DESIGN AND CONSTRUCTION OF 250V, 1AMPERE ELECTROMAGNETIC RELAY.

BY
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2003/15280EE

A RESEARCH PROJECT SUBMITTED TO THE DEPARTMENT OF ELECTRICAL COMPUTER ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLGY MINNA, NIGER STATE IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE.

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DEDICATION

The research project, the first in my career, is dedicated to Almighty Allah (S.W.T), my creator, for his endless mercies on me and through out my life. And also to my late mum, Alhaja Aminat Akanke Abdulkadir a woman that suffered so much for her children to become somebody in life but never lived to see her dreams come through. Mum u may be dead but I believe your spirit lives on . I love you mum,are the greatest in the world

DECLARATION

I hereby declare that this research project was carried out by me, Abdulkadir Bidemi taofeek under the able supervision of professor Oria Usifo of the Electrical Computer Engineering Department, Federal University of Technology Minna, and to the best of my knowledge, it has not been submitted anywhere else for the award of a similar degree.

All other works cited have been duly acknowledge in my refrences.

Abdulkadir

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Abdulkadir Bidemi Taofeek DATE

2003/15280EE

CERTIFICATION

This is to certify that I have supervised, read, considered and approved this research project report

"DESIGN AND CONSTRUCTION OF 250V, 1AMP ELECTROMAGNETIC RELAY" which I found adequate both in scope and quality for the partial fulfillment of the requirement for the award of Bachelor of Engineering (B.Eng) Degree in Electrical and Computer Engineering.

Prof. ORIA USIFO
Project supervisor

30/10/08
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ACKNOWLEDGEMENT

The journey so far has been one of greatest challenges and rewards which would not have been possible without the mercy and compassion of my creator, the Almighty Allah (S.W.T).

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ABSTRACT

This project is concerned with the design and construction of an electromagnetic relay. It was done by taking into considerations the design specifications and requirement and Requirements to ensure a well-designed and functional protective device which will operate by detecting any dangerous current i.e. the relay will disconnect the circuit on sensing or detecting this dangerous current.

The basic concept used in achieving the aim of this project was the use of the electromagnetic effect of current and test show that exciting current of the solenoid was 0.11A.

The type of relay designed and constructed is an electromagnetic type operating on A.C i.e. alternating current.

The importance of this project lies in the fact that adequate shock-risk and fire-risk protection should be provided for consumers.

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1.1 INTRODUCTION

As human need for power consumption escalates on daily basis, care and protection are taken into consideration. This protection is needed to shield consumer or personal from risks of shock, ignition of fire and also damages to life and properties. Hence the use of protective devices like switchgears, over current relays fuses came to play.

The aim of the project is to design and construct an electromagnetic relay to protect a part

Of a power system single phase 230 supply and carrying a maximum current of 10 amps At a frequency of 50Hz .Earth fault for example, if by some mischance perhaps by some damages to the cables during draw in, the positive wire comes in contact with the metal conduct of an installation, this if not earthed will become charged to a potential above earth of 240V..Hence, any person who touches the conduct and who is at the same time in contact with the earth by standing on a non insulated floor or who is touching earthed metal will complete the circuit that is formed.

To afford adequate protection against the aforementioned the relay acts as a device which break when an earth an leakage current flows through it . The relay coil can also de-energised on its own if there is short circuit or any other fault within its area of protection.

1.2 RELAY: DEFINITION

An electrical switch is simply defined as a device for making breaking or changing the connections in an electric circuit. A relay is an electrically operated switch. This definition is non-resistive enough to embrace both solid state (semi-conductor) relays and electromagnetic or electromechanical and hybrid types. A relay is an electrically controlled device that opens or closes electrical contact to effect the operation of other devices in the same or another electric circuit. [1]

Note; the reference to contacts obviously restricts this definition to only the common form, the electromechanical relay.

But according to institute of Electrical and Electronic Engineering (IEE) a relay is defined as an electric device that is designed to interpret input conditions in a prescribed manner and after specified conditions are met to respond to cause contact operation or similar abrupt changes in associated electric control circuits.

Fuses can also be used as an over- current protective device with a current opening feasible part that is heated and severed by the passage of the over- current through it.[1]

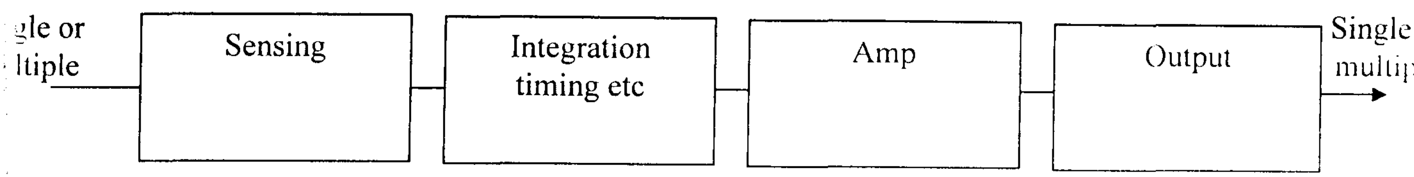


Fig 1.1 a typical logic representation of relay

1.3 BASIC OBJECTIVE OF SYSTEM PROTECTION

1. Reliability: Assurance that the protection will perform correctly well as prescribed.

2. Selectivity: Maximum continuity of service with minimum system disconnection.

3. Speed of operation: Obviously, it is desirable that the protection isolates a trouble zone as rapidly as possible.A high-speed relay is one that operates in less than 50ms(3 cycles on a 60Hz) basis. Modern high speeds are used interchangeably to describe protective relays that operates 50ms or less.

4. Simplicity: Minimum protective equipment protective and associated circuitry to Achieve the protective objective. Earth added unit or component which may offer Enhancement of the protection but which is not necessarily basic to the protection requirement should be considered carefully.

5. Economics: It is fundamental to obtain the max protection for the minimum cost and cost is always a major factor. The lowest – priced initial cost protective system may not be the most reliable system .Maintenance and installation [1]

1.4 FACTORS AFFECTING PROTECTION SYSTEM

1. Economics: As already explained above, protection does not produced revenue, it is not required for normal system operation. Fortunately, faults and trouble are relatively infrequent, so it is easy to decide not to spend money on protection since there have not been problems.

2. Personality factor: When, where an intolerable condition will occur, in the power system is unpredictable .Almost an infinity of possibilities exists. Thus, the Engineer must Design the protective device system for the most probable events based on past experience, anticipated possibilities that seem most likely to occur.

3. Location of Disconnecting the input Device: Protection can be applied only where There are circuit breakers or similar devices to enable isolation of the trouble area and where current and voltage transformer are where required as available to provide information about faults and trouble in power system.

4. Available fault indicators: the troubles, faults and intolerable condition must Provide a distinguishable difference from the normal operating or tolerable condition.

1.5 CLASSIFICATION OF RELAYS

Relays may be classified in several different ways, such as by function, input, Performance characteristics, or operating principles. Classification by function is the most common. There are five basis function types.

1. Protective: Protective relays and associated systems (and fuses) operate on the intolerable power system condition and are the main thrust in the work. They are applied to all parts of the power system, generators, buses, transformers, transmission lines, distribution lines and feeder motors and utilization loads, capacitor banks, and reactors [2]. These relays are separate devices that are connected to the power through current and voltage transformer from the highest system voltage down to service levels of 480V

2. Regulating Relay: They are associated with taps changers on transformers and on governors of generating equipment to control the voltage levels with varying loads. Regulating relays are used during normal system operation and do not respond to the systems fault unless the faults are left on the system far too long.

3. Reclosing, Synchronism Check, Synchronising Relays: Reclosing, synchronism check and synchronizing relays were formerly classed as programming but since this term is now widely used in a different context as related to computers. Relays of this type are used in energizing or restoring lines to service after an outage and in interconnecting pre-energized parts of the systems.

4. Monitoring Relays: They are used to verify conditions in the power system or in the protective system. Examples in power systems are faults detectors, voltage check, or directional sensing units which confirm power system condition but do not directly sense the fault or trouble. In protection systems they are used to monitor the continuity of circuits, such as pilot wires and trip circuits.[2]

5.Auxiliary Relays: Auxiliary relays are used throughout a protective system forA variety of purposes. Generally, there are two categories: Contact multiplication and circuit isolation. In relaying and control system there are frequent requirement for:

1. More outputs for multiple tripping, alarms, and operating other equipment.Such as recording and data acquisition, lock out and so on.

2. contact that will handle higher current or voltages in the secondary system.

3. Electrical and magnetic isolation of several secondary circuits.[2]

6 . Other relays have Classification: Protective relays classified by input are known as current, voltage, frequency, and temperature relays. Those classified by operating principle include digital, percentage differential, etc .

1.6 FORMS OF RELAY

There are three forms of relay.

1.Electromagnetic/ Electromechanical Relay

2. Solid State Relay (SSR) : It's a device without any moving parts which performs a relaying or electrical switching function. It employs semiconductors in both input and output electric circuits to perform essentially the switching function normal to the simple electromagnetic relay.

3. Hybrid Relay : A hybrid relay is an electrical device or unit having a solid state input and electromagnetic output or vice versa, to perform and electrical – switching function.

1.7 THE FUNCTION OF A RELAY

Protective relays have been called sentinels and electric brains. From the economics point of view, relay can be likened to insurance i.e they protect the power utility from financial loss due to damage to equipment. From the under writers point of view, they prevent accident to personnel and minimize damage to equipment. From the customer point of view good service depends more upon any other equipment [3] .The cost of this protection is between 1and 2% of the cost of the power system i.e equivalent to an insurance premium, costing about 0.1% per year, assuming 15 years before replacement due to obsolescence. The basis electrical quantities which may change in the transition from healthy to faulty conditions are current, voltage, direction of power flow, power factor (phase angle) and of course the frequency.

Circuitry Diagram of Over Current Relay

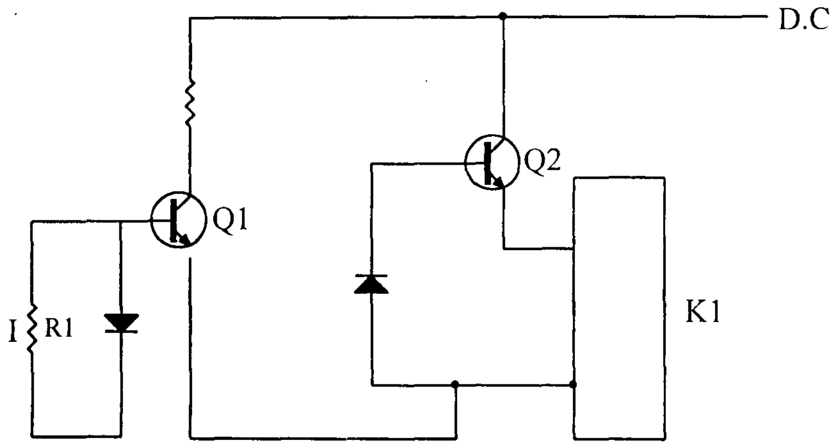


Fig 1.2 The circuit diagram for an over-current relay

When d.c voltage is applied, the relay k, pulls in through Q2. Q1 is in the off Modeas long as the current remains below a predetermined value, tunnel diode D1 maintains a very small differential voltage, between base and emitter of Q1. when current increases above desired value , the tunnel diode acts to increase this differential voltage, causing it to drop out.

1.8 PROTECTIVE RELAY PERFORMANCE

It is difficult to specify or evaluate protective relay performance by statistical techniques. As indicated, relays are connected to the power system and energized but the are basically inactive (i.e. in a quiescent mode) until an intolerable situation occurs within their operating zones.[1] Thus it is impossible to know from the experience of normal operation whether the relay will respond and operates correctly at the onset of an emergency. This is one of the primary reasons for regular maintenance with relatively few faults. When a fault occurs in a power system the primary relays for the faulted zone are expected to operate and initiate isolation. However, many relays surrounding the trouble area will be alerted by the fault and begin to operate.[2]

Relay performance is documented by those relays that provide direct or specific evidence of operation and can be classified as:

1. Correct operation: correct operation indicates that:

(a). At least one of the primary relays operated correctly.

(b). None of the backup relays operated to trip for the fault.

(c). The trouble area was properly isolated in the time expected.

Around 99% or all relay operated are corrected and wanted, i.e. operated is as planned and programmed. The correct but unwanted operated described the few cases where all relays and associated equipment performed correctly. However, their position was not desired or anticipated. An example of this was the 1965 Northeast power blackout. This
was initiated by an unanticipated operating condition during the unusual system emergency at that time.[3]

This resulted in correct but unwanted relay operations over a very wise area. The relays performed correctly since the system conditions of the emergency provided currents and voltages that were within the relay operating zones.

2. Incorrect operation :

Incorrect operation results from a failure, a multiplication or an unanticipated or unplanned operation of the protective area of the system. This can cause either incorrect operation can be one or a combination of:

(1) Misapplication of relays

(2) Incorrect setting.

(3) Personnel errors.

(4) Equipment problems or failures (relay, breakers current transformers, voltage transformers, station battery, wiring, pilot channel and so on).

With the best of planning and design there will always be a potential situation that may not be protected or an error not detected. Occasionally, these are covered by incorrect operation that can be classified as acceptable for the particular situation.[3]

3. No conclusion:

This refers to cases where one or more relays have or appear to have operations such as the circuit breaker tripping, but no cause can be found. No evidence of a power system fault or trouble nor apparent failure of the equipment, causes an extremely frustrating situation.

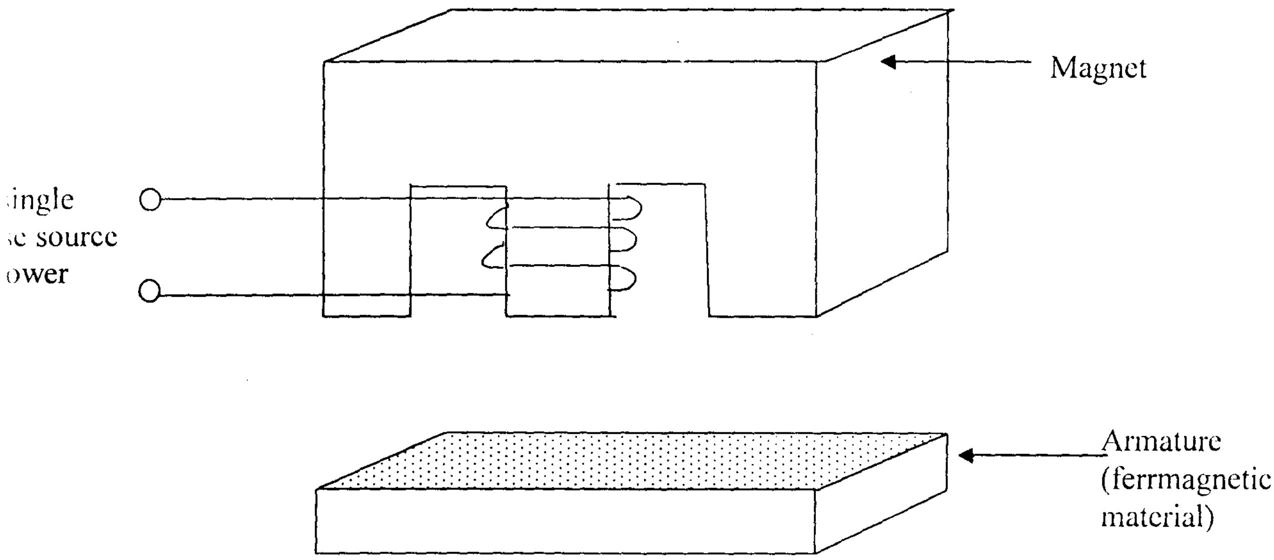
Thus no conclusion cases involve considerable concern accompanied by many hours of post mortem investigation. It is suspected that many of these cases are the result of personnel involvement that is not reported and from intermittent troubles that do not become apparent during testing and investigation.

CHAPTER TWO

LITERATURE REVIEW

2.1 FUNDAMENTAL PRINCIPLE OF AN ELECTROMAGNETIC RELAY.

An electromagnetic relay has four major physical component which are the magnetic core the coil, the armature and the contact.



When power is supplied to the coil, it energized and an electromagnetic field will be set up around the coil. The field of the magnet however, will hold the armature against the pole faces of the magnet indefinitely until it is physically pulled away. Only a fault can pull it away. In the electromagnet, the current flowing through the [4] coil causes the armature to drop out.

The magnet circuit of a relay consists of a magnetic assembly, a coil and an armature.

The magnetic assembly is the stationary part of the magnetic circuit. The coil is supported by surrounded part of the magnet assembly to induce magnetic flux into the magnetic circuit. When it has been attracted to its sealed position, it completes the magnetic circuit.[5]

In the construction of a relay, the armature is mechanically connected to a set of contacts so that when the armature moves to its closed position, the contact also close.

The armature is attracted to the electromagnet when the current reaches a certain predetermined value that is above the rated current value of the relay. The magnetmotive force (mmf). Equals the number of turns mutplied by the current i.e.

Mmf (F) = IN ....equation 1.

But the number of turns (N) is constant and therefore mmf is directly proportional to the current. From this analysis an increase in current above rated values will increase the mmf. The mmf increases the field force and the armature is therefore attracted to the electromagnet thereby closing the contacts of a separated tripping circuit. By adjusting the distance the armature from electromagnet, the current at which the attraction of the armature occurs can vary at will.[5]

2.2 THE FUNCTION OF A RELAY.

Protective relays have been called sentinels and electric brains. From the economic point of view, relays are akin to insurance; they protect the power utility from financial loss due to damage to equipment. From the underwriter point of view, they prevent accident to personnel and minimize damage to equipment. From the consumer point of view, good service depends more upon adequate relaying that upon any other equipment. The cost of protection is between 1 and 2% of the cost of the power system i.e. equivalent to an insurance premium, costing about 0.1% per year, assuming 15 years before replacement due to obsolescence.[6]

In the dictionary, four definitions of relays will be found which deals with foot races, post coaches, etc. but none even remotely fits the application.

Definition:

A protection relay is a device which depends to abnormal conditions on an electrical power system to control a circuit breakers , so as to isolate the faulty section of the system with the minimum interruption to service. To do this, relays must be able to decide properly which circuit breakers are to trip in order to isolate only the faulty section(s).

These relays must be designed, therefore to be responsive to electrical quantities which are different during normal and abnormal conditions. The basic electrical quantities, which may change in the transition from healthy to faulty conditions, are current, voltage, direction of power flow, power factor (phase angle) and frequency.

2.3 FACTORS DETERMINING RELAY SELECTION

For power input, either A.C or D.C

1. Suitable power supply is a part of the basic design a decision on choice of operation from alternating or direct current is required early in the design. Commercial alternating current usually offers economic advantages, but direct current is most often employed for reasons discussed below.[6]
2. Many relay applications are so complex that d.c power in some form is required.
3. D.c relays usually have longer life.

4. Two contacts of a.c relays flatten premature as a result of wear due to noticeable vibrations during closing and opening.

5. D.c relays usually have greater sensitivity.

6. D.c relays reduce bearing wear resulting from absence of ac vibration at this point.

7. Heat loss of d.c coil is usually noticeably lower. There are both fewer iron losses (no hysteric on direct current) and fewer copper losses (because usually the required holding power is less.[7]

8. Cost favours d.c relays less expensive to make than a.c (a solid coil core is cheaper than laminated and so shading coil is required for direct current.

9. D.c relays especially if heavily loaded can accommodate a wider voltage range than a.c relays.

Desired timing variations are almost impossible of achievement when operating convectional relays on alternating current.

2.4 SOME TERMS USED IN DECRIBING RELAYS:

1. Operating Force or Torque: that which tend to close the contacts of the relay.

2. Restraining Force or torque: that which opposes the operating force or torque and tends to prevent the closure of the relay contacts.

3. Pick-up(level): The value of current or voltage etc which is the threshold above which the relay will open its contacts and return to normal position or state.[7]

4. Characteristics (of a relay in the steady state): The locus of the pick-up or rest when drawn on a graphic. In some relays the two [8]curves are coincident and become the locus of the balance or zero torque.

5. Reinforcing relay: one which is energized by the contacts of the main relay and with its contacts in parallel with those of the main relay, relieves them of their current carrying duty. The seal-in contacts are usually heavier than those of the main relay .[8]

6. Seal-in Relay: Similar to reinforcing relay except connected to stay until its coil current is interrupted by a switch on the circuit breaker.[8

7. Back-up Relays: A relay, which operates, usually after a slight delay, if the normal relay does not operate to trip its circuit breaker.

8. Primary Relays: Those, which are connected directly to the protected circuit.

9. Secondary Relays :Those, which are connected to the protected circuit through current transformer (c.t's) and potential transformers.

10. Selectivity; The abilty of the relay to discriminate between a fault in the protected section and normal condition and a fault elsewhere in the system.

11. Consistency: The accuracy with which the relay can repeat it's electrical or time characteristics

12. Synchronizing Relay: relay which functions when two alternating current sources are in agreement within predetermined limit of phase angle and frequency.

13. Reliability: anytime there is a fault must operate.

14. Accuracy: Ability to operate at the specified rated time and current.

Performance Criteria: The design or selection of a relay should be based on the following circuit performance criteria.

1. Operating frequency: Electrical operating frequency of relay coil.

2. Rated coil voltage : Normal operating voltage of a relay coil.

3. Rated coil current: Normal operating current for a relay.

4. Monoperate current (or voltage): Maximum[1] value of coil current(or voltage) at which relay will not operate.

5. Operate voltage (or current): Minimum value of coil voltage (or current) at which switching functions is completed.[1]

6. Release voltage (or current): Value of coil voltage (or current) at which contacts return to the de-energised position.[1]

7. Operate time: Time interval between application of power to coil and completion of relay switching function.

8. Release time: This is the time interval removal of power from coil and return of contacts to de-energized position.[2]

9. Contact bounce: Uncontrolled opening and closing of contacts due to external forces such as shock or vibration.

10. Contact rating: Electrical load on the contact interns of closing surge current, steady-state voltage and current and induced breaking voltage.

SOME DEFINITIONS OF RELAY:

1. Sensing Relay: A relay responding to a condition of overvoltage, undercurrent, and the like.

2. Thermal Relay: A relay actuated by the heating of an electric current.

3. Overload Relay: An alarm or protective relay that is specially designed to be operated when it's coil current reaches pre-determined or unsafe value above which is the normal time delay may be introduced as a requirement of overload.

2.5 ESSENCE OF PROTECTION AND RELAYING.

Faults can be very destructive to power systems. Knowledge of the current resulting from various types of fault at a location is essential for the effective operation of what is known as a system protection. Thus a great deal of study, development of devices and design of protection schemes have resulted in continual improvement in the prevention of damage to installations and interruptions in power generations following the occurrence of a fault. It is therefore the object of protection to accomplish this by means of automatic devices for opening the appropriate circuit breakers when abnormal currents and voltage are detected.

It is common to find disturbances in a circuit containing a connected load. These disturbances are usually variation in the circuits which tend to undermine the desired operation conditions and they are mostly time variant, i.e. they die out with time. These disturbances could be inconsistently varying amplitude and shape of the voltage or current wave forms which causes distortion in the average r.m.s value and hence the output of the load (for a.c circuit). Also it could be in form of ripples, transients or even visual distortion in video systems. These undesired occurrences are taken care of "screening" department of the power source.

There are five major faults, which could be associated with both a.c and d.c circuits,

These are :

1. Over-voltage (excessive voltage).
2. Under-voltage(insufficient voltage).
3. Short Circuit (Excessive current).

4. Open Circuit or intermittent Contact.

5. Earth Fault.

Over –voltage and short circuit can be quite destructive on the system or appliances concerned and this exposes the component to adverse operating mode and this exposes the component to adverse operating mode and this eventually damage them due to over heating (in most cases) or total breakdown of the device[2]. Semiconductors e.g. diodes, transistors, I.C etc which are the basis for construction of most electrical appliances and gadgets today are mostly affected by these adverse condition and they seldom withstand the stress they are set through. Thus the are mostly protected from such fault conditions by protective units.

However, devices that can readily protect the load in a circuit from over voltage and short circuit fault condition are mainly circuit breakers and fuses. Contrary to their protective abilities, they still have their shortcomings, which render them ineffective for protecting sensitive loads. For instance, fuses do not melt soon enough to protect the load and in most cases, the load is damaged before the fuse opens [2]circuit. The circuit breakers though they operate much faster than the fuse , yet is not fast enough for sensitive loads.

It is not understatement that fuses and circuit breakers are not suitable as protection for sensitive loads e.g. Tv, computers system, photocopying machine, video set, etc because of their slow response to any fault in such appliances. There is therefore a need for a protective circuit made of a highly sensitive components with a fast switching time would match the load "speed for speed" in terms of protective capacity.

The mode of protection employed against over-voltage and over-current are the isolation of the excess voltage conditionfrom the terminals of the load almost instantly as it occurs. Thus any variation in the a.c source will give a corresponding variation in the voltage parameter of the protective circuit (high voltage) and this affects the appropriate response to these variations. The d.c circuit of the protective devices high voltage protector (for excess voltage) serves as a control circuit for an external a.c load.

Another simple but extremely effective form of protection is the electromechanical relay which closes the contacts and hence engages the circuit breaker opening mechanism when currents larger than specified pass through the[3] equipment. The protection used in an electrical installation can be looked upon as a form of INSURANCE in which a very small percentage say 1 to 2% of the total capital cost is used to safeguard apparatus and ensure continual operation when faults occur.

Conclusively, protection and the automatic tripping opening or disconnecting of the circuit of the associated circuit breakers has two main functions.

1. Isolate faulty equipment, so that the remainder of the system can continue to operate successfully

2. To limit damages to equipment due to overheating and mechanical forces etc. the purpose of protective relays and relaying system is to operate the current circuit breakers so as to disconnect only the faulty equipment from the system as quickly as possible. thus minimizing the trouble and damage caused by faults when they do occur.

2.6 CONCEPTS OF RELAYS

A relay may be defined as an electrical device that responds to its input information in a prescribed way and by its contact operation, causes an abrupt change in associated control circuits.

The principle of operation of relay may be described by considering the operation of the Hinged armature type. Fig 2.2 below shows the operating mechanism of a hinged armature type relay, this consist of a flat plate or bar type of armature which pivots at a fixed point when attracted to the pole face of an electromagnet. The armature carries the moving contact, which meets the fixed contact the armature is picking up. The pivoted beam has a weight on one end and the pull of the electromagnet is too much or little to balance the weight at the end of the beam.

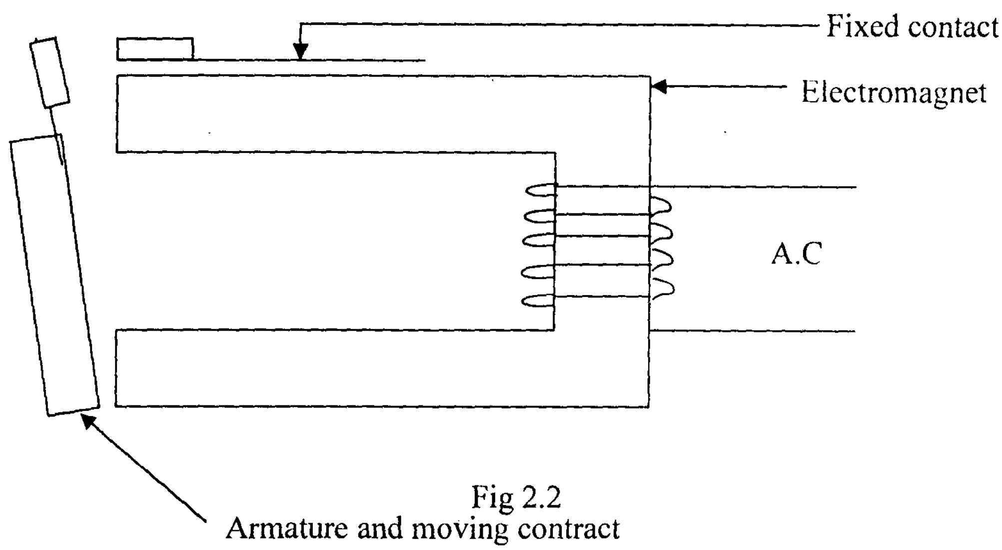


Fig 2.2

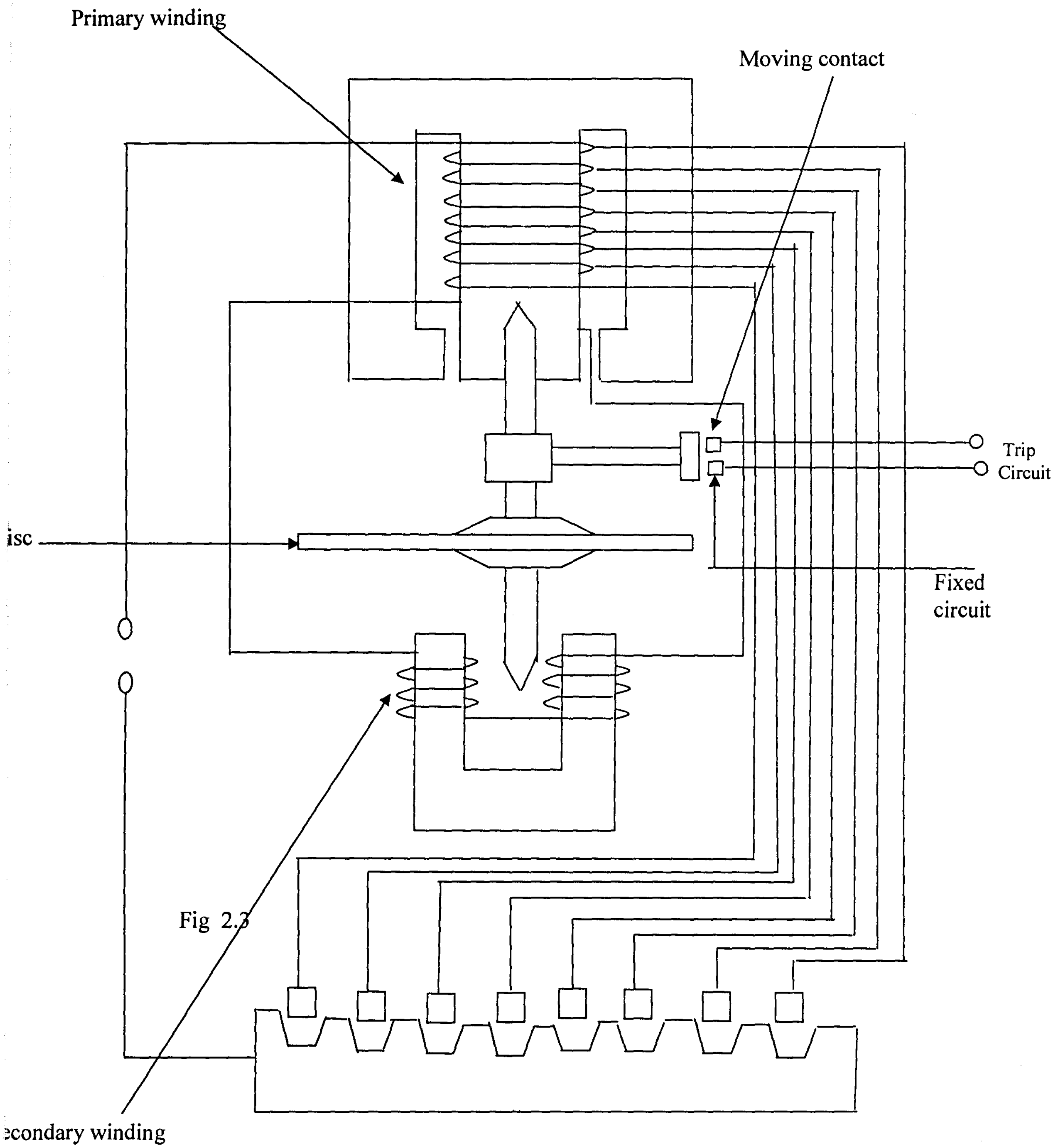


Fig. 2.4 Diagram Over-current relay

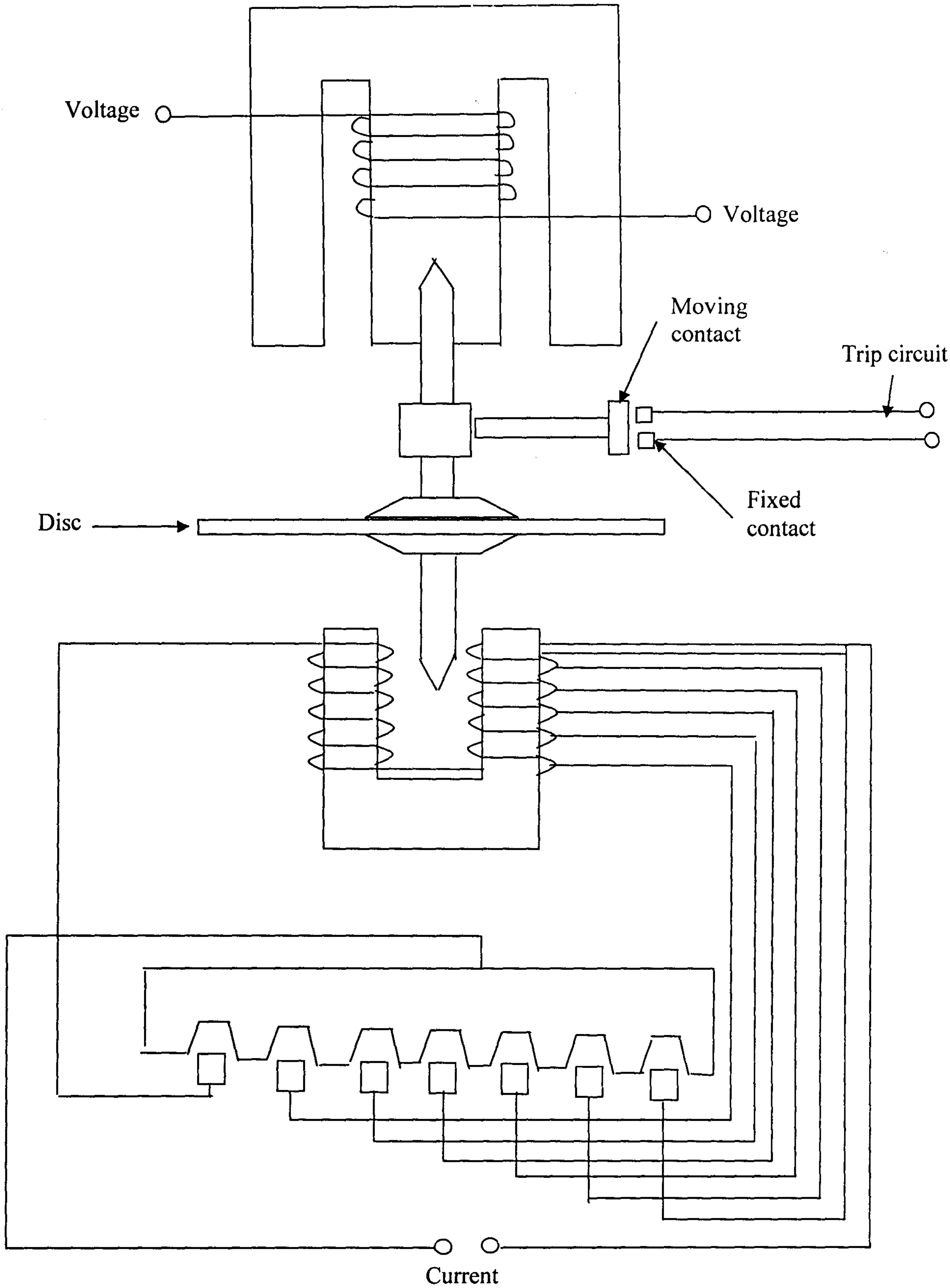


Fig. 2.5 Diagram showing reverse relay

2.7 RELAYS FOUND WITHIN PHCN SYSTEM

Different types of relays are used within PHCN system, some of which: over voltage, Over current or overpower relays. The principle of operation of these types of relays is similar to that of Under - voltage, Under current or Under power relays, but these relays are actuated only when the voltage, current or power rises above a certain specified value.

i Under-Voltage, Under – current or Under-Power Relays: these relays are actuated when the rated voltage current or power falls below specified values.[4]

ii. An Overload Relay: This relay is actuated when the load rises above a specified load.[1]

iii. Directional or Reverse Current types: The relay is actuated only when the direction of the current is reversed or the phase angle of the current takes up a phase displacement more than the desired [5]] values.

iv. Directional or Reverse Power Relay: This type of relay is actuated when applied voltage and current attains a certain specified phase displacement. No under- Voltage compensation is provided.

v. Inverse Time Delay Relays: These types include:

a. The normal inverse time delay which is a time dependant relay having an operating time which is an inverse function of the electrical characteristic quantity.

PRINCIPLE OF OPERATION OF SOME RELAYS

i. Over-current relay: Figure 2.4 shows an induction type of over current relay. The current enters a trapped primary, the turns which can be chosen by a plug which thus give a current setting. It consist of two electromagnets, the upper magnet which produce flux, and consist of three limbs, the central limb carries two windings, the upper winding of this limb act as primary winding and the lower winding acts as the secondary winding. The emf induced on the low U magnet and this results in the production of flux Φ_2. these fluxes (Φ_1 andΦ_2.) are sufficiently displaced from each other to produce the eddy current in the[8] disc to cause rotation of the disc.

ii. Reverse Power Relay: figure 2.5 shows a kind of a reverse power relay. The principle f operation of this relay is similar to that of an overcurrent induction relay. The difference lies in the fact that in case of over current relay the torque is produced due to interaction of magnetic field obtained from the current[8] in the circuit through current transformer. While in case of reverse or directional power relay, the driving torque is derived from both voltage and current of the circuit in which the relay is provided. Since the relay can essentially be called a wattmeter's the torque developed is dependent upon the direction of current in relation to voltage and current. The driving torque is proportional to the power.

iii. Over Load Relay: A directional overloads relay can be made of two induction disc type relays, one of which is a simple over-current relay and the other a reverse power relay. The two relays are fitted in one case, their contacts are connected in series so [6] that the trip circuit is not energized unless both operation.

2.9 THE ELECTROMAGNETIC TYPE OF RELAY

The relay consists of a coil of insulated wire wound round a soft iron. When the coil is energized the hinged armature is attracted to the electromagnet and presses two contacts together [3].

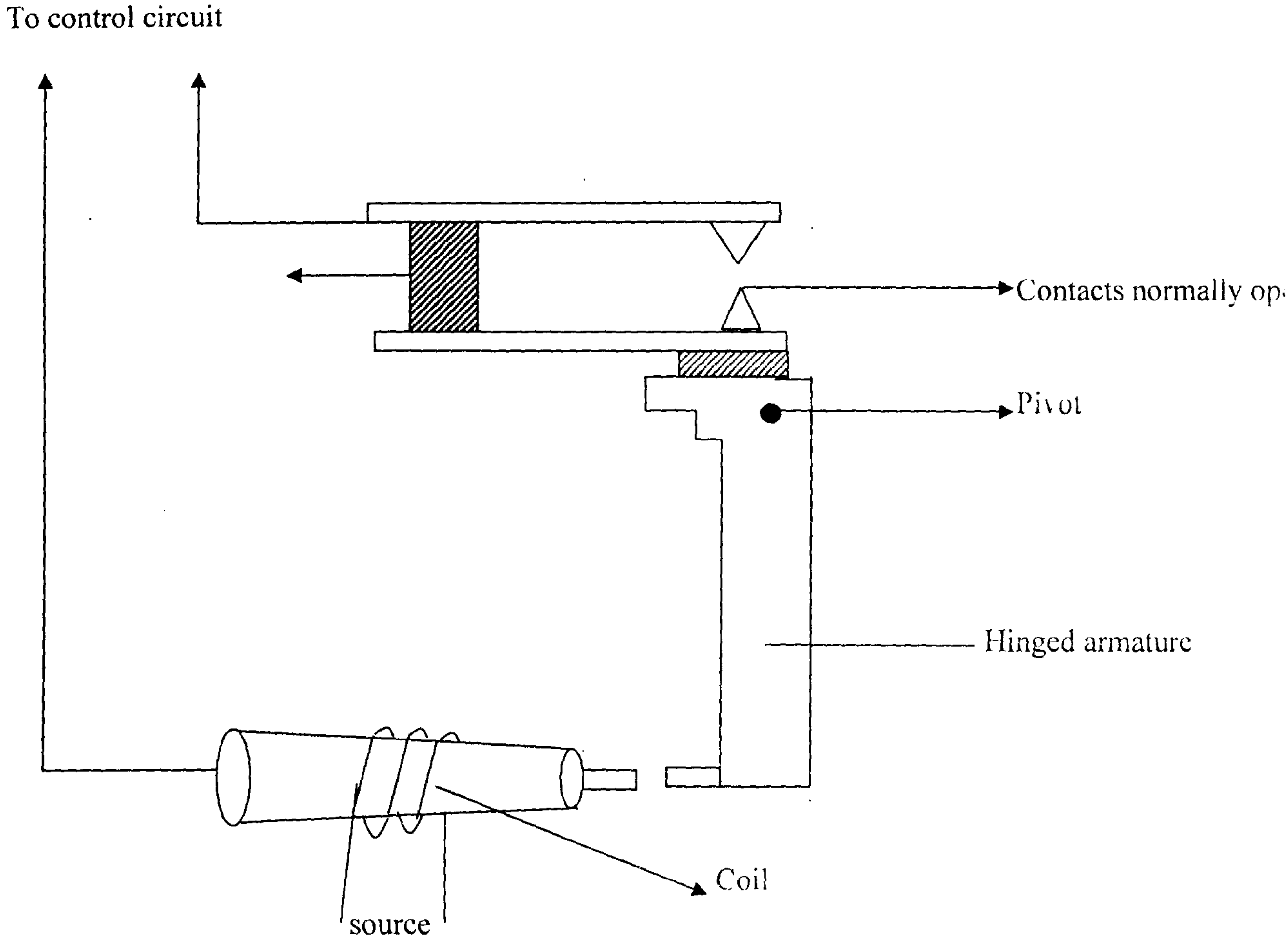


Fig 2.6 schematic diagram or relay parts.

The contacts are open until the coil is energized. When the coil de-energizes, the contacts open. As soon as the current stops, the core ceases to attract the armature taking it back to its original position and the contacts open. The importance of this system lies in the fact that the current in the electromagnet is completely separate the current from a distance so that the power losses I^2R in the cables will be[3] minimised.

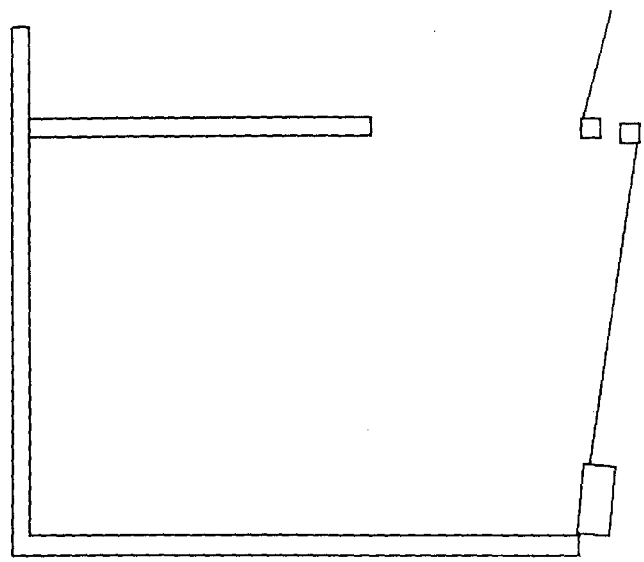


Fig 2.7 Schematic diagram of attracted armature relays.

To provide maximum pull to close the contacts and to help ensure quietness, the faces of the armature and the magnet assembly are grounded to a very close tolerance.

Air gap – when a relay's armature had sealed in, it is held closely against the magnet assembly, however, a small gap is always deliberately left in the iron circuit. When the coil is de-energised, some magnet flux (residual magnetism) always remains and if it were not for the air gap in the iron circuit, the residual magnetism might be sufficient to hold the armature in the sealed position. As soon as the current stops, the core ceases to attract; the armature returning back to its original position and the contact open. The importance of this system lies in the fact that the current in the electromagnet is completely separate from the current carried by the contacts.

One of the basic principle behind electromagnetic relay can also be considered using Faraday's L aw of Electricity. A relay is an electrically operated switch.

$E = -Nd\Phi/dt$ equation 2

.i.e in a magnetic field the induced voltage is directly proportional to the rate change of flux and is always tending to oppose the flow of the current producing. (Lenz' Law).

E = Induced Voltage

Φ= Magnet Flux

N = Numbers of turns of the coil.

The minus sign is put there because of lenz's law. Other types of relay also exist which are moving coil relays, induction cup relays, induction disc relays and thermal relays. Attracted armature relays include plunger, hinged armature, balance beam and moving iron relays. As measuring units they are handicapped by inherently low reset/ kick-up ratio and inadvertent operation on sudden changes in circuit conditions.

In this family, there are also magnetized short relays; these consists of steel balls in a container surrounded by coil which when energized, causes the shot to move in the axial magnetic field with a considerable force after a time interval depending on the current magnitude during which they align their magnetic axes.

2.10 MAGNETOMOTIVE FORCE (M.M.F)

The magnetomotive can be regarded as a magnetic potential difference responsible for setting up the magnetic flux.

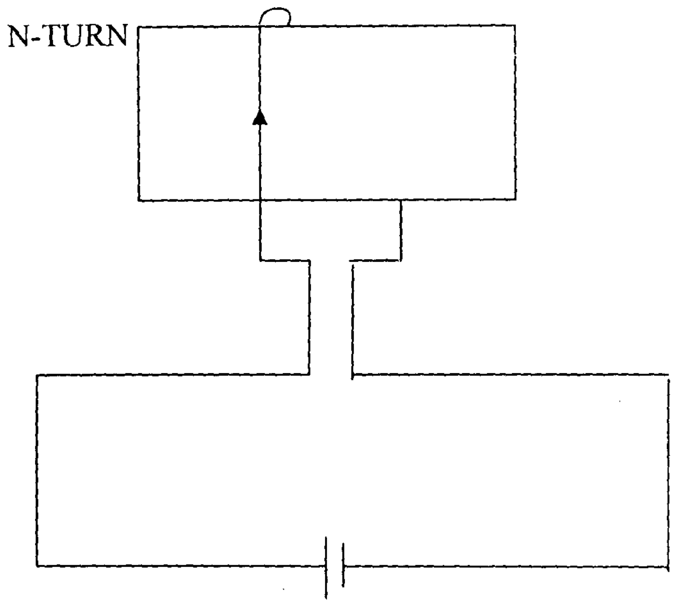


Fig. 2.8(a) Shows a current flowing in a single turn conductor.

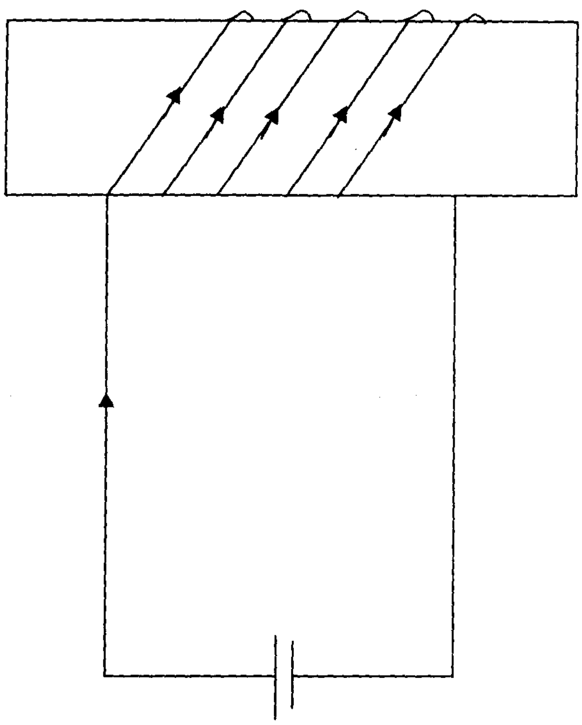


Fig.2.8(b) which in turn shows a current I_2 flowing in conductor of N-turns.

I1=I2N if identical magnetic effect is produced by circuits A and B.

The product of current and turns N or the ampere-turns of the coil is responsible for the production of the magnetic flux and is termed the magnetomotive force (mmf) with a unit of A-t or ampere-turns. Where A = current and t is turns. The field direction of a magnetic field set up by a current carrying conductor can be determined by the application of the screw rule (Maxwell).

The rule states that if a few screw is turned clockwise as to travel in the direction of the current, the direction of the turning gives the direction of magnetic field.

$$B = \Phi/A.$$

Where B =Flux density in Tesla.

Φ =Magnetic flux in weber.

A= Area covered where B exists.

Since the mmf is expanded over any closed path linking the circuit, the total mmf can be summed around a closed path linking an N- turns carrying current I.

$$F = IN$$

Magnetic energy is released in mechanical form if the movement lowers the mmf require for a given flux stored. The observed effects may be mechanical, generative and inductive.[4]

2.11 HYSTERISIS.

If the flux density in a magnetic material is measured as the applied strength varies a curve of B against H is shown in figure below.

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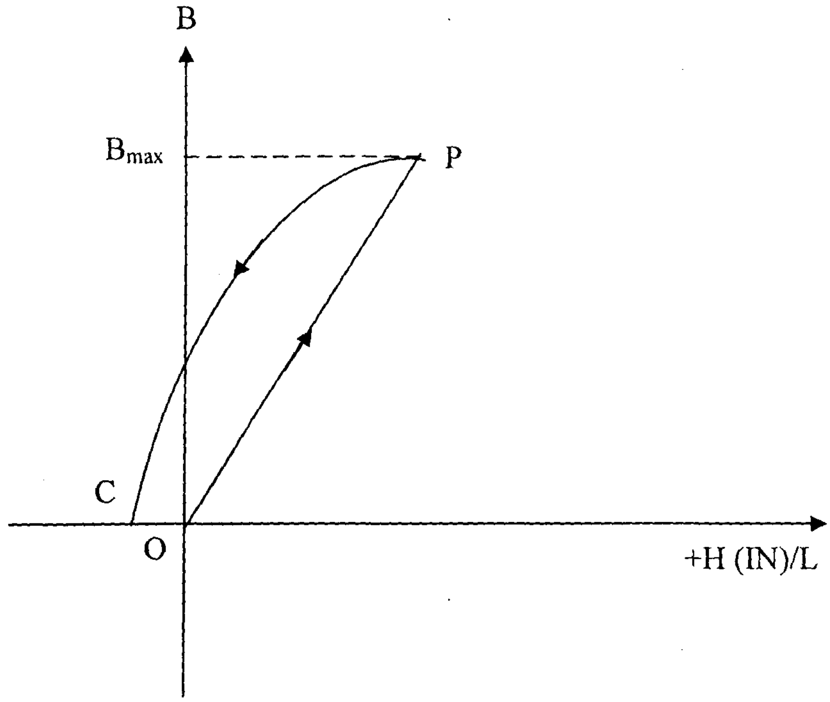


Fig 2.11 Showing Hysterisis Effect.

B increases with H to a maximum value (saturation) ay point P. when the applied H is gradually reduced to zero, B does not return to zero. This phenomenon is known as the hysterisis effect. The quantity OQ is called the remnant flux density or residual magnetism.

SOME FORMS OF RELAY {ELECTROMAGNETIC WORKING PRINCIPLES}.

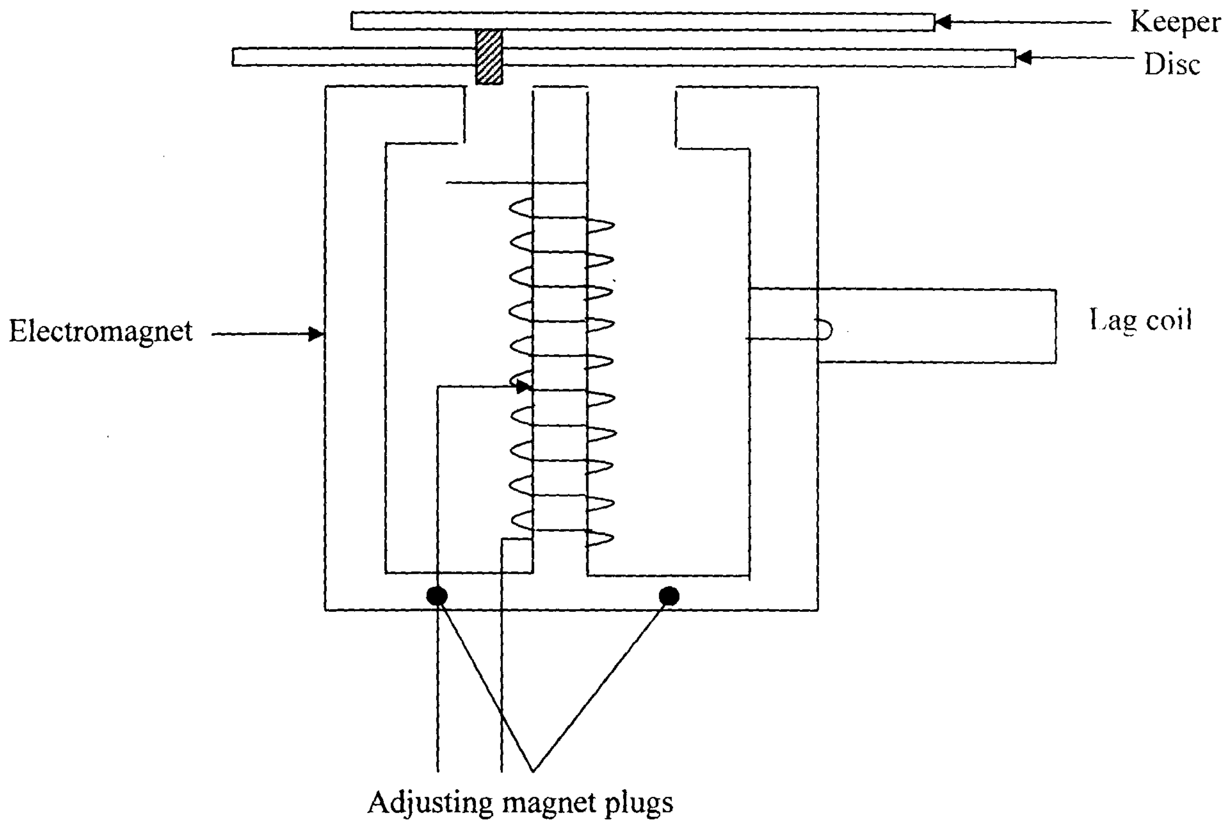


Fig 2.12 Showing the induction disk inverse time over- current or voltage relay.

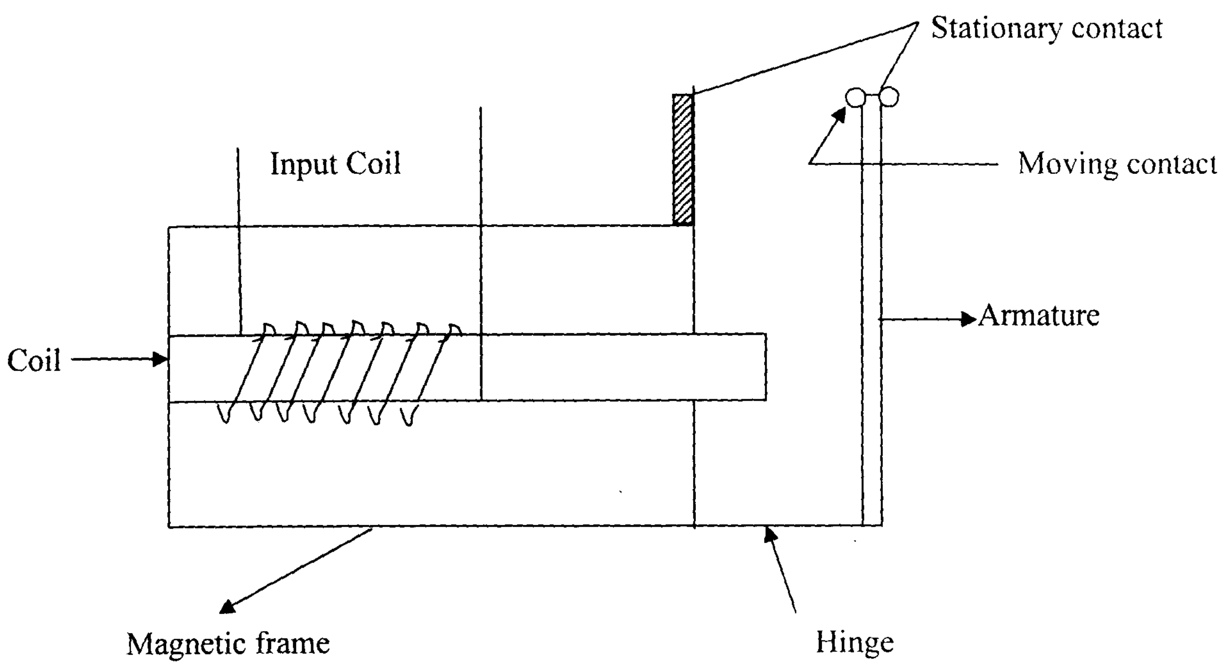


Fig 2.13 Showing electromechanical clapper or telephone relay.

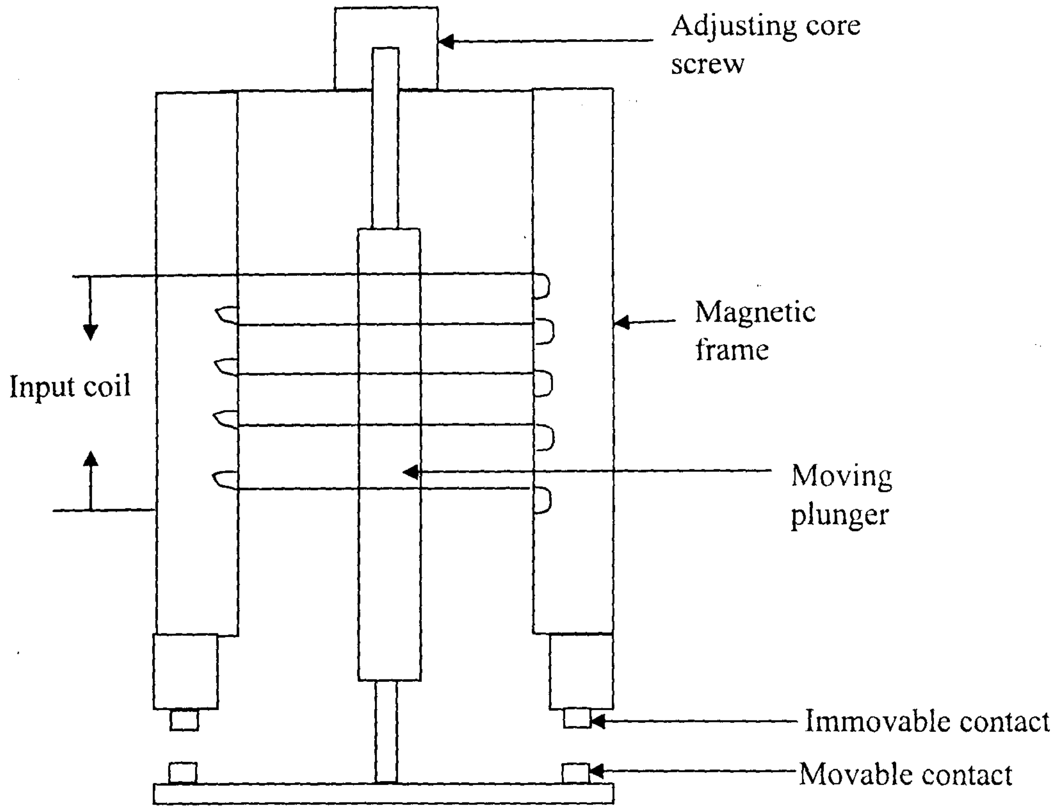


Fig 2.14 showing the moving plunger type of relay.

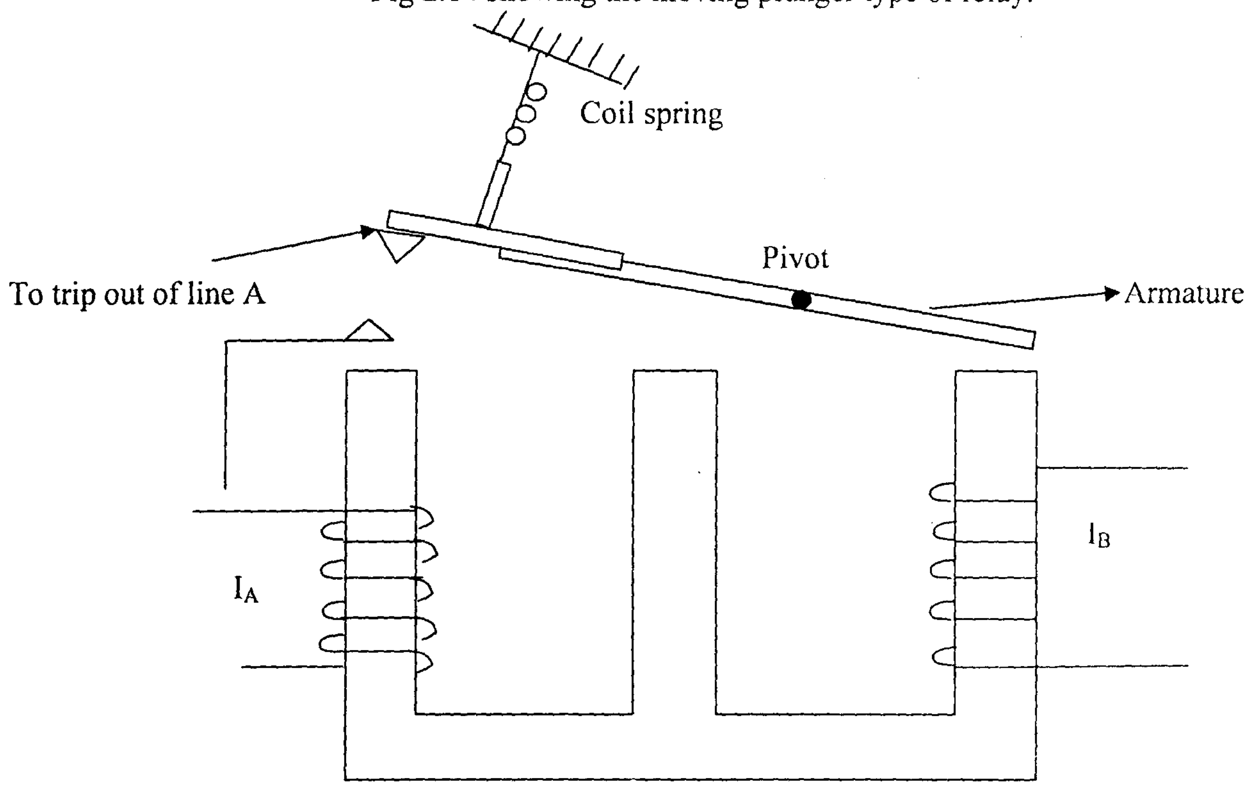
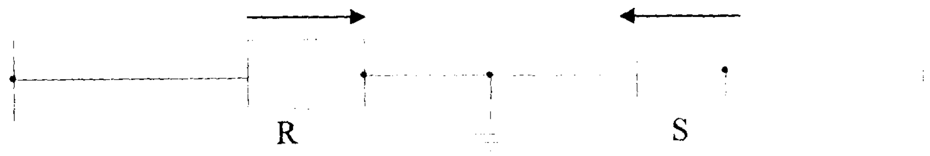


Fig 2.15 Showing an electromagnet current- balance relay.

When the current 1A is > IB, the armature moves and closes the contact to trip out line A



S and R are relays. If there is no fault, the flow of current is in the same direction depending on power flow. But when fault occurs directions of I through S and R will be opposite for both will be feeding the fault as shown and the relay which normally are energized will now trip.

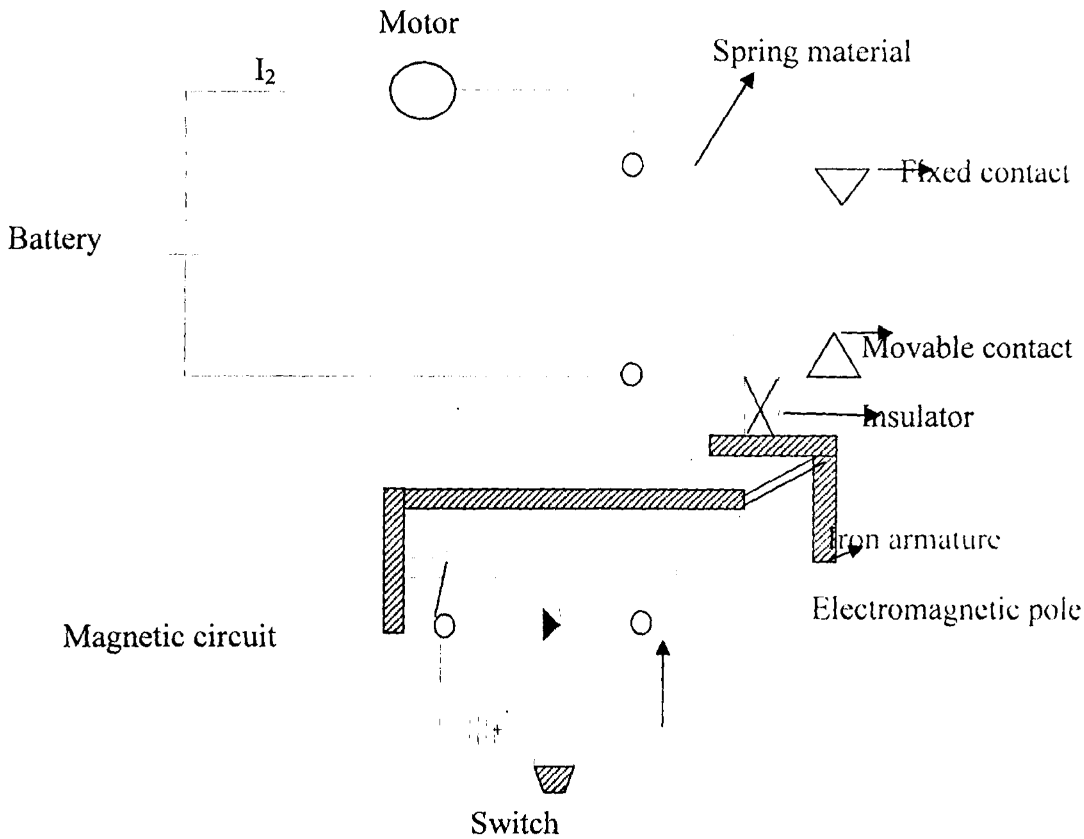


Fig 2.16 Showing an electrical relay.

When designing a relay it is very essential to take the material of our core and armature into consideration. They are broadly divided into soft and hard magnetic material.

CHAPTER THREE

3.1 DESIGN ANALYSI S AND CONSTRUCTION.

PRELIMINARY CONSIDERATION

Since the objective of producing an electromagnetic relay must be to meet the technical needs of power systems, the product must be the one that will be competitive and should be able to produce satisfactory financial return over the period that the apparatus will be in operation .

This requires that the design shall be judged not solely by the quality of it's performance nor solely by its cost but by its cost effectiveness which is a measure of the performance afforded in relation to both the realistic market requirements and costs.

The quality of performance all those attribute that define the operation of a relay under service conditions. It must, therefore be dependent on the effectiveness of the specification on which the design has been based, including the associated characteristics such as the level of reliability, electrical and mechanical safety, degree of maintainance required and the flexibility of the design necessary to meet various requirements. Attempts will therefore be made during the design to ensure that the information necessary of optimum use of the apparatus will be available to the user.

Various factors are taken into consideration including the supply and load voltages, the solenoid tripping current, tripping time and the electromagnetic pulling force.

3.2 DESIGN SPECIFICATION AND REQUIREMENTS

1. Standardization: The use of standard components is essential to reduce cost.
2. Reliability: The proposed electromagnet relay should be reliable under the conditions which the device will be operated fully.
3. Maintainability: The device should be easy to maintain such that the average electrical service men should be able to do this.
4. Accuracy; Ability: It should operate at the specified rated current and time.
5. Fault detection: The relay must be able to identify a fault and know the area where the fault occurs and quickly isolate the area of fault to protect the circuit breaker of which it functions.
6. Production methods : The design should ensure that even with available manufacturing methods optimum results of production would be attained.
7. Size and weight limitation: The design should be one in which the presence of other electrical components competing for available space has been considered it should be portable and handy.
8. Life expectancy: Ratings must be determined by application requirements. Relay life varies with the application and is not directly related to ratings. When life is specified, levels are preferred or should be used as a guide line for actual application requirements.
9. Safety: The design should be one that is free of features likely to cause injury, enables faulty circuits to be readily identified, gives accurate protection.
    a. Enviromental factors: The design is carried out to withstand atmospheric pressure and temperature.

10. an not contribute to atmospheric pollution and it is tolerable to noise vibration.

11. Standardization and cost requirement: The design makes use of standard components to reduce cost

3.3 CONSTRUCTION

The topic deals with the general construction of the actual designed project choice of materials, availability of the material and of course the assemblage of the components.

3.4 CHOICE AND SOURCE OF MATERIALS

The mild steel iron bar was used for the construction of the electromagnet and armature because of its permeability to magnetic flux.

The rigid support and the spring are used to maintain the armature at a particular distance and the spring also act as restraining force. The spring stretches when the armature when the armature is in seal position and tends to pull the armature back to normal position if the coils are not energized.

For the contact, copper was used and it was chosen because of its high conducting capabilities and also because of its ability to withstand heat. We need a contact that would withstand openings and closures for a long time without burning or arcing away.

The coil was wound on the electromagnet having first of insulated core with insulating paper before the winding was carried out. The winding was carried out manually. I made sure it was compact enough to reduce losses which in turn may lead to the general overheating of the coil. After the number of turns was completed, it was covered by insulating paper and both ends of the coils were brought out and sleeved in.

3.3 ACTUAL DESIGN

Supply voltage along A/c line - 240v

Current controlled – 1A

3.3.1 FREQUENCY

This is the frequency of the supply which is 50Hz. Higher frequency will affect the interrupting capacity.

3.3.2 CURRENT RATING

Rated exciting current =100mA=0.1 which is based on IEEE regulation

3.3.3 TEMPERATURE

The required temperature range is between 10- 40^{O} C.

3.3.4 HUMIDITY

Relative humidity up to 50% is considered state

3.5 THE COIL AND ARMATURE

The armature (core) consist of laminated soft iron strips in the shape of an alphabet E which hosts the insulated copper wire guage (coil).

The laminated soft iron is insulated from the moving part of the relay to prevent electric conduction but allow magnetic conduction. The design of the core(the armature) is shown below.

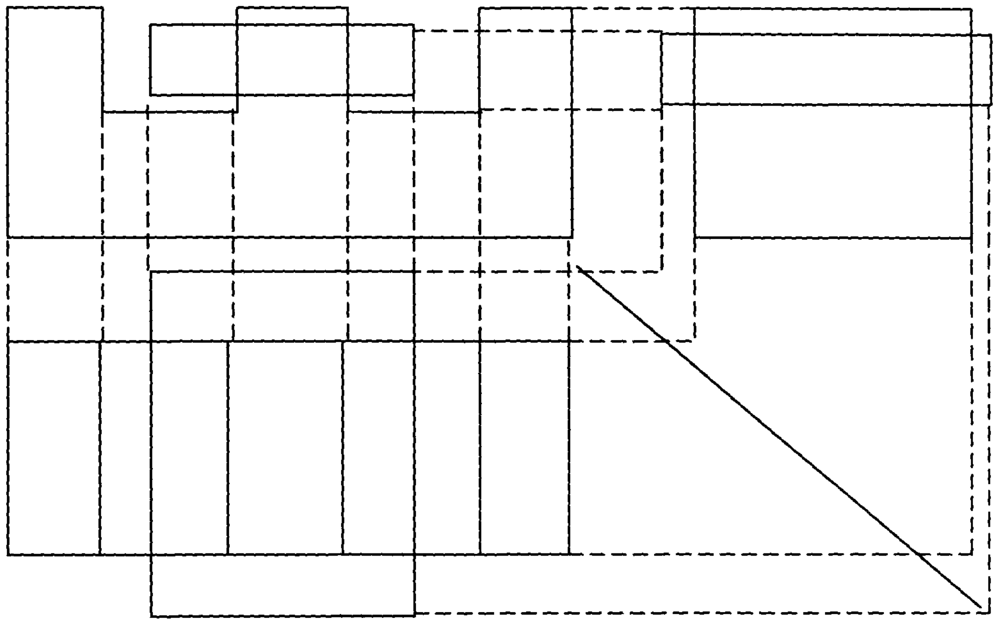


Fig2.17 diagram showing the electromagnet of the coil

Moving part (magnetized soft iron bar)

The moving part consists of soft iron bar supported by an elastic spring which is rigidly held by one of the contact conductors. It is shown below.

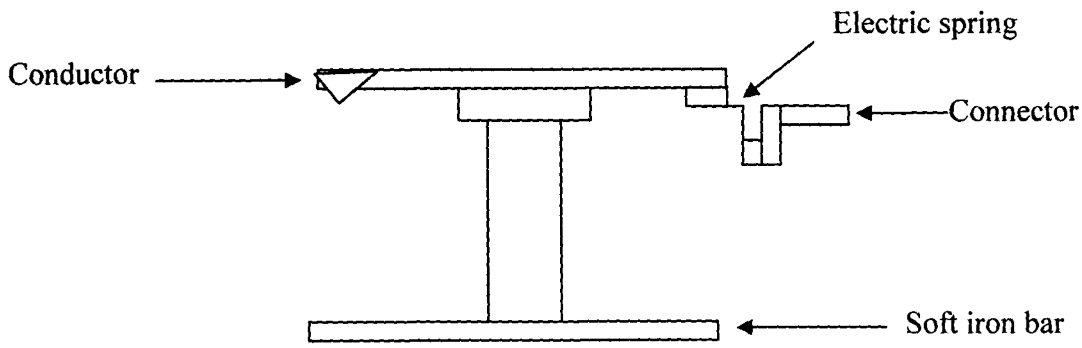


Fig 2.19 diagram showing the moving part of a relay [armature].

The contacts

These consists of copper strips which makes or breaks an electric current when the electromagnet is energized.

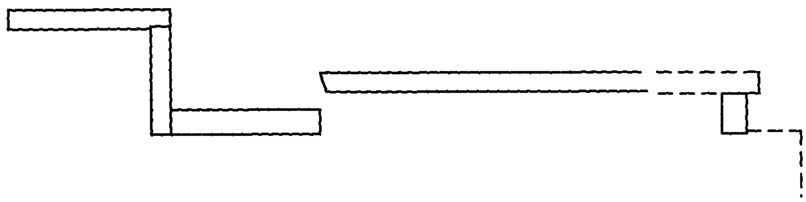
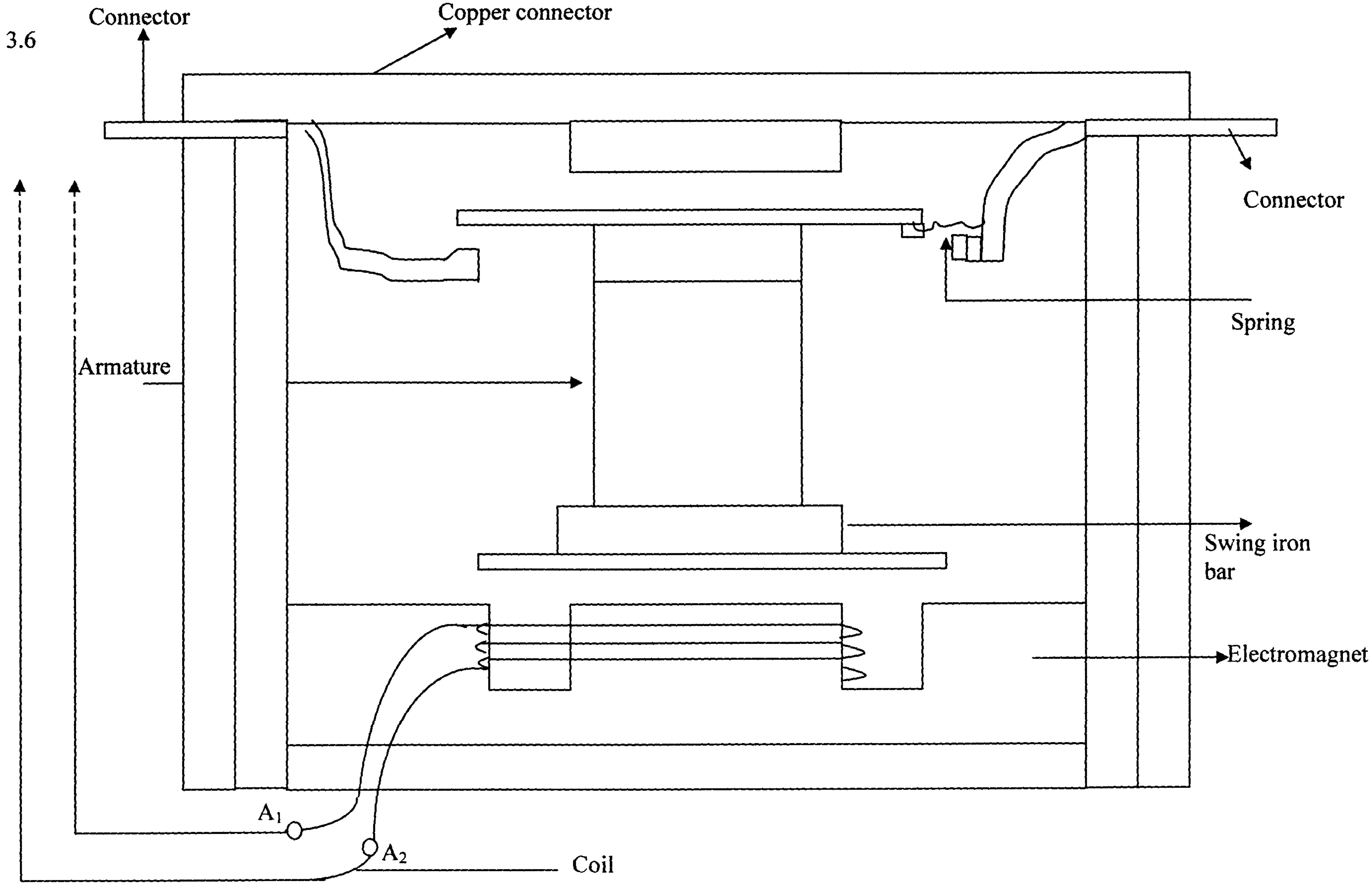


Fig2.20 diagram showing the contacts

3.6



SYSTEM OUTLAY

3.7 COIL SPECIFICATION

Tongue width = 1.3cm

Stack height = 2.0cm

The area of cross section (core area) A_c= 1.3 x 2.0 =2.6 cm^2

From the equation E = 4.44FB A_cN

Mains =240 F= 50Hz. A_c =2.6cm^2

For iron core B=1.0-1.3 Tesla for normal working operation.

B = 1.5 Tesla taking the average

240 = 4.44 x 50Hz x1.15 x2.6 x10^{-4}m2 x N

240 = 0.06638 x N

N = 3616 Turns

Inductance of the coil.

$L = N^2 A_c\mu_r\mu_o/l$

N = No of turns, A_c = core area μ_r = Relative permeability of medium (iron)

μ_o = Permeability of free space = 4л x $10^{-7}Hm^{-1}$

l = span length of the coil. From the design, N = 3616 A_c = 2.6cm2 =2.6x10-4m2

μ_r =700 (for soft iron) l = 0.9 cm = 0.9 x10^{-2}

L = 36162 x 2.6 x 10-4 x700 4 л x10-7 = 332.3H

0.90x10-2

Since the resistance is negligible compared with the reactance

The impedance Z= j2лfL= j2 л x 50 x 323.3 =j104.4kΩ

Z =√ $R^2 + XL^2$ Z =104.4 kΩ

The minimum mass of the moving part is 1mg therefore the higher the value the better the contact. It should also be noted that excess weight of the moving part will lead to excessive strain on the spring

I= V/Z =240/104.48 = 2.29mA

Force of attraction, F = IN F =2.29 x3616 = 8.28 A/turns

Magnetic field strength H=NI/y where y= air gap

The air gap between the electromagnet and the moving soft iron is 2.0mm approximately.

H = 3616 x 2.29x10-3/0.002 =4140 A/M

The magnetic flux density $B = \mu_r \mu_o H$, $\mu_o = 4\pi \times 10^{-7} Hm^{-1}$ $\mu_r = 1.005$

$B = 1.005 \times 4\pi \times 10^{-7} Hm^{-1} \times 4140 = 5.23 \times 10^{-3}$ Tesla

Force in Newt = on exerted by the electromagnet $F = B^2 A_c/2 \mu_o$

Elastic force = ke

Weight = mg.

For the relay to close, the downward force (that is the sum of the weight and electrical force) must be greater or equal to the elastic force.

$Mg + B^2 A_c/2 \mu_o > ke$

For the design an elastic spring constant of force constant (k=6.3) was used the deformation e = air gap = 2.00mm

Hence the mass of the moving part for the good contact is calculated as.

$Mg > ke - B^2 A_c/2 \mu_o$ $g = 10ms^{-2}$

$Mg > 6.3 \times 2.0 \times 10^{-3} - 2.52 \times 10^{-3}$

Mg > 0.0101 N

M > 0.0101/10 = 1mg

The minimum mass of the moving part is 1mg therefore the higher the value the better the contact. It should also be noted that excess weight of the moving part will lead to excessive strain on the spring

4.1 CHAPTER FOUR

TESTS, RESULTS AND DISCUSSION OF RESULTS

4.2 TESTING

AIM: To determine the current at which the electromagnet attracts the armature.

APPARATUS: Ammeter (0 – 500A)

PROCEDURE: The ammeter was connected in series with the electromagnet as shown in the figure below.

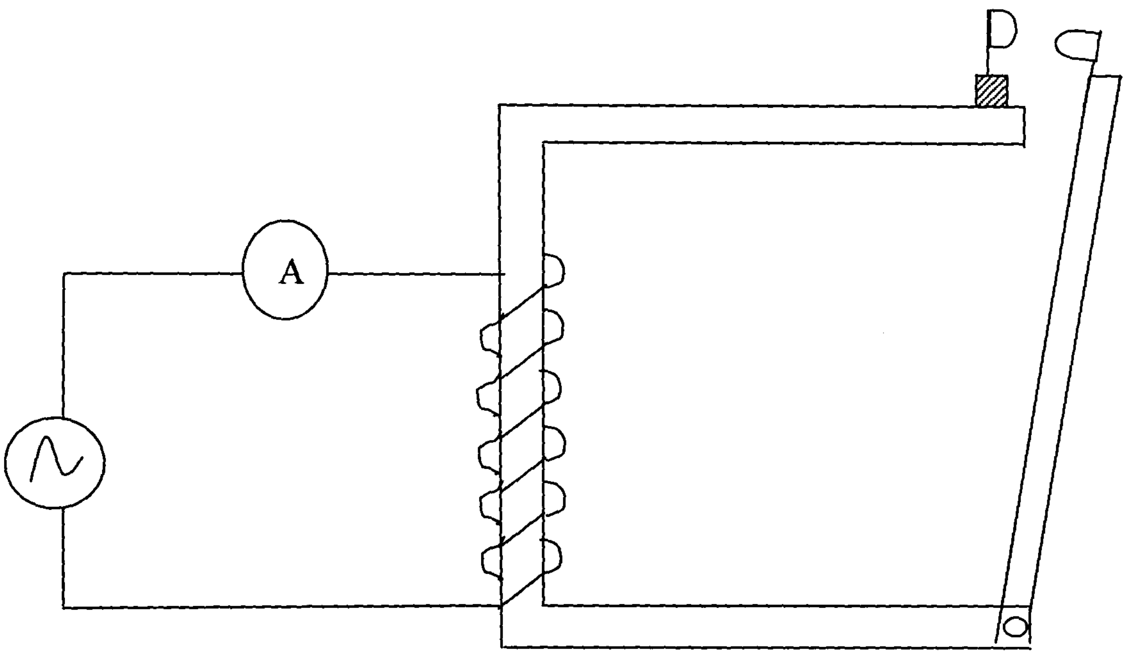


Fig 4.1 showing test diagram for the relay

Table 4.1

V (volts)	I (amp)
240	0.11

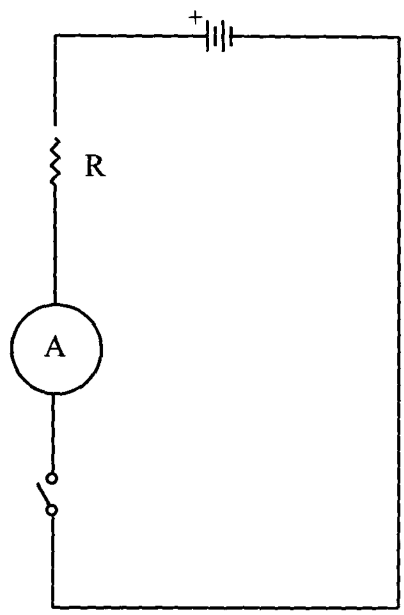


Fig 2.2.2 the circuit diagram

4.3 COIL TEST

Insulation resistance test was carried out on the coil in order to ensure that there is no possibility of leakage current flowing between insulated conductors of the coil.

4.4 CONTINUITY TEST

This is to ensure that voltage drop is minimal and no breakage of the coil along the line. This was done with the aid of avometer.

4.5 HEAT TEST

It was carried out taking direct measurement using the laboratory thermometer having a sensing probe.

Also thermocouple could be used where resistance change of the winding (due to change with increase in temperature).

Using the thermometer method at an ambient temperature of about 36^{o} c

CHAPTER FIVE

5.1 CONCLUSION AND RECOMMENDATIONS

5.2 PERFORMANCE

It was seen that that the current which is needed to power the coil is very small i.e o.11A which is the exciting current. It should be noted that this current is totally different from the current at the contacts.

It was also noted that the relay contacts were open as soon as the load current exceeded 1A with the milliammeter indicating the exact current at which the contacts open up. Its operation time was considered good enough as it was enough for the contact to open before the over current gets to the contacts and from there on the protected circuit components, or circuit breaker as the case may be.

5.3 CONCLUSION

The major objectives of this project was achieved and that is to enable us, students of electrical engineering make use of the learnt theory in practical and industrial world and also to enable us appreciate the limitations of the theory in actual practice.

The project was successfully completed within the scope of its objectives. By actual design and construction.

There may be some demerits like any other design so modifications or suggestions and also constructive criticism would be highly welcome.

5.4 RECOMMENDATION

The reduction in weight of the armature should be looked into . If only it weighs a little bit less, it would enhance the switching speed making it more reliable. The insulation and winding should also be looked into so that hysterisis loss and copper losses are reduced to bearest minimum thereby offering greater life span for the relay hence, saving money.

. Furthermore, a magnetically soft material should be used for both the electromagnetic core and the armature so that if the coils are de-energised little restraining force is needed in pulling the armature away from the contacts.

To ensure high performance and durability:

a. The system should be kept in a well ventilated area where the ambient of the system should not be more than normal room temperature, otherwise the system will suffer a great loss of heat which might damage it.
b. The system should not be overloaded by connecting it to many equipments simultaneously
c. No object should be kept on top of the equipment as much as possible, shock and vibration should be avoided as this might result in short circuit or open circuit in the internal circuitry.

5.5 REFERENCES

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5.6 BILL OF QUANTITY

NO	DESCRIPTION OF MATERIALS	QUANTITY (UNIT)	UNIT RATE ₦ : K	TOTAL AMOUNT ₦ : K
1.	COPPER WIRE(COIL)	1 ROLL	1000:00	1000:00
2.	MILD STEEL IRON BAR	2	1500:00	1500:00
3.	BOLTS & NUTS	8	120:00	120:00
4.	SCREWS	10	150:00	150.00
5.	CASING	1	1000:00	1000:00
6	COPPER CONTACTS	2	500: 00	500:00
7.	FLEXIBLE WIRE	3	450 :00	450:00
8.	OTHER MATERIALS	4	2800:00	2800:00
9.	SUB-TOTAL (ST1)			7520:
10	TRANSPORTATION OF MATERIAL 5% OF ST1			376
11	SUB-TOTAL (ST2)			7896
12	LABOUR 30% OF ST2			2368

13	SUB-TOTAL (ST3)			10264.8
14	OVER HEAD 5% OF ST3			513.24
15	SUB-TOTAL (ST4)			1077804
16	PROFIT 10%			107.78
17	SUB-TOTAL (ST5)			10885.82
18	CONTINGENCY 5% OF ST5			544.29
19	TOTAL COST			11430.11