SURGE PROTECTION IN LOW VOLTAGE AC POWER SYSTEM

DISSERTATION

Submitted in partial fulfillment of the
Requirement for the award of the
Degree of

MASTER OF TECHNOLOGY
IN
ELECTRICAL ENGINEERING

By

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Under the Esteemed Guidance of

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CERTIFICATE

This is to certify that the Thesis titled "**SURGE PROTECTION IN LOW VOLTAGE AC POWER SYSTEM**" that is being submitted by " **VINAY BELWAL**" is in partial fulfillment of the requirements for the award of MASTER OF TECHNOLOGY, is a record of bonafide work done under my our guidance. The contents of this Thesis, in full or in parts, have neither been taken from any other source nor have been submitted to any other Institute or University for award of any degree or diploma and the same is certified.

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Objective of the Thesis is satisfactory / unsatisfactory

Examiner I **Examiner II**

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I express my sincere thanks to my Guide **Mr. Amardeep Singh Virdi** for his invaluable assistance, motivation, guidance and encouragement without which for the project have remained a dream. He provided me with spark required to set in motion this particular project. In spite of his busy schedule, he was always there to iron out the difficulties which kept on arising at regular intervals. I also extend my thanks to the entire **Faculty** of the **School of Electronics and Electrical Engineering LOVELY PROFESSIONAL UNIVERSITY** who has encouraged me to complete the project. Last but not the least I am greatly indebted to all of my friends who have encouraged directly or indirectly for successful completion of this project.

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This is to certify that **VINAY BELWAL** bearing Registration no. 11204755 has completed objective formulation of thesis titled, **“SURGE PROTECTION IN LOW VOLTAGE AC POWER SYSTEM”** under my guidance and supervision. To the best of my knowledge, the present work is the result of his original investigation and study. No part of the thesis has ever been submitted for any other degree at any University.

The thesis is fit for submission and the partial fulfillment of the conditions for the award of **MASTER OF TECHNOLOGY.**

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DECLARATION

I, **Vinay Belwal**, student of **MASTER OF TECHNOLOGY (POWER SYSTEMS)** under Department of **ELECTRICAL ENGINEERING** of Lovely Professional University, Punjab, hereby declare that all the information furnished in this thesis report is based on my own intensive research and is genuine.

This thesis does not, to the best of my knowledge, contain part of my work which has been submitted for the award of my degree either of this university or any other university without proper citation.

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ABSTRACT

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The electric power system is a vast, complex and uncertain system due to the presence of many electrical equipment like relays, conductor and sources as well as mechanical equipment like generator, motor etc. Besides the presence of this equipment the transmission line is long and comprises of inductance, capacitance, resistance and conductance. So any abnormality in the power system any where causes the performance of each and every equipment and hence the entire power system's gets disturbed. For minor disturbances like switching, faults, load variation etc. The system is inbuilt to resist the change in the system performance. But surges are high magnitude voltage spikes which when impressed on the line makes the system not only gets affected adversely but also lead the system to damage. So this paper presents method of protecting the system from these surges. The method here uses series compensation along with the surge protection equipment to obtain better result.

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LIST OF ABBRIVATION

SSSC Static Synchronous Series Compensation

CB Circuit Breaker

CHAPTER 1
INTRODUCTION

1.1 Background of Surge Phenomena

There are several instances when the elements of a power system (e.g. generators, transformers, transmission lines, insulators etc.) are subjected to overvoltages i.e. voltages greater than the normal value. These overvoltages on the power system may be caused due to many reasons such as lightning, the opening of a circuit breaker, the grounding of a conductor etc. Most of the overvoltages are not of large magnitude. But may still be important because of their effect on the performance of circuit interrupting equipment and protective devices. An appreciable number of these overvoltages are of sufficient magnitude to cause insulation breakdown of the equipment in the power system. Therefore, power system engineers always device ways and means to limit the magnitude of the overvoltages produced and to control their effects on the operating equipment. In this thesis we shall confine our attention to the various causes of overvoltages on the power system with special emphasis on the protective devices used for the purpose.

A surge is a random, short burst of excess electrical energy to a system. It is typically measured in \micro & milli-seconds. Also referred to as a transient, impulse or spike, these electrical disturbances can damage or even destroy sensitive microprocessor-based equipment. Surge protection devices are designed to reduce the amount of harmful energy that flows into a system. 80% of transients are generated from internal sources such as load switching, motors starting up or even turning on air conditioning systems. The other 20% of transients are typically generated from external sources such as lightning strikes & power company grid switching. Like it or not, most electrical systems are subjected to some level of transients. A device designed to protect electrical equipment from power surges & voltage spikes is called surge protective device.

Varistors, variable resistors, are voltage-dependent resistors with bidirectional and symmetrical V/I characteristics. Metal Oxide Varistors, MOV, are primarily made of Zinc Oxide and some suitable additives. When varistors are exposed to over voltage transient or surge, the varistors switch from standby state(nearly open circuits) to clamping state (highly conductive state). The major function is to protect equipments from being damaged by over voltage transient.

At leakage region, the V-I curve shows a linear relationship. The varistor is in high resistance mode and shows as an open circuit. In normal operation, the V-I curve of a varistor can be described by power law:

$$I=KVa$$

Where K is a constant and a defines the degree of nonlinearity. At high current, the varistor is in low resistance.

1.2 Surge Voltage

Surge voltage is defined as when a sudden increase value occurs in line for a very short duration in power system is called a transient voltage or surge voltage. Surge has a temporary nature which remains for a very short duration (few hundred micro second) and the produced overvoltage. Its originate from switching. Transient are caused by lightning strikes a transmission line. When lightning strikes a line surge rushes along a line and flood of water along a narrow valley. Internal overvoltage caused in a system itself and may be transient, dynamic or stationary. They can be caused by the operation of circuit breakers when switching inductive or capacitive load. Dynamic overvoltages occur at normal frequency and persist only for a few second. It cause by large portion of load is suddenly thrown off. Stationary over voltages also occur at system frequency but it may persist for some time perhaps.

External overvoltage caused by atmospheric discharges such as static charges or lightning strokes and related to system. They are often of such magnitude as to cause stress on insulation and in case of lightning will vary in intensity depending on how directly line is struck.

1.3 CAUSES OF OVERVOLTAGE:

(i) Internal Cause

(ii) External Cause

1.3.1 INTERNAL CAUSES OF OVERVOLTAGES

Internal overvoltage arise during sudden change in operating condition of installation as for example switch in, switch out or sudden change in load, opening a circuit with large inductance or capacitance, interruption of short circuit current, appearance of an arc fault between one phase and earth .

Switching Surges Overvoltage produce on the power system due to switching operation is known as switching surge. Case of an open line, during switching operation of unloaded line travelling waves is set up which produce overvoltage. When unloaded line is connected to voltage source a voltage wave is set up which travels along the line. On reaching the terminal point it is reflected back to supply end without change of sign. This cause voltage on line becomes twice the normal value. Case of loaded line, overvoltage voltage also is produce during the switching operation of loaded line. Suppose line is suddenly interrupted this will set up voltage of 2Zi across the switch where I be the instantaneous value of current at time opening of line and Z be natural impendence. Current chopping it is used in production of high voltage transient across the contact of air blast circuit breaker. When transformer magnetizing current with air blast breaker the powerful de ionizing effect of air blast causes current to fall abruptly to zero well before natural current zero is reached. Arcing ground the phenomena of intermittent arc taking place in line to ground fault of 3 phase system with consequent production of transient .It has two advantages such as

(1)In case of LG fault line is not put out of action

(2)Zero sequence current is eliminated resulting in decrease of interference with communication line.

1.3.2 EXTERNAL CAUSE

1.3.2.1 LIGHTNING

An electric discharge between cloud and earth, between clouds or between the charges centre of same cloud .Lightning is huge spark and take place when clouds are charged to such high potential with respect to earth. The most accepted one is that during the up rush of warm moist air from earth, the friction between air and tiny particle of water cause building up of charges. When drop of water are formed the larger drop becomes positively charged and smaller drop becomes negatively charged. When the drops of water accumulate they form cloud and hence cloud may possess either positive or negative charge depending upon charge of drop of water they contain. The charge on a cloud may become so great that it may discharge to another cloud or earth we call this discharge as lightning. Clouds are basically depend on the positive and negative charges and each positive and negative charge are joined to each other and produced the lightning phenomena and surges and lightning are damage the equipment in generation and transmission system and generate the losses in transmission line. These are the serious problem in our practical life and generate the losses and damage the protective device. Clouds are produced activity from the direct and indirect strokes which depend on the positive and negative charges.

1.4 Mechanism of Lightning Discharge

This mechanism is depend on the positive and negative charge cloud and produced the surge phenomena and produced the surges which due to losses are generate in transmission and generation system as well as performance are very effected of equipment. When the warm air is produced from the sea then the warm air reach in the sky then the cloud are formed which has a negative and positive charge and joined together each other. Due to this voltage gradient value are effected between the cloud and earth. As soon as air near cloud breaks down a streamer called pilot streamer starts from the cloud towards the earth and carries charge with it. In this phenomena cloud increase and the potential between earth and cloud increase as well as gradient in air increase. When the gradient value between 5kv/cm to 10kv/cm then the lightning strokes start. This mechanism is depends these points. Lightning discharge is formed by the cloud and clouds have a positive and negative charges which due to the surge are generate in earth. Clouds are made by the warm air which are generate from the ocean. Due to this gradient value are effected of both earth and clouds and main work of the clouds pairing with each other and then generate the surge. When the clouds are paired each other then lightning and sound are generate and then firstly reach till the earth is lightning and then come the sound which reach till the earth after the lightning. These mechanisms are fully depending on the positive and negative charge clouds and also depend on warm air. When the air near the cloud breaks down streamer called pilot streamer. Its depend on the ionization and the insulation. When the streamer reaches near the earth then the streamer is called return streamer. Lightning discharge is basically depending on the number of separate strokes and which travel down the same path. Lightning discharge is found the 87% from the negative charge while the 13% from the positive charges. It has been predictable value that throughout world there occurs 100 lightning stroke per second. Current range value of the discharge current 10KA to 90KA. This discharge made up of a number of separate strokes that travel down the same path. The interval value lies between .0005 to 0.5

second. Velocity of leader exceeds one sixth of that of light and value of distance travelled in one step is about 50m. The paths of pilot streamer depend on the ionization and complete breakdown of insulation. These phenomena generate from a sudden spark which is called lightning. Impulse ratio of lightning arrester is very low.

1.5 Types of Lightning Strokes

Basically two types of lightning strokes which falls down at the line such as overhead line, towers, substation etc. These are given below:

1.5.1 Direct stroke

In this stroke equipment and line are affected by the direct stroke and this generate from the clouds. Clouds have a positive and negative charge and which make a paired with each other and then surges and lightning are produced in earth and overhead line is affected. In case two clouds are joined each other and then charge produced and firstly surge produce and then lightning is generate. A direct stroke is directly falls over the overhead line and then losses are generated and electrical equipment is damage.

1.5.2 Indirect Stroke

Indirect stroke is depending on the cloud and overhead line and produced the surges and losses are generating in transmission system. In case of this stroke a positive charge cloud is above the overhead line then negative charge are produce according the principle of electrostatic induction. Due to this stroke surges and lightning are produced above the line and losses are generated.

1.6 Harmful Effects of Lightning

A direct or indirect lightning stroke on a transmission line produces a steep-fronted voltage wave on the line. The voltage of this wave may rise from zero to peak value (perhaps 2000 kV) in about 1 μs and decay to half the peak value in about 5μs. Such a steep-fronted voltage wave will initiate travelling waves along the line in both directions with the velocity dependent upon the L and C parameters of the line.

(1)The travelling waves produced due to lightning surges will shatter the insulators and may even wreck poles.

(2) If the travelling waves produced due to lightning strike the windings of a transformer or generator, it may cause considerable damage.

(3) The inductance of the windings opposes any sudden passage of electric charge through it. Therefore, the electric charges "piles up" against the transformer (or generator). This induces such an excessive pressure between the windings that insulation may breakdown, resulting in the production of arc. While the normal voltage between the turns is never enough to start an arc, once the insulation has broken down and an arc has been started by a momentary overvoltage, the line voltage is usually sufficient to maintain the arc long enough to severely damage the machine.

(4) If the arc is initiated in any part of the power system by the lightning stroke, this arc will set up very disturbing oscillations in the line.

1.7 Protection against Lightning

Surges on the power system may create from switch and from other causes but the most important and dangerous surges are those caused by lightning. The lightning surges may cause serious damage to the expensive equipment in the power system (e.g. generators, transformers etc.) either by direct strokes on the equipment or by strokes on the transmission lines that reach the equipment as travelling waves. It is necessary to provide protection against both kinds of surges. The most commonly used devices for protection against lightning surges are:

(i) Earthing screen
(ii) Overhead ground wires
(iii) Lightning arrester

1.7.1 The Earthing Screen

The power stations and sub-stations generally house expensive equipment. These stations can be protected against direct lightning strikes by providing ear thing screen. It consists of a network of copper conductors (generally called shield or screen) mounted all over the electrical equipment in the sub-station or power station. The shield is properly connected to earth on at least two points through low impedance. On the occurrence of direct stroke on the station, screen provides a low resistance path by which lightning surges are conducted to ground. In this way, station equipment is protected against damage. The limitation of this method is that it does not provide protection against the travelling waves which may reach the equipment in the station.

1.7.2 Overhead Ground Wires

The most effective method of providing protection to transmission lines against direct lightning strokes is by the use of overhead ground wires. The ground wires are placed above the line conductors at such positions that practically all lightning strokes are intercepted by them (i.e. ground wires). The ground wires are grounded at each tower or pole through as low resistance. When the direct lightning strike occurs on the transmission line, it will be taken up by the ground wires. The heavy lightning current (10 kA to 50 kA) from the ground wire flows to the ground, thus protecting the line from the harmful effects of lightning. Here that the degree of protection provided by the ground wires depends upon the footing resistance of the tower. Suppose, for example, tower-footing resistance is R_1 ohms and that the lightning current from tower to ground is I_1 amperes. Then the tower rises to a potential V_t given by;

$$V_t = I_1R_1$$

Since V_t (= I_1R_1) is the approximate voltage between tower and line conductor, this is also the voltage that will appear across the string of insulators. If the value of V_t is less than that required to cause insulator flashover, no trouble results. On the other hand, if V_t is excessive, the insulator flashover may occur. Since the value of V_t depends upon tower-footing resistance R_1, the value of this resistance must be kept as low as possible to avoid insulator flashover.

Advantages

(i)It provides considerable protection against direct lightning strokes on transmission lines.

(ii) A grounding wire provides damping effect on any disturbance travelling along the line.

(iii) Ground wires acts as a short circuited secondary.

(iv)It provides a certain amount of electrostatic shielding against external fields. Thus it reduces the voltages induced in the line conductors due to the discharge of a neighboring cloud.

Disadvantages

(i) It requires additional cost.

(ii) There is a possibility of its breaking and falling across the line conductors, thereby causing a short-circuit fault.

(iii) Eliminated of this objection by the use of galvanized stranded steel conductor as ground wire.

1.7.3 Lightning Arrester

A lightning arrester is protective devices which conduct the high voltage surge on the power system to ground. It consists of a spark gap in series with a non-linear resistor. One end of the diverter is connected to the terminal of the equipment to be protected and the other end is effectively grounded. Surge arrester is protective devices which are used in transmission line and provide the better performance in lightning phenomena. Arrester is used for safety purpose in line from the direct stroke. Lightning arrester has very important role in power system as well as electrical transient and due to this use of device all electrical equipments are safe and not damage. In power system many equipment can use for the protection of transmission and generation system. Power system is made from the construction and working of protective and electrical equipment and transmission and generation system as well as distributed system and type of arrester etc. Main works of electrical engineers are making the electrical equipment and provide the good performance in power system field. Arresters are basically used before the electrical equipment in system and provide the good performance. Arrester is placed in system for protection of transformer and other equipment.

Action:

(i)Under normal operation, the lightning arrester is off the line i.e. it conducts no current to earth or the gap is non-conducting.

(ii) On the occurrence of overvoltage, the air insulation across the gap breaks down and an arc is formed, providing a low resistance path for the surge to the ground.

(iii) The excess charge on the line due to the surge is harmlessly conducted through the arrester to the ground instead of being sent back over the line.

(iv) It is worthwhile to mention the function of non-linear resistor in the operation of arrester. As the gap sparks over due to overvoltage, the arc would be a short circuit on the power system and may cause power-follow current in the arrester.

(v) Characteristic of the resistor is to offer high resistance to high voltage (or current), it prevents the effect of a short circuit. After the surge is over, the resistor offers high resistance to make the gap non-conducting.

1.8 Types of arrester

(1) Rod gap arrester
(2) Horn gap arrester
(3) Multi gap
(4) Expulsion type
(5) Valve type

1.8.1 Rod gap arrester

Rod gap arresters are very simple type of diverter and consist of two 1.5cm rods which are bent at right angle. One rod connect from the circuit and other connected ground. Distance between gap and insulator must not be less than one third of the gap length that are may not be reach the insulator and damage it. Breakdown occurs 80% of spark over voltage to avoid cascading of very steep wave front across the insulator. Rod gap arrester is used for backup protection due to the below limitations. In which string of insulator for line on bushing of transformer has frequently rod gap across it.

Limitations

(i)Rod may damage due to excessive current.

(ii)Climates affect performance of this arrester.

(iii)Polarity of surge also affected.

1.8.2 Horn gap arrester

It has two horn shaped metal rods separated by small gap. Horns are mounted on porcelain insulator. One end of horn is connected to line through a resistance and choke coil while other end is effectively grounded. Choke coil offers small reactance at normal frequency but very high reactance at transient frequency. The gap between horns is so adjust that normal voltage is not enough to cause an arc across the gap. Under normal condition gap is no conducting. On occurrence of overvoltage, spark over take place across the small gap. Heated air around arc the magnetic effect of arc cause the arc to travel up the gap. The arc moves progressive into position.

Advantages

(i)Arc is self clearing.

(ii)Series resistance used in limiting the follow current to a small value.

Limitations

(i)Bridging of gap can render device useless.

(ii)Setting of horn gap is change due to corrosion.

(iii)Time of operation is 3second.

1.8.3 Multigap arrester

It has a series of metallic cylinder insulated from one another and separated by small intervals of air gap. The first cylinder in the series is connected from the line and other to ground through series resistance. Series resistances limit the power arc. By the help of series resistance degree of protection against travelling waves reduced.

1.8.4 Expulsion type arrester

It also called protector tube which is commonly used on system operating at voltage up to 33KV. It consists of rod gap in series and second gap enclosed within the fiber tube. The gap in fiber tube is formed by two electrodes. Upper electrode is connected to rod gap and lower to earth.

Advantages

(i)It is not expensive.

(ii)It can be easily installed.

(iii)Its improve form of rod gap arrester.

Limitations

(i)It performs only limited number of operation during when fiber is used.

(iii)It cannot be mounted in enclose equipment due to discharge of gases.

(iii)Due to poor volt/amp characteristic of arrester it is not suitable for protection of expensive equipments.

1.8.5 Valve type arrester

It is used for nonlinear resistor and it is used on system operating at high voltage. It consists of two assemblies such as series spark gap and nonlinear resistor. Spark gap is multiple assemblies consist of number of spark gap in series and each gap consists of two electrodes with fixed gap spacing. Under normal condition system voltage is insufficient to cause breakdown of air gap. On occurrence of overvoltage breakdown of series spark gap take place which due to surge current to earth. This value is very large. Nonlinear resistor offers a very large resistance.

Advantages

(i)Its provide very effective protection.

(ii)It is operate very rapidly.

(iii)Impulse ratio is unity.

Limitations

(i) It may fail to check surge of very steep front.

(ii)Its performance is affected by moisture.

Application

According to this application valve type arrester is classified

(1)Station type which is used for voltage 220KV.

(2)Line type which is used for voltage 66KV.

1.9 Protective devices

1.9.1 Lightning arrester

A lightning arrester is protective devices which conduct the high voltage surge on the power system to ground. It consists of a spark gap in series with a non-linear resistor. One end of the diverter is connected to the terminal of the equipment to be protected and the other end is effectively grounded. Surge arrester is protective devices which are used in transmission line and provide the better performance in lightning phenomena. Arrester is used for safety purpose in line from the direct stroke. Lightning arrester has very important role in power system as well as electrical transient and due to this use of device all electrical equipments are safe and not damage. In power system many equipment can use for the protection of transmission and generation system. Power system is made from the construction and working of protective and electrical equipment and transmission and generation system as well as distributed system and type of arrester etc. Main works of electrical engineers are making the electrical equipment and provide the good performance in power system field. Arresters are basically used before the electrical equipment in system and provide the good performance. Arrester is placed in system for protection of transformer and other equipment. Under normal operation, the lightning arrester is off the line i.e. it conducts no current to earth or the gap is non-conducting. On the occurrence of overvoltage, the air insulation across the gap breaks down and an arc is formed, providing a low resistance path for the surge to the ground. The excess charge on the line due to the surge is harmlessly conducted through the arrester to the ground instead of being sent back over the line. It is worthwhile to mention the function of non-linear resistor in the operation of arrester. As the gap sparks over due to overvoltage, the arc would be a short circuit on the power system and may cause power-follow current in the arrester. Characteristic of the resistor is to offer high resistance to high voltage (or current), it prevents the effect of a short circuit. After the surge is over, the resistor offers high resistance to make the gap non-conducting.

1.9.2 Surge Absorber

Surge absorber is a protective device which reduces the steepness of wave front of a surge by absorbing surge energy. Although both surge diverter and surge absorber eliminate the surge, the manner in which it is done is different in the two devices. The surge diverter diverts the surge to earth but the surge absorber absorbs the surge energy. A few cases of surge absorption first are a condenser connected between the line and earth can act as a surge absorber. A capacitor acts as surge absorber to protect the transformer winding. Reactance of a condenser is inversely proportional to frequency; it will be low at high frequency and high at low frequency. Since the surges are of high frequency, the capacitor acts as a short circuit and passes them directly to earth. However, for power frequency, the reactance of the capacitor is very high and practically no current flows to the ground.

Second is another type of surge absorber consists of a parallel combination of choke and resistance connected in series with the line. The choke offers high reactance to surge frequencies ($X_L = 2\pi f L$). The surges are, therefore, forced to flow through the resistance *R* where they are dissipated. Third is it is called Ferranti surge absorber. It consists of an air cored inductor connected in series with the line. The inductor is surrounded by but insulated from an earthed metallic sheet called dissipater. This arrangement is equivalent to a transformer with short-circuited secondary. The inductor forms the primary whereas the dissipater forms the short-circuited secondary. The energy of the surge is used up in the form of heat generated in the dissipater due to transformer action. This type of surge absorber is mainly used for the protection of transformers.

1.9.3 Circuit Breaker

A circuit breaker is a piece of equipment which can make or break a circuit either manually or by remote control under normal conditions, break a circuit automatically under fault conditions, make a circuit either manually or by remote control under fault conditions

Operating Principle

A circuit breaker essentially consists of fixed and moving contacts, called electrodes. Under normal operating conditions, these contacts remain closed and will not open automatically until and unless the system becomes faulty. Of course, the contacts can be opened manually or by remote control whenever desired. When a fault occurs on any part of the system, the trip coils of the circuit breaker get energized and the moving contacts are pulled apart by some mechanism, thus opening the circuit. When the contacts of a circuit breaker are separated under fault conditions, an arc is struck between them. The current is thus able to continue until the discharge ceases. The production of arc not only delays the current interruption process but it also generates enormous heat which may cause damage to the system or to the circuit breaker itself. Therefore, the main problem in a circuit breaker is to extinguish the arc within the shortest possible time so that heat generated by it may not reach a dangerous value.

1.10 Series compensation

Series compensation is used as a capacitor to compensate the inductive reactance of long life. It is a highly effective and series compensation increase power transfer capability by raising transient stability limit and improve of voltage stability. It is reduce transmission losses optimizing the sharing of active power between lines.

1.10.1 Sub synchronous Resonance(SSR)

Whenever in any system if there are both mechanical and electrical components then this problem occurs. Sub synchronous is the name designated from the electric parameters system speed or frequency. Mechanical system will have frequencies less than electrical system due to the mechanical losses. If at any instant the electrical system frequency coincides with mechanical system frequency, this situation is said to be sub synchronous resonance phenomena. If there is SSR phenomena in any system then there will be frequent interchange of energy between electrical system and mechanical system due to this the energy will not be delivered to other parts of the transmission

1.11 Existing and Proposed Standards on Overvoltage

Several guide or standards have been issued or proposed in Europe by VDE, IEC, CECC, Pro Electron and CCITT; in the USA by NEMA, UL, REA, and FCC. NEMA means National Electrical Manufacturers Association. It is nonprofit organizations that develop over 500 standards regarding the production and manufacturing processes for technology involving generation; transmissions and use of electricity FCC stand for Federal Communication Commission.IEC mean International Electro technical Commission

CHAPTER 2

LITERATURE SURVEY

Jiansheng Li, Jun Liang(2013) In order to protect the equipments and make rules for lightning protections, it's essential to record accurate lightning overvoltage waves. The use of serial reactors which are intended to limit large current brings new problems for measuring the lightning overvoltage. This paper analyzes the change of the lightning overvoltage through the serial reactor and the bus, and concludes that the overvoltage at the entrance of the transformer can't reflect the invasion voltage of the substation well. In review of the position of the arrester in the substation, a method for calculating the lightning overvoltage is presented by using the leakage current of the arrester, and reverse iterative method is put forward in the calculation of the PINCETI model. The leakage current of 110kV arrester is simulated with ATPEMTP and the amplitude and steepness of the lightning overvoltage are calculated, which verified the effectiveness of the proposed method.

Liliana Arevalo(2011) The research work presented here is concerned with numerical simulation of two different electrical phenomena. Long gap electrical discharge under switching impulses and the lightning attachment process associated with positive upward leaders. The development of positive upward leaders and the progression of discharge in long gaps are attributable to two intertwined physical phenomena namely the leaders channel and the streamer zone. The physical description and the proposed calculation of phenomena are based on experimental test conducted in long spark gap.

Soon-Man Yang(2011) This paper presents the characteristics of leakage currents flowing through zinc oxide (ZnO) surge arrester elements under the combined direct-current (DC) and 60 Hz alternating-current (AC) voltages. The current-voltage characteristic curves (I-V curves) of the commercial ZnO surge arrester elements were obtained as a function of the voltage ratio α. At constant peak value of the combined DC and AC voltage, the resistive leakage current of the ZnO blocks was significantly increased as the voltage ratio α increased. The I-V curves under the combined DC and AC voltages were placed between the pure DC and AC characteristics, and the cross-over phenomenon in both the I-V curves and R-V curves was observed at the low current region. The ZnO power dissipation for DC voltages was less than that for AC voltage in the pre-breakdown region and reversed at higher voltages.

Andrzej Sowa(2011) Lower voltage protection levels of surge protective devices type 1 caused, that they can be applied as a single system for lightning and overvoltage protection in low-voltage power installation. This fact creates necessity to coordination between properties of surge protective devices and requirements for surge immunity of electronic equipment, which results from EMC recommendations.

Tom Mueller(2010) Without clean power, petroleum and petrochemical equipment is subject to possible upset or catastrophic failure. To cost-effectively eliminate power disturbances due to lightning, fast ringing transients and electrical noise, the use of surge protection devices at building entrance feeders, key branch panels, critical loads and communication lines is recommended. Their use improves the operating reliability of electronic equipment.

Roger Witt(2010) Caught among contradictory stories on the need for surge protection as well as unsupported anecdotes of surge related failures, the typical consumer is in a quandary on how to best allocate personal resources to protect the expensive electronic equipment found his in a modern household. To help provide some answers to this quandary, a team of experts is currently developing a practical application guide on the basics of surge protection, providing a tutorial suitable for the “average consumer.” This paper shows how the guide intends to take the reader through the thicket of surge protective devices and applications. The guide covers a range of application issues from basic information on the occurrence of lightning and switching surges to the selection of cost-effective and technically sound mitigation methods. It explains how protection applications must be suitable for the geographic area (lightning flash density), power distribution type (urban or suburban), and grounding practices (recent NEC or grandfather). The ultimate goal is that the guide will become the basis for better mitigation practices, will decrease losses and the number of loss claims, and will reduce the fear and frustration levels among end-users relative to surge-related upset or damage to their appliances and electronics.

André Meister(2010) During switching or lightning overvoltage, surge arresters play an important role in limiting voltage levels and protecting substation equipment, by conducting the excess of current in the system, which would otherwise damage the equipment. This paper aimed to conduct a technical comparison of the models developed to represent the frequency dependent characteristic of metal oxide surge arresters. The scope of this paper also included outlining a methodology to choose which one would be more appropriate. The major contribution of this article is the validation of the models in a typical 500 kV substation insulation coordination study.

Sungeon Kim(2010) This paper discusses the application and the effect of the electric surge protection device (SPD) in the power line communication channel. The comparative analysis of the effect is carried out based on the performance of the power line communication (PLC) system. The SPDs used for the laboratory experiment are categorized into different types of classes depending on the surge protection level. Various combinations of the SPD with different classes are tested to accommodate the real field environment. The transmission line length is also considered as a test parameter. The OFDM based data transmission system is assumed for the data throughput performance test for given channel conditions. Experiment results show that the effects on the PLC network vary depending on classes and locations of the installed SPDs as well as the channel length between the transmitter and the receiver end. The result confirms that systematic SPD installation requirements should be set up to maintain the stable performance of the data transmission system and the SPDs which coexist in the same power transmission lines.

Farouk A. M. Rizk(2010) This paper starts with a review of anode corona modes with particularly streamer-free glow known as ultra-corona, with the view of exploring its application in lightning protection. Due to the inherent intensification of the ambient electric field atop a tall structure, strict conditions have to be imposed on the streamer-free space charge generation and the stability of that mode of corona when exposed to rapid field variations due to remote lightning. A novel ultra-corona electrode satisfying the above conditions is introduced. High voltage test results on such electrodes are presented including corona current, charge and laboratory air gap breakdown voltage. By applying dimensional analysis, a generalized formula for corona currents from such a device atop a tall structure is presented which includes the effects of the ambient ground field, structure height, and ambient electric field at the top of the structure, electrode dimensions, and wind speed.

Daniel Salomonson(2008) et al. Current trends in electric power consumption indicate an increasing use of dc in end-user equipment, such as computers and other electronic appliances used in households and offices. With a dc power system, ac/dc conversion within these loads can be avoided, and losses reduced. AC/DC conversion is instead centralized, and by using efficient, fully controllable power-electronic interfaces, high power quality for both ac and dc systems during steady state and ac grid disturbances can be obtained. Connection of back-up energy storage and small-size generation is also easier to realize in a dc power system. To facilitate practical application, it is important that the shift from ac to dc can be implemented with minimal changes. Results from measurements carried out on common household appliances show that most loads are able to operate with dc supply without any modifications. Furthermore, simple, and yet sufficiently accurate, load models have been derived using the measurement results. The models have been used for further analysis of the dc system, both in steady state and during transients.

Min Luo, Huachun Li (2008) et al. A new type surge protective grounding device for high voltage power cable line was design and developed by theory analysis and validating tests in this paper. This device is made up of three main parts including high strength polymeric framework, copper bus-bar and over voltage protector. All parts were sealed in one piece of EPR body which molded by continuously injecting rubber. This device combined cable metallic shield grounding and cable sheath over voltage protecting techniques with waterproof technique to overcome defects of conventional protective grounding device such as protection failure due to water intruding, coagulated dew and incorrect connection etc. This protective grounding device not only protects power cable line from over voltage damaged and/or circulating current affected effectively, but also its weight and volume were decreased much more. Furthermore, type test was used for validating operation reliability and production quality of the protective device in the paper. The results of application research and type test had been proved that this new type surge protective device can satisfy the technical requirements of the standards and meet the practical demands of protective grounding and over voltage protecting of power cable lines in the field.

N. Mungkung(2007) This study examines the design and construction of AC Electronics load surge protection in order to carry electric surge load arisen from faults in low voltage electricity system (single phase/220V) by using the principle of electronics load clamping voltage during induction period so that electric voltage could go through to safe load and continue to work. The qualification of the designed device could prevent both transient over voltage and voltage swell. Both will work in cooperation, resulting in the ability to improve and modify the quality of electrical power in Thailand electricity distribution system more effective than the past and help increase the lifetime of electric appliances, electric devices, and electricity protection equipments.

Chris J. Salmas(2007) Industrial facilities are becoming more and more dependent on computer control of their processes and as a consequence, require an increase in cleanliness and reliability of the electrical power supply system. Electromechanical subsystems are being replaced by electronic logic. Harmonics interference, welding, variable speed drives and other in plant noise have a reliable mitigation procedure. However lightning and other external sourced power disturbance rank high on the list of uncontrollable event that has a shunt down facilities in recent years. This paper provides an overview of the causes of power line surges and their consequence for industrial plant. The relevant international surge protection standards will be briefly reviewed and their differences will be analyzed. Different technologies utilized in the implantation of various commercially available surge protection devices will be presented, followed by a comparative analysis. Finally the latest trends and most promising technologies in surge protection system as well as their ability to overcome the problem associated with conventional protection devices will be overviewed and experimental data based on field trials are reported.

Jean Picard(2006) Electrical overstresses can cause failure, permanent degradation, or temporary erratic behavior of electronic devices or systems. The trend to reduce circuit geometries for communication systems and applications results in an increasing sensitivity to such electrical transients. The suppression of these transients can be a challenge to designers because the origin and severity of the overvoltage may be unknown. To assist designers in coping with these issues, this application report defines simple design rules that can adequately protect the sensitive electronic parts of the system with cost-effective solutions.

A.L.Or ilk(2006) et al. As lightning surges are considered to be the most dangerous events in power distribution systems, the more we know about them the better we can select and coordinate protection devices. Moreover, a better knowledge of lightning surges gives rise to the accurate positioning of device protection, the reduction of insulation costs at installations and allows operation with well-known risks of failure. The development of a computer application based on fuzzy logic techniques, which allow the determination of the accurate position of the surge arrester in power systems, controls the risk of failure, thus permitting the selection of appropriate protection schemes for each network As a consequence, protection costs are reduced in accordance with the costs of the elements actually protected and the continuity of service to be achieved.

M. A. Grau(2005) et al. Lightning surges can cause major damage to distribution network components, especially to transformers, therefore it is important to select an appropriate protection scheme to limit the damage caused by these over voltages. The purpose of this work is the development of a method to calculate the surge arrester position in distribution systems, using fuzzy logic techniques, in order to establish failure risks lower than the admissible and to install the least number of arresters. The development of a computer applications using the Mat lab program allows the determination of the accurate position of the surge arrester in power systems, controls the risk of failure, thus permitting the selection of appropriate protection schemes for each network we can reach important conclusions of the transformer protection using simplified models in the network analysis.

M. de Nigris(2005) et al. Surge arresters are used in electric power systems to protect the equipments against overvoltage that may arise from lightning events or from internal switching operations. The technology adopted for the construction of such components has evolved during the years. Silicon-carbide type gapped surge arresters has been replaced by most advanced metal oxide surge arrester without gaps, that can guarantee better performance and a higher degree of reliability. New developments, presently achieved for distribution range, foresee the replacement of the conventional porcelain housing with a polymeric one, allowing improving the mechanical characteristics and the failure mode behavior. Furthermore special applications for surge arresters, such as protection of gas insulated 'substations and prevention of lightning faults in transmissions lines are now taken into consideration by several utilities. The evolution of surge arrester construction technologies and application requires a continuous revision of relevant Standards and testing techniques. CESI is actively involved in testing surge arresters since the years 1960's, through the development and setting up of testing facilities and the participation to the major technical and standardization bodies. The paper analyses the most important aspects relevant to surge arrester testing, based on the most recent experience developed in CESI. Particular attention is focused on the short circuit test techniques to address the failure mode and on the ageing test procedures to investigate the long term performance of surge arresters.

Hidetaka Satoh(2005) et al. This paper describes design techniques for increasing the surge capability of a bidirectional SCR (Silicon Controlled Rectifier) lightning surge protection device for communications equipment. The relationships between surge capability and doping profiles with different p-base widths and base impurity concentrations are studied by analyzing failure modes and surge response characteristics. A narrow p-base width is effective for increasing surge capability because it can reduce turn-on energy dissipation that leads to hot-spot failure. Furthermore, reducing the on-state energy dissipation can increase surge capability without increasing device size.

J. Iglesias(2005) Lightning surges can cause major damage to distribution network components, especially to transformers, therefore it is important to select an appropriate protection scheme to limit the damage caused by these over voltages. The purpose of this work is the development of a method to calculate the surge arrester position in distribution systems, using fuzzy logic techniques, in order to establish failure risks lower than the admissible and to install the least number of arresters. The development of a computer applications using the Mat lab program allows the determination of the accurate position of the surge arrester in power systems, controls the risk of failure, thus permitting the selections of appropriate protection schemes for each network we can reach important conclusions of the transformer protection using simplified models in the network analysis.

Index Term-Fuzzy Logic, Lightning Surges, Power Distribution Protection, Risk Analysis, Surge Arresters.

Teruo Kageyama(2005) Power equipment for telecommunications which uses commercial power as its input source, is easily damaged by lightning from commercial power distribution lines. The stations which have antenna towers such as microwave relay stations are often damaged by direct lightning strike surge. Consequently, lightning protection for power equipment in order to maintain its reliability. NTT has therefore investigated the actual conditions of an invading lightning surge, the grounding impedance, lightning damage, etc., about microwave relay stations and small scale telephone offices which are often damaged by an invading lightning surge. NTT further has examined systematic lightning protections of telecommunication power equipment. As a result, it was found that enlargement of arrester capacity, multi installation of arresters and grounding surge impedance Reductions by using interconnected grounding and by improving the technique for laying grounding wire, etc., is effective against lightning surge.

F.D. Martzloff(2004) Designers involved in the ac power side of telecommunications equipment have been justifiably concerned with surge protection because field experience is rich in case histories of failures attributable to transient over voltages. Insufficient knowledge of the exact nature of this overvoltage, however, has made the task difficult in the past. After several years of data collection by a number of organizations, a more definitive understandings of the surge environment is emerging. The next few years' publications from the IEEE, the IEC, NEMA, and other interested groups will document that understanding. This paper presents an overview of the results of data collection and environment descriptions from the point of view of telecommunications power supply problems, as well as a review of applicable techniques and devices

CHAPTER 3

PRESENT WORK

We are not concentrating to enter energy or power to ground so capacitor is not getting used .But in case of surge arrester uses we are concentrating the high voltage surge to ground with the used of capacitor .So finite voltage value of very high magnitude will be observed across the capacitor .

As voltage is zero across the capacitor without surge arrester uses, the energy is also zero (E= vit). But in case of use of surge arrester energy will not be zero as capacitor voltage is not equal to zero. When any surge is impressed on the line the enter equipment (equipment of low impendence) gets effected due to the high voltage magnitude (short circuit current).So we need to protect these equipment from the short circuit current .The circuit breaker used here makes the remaining parts of the circuit which will not take an active part in clearing the surge isolated.

For B1 bus, there is no surge arrester connected in between bus 1 and other section so the value of voltage across bus 1 will not differ with and without surge arrester.

For B2 bus, here surge arrester is connected so value of voltage differs with and without surge arrester.

In simulation at input side step up transformer connected which means it use for transmission purpose to decrease the losses in line.

$$P = V\ I\ Cos\Phi$$

So $$I = P/VCos\Phi$$

Both current and voltage are inversely proportional to each other and vice versa.

Copper loss is proportional to square of current value. So increase voltage value then losses is decrease.

Distribution transformer is used to deliver power to consumer we need to have a transformer which step down the line voltage (high voltage) to low voltage .This task is performed by distribution transformer or step down transformer.

There are three buses and four sections. The load section and source section does not need compensation because their length are very small compare to transmission line (remaining two section).So they application of compensation does not effect on two section .At the starting point where the voltage or power is being supplied the voltage angle is taken as zero decrease . Whenever next consecutive voltage measurement comes (buses) there will be some change shift in the angle from starting point due to drop in the line (impendence).

In case of surge our motive is to ground the high voltage are energy to ground. In case of value of impendence of remaining section is less than ground resistance the enter surge will appear across remaining section but does not goes through ground. So by the use of compensation we will reduce the value of impendence at the point where entire surge should be concentrated so that from point the surge goes through ground. To design surge arrester the basic function is to realize series compensation technique besides the series compensation technique we should to work on subsystem resonance related problem also. By designing a transmission system and modeling these two phenomena (series compensation and SSR).

3.1 Sub synchronous Resonance

Whenever in any system if there are both mechanical and electrical components then this problem occurs. Sub synchronous is the name designated from the electric parameters system speed or frequency. Mechanical system will have frequencies less than electrical system due to the mechanical losses. If at any instant the electrical system frequency coincides with mechanical system frequency, this situation is said to be sub synchronous resonance phenomena. If there is SSR phenomena in any system then there will be frequent interchange of energy between electrical system and mechanical system due to this the energy will not be delivered to other parts of the transmission or any system.

To study both these compensation and sub synchronous resonance phenomena we are considering a test system (model) consisting of parameters as given below:

f = 60Hz, supply=three phase, transmission voltage =735kv

6MVA generator, 230KV line, three buses B1, B2, B3.

If we want to increase the power transfer capability then we should to work on either sending end voltage or receiving end voltage or transmission line impendence. Sending end voltage cannot be control by us because it is generated by system generator. Receiving end voltage cannot be predicted as load is varying so the possible way to increase power transfer capability is to work on transmission line impendence.

$P = V_s \times V_r \sin\delta \div X$

According to this equation load reactance should be reduced to increase power transfer capability.

Equipment of Simulation

(1)Two transmission lines are series compensated by 40%.

(2)The both transmission line are shunt compensated by using 330Mvar capacity shunt reactance.

(3)The compensation done at bus B2 and in this bus we are having 300Mva =735/230 KV (step down).Transformer which is feeding a load of 250Mw. For protecting the series compensation we are providing metal oxide varistor MOV1 and MOV2.

NOTE: In case of any fault in any line the fault current will be equal to short circuit current in line which is equal 10 to 15 times the rated line current will flow through to series compensating capacitor will be damage. Hence we are using MOV.

(4) Two circuit breaker CB1 and CB2.

(5)Three phase VI measurement block.

3.2 Analysis of Simulation:

A fault is applied any one line on the line side of capacitor bank. Here I am considering line1 as fault line. To make line 1 as fault line we should to open the three phase fault block and three phase breaker block, select the required the line. Now see the initial breaker status (either on or off) and switching time which are specified before. Now select phase A at t= 1 which means a line to ground fault is applied on phase A at t= 1 cycle. Now circuit breaker CB1 and CB2 are open at t= 5 cycles which are initially closed. This means we are simulating fault detection in time of 4 cycle (fault persist for 4 cycle). And then fault is eliminated at t= 6 cycle after opening the line.

3.3 Series compensation Sub system:

Open the subsystem of series compensation block there exist three phase module consisting of identical subsystem. Each subsystem represents each phase open the phase A subsystem the line is compensate by 62.8mf capacitor 240%. The protection of capacitor is done by MOV block by setting MOV reference current to 500 amps.

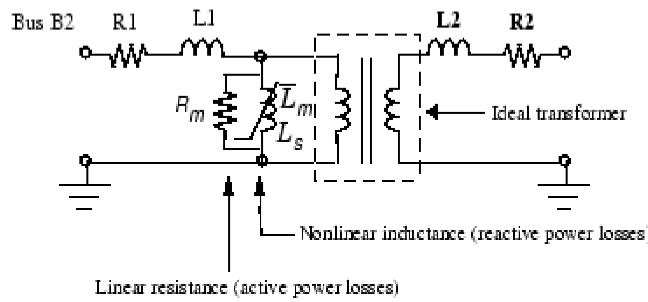
60×500amp = 30 KA

Voltage will set at = 298.7kv

The voltage correspond 2.5 time that of capacitor voltage. The gap connected in parallel with MOV block is fired with a surge arrester having a critical value of 30MJ. While firing the gap damping RC circuit is connected in series to reduce the rate of rise of capacitor current. When the energy exceeds 30MJ is equal sent to break block.

3.4 Three phase saturable transformer model

It has the following characteristic.



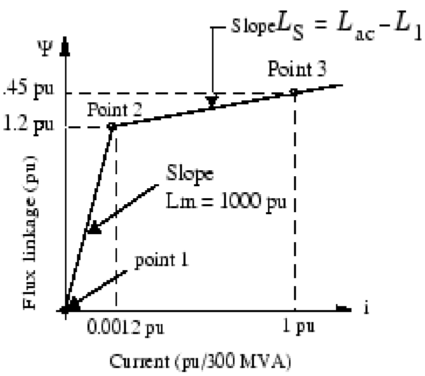


Fig:3.1 Flux Current Characteristic [15]

Assuming knee point as 1.2pu there are two segments here

Segment 1 is linear and segment 2 is nonlinear. The current and flux value are denoted in the graph. Core losses are denoted by Rm = 1000pu that is 0.1% losses at nonlinear voltage slope of curve in saturated region is 0.25pu therefore leakage reactance = 0.15pu.Reactance of air core transformer referring the primary winding is 0.4pu.

Initial load flow parameter setting

Active power = 1500MW

Terminal voltage = 13.8KV

Mechanical power = 1 W

3.5 Transient Performance for Line Fault

Open power gui block and set sample time as 50e^-6 use discrete power gui block.

Setting are given below.Three phase fault applied on line 1 open the three phase fault block select the phase B, C also as it is three phase fault and again start.

3.6 Analysis

This section explain how the impendence measurement block allows us to complete the impendence measurement block allows us to complete the impendence of linear system by using state space model. Before measuring the impendence replace the machine block having the same impendence as that of transformer.

3.7 Parameters

Phase-to-phase rms voltage	13.8e3
Phase angle of phase A	0
Frequency (Hz)	60
Internal connection Yg	Specify impedance using short-circuit level
3-phase short-circuit level	6*350e6
Base voltage	13.8e3
X/R ratio	15

Open the measurement library and the copy the impendence measurement block in mode connect the measurement block between phase A and B of bus 2. This measures the impendence of two phases which is not exact value so to get correct value of only one phase we should must the present value with 0.5/2. Select impendence versus frequency measurement. Now winding open showing the name of impendence of measurement block. Now fill the frequency range as 0:500.Select the linear scale to display impendence magnitude versus frequency block. Click the save data to work space button and given any variable name (impendence case). Now click the display button.

NOTE: If we are having more than one measurement then we should to assume one more variable say impendence case and work on.

3.8 Modes of Frequency

(1)9Hz –this is mainly due to parallel resonance of series capacitor with shunt inductor.

(2)175Hz- this is due to 600Km distributed parameter line

(3)370Hz –this is also due to 600Km line. Now zoom on the impendence in 60Hz region and find system short circuit level at bus 2 value observed are 58ohm,60Hz.The respective short circuit power is (735Kv)^2/58 = 9314MVA.

Transient Performance for fault bus 2

Bus fault should be cleared without any loss of line or transformer from the system. So we should to design a model such that our need is satisfied.

3.9 Simulation Procedure

(1)Disconnect the three phase fault block and reconnect it such that fault is applied on bus 2.

(2)Open the three phase fault block and select phase A, B and phase C and ground fault.

(3)Set the transition times 2/60 and 5/60. Set the transition status as zero/1. It means we have programmed three phase to ground fault applied at t = 2 second.

(4)Open the CB1 and CB2 block make the following modification

Switching of Phase A	Not selected
Switching of Phase B	Not selected
Switching of Phase C	Not selected

This means CB are not switched at any mode.

(1)Select scope and place it on our simulation so that we can observe phase A voltage clearly on that scope.

(2)We should to add the block for flux and magnetization current of transformer connect at bus 2 for this purpose .We should to copy multimeter block from measurement library into our model. Open the transformer block in the measurement list flux and magnetization current open multimeter block and verify that we are having six signal available or not. Select flux and magnetization current at phase A and click ok.

(3)Now we are having two signal are available the output of multimeter block using the demultiplexer block send the two signal to a two trace scope.

(4)In this simulation select mode configuration parameters dialogue block, set stop time 0.5.

(5)This makes us to observe the expected low frequency modes (9Hz).

(6)Start the simulation and observe the waveform.

3.10 Observation:

(1)9Hz sub synchronous mode excited at fault is clearly seen on phase A voltage at bus B2 (trace1) and capacitor voltage (trace 3).

(2)9Hz component at bus2 drives the transformer into saturation as shown on transformer magnetizing current (trace 5).

(3)Flux in phase A of transformer is plotted on trace 4.At fault voltage at the transformer drop zero flux will become constant during the fault.

(4)At the fault clearing when voltage recovers the transformer is driven into saturation as result of the flux offset created by 60Hz and 9Hz voltage component.

(5)The pulse of transformer magnetizing current appears when flux exceed it saturation level. This current contains 60Hz reactive component modulated at 9Hz

CHAPTER 4
SIMULATION AND RESULTS

4.1 SIMULATION

For B1 bus, there is no surge arrester connected in between bus 1 and other section so the value of voltage across bus 1 will not differ with and without surge arrester. For B2 bus, here surge arrester is connected so value of voltage differs with and without surge arrester. In simulation at input side step up transformer connected which means it use for transmission purpose to decrease the losses in line.

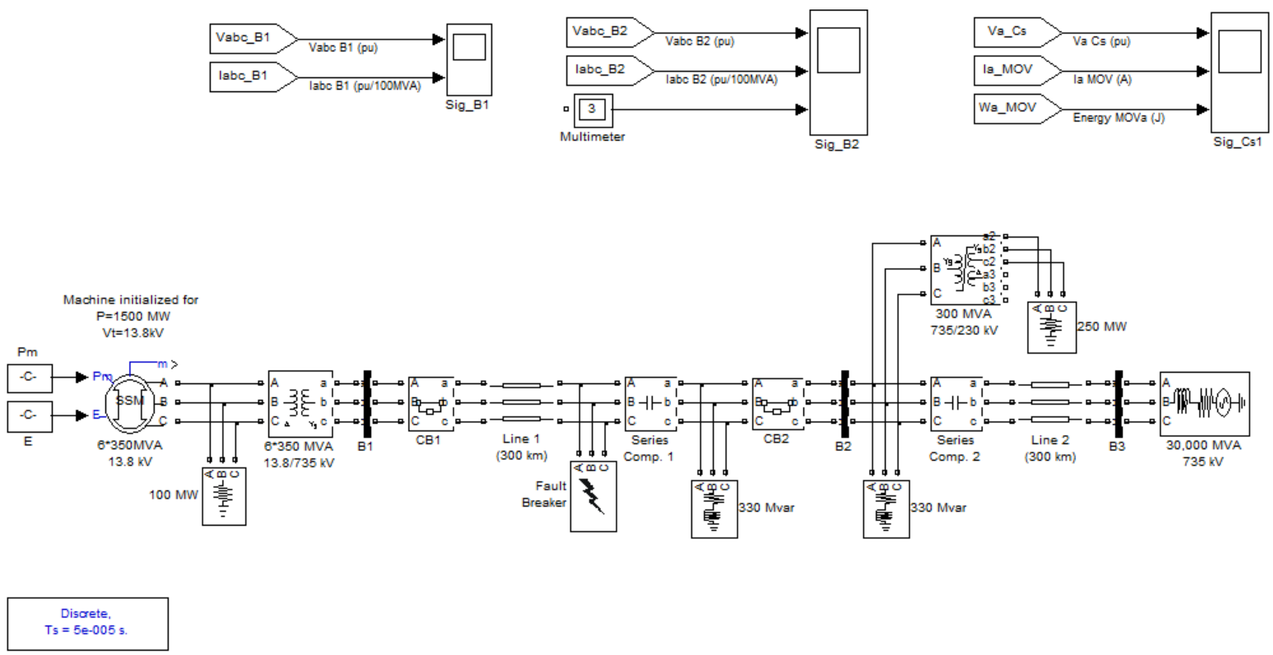


Fig 4.1 Simulation diagram of Lightning arrester

4.2 RESULTS

4.2.1 WITH SURGE

In case of surge arrester uses we are concentrating the high voltage surge to ground with the used of capacitor .So finite voltage value of very high magnitude will be observed across the Capacitor. But in case of use of surge arrester energy will not be zero as capacitor voltage is not equal to zero. When any surge is impressed on the line the enter equipment (equipment of low impendence) gets effected due to the high voltage magnitude (short circuit current).So we need to protect these equipment from the short circuit current .The circuit breaker used here makes the remaining parts of the circuit which will not take an active part in clearing the surge isolated.

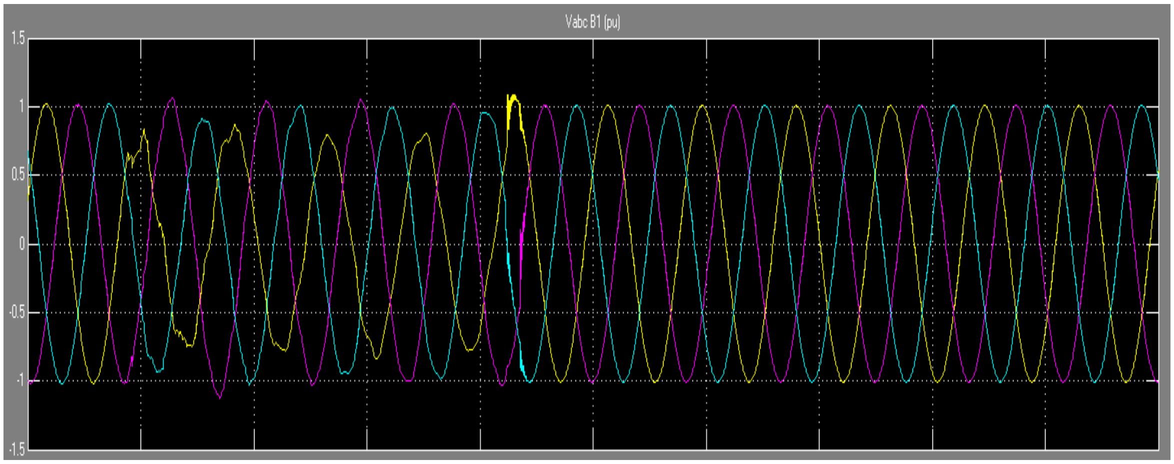


Fig 4.2 waveform for Vabc at bus B_1 with respect to time

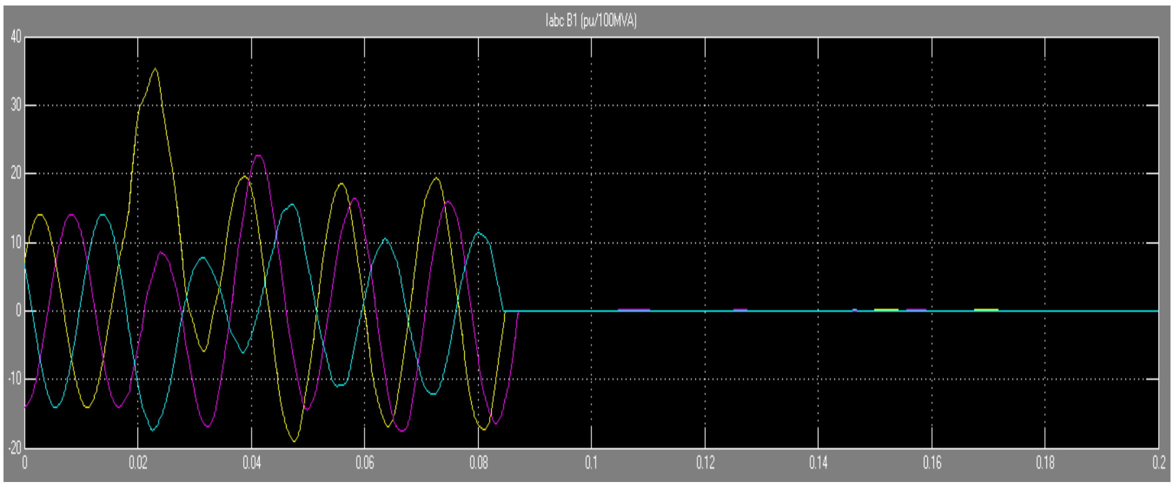


Fig 4.3 for Iabc at bus B_1

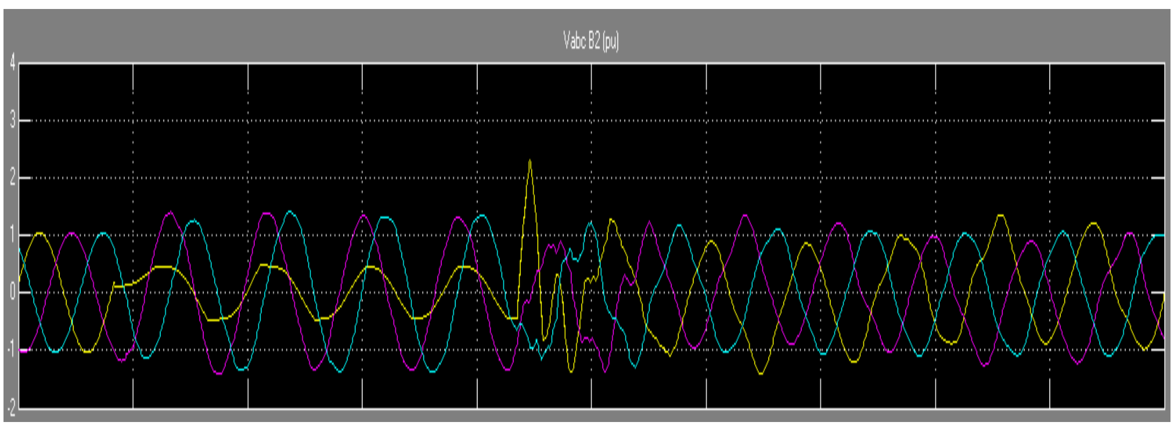


Fig 4.4 Waveform for Vabc at bus B_2

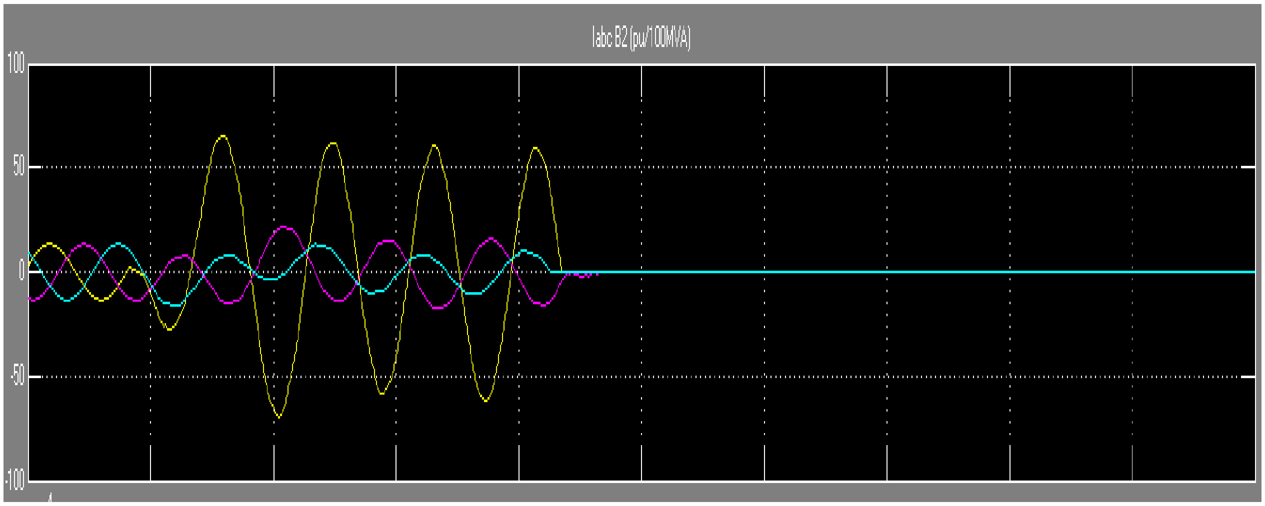


Fig 4.5 for Iabc at bus B_2

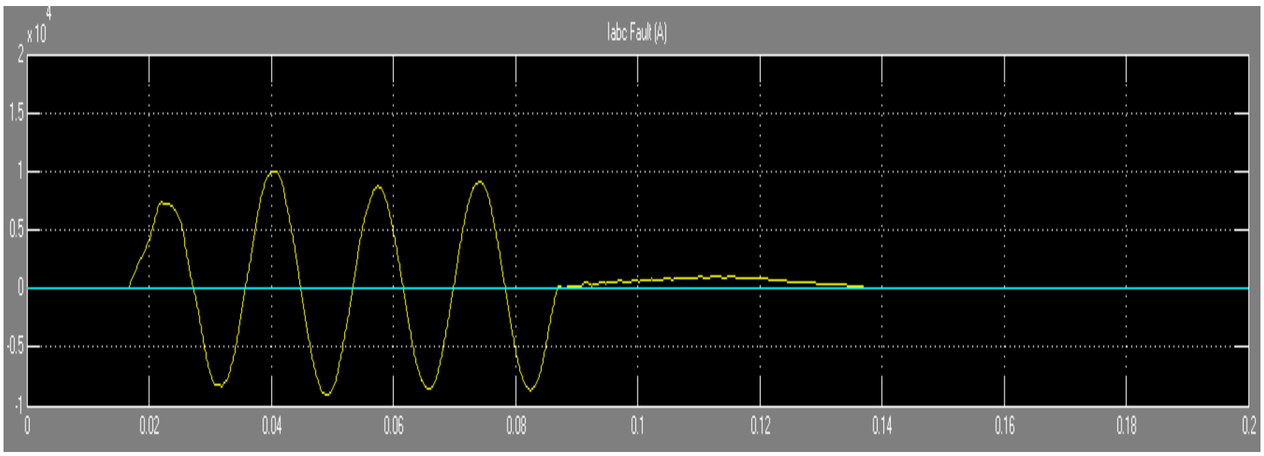


Fig 4.6 for fault current Iabc

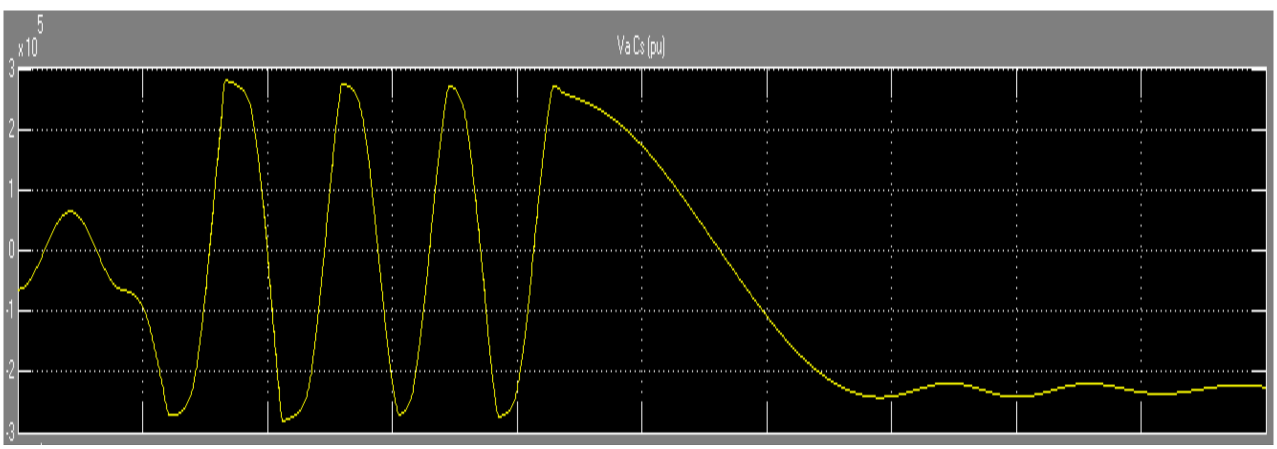


Fig 4.7 for Va Cs

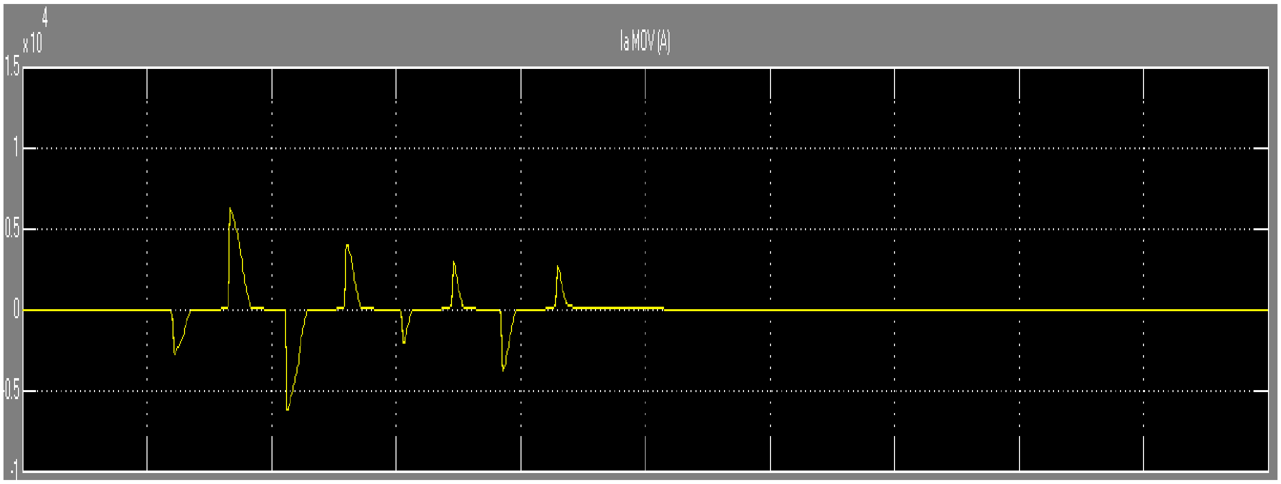


Fig 4.8 for arrester current

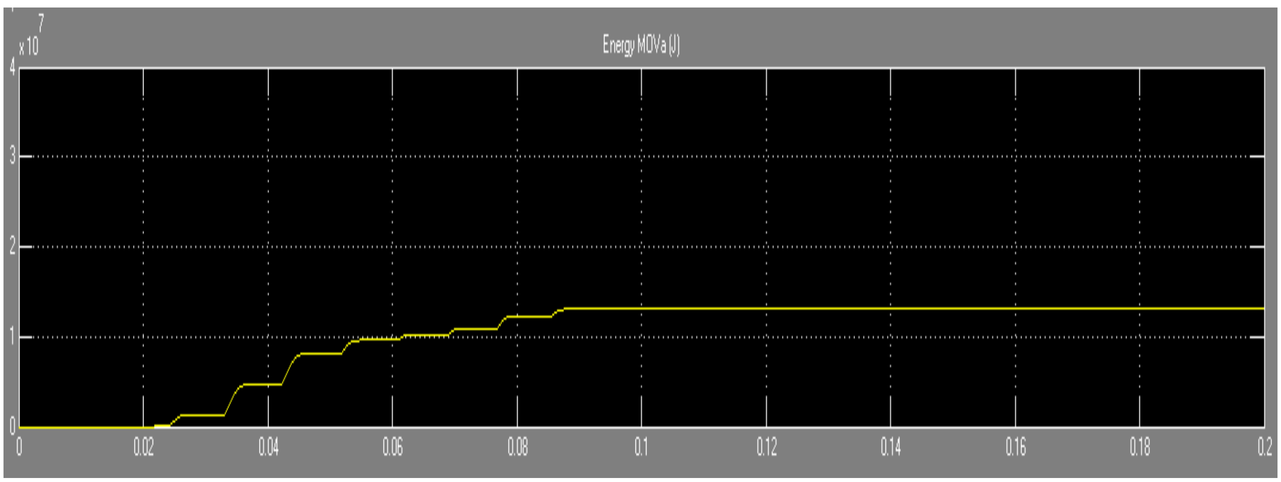


Fig 4.9 for energy level value

4.2.2 WITHOUT SURGE

As voltage is zero across the capacitor without surge arrester uses, the energy is also zero (E=vit).

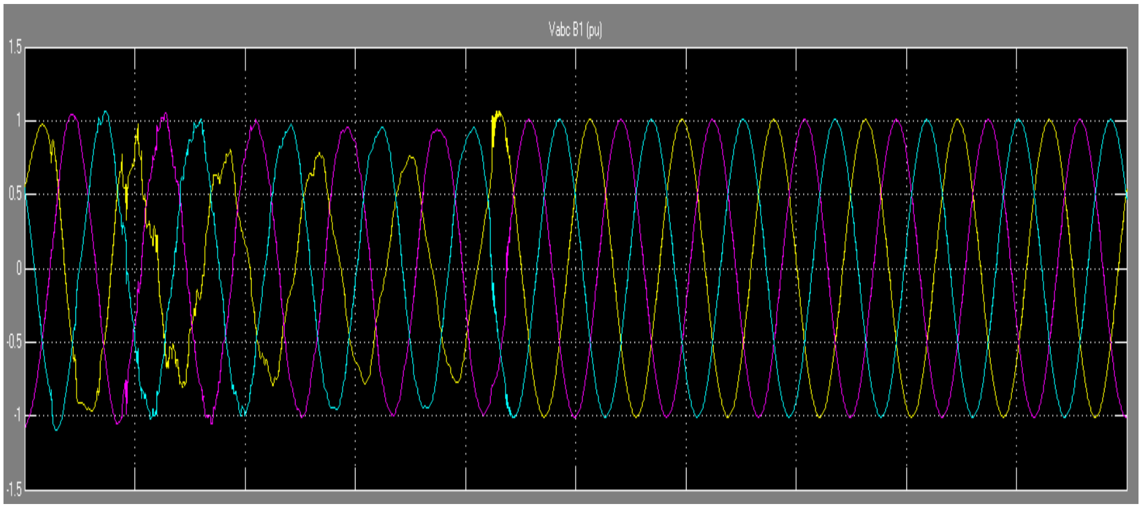


Fig 4.10 waveform for Vabc at bus B_1

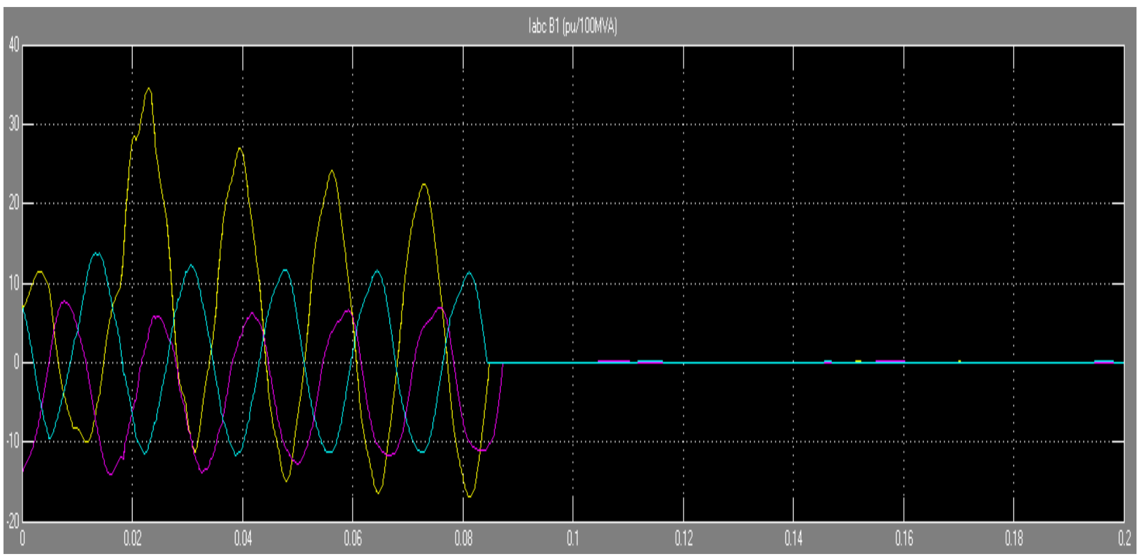


Fig 4.11 For Iabc at bus B_1

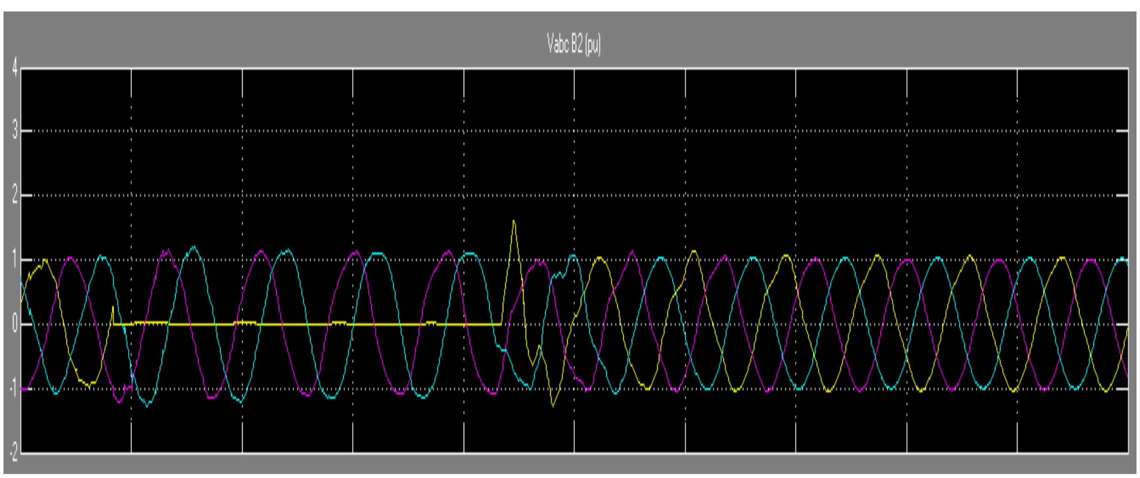


Fig 4.12 for Vabc at bus B_2

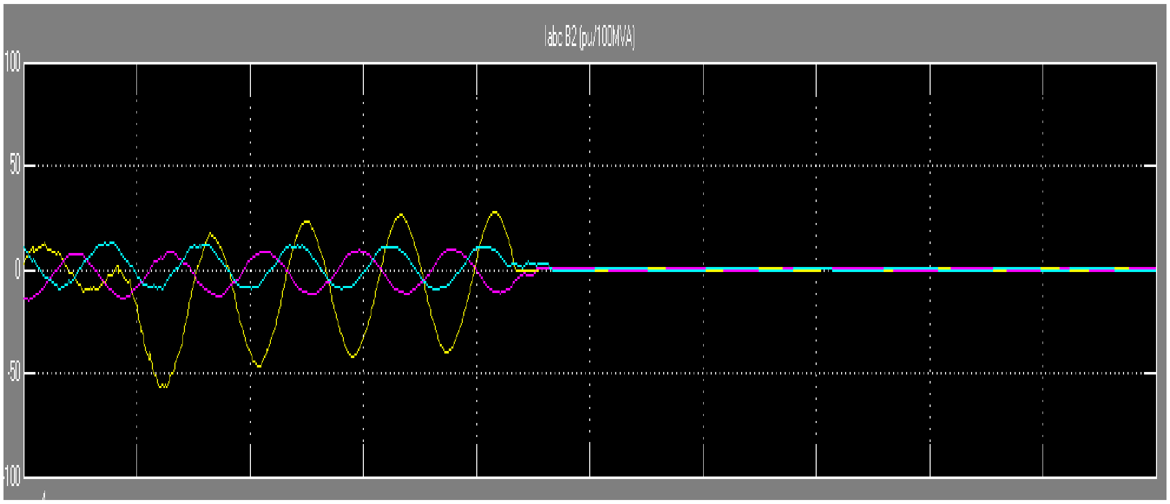


Fig 4.13 for Iabc at bus B_2

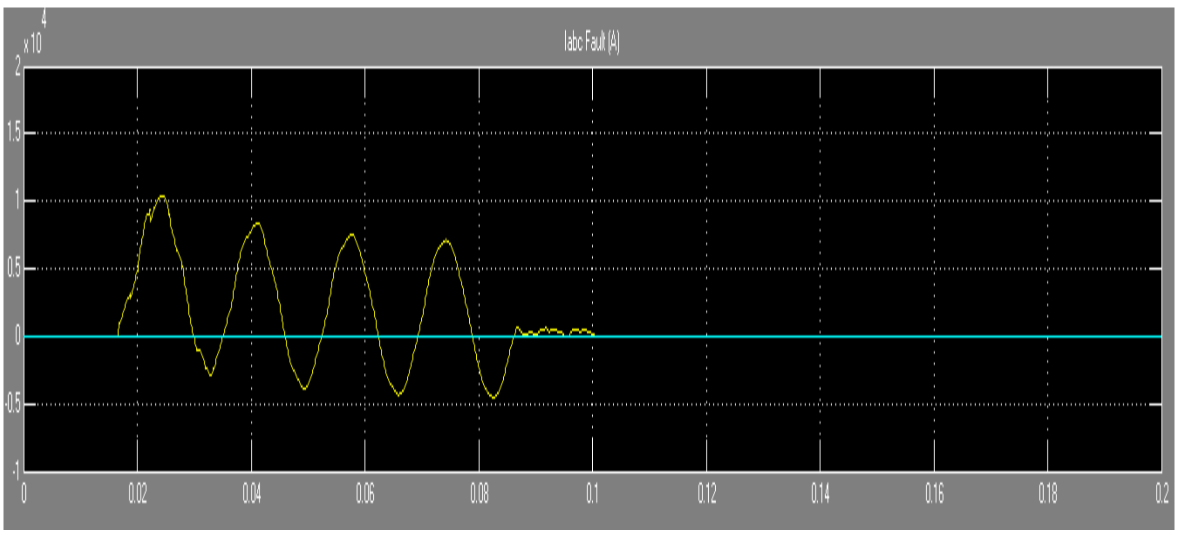


Fig 4.14 for fault current Iabc

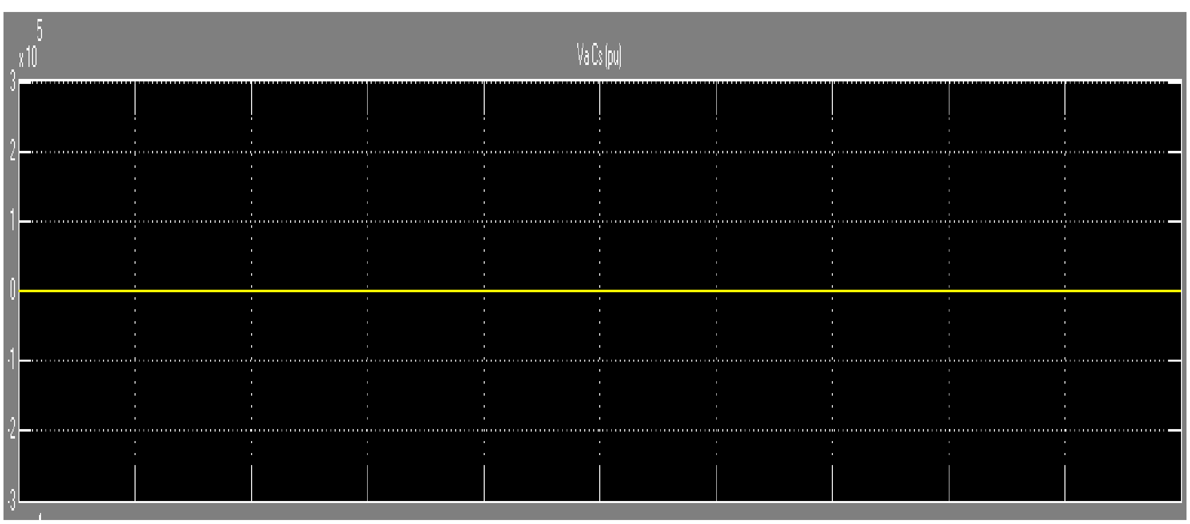


Fig 4.15 for Va across capacitor

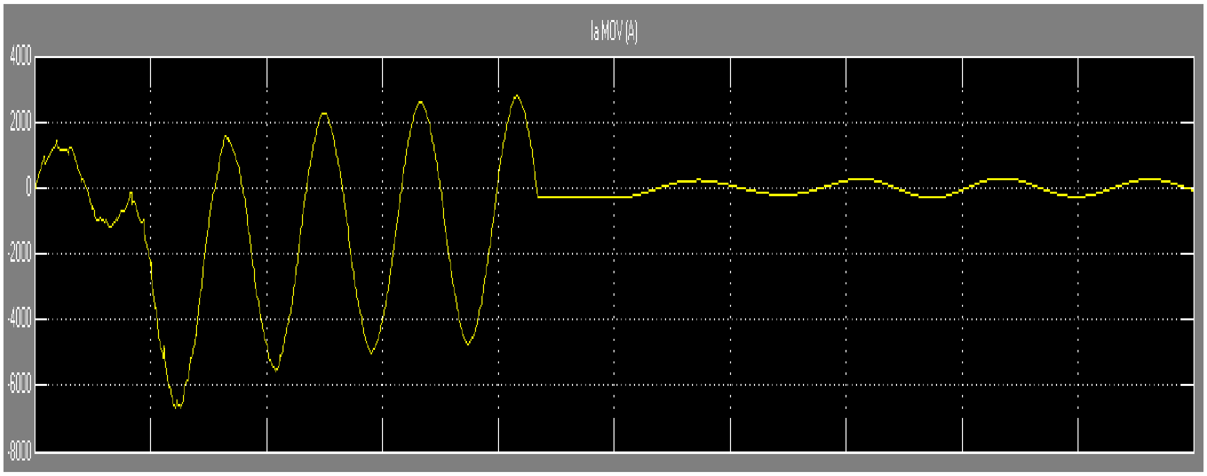


Fig 4.16 for arrester current in without arrester case

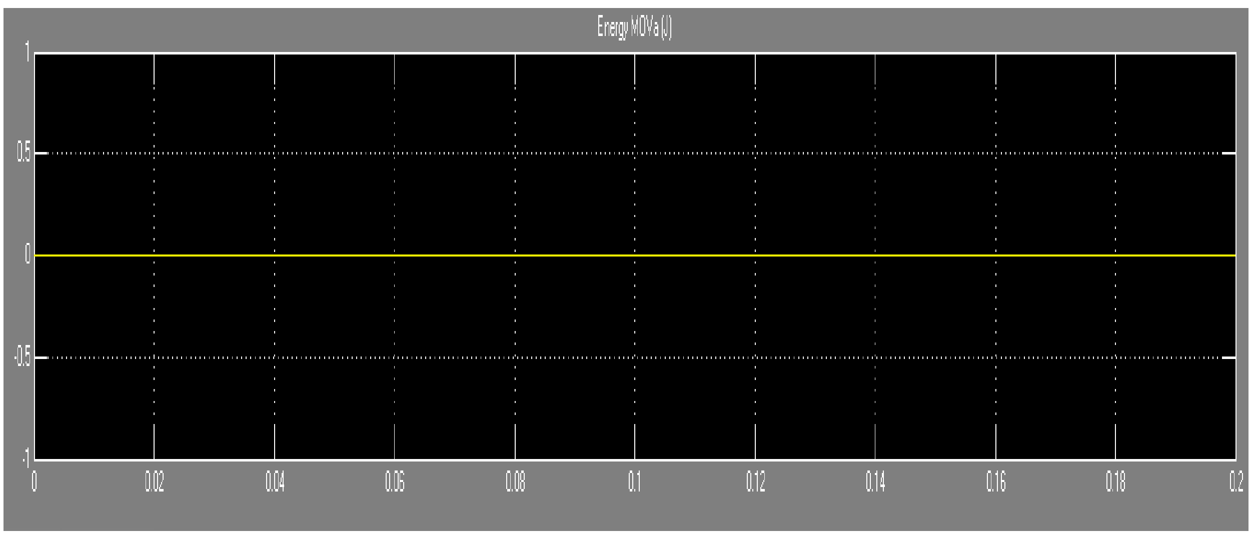


Fig 4.17 for energy in without arrester

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

5.1 Conclusion:

By observing the simulation result done by taking into account the model comprising of surge protector and the model without surge arrester. It can be concluded that the system is regaining. Its previous ability is more with surge arrester. The system can be made safer, efficient and reliable by using this surge protection technique. As proved by simulation results.

5.2 Future Scope:

This technique is used to protect the electrical equipment and transmission line from the surges by the use of series compensation. Series compensation is mostly used for increase stability and transmission capability but reduced the losses in line. This technique is very expensive.

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