A PROJECT REPORT ON

Panel Design for Transformer Protection

Project Report Submitted in partial fulfillment of the degree of
Bachelor of Engineering

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An

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PREFACE

We take the opportunity to present this report "Panel Design for Transformer Protection**".** The objective of this report is on the protection of Transformer from different faults.

The report is supported by images to bring out the purpose and message. We have made sincere attempts and taken every care to present this report in precise and compact form, the language being as simple as possible.

The task of completion of the project though being difficulty was made quite simple, interesting and successful due to deep involvement and complete dedication of our group members.

CERTIFICATE

This is to certify that the report entitled "**Panel Design for Transformer Protection**" submitted by **KHAN SHABNAM FIROZ, SHAIKH KHALEDA BEGUM FAROOQUE, SHEEBANAAZ AKEEL AHMED, KAZI TEHSEEN ABDUL RAZZAK** in partial fulfillment of the requirement for the award of Bachelor of engineering in "**ELECTRICAL ENGINEERING**" is an authentic word carried by them under my supervision and guidance.

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ABSTRACT

Transformer are static devices totally enclosed and generally oil immersed. Therefore, chances of fault occurring on them are very rare. However the consequences of even a rare fault may be very serious unless the transformer is quickly disconnected from the System. This necessitates providing adequate automatic protection for transformer again possible faults.

This thesis explores the automatic protection which is needed for transformer. This protection is mainly provided through panels. A panel is used for controlling and giving the indication about the faults in transformer. It also disconnect the transformer from supply of there is a fault. Different panels are used for different location, scheme of protection, according to consumer demand etc. In which some of the panels are RTCC, MBox, TJB, etc. An RTCC is basically for raising and lowering transformer voltage from DM Box which is connected to OLTC.

A RTCC Panel can be operated from a substation where as an MBOX consist of fan and pump motor controlling, indications, alarms, power circuit etc. TI is located on the transformer itself. Here we deal with different methods or steps that are involved in designing of these panels.

DECLARATION

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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TABLE OF CONTENTS

INTRODUCTION

CHAPTER 1: TRANSFORMER

1.1	Introduction of Transformer	1
1.2	Basic parts of Transformer	2
1.2.1	Core	2
1.2.2	Winding	3
1.2.3	Insulating Material	4
1.2.4	Conservative	4
1.2.5	Breather	5
1.2.6	Tap Changer	6
1.2.7	Cooling tubes	6
1.2.8	Buchholz Relay	6
1.2.9	Explosion Vent	7

CHAPTER 2: TYPES OF TRANSFORMER

2.1	Step Up Transformer	8
2.2	Step Down Transformer	8
2.3	Air Core Transformer	9
2.4	Iron Core Transformer	9
2.5	Auto Transformer	9
2.6	Power Transformer	10
2.7	Distribution transformer	10
2.8	Potential Transformer	10
2.9	Current Transformer	10

CHAPTER 3: FAILURE /FAULTS IN TRANSFORMER:

3.1 Winding Failure 11

3.2 Bushing Failure 12

3.3 Tap Changer Failure 12

3.4 Core Failure 13

3.5 Tank Failure 14

3.6 Protection system Failure 14

3.7 Cooling System Failure 15

CHAPTER 4: PROTECTION OF TRANSFORMER

CHAPTER 5: PANEL DESIGN

5.1 Types of Panel 23

5.1.1 Marshalling Box 24

5.1.2 RTCC 24

5.1.3 VFD 25

5.1.4 TJB 26

5.2 Linking Process of Panel 27

CHAPTER 6: DEVELOPMENT STAGES & PROCESS OF PANEL

6.1 General Arrangement 28

6.2 Fabrication 29

6.3 Special Instruction 29

6.4 Bill of Material 30

6.5 Different Circuits

6.5.1 Trip Circuit 32

6.5.2 Alarm Circuit 32

6.5.3 Control Circuit 33

6.5.4 Phase Feeder 33

6.5.5 Power Circuit 34
6.6 Wiring 35
6.7 Check List 36
6.8 Testing 36
6.9 Dispatch 40
CHAPTER 7: EQUIPMENT USED IN PANEL
7.1 Temperature Transducers 41
7.2 CONTACTOR 42
7.3 MCB 42
7.4 Motor Protection Circuit Breaker 44
7.5 OIL / WINDING TEMPERATURE INDICATORS 48
7.6 TAP POSITION INDICATOR / TRANSMITTERS 49
7.7 Thermostats 50
7.8 Relay / Timer 53
7.9 Details of Winding temperature indicator(WTI) 56
7.10 Oil Temperature Indicator (OTI) 58
CERTIFICATES 59
BIBLIOGRAPHY 63

LIST OF FIGURES

Sr. No.	Figure	Page No.
1.1	Conservator	4
1.2	Breather	5
1.3	Cooling Tubes	6
1.4	Buchholz Relay	7
1.5	Explosion Vent	7
4.1	over current and earth fault Protection	16
4.2	Over Voltage Protection	18
4.3	Restricted Earth Fault Protection in Transformer	21
4.4	Differential Protection Scheme	22
5.1	Panel	23
5.2	Marshalling Box	24
5.3	RTCC	25
5.4	VFD	26
5.5	TJB Panel	26
5.6	Linking Process	27
6.1	General Arrangement	28
6.2	Fabrication	29
6.3	Bill of Material	31
6.4	Trip Circuit	32
6.5	Alarm Circuit	32
6.6	Control Circuit	33
6.7	3-Phase Feeder	33
6.8	Power Circuit - 1	34

Sr. No.	Figure	Page No.
6.9	Power Circuit - 2	34
6.1	Wiring	35
6.11	RTCC Operation	36
6.12	Wire Pull Check	36
6.13	Alarm/Trip Circuit & Wire Pull Check	37
6.14	Insulation Resistance Test	37
6.15	Testing Socket & Lamp	38
6.16	Testing Fan & Pump Operation	38
6.17	Procedure for HV Test	39
6.18	Testing Heater Circuit	39
6.19	Testing	40
7.1	Temperature Transducer	41
7.2	Miniature Circuit Breaker	43
7.3	Motor Protection Circuit Breaker	45
7.4	Tap Position Indicator	49
7.5	Thermostat	50
7.7	Bimetallic Strip	51
7.8	Relay / Timer	54
7.9	Winding Temperature Indicator (WTI)	57
7.1	Oil Temperature Indicator	58

INTRODUCTION

An Electrical transformer is a static device but due to internal stresses and abnormal conditions fault occur faults such as over current due to overloads, terminal faults, incipent faults, winding faults etc.

These different faults demand different schemes of transfomer protection. For which the panels are designed. The function of the panel is to provide appropriate protection of transformer in faulty condition. It also gives indication about the faults, the fan s and pumps used for cooling purpose are also controlled through panel. Panels have different types which include RTCC, MBox, TJB, Common MBOX, VFD, PLC, etc. The RTCC is used for raising and lowering the transformer voltage through D Box which is in a substation, the MBox mainly contains controlling of fans and pump motor indication, alarm tripping etc. MBOX is located near to the transformer. The VFD and PLC Panels are special type of panels and it is the new technology introduced in the field of panel designing. The panels which are made for the controlling and protection of transformer undergo different or steps in which they are designed.

The company process of manufacturing a panel mainly depends on the demand of the consumer. According to the consumer need s it include general arrangement, special instruction,bill of material, changeover circuit/power circuit, control circuit, alarm circuit, trip, firefighting, indication circuit etc. Fabrication and wiring in done after the above process is complete then The final checklist is made and the panel is tested for the desired purpose after a the procedures are being done the panel is dispatched to the consumer.

CHAPTER 1 : TRANSFORMER

1.1 Introduction of Transformer

The transformers are one of the most expensive components in this network which makes it another reason for being very important. As an important component the study of the faults and failures of the transformer is also very important.

Transformer is a static device plus it is protected by the main circuit breaker thus there is almost no possibility of external fault to it other than internal faults like open circuit fault, over heating fault and winding short circuit fault.

Open circuit fault occurs when one phase of transformer become open which is relatively harmless just cause temperature rise that can be detected by temperature alarm and disconnect the transformer. Short circuit fault is relatively dangerous and need extra caution.

The complete protection schemes of transformer is not a single protection system unlike alternator which can be protected by only Mertz Price differential circulating current protection system.

A combination of protection system is needed for the complete protection of transformer. The deciding factors of requiring protection system are

1. Size of transformer
2. Type of cooling system
3. Transformer location in the network
4. Load type & Nature
5. Importance of Transformer

1.2 Basic Parts of a Transformer

These are the basic components of a transformer.

- Laminated core
- Winding
- Insulating materials
- Transformer oil Tap changer
- Conservator
- Breather
- Cooling Tubes
- Buchholz Relay
- Explosion vent

Of the above, the first four are found in almost all the transformers, whereas the rest are found only in transformers that are more than 50 KVA.

1.2.1 Core

The core is used to support the winding in the transformer. It also provides a low reluctance path to the flow of magnetic flux. It is made of laminated soft iron core in order to reduce eddy current loss and Hysteresis loss. The composition of a transformer core depends on such factors as voltage, current, and frequency. The diameter of the transformer core is directly proportional to copper loss and is inversely proportional to iron loss. If the diameter of the core is decreased, the weight of the steel in the core is reduced, which leads to less core loss of the transformer and the copper loss increase. When the diameter of the core is increased, the opposite occurs.

Why Are Winding Made of Copper?

Copper has high conductivity. This minimizes losses as well as the amount of copper needed for the winding (volume & weight of winding).Copper has high ductility. This means it is easy to bend conductors into tight winding around the transformer's core, thus minimizing the amount of copper needed as well as the overall volume of the winding.

1.2.2 Winding

There are two winding wound over the transformer core that are insulated from each other. Winding consists of several turns of copper coils bundled together, and each bundle is connected in series to form a winding.

Winding can be classified in two different ways

- ◆ Based on the input and output supply
- ◆Based on the voltage range

Within the input/output supply classification, windings are further categorized:
Primary winding - These are the windings to which the input voltage is applied.
Secondary winding - These are the windings to which the output voltage is applied.

Within the voltage range classification, windings are further categorized:
High voltage winding - These are made of copper coil. The number of turns is the multiple of the number of turns in the low voltage windings. The copper coils are thinner than those of the low voltage windings.
Low voltage windings - These have fewer turns than the high voltage windings. It is made of thick copper conductors. This is because the current in the low voltage windings is higher than that of high voltage windings.
Transformers can be supplied from either low voltage (LV) or high voltage (HV) winding based on the requirement.

1.2.3 Insulating Materials

Insulating paper and cardboard are used in transformers to isolate primary and secondary winding from each other and from the transformer core. Transformer oil is another insulating material. Transformer oil can actually have two functions: in addition to insulating it can also work to cool the core and coil assembly. The transformer's core and winding must be completely immersed in the oil. Normally, hydrocarbon mineral oils are used as transformer oil. Oil contamination is a serious problem because contamination robs the oil of its dielectric properties and renders it useless as an insulating medium.

1.2.4 Conservator

The conservator conserves the transformer oil. It is an airtight, metallic, cylindrical drum that is fitted above the transformer. The conservator tank is vented to the atmosphere at the top, and the normal oil level is approximately in the middle of the conservator to allow the oil to expand and contract as the temperature varies. The conservator is connected to the main tank inside the transformer, which is completely filled with transformer oil through a pipeline.

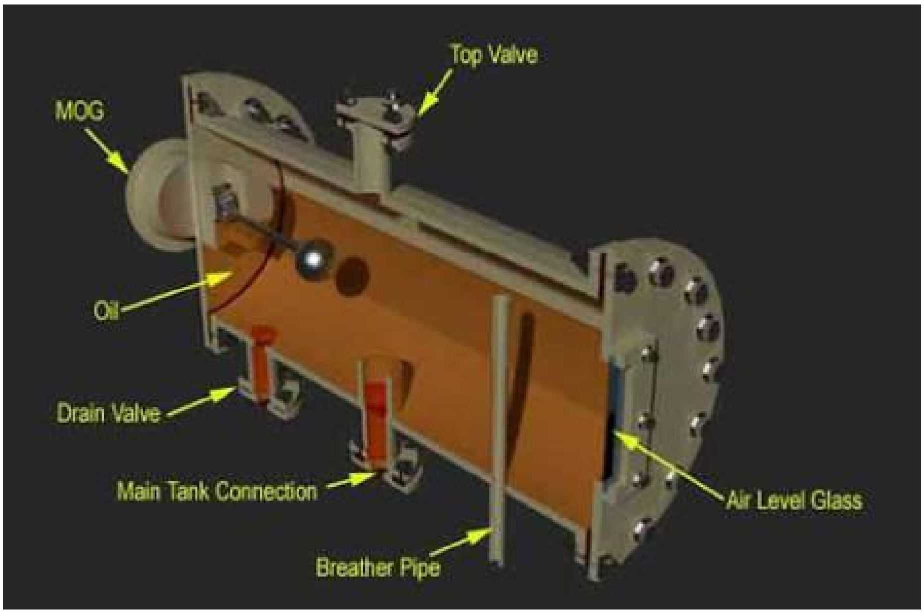


Fig. 1.1 Conservator

1.2.5 Breather

The breather controls the moisture level in the transformer. Moisture can arise when temperature variations cause expansion and contraction of the insulating oil, which then causes the pressure to change inside the conservator. Pressure changes are balanced by a flow of atmospheric air in and out of the conservator, which is how moisture can enter the system.

If the insulating oil encounters moisture, it can affect the paper insulation or may even lead to internal faults. Therefore, it is necessary that the air entering the tank is moisture-free.

Fig. 1.2 Breather

The transformer's breather is a cylindrical container that is filled with silica gel. When the atmospheric air passes through the silica gel of the breather, the air's moisture is absorbed by the silica crystals. The breather acts like an air filter for the transformer and controls the moisture level inside a transformer. It is connected to the end of breather pipe.

1.2.6 Tap Changer

The output voltage may vary according to the input voltage and the load. During loaded conditions, the voltage on the output terminal decreases, whereas during off-load conditions the output voltage increases. In order to balance the voltage variations, tap changers are used. Tap changers can be either on-load tap changers or off-load tap changers. In an on-load tap changer, the tapping can be changed without isolating the transformer from the supply. In an off-load tap changer, it is done after disconnecting the transformer. Automatic tap changers are also available.

1.2.7 Cooling Tubes

Cooling tubes are used to cool the transformer oil. The transformer oil is circulated through the cooling tubes. The circulation of the oil may either be natural or forced. In natural circulation, when the temperature of the oil rises the hot oil naturally rises to the top and the cold oil sinks downward. Thus the oil naturally circulates through the tubes. In forced circulation, an external pump is used to circulate the oil.

Fig. 1.3 Cooling Tubes

1.2.8 Buchholz Relay

The Bochholz Relay is a protective device container housed over the connecting pipe from the main tank to the conservator tank. It is used to sense the faults occurring inside the transformer. It is a simple relay that operates by the gases emitted due to the decomposition of transformer oil during internal faults. It helps in sensing and protecting the transformer from internal faults.

Fig. 1.4 Buchholz Relay

1.2.9 Explosion Vent

The explosion vent is used to expel boiling oil in the transformer during heavy internal faults in order to avoid the explosion of the transformer. During heavy faults, the oil rushes out of the vent. The level of the explosion vent is normally maintained above the level of the conservatory tank.

Fig. 1.5 Explosion Vent

CHAPTER 2 : TYPES OF TRANSFORMER

The transformers are classified based on voltage levels, Core medium used, winding arrangements, use and installation place etc.

Transformers based on voltage levels

The transformers are classified as step-up and step-down transformers as the voltage ratios from primary to secondary. These are widely used transformer types for all the applications. Here the important thing to remember is that there will not be any difference in primary power and secondary power. I.e. if the voltage is high at secondary side then the current drawn from the secondary will low so that the power will be same. Same as in the reverse case when the voltage is low the current drawn will be high.

2.1 Step-up transformer

As the name specifies the secondary voltage is stepped up with a ratio compared to primary voltage. This is achieved by increasing the number of coil turns in the secondary.

In power plant this transformer is used as connecting transformer of Generator to Grid. I.e. the Generated to low voltage should be suitably stepped up to connect to high voltage grid.

2.2 Step-down transformer

In this transformer the voltage is stepped down at the secondary from high voltage primary so that it is called as step-down transformer. The winding turns will be high at primary side where as it will less at secondary side. In power plant the use of this transformer are very high where the grid power supply stepped down and given to corresponding plant auxiliaries during starting of the power plant. Once the plant has started then the voltage stepping down is necessary where the plant auxiliaries will operate at low voltage compared to its generated voltage. In distribution also the step down transformer is widely used to convert the high grid voltage to the low voltage which can be used at house purposes.

Transformer based on the core medium used

The transformers are divided as Air core and iron core under this classification. I.e. the medium placed between the primary and secondary air in air core type transformer and iron in iron core type transformer.

2.3 Air core transformer

The primary and secondary windings wounded on non magnetic strip where the flux linkage between primary and secondary is through the air. The mutual inductance effect is less in air core compared to iron core i.e. the reluctance offered to the generated flux is high in the air medium where as in the iron core it is less. But the hysteresis and eddy current losses which are dominant in iron core type are less or completely eliminated in air core type transformer.

2.4 Iron core transformer

The two windings are wounded on iron plates which provide a perfect linkage path to the generated flux. Due to the conductive or magnetic property of the iron it offers less reluctance to the linkage flux. These are widely used transformers in which is efficiency is high compared to air core type transformer.

Transformer based on winding arrangements

2.5 Auto Transformer

Normal transformers have two windings placed on two different sides i.e. primary and secondary but in auto transformer, the both the windings that is primary and secondary windings are connected to each other both physically and magnetically. There is one common winding which forms both primary and secondary winding in which voltage is varied by changing the position of secondary tapping on the body of the coil.

Transformer based on usage

The transformers are used to do many functions according to the necessarily. These are classified as power transformer, measuring transformer, protection transformer and distribution transformer.

2.6 Power Transformer

The power transformers are big in size and used for high power transfer applications, where the transmission voltage is greater than 33KV. It used in generating station and Transmission substation .high insulation level.

2.7 Distribution Transformer

It is used for the distribution of electrical energy at low voltage as less than 33KV in industrial purpose and 440v-220v in domestic purpose. It work at low efficiency at 50-70%, small size, easy in installation, having low magnetic losses & it is not always fully loaded.

2.8 Potential Transformer

These are used to measure the some electrical quantity like voltage, current etc. As their name specifies these are classified as potential transformers, current transformers etc.

2.9 Current Transformer

These types of transformers are used in component protections. The major difference between measuring and protection transformers is the accuracy i.e. the protection transformers should be more accurate compared to measuring transformers.

Transformers based on the place of use

These are classified as indoor and outdoor transformers. Indoor transformers are covered with proper roof like as in the process industry. The outdoor transformers are distribution type which are placed in substations etc.

CHAPTER 3 : FAILURES/FAULTS IN TRANSFORMER

Faults may occur in different parts and components of the transformer due to mechanical, electrical or thermal stress caused due to different conditions. Some of the most commonly occurring failures of the transformer and their causes are listed below.

3.1 Winding failure

Windings are an important part of a transformer. In distribution side transformers there are commonly two windings. One on the primary side and the second on the secondary side.

High voltage/low current flows in the primary side winding and through electromagnetic induction voltage is stepped down and current stepped up in the secondary side winding. These windings withstand dielectric, thermal and mechanical stress during this process. The faults that occur in the winding are due to these stresses. This causes the breaking of the windings or the burn-out. The winding fault PN number is usually between 6 to 30.

A. Dielectric faults occur in the winding due to turn-to-turn insulation breakdown. These are the insulation between the turns of the winding. Insulation breakdown commonly occur due to high current and voltage which are high above the rated values. The breakdown of the insulation results in the flash over of the winding turns and cause short circuit. Two reasons for the high rating are

   i. Lightning impulse attack with no lightning arresters
   ii. Fault voltages

B. The windings are usually of copper. Due to the copper line resistance thermal losses occur. These thermal losses make hot spots in the winding due to bad or lack of maintenance. This over time causes wear and tear and the decrease of the physical strength up to the point of breaking of the winding.

C. Mechanical faults are the distortion, loosening or displacement of the windings.

This results in the decrease of the performance of the transformer and the tearing of the turn-to-turn ratio. The main reasons that cause this fault are the improper repair, bad maintenance, corrosion, manufacturing deficiencies, vibration and mechanical movement within the transformer.

3.2 Bushing Failure

Bushes are insulating devices that insulate a high voltage electrical conductor to pass through an earth conductor. In transformers it provides a current path through the tank wall. Inside the transformer paper insulators are used which are surrounded by oil that provides further insulation. Bushing failure usually occurs over time [5]. Bushes failure PN number is between 24 to 48. Some of the main reasons for bushing failure are discussed below.

A. Loosening of conductors is caused by transformer vibrations which results in overheating. This heat damage the insulating paper and the oil used.

B. sudden high fault voltages causes' partial discharge (breakdown of solid/liquid electrical insulators) which damage the bushes and causes its degeneration and complete breakdown within hours.

C. Seal breaking of bushes happen due to ingress of water, aging or excessive dielectric losses. Due to this fault core failure of the transformer occurs.

D. Not replacing of old oil over long time or its deficiency due to leakage causes internal over-flashing.

3.3 Tap Changer Failure

The tap changer function in the transformer is to regulate the voltage level. This is done by either adding or removing turns from the secondary transformer winding. It is the most complex part of the transformer and also an important one. Even the smallest fault results in the wrong power output. The PN number is usually between 28 to 52.

Some fault and causes are

A. In Run-Through fault the tap changer takes time and after a delay changes the turn ratio. The main reason for it is the relay responsible for the tap change has residue flux because of polluted oil, therefore taking time to change. The other reason for run-through fault is the spring becoming fragile over time.

B. Lack of maintenance causes the shaft connection between the tap and the motor driver of the ta no changer to be not synchronous. Because of this the tap changer is not in the position where it needs to be.

C. Old capacitors or burned-out capacitor in the motor causes the tap changer to fail to control its direction movement.

D. Regular use of the tap changer causes the spring in it to slowly become fragile over time and then finally break. Because of this the tap changer is not able to change the turn ratio of the winding.

E. Breakdown of the motor in the tap changer because of over voltage or miss-use also causes the tap changer to fail to change the turn ratio of the winding.

3.4 Core failure

The transformers have laminated steel cores in the middle surrounded by the transformer windings. The function of the core is to concentrate the magnetic flux. Fault in the core directly affect the transformer windings, causing faults in them. The cores of the transformers are laminated to reduce eddy-current. The lamination of the core can become defected by poor maintenance, old oil or corrosion. The breakdown of the smallest part of the lamination results in increase of thermal heat due to eddy-current . The effects of this over heating are

A. The over-heating reaches the core surface which is in direct contact with the windings. As a result of this the windings are damaged by The heat.

B. This heat also damages the oil in the transformers resulting in the release of a gas from the oil that damages other parts of the transformer. The PN number of the core failure is often 6.

3.5 Tank Failures

The function of the tank in the transformer is to be a container for the oil used in it. The oil in the tank is used for insulation and cooling. The tank can also be used as a support for other equipment of the transformer . The PN number for the failure is 18. The fault in the tank occurs due to environmental stress, corrosion, high humidity and sun radiation resulting in a leakage or cracks in the tank walls. From these leakages and cracks oil spill from the tank causing the reduction of oil.

A. The reduction in oil level results in the reduction of insulation in the transformer and affecting the windings.

B. The oil is also used for cooling purposes so the reduction of oil causes overheating with damages different parts of the transformer.

3.6 Protection system Failure

The main function of the protection system is to protect the transformer from faults by first detecting the fault and then resolving it as fast as possible. If it cannot fix the fault, it isolates it so that it may not damage the transformer. Protection systems include the Buchholz protection, pressure relief valve circuitry, surge protection and Sudden Pressure Relays.
This is the most occurring failure with a PN between 22 to 64.

A. Buchholz protection is a protective device that is sensitive to dielectric faults in the transformer. Overheating of the relay occurs because of accumulation of gasses over time, which reduces its sensitivity to dielectric faults. Low level oil due to leakage causes the Buchholz protection to come into action even if there is not a fault which is not needed and waste of energy.

B. Pressure relief valve circuitry protects the transformer from exploding due to gas pressure. The gas pressure is produced due to overheating of oil . Pressure relief valve circuitry slowly reduces the pressure of the gasses. Fault in this circuitry mainly occurs due to the spring init becoming fragile over time resulting in the circuitry not being able to reduce pressure quickly. This circuitry also fails when gas pressure increases quickly as this is only able to release pressure slowly.

C. Surge protector protects the transformer from over voltage by allowing specific magnitude of voltage to go to transformer and for the rest alternate route is found. Failure in surge protection causes high voltage to pass to the windings which becomes damaged because of it. Moisture, heat and corrosion are the main reasons of the failure of surge protection as it causes overheating and short circuit in it.

D. Sudden Pressure Relays protects the transformers from blowing up from sudden exponential increase of gas pressure. If it fails to release the sudden pressure the transformer blows up. Relay fails due to humidity and moisture affecting its internal circuitry.

3.7 Cooling system failure

Cooling system reduces the heat produced in transformers due to copper and iron losses. The cooling system contains cooling fans, oil pumps and water-cooled heat exchangers. The failure in the cooling system causes the heat to build up in the transformer which effect different parts of the transformer and also causes more gas pressure to be built inside which may cause the transformer to blow. The PN is between 26 to 48. Some of the main reasons for failure are discussed below.

A. One of the biggest reasons of cooling system failure is leak in the oil/water pipes. This causes the reduction in the fluids which results in low heat exchange which is not good for the transformer. Leakage happens because of environmental stress, corrosion, high humidity and sun radiation.

B. Some failure occurs due to fault in the cooling fans which rush-in cool air into the tanks for cooling purpose. The fans create faults because of poor maintenance, over use or motor wear-out. Cooling system can perform wrong due to bad thermostats which measure the heat in the transformer. Faulty thermostats show wrong temperature causing the cooling system to operate

CHAPTER 4: PROTECTION OF TRANSFORMER

Over Current and Earth Fault Protection of Transformer:

Backup protection of electrical transformer is simple Over Current and Earth Fault protection applied against external short circuit and excessive over loads. These over current and earth Fault relays may be of Inverse Definite Minimum Time (IDMT) or Definite Time type relays. Generally IDMT relays are connected to the in-feed side of the transformer. The over current relays can not distinguish between external short circuit, over load and internal faults of the transformer. For any of the above fault, backup protection i.e. over current and earth fault protection connected to in-feed side of the transformer will operate.

Backup protection is although generally installed at in feed side of the transformer, but it should trip both the primary and secondary circuit breakers of the transformer.Over Current and Earth Fault protection relays may be also provided in load side of the transformer too, but it should not inter trip the primary side circuit breaker like the case of backup protection at in-feed side. The operation is governed primarily by current and time settings and the characteristic curve of the relay. To permit use of over load capacity of the transformer and co-ordination with other similar relays at about 125 to 150 % of full load current of the transformer but below the minimum short circuit current.

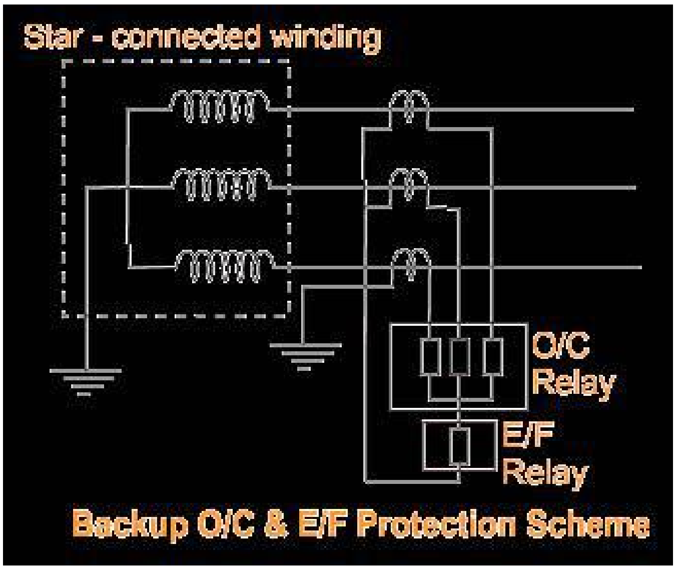


Fig. 4.1 Over current and earth fault protection

Backup protection of transformer has four elements, three over current relays connected each in each phase and one earth fault relay connected to the common point of three over current relays as shown in the figure. The normal range of current settings available on IDMT over current relays is 50 % to 200 % and on earth fault relay 20 to 80 %.

Another range of setting on earth fault relay is also available and may be selected where the earth fault current is restricted due to insertion of impedance in the neutral grounding. In the case of transformer winding with neutral earthed, unrestricted earth fault protection is obtained by connecting an ordinary earth fault relay across a neutral current transformer. The unrestricted over current and earth fault relays should have proper time lag to co-ordinate with the protective relays of other circuit to avoid indiscriminate tripping.

Protection System in Power System

There are always a chance of suffering an electrical power system from abnormal over voltages. These abnormal over voltages may be caused due to various reason such as, sudden interruption of heavy load, lightening impulses, switching impulses etc. These over voltage stresses may damage insulation of various equipments and insulators of the power system. Although, all the over voltage stresses are not strong enough to damage insulation of system, but still these over voltages also to be avoided to ensure the smooth operation of electrical power system. These all types of destructive and non destructive abnormal over voltages are eliminated from the system by means of over voltage protection.

Voltage Surge

The over voltage stresses applied upon the power system, are generally transient in nature. Transient voltage or voltage surge is defined as sudden sizing of voltage to a high peak in very short duration.

The voltage surges are transient in nature, that means they exist for very short duration. The main cause of these voltage surges in power system are due to lightning impulses and switching impulses of the system. But over voltage in the power system may also be caused by, insulation failure, arcing ground and resonance etc. The voltage surges appear in the electrical power system due to switching surge, insulation failure, arcing ground and resonance are not very large in magnitude. These over voltages hardly cross the twice of the normal voltage level. Generally, proper insulation to the different equipment of power system is sufficient to prevent any damage due to these over voltages. But over voltages occur in the power system due to lightning is very high. If over voltage protection is not provided to the power system, there may be high chance of severe damage. Hence all over voltage protection devices used in power system mainly due to lightning surges.

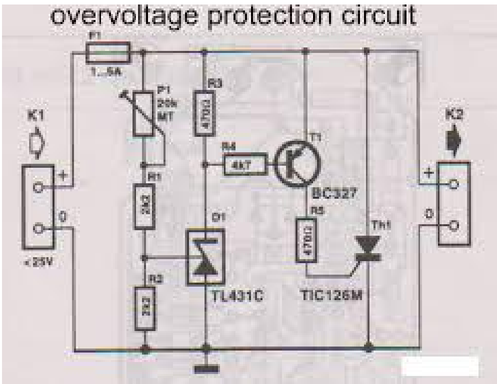


Fig. 4.2 Over Voltage Protection

Let us discuss different causes of over voltages one by one.

- **Switching Impulse or Switching Surge**

  When a no load transmission line is suddenly switched on, the voltage on the line becomes twice of normal system voltage. This voltage is transient in nature. When a loaded line is suddenly switched off or interrupted, voltage across the line also becomes high enough current chopping in the system mainly during opening operation of air blast circuit breaker, causes over voltage in the system. During insulation failure, a live conductor is suddenly earthed. This may also caused sudden over voltage in the system. If emf wave produced by alternator is distorted, the trouble of resonance may occur due to 5th or higher harmonics. Actually for frequencies of 5th or higher harmonics, a critical situation in the system so appears, that inductive reactance of the system becomes just equal to capacitive reactance of the system. As these both reactance cancel each other the system becomes purely resistive. This phenomenon is called resonance and at resonance the system voltage may be increased enough. But all these above mentioned reasons create over voltages in the system which are not very high in magnitude. But over voltage surges appear in the system due to lightning impulses are very high in amplitude and highly destructive. The affect of lightning impulse hence must be avoided for over voltage protection of power system.

- **Methods of Protection Against Lightning**

These are mainly three main methods generally used for protection against lightning. They are Earthing screen.Overhead earth wire. Lightning arrester or surge dividers.

- **Earthing Screen**

Earthing screen is generally used over electrical sub-station. In this arrangement a net of GI wire is mounted over the sub-station. The GI wires, used for earthing screen are properly grounded through different sub-station structures. This network of grounded GI wire over electrical sub-station, provides very low resistance path to the ground for lightning strokes.

This method of high voltage protection is very simple and economic but the main drawback is, it can not protect the system from traveling wave which may reach to the sub-station via different feeders.

- **Overhead Earth Wire**

This method of over voltage protection is similar as earthing screen. The only difference is, an earthing screen is placed over an electrical sub-station, whereas, overhead earthwire is placed over electrical transmission network. One or two stranded GI wires of suitable cross-section are placed over the transmission conductors. These GI wires are properly grounded at each transmission tower. These overhead ground wires or earth wire divert all the lightning strokes to the ground instead of allowing them to strike directly on the transmission conductors.

- **Lightning Arrester**

  The previously discussed two methods, i.e. earthing screen and over-head earth wire are very suitable for protecting an electrical power system from directed lightning strokes but system from directed lightning strokes but these methods can not provide any protection against high voltage travelling wave which may propagate through the line to the equipment of the sub-station. The lightning arrester is a devices which provides very low impedance path to the ground for high voltage travelling waves. The concept of a lightning arrester is very simple. This device behaves like a nonlinear electrical resistance. The resistance decreases as voltage increases and vice-versa, after a certain level of voltage. The functions of a lightning arrester or surge dividers can be listed as below.Under normal voltage level, these devices withstand easily the system voltage as electrical insulator and provide no conducting path to the system current. On occurrence of voltage surge in the system, these devices provide very low impedance path for the excess charge of the surge to the ground.After conducting the charges of surge, to the ground, the voltage becomes to its normal level. Then lightning arrester regains its insulation properly and prevents regains its insulation property and prevents further conduction of current, to the ground. There are different types of lightning arresters used in power system, such as rod gap arrester, horn gap arrester, multi-gap arrester, expulsion type LA, value type LA. In addition to these the most commonly used lightning arrester for over voltage protection now-a-days gapless ZnO lightning arrester is also used.

Restricted Earth Fault protection in Transformers

Transformers form the heart of all distribution systems. As a member of the Medium Voltage community, I have to explain Transformer Protection schemes routinely to my clients. Although I manage to answer most of their questions, some questions make me go to my library. This article is about answering some of the questions on a particularly interesting topic.

What is Restricted Earth Fault protection? How is it used in combination with

Differential Protection? I believe many of us must have had these questions in mind and also found answers at various places. I am only trying to combine the answers to derive a coherent understanding.

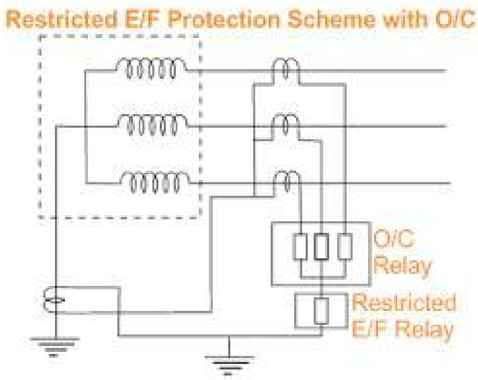
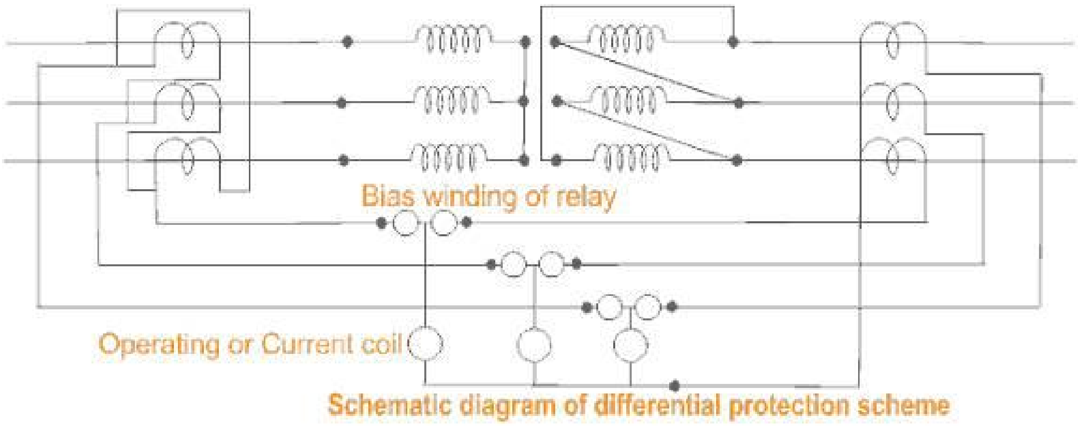


Fig. 4.3 Restricted Earth Fault Protection in Transformer

Restricted Earth Fault (REF) means an earth fault from a restricted/localized zone of a circuit. The term "REF protection method " means not to sense any earth faults outside this restricted zone. This type of protection is prevalent in Dyn group of transformers (Delta Primary and Star Secondary). The basic scheme for REF Protection is as below

Under normal conditions, the vector sum of currents in RYB current transformers (CTs) and NCT equals zero. If there is an earth fault between the CTs then some current will bypass the CT's and the sum of currents will not be zero. By measuring this current imbalance faults between the CTs can be easily identified and quickly cleared.

Fault detection is confined to the zone between the two CTs hence the name 'Restricted Earth Fault'. REF protection is fast and can isolate winding faults extremely quickly, thereby limiting damage and consequent repair costs. If CTs are located on the transformer terminals only the winding is protected. However, quite often the secondary CT is placed in the distribution switchboard, thereby extending the protection zone to include the main cable. Now this scheme is similar to differential protection in many aspects. Differential protection scheme is as below



Fi

g. 4.4 Differential Protection Scheme

Differential protection is to detect phase faults within the TRF on both primary and secondary sides. Restricted earth fault is to detect earth faults in the zone from secondary winding to Secondary CTs. The working principle is "Merz-Prize Circulating Current Principle". In Normal scenario, Current entering and leaving the zone will be same . The CT arrangement will generate equal and opposite currents which cancel out each other at the relay. During an internal fault, there shall be a difference between the current entering and leaving which shall be sufficient to operate the relay.

Please note that the differential relay will operate for earth faults inside the zone only if the earth fault current is more than the bias setting in the relay. The normal bias setting in a differential relay is 20%. So, complete earth fault protection is not possible with differential relay. That is why you need a restricted earth fault relay with sensitive settings like 5%.

Without REF, faults in the transformer star secondary winding need to be detected on the primary of the transformer by the reflected current. As the winding fault position moves towards the neutral, the magnitude of the current seen on the primary rapidly decreases and could potentially not be detected (limiting the amount of winding which can be protected). As the magnitude of the currents remain relatively large on the secondary (particularly if solidly earthed), nearly the entire winding can be protected using REF. REF cannot have an intentional time delay. They must operate instantaneously in the event of an internal fault.

CHAPTER 5 : PANELS DESIGN

Panels are used for the protection of transformer. The different protection schemes of transformer are employed by using panels. Panels mainly serve the purpose of control and giving indication of the faults that occur.

Fig. 5.1 Panel

5.1 Types of Panel

- **Marshalling Box -** [Fan, pump, CT, 4-20V Analog]
- **RTCC - Remote Tap Changer Control Cubical -** [Raise, Lower, AVR, RWTI, ROTI, RTPI etc]
- **TJB- Thermo Junction Box** [Only for WTI & OTI]
- **CM. Box - Common Marshalling Box**
- **DM Box - Drive Mechanism Box -** [Raise Lower]
- **VFD - Variable Frequency Drive**
- **PLC Panels**

5.1.1 Marshalling Box:

As the name suggests, Marshalling box is installed on transformer for protection& cooling. Various monitoring equipment like Oil temperature indicators, winding temperature indicators can be installed in marshalling box.

Fig. 5.2 Marshalling Box

5.1.2 RTCC :

RTCC is Remote Tap Changer Control Cubicle is connected to OLTC drive mechanism of Transformer through control cables. It raises & lower the voltages remotely specified by controlling the motor drive in OLTC electrically (and manually through Push Buttons). In RTCC an AVR (Automatic Voltage Regulator) is fixed to maintain the output voltage level (raise & lower) by controlling the motor. Annunciators, Indications circuits are also incorporated in RTCC panels.

Fig. 5.2 RTCC

5.1.3 VFD:

The main component of the motor control panel. The VFD inside will vary in voltage, horsepower, full load amps (FLA), and other specifications. Sometimes you may find redundant VFDs installed in case of a VFD failure.

- Line reactors : 3% or 5% to reduce harmonic distortion
- Harmonic filters : A more effective way to reduce harmonic distortion
- Circuit breaker : Protects the electrical circuit from overload or short
- Circuit bypass : Keeps the system running even if the VFD fails
- PLC (Programmable Logic Controller) : For more advanced operations
- Modem : For communication purpose
- AC or other cooling units : Keeps the panel at a certain temperature depending on surrounding environment
- Soft-starter : starts motor slowly but without speed control
- Surge protector :Protects the system from voltage spikes
- Multiple motor overloads : An option for powering multiple motors off

one VFD, typically used on fan walls

- Anti-condensation heater (available in NEMA 3R panels) : Eliminates the buildup of dew inside the VFD panel
- Motor starters : For running motors across the line

Fig. 5.3 VFD Panel

5.1.4 TJB:

It is a special kind of panel designed only if the customer demands for it. It is mainly used when the space available is less for the marshalling box. It only consist of winding temperature indicator and oil temperature indicator.

Fig. 5.4 TJB Panel

5.2 Linking Process of Panel

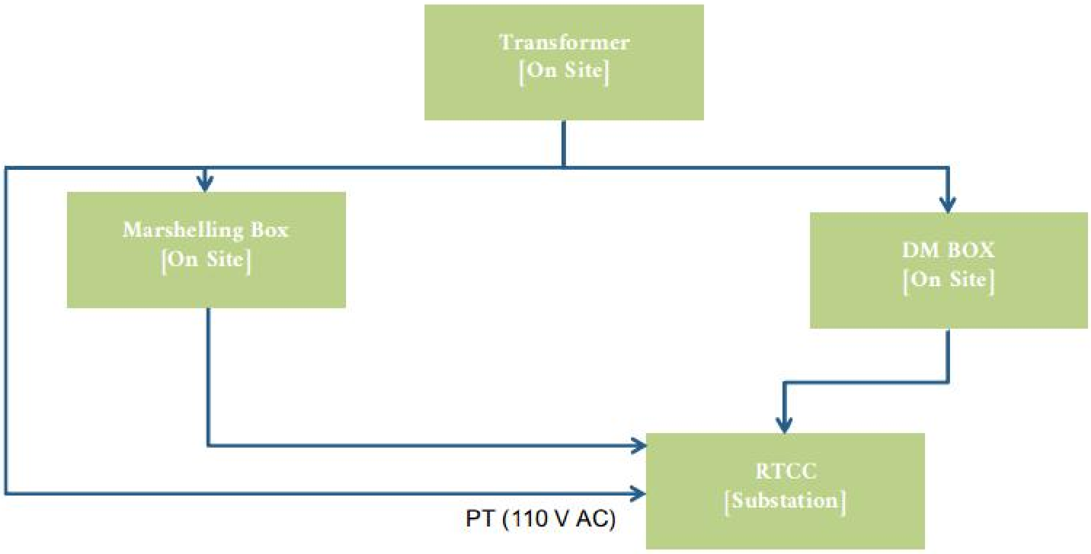


Fig. 5.5 Linking Process

CHAPTER 6 : DEVELOPMENT STAGES AND PROCESS OF PANEL

- General Arrangement
- Fabrication
- Special Instructions
- Bill of Material
- Different Circuits
- Wiring
- Check List
- Testing
- Dispatch

6.1 General Arrangement:

It gives detail description about the length, height, width of the panel. It also gives measurement of equipment which are mounted on the panel door and the foundation of the panel.

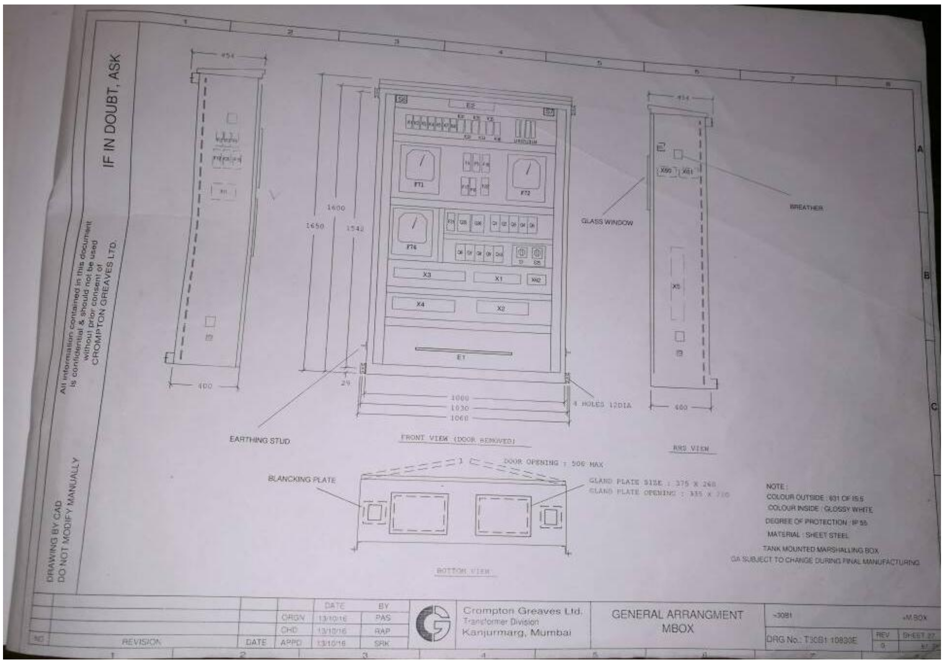


Fig. 6.1 General Arrangement

6.2 Fabrication:

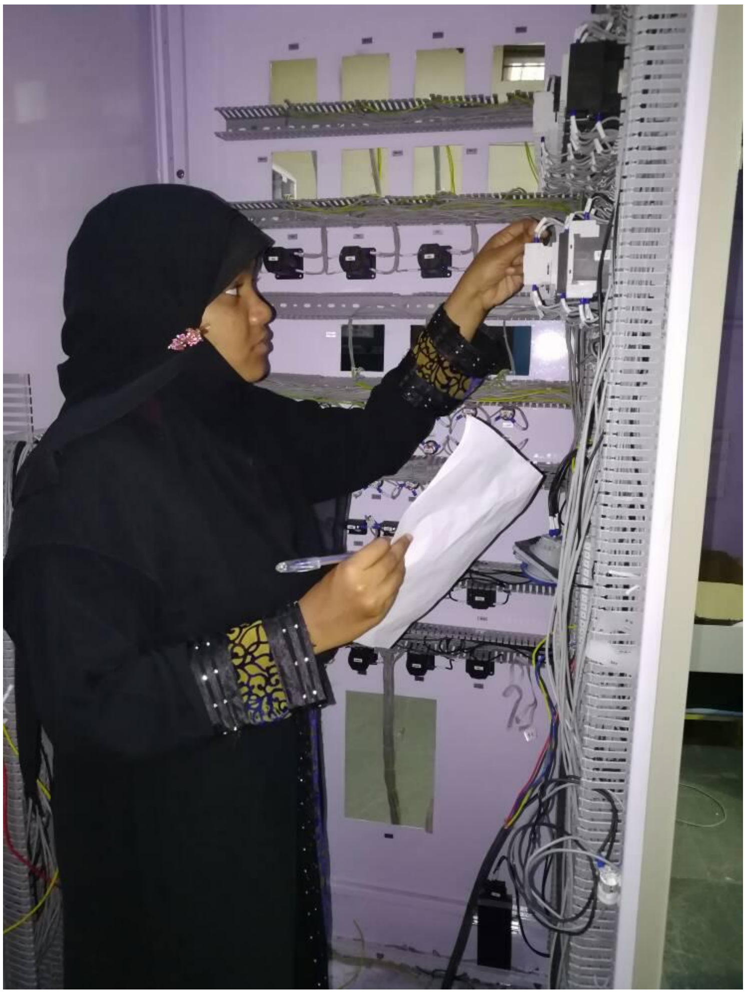


Fig. 6.2 Fabrication

6.3 Special Instruction:

- Circuit shown in de-energised Condition
- Recommended Setting of widning temperature indicator
    - ➢ ALARM - 100 C Trip: 110 C
    - ➢ FAN ON: 75 C FAN OFF: 65 C
- Recommended Settings of oil temperature indicator
    - ➢ ALARM: 85 C TRIP: 95 C
- All apparatus Mounted in marshalling box shall be effectively earthed.
- Copper stranded able used for wiring inside the marshalling box:
    - ➢ Control: 2.5 SQ. MM. FRLS 1100V Grade
    - ➢ Power: 2.5, 4,6,10,16, SQ.MM FRLS 1100V Grade

- ➢ Color: Red
- ➢ Yellow Power Circuit
- ➢ Blue
- ➢ Black Control Circuit
- ➢ Grey DC Circuit
- ➢ Yellow/GREEN Earth Wire

- Both ends of all wires shall be provided with crimping terminals for connection on terminal blocks
- All earth leads from devices in the M. Box shall be connected to two different earth studs
- Not more than two wires shall be taken from any of the terminals of devices mounted in the marshalling box
- All apparatus shall be tested at a voltage of 2KV to Earth for one minutes except electronic devices
- All trip circuit wires shall be marked with red ferrule 'TRIP'
- Switch n all motor breakers(MCB) before commencing electrical operation
- For selection of source 'A' as main supply keep switch S11 on "SOURCE A ON"
- RTCC Panel shall be crca Sheet of Minimum thickness of 2.5MM
- Abbreviation:
  - ➢ TRFR: Transformer
  - ➢ RTCC: Remote Tap change Control Cubicle
  - ➢ M.Box: Marshalling Box
  - ➢ DM: Drive Mechanism Box

6.4 Bill of Material

It gives detail description about the equipments used in panel. Their rating is also specified in the bill of material. The consumer also specifies the company make of the equipments and the quantity in which they are needed.

Device ID Location	Page	Technical Description/ Rating	Make
B1 M. Box	16 . C3	Thermostat	STAGO
E2 M. Box	16 . C4	Illumination Lamp (240V,11W CFL)	Phillips

Table Bill of Material

Fig. 6.3 Bill of Material

6.5 Circuits:

6.5.1 Trip Circuit:

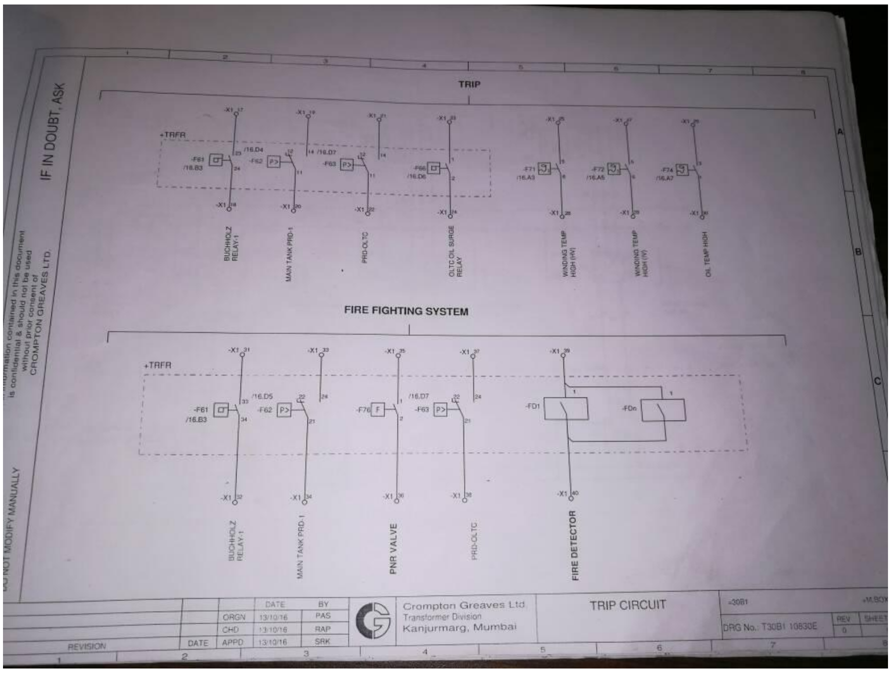


Fig. 6.4 Trip Circuit

6.5.2 Alarm Circuit:

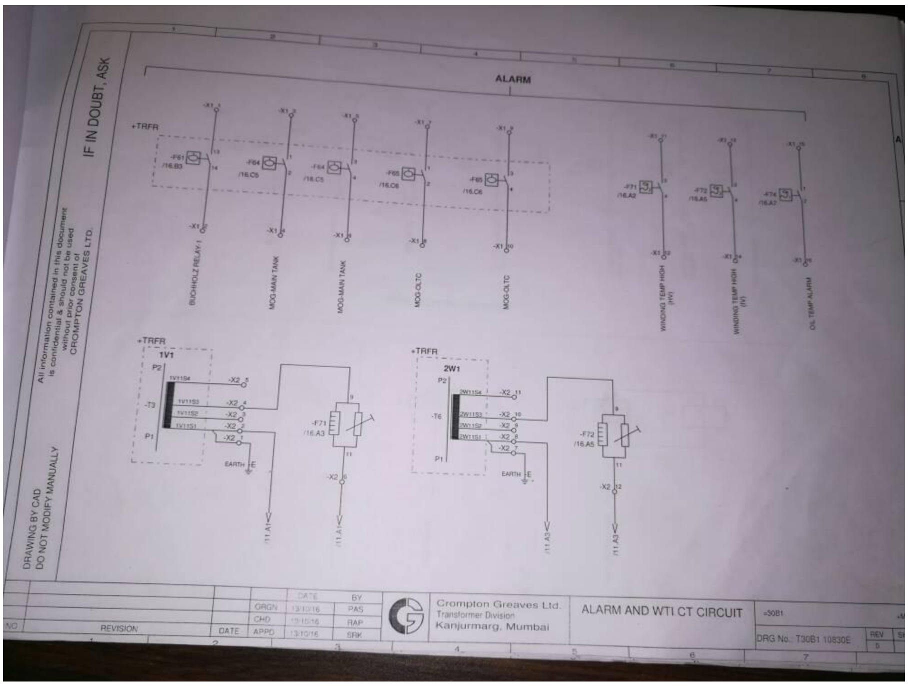


Fig. 6.5 Alarm Circuit

6.5.3 Control Circuit:

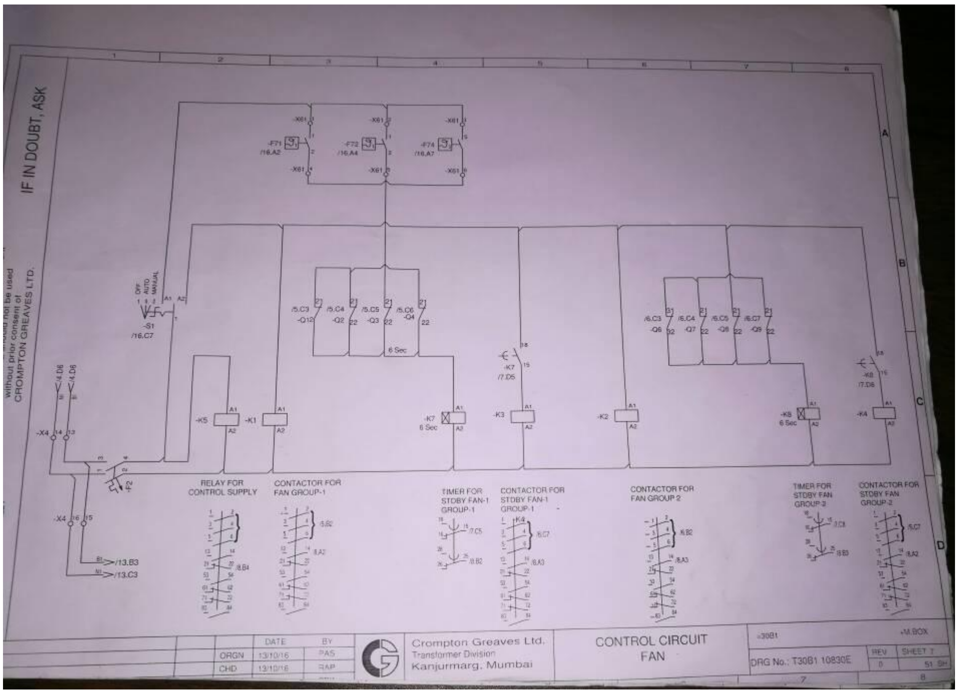


Fig. 6.6 Control Circuit

6.5.4 Phase Feeder - Incoming:

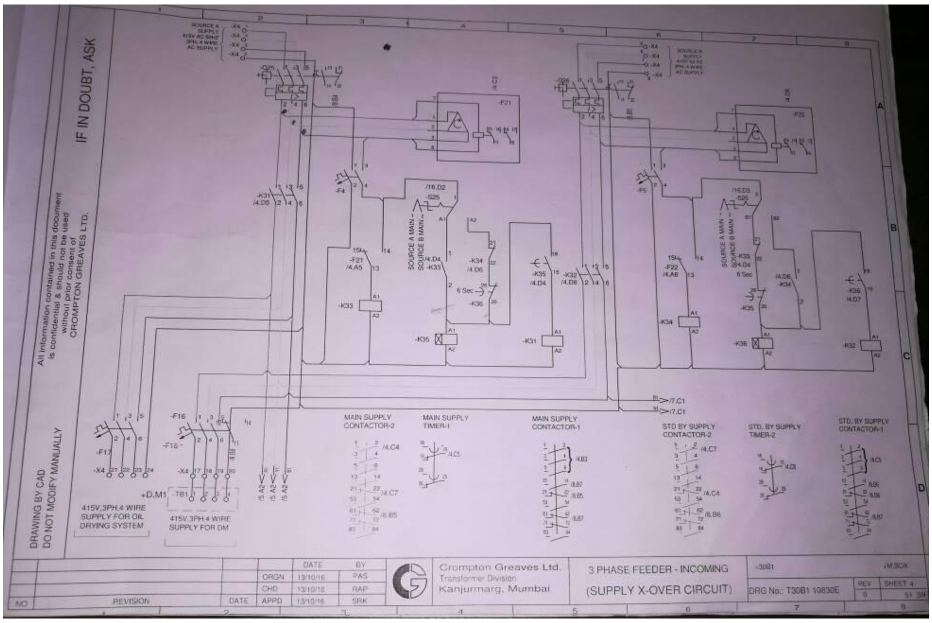


Fig. 6.7 3-Phase Feeder

6.5.5 Power Circuit

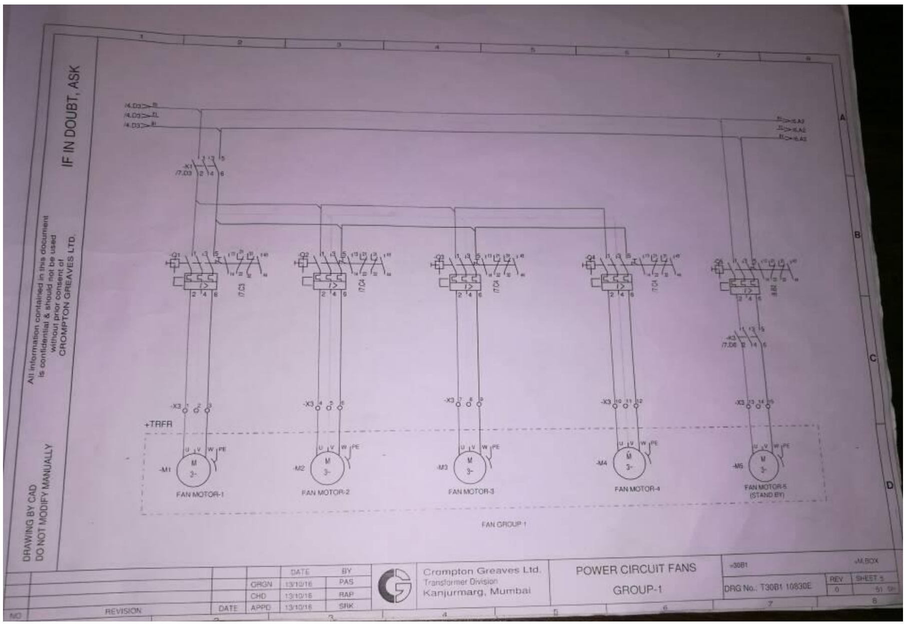


Fig.6.8 Power Circuit - 1

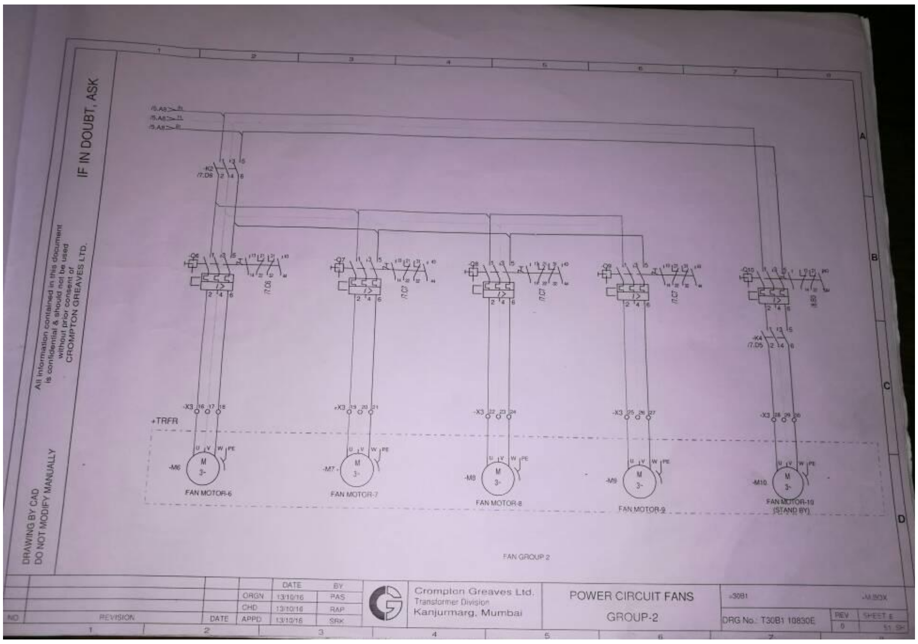


Fig.6.9 Power Circuit -2

6.6 Wiring:

Fig. 6.10 Wiring

6.7 Testing:

6.7.1 Testing RTCC Operation:

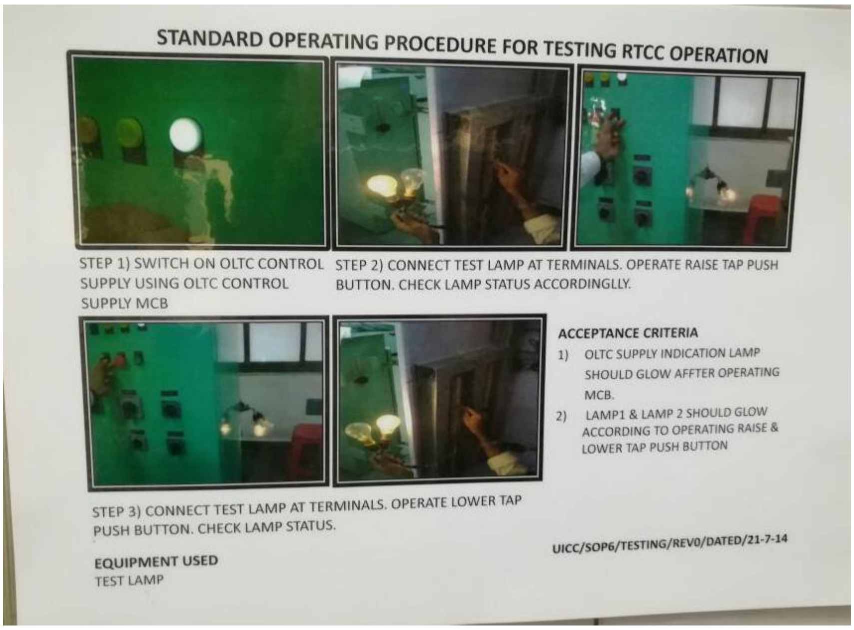


Fig. 6.11 Testing RTCC Operation

6.7.2 Wire Pull Check:

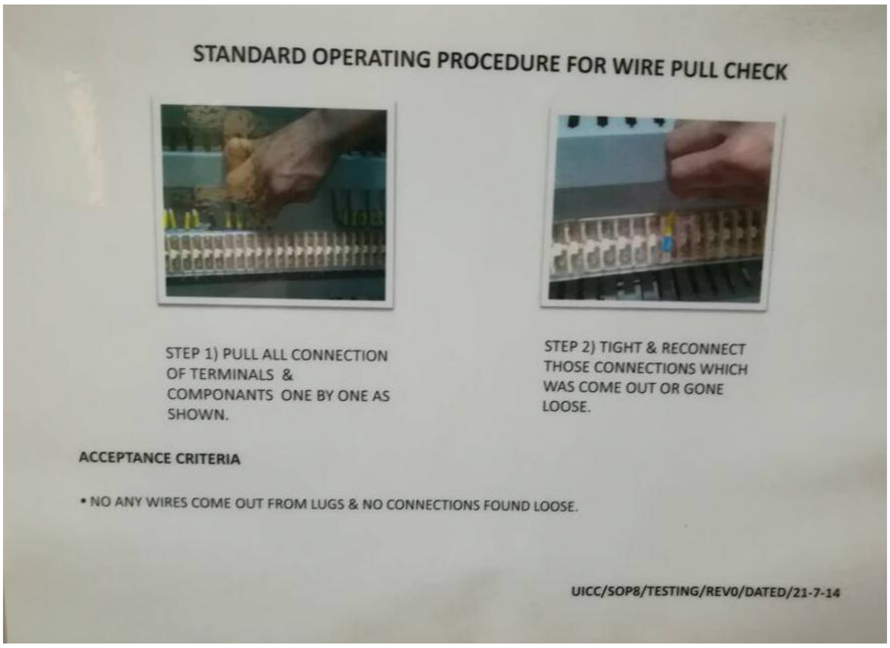


Fig. 6.12 Wire Pull Check

6.7.3 Testing Alarm/Trip Circuit & Wire Pull Check:

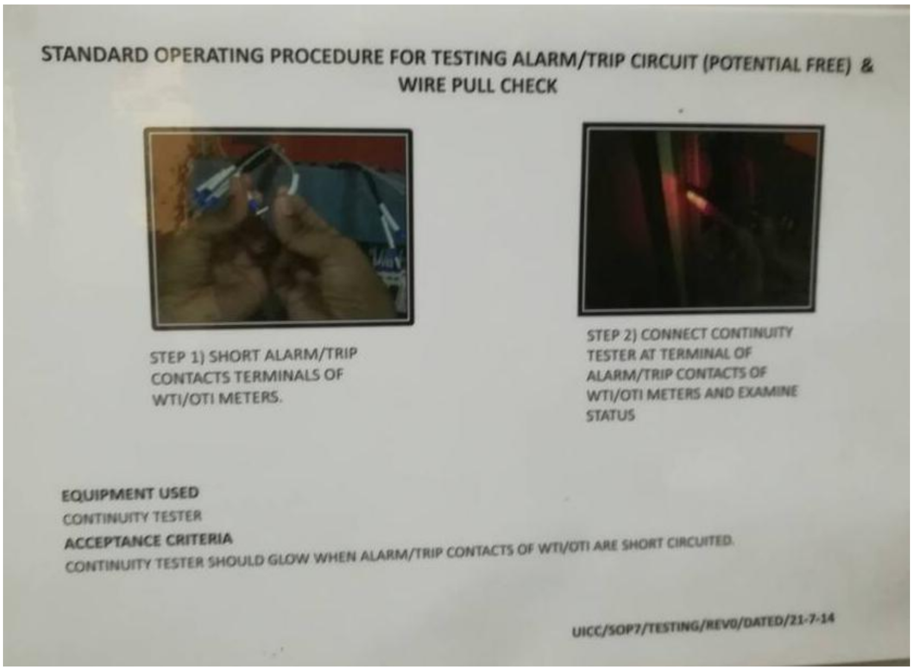


Fig. 6.13 Testing Alarm/Trip Circuit & Wire Pull Check

6.7.4 Insulation Resistance Test:

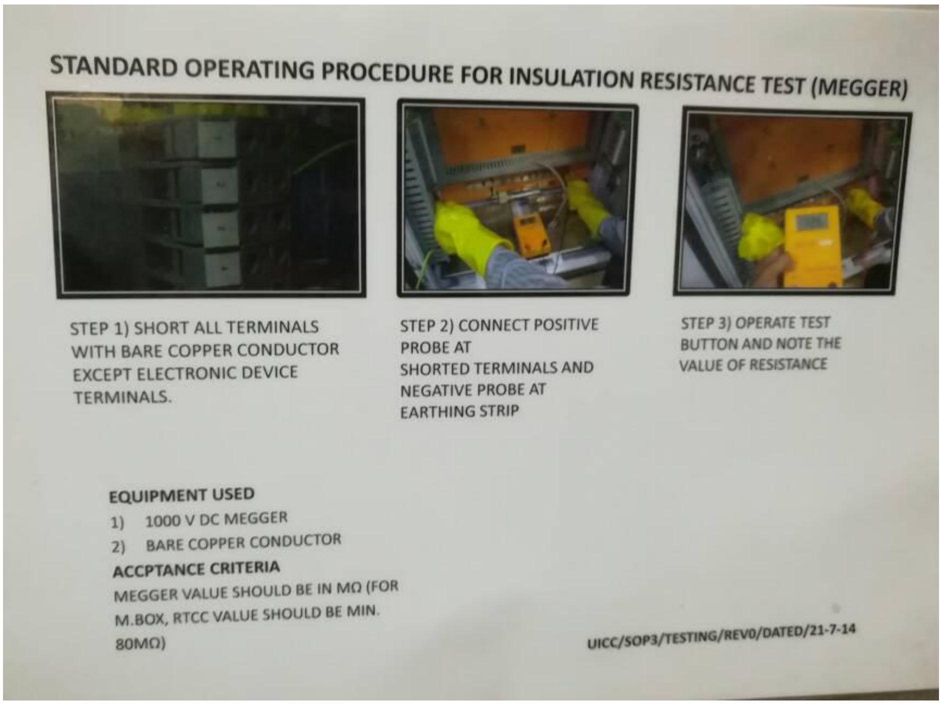


Fig. 6.14 Insulation Resistance Test

6.7.5 Testing Socket and Lamp:

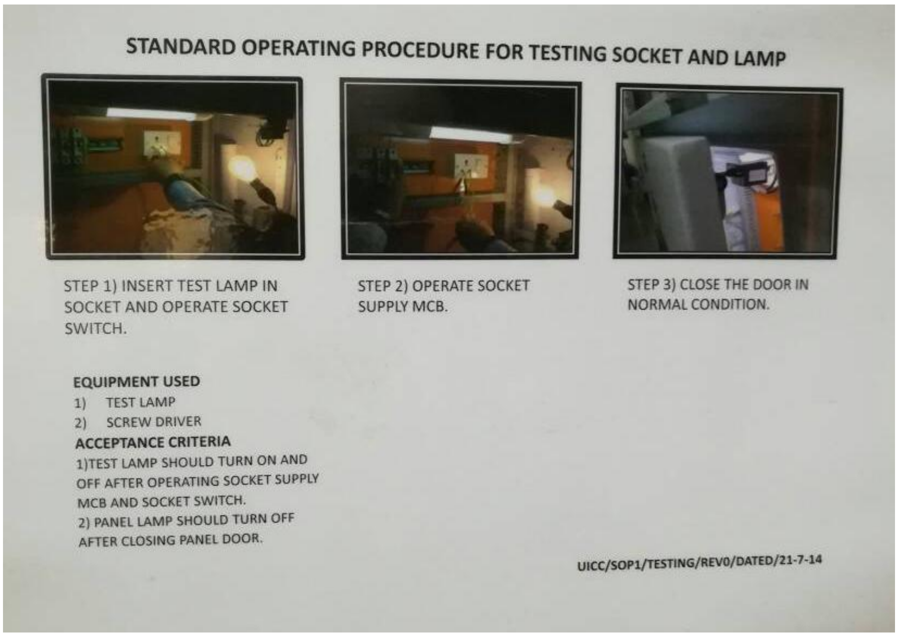


Fig. 6.15 Testing Socket and Lamp

6.7.6 Testing Fan & Pump Operation:

Fig. 6.16 Testing Fan & Pump Operation

6.7.7 Procedure for HV Test:

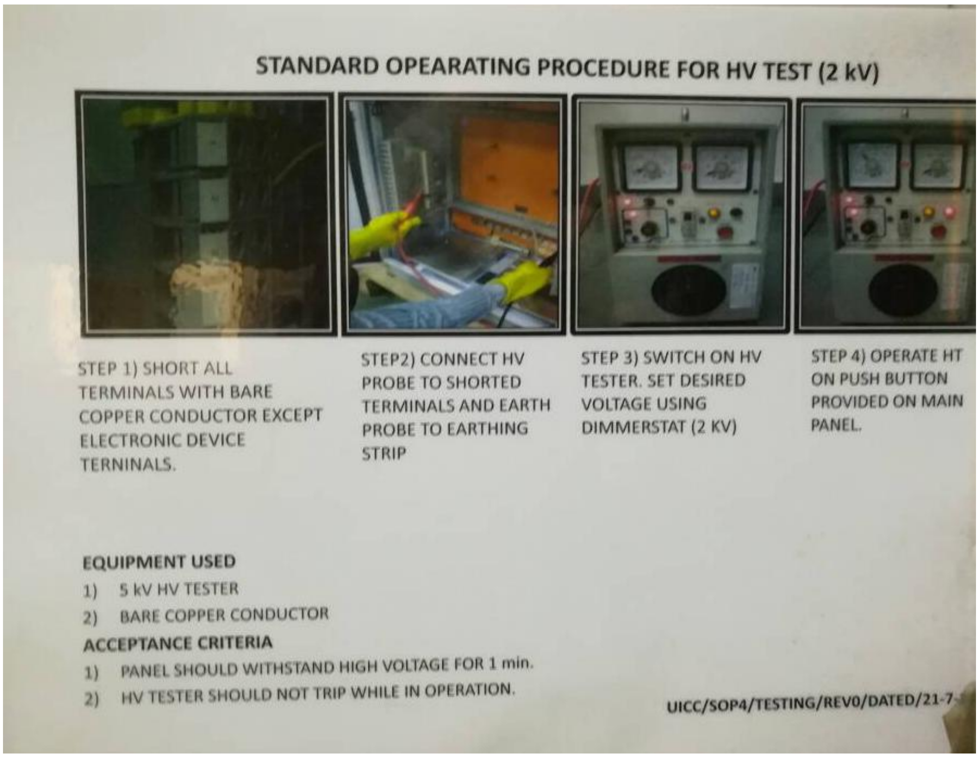


Fig. 6.17 Procedure for HV Test

6.7.8 Testing Heater Circuit:

Fig. 6.18 Testing Heater Circuit

Fig. 6.19 Testing

6.8 Dispatch:

After the process is done the Panel is dispatched to the respective customer

CHAPTER 7 : SOME COMMONLY USED EQUIPMENTS IN PANEL

7.1 Temperature Transducers

Temperature transducers are very common nowadays. They are used in the heating, ventilation and air-conditioning sectors as well as in any other place where it is required to test the production process temperature. Temperature transducers vary depending on the measuring principle. Different temperature transducer models are available. Temperature transducers to measure temperature by means of infrared radiation are used to determine surface temperature. Besides, there are other temperature transducers used to measure the air temperature, converting it to a normalized signal. Temperature transducers are usually connected to a separate control unit. Temperature transducers transform a temperature physical magnitude into electrical normalized signal which are transferred to a control device. This fact allows to reach maximum or minimum alarm value, turn on/off a heating machine, etc.

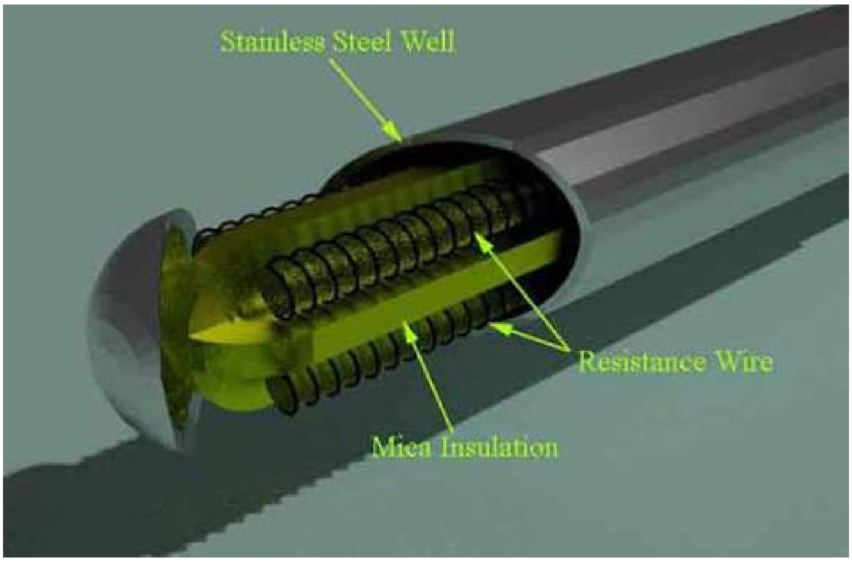


Fig. 7.1 Temperature Transducer

7.2 CONTACTOR

A contactor is an electrically controlled switch used for switching an electrical power circuit, similar to a relay except with higher current ratings and a few other differences. A contactor is controlled by a circuit which has a much lower power level than the switched circuit.

Contactors come in many forms with varying capacities and features. Unlike a circuit breaker, a contactor is not intended to interrupt a short circuit current. Contactors range from those having a breaking current of several amperes to thousands of amperes and 24 V DC to many kilovolts. The physical size of contactors ranges from a device small enough to pick up with one hand, to large devices approximately a meter on a side. Contactors are used to control electric motors, lighting, heating, capacitor banks, thermal evaporators, and other electrical loads.

7.3 MCB:

Nowadays we use more commonly miniature circuit breaker or MCB in low voltage electrical network instead of fuse. The MCB has some advantages compared to fuse.It automatically switches off the electrical circuit during abnormal condition of the network means in over load condition as well as faulty condition. The fuse does not sense but miniature circuit breaker does it in more reliable way. MCB is much more sensitive to over current than fuse.Another advantage is, as the switch operating knob comes at its off position during tripping, the faulty zone of the electrical circuit can easily be identified. But in case of fuse, fuse wire should be checked by opening fuse grip or cutout from fuse base, for confirming the blow of fuse wire.

Fig. 7.2 Miniature Circuit Breaker (MCB)

Quick restoration of supply can not be possible in case of fuse as because fuses have to be rewirable or replaced for restoring the supply. But in the case of MCB, quick restoration is possible by just switching on operation.Handling MCB is more electrically safe than fuse. Because of to many advantages of MCB over fuse units, in modern low voltage electrical network, miniature circuit breaker is mostly used instead of backdated fuse unit.Only one disadvantage of MCB over fuse is that this system is more costlier than fuse unit system.

Working Principle Miniature Circuit Breaker

There are two arrangement of operation of miniature circuit breaker. One due to thermal effect of over current and other due to electromagnetic effect of over current. The thermal operation of miniature circuit breaker is achieved with a bimetallic strip whenever continuous over current flows through MCB, the bimetallic strip is heated and deflects by bending. This deflection of bimetallic strip releases mechanical latch. As this mechanical latch is attached with operating mechanism, it causes to open the miniature circuit breaker contacts. But during short circuit condition, sudden rising of current, causes electro mechanical displacement of plunger associated with tripping coil or solenoid of MCB. The plunger strikes the trip lever causing immediate release of latch mechanism consequently open the circuit breaker contacts. This was a simple explanation of miniature circuit breaker working principle.

Miniature Circuit Breaker Construction

Miniature circuit breaker construction is very simple, robust and maintenance free. Generally a MCB is not repaired or maintained, it just replaced by new one when required. A miniature circuit breaker has normally three main constructional parts. These are:

Frame of Miniature Circuit Breaker

The frame of miniature circuit breaker is a molded case. This is a rigid, strong, insulated housing in which the other components are mounted.

Operating Mechanism of Miniature Circuit Breaker

The operating mechanism of miniature circuit breaker provides the means of manual opening and closing operation of miniature circuit breaker. It has three-positions "ON," "OFF," and "TRIPPED". The external switching latch can be in the "TRIPPED" position, if the MCB is tripped due to over-current. When manually switch off the MCB, the switching latch will be in "OFF" position. In close condition of MCB, the switch is positioned at "ON". By observing the positions of the switching latch one can determine the condition of MCB whether it is closed, tripped or manually switched off.

Trip Unit of Miniature Circuit Breaker

The trip unit is the main part, responsible for proper working of miniature circuit breaker. Two main types of trip mechanism are provided in MCB. Abimetal provides protection against over load current and an electromagnet provides protection against short-circuit current.

7.4 Motor Protection Circuit Breaker

The motor protection circuit breaker can be considered a sub type of thermal magnetic circuit breaker, but with additional functions that are specially designed to protect electric motors. The basic working principle is similar to all other circuit breakers.Thermal protection is used to guard the electric motor against overload. It is based on an expanding and contracting contact that disconnects the motor if excessive current is detected. It is very important to know that thermal protection has a delayed response, to allow the high inrush currents when a motor starts.

However, if the motor is unable to start for some reason, thermal protection will trip in response to the extended inrush current.Magnetic protection is used when there is a short circuit, line fault, or other high current electric fault. Unlike thermal protection, magnetic protection is instantaneous, to immediately disconnect the dangerous fault currents.The main difference between the MPCB and other circuit breakers is that the MPCB can provide protection against phase unbalance and phase loss. Three-phase circuit motors require three live conductors with balanced voltages in order to operate effectively. An unbalance of more than 2% will be detrimental to the motor's service life. If one of the phase voltages is suddenly lost, the effect is even more damaging because the motor will keep on running with only two phases. The motor protection circuit breaker is capable of detecting these conditions by measuring the differences among phase voltages, and disconnects the motor immediately when they occur. It is important to note that phase current unbalance is normal in three-phase systems that power separate single-phase loads, but is unacceptable when the three-phase circuit powers an electric motor. MPCBs are also equipped with a manual interruption mechanism, allowing disconnection of electric motors for replacement or maintenance.Motor protection circuit breakers are available in a wide variety of current ratings, and one of their best features is that many models allow the current rating to be adjusted. This means that the same MCPB can be configured to protect motors of different capacities.

Fig. 7.3 Motor Protection Circuit Breaker

Asynchronous Motor Protection

Most motors used in the industry are asynchronous motors, also known a squirrel-cage induction motors. These motors use three-phase power to create a rotating magnetic field, which in turn magnetizes the rotor an creates rotational movement. When designing the electrical protection for an asynchronous motor and selecting motor protection circuit breakers, there are some very important factors to consider that aren't present when protecting other types of electric circuits.Asynchronous motors draw a very high inrush current during start up, because they must establish a rotating magnetic field. This current can reach values of 500% to 800% of the rated value for a few fractions of a second. For this reason, the MPCB magnetic protection trips at values greater than 10 times the rated current, unlike some types of miniature circuit breaker switch trip at values as low as 3 times rated current. In these cases, using a circuit breaker other than an MPCB will not even allow starting the motor before the magnetic protection trips. In order to reduce the inrush current, a very common practice is to complement the motor protection circuit breaker with a reduced voltage motor starter.Asynchronous motors require the three phase conductors to have a balanced voltage in order to operate properly. If the phase conductors have an unbalance greater than 2%, the motor will suffer damage over time and will have a reduced service life. The electric motor will also tend to overheat, causing additional energy expenses as waste heat. For this reason, a motor circuit breaker must be able to detect phase imbalance and disconnect the motor accordingly.If one of the phases is disconnected completely, the motor will keep operating but the current in the remaining two phases will rise above the rated value due to the electrical unbalance, and will probably burn the motor's windings. For this reason, motor protectors must trip immediately as soon as phase unbalance or phase loss is detected. This is normally achieved by measuring the differences in current among the phase conductors. If one of the phase currents rises or drops considerably compared with the other two, it is indicative of unbalance. Likewise, if one of the phase currents drops to zero while the other two remain, a phase loss has occurred.Then, what kinds of breakers can be used for the protection of asynchronous motors? Manufacturers generally offer three different motor protection circuit breakers, available for a wide range of voltages and currents, in order to meet most asynchronous motor protection needs.

It is very common to complement motor protection circuit breakers with a contactor to allow automatic control of motor start up and disconnection. The system might also include and under-voltage protection device, which disconnects the motor in case the system voltage drops considerably below the rated value.

Motor Protection Circuit Breaker Sizing (Selection Guide)

The two main factors that determine the adequate motor protection circuit breaker size are the nameplate voltage and nameplate current of the motor itself.The MPCB voltage rating must match the nameplate voltage of the motor. Normally, motor protection circuit breakers can be used in a wide variety of voltage ratings such as 230 V, 380 V, 415 V, 440 V, 500 V, and 660 V.Once the voltage is known, it is necessary to check the nameplate current of the electric motor. It is important to note that the actual operating current may be lower than nameplate current, especially if the motor isn't fully loaded. However, the MPCB must always be selected according to nameplate current value in order to allow the inrush current when a motor starts. For example, a motor with a nameplate current of 20 amperes might draw a much lower current during part-load operation, but the MPCB must be selected according to the rated value of 20 amperes, or it might trip if the motor is used at full load.Motor protection circuit breakers can then be calibrated to the exact current value that is adequate for the electric motor being protected. They typically have an adjustment range. For example, a MPCB rated at 32 amperes might be usable for motors with rated currents as low as 22 amperes. This is very useful if an electric motor is replaced with a more efficient model that requires a lower current, since it will not be necessary to replace the motor breaker.Even if a motor protection circuit breaker is sized correctly according to the electric motor being protected, it is also important to use adequate wiring. In order to provide adequate protection, the wire must be able to conduct the rated current safely. An undersized wire will overheat, the insulation will melt, and electric faults may occur even with a breaker installed.

Motor Protection Circuit Breaker Specification Chart

MPCB manufacturers typically provide charts where the technical specifications of the circuit breaker are presented, in order to simplify the selection process. The following chart, provided as an example, is for the motor circuit breakerSGV2-ME model manufactured by CGSL. The current values at which the thermal and magnetic protections operate are displayed in the thermal release and magnetic release columns. Before installing a MPCB, it is very important to verify that voltage and current ratings are compatible with the motor being protected.

Conclusions of Motor Protection Circuit Breaker

Motor protection circuit breakers have a very important role in electrical safety, since the motors they protect have a wide variety of applications in commercial buildings and industry. Asynchronous motors, the most common type of electric motor in industrial and commercial settings, has special protection requirements that can only be met by a motor protection circuit breaker. It is also possible to complement MPCB with other protection or automation devices such as under-voltage protection, timers, and reduced voltage motor starters. Adequate selection of the MPCB is key in order to provide reliable motor protection. An undersized MPCB will not even allow the motor to start, while an over sized MPCB might be unable to detect over-current conditions for the electric motor being protected.

7.5 OIL / WINDING TEMPERATURE INDICATORS

Precimeasure offers Oil Temperature Indicators (OTIs) and Winding Temperature Indicators (WTIs) for transformers. The WTI measures the hot-spot winding temperature of the transformers. The cost-effective WTIs are available in different models. This is basically an OTI with additional heater coil connected to CT.

The WTI is very essential for smooth running of a transformer as impacts the life of transformers and causes deterioration of the insulating material. Both OTI and WTI are fully compensated for ambient temperature changes in line and case. They are available with up to 50mof capillary length and up to four control switches.

Digital Signal Converters and Transmitter Scheme:

Precimeasure electronic instruments are known for their accuracy and repeatability for longer periods. These instruments are electrically isolated from input power supplies and hence safe to use in a computerised data acquisition system or recorder.

The scheme is used to indicate the OTI / WTI of oil-immersed transformers in remote control room. This has an output of 4mA to 20mA DC proportional to the temperature range.

Precimeasure Controls manufactures a wide range of electronic instruments to meet all the requirements of transformer industries.

7.6 TAP POSITION INDICATOR / TRANSMITTERS:

Precimeasure offers tap position transmitters and indicators that are used to indicate the tap position of the on-load tap changers employed in power transformers. The on-load tap changer changes the output voltage of transformer, maintaining a reasonably constant voltage by selecting the proper tapping in the transformer winding. The tap position is indicated in numbers depending upon the numbers of steps used in the tap changer.

Fig. 7.4 Tap Position Indicator

7.7 Thermostats:

Feeling too hot? You'll be wanting to cool down, then. Feeling too cold? You'll need to warm up. Our bodies are amazing, self-regulating mechanisms that can constantly adjust to keep their temperature within a whisker of 37°C (98.6°F). But the rest of the world isn't quite so helpful. If we want our homes to keep their temperature more or less constant, we have to keep switching our heaters on and off—or, alternatively, rely on clever gadgets called thermostats to do the job for us. What are they and how do they work? Let's take a look inside!

Fig. 7.5 Thermostat

Fig. 7.6 Thermostat

What is a thermostat?

You might have a temperature control on a wall in your home to control the heating system but, although it's probably marked in degrees, it's not a thermometer. It's called a thermostat, a modern word based on two ancient Greek ones: thermo (meaning heat) and statos (which means standing and is related to words like stasis, status quo, and static—meaning to stay the same). We can tell just from its name that a thermostat is something that "keeps heat the same": when our home is too cold, the thermostat switches on the heating so things quickly warm up; once the temperature reaches the level we've set, the thermostat switches the heating off so we don't boil.

Let's just be clear about the difference: a thermometer is something that measures the temperature; a thermostat is something that tries to maintain the temperature (keep it roughly the same).

How thermostats work

So how does a thermostat work? Most things get bigger when they heat up and smaller when they cool down (water is a notable exception: it expands when it heats up and when it freezes too). Mechanical thermostats use this idea (which is called thermal expansion) to switch an electric circuit on and and off. The two most common types use bimetallic strips and gas-filled bellows.

Bimetallic strips

A traditional thermostat has two pieces of different metals bolted together to form what's called a bimetallic strip (or bimetal strip). The strip works as a bridge in an electrical circuit connected to your heating system. Normally the "bridge is down", the strip carries electricity through the circuit, and the heating is on. When the strip gets hot, one of the metals expands more than the other so the whole strip bends very slightly. Eventually, it bends so much that it breaks open the circuit. The "bridge is up", the electricity instantly switches off, the heating cuts out, and the room starts to cool.

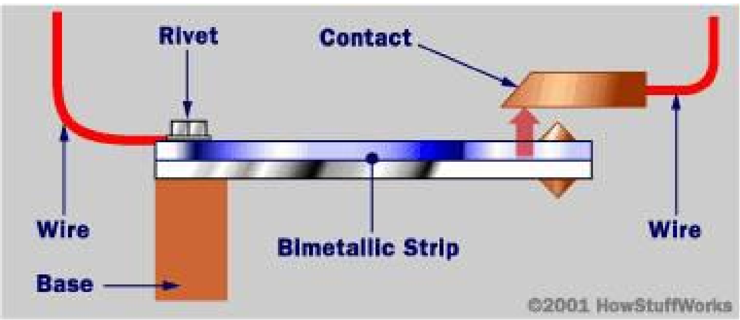


Fig. 7.7 Bimetallic Strip

But then what happens? As the room cools, the strip cools too and bends back to its original shape. Sooner or later, it snaps back into the circuit and makes the electricity flow again, so the heating switches back on. By adjusting the temperature dial, you change the temperature at which the circuit switches on and off. Because it takes some time for the metal strip to expand and contract, the heating isn't constantly switching on and off every few seconds, which would be pointless (and quite irritating); depending on how well-insulated your home is, and how cold it is outside, it might take an hour or more for the thermostat to switch back on once it's switched off.

When a relay is used to switch a large amount of electrical power through its contacts, it is designated by a special name: contactor. Contactors typically have multiple contacts, and those contacts are usually (but not always) normally-open, so that power to the load is shut off when the coil is de-energized. Perhaps the most common industrial use for contactors is the control of electric motors.

The top three contacts switch the respective phases of the incoming 3-phase AC power, typically at least 480 Volts for motors 1 horsepower or greater. The lowest contact is an "auxiliary" contact which has a current rating much lower than that of the large motor power contacts, but is actuated by the same armature as the power contacts. The auxiliary contact is often used in a relay logic circuit, or for some other part of the motor control scheme, typically switching 120 Volt AC power instead of the motor voltage. One contactor may have several auxiliary contacts, either normally-open or normally-closed, if required.

The three "opposed-question-mark" shaped devices in series with each phase going to the motor are called overload heaters. Each "heater" element is a low-resistance strip of metal intended to heat up as the motor draws current. If the temperature of any of these heater elements reaches a critical point (equivalent to a moderate overloading of the motor), a normally-closed switch contact (not shown in the diagram) will spring open. This normally-closed contact is usually connected in series with the relay coil, so that when it opens the relay will automatically de-energize, thereby shutting off power to the motor. We will see more of this overload protection wiring in the next chapter. Overload heaters are intended to provide over current protection for large electric motors, unlike circuit breakers and fuses which serve the primary purpose of providing over current protection for power conductors.

Overload heater function is often misunderstood. They are not fuses; that is, it is not their function to burn open and directly break the circuit as a fuse is designed to do. Rather, overload heaters are designed to thermally mimic the heating characteristic of the particular electric motor to be protected. All motors have thermal characteristics, including the amount of heat energy generated by resistive dissipation (I2R), the thermal transfer characteristics of heat "conducted" to the cooling medium through the metal frame of the motor, the physical mass and specific heat of the materials constituting the motor, etc. These characteristics are mimicked by the overload heater on a miniature scale: when the motor heats up toward its critical temperature, so will the heater toward its critical temperature, ideally at the same rate and approach curve. Thus, the overload contact, in sensing heater temperature with a thermo-mechanical mechanism, will sense an analogue of the real motor. If the overload contact trips due to excessive heater temperature, it will be an indication that the real motor has reached its critical temperature (or, would have done so in a short while). After tripping, the heaters are supposed to cool down at the same rate and approach curve as the real motor, so that they indicate an accurate proportion of the motor's thermal condition, and will not allow power to be re-applied until the motor is truly ready for start-up again.

7.8 Relay / Timer

Shown here is a contactor for a three-phase electric motor, installed on a panel as part of an electrical control system at a municipal water treatment plant:

Time-delay relay contacts must be specified not only as either normally-open or normally-closed, but whether the delay operates in the direction of closing or in the direction of opening. The following is a description of the four basic types of time-delay relay contacts.

First we have the normally-open, timed-closed (NOTC) contact. This type of contact is normally open when the coil is unpowered (de-energized). The contact is closed by the application of power to the relay coil, but only after the coil has been continuously powered for the specified amount of time. In other words, the direction of the contact's motion (either to close or to open) is identical to a regular NO contact, but there is a delay in closing direction. Because the delay occurs in the direction of coil energization, this type of contact is alternatively known as a normally-open, on-delay

Fig. 7.8 Relay / Timer

Next we have the normally-open, timed-open (NOTO) contact. Like the NOTC contact, this type of contact is normally open when the coil is unpowered (de-energized), and closed by the application of power to the relay coil. However, unlike the NOTC contact, the timing action occurs upon de-energization of the coil rather than upon energization. Because the delay occurs in the direction of coil de-energization, this type of contact is alternatively known as a normally-open, off-delay

Next we have the normally-closed, timed-open (NCTO) contact. This type of contact is normally closed when the coil is unpowered (de-energized). The contact is opened with the application of power to the relay coil, but only after the coil has been continuously powered for the specified amount of time. In other words, the direction of the contact's motion (either to close or to open) is identical to a regular NC contact, but there is a delay in the opening direction. Because the delay occurs in the direction of coil energization, this type of contact is alternatively known as a normally-closed, on-delay:

The following is a timing diagram of this relay contact's operation:

Finally we have the normally-closed, timed-closed (NCTC) contact. Like the NCTO contact, this type of contact is normally closed when the coil is unpowered (de-energized), and opened by the application of power to the relay coil. However, unlike the NCTO contact, the timing action occurs upon de-energization of the coil rather than upon energization. Because the delay occurs in the direction of coil de-energization, this type of contact is alternatively known as a normally-closed, off-delay:

Time-delay relays are very important for use in industrial control logic circuits. Some examples of their use include:

Flashing light control (time on, time off): two time-delay relays are used in conjunction with one another to provide a constant-frequency on/off pulsing of contacts for sending intermittent power to a lamp.Engine autostart control: Engines that are used to power emergency generators are often equipped with "autostart" controls that allow for automatic start-up if the main electric power fails. To properly start a large engine, certain auxiliary devices must be started first and allowed some brief time to stabilize (fuel pumps, pre-lubrication oil pumps) before the engine's starter motor is energized. Time-delay relays help sequence these events for proper start-up of the engine.Furnace safety purge control: Before a combustion-type furnace can be safely lit, the air fan must be run for a specified amount of time to "purge" the furnace chamber of any potentially flammable or explosive vapors. A time-delay relay provides the furnace control logic with this necessary time element.Motor soft-start delay control: Instead of starting large electric motors by switching full power from a dead stop condition, reduced voltage can be switched for a "softer" start and less inrush current. After a prescribed time delay (provided by a time-delay relay), full power is applied.Conveyor belt sequence delay: when multiple conveyor belts are arranged to transport material, the conveyor belts must be started in reverse sequence (the last one first and the first one last) so that material doesn't get piled on to a stopped or slow-moving conveyor. In order to get large belts up to full speed, some time may be needed (especially if soft-start motor controls are used). For this reason, there is usually a time-delay circuit arranged on each conveyor to give it adequate time to attain full belt speed before the next conveyor belt feeding it is started.

The older, mechanical time-delay relays used pneumatic dashpots or fluid-filled piston/cylinder arrangements to provide the "shock absorbing" needed to delay the motion of the armature. Newer designs of time-delay relays use electronic circuits with resistor-capacitor (RC) networks to generate a time delay, then energize a normal (instantaneous) electro-mechanical relay coil with the electronic circuit's output. The electronic-timer relays are more versatile than the older, mechanical models, and less prone to failure. Many models provide advanced timer features such as "one-shot" (one measured output pulse for every transition of the input from de-energized to energized), "recycle" (repeated on/off output cycles for as long as the input connection is energized) and "watchdog" (changes state if the input signal does not repeatedly cycle on and off).

The WTI means winding temperature Indicator and OTI means Oil temperature Indicator which indicates the winding temperature & oil temperature of the transformer and operates the alarm, trip, and cooler control contacts.This instrument operates on the principle of thermal imaging and it is not an actual measurement.

7.9 Details of Winding temperature indicator(WTI):-

Winding temperature indicator (WTI) consists of a sensor bulb placed in the oil filled pocket in the transformer tank top cover. The bulb is connected to the instrument housing by means of two flexible capillary tubes. One capillary is connected to the measuring bellow of the instrument and the other to a compensation bellow.

Fig. 7.9 Winding Temperature Indicator (WTI)

The measuring system is filled with a liquid, which changes its volume with rising temperature. Inside the instrument is fitted with a heating resistance which is fed by a current proportionate to the current flowing resistance which is fed by a current proportionate to the current flowing through the transformer winding.

The instrument is provided with a maximum temperature indicator. The heating resistance is fed by a current transformer associated with the loaded winding of the transformer. (The heating resistance is made out of the same materials as that of the winding) The increase in the temperature of the resistance is proportionate to that of the winding. The sensor bulb of the instrument is located in the hottest oil of the transformer, therefore, the winding temperature indicates(WTI) a temperature of hottest oil plus the winding temperature above hot oil i.e the hot spot temperature. In the WTI, there are four nos. of the mercury switch. Two of them is used for Fan and motor pump control and another two nos. switch are used for high-temperature warning alarm and trip circuit contact.

The switch are, S1, S2, S3, S4. The setting of the switches is given below:-

Fan control Motor pump control WTI alarm WTI Trip Fan on : 640 C ,

Fan Off: 580 C Pump on: 720 C ,

Pump Off: 680 C WTI alarm: 850 C WTI Trip: 950 C

7.10 Oil Temperature Indicator (OTI):

The (OTI) oil temperature indicator consists of a sensor bulb, capacity tube, and a dial thermometer, the sensor bulb is fitted at the location of hottest oil. The sensor bulb and capacity tube are fitted with an evaporation liquid. The vapor pressure varies with temperature and is transmitted to a bourdon tube inside the dial thermometer, which moves in accordance with the changes in pressure, which is proportional to the temperature. In OTI, there are 2 (two) nos. of mercury switch i.e (S1 and S2). S1 is used for Alarm and the S2 switch is used for Trip.
The setting of the switches is given below:-

OTI alarm OTI Trip OTI alarm: 800 C OTI Trip: 900 C

Fig. 7.10 Oil Temperature Indicator

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Date : 20th April, 2017.

This is to certify and confirm that **Ms. KHAN SHABNAM FIROZ** student of ANJUMAN-I-ISLAM, KALSEKAR TECHNICAL CAMPUS, PANVEL, had attended and undergone training in our organisation for the period from 1st January, 2017 to 15th April, 2017.

This information will be used by her for final year B.E (Electrical) project on **"PANEL DESIGN FOR TRANSFORMER PROTECTION"** to be submitted to University of Mumbai for the academic year 2016-17.

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