Performance and Operation of DVR (Dynamic Voltage Restorer) Under Fault Condition Using PI Controller

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD

OF THE DEGREE OF

MASTER OF TECHNOLOGY

IN

POWER SYSTEM

SUBMITTED BY

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CANDIDATE'S DECLARATION

I, Himanshu Parashar, Roll No. 2K19/PSY/07, student of MTech. (Power System), hereby declare that the project Dissertation titled "**Performance and Operation of DVR (Dynamic Voltage Restorer) Under Fault Condition Using PI Controller**" which is submitted by me to the Department of Electrical Engineering Department, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associate ship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the major project titled "**Performance and Operation of DVR (Dynamic Voltage Restorer) Under Fault Condition Using PI Controller**" which is submitted by **HIMANSHU PARASHAR**, Roll No- **2K19/PSY/07** ELECTRICAL ENGINEERING DEPARTMENT, Delhi Technological University, Delhi, in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree to this University or elsewhere.

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I would like to express a deep sense of gratitude and thanks to **DR. NARENDRA KUMAR** for allowing me to work in Power System laboratory to carry out this project work.

Finally, I would like to expresses gratitude to all faculty members of Electrical Engineering Department, DTU for their intellectual support in my M. Tech study at DTU.

Place: Delhi **HIMANSHU PARASHAR**

Date: 01-08-2022 **(2K19/PSY/07)**

M.Tech (Power System)

ABSTRACT

The chief objective this research paper holds are improvement of the quality of power. One of the important characteristics for improving the quality of power is the THD i.e., Total Harmonic Distortion. A THD analysis with various injection transformer ratings of DVR is shown in Fig 16. With the help of the Fast Fourier Transform (FFT) analysis for the voltage signal to analyse the Total harmonic distortion (THD). Before moderation we have 24.12% THD, while after moderation, for PI controller it is 2.77 % THD and 2.15% for ANN controller. We have also learnt about various devices which are used for this purpose and further we investigated about the dynamic voltage restorer it's constructional features. It's working principle and various operating mode by which it improves the power quality in the supply and distribution network. All this work is shown by using MATLAB/ SIMULATION to observe real time operation of the DVR.

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List of Abbreviations

D-STATCOM	Distribution Static Compensator
DVR	Dynamic Voltage Restorer
UPQC	Unified Power Quality Conditioner
VSI	Voltage Source Inverter
SPWM	Sinusoidal Pulse Width Modulation
SVPWM	Space Vector Pulse Width Modulation
SVM	Space Vector Modulation
PLC	Programmable Logic Control
PQ	Power Quality
SLG	Single Line to Ground fault
PCC	Common Point of Coupling
HV	High Voltage
Pf	Power Factor
PLL	Phase Locked Loop
PWM	Pulse Width Modulation
FACTS	Flexible AC Transmission System

CHAPTER 1

INTRODUCTION

1. Introduction

- With the rise in usage of electronic equipment, problems related to power quality are rising on a daily basis. Power quality is the furthermost constraint in current-day period. DVR is known to be a means to decompensate the power insufficiencies for a short-term in insensitive loads. Ability for the compensation of the restorer for the Dynamic-Voltage depends on the extreme voltage of injection.

- The minute the constant voltage drips befall, Dynamic Voltage Restorer can rectify it with an effective line of control such as DVR algorithm. The procedure diminishes the real power allocating need. Though, the boundaries of the same on re-establishing the load current also the load voltage cause variations of the phase angle.

- In spite of the wide-ranging traditional usage of sensitive equipment like computers as well as of the PLCs, quickness of the events of manufacturing is high and dry against the disabilities related to the voltages.

- Electrical energy is well-regulated as well as the simple form of energy, that transforms to other forms with an ease. Along with its continuity as well as it's quality, one has to sustain for good economic structure of the system. The Quality of the power is one of the major concerns for today's consumers as well as for the power industries. The issues in the quality of power happened because of the increment of demand in electronic loads as well as equipment. Voltage flickering, voltage swelling, sagging as well as the harmonic contents are the major reason for most disturbances connected with electrical power. This reduces the effectiveness as well as it lowers the life time of end user equipment. Data as well as the memory loss of most equipment such as computer also happens because of the same.
- Because of the complex structure of the network of power system, the end user consumers have been affected by the voltage sagging as well as the voltage swelling and has became the major power quality issue. It usually occurs recurrently as well as results in the high losses. Because of the abrupt interruption of load, it causes voltage sagging, which makes the system faulty. Voltage swelling occurs because of the single line to ground fault which outcomes in voltage escalation of un-faulted phases. The continuousness of the supply can be sustained by clearance of the faults at quicker rate. Additional power quality problems are like transients, flickering of the voltage, harmonics, etc. that needed to compensated to improve the

quality of the power.

- It is known as the basis of t/f to the voltage underneath the control and also, it's been fitted in between the primary energy source also the load such that the levels of these particular voltages can be alleviated [4-5]. It is uable to intellect the hasty disturbance as well as the noise in the power of the system. Fig.1.1 grants the structure that is generally n/w with mockups in the article.
- In this thesis, the reactive power is being provided to the DVR. The DVR is connected to load side so that the harmonic could be removed by the injected current by the DVR and also for the selection of firing angle for the TCR
- Super quick discharging as well as charging is possible in a supercapacitor and supercapacitors can go over enormous numbers of cycles for charging and also for the discharging, without deprivation on comparison with batteries. Hence, it is planned to work the storage system of the same to store appropriate quantity of energy in the system that could be released for the betterment of the fluctuations. Number of energies stored in single unit weight in the supercapacitor is much lesser than batteries made of electro chemicals.

CHAPTER 2

LITERATURE REVIEW

- G. Emayavaramban, S.K. Mayurinathan, R. Saravanan, T. Ramesh, "Enhancing power quality of ANN controller based Photovoltaic source injected DVR", International Journal of Engineering & Technology. The DVR device is a FACTS controller that is put in series connected and is used in distribution systems for compensating the voltage disturbance. DVR's main use is to study if any disorder happens then regularly observe load voltage waveform, the load voltage is inoculated with the excess or balanced voltage. One crucial DVR's advantage is observance users on-line all the time with stable voltage which is of high quality to maintain production's permanence. In this study, DVR is injected with the photovoltaic voltage by using method named ANN control method which helps in protecting the sensitive load as well as in countering voltage sag when it is under uneven (linear, non-linear) loading conditions. Software MATLAB/ SIMULINK are used to do simulation of DVR and other distribution system parts.

- A.Kiani Haft lang, Ehsan Gharibreza, Atefe Kiani Haft lang, M.Baledi, "New Compensation Algorithm for Dynamic Voltage Restorer in Medium Voltages Level", International Journal of Engineering and Innovative Technology (IJEIT). According to this study, the restorer's compensation ability depends on its power capabilities and maximum injection voltage during sag voltages. DVR can compensate reoccurring voltage drops with efficient strategy like minimum energy algorithm. With the help of minimum energy algorithm, the DVR‘s delivering requirement of real power is minimized. This method, there will not as much of concern on the energy storage capacity of DVR. However, the method has its limitations on current cause fluctuations of the phase angle and restoring the load voltage. In this paper, TCR is used for providing reactive power. TCR is installed on the network's load side and helps to eliminate the harmonics with the use of injecting current and then choose the best firing angles for the electronic device.

- Priyanka kumara and Vijay kumar Garg," Power quality enhancement using dynamic voltage restorer (DVR): an overview, IJSRP volume-3, issue-8. The issues revolving around voltage unbalance and the impact on sensitive loads of the voltage unbalance are well known. For addressing these issues, custom power devices are put into place like DVR which stands for Dynamic Voltage Restorer, which is most effective as well as efficient modern device. The mentioned paper illustrates a review done by the researches on the Dynamic voltage restorer (DVR) to understand its impact for improvement in quality of power in the networks of distribution of power. Utility distribution networks, Critical commercial operations, Sensitivity industrial loads are affected from distinct kinds of outages as well as service interruptions which in return provides financial losses. The paper explains DVR's basic component, operating principle, types of DVR control strategies, type of topologies system of DVRs in distribution system as well as compensation techniques.

- Green P, Fitzer C, James M, "The detection method of the voltage for the dynamic restorer of the voltage" IEEE transactions on industry applications. The paper presents a systematic review and brief description of standards, design as well as the tasks faced in DVR-technology [23].

  Brief survey has been conducted on the study that was published to mobilize the various aspects and issues of the DVR system. The arrangement of this literature provides insights about the structure, working fundamentals, compensation techniques, different topologies, control methods and voltage sag detection methods of the DVR under different segments.

  The part named "Challenges faced by the DVR" discussed in study is useful for the researchers as it can act as a starting point to begin their work in the domain of DVR. The sim-power-system tool of Simulink software /MATLAB are used to provide simulation results which are used for analysis and comparison.

- M.S.El-Koliel, A.H.A. hamza, M.M.Hafez, M.N.Ali and H.El-Eissawi, "improvement in the DVR with the use of PI controller to mitigate the sag of the voltage[24]. One of the common power quality problems is Voltage sag. In nuclear installations, it has a great effect on sensitive as well as the sophisticated equipment of the electronic. For resolving the issue, Flexible Alternating Current Transmission Systems (FACTS) have been used. In power distribution networks, DVR reflects the most efficiency in the FACTS is used for the mitigation of the sag of the voltage.

  It has been a chain of the connected devices that are based on power electronic which help in rapidly mitigating the sags of the voltage as well as restoring the voltage of the load to pre-fault-value. The study suggests that using Proportional Integral (PI) controller, there can be an improvement in DVR's conventional (d-q-0) transformation which will help mitigating the sag of voltage in the network of distribution.

The implementation of the PI controller's is not same as the work that was proposed in study. This led to the reflected improvement in performance. MATLAB/SIMULINK are used to model different types of faults and to examine the improved proposed technique over the conventional one.

- Zhan, C., A., Ramachandaramurthy, C., Barnes, A., Arularnpalam, and Jenkins, N. V. K., Fitzer, (2001). DVR that is based on the 3D voltage space vector PWM algorithm. In Power Electronics Specialists Conference, 2001. PESC. 2001 IEEE 32nd Annual (Vol. 2, pp. 533–538). IEEE. Based on a 3-dimensional /spl alpha//spl beta/0 voltage space, a voltage space vector PWM algorithm for a dynamic voltage restorer (DVR) is described.

  The switching strategy is applicable to the control of 3-phase 4-wire inverter systems like the 4-leg PWM inverter and the split-capacitor PWM inverter [25]. When done comparison with the conventional method, the voltage space vector PWM method instantaneously controls /spl alpha//spl beta/0 components of the terminal voltages. The control algorithm was confirmed by simulation. The results of the 3 kW DVR system experiment using a split-capacitor PWM inverter are given to validate the results of simulation.

- Woodley, N. H. (2000), Field experience with the DVR system. In the Power Engineering Society Winter Meeting, 2000. IEEE (Vol. 4, pp. 2864–2871). IEEE. The issues related with PQ problems in industries are damage of equipment, deprivation of the quality of product as well as the temporary shutdowns. There are huge monetary losses incurred if any damage or mal-operation of the industrial sensitive loads happens and the resultant losses are disproportionately higher when compared to the severity of the PQ issues [27].

  The power quality traditional to the technique of mitigation, with the evolution of the power electronics technology, are replaced with introduction of the Custom Power System devices (CUPS). DSTATCOM, DVR and UPQC are some of the electronic controller of major power which is based on the CUPS.

  The DVR is the solution for losses in the economy that is caused due to the PQ issues in industries. One of the most cost-effective CUPS is DVR. In the published literature, there are limited papers which are related to review of the DVR technology. In the study, systematic review of the literature has been conducted as well as brief details are given on the standards, designs as well as the tasks in DVR technology. A brief survey has been conducted on published.

- A.Kiani Haft lang, Atefe Kiani Haft lang, M.Baledi, Ehsan Gharibreza, "The algorithm for the new compensation for the DVR in the Level of voltage of the medium level", International Journal of Engineering and Innovative Technology (IJEIT). According to this study, the restorer's compensation ability depends on its power capabilities and maximum injection voltage during sag voltages. DVR can compensate reoccurring voltage drops with efficient strategy like minimum energy algorithm [30-34].

With the help of algorithm with the minimum energy, the DVRs delivering needs of real power is minimized. This technique will not be of as much concern on the capacity of the storage of energy of the Dynamic Voltage Restorer. Nevertheless, the method has its restrictions on current cause fluctuations of the phase angle and restoring the load voltage. In the paper, the TCR is used to provide the reactive power.

TCR has been fixed on network's load side and helps for the elimination of the harmonics with the use of injecting current and then choose the best firing angles for the electronic device.

- Priyanka kumara and Vijay kumar Garg," The quality of the Power enhancement using the DVR: an overview, IJSRP volume-3, issue-8. The issues revolving around voltage unbalance and the impact of the voltage unbalance on loads that are sensitive are well known.

  For mobilizing these issues, power devices which are custom have been put into place like DVR, that is effective as well as efficient modern device [31]. The paper illustrates the point of view of researches on DVR for the quality of power;

  Improvement in the distribution networks of power. Sensitivity-industrial-loads, critical commercial-operations, Utility-distribution-networks influenced from different kinds of outages and the interruptions of the service as well as the outcomes of the financial loss. This report explains the primary substance of DVR, fundamental of the operation, kinds of the strategies of control for the DVR, DVRs topologies system; in the system of distribution as well as the methods of compensation.

- M.S.El-Koliel, M.M.Hafez' and H.El-Eissawi, "improvement of the DVR with the usage of the proportional Integral(PI) controller to mitigate the voltage sag. One of the common power quality problems is Voltage sag. In nuclear installations, it has a great influence on sensitive as well as sophisticated equipment of electronics. For resolving this issue, Flexible Alternating Current Transmission Systems (FACTS) have been used. In power distribution networks, Dynamic Voltage Restorer (DVR) which is one of the most efficient FACTS, is used for mitigation of the sag of the voltage [32].

- It is a series of connected power electronic based devices which help in quickly mitigating the voltage sags and restoring the load voltage to the pre-fault-value. This study proposes that using Proportional Integral (PI) controller, there can be an improvement in DVR's conventional (d-q-0) transformation which will help for the mitigation of the sag of voltage in the network of distribution. PI controller's application is different than planned work of study. This reflected improvement in the performance. MATLAB/SIMULINK are used to model different types of faults and to examine the improved proposed technique over the conventional one.

- Johan Morren who is a Student Member of the IEEE along with Sjoerd W. H. de Haan had published "Ride through turbine of the wind with the DFIG during dip of voltage" in IEEE TRANSACTIONS ON ENERGY CONVERSION, VOL. 20, NO. 2, JUNE 2005.

  A solution is defined in the following paper, making it probable for the turbines of the wind using DFIG generators to remain in touch with the grid in the grid faults. Aim of the solution is restriction of high current of rotor for the protection of converter and for providing a sidestep for this current through many resistors connected with the rotor windings.

  Using such resistors, it's made probable to ride via grid-faults without any disconnections in the turbine from grid. Due to the connection of the generator and converter, the simultaneous operation is established during as well as after the fault. Also, the operation that is normal could be sustained instantly after clearing of the fault.

  Another important characteristic is the reactive power to be supplied to the grid during the long dips for the facilitation of the restoration of the voltage[33]. A strategy for the control has been developed which helps to make the transition again to the normal operation. Without any special action for the control, large transients would be there.

- Xunwei Yu and Zhenhua Jiang [6] advised an alike scheme except that the SC has been exchanged by a system of storage of the battery energy. The main aim of the system for the battery conversion is for having a regular DC link voltage, so undulation of voltage of the capacitor remains low [34]. Also, converter of the side stator could be taken in use for ordering the constant amount of real as well as the reactive power for grid.

- Fitzer,C, James M, Green P, "Voltage detection technique for dynamic voltage voltage restrorer" IEEE transactions on industry applications. The paper presents a systematic review and brief description regarding the standards, design as well as challenges faced in the technology concerning DVR. A brief survey is done for the published study to address as well as highlight the aspects and problems in the DVR system. The literature arrangement provides insights about the structure, principle of working, compensation techniques, and various types of topologies, control methods and detection method of the voltage sag of DVR under various segments. The part named "Challenges faced by the DVR" in the study is beneficial as well as helpful for the researchers as it can act as a starting point to begin their work in the domain of DVR. Software like Simulink/MATLAB's power system tool Sim is used to provide simulation results which are used for analysis and comparison.

- H.El-Eissawi, A.H.A. hamza, M.N.Ali, M.S.El-Koliel and M.M.Hafez' "improvement of DVR utilizing

Proportional Integral (PI) controller which helps in voltage sag mitigation. One of the common power quality problems is Voltage sag. In nuclear installations, it has a great effect on the sensitive as well as sophisticated electronic equipment. For resolving this issue, FACTS which stands for Flexible Alternating Current Transmission Systems are used. In power distribution networks, one of the highly effective FACTS which is Dynamic Voltage Restorer (DVR), is used for mitigating voltage sag. It is a connection of power electronic based devices which are placed in series format, which help in faster mitigating the voltage sags as well as restoring pre-fault value for the load voltage. The study highlights that using Proportional Integral (PI) controller, there can be an improvement in DVR's conventional (d-q-0) transformation which will help in the voltage sag mitigation mainly in distribution network. PI controller's implementation is distinct as compared to the proposed work stated in study. This reflected improvement in the performance. MATLAB/SIMULINK are used to model different types of faults and to examine the improved proposed technique over the conventional one.

- Arulampalam, V. K., Fitzer, C., A., Zhan, Ramachandaramurthy, C., Barnes, M., and Jenkins, N. (2002). IEE Proceedings-Generation, Transmission and Distribution, 149(5), 533–542. A battery's control supported DVR. Established on the basis of Space Vector PWM, Control of a DVR which stands for Dynamic Voltage Restorer is mentioned. The control algorithm allows in compensation of any voltage sag kind as well as during a fault for tracking of phase jumps, it makes the utilization of a software phase-locked loop. With the control algorithm's help, depressed voltages are restored to same magnitude as well as phase which is similar to nominal pre-sag voltages. Step by step, it keeps check on the depressed voltages phase. The experiment results confirm control algorithm by utilizing a prototype of three-phase with the specification of power rating of 10 kVA.

- Zhan, C., Arularnpalam, A., Ramachandaramurthy, V. K., Fitzer, C., Barnes, A., and Jenkins, N. (2001). DVR Established on PWM algorithm which is a three-dimensional voltage space vector. In Power Electronics Specialists Conference, 2001. PESC. 2001 IEEE 32nd Annual (Vol. 2, pp. 533–538). IEEE. Based on a 3-dimensional /spl alpha//spl beta/0 voltage space, for a DVR which stands for Dynamic Voltage Restorer (DVR) an algorithm named voltage space vector PWM is mentioned. For controlling 3-phase 4-wire inverter systems, a switching strategy is applied for the inverter systems like 4-leg PWM inverter as well as the split-capacitor PWM inverter. When done comparison with the conventional method, the voltage space vector PWM method instantaneously manages /spl alpha//spl beta/0 terminal voltages components. By using simulation, control algorithm was confirmed. The 3 kW DVR system experiment results which uses a split-capacitor PWM inverter and it is given to confirm the simulation results.

- Abi-Samra, N., Carnovale, D., Sundaram,A., and Malcolm, W. (1996). In Dynamic Voltage Restorer, execution of the system of distribution at sensitive facilities in improving the power. In WESCON/96 (pp. 167–181). IEEE. Voltage sags (which are primarily defined as reductions of short-duration in RMS voltage on one or more electrical phases) are coming up as a prime concern for utility customers of power quality and these consumers have sensitive loads. It has been characterized by their typically 0.5 to 30 cycles- duration as well as magnitude. The cause of sags is the unavoidable faults which occur are on distribution systems and the reason for the same is the utility systems' interconnectivity. The distribution-class DVR which stands for Dynamic Voltage Restorer is the connection of the power electronics device which are placed in series format and are used to make up for the swells as well as sags of the distribution system. DVR can expand the sensitive loads availability by increasing the voltage. For Electric Power Research Institute (EPRI) a 2 MVA DVR was developed by Westinghouse.

- Woodley, N. H. (2000). Field experience with Dynamic Voltage Restorer (DVR/sup TM/MV) systems. In Power Engineering Society Winter Meeting, 2000. IEEE (Vol. 4, pp. 2864–2871). IEEE. The issues related with PQ problems in industries are damage of equipment, product quality degradation as well as temporary shutdowns. There are huge monetary losses incurred if any damage or mal-operation of the industrial sensitive loads happens and the resultant losses are disproportionately higher when compared to the severity of the PQ issues.

  The traditional methods which were used for the power quality mitigation, with respect to the development of the technology of power electronics, are swapped with introduction of CUPS devices which stands for Custom Power System. DSTATCOM, DVR and UPQC are some of the main power electronic controller-based CUPS. For the economic loss in the industries due to the PQ issues, DVR is the answer. One of the most cost-effective CUPS is Dynamic Voltage Restorer. In published literature, there are limited papers which are related to the examination of the DVR technology. Well in the mentioned study, literature's systematic brief is done as well as brief details are provided on the standards, design as well as on the challenges in the DVR technology. For these purposes and study, a brief survey is done.

CHAPTER 3

DYNAMIC VOLTAGE RESTORER

3.1 Introduction

- DVR shields the load in contrast to the swell as well as the saggy voltages using another voltage of 3-Phase with the same frequency as of system coupled in the chain with voltage of the load. On basis of sensitivity of the load, pre-fault, in-phase, as well as strategies with the minimum energy are established for scheming the restorer DVR. If injected voltage, V_d is in phase along with voltage of the source, the system of in-phase monitoring is attained.
- It is a solid-state device that used to be connected in series b/w the supply side as well as the load via injection transformer.
- The load voltage is being regulated using the DVR device by inserting the voltage deviation into the system at any magnitude as well as the phase angle. In [3], 4 variations of DVR are being used with the scene of energy storage also without energy storage.
- There are various kind of devices for storing the energy applied in the DVR like super capacitors, batteries, flywheels as well as super magnetic coils. These diverse varieties of storages of energy are essential to supply reactive power as well as active power to DVR.
- Outcome of Dynamic Voltage Restorer on network has been by experimentation studied under the system that is faulted for a nonlinear load. In [9] calculated schemes for control, it includes the popularly-used single voltage loop control, an inner current loop, double-loop control with an outer voltage loop as well as the voltage feedback plus reference feed-forward control.

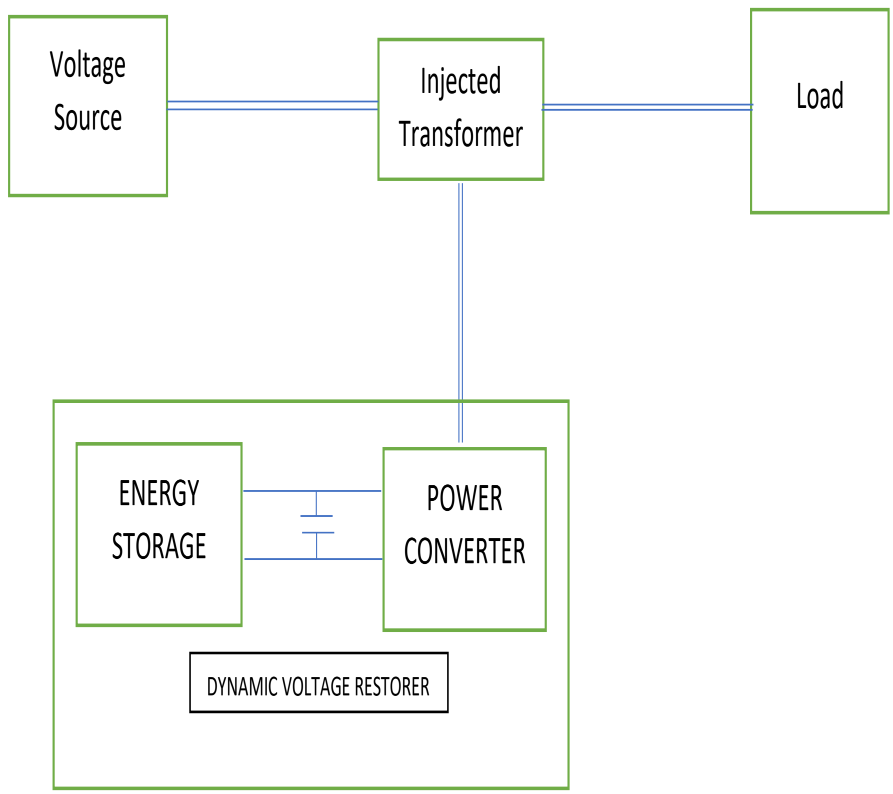

Fig 3.1: Block Diagram for Understanding the DVR

- DVR was a way to restore temporary power outages to resistant loads. DVR compensation capability varies with excessive injection power and power exposure during saggy issues.
- When a power outage continues, the DVR could charge it in an efficient way using the DVR algorithm. The algorithm decreases the actual power to distribute the need. Although, the limitations in regaining the current load as well as the volume capacity cause a decrease in phase angle.

3.2 Conventional Configuration of DVR:

- Almost every key block of the Dynamic Voltage Restorer building is an uncontrolled voltage converter. An in charge of signal (error) signal detection and design of appropriate control signals in a very short time.
- There are two parts in particular: the control strategy and the measurement phase to determine the power injection method and the response time of the Dynamic Voltage Restorer has been determined respectively.
- The more sensitive loads are used to be placed on the low voltage side of the system, the more suitable the setting for Dynamic Voltage Restorer is below the low voltage of the bus bar and should also be closed to the system source.

- As mentioned at the beginning of the introduction, Dynamic Voltage Restorers are often used to protect sensitive loads in contrast to the disturbances and noise used to set the power source. In Fig.3.2, various controls can be taken from the application producing 3 parts of asymmetric power compensation for saggy power.

The general configuration of the DVR consists of:

i. An Injection transformer
ii. DC charging circuit
iii. Device for Storage (Supercapacitor)
iv. A Voltage Source Converter (VSC)
v. A Harmonic filter
vi. A Controlling as well as Protection system

Procedure of DVR:

- In normal situations, the DVR used to be operated in standby mode. And when there is noise or any kind of fault or disturbance, the system voltage, the nominal one, would be distinguished to the voltage variations.
- Using this, we have received the differential voltage value, that has been injected by the DVR, that helps the voltage to sustain for the supply and load and that too, inside limits.
- The magnitude in addition to the phasor angle of the voltages that have been injected are modifiable that concurs controlling of the actual voltage in addition to reactive voltage b/w DVR in addition to device of the distribution.
- Input of DVR's (DC Voltage) is being connected/attached to for energy storage purpose with a proper device.
- For the storage of energy, the DVR input port has to be linked to a proper device as we have discussed in above point, that device is super capacitor.
- The transmission of reactive strength a number of the distribution system in addition to the same Voltage Restorer (DVR) has been generated using DVR without having the reactive components of alternating current passive internally.
- The actual power the usage of the same Voltage Restorer (DVR)n entering direct current port has been supplied.

3.3 Mode of Operation:

Protection Mode:

- Whenever there is some short circuit or high current situation occurs, then to isolate the Dynamic Voltage Restorer switches called bypass switches are required, which provides the current to the system from some other way.

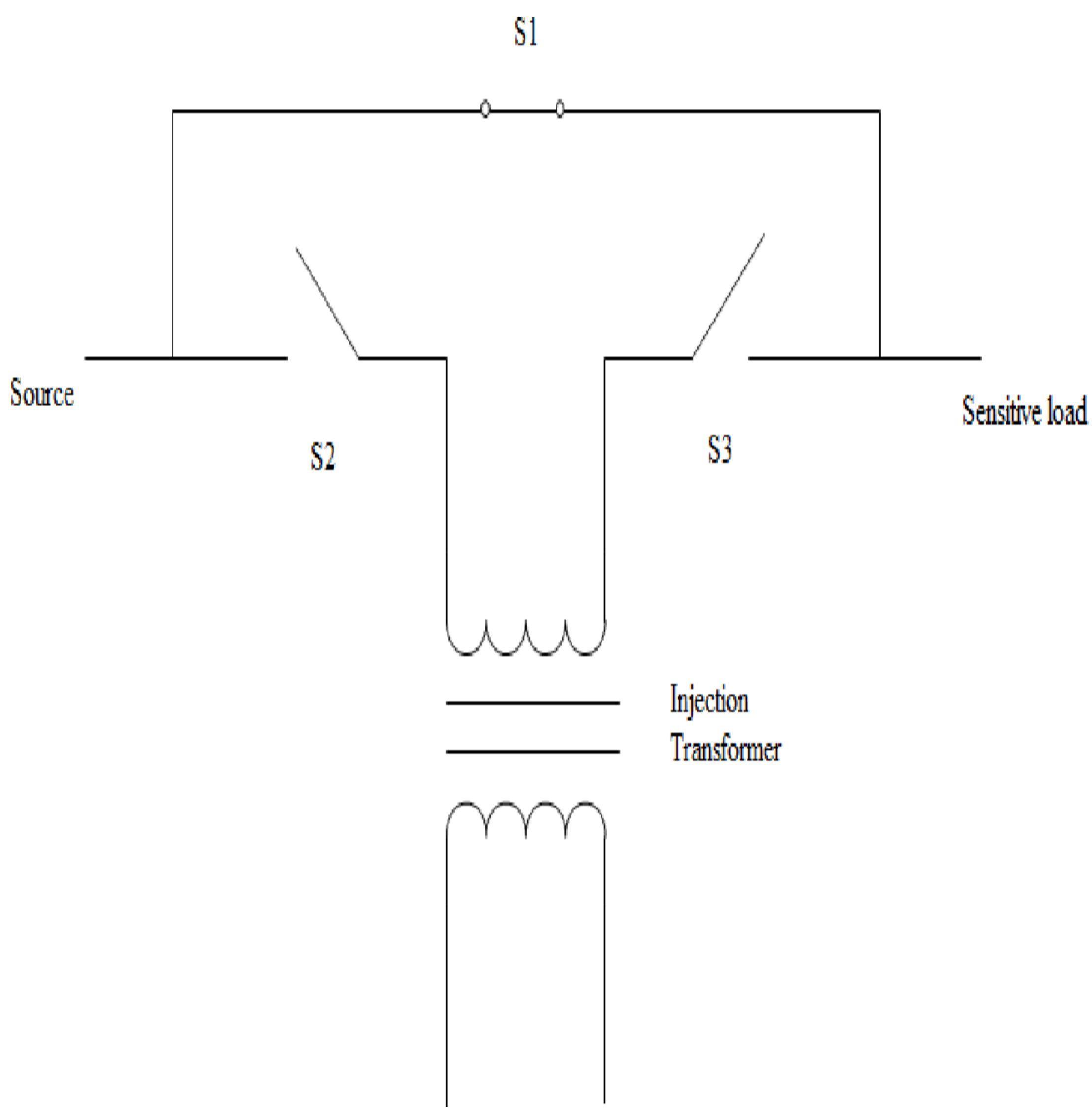

Fig.3.2: Protection mode

Standby Mode:

- In the type of mode, the injection t/f winding of low voltage side are being shorted.
    - In this mode, no switching operation is being done.

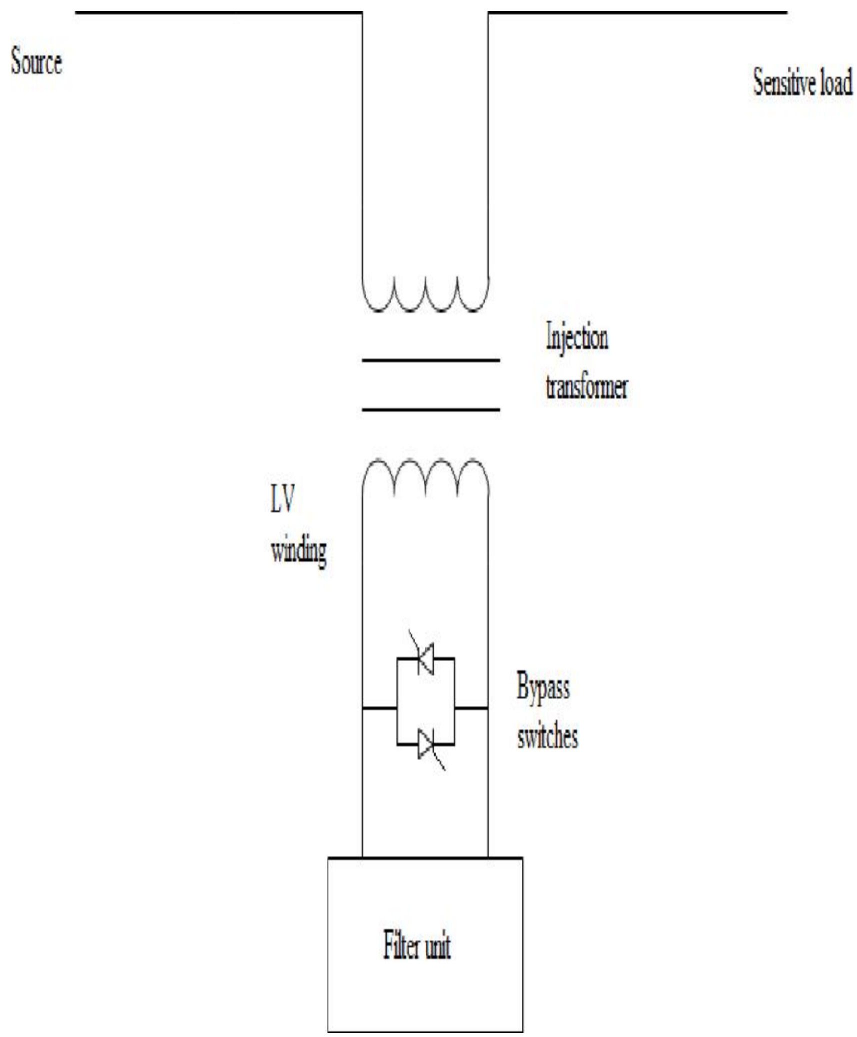

Fig. 3.3: Standby mode

3.4 Basic Structure and Principle:

- Dynamic Voltage Restorer used to be connected in series and is a compensating device that is being used to restore the unbalance of the voltage for different kind of loads. The DVR is generally being used in the distribution type of network among the load as well as common coupling point.

- The control scheme used in the system is being used o detect the disturbance in the system. The control scheme used to generate the triggering pulses for voltage source inverter. The harmonics present in the frequency are being removed using the passive filters.

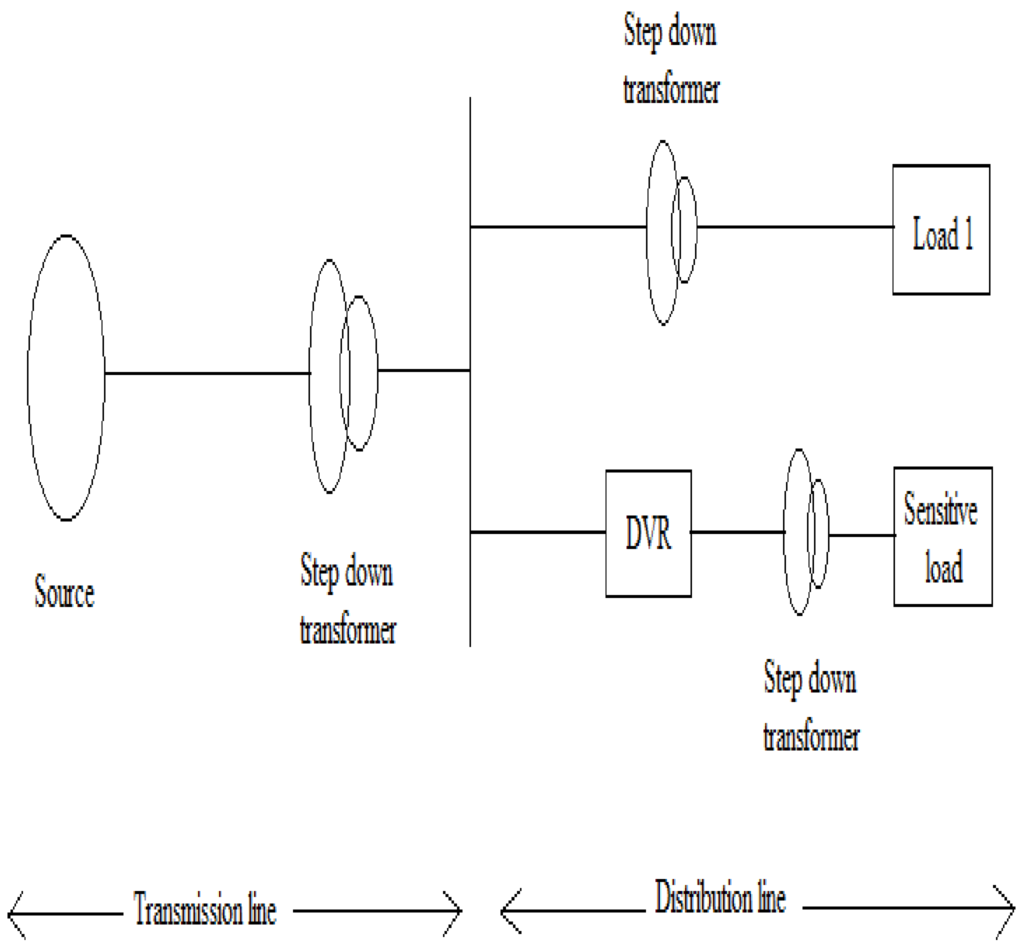

Fig.3.4: Location of DVR

Dynamic Voltage Restorer blocks to form the complete structure are given below:

1. Injection transformer
2. Storage System for Energy
3. Control circuit
4. Passive filter
5. Voltage Source Inverter

- **VSI**

The stored static supply voltage is altered into flexible supply voltage by VSI. The transformer boosts the converted voltage.

As step-up injection transformer is brought into use, the rating is usually low voltage and high current. VSI's output voltage must be:

i. Desirable magnitude
ii. Must be instantaneous
iii. Pure as well as Balanced Sinusoidal
iv. For Certain Interval

- **Voltage Injection transformer:**

The injection t/f has been used to provide the AC voltage using the Voltage Source Inverter to the required voltage. The Buck Transformer is responsible for the winding connection in the injection t/f.

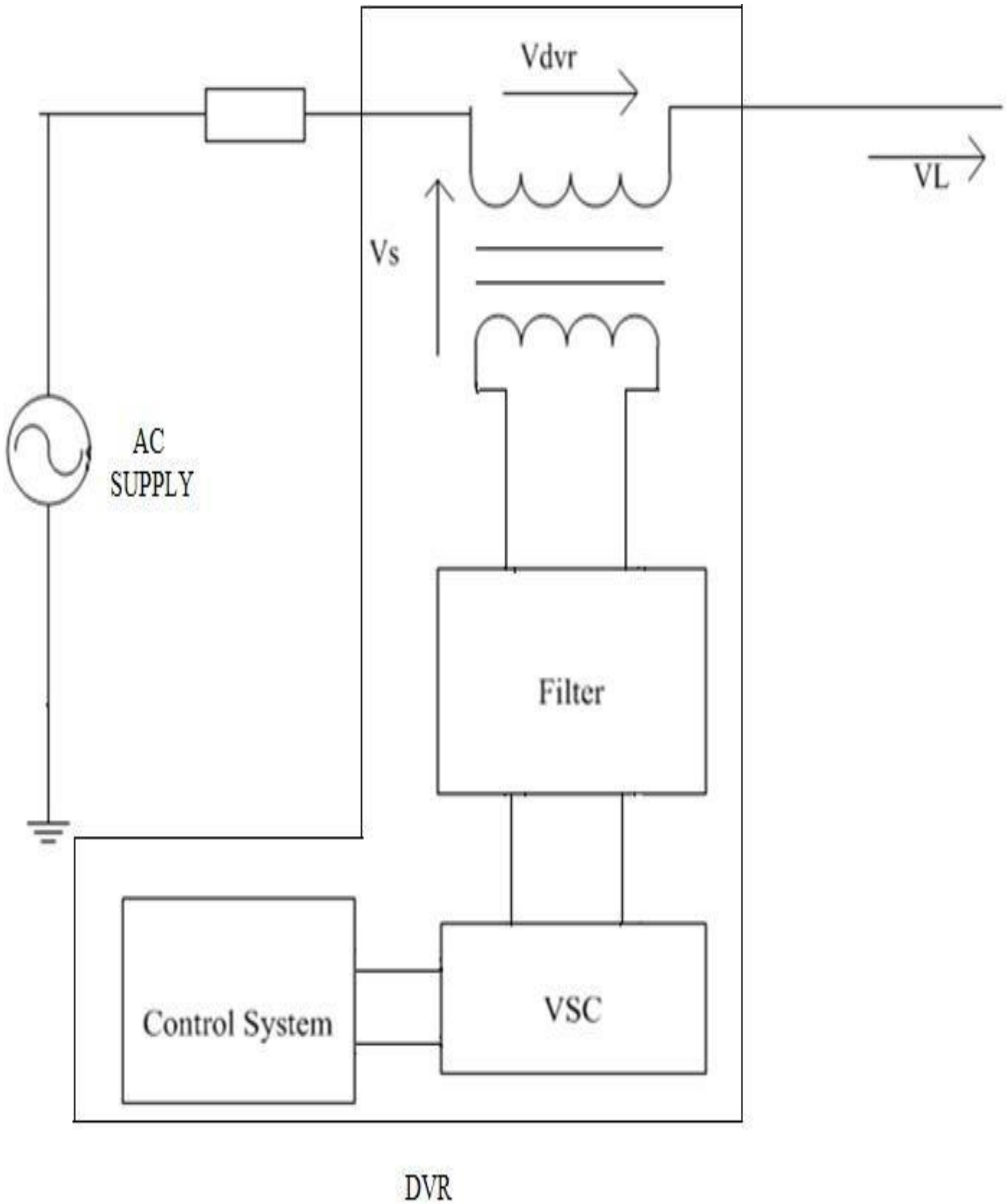

Fig3.5: Basic structure of DVR

The star connection consents the inoculation of components which are zero sequence but the open star winding connections does not agree for the same. The 3-phase single t/f has been used.

- **Passive filter:**

The harmonics which are available in the resultant of the Voltage source Inverter are being filtered out using the passive filter. The placement of the filter is possible on both sides which are High-Voltage side or the Inverter Side of the transformer. If we place the same filter at the inverter side, there is a possibility of reduction of voltage stress as well as rating because the switching harmonics are restricted. Placing the filter at High Voltage side, rating of transformer can be increased as harmonics can enter into High Voltage side.

- **Energy Storage Unit:**

During compensation, energy storage unit is responsible to generate the compensating voltage to the real power. Some examples of the same are flywheels, dc capacitors, lead acid batteries as well as super capacitors. The systems which have huge amount of disturbance are in a need to compensate the real power.

- **Control circuit:**

It progressively witnesses the system. The main function of the control circuit is to identify the noises in the system which is being done by comparison of reference voltage to the supply voltage as well as generation of the signals for switching for Voltage Source Inverter so that the Dynamic Voltage Restorer could compensate the voltage.

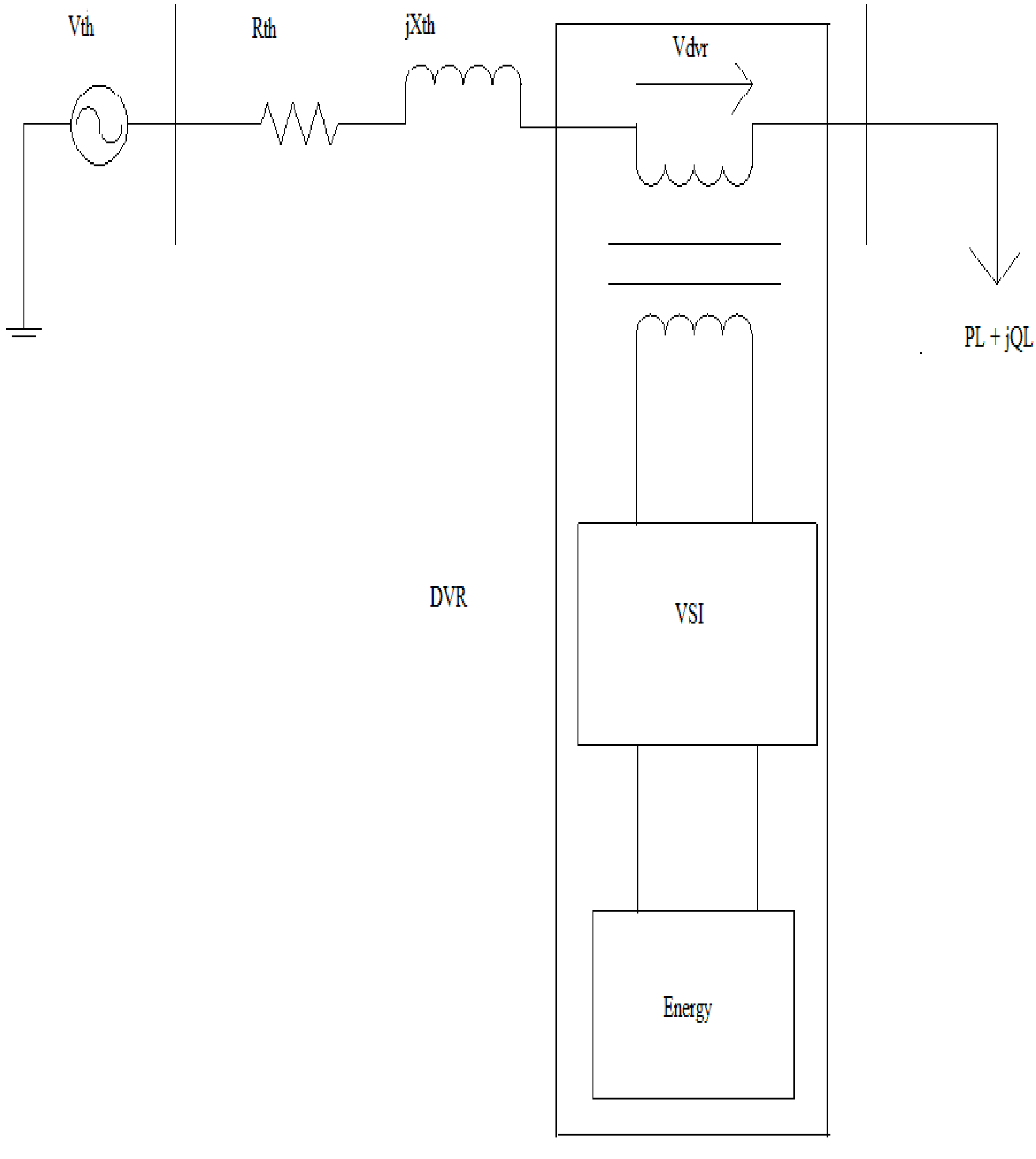

Fig.3.6: Schematic diagram of a DVR

3.5 Calculation of Voltage injected by DVR:

Circuit corresponding to the circuit of the electrical network is depicted by the left side circuit of the Dynamic Voltage Restorer in fig. (4.6). To maintain the constant profile of voltage, whenever there disbalance, the required voltage is injected by Dynamic Voltage Restorer through injection transformer. The value of Z_{th} which is the corresponding system resistance rests on the type of fault.

CHAPTER 4

MODELLING AND SIMULATION

4.1 MODELLING OF THE DVR POWER CIRCUIT

Fig. 4.1 highpoints the Dynamic Voltage Restorer's power circuit diagram.

Being a static var, DVR's uses are visible in a combination of transmission and distribution systems.

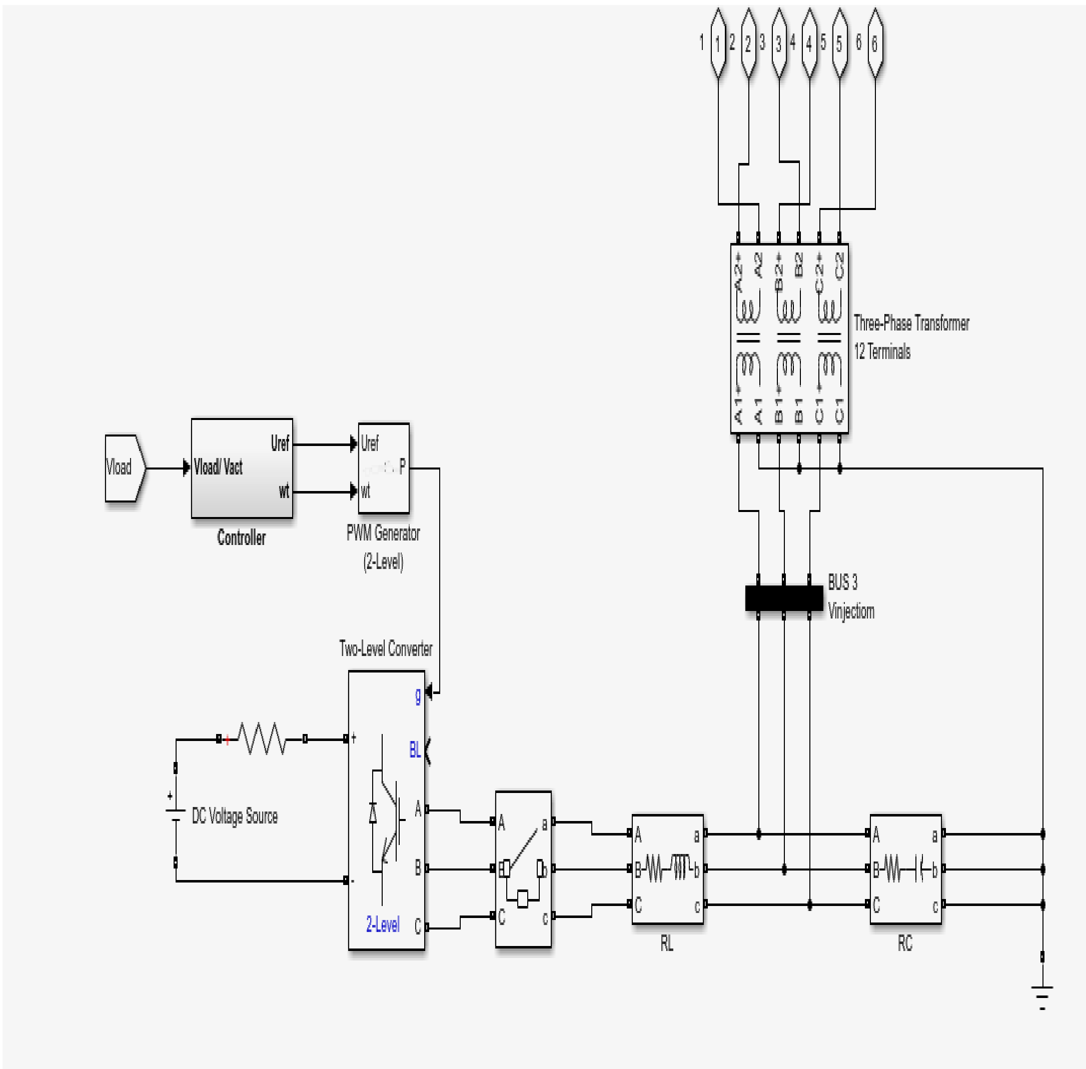

Fig 4.1: The System's Simulink Model

It is device that has the capability to compensate the voltages. It usually connects in series formation as well as supports in shielding the sensitive load from issues regarding the quality of power such as swelling, disruption, imbalance as well as voltage sagging that use VSC representing power converters with power regulators.

4.2 Conventional Configuration of DVR:

The Model consists of:

i. Injection transformer.
ii. Bi-directional Voltage Converter.
iii. Super Capacitor.
iv. DC charging circuit.

- Voltage dip happens due to sudden termination of load or errors in the system and voltage swell occurs due to capacitive load connection. Voltage imbalances occur for some time in the system due to network errors.
- During this time power outages occur in the PCC (Point Of Coupling) and the DVR is working to preserve the voltage profile. Here all values are included in unit values, in the event of a disruption it may be seen that the maximum power profile is rising / decreasing from its estimated value. The DVR operates and sets the voltage you want to compensate for this increase / immersion.
- After compensation, there is a slight disturbance at the beginning and end of the sag / swelling point that occurs due to the increase in the electric charge at this time.

4.3 **Processes of Dynamic Voltage Restorer**

- The dynamic electric return is typically in normal conditions used to be operated in the standby mode. During disturbance and noise or any kind of defective circumstances, the electrical power of the system can be compared to power variations. With this we have found the amount of different electrical energy that should be returned to restore the effect of conserving the power supply within the limits.
- The power and angle of the variable voltages that is being injected allowed for real control and performance of the exchange power b / w DVR and distribution system. The DVR's terminal input (DC Voltage) is connected to the appropriate power storage device.
- As mentioned, the transfer of active power between the distribution system and the Dynamic Voltage Restorer is done using Dynamic Voltage Restorer without the active AC passive components inside. Real power is provided using Dynamic Voltage Restorer DC input alternating with the effect of DVR AC terminals is an external power source or we can say a power saving system.

4.4 Total Harmonic Distortion

- THD representing a complete Harmonic distortion is a measure of harmonic distortion present in the signal. THD can be said to be the average energy rating of all harmonic components in the primary frequency energy.

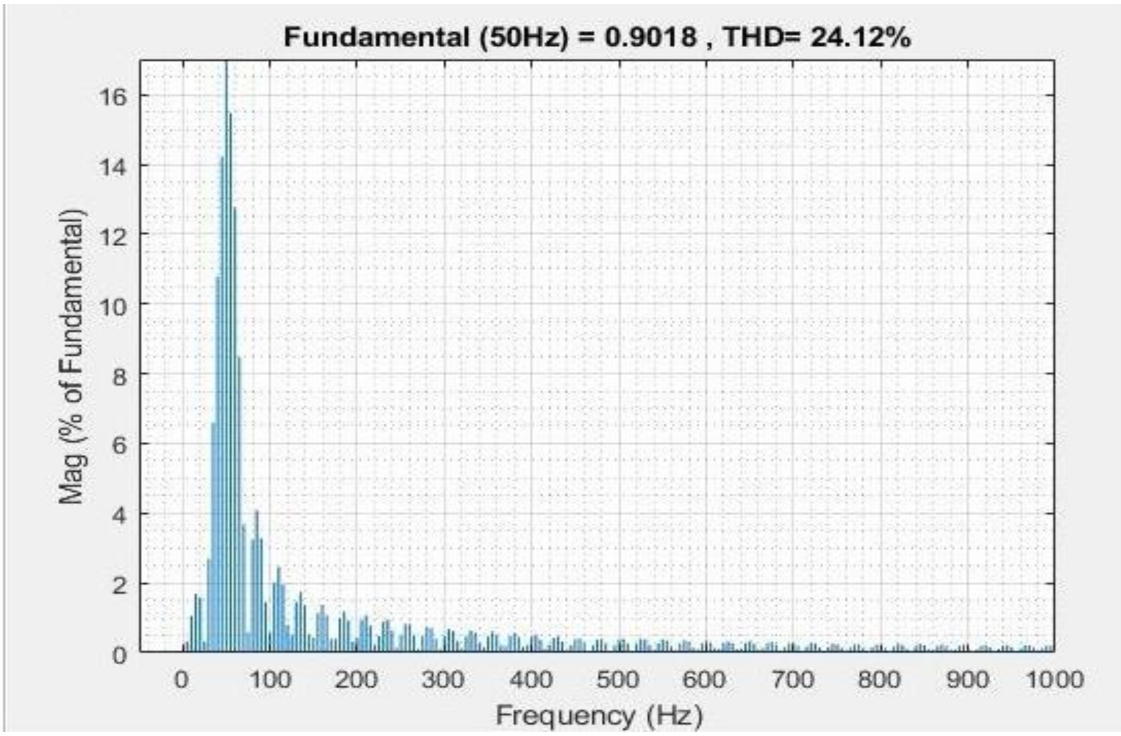

Fig 4.2. The Total Harmonic Distortion (THD) of the Main System (uncontrolled)

- The THD of the large (uncontrolled) system is shown in Figure 2. The 50 Hz THD frequency is 24.12% very high as it is sufficient to reduce the system level by heating or by providing high electromagnetic emissions. Also, high basic losses.

- To fix this problem, we need to keep an eye on the size of the injected energy to reduce THD. The biggest problem is overcoming the unwanted power supply and maintaining the maximum power supply that is constantly loaded during the supply interruption i.e., to get a controlled voltage from the DVR, the controller needs to be built.

CHAPTER 5
CONTROLLERS

5.1 Proportional-Integral (PI) Controller

- In the fourth chapter, as we have got the explanation and the main purpose of the controller is to maintain the maximum voltage capacity during a critical load supply crisis.
- The said control method is being developed on the basis of comparing the source voltage with the load voltage. Using the park modification algorithm, a three-phase power conversion is performed into the dqo.
- Voltage remains constant even after the conversion using the d-voltage, which is 1 in pu and q-voltage that has been taken 0 in p.u under consideration of normal and moderate conditions but very varied which puts them under abnormal conditions. After that, the voltage difference is enhanced by the PI controller by making comparisons of d-voltage and q-voltage with the desired voltage.
- After this, it drives over a dq0-to-abc conversion and has been converted to an abc part such that it has been considered to be the main indicator for the production of the PWM inverter pulse voltage switching source. One of the key components is removed from the controller when a power outage occurs in the system to install a power outage, detect a voltage sag and turn off the inverter. Fig 5.2, highlights the PI control placed in the response path [8].
- From the Sensitive load voltage, the control input arrives and the VSL is measured in the Sensitive Load with the help of a three-phase V-I rating in p.u. After that the VSL conversion was performed on dq data.
- The detection of a decrease in power is done with the help of an error measurement between the dq-voltage and the values \ reference \. The PI controller is processing such errors. The d reference is set to the rated voltage as one in p.u while the reference q is set to zero.

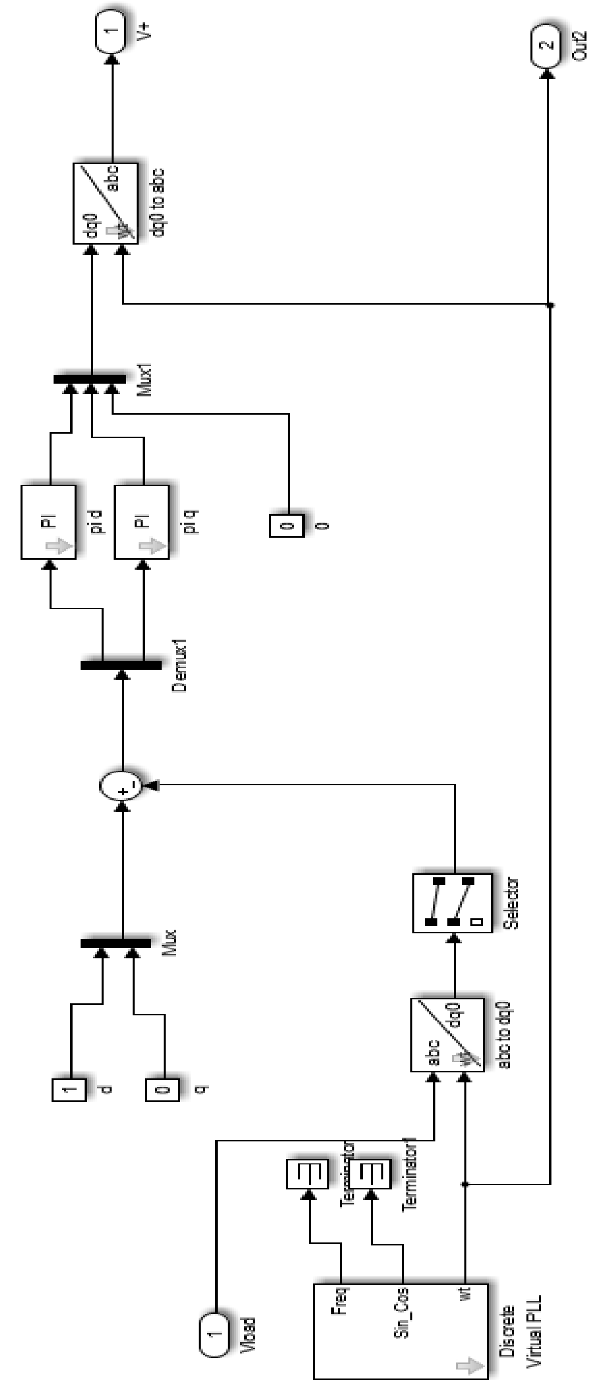

Fig 5.1: PI controller based d-q transformation

5.2 TOTAL HARMONIC DISTORTION

- The Total Harmonic Distortion that has been available in the model (input 1) is greater i.e., 24.12% and hence it is required to decrease the THD whatever level is achievable. The reason being that the lower Harmonic Distortion in the system indicates that the core loss has been minimized, heating losses reduces as well as lower peak currents.

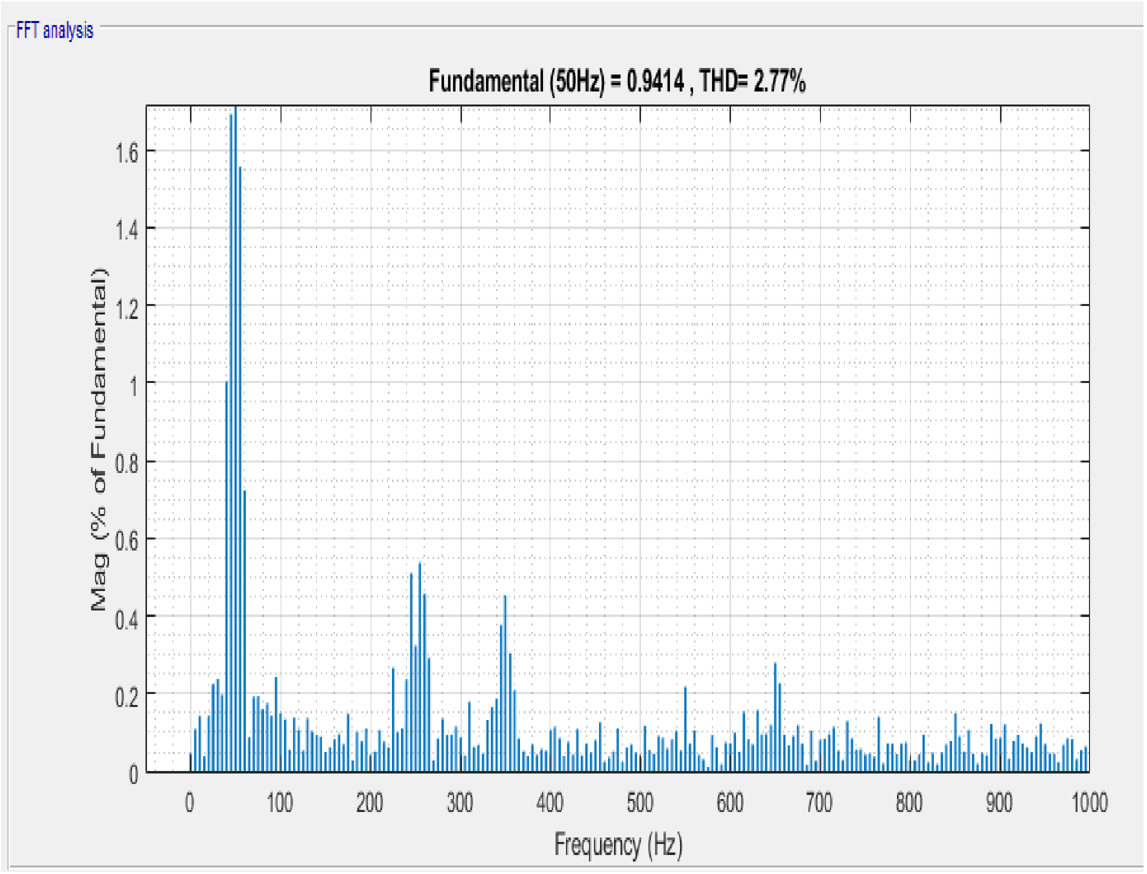

Fig 5.2. THD of the PI controller controlled Main System

- From the figure above, it can be noted that the Total Harmonic Distortion after controlling the system using PI controller has been limited to 2.77%. From this it can be easily concluded that the implementation of the same has rectified the issues of THD to the great extent but there is some more scope of better system controllability so in the next section we have tried to implement the Neural Network to improve the same.

5.3 NEURAL NETWORK BASED CONTROL

- ANN has been originated from the collection of nodes or connected units known as the manmade neurons, quite alike to human brain, that freely release neurons. Alike synapses that occur in the bloodstream, each link transmits a indication to various different neurons. At signal reception by a manmade neuron, it shows progression and indicates the neurons interlinked. In any linking, the "signal" is considered to be a real no., as well as the output of each neuron is obtained by the amount of input using indirect activity. These connections are terminated. The neurons as well as the edges take a weight that shifts as we further increase in our study.

- Signal strength in the connection increases or decreases in weight. Neurons are limited as in the case where the signal is transmitted as soon as the integrated signal exceeds the limit. Neurons have been grouped in different layers as well as the task of different layers has been defined to make different changes in inputs. From the first layer which is the input layer itself, the signal goes to the end layer which is the output layer of the system immediately after traversing several times.

- By analyzing different examples, the same are being or learned or trained and all of them contain “inputs” as well as the “effect” that help to create weighted midnight organizations and this is stored inside the data-structure. The training of neural network from the aforementioned model is done by differentiating the target output and the output processing network (usually predicting). This is a mistake. According to the law of learning, the network fixes its weighted organizations and uses this error number.

- Subsequent mutations lead to the production of neural network output that is very similar compared to targeted output. After making a number of adjustments, according to certain terms the termination of training is announced.

5.4 Components of ANNs

- Neurons
- Connection and weights
- Propagation Function
- Organization
- Learning
- Learning Rate
- Cost Function

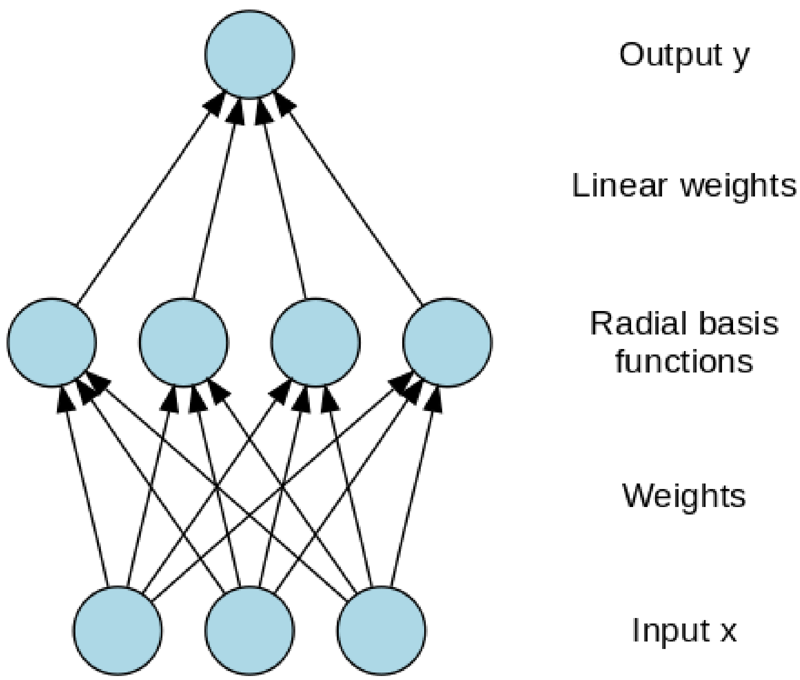

Fig 5.3. Artificial Neural Network (ANN)

- The block drawing explains the operation of the method as well as framework given here in Fig.5. Multilayer-perceptron arrangement of the developed ANN is put along a hidden layer, an input layer, as well as output layer. The two input areas form the input layer: the DC capacitor voltage and the base voltage while referring to the twenty notes including the hidden layer - with sigmoid function and active. One node forms an output layer and is a highly thought-of gate control signal. The sheer amount of input function and selection produces neuron output as shown below:

$$y = f(w_{ij}x_{ij}) + b_j \qquad (1)$$

$$e = \frac{1}{p}\sum_{i=1}^{p}\left\|y^{(i)} - v^{(i)}\right\|^2 \qquad (2)$$

$$a_j = \tan sig\left(\sum\nolimits_{k=1}^{n} w_k v_k + bias\right) \qquad (3)$$

- Fig.5.3 ANN DVR set of inverter control system. In the aforementioned case, there is a system input and power supply with 1200 patterns in the set of information, which can be divided into two details below. 70%, samples used to train ANN, while all 30% mentioned, were used for authorization and network testing. Using mean-square error¸ the performance is calculated as given in Fig. 7 and Equation (3).
- Where, p = number of training information; v = required output; y = ANN vector output A well-trained ANN provides as a set of output parameter output, the directing voltage and the desired value are very close and indicate an error close to zero. The total weight is calculated for the input of n, V_k, k = 1, 2 ... n, for each neuron, a_j and give an effect similar to the highlighting of Equation (4).

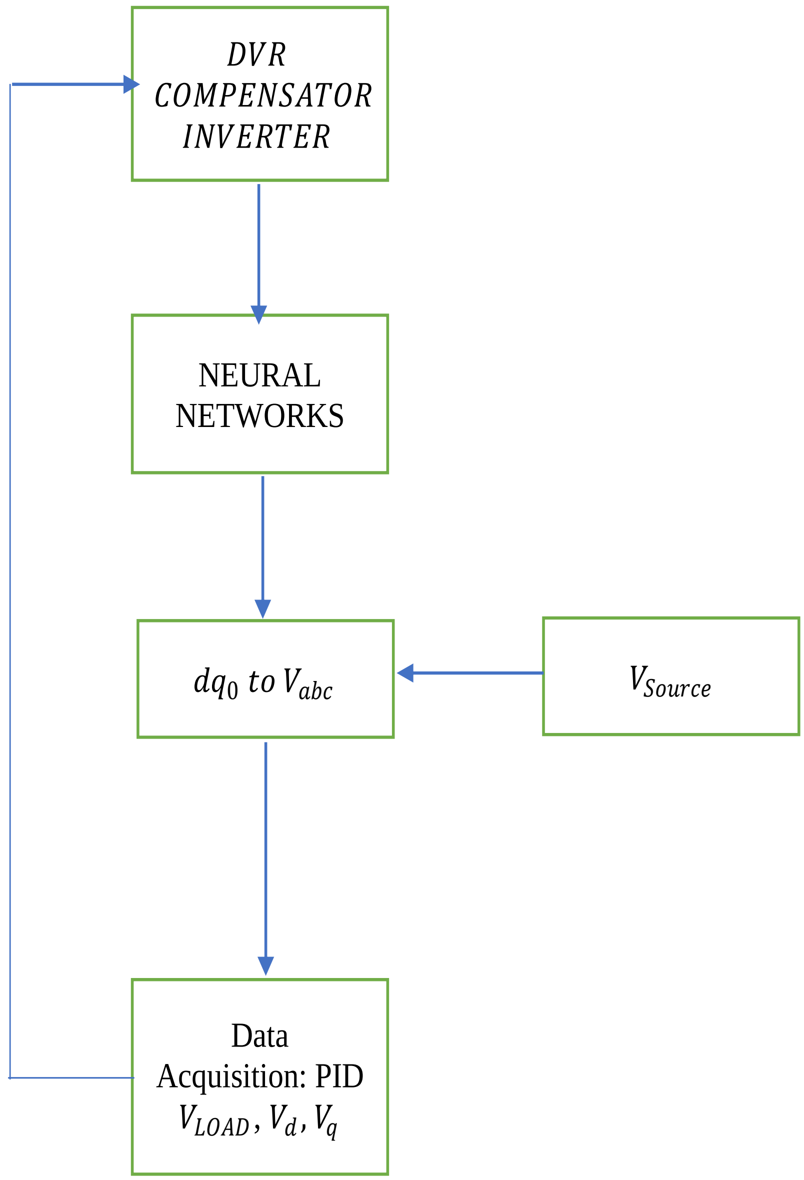

Fig 5.4: Block Diagram of Artificial Neural Network (ANN) System

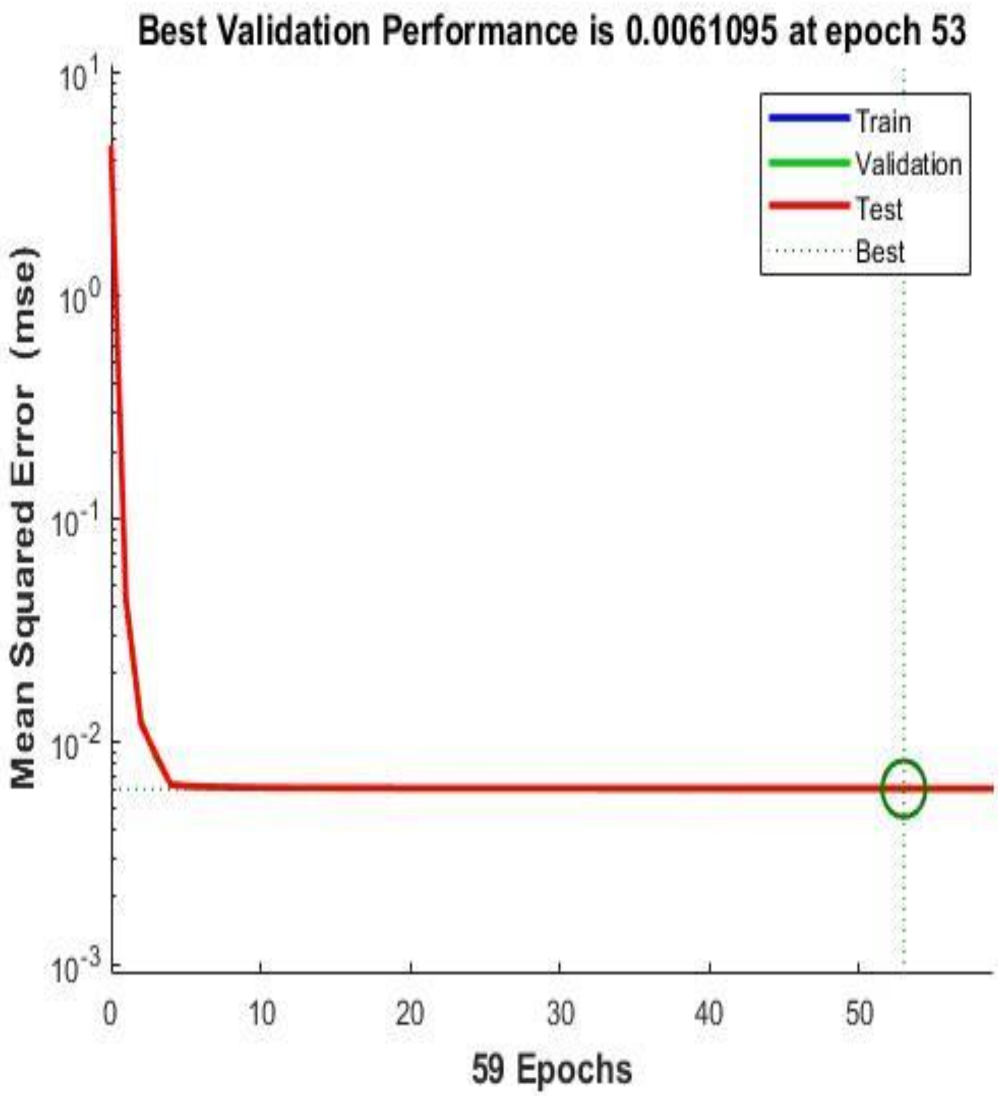

Fig 5.5: Convergence Curve of Iterations

- An important amount of tan sigmoid activity that continues the bias communication to it can be viewed as an additional input that gives effect. W_k = synapse weight connected to input n.
- The goal of system management is to maintain a level of power in a situation where the situation is not subject to system disruption that critical load is related to.
- Load terminals produce harmonics related to core driving and are similar to critical load. At load stations, the voltage sag is twisted by a phase 3 error. The stated voltage problem is detected independently and passed to the sequence analyst.
- The standard configuration control format has a power conversion system that includes specified power supplies that can be provided by the DVR.

- The controller input is an error signal obtained from the injected gas capacity and the reference voltage. The proposed DVR control is based on the ANN controller shown in Fig. 5.4. To generate the required injector power, the PWM signal generator keeps the DVR inverter.
- To improve temporary performance and stability, there are careful documentation designed for ANN control.

5.5 TOTAL HARMONIC DISTORTION (THD)

- The THD present in the system (input 1) is very high at 24.12% and needed to be reduced due to the use of the PI control and the THD PI was reduced to 2.77%. To further reduce THD, we used Neural Network and the results obtained were better than PI control. System THD is now reduced to 2.15% at the same frequency of 50 Hz. The figure below shows the same.

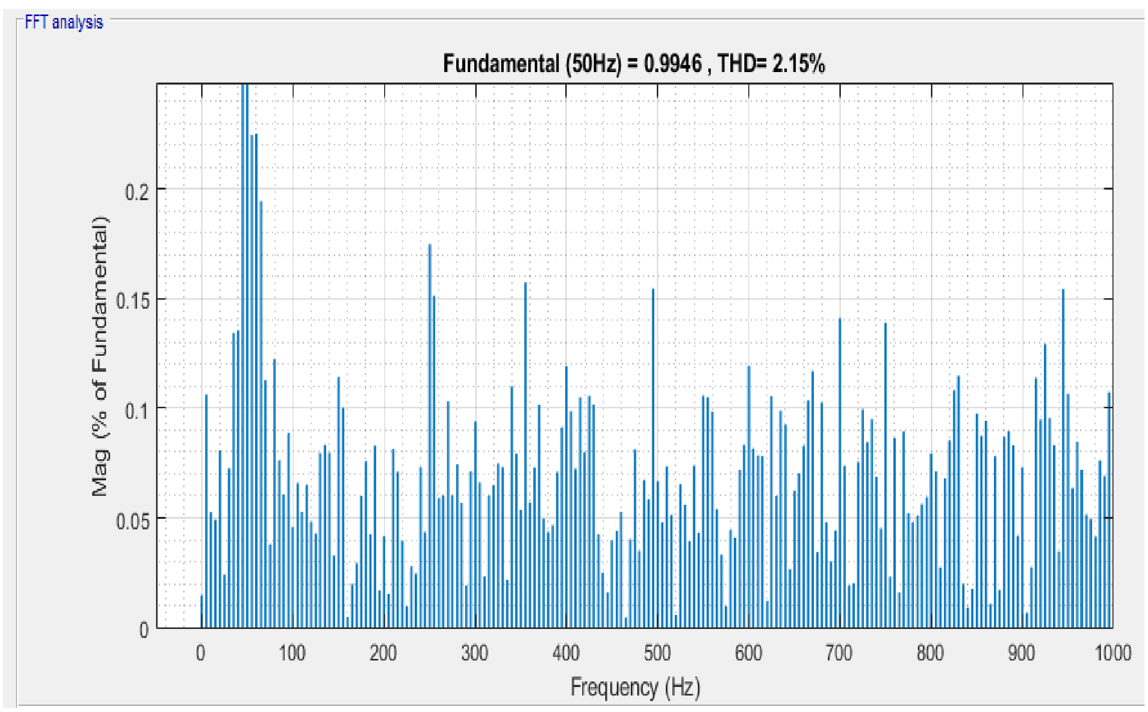

Fig 5.6: The Total Harmonic Distortion (THD) of the Main System (ANN controller based)

CHAPTER 6

RESULTS AND CONCLUSION

6.1 RESULTS

- In the event of the first simulation, it is done without DVR and a phase three error is provided by the system.

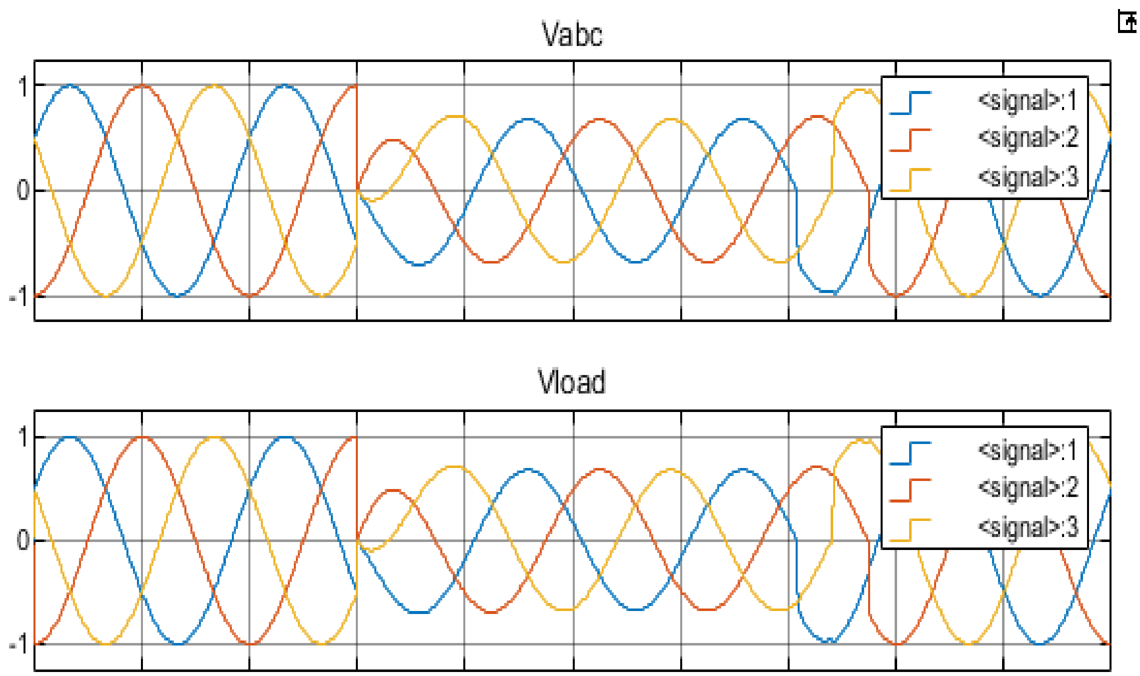

Fig 6.1. shows the output of the saggy voltage. (a) Source Voltage with fault (b) Output voltage of load side

- Current power and power after designing the DVR and adding injectable electrical power. No controller has been configured so far, except for DVR control.

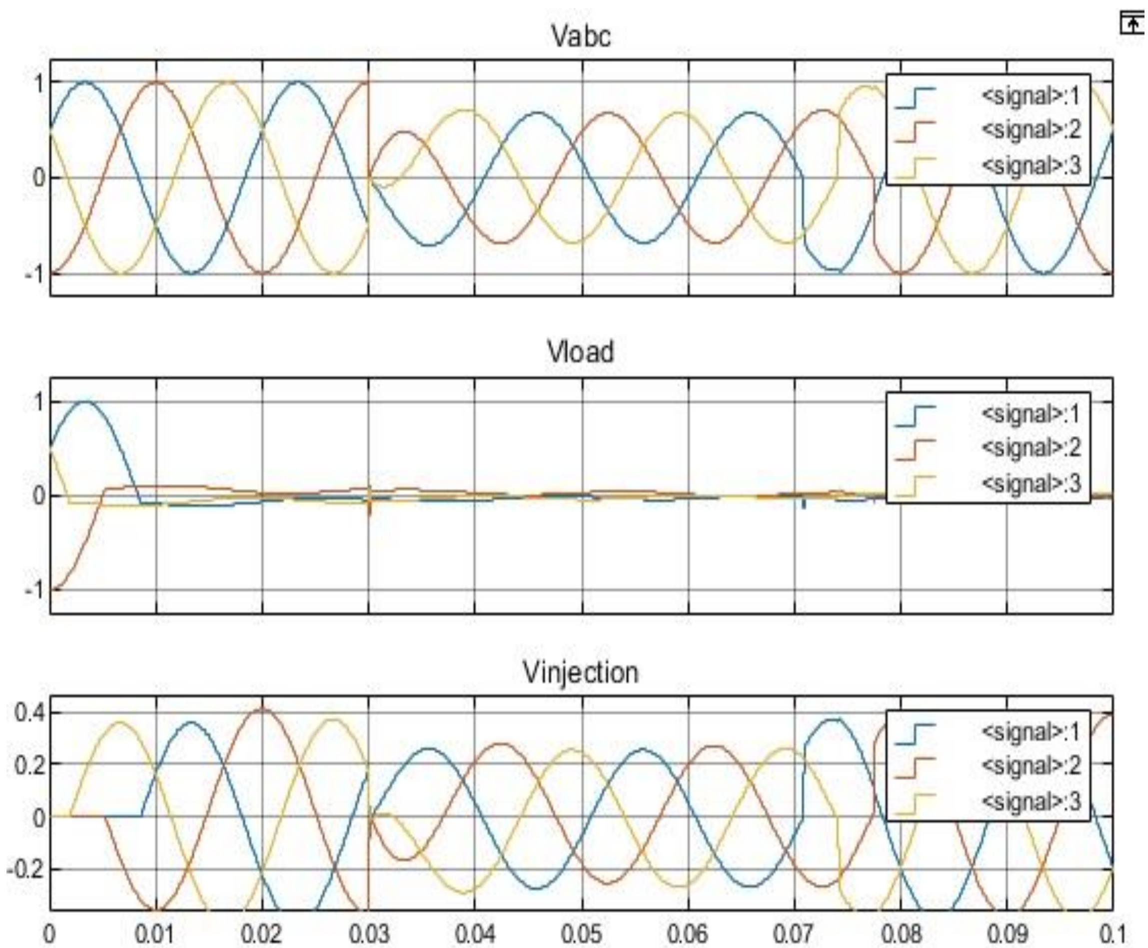

Fig 6.2. shows the output of the saggy voltage after DVR inject voltage (a) Source Voltage with fault (b) Saggy Output voltage of load side (c) Uncontrolled DCR injected Voltage

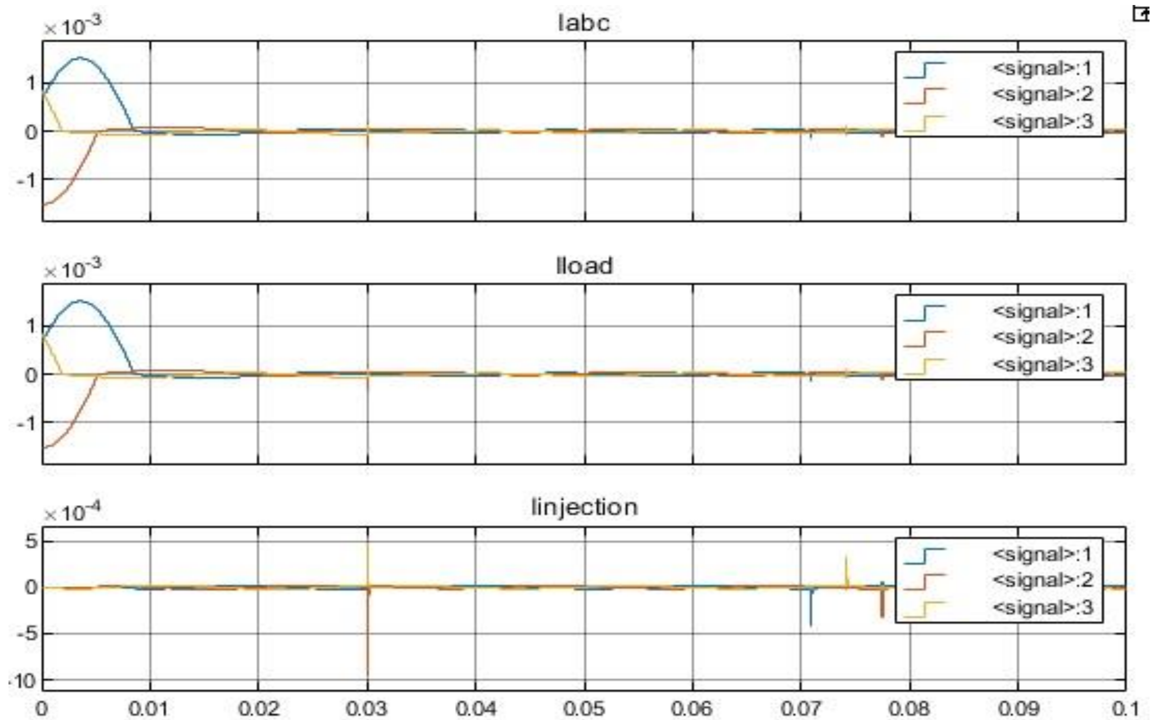

Fig 6.3. shows the output of the saggy current after DVR inject voltage (a) Source Current with fault (b) Output Current of load side (c) Uncontrolled DCR injected Voltage

- Voltage and current after designing a DVR-based PI Controller and adding inject voltage

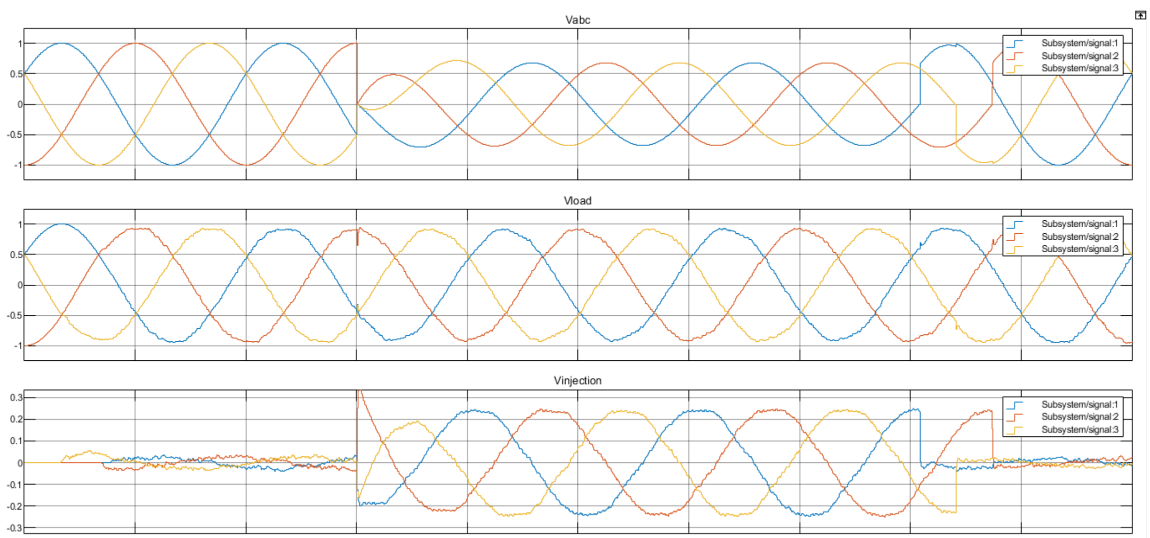

Fig 6.4. shows the output of the saggy voltage after DVR inject voltage (controlled using PI Controller) (a) Source Voltage with fault (b) Saggy Output voltage of load side (c) PI controller based controlled DVR injected Voltage

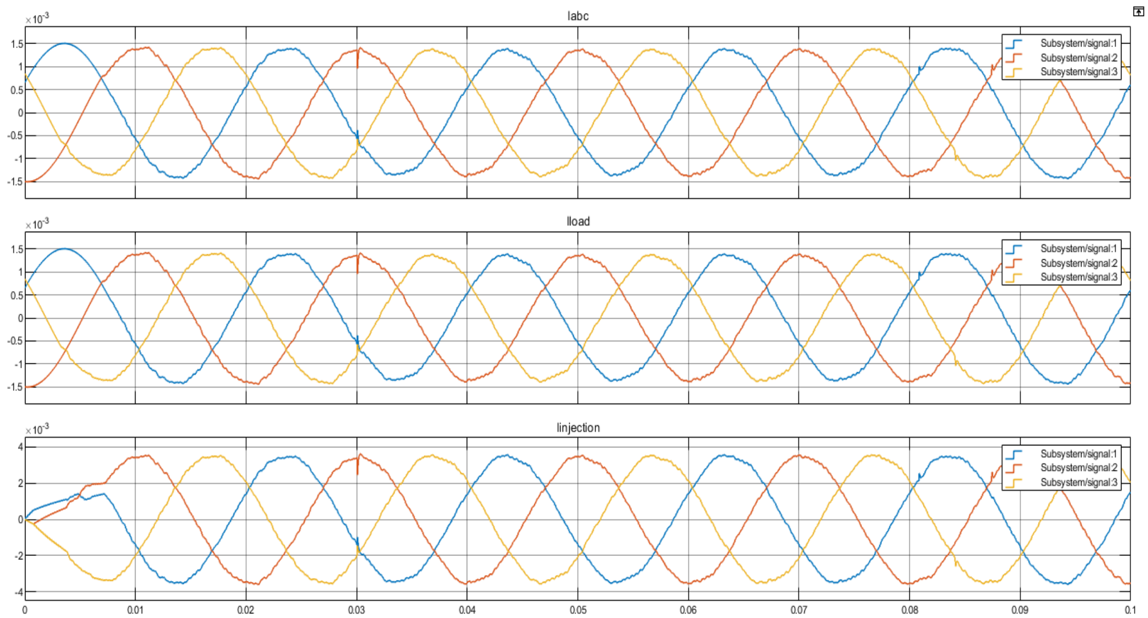

Fig 6.5 shows the output of the current after DVR inject voltage (controlled using PI Controller) (a) Source Current with fault (b) Output Current of load side (c) PI controller based controlled DVR injected Current

- Voltage and current after designing ANN-based control for DVR control and installation voltage

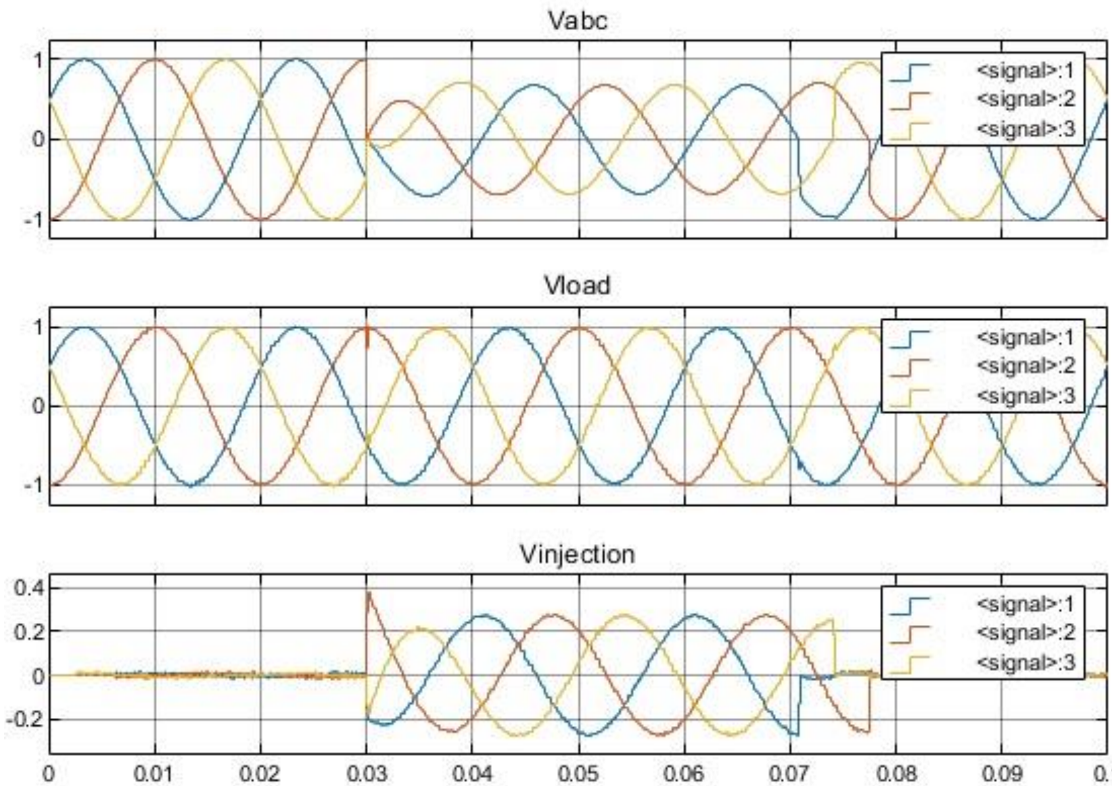

Fig 6.6. shows the output of the Voltage after DVR inject voltage (controlled using Neural Network Controller) (a) Source Voltage with fault (b) Output Voltage of load side (c) Neural Network controller-controlled DVR injected Voltage

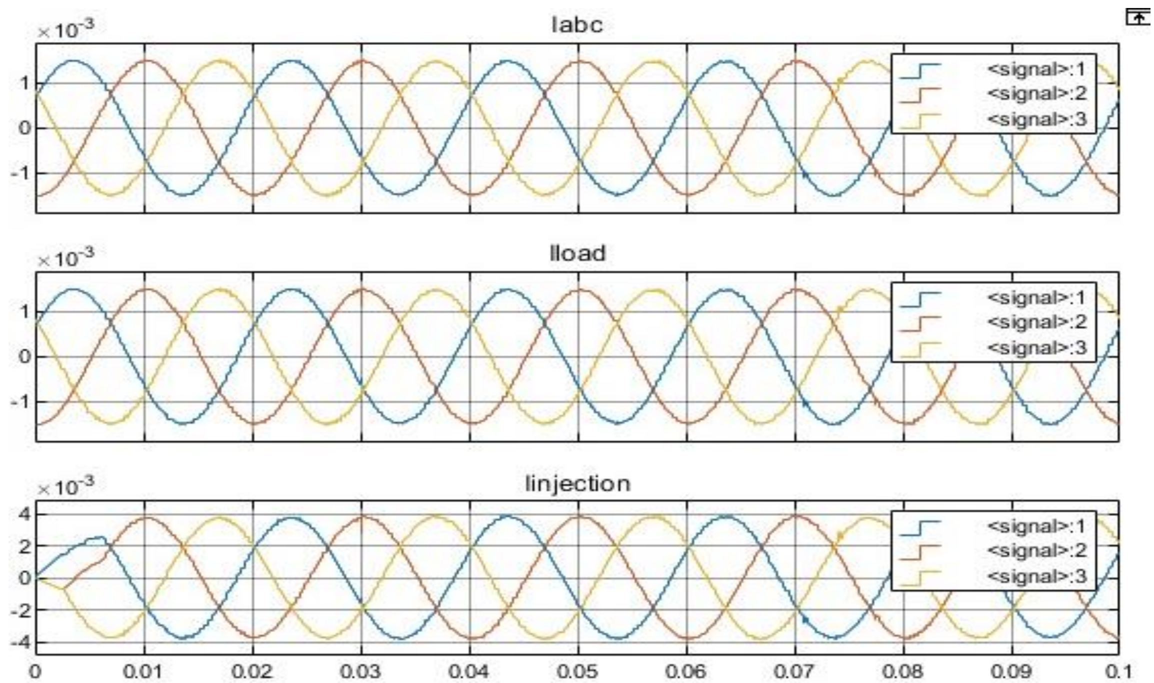

Fig 6.7. shows the output of the Current after DVR inject voltage (controlled using Neural Network Controller) (a) Source Current with fault (b) Output Current of load side (c) Neural Network controller controlled DCR injected Current

6.2 CONCLUSION

- The main purpose of our research work and concept is to implement a program to improve the quality of the system. A major factor in the system's problems was THD.
- Therefore, to make improvements in energy quality in our system, we have looked at a number of ways to reduce THD, namely, Complete System Disruption.
- Total Harmonic Distension has been analyzed with a transformer measurement with Dynamic Voltage Restorer shown in Fig. 16.
- Total Harmonic Distension of the power system was analyzed using algorithm analysis based on Fast Fourier Transform (FFT).
- Prior to program modification or pre-regulation, Totla Harmonic Distension (THD) is now known as 24.12%.
- After testing, using the Proportional Integral control, reduced to 3.1%
- Further reduction, after using the neural network again, THD was reduced to 2.15% of the ANN control.
- Apart from this, in this study, we learned about the devices used for this purpose such as DVR, its features, the operating principle and the various operating modes that help to improve the quality of power distribution and distribution network. We can expect further improvements in this DVR technology to overcome existing problems.

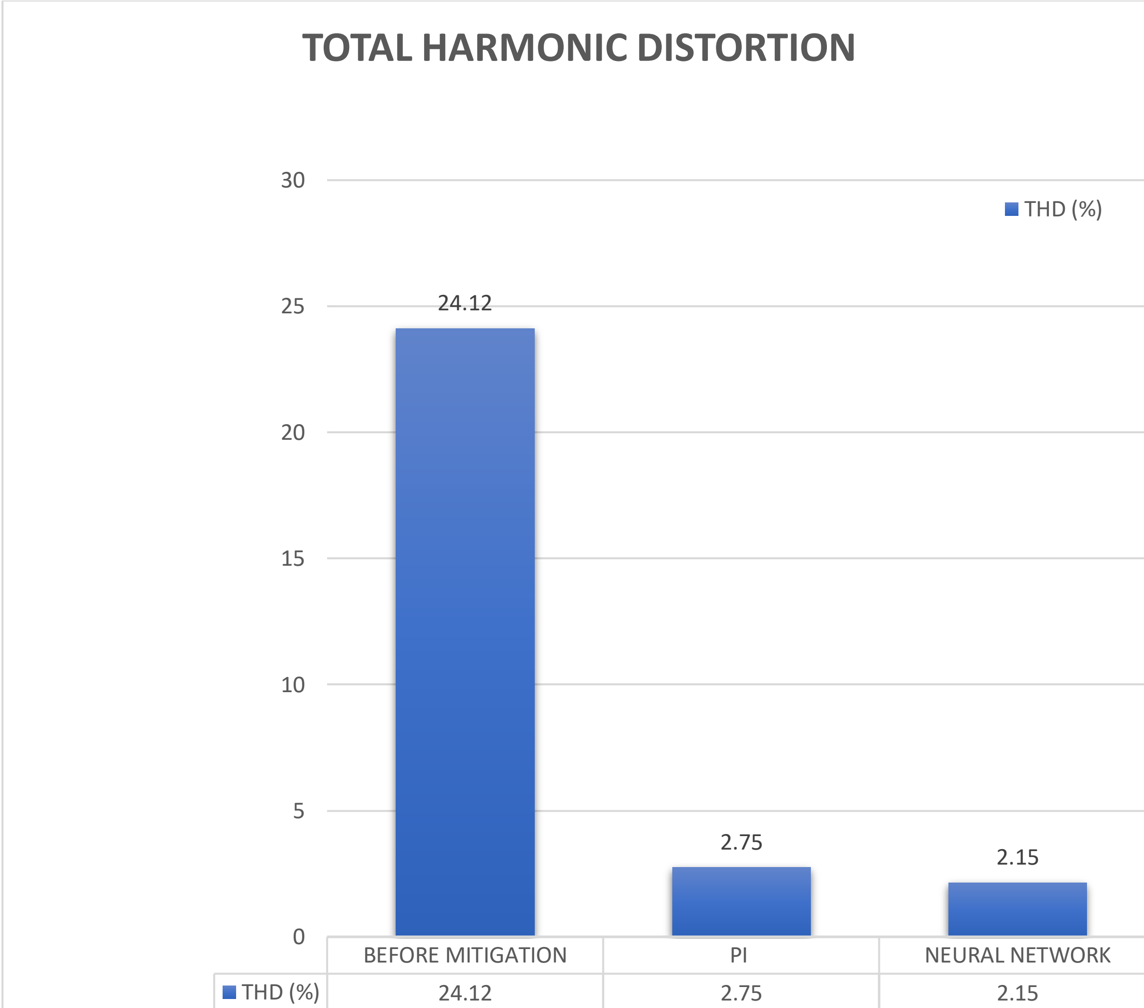

Fig 6.8. Graphical Presentation of THD values of the system for various controllers

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