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Simulation Performance of DVR in Distribution System during Voltage Sags and Voltage Swells

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Abstract: **Today Power Quality is a prime concern due to the introduction of high-tech devices. Power quality problem is natural event such as non-sinusoidal voltage, current or frequency whose outcome is failure of end use equipments. Usually, Voltage Perturbation is a major power quality problem. Voltage Perturbation is due to use of much electronic equipment in industrial distribution system. The voltage perturbation is such as voltage sags, swells, harmonics, Unbalance & Flickers. To figure out these difficulties, custom power devices are used. Among them the DVR (Dynamic Voltage Restorer) is the most efficient & effective in power distribution. DVR gives fast dynamic response to the perturbation. In this thesis modeling of DVR for voltage compensation is done by using MATLAB software is presented in which we use PI Controller and Discrete PWM Generator.**

Keywords: **Dynamic Voltage Restorer, voltage sags/swells, VSI, Phase Sequence Analyzer.**

I. INTRODUCTION

Electrical energy is the most efficient and big form of energy and the modern social club is important to great extent dependent on the electric supply. We cannot imagine the life without supply of electricity. At the same time the quality and persistence of electric power supplied is also very important for the efficient functioning of the end user equipment. Most of the commercial and industrial loads demand high quality uninterrupted power. Thus maintaining the qualitative power is of important. Power quality measures the fitness of electric power transmitted from utilities. Power Quality disturbance can be defined as the deviation of the voltage and the current from its perfect waveform. So many methods are used to extenuate/palliate voltage sags and swells, but we use the most efficient method of custom power devices which is Dynamic Voltage Restorer. DVR can be used to compensate load Voltage .They improves the Power Quality and protects the system from voltage sags and Swells .Voltage sag is short duration decrease in rms voltage value from 0.1 to 0.9 pu. Voltage sags cause when the rms voltage decreases between 10% to 90% of nominal voltage i.e. equipment failure, power system failure, Customer load additions, and large load additions in the utility service area. voltage swell is opposite of voltage sag and less common in nature. And it is defined as short duration increase in voltage values level 110% to 180% of nominal voltage for duration of ½ cycle to one minute .Voltage swell is always caused by an abrupt reduction in load. Although they can also be caused by loose neutral connection, by capacitor bank load power line switching and change in ground reference on ungrounded phases.

Dynamic Voltage Restorer (DVR) is a Custom Power Device used to eliminate supply side voltage disturbances. DVR also known as Static Series Compensator maintains the load voltage at a desired magnitude and phase by compensating the voltage sags/swells and voltage unbalances presented at the point of common coupling.The DVR can be classified as follows:

i. An Injection Transformer / Booster transformer
ii. Filter
iii. Storage Device
iv. Voltage source Converter (VSC)
v. Control unit

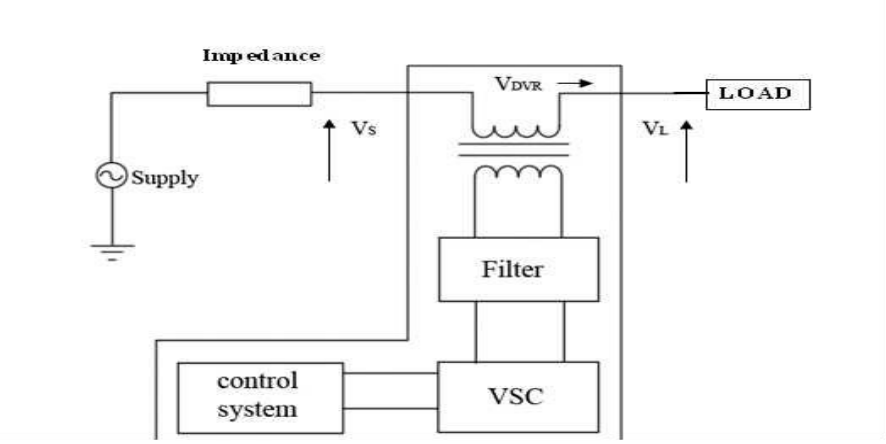

Fig no.1 Schematic diagram of DVR

i. AN INJECTION TRANSFORMER/ BOOSTER TRANSFORMER

An ac electrical energy is converted from one ac voltage level to another level at same or constant frequency by transformer. It is a specially designed transformer which set about to bound the coupling of noise and transient energy from the primary side to the secondary side.

It connects the DVR to the distribution network by HV windings and transform and couples the injected compensating voltage which is missing voltage generated by voltage source converters to the incoming supply voltage. It also serves the purpose of separating the load from the system.

ii. FILTER:

The main aspire of filter is to keep the harmonics voltage substance which is generated by the VSC to the allowable level. The semiconductor device having non linear characteristics which cause distortion associated with harmonics. And now a day's semiconductor devices are broadly used in industries. Filter is connected across the inverter side having a advantage of being nearer to harmonics source thus high order current are prevented to diffuse into the series injection transformer.

LC Passive filter:A simple output filter composed of passive elements such as a resistance R, Inductance L & a Capacitance C. LC filter is used to trim down harmonics components of waveform generated by the converter to their permissible limits. Its output is sinusoidal with low total harmonics distortion.

iii. STORAGE DEVICE:

The task of energy storage device is to supply the energy to VSI which converts the alternating quantity and fed to the Injection transformer. Regularly used storage device is battery.

iv. VOLTAGE SOURCE CONVERTOR:

It is a Power Electronic device consists of a switch and a storage device. VSC is used to generate the temporarily supply voltage at any required frequency , magnitude and phase angle during or after fault which is missing voltage. In DVR it temporarily replaces the supply to generate missing voltage during voltage sag. IGBT is used as switching device because of fast response.

v. CONTROL UNIT:

Control unit is used to detect the presence of sag and swell in the system. In other word, It is considered as a monitor of the load bus voltage. When control unit sense sag voltage then suddenly it injected the missing voltage after determining its magnitude & its Phase Value. And during Swell it stores the voltage which is more than rated voltage.

Modes of Operation:

*Protection mode: I*f the system parameters exceeds from its reference or preset value on load side so system will be isolated. When the system observes any disturbance or detects any fault or abnormal condition bypass switch removes the DVR from the system to protects from damages and it protects from over current also and provide different path to current.

StandBy mode (V_{DVR} =0):In StandBy mode the DVR may either go into short circuit operation or inject small voltage to compensate voltage sag. The injection transformer's low voltage winding is shorted through the voltage source converter. There is no switching of semiconductor occurs full load current pass through the primary winding. Solid state bypass switches are used to perform short circuit operation.

Injection Mode (V_{DVR}< 0):In injection mode DVR injects a compensating voltage through injection / booster transformer after disturbance of required phase and magnitude. The primary function of DVR is compensating voltage disturbances on distribution system. To attain compensation , three phase ac voltages are injected in series with required magnitude ,phase angle and wave shape. The types of voltage sags , load conditions and power rating of DVR will determines the possibility of compensating voltage sag.

2. COMPENSATION METHOD OF RELIAZATION

To compensation the sag voltage in realistic application, a discrete PWM (Pulse Width Modulation) technique is used. It is extremely popular method of high switching frequency in industrial application. The main function of PWM is to keep a constant voltage magnitude of sensitive load under system disturbance. They only measures rms voltage.When there is voltage sag then an error occurs which is observed by PI controller and based on error value PWM generates pulses to the IGBT switch in VSI.

PI Controller observes the error produced by the difference between the fault voltage & the supply voltage. Then it generates a required δ angle to drive the error to zero. With this phase angle a control voltage is generated. The magnitude of control voltage is depends on phase angle δ. The phase angle is proportional to the degree of disturbance. The generated voltage is called the controlled voltage.

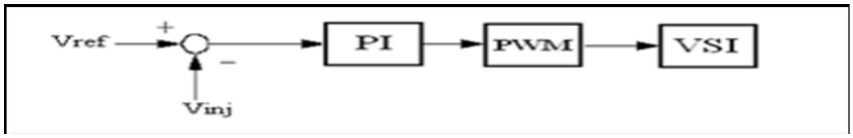

Fig. No. 2 Pi Controller Block Representation

Phase modulation: It is used in many application to carry both analogue and digital signals. Maintain the amplitude of the signal constant the phase is varied to bring the required information or signal. The modulation angle δ is generated by phase modulation. And δ angle is applied to PWM generators in phase A ,where as the angle for phase B & C are shifted by240° or -120° & 120° respectively

$V_A = \sin(\omega t + \delta)$

$V_B = \sin(\omega t + \delta - 2\pi/3)$

$V_C = \sin(\omega t + \delta + 2\pi/3)$

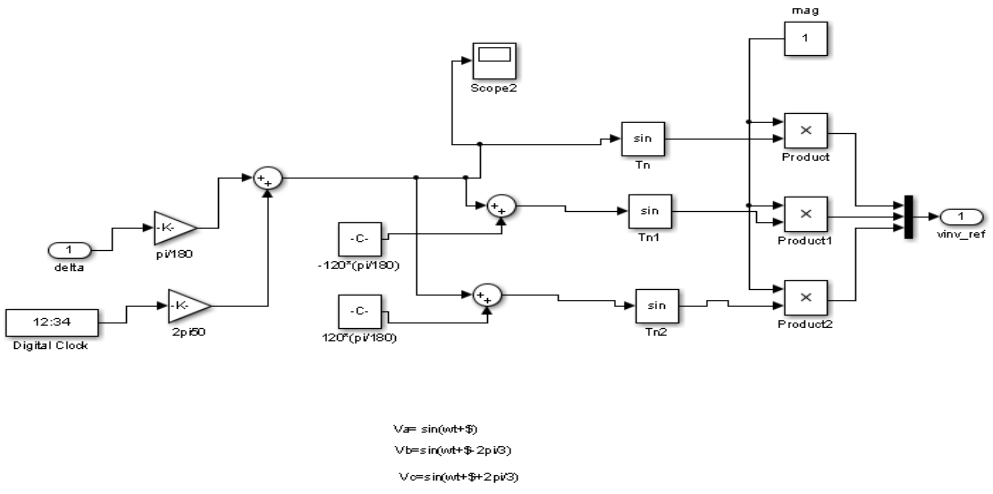

Fig.no. 3 Phase Modulation of the Control Angle δ

Three phase sequence analyzer: This block outputs the magnitude and segment of positive, negative and zero balance & unstable signals. Discrete form of this block specifies the magnitude and phase.

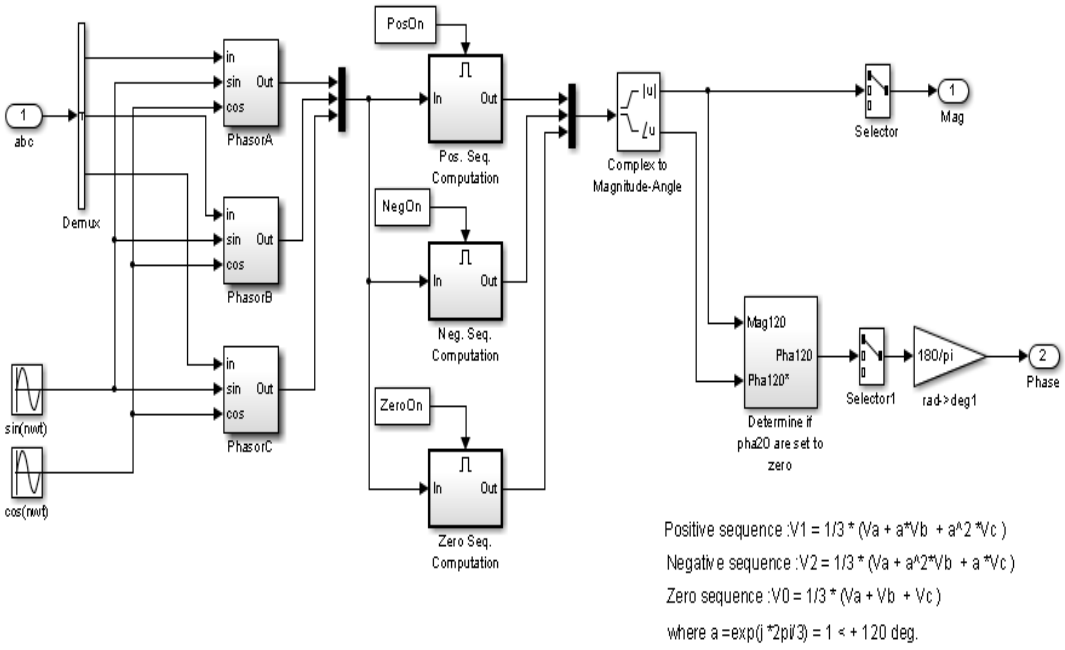

Fig.no.4 Phase Sequence Analyser

3. SIMULATION OF TEST SYSTEM OF SAG & SWELL

In this paper, DVR system connected to the distribution system which presents both with DVR & without DVR condition for sags/swells.

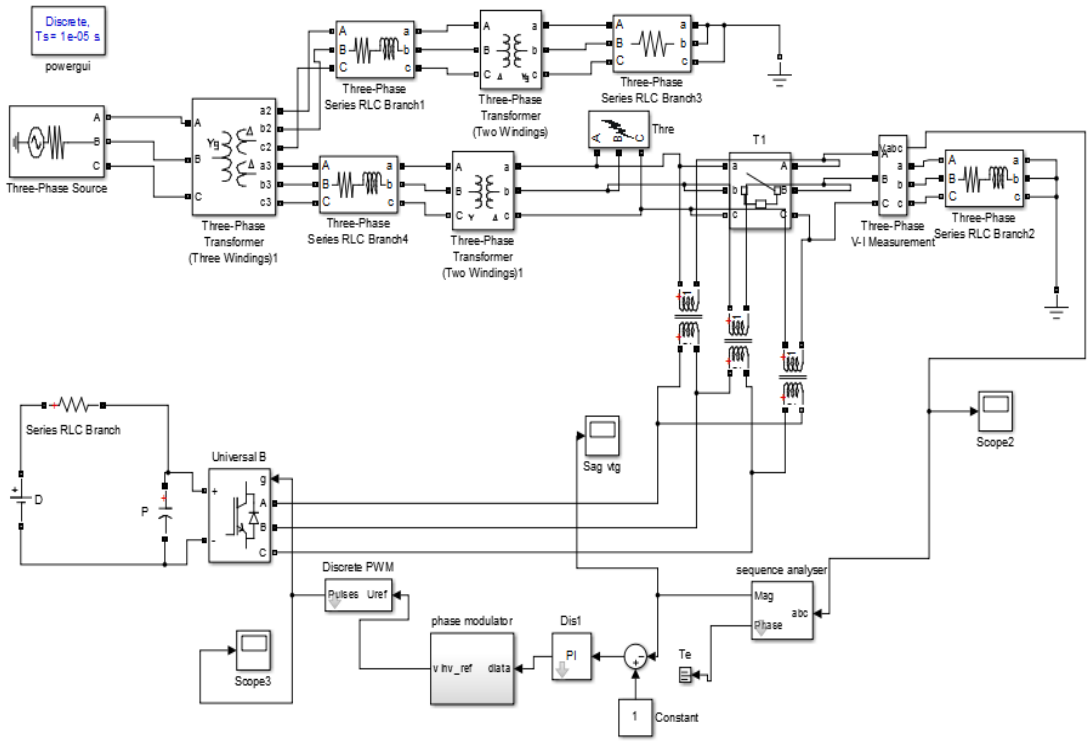

Fig no.5 Simulation Circuit of Sag generation and compensation using DVR

This figure represents the sag generation which is compensated by DVR. When fault occurs in the system then circuit breaker is open circuited and protect the system from damage and connect the DVR through injection transformer to the bus. The required voltage is generated by PWM generator which is energised by DC source. Now the injected voltage is inserted to the load by injection transformer to protect from damages.

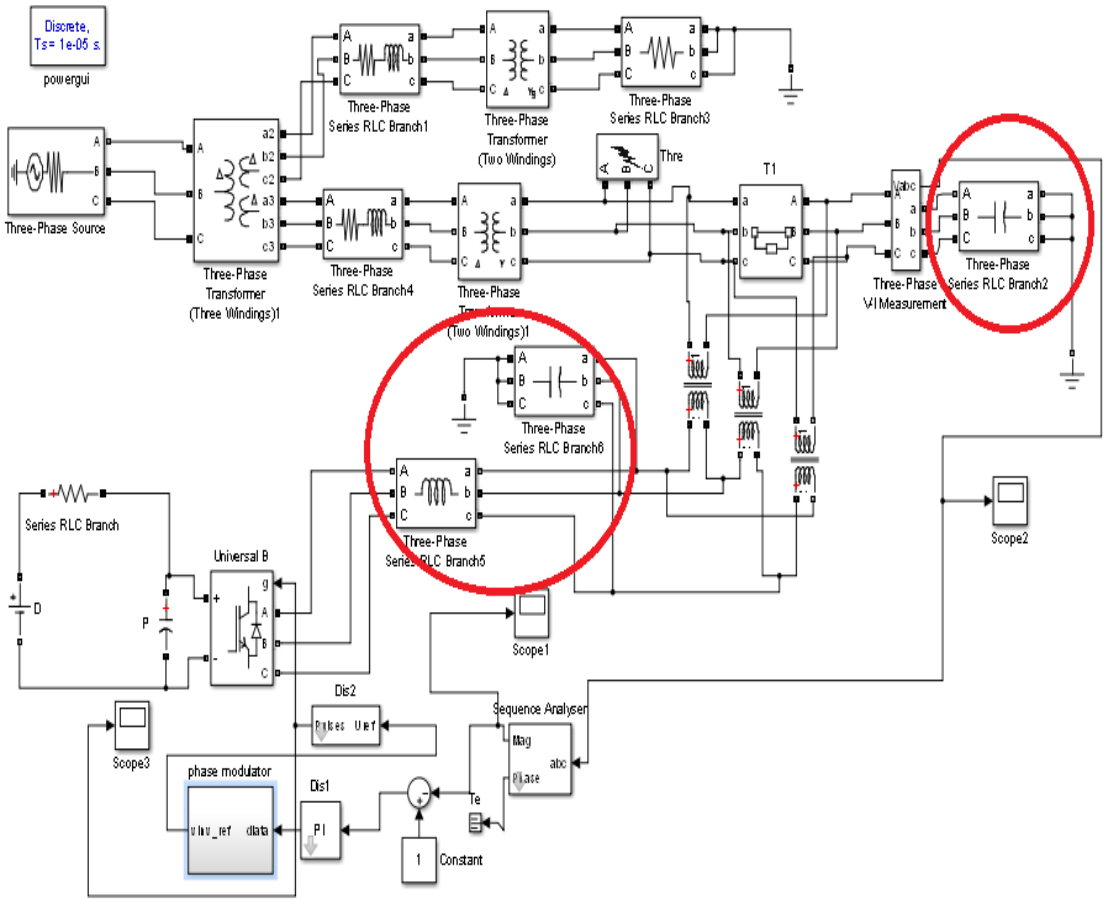

Fig.no.6 Simulation Circuit of Swell generation and compensation using DVR

This figure represents the swell generation which is compensated by DVR. When fault occurs because of capacitor bank in the system then circuit breaker is open circuited and protect the system from damage and connect the DVR through injection transformer to the bus. Now in swell there is a momentary increase in voltage so it can be stored by capacitor. The stored voltage is analysed by error detection of PI controller. The LC filter is connected across the circuit to reduce the harmonics of the system.

4. SIMULATION RESULT

The first simulation done with no DVR and a three phase fault is applied to the system at a point of .44 fault resistance. And the second simulation is carried out at above same scenario but a DVR is now introduced at a load side to compensate the voltage sag occurs due to fault.

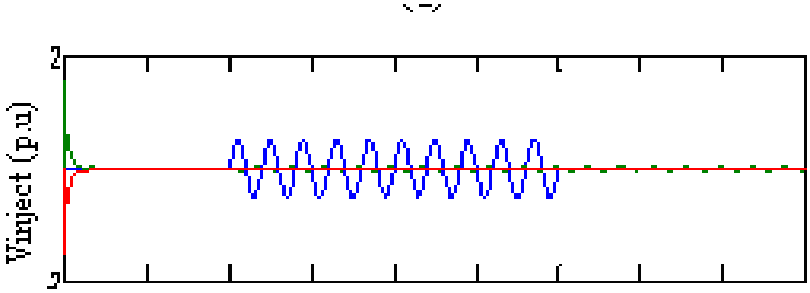

Fig no.7 Injected voltage

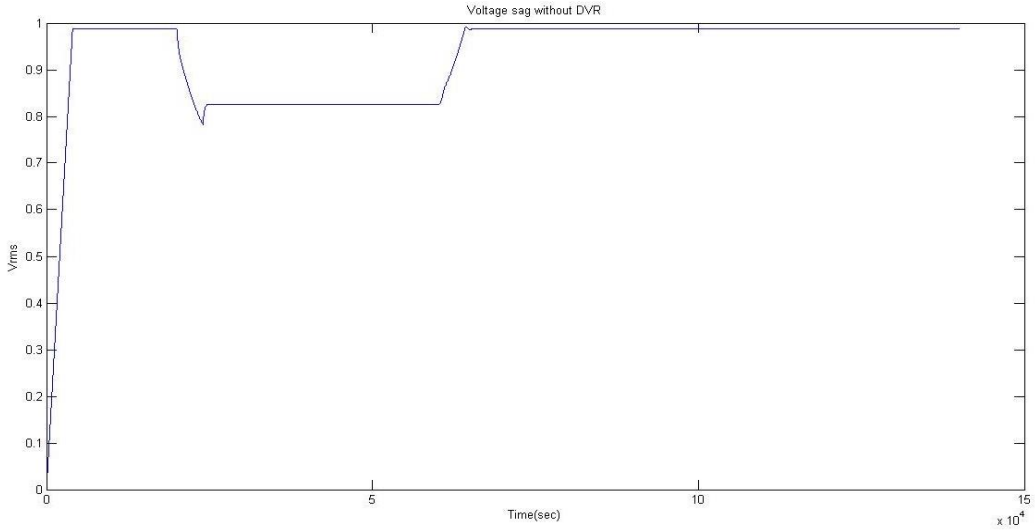

Fig no.8 Sag Voltage Vrms at load point with three phase fault .66 fault resistance without DVR

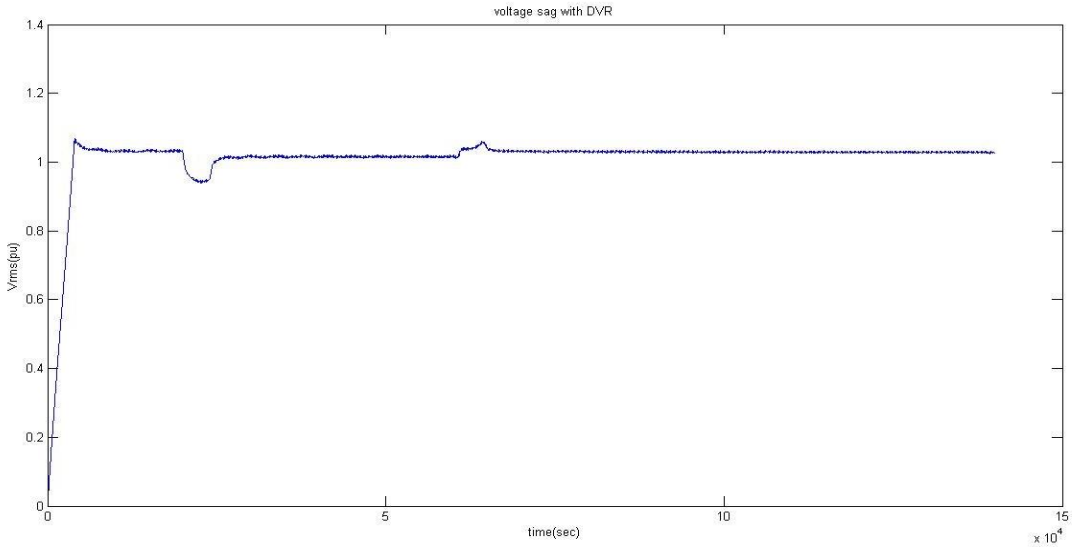

Fig no. 9 Sag Voltage Vrms at load point with three phase fault 0.66with DVR

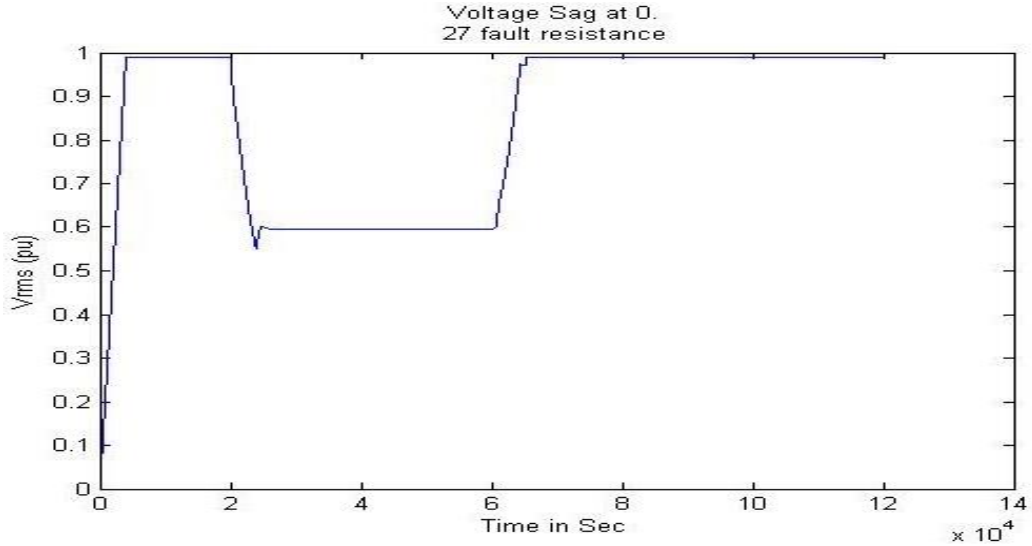

Fig no. 10 Sag Voltage Vrms at load point with three phase fault.27 fault resistance without DVR

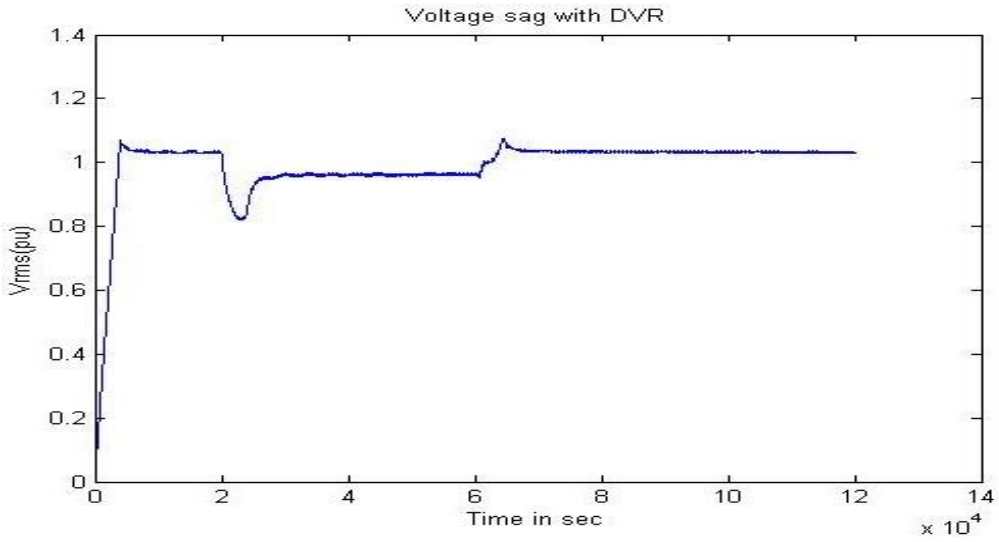

Fig no.11 Sag Voltage Vrms at load point with three phase fault.27 fault resistance with DVR

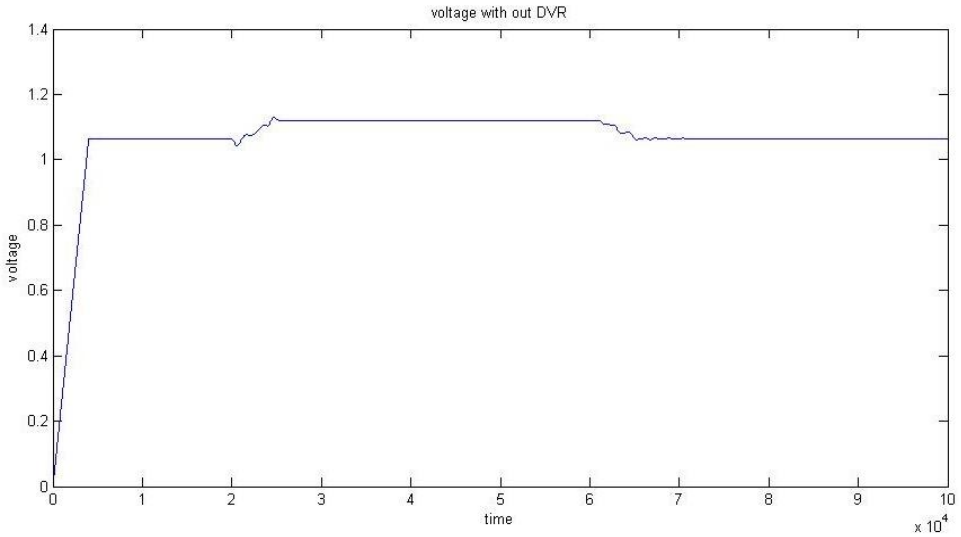

Fig no.12 Swell Voltage Vrms at load point with three phase fault without DVR

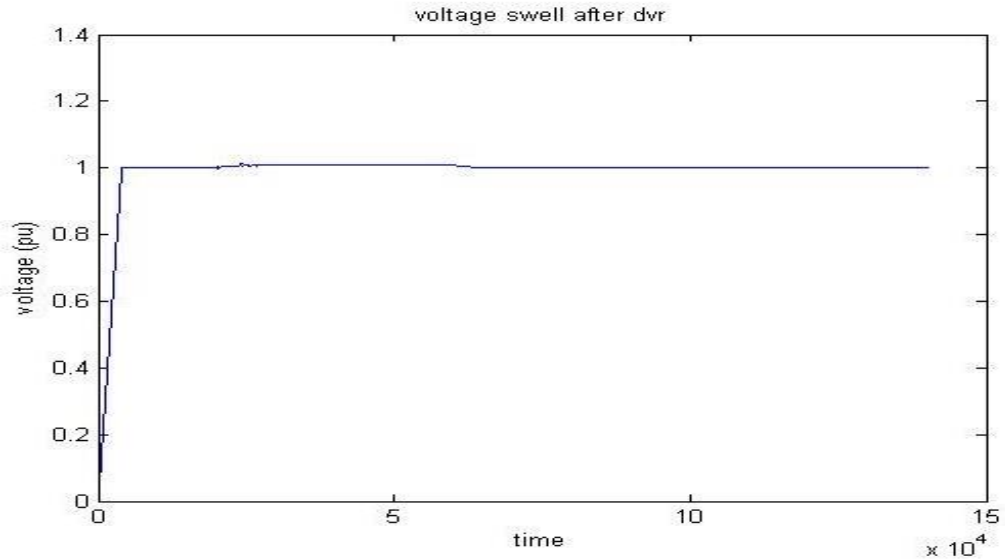

Fig no. 13 Sag Voltage Vrms at load point with three phase fault with DVR

5. CONCLUSION

This thesis has presented the power quality problems of voltage sags and swells. Compensation technique of DVR is presented to solve the problem of distortion. The design & simulation of DVR was presented .The aim of this thesis is to compensate the voltage sag and swell problem. For any fault situation of voltage sag this method is effective. Modelling & Simulation was done by using MATLAB. Here DVR acts as an additional energy source also. The DVR is smaller in size, economical, fast, flexible and efficient. This simulation shows DVR provides better regulation. In this PI controller is used to composite the error. The efficiency and the effectiveness in voltage sags compensation showed by the DVR makes it an interesting power quality device compared to other custom power devices.

6. FUTURE SCOPE

1. The DVR should be tested examine by connecting the DVR into a real network where the efficiency & accuracy can be better evaluated.

2. The performance comparison of DVR done by comparing fuzzy controlled DVR, neural network controller DVR, ANN based controller of DVR , Particle Spam Optimization (PSO) based DVR controller.

3. Multi-level DVR can be looked for future work.

4. For interconnecting the renewable source to grid DVR should be used.

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