



## International Journal of Intellectual Advancements and Research in Engineering Computations

### Multiple transformer parameter protection and monitoring using microcontroller

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#### I. ABSTRACT

This work develops a Digital Relay for the protection of Generator Transformer in Mettur Thermal Power Plant. The Digital Relay, also called a numerical relay, refer to protective relay uses an advanced microcontroller to analyse power system voltages and currents for the purpose of detecting the faults in an electric power system. The main objective of this work is to give Digital Relay protection for Generator Transformer against over current of three phases, negative sequence (or) unbalanced currents of three phases and earth fault current.

The present system with Electromagnetic Relay, existing there makes use of individual relays and monitoring equipments for identification and isolation of each fault. Thus the monitoring and control of the faults becomes very difficult and apart it is costlier as it involves lot of relays and control equipment's. In addition the accurate values of monitored parameters cannot be obtained in these types of relays. These electromagnetic relays are replaced with a digital relay to give various advantages which includes advanced programmable functionality providing high performance level, flexibility as well as additional monitoring capabilities and they are able to communicate with other digital equipment while these functions are not quite possible in Electromagnetic relays.

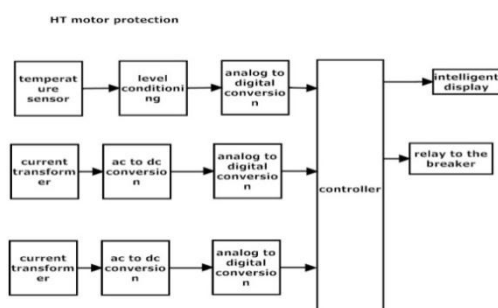
#### II. BLOCK DIAGRAM

#### III. FACTORS MONITORED

- Over current
- Over under voltage
- Winding temperature

#### IV. TRANSFORMER

A transformer is an electrical device which, by the principles of electromagnetic induction, transfers electrical energy from one electric circuit to another, without changing the frequency. The energy transfer usually takes place with a change of voltage and current. Transformers either increases or decreases AC voltage. Transformers are used to meet a wide variety of needs. Some transformers can be several stories high, like the type found at a generating station or small enough to hold in your hand, which might be used with the charging cradle for a video camera. No matter what the shape or size, a transformers purpose remains the same: transforming electrical power from one type to another. There are many different types of transformers in use today. This resource will take a closer look at Power Transformers, Auto Transformers, Distribution Transformers, Instrument Transformers, Isolation Transformers, Potential Transformers and Current Transformers.



## V. HOW DOES TRANSFORMER WORK

It is important to remember that transformers do not generate electrical power; they transfer electrical power from one AC circuit to another using magnetic coupling. The core of the transformer is used to provide a controlled path for the magnetic flux generated in the transformer by the current flowing through the windings, which are also known as coils. There are four primary parts to the basic transformer. The parts include the Input Connection, the Output Connection, the Windings or Coils and the Core.

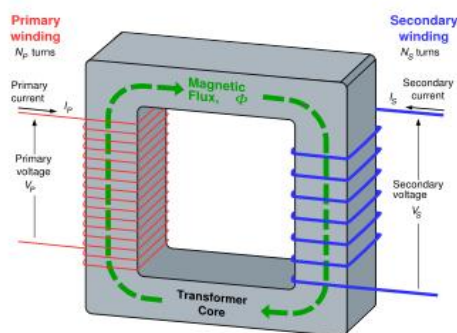


Figure 2

**A. Input Connections** - The input side of a transformer is called the *primary side* because the main electrical power to be changed is connected at this point.

**B. Output Connections** - The output side or *secondary side* of the transformer is where the electrical power is sent to the load. Depending on the requirement of the load, the incoming electric power is either increased or decreased.

**C. Winding** - Transformers have two windings, being the primary winding and the secondary winding. The primary winding is the coil that draws power from the source. The secondary winding is the coil that delivers the energy at the transformed or changed voltage to the load. Usually, these two coils are subdivided into several coils in order to reduce the creation of flux.

**D. Core** - The transformer core is used to provide a controlled path for the magnetic flux generated in the transformer. The core is generally not a solid bar of steel, rather a construction of many thin laminated steel sheets or layers. This construction is used to help eliminate and reduce heating.

Transformers generally have one of two types of cores: Core Type and Shell Type. These two types are distinguished from each other by the manner in which the primary and secondary coils are placed around the steel core.

**Core type** - With this type, the windings surround the laminated core.

**Shell type** - With this type, the windings are surrounded by the laminated core.

When an input voltage is applied to the primary winding, alternating current starts to flow in the primary winding. As the current flows, a changing magnetic field is set up in the transformer core. As this magnetic field cuts across the secondary winding, alternating voltage is produced in the secondary winding. The ratio between the number of actual turns of wire in each coil is the key in determining the type of transformer and what the output voltage will be. The ratio between output voltage and input voltage is the same as the ratio of the number of turns between the two windings. A transformer's output voltage is greater than the input voltage if the secondary winding has more turns of wire than the primary winding. The output voltage is stepped up, and considered to be a "step-up transformer". If the secondary winding has fewer turns than the primary winding, the output voltage is lower. This is a "step-down transformer".

## VI. TRANSFORMER CONFIGURATIONS

There are different configurations for both single-phase and three-phase systems.

**A. Single phase Power** - Single-phase transformers are often used to supply power for residential lighting, receptacle, air-conditioning, and heating needs. Single phase transformers can be made even more versatile by having both the primary winding and secondary winding made in two equal parts. The two parts of either winding can then be reconnected in series or parallel configurations.

**B. Three phase Power** - Power may be supplied through a three-phase circuit containing transformers in which a set of three single-phase transformers is used, or on three-phase transformer

is used. When a considerable amount of power is involved in the transformation of three-phase power, it is more economical to use a three-phase transformer. The unique arrangement of the windings and core saves a lot of iron.

**C. Delta and Wye Defined** - There are two connection configurations for three-phase power: Delta and Wye. Delta and Wye are Greek letters that represent the way the conductors on the transformers are configured. In a delta connection, the three conductors are connected end to end in a triangle or delta shape. For a wye, all the conductors radiate from the center, meaning they are connected at one common point.

**D. Three phase Transformers** - Three-phase transformers have six windings; three primary and three secondary. The six windings are connected by the manufacturer as either delta or wye. As previously stated, the primary windings and secondary windings may each be connected in a delta or wye configuration. They do not have to be connected in the same configuration in the same transformer. The actual connection configurations used depend upon the application.

#### **E. Power Transformer:**

A power transformer is used primarily to couple electrical energy from a power supply line to a circuit system, or to one or more components of the system. A power transformer used with solid state circuits is called a rectifier transformer. A power transformer's rating is given in terms of the secondary's maximum voltage and current-delivering capacity.

#### **F. Distribution Transformer:**

A pole-type distribution transformer is used to supply relatively small amounts of power to residences. It is used at the end of the electrical utility's delivery system.

#### **G. Auto Transformer:**

The autotransformer is a special type of power transformer. It consists of a single,

continuous winding that is tapped on one side to provide either a step-up or a step-down function. This is different from a conventional two-winding transformer, which has the primary and secondary completely isolated from each other, but magnetically linked by a common core. The autotransformer's windings are both electrically and magnetically interconnected. An autotransformer is initially cheaper than a similarly-rated two-winding transformer. It also has better regulation (smaller voltage drops), and greater efficiency. Furthermore, it can be used to obtain the neutral wire of a three-wire 240/120-volt service, just like the secondary of a two winding transformer. The autotransformer is considered unsafe for use on ordinary distribution circuits. This is because the high-voltage primary circuits are connected directly to the low-voltage secondary circuit.



**Figure 3**

#### **H. Isolation Transformer:**

An isolation transformer is a very unique transformer. It has a 1:1 turn's ratio. Therefore, it does not step voltage up or down. Instead, it serves as a safety device. It is used to isolate the grounded conductor of a power line from the chassis or any portion of a circuit load. Using an isolation transformer does not reduce the danger or shock if contact is made across the transformer's secondary winding. Technically, any true transformer, whether used to transfer signals or power, is isolating, as the primary and secondary are not connected by conductors but only by induction. However, only transformers whose primary purpose is to isolate circuits (opposed to the more common transformer function of voltage

conversion), are routinely described as isolation transformers.

### I. Current Transformer:

A current transformer has a primary coil of one or more turns of heavy wire. It is always



connected in series in the circuit in which current is to be measured. The secondary coil is made up of many turns of fine wire, which must always be connected across the ammeter terminals. The secondary of a current transformer must never be open-circuited. This is because the primary is not connected to a constant source. There is a wide range of possible primary voltages, because the device can be connected to many types of conductors. The secondary must always be available (closed-circuited) to react with the primary, to prevent the core from becoming completely magnetized. If this happens, the instruments will no longer read accurately. A clamp-on ammeter works in a similar way. By opening the clamp and placing it around a current carrying conductor, the conductor itself acts as a single turn primary. The secondary and the ammeter are conveniently mounted in the handle of the device. The dial allows a number of current ranges to be gauged accurately.



Figure 5

### J. Potential Transformer:

A potential transformer is a carefully designed, extremely accurate step-down transformer. It is normally used with a standard 120-volt voltmeter. By multiplying the reading on

the voltmeter (called the deflections) by the ratio of transformation, the user can determine the voltage on the high side. Common transformation ratios are 10:1, 20:1, 40:1, 80:1, 100:1, 120:1, and even higher. In general, a potential transformer is very similar to a standard two-winding transformer, except that it handles a very small amount of power. Transformers for this service are always the shell type, because this construction has been proven to provide better accuracy.



Figure

6

Potential Transformers (like the one pictured above) are designed for monitoring single-phase and three-phase power line voltages in power metering applications.

## VII. TRANSFORMER WINDING TEMPERATURE INDICATOR

The winding is the component with the highest temperature within the transformer and it is the component which is subjected to the fastest temperature increases as the load increases. Therefore for the control of the temperature parameter within the transformer, the temperature of the winding, as well as top oil, is measured. The temperature of winding of Transformer is measured using Winding Temperature Indicator (WTI) and the temperature of Transformer Oil is measured using Oil Temperature Indicator.

The purpose of WTI is to indicate the winding temperature of HV and LV winding of the Transformer and operates the alarm, trip and cooler control contacts (For detail on Cooler Unit visit Transformer Cooling Classes).

As can be seen from the above figure, Black needle shows the current winding temperature while the Red needle shows the highest winding temperature reached for a particular day. This Red needle needs to be reset manually.

Also, for setting winding temperature for Alarm and Trip, two knobs are provided. The Green knob shows the setting of winding temperature for Alarm and Red knob shows the Trip temperature setting as shown in figure.

### VIII. CONSTRUCTION DETAIL OF WINDING TEMPERATURE INDICATOR (WTI)

Winding temperature indicator consists of a sensor bulb placed in an oil filled pocket in the transformer tank 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 compensating bellow.

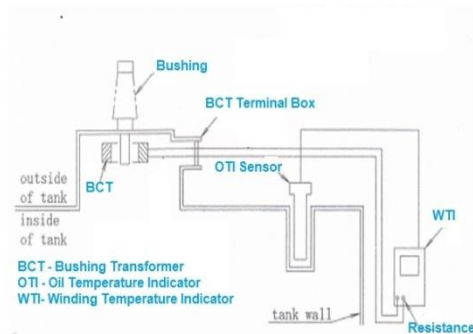


Figure 7

### IX. WORKING PRINCIPLE OF WTI

An indirect system is used to measure winding temperature, since it is dangerous to place a sensor close to the winding due to the high voltage. The indirect measurement is done by means of a Thermal Image. The measuring system is filled with a liquid which changes its volume with rising of temperature. Inside the instrument is fitted a heating resistance which is fed by a current proportionate to the current flowing through the transformer winding. To do this we connect the terminal of the heating resistance with the Bushing Current Transformer so that reflection of change in load is reflected in the Winding Temperature Indicator, WTI.

The Winding Temperature Indicator, WTI is provided with a maximum temperature indicator. The heating resistance is fed by a current

transformer associated to the loaded winding of the transformer. 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 a temperature of hottest oil plus the winding temperature rise above hot oil Level the hotspot temperature.

Winding Temperature of Transformer may rise due to increased loading of Transformer or due to some internal fault. Normally the Winding Temperature Indicator, WTI gives alarm at 85 °C and Trip signal at 95 °C in India.

### X. DEVICE OVERVIEW (MICROCONTROLLER)

This document contains device specific information about the following devices:

- PIC16F873A
- PIC16F874A
- PIC16F876A
- PIC16F877A

PIC16F873A/876A devices are available only in 28-pin packages, while PIC16F874A/877A devices are available in 40-pin and 44-pin packages. All devices in the PIC16F87XA family share common architecture with the following differences:

- The PIC16F873A and PIC16F874A have one-half of the total on-chip memory of the PIC16F876A and PIC16F877A
- The 28-pin devices have three I/O ports, while the 40/44-pin devices have five
- The 28-pin devices have fourteen interrupts, while the 40/44-pin devices have fifteen
- The 28-pin devices have five A/D input channels, while the 40/44-pin devices have eight
- The Parallel Slave Port is implemented only on the 40/44-pin devices

## XI. FAULTS IN ELECTRICAL POWER SYSTEM

Electrical networks, machines and equipments are often subjected to various types of faults while they are in operation. When a fault occurs, the characteristic values (such as impedance) of the machines may change from existing values to different values till the fault is cleared.

There may be lot of probabilities of faults to appear in the power system network, including lightning, wind, tree falling on lines, apparatus failure, etc.

A fault in an electric power system can be defined as, any abnormal condition of the system that involves the electrical failure of the equipment, such as, transformers, generators, busbars, etc.

The fault inception also involves in insulation failures and conducting path failures which results short circuit and open circuit of conductors.

Under normal or safe operating conditions, the electric equipments in a power system network operate at normal voltage and current ratings. Once the fault takes place in a circuit or device, voltage and current values deviates from their nominal ranges.

The faults in power system causes over current, under voltage, unbalance of the phases, reversed power and high voltage surges. This results in the interruption of the normal operation of the network, failure of equipments, electrical fires, etc.

Usually power system networks are protected with switchgear protection equipments such as circuit breakers and relays in order to limit the loss of service due to the electrical failures.

## XII. TYPES OF FAULTS

Electrical faults in three-phase power system mainly classified into two types, namely open and short circuit faults. Further, these faults can be symmetrical or unsymmetrical faults. Let us discuss these faults in detail.

### A. Open Circuit Faults:

These faults occur due to the failure of one or more conductors. The figure below illustrates the open circuit faults for single, two and three phases (or conductors) open condition.

The most common causes of these faults include joint failures of cables and overhead lines, and failure of one or more phase of circuit breaker and also due to melting of a fuse or conductor in one or more phases.

Open circuit faults are also called as series faults. These are unsymmetrical or unbalanced type of faults except three phase open fault.

Consider that a transmission line is working with a balanced load before the occurrence of open circuit fault. If one of the phase gets melted, the actual loading of the alternator is reduced and this cause to raise the acceleration of the alternator, thereby it runs at a speed slightly greater than synchronous speed. This over speed causes over voltages in other transmission lines.

Thus, single and two phase open conditions can produce the unbalance of the power system voltages and currents that causes great damage to the equipments.

#### Causes:

- Broken conductor and malfunctioning of circuit breaker in one or more phases.

#### Effects:

- Abnormal operation of the system
- Danger to the personnel as well as animals
- Exceeding the voltages beyond normal values in certain parts of the network, which further leads to insulation failures and developing of short circuit faults.
- Although open circuit faults can be tolerated for longer periods than short circuit faults, these must be removed as early as possible to reduce the greater damage.

### B. Short Circuit Faults:

A short circuit can be defined as an abnormal connection of very low impedance

between two points of different potential, whether made intentionally or accidentally.

These are the most common and severe kind of faults, resulting in the flow of abnormal high currents through the equipment or transmission lines. If these faults are allowed to persist even for a short period, it leads to the extensive damage to the equipment.

Short circuit faults are also called as shunt faults. These faults are caused due to the insulation failure between phase conductors or between earth and phase conductors or both.

The various possible short circuit fault conditions include three phase to earth, three phase clear of earth, phase to phase, single phase to earth, two phase to earth and phase to phase plus single phase to earth as shown in figure.

The three phase fault clear of earth and three phase fault to earth are balanced or symmetrical short circuit faults while other remaining faults are unsymmetrical faults.

#### Causes:

- These may be due to internal or external effects
- Internal effects include breakdown of transmission lines or equipment, aging of insulation, deterioration of insulation in generator, transformer and other electrical equipments, improper installations and inadequate design.
- External effects include overloading of equipments, insulation failure due to lighting surges and mechanical damage by public.

#### Effects:

- Arcing faults can lead to fire and explosion in equipments such as transformers and circuit breakers.
- Abnormal currents cause the equipments to get overheated, which further leads to reduction of life span of their insulation.
- The operating voltages of the system can go below or above their acceptance values that creates harmful effect to the service rendered by the power system.

- The power flow is severely restricted or even completely blocked as long as the short circuit fault persists.

#### C. Symmetrical and Unsymmetrical Faults:

As discussed above that faults are mainly classified into open and short circuit faults and again these can be symmetrical or unsymmetrical faults.

##### Symmetrical Faults:

A symmetrical fault gives rise to symmetrical fault currents that are displaced with 120° each other. Symmetrical fault is also called as balanced fault. This fault occurs when all the three phases are simultaneously short circuited.

These faults rarely occur in practice as compared with unsymmetrical faults. Two kinds of symmetrical faults include line to line to line (L-L-L) and line to line to line to ground (L-L-L-G) as shown in figure below.

A rough occurrence of symmetrical faults is in the range of 2 to 5% of the total system faults. However, if these faults occur, they cause a very severe damage to the equipments even though the system remains in balanced condition.

The analysis of these faults is required for selecting the rupturing capacity of the circuit breakers, choosing set-phase relays and other protective switchgear. These faults are analyzed on per phase basis using bus impedance matrix or Thevenin's theorem.

##### Unsymmetrical Faults:

The most common faults that occur in the power system network are unsymmetrical faults. This kind of fault gives rise to unsymmetrical fault currents (having different magnitudes with unequal phase displacement). These faults are also called as unbalanced faults as it causes unbalanced currents in the system.

Up to the above discussion, unsymmetrical faults include both open circuit faults (single and two phase open condition) and short circuit faults (excluding L-L-L-G and L-L-L).

The figure below shows the three types of symmetrical faults occurred due to the short circuit

conditions, namely phase or line to ground (L-G) fault, phase to phase (L-L) fault and double line to ground (L-L-G) fault.

A single line-to-ground (LG) fault is one of the most common faults and experiences show that 70-80 percent of the faults that occur in power system are of this type. This forms a short circuit path between the line and ground. These are very less severe faults compared to other faults.

A line to line fault occur when a live conductor get in contact with other live conductor. Heavy winds are the major cause for this fault during which swinging of overhead conductors may touch together. These are less severe faults and its occurrence range may be between 15-20%.

In double line to ground faults, two lines come into the contact with each other as well as with ground. These are severe faults and the occurrence these faults is about 10% when compared with total system faults.

Unsymmetrical faults are analyzed using methods of unsymmetrical components in order to determine the voltage and currents in all parts of the system. The analysis of these faults is more difficult compared to symmetrical faults.

This analysis is necessary for determining the size of a circuit breaker for largest short circuit current. The greater current usually occurs for either L-G or L-L fault.

### **XIII. PROTECTION DEVICES AGAINST FAULTS**

When the fault occurs in any part of the system, it must be cleared in a very short period in order to avoid greater damage to equipments and personnel and also to avoid interruption of power to the customers.

The fault clearing system uses various protection devices such as relays and circuit breakers to detect and clear the fault. Some of these fault clearing or faults limiting devices are given below.

#### **A. Fuse:**

It opens the circuit whenever a fault exists in the system. It consists of a thin copper wire enclosed in a glass or a casing with two metallic contacts. The high fault current rises the temperature of the wire and hence it melts. A fuse necessitates the manual replacement of wire each time when it blows.

#### **B. Circuit Breaker:**

It is the most common protection device that can make or break the circuit either manually or through remote control under normal operating conditions.

There are several types of circuit breakers available depending on the operating voltage, including air brake, oil, vacuum and SF6 circuit breakers. For more information on circuit breakers, follow the link attached.

#### **C. Protective Relays:**

These are the fault detecting devices. These devices detect the fault and initiate the operation of the circuit breaker so as to isolate the faulty circuit. A relay consists of a magnetic coil and contacts (NC and NO). The fault current energizes the coil and this causes to produce the field, thereby the contacts get operated

Some of the types of protective relays include

- Magnitude relays
- Impedance relays
- Directional relays
- Pilot relays
- Differential relays
- Lighting Arrestor

Surges in the power system network caused when lightning strikes on transmission lines and equipments. This causes high voltage and currents in the system. These lighting faults are reduced by placing lighting arrestors at transmission equipments.

### **XIV. EXISTING AND PROPOSED SYSTEM**

The present system with Electromagnetic Relay, existing there makes use of individual relays and monitoring equipments for identification and

isolation of each fault. Thus the monitoring and control of the faults becomes very difficult and apart it is costlier as it involves lot of relays and control equipment's. In addition the accurate values of monitored parameters cannot be obtained in these types of relays. These electromagnetic relays are replaced with a digital relay to give various advantages which includes advanced programmable functionality providing high performance level, flexibility as well as additional monitoring capabilities and they are able to communicate with other digital equipment while these functions are not quite possible in Electromagnetic relays.

#### XV. ADVANTAGES

- Efficient and low cost design
- Low power consumption
- Real time monitoring

#### XVI. DISADVANTAGES

- Depends on the network signal strength

#### XVII. APPLICATIONS

- This system can be implemented in industries
- This system can be used for monitoring and controlling the home appliances

#### XVIII. CONCLUSION

Thus this project develops Digital Relay for the protection of Transformer. It uses an advanced microcontroller to analyse power system voltages and currents for the purpose of detecting the faults in an electric power system and to control and monitor parameters such as current, voltage and temperature.

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