this world of technology, the demand for better and hassle free electrical energy is an absolute necessity. One of the most crucial roles played in supply of electrical energy is by the transformer. Without transformer the electrical energy generated at generating stations won't probably be sufficient enough to power up a city. Just imagine there are no transformers. How many power plants do you think have to be set up in order to power up a city? It's not easy and it's expensive. Transformer helps in amplifying the transformer output by stepping up or down the level of voltage and current. Over excitation leads to excessive flux which causes heating and increased current, noise and vibration. All devices that use electricity gives off waste heat as a byproduct of their operation. Transformers are no exception. The heat generated in transformer causes temperature rise in internal structure of the transformer. When the temperature of the transformer rises, oil level in the tank, decreases due to heating effect. If the oil level goes beyond marked level, it will affect the cooling and insulation of transformer. Insulation breakdown can occur between winding and earth, between phases and in between adjacent turns. These failures can also be due to some reasons like Natural deterioration due to aging , excessive heat and moisture, chemical deterioration, mechanical damage, sunlight and excessive voltage stresses . All these faults increase the heating and thereby increase the temperature of the transformer resulting in local hotspots and even the insulation failure. Failure of insulation is the most common cause of problems in electrical equipment. Initially, the degradation of insulation occurs slowly but increases at faster rate ,which leads to final failure of transformer. So, it is necessary to ensure proper working of cooling system when required. In this paper an attempt has been made to operate the cooling banks in a smarter way by using PLC. And also use of HMI is considered as an interface between the user and the machine.

II. LITERATURE SURVEY

In the process of power production, the transformer is placed between the alternator and grid through necessary switchgear arrangements like circuit breaker, isolators,etc., if the transformer is not working properly due to ineffective cooling method,then the transmission will be affected resulting in revenue loss for the power station. So, it is necessary that the transformer should be given at mostcare for its effective operation. This can be done by monitoring processes,the temperature of oil and winding plays a major role and has to be controlled within limit. Since the transformer used in generating station whose capacity is around 250MVA, monitoring the temperature of oil and winding is difficult task.Traditionally the transformer cooling system is controlled via contactors, intermediate relays, timer relays, temperature relays etc.

In earlier system designs, the transformer cooling banks suffered from the problem of redundancy of standby cooling bank. The lack of operation resulted in damage/failure of transformer. The monitoring and switching between different cooling banks of a transformer was manually done where a person would visit the transformer site for periodic switching of cooling banks, maintenance and recording the various necessary parameters. This type of switching usually lead to human errors and was also time consuming. It also needed skilled labor for switching operations which increased labor cost.

In order to overcome the disadvantage of the above faults and errors of the existing control scheme, a programmable logic controller (plc) can be used. Plc is an user-friendly software whose operation mainly depends on the program written in the memory. One of the common programming methods used in plc is the ladder program. Computer with PLC ladder logic for controlling transformer cooling system is automatic, reliable and cost effective.

III. SYSTEM DESCRIPTION

A. Components:

The various components needed for the main operation of transformer cooling and used for prototype model are 50 W SMPS, PLC, 8 contact relays (24V DC), HMI, indicator lamps and 24V DC toggle switches.

B. Proggramable Logic Controller (PLC) MODEL NO: SCHEMATIC CP Series – CP1E-20DR:

1) Hardware Model and Specifications:

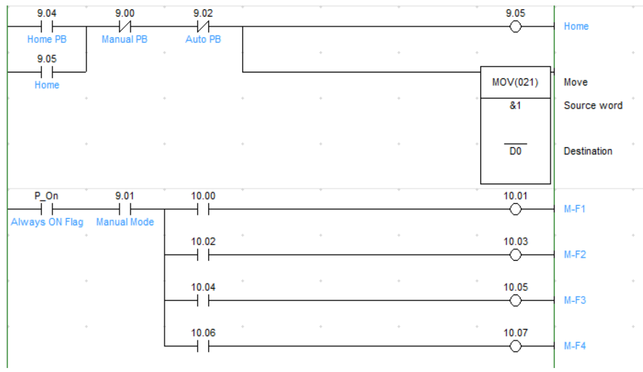


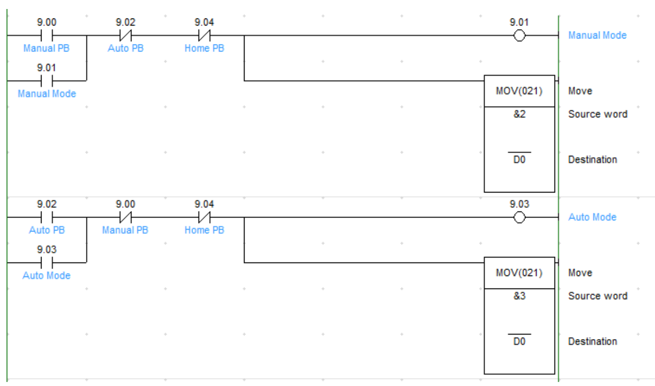
Fig.1 SYSMAC – CP1E

In the designed transformer cooling system PLC is being used for sequential logic operation, timing, counting and for multiply other controls of various components e.g. relays, fans, pumps, switches etc. In comparison with conventional controller, the PLC is rugged; least affected by external disturbances, flexible configuration and can control n number of input and output devices depending upon the PLC I/O ports.

PLC is being used for serial communication with other intelligent devices. The CP1E-20DR PLC is a solution for controlling a wide variety of applications. After the program is downloaded, the CPU contains the logic required for any alterations if any needed in future and for corrections for any fault in the control unit.

2) Software and Specifications:

Sample programs can be downloaded online for understanding the algorithm and logics.



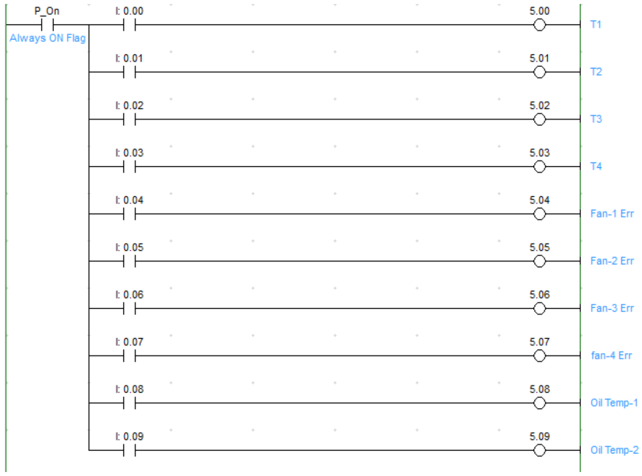


Fig.2

C. Human Machine Interface (HMI) DELTA DOP-BO3S211:

1) Hardware Model and Specifications:

Fig.3

A Human machine interface is the user interface that connects an operator to the controller for the industrial system.The interface consists of hardware and software that allow user input to be translated as a signal for machine, in turn provides the required result to the user.Touchscreens and membrane switches can been considered as an example of HMI.

HMI gives the user interface as various screens of our choice. HMI has more than 200 screens. It acts as a Master-Slave with the PLC. HMI can be placed at the remote area to continuously record and operate the control unit. HMI provides the history of error or malfunctions occurred for the last two years. The datas can be obtained easily with accurate time and date of occurrence.

2) Software and Specifications:

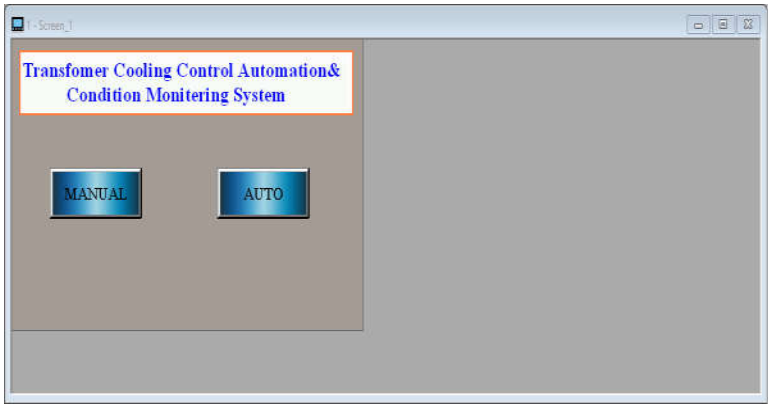


Fig.4

IV. SYSTEM CONFIGURATION

All the output pins of the PLC are connected to the output devices cooling fans. The input pins are connected to power supply which is a 24V DC SMPS and also to the 24V DC toggle swtiches.

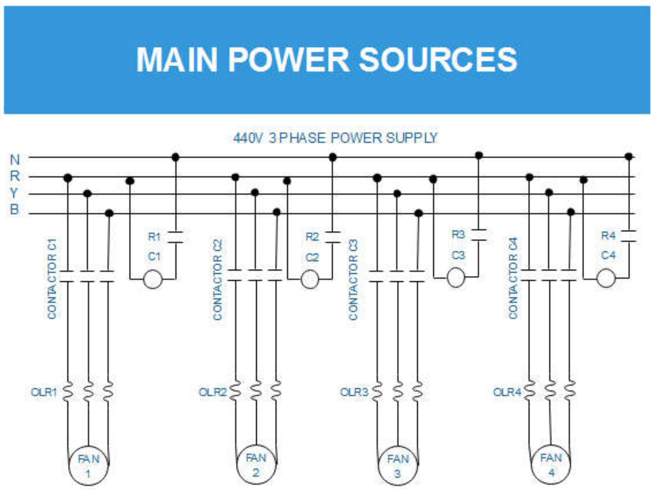


Fig.5

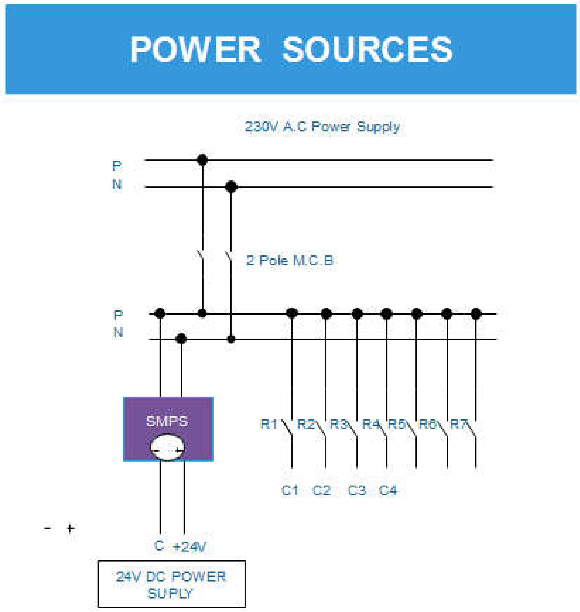

POWER SOURCES
230V A.C Power Supply
P
N
2 Pole M.C.B
P
N
SMPS
R1 R2 R3 R4 R5 R6 R7
C1 C2 C3 C4
- +
C +24V
24V DC POWER SUPLY

Fig.6

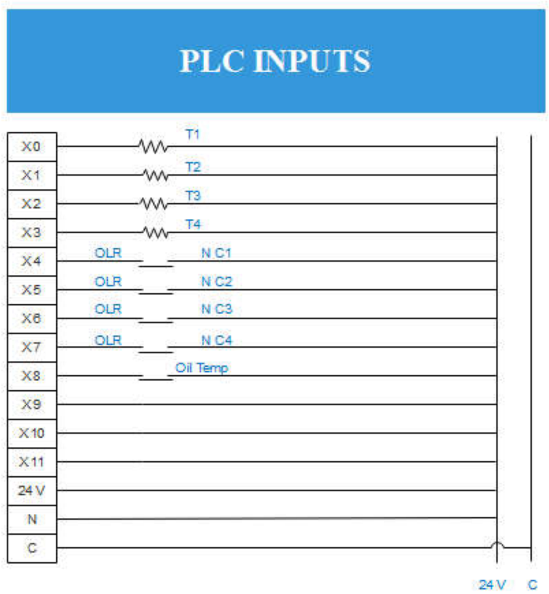

PLC INPUTS
X0
X1
X2
X3
X4
X5
X6
X7
X8
X9
X10
X11
24 V
N
C
T1
T2
T3
T4
OLR
N C1
OLR
N C2
OLR
N C3
OLR
N C4
Oil Temp
24 V
C

Fig.7

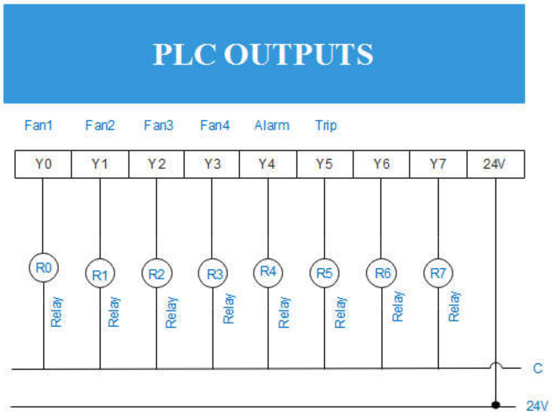


Fig.8

System configuration of HMI acts as a Master – Slave with PLC. RS232 USB is used as the communication between HMI and PLC.

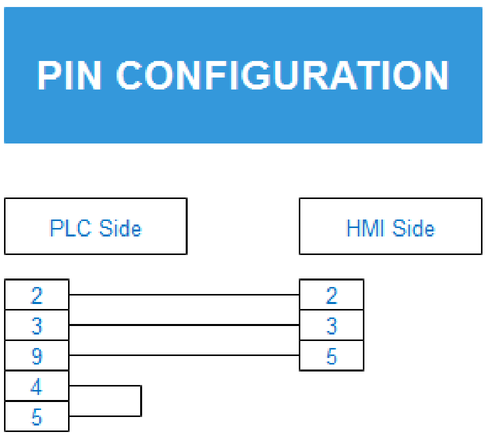


Fig.9

V. BLOCK DIAGRAM

Fig.10

The following steps are th process of the flow chart. As soon as the 24v supply is sensed by PLC the below following steps takes place.

STEP 1: The PLC starts its operation after the supply is sensed.

STEP 2: It then checks the operation of modes. There are two modes of operation ie, MANUAL /AUTOMATIC mode.

STEP 3:If the working mode is automatic then the WTI (winding temperature) checks the temperature T1< /= 50’C.If the condition is true then the PLC will automatically turns ON/OFF the all the fans periodically for 72 hours. Since it is periodic checking of fans .Now the WTI Checks for the temperature T1>/=50’C If the T1 satisfies the condition then the OTI Will check whether it is </=65’C if it is true then all the fans (F1,F2,F3,F4) and alarm gets turned OFF. if this condition is False then F1 gets turned ON/OFF . if there is a fault occurred in F1 then the stand by mode F2 will get turned ON. Similarly for other group if F3 gets ON/OFF according to the condition. If F3 has undergone any fault then its standby fan F4 gets turned ON.

STEP 4: if the WTI does not satisfies the temperature T2 Then it checks for the condition T2>/=60’C, if his condition is true and checks the OTI</=65’C, if this condition is true all the fans (F1,F2,F3,F4) gets turned ON else all the fan and alarm gets turned OFF.

STEP 5: In this step if the WTI does not satisfies the temperature T2 then it moves on to temperature T3>/=70’C. if this condition satisfies OTI</=65’C then all the fans and alrm gets turned OFF, else ALARM turns ON.

STEP 6: Finally the WTI checks for temperature t4>/=80’C, if the condition satisfies then the circuit gets tripped else it again checks the condition T1</=50’C.again the process repeats.

STEP 7: the mode of operation is manual then all fans can be turned ON/OFF manually that is displayed on the HMI.

VI. WORKING

A. WORKING:

1) Transformer starts Operating:

As soon as a transformer is installed , its working is based upon the energy flow in the coils. This energy flow is undergone by the stepping up and stepping down of the transformer. This energy flow through the coils causes heat . This rise in heat is the major problem occurred in the transformer and its loss in efficiency.

2) Rise in Temperature Detection & PLC Operation:

All devices that use electricity give off waste as a byproduct of their operation. In general more efficient transformer tend to have low temperature rise,while less efficient units tends to have high temperature rise. This temperature rise is caused due to overload. There is a temperature control as a interface for sensing the temperature from the oil winding . And this temperature control is connected to the Analog Pins of a PLC which later convert the data to Digital from Analog and actuate commands accordingly. Now, as soon as there is a rise in the temperature, the PLC detects it and sends a command to operate the fans accordingly.

3) Operation of cooling fans as per PLC Logic:

As soon as the PLC senses the rise in temperature the PLC sends a command to start the accordingly to the mode of operation whether it is automatic or manual.. In the Cooling Banks, as soon as a trigger command is received after opting the mode of operation , if the operating mode is manual then all the fans can be turned ON/OFF by pressing the button on the HMI. Else if the mode is automatic then the working cycle begins according to the ladder logic of the PLC.

4) Fault Condition in Cooling Bank:

Consider a scenario where a fault is developed inside the cooling fan due to some arbitrary reason. As soon as a fault develops, the corresponding fan stop operating. If in case this is not rectified soon enough, the temperature inside would exceed and it could lead to faults in the transformer as well. To avoid this from happening, our Ladder Logic has incorporated solutions for problems in the cooling fans. As soon as a fault is developed, for eg if a fault is occurred in any of one fan in a group ie, If F1 has caused a fault then its stand by mode fan gets operated automatically to compramise the fault. This is the flexibility of the ladder logic.

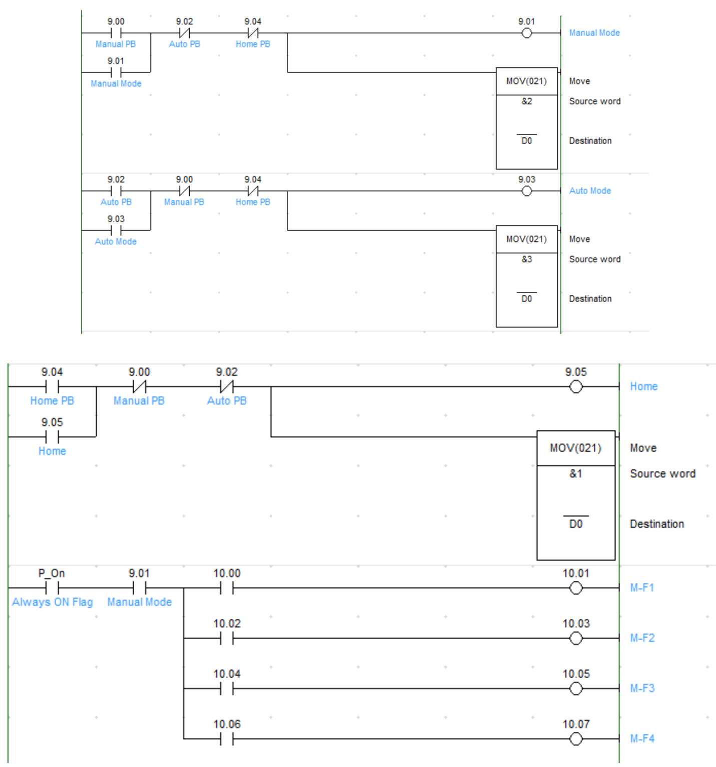
There is a standby cooling bank which is in a stand-by position and operates only when a fault developed in the other fan. As soon as the Standby operates ,make sure that proper amount of cooling is received by the Transformer. This Standby Bank operates until the malfunctioned cooling bank recovers completely .

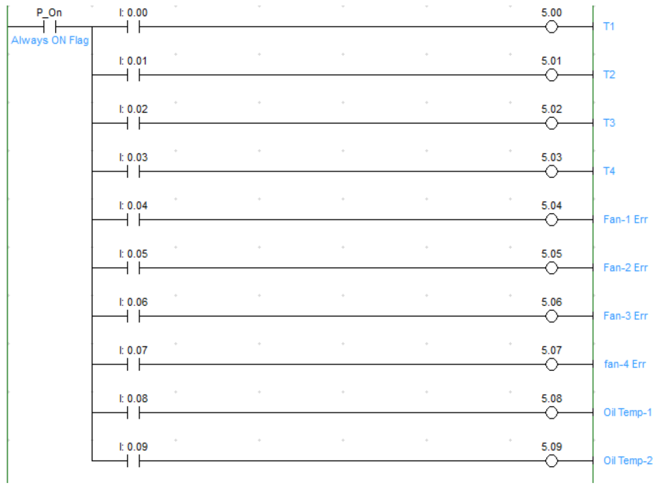
5) Periodic Use Of Stand-by mode fans

Once the Standby bank stops operating after the malfunctioned cooling bank has resumed, the process of cooling continues. The flexibility and the ability of the Ladder Logic ensures that none of the cooling banks exceed a certain amount of time for which they operate. Even if the cooling banks stay completely healthy and there is no fault caused across their terminals, the fans get operated periodically for about 72 hours . This ensures that each and every cooling fan is utilized to its best potential. It also ensures that each and every group of fans get sufficient amount of time for maintenance.

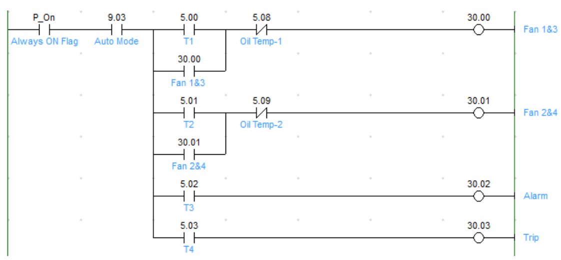
B. PLC LADDER LOGIC:

MANUAL

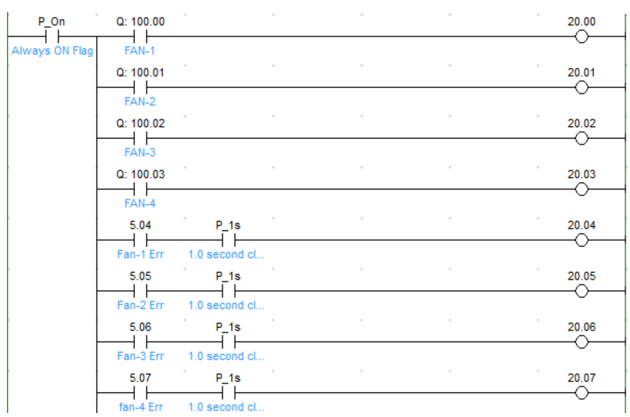


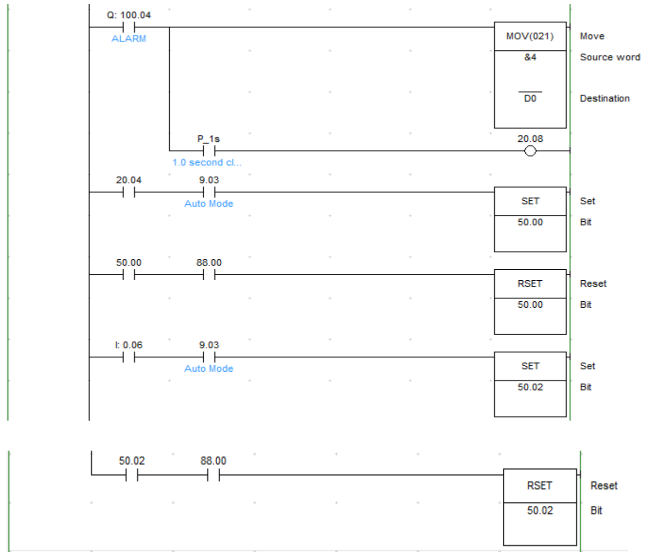

P_On
Always ON Flag
I: 0.00
5.00
T1
I: 0.01
5.01
T2
I: 0.02
5.02
T3
I: 0.03
5.03
T4
I: 0.04
5.04
Fan-1 Err
I: 0.05
5.05
Fan-2 Err
I: 0.06
5.06
Fan-3 Err
I: 0.07
5.07
fan-4 Err
I: 0.08
5.08
Oil Temp-1
I: 0.09
5.09
Oil Temp-2

AUTO

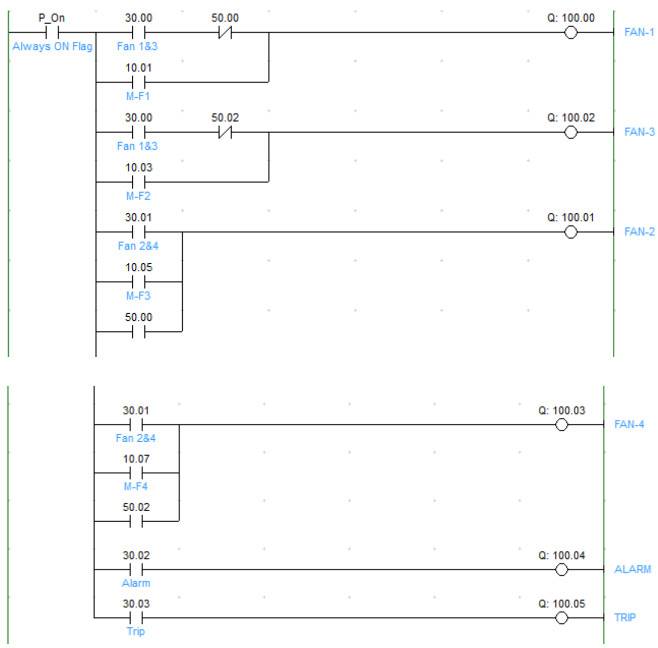

P_On
Always ON Flag
9.03
Auto Mode
5.00
T1
5.08
Oil Temp-1
30.00
Fan 1&3
30.00
Fan 1&3
5.01
T2
5.09
Oil Temp-2
30.01
Fan 2&4
30.01
Fan 2&4
5.02
T3
30.02
Alarm
5.03
T4
30.03
Trip

MMI

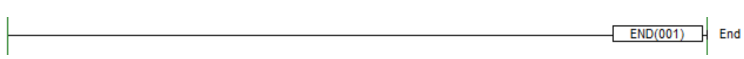

P_On
Always ON Flag
Q: 100.00
FAN-1
20.00
Q: 100.01
FAN-2
20.01
Q: 100.02
FAN-3
20.02
Q: 100.03
FAN-4
20.03
5.04
Fan-1 Err
P_1s
1.0 second cl...
20.04
5.05
Fan-2 Err
P_1s
1.0 second cl...
20.05
5.06
Fan-3 Err
P_1s
1.0 second cl...
20.06
5.07
fan-4 Err
P_1s
1.0 second cl...
20.07


Q: 100.04
ALARM
MOV(021)
Move
&4
Source word
D0
Destination
P_1s
1.0 second cl...
20.08
20.04
9.03
Auto Mode
SET
50.00
Set
Bit
50.00
88.00
RSET
50.00
Reset
Bit
I: 0.06
9.03
Auto Mode
SET
50.02
Set
Bit
50.02
88.00
RSET
50.02
Reset
Bit

OUTPUT

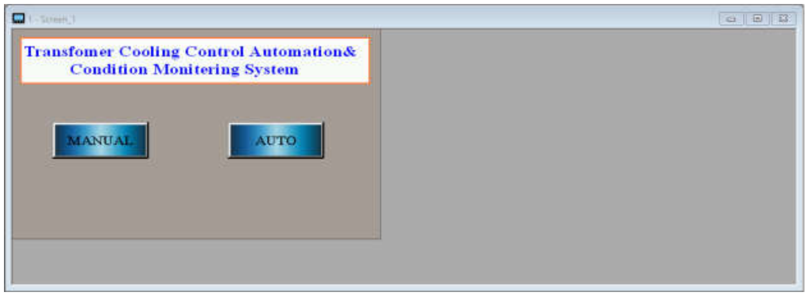

P_On
Always ON Flag
30.00
Fan 1&3
50.00
Q: 100.00
FAN-1
10.01
M-F1
30.00
Fan 1&3
50.02
Q: 100.02
FAN-3
10.03
M-F2
30.01
Fan 2&4
Q: 100.01
FAN-2
10.05
M-F3
50.00
30.01
Fan 2&4
Q: 100.03
FAN-4
10.07
M-F4
50.02
30.02
Alarm
Q: 100.04
ALARM
30.03
Trip
Q: 100.05
TRIP

END


END(001)
End

C. HMI SCREENS:

Page 1



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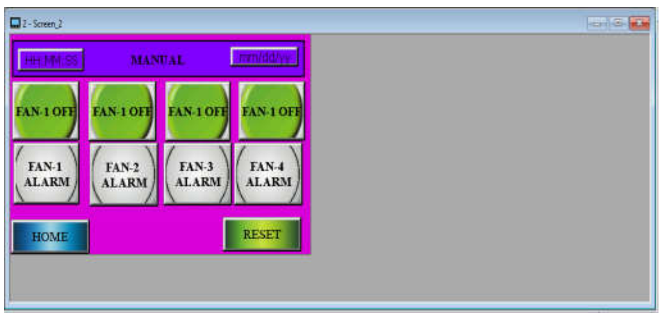
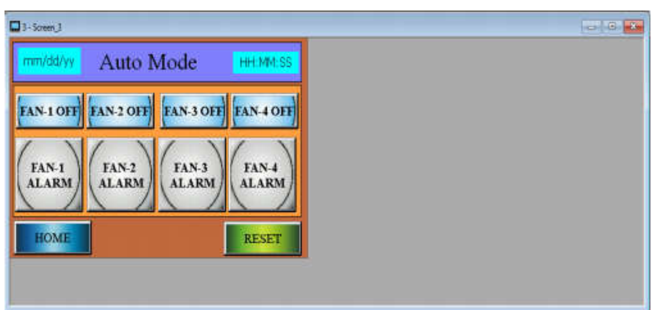


Page 3



Page 4

D. Hardware Assembly:

VII. RESULTS & CONCLUSION

1) The PLC and HMI based transformer cooler control and monitoring is designed successfully and implemented efficiently. Actions like monitoring temperature oil and winding will be a crucial and most required one.
2) The PLC based system provides the following advantages:-

- PLC can be programmed easily.
- The controller has input and output for interfacing.
- Cost efficient.
- User friendly software.
- Relay logic can be replaced.
- Human intervention is reduced.
- PLC'S are re-programmable.

3) By introducing PLC into action the process becomes more flexible, reliable and PC friendly.

4) .The logic allowed efficient and timely use of the standby cooling banks in case of maintenance and faults. The Ladder Logic and the PLC also incorporate the switching ofCooling banks after a prescribed period so that every cooling bank is made use of and none is left redundant.

4)HMI activities are availed to have better visualization of our process and control. The control technology is simply converted to software here makes even complicated process to simple one.

5)It is even data recording . Trouble shooting experience becomes easier now compared to existing technology. In this method physical wiring 90% can be avoided.

6)Data will not be lost when updating software to the latest software revisions. No data to be lost if network connection or communication goes down due to network failure.

7)Touchscreens and membrane switches can be considered as an example of HMI. Hence HMI typically connected to PLC to get the real time data.

VIII. FUTURE SCOPE

- Using Analog Card for integrating Temperature Sensors or other sensors.
- Sending Data over large distances and displaying it via a webpage.
- HMI activities can be availed to have better visualization of process and control.
- By changing the PLC module according to the needs it can be used for various functions.
- Chiller unit can be of Fans, Pumps, Cooling oil, Condenser, etc.,

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