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Compensation of Sag and Swell Voltage by using Dynamic Voltage Restorer During Single Line to Ground and Three Phase Fault

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Abstract: *Modern power system is complex power network. The main concern to the customer is to provide reliable and quality of power supply but due to use of sophisticated equipment based on semiconductor devices, quality of power may poor. Poor power quality problem causes sag and swell, harmonics in the system in the system. To overcome this problem DVR is used. The condition of voltage sag caused by various faults. This work represents simulation modelling and analysis of DVR system of sag and swell during single line to ground and three phase fault. The controlling of DVR and generation of gate pulses for VSI can be done by SRF controller. In addition performance of DVR is examined under various faults with sag and swell voltage condition using MATLAB/ SIMULINK*

Keywords*: DVR, voltage sag,voltage swell, In Phase compensation, Battery Energy storage, SRF controller*

I. Introduction

Power quality disturbances are voltage sag, voltage swells, interruptions, harmonics and transients. These power quality related problem have become important issue. Many solution have been proposed to address power quality problem. The most attractive and flexible way to use power electronics based devices such as DSTATCOM, DVR, UPS,UPQC,UPFC etc. and usually they are called custom power devices. Among this custom power devices DVR is most flexible and reliable method to overcome voltage related PQ problem as compared with other.

Voltage distortion might occur due to power system harmonics. Voltage sag is widely recognized as most severe issue affecting power quality. IEEE standards 1159-1995 defines voltage sag as a RMS variation with magnitude between 10% to 90% of nominal voltage and duration ranging from 10 ms to 60 sec. The condition of voltage sag caused by various faults. The voltage sag has two type i.e. symmetrical and unsymmetrical. Three phase fault produces symmetrical sag and others like single line to ground fault, phase to phase fault, double line to ground fault are due to lightening produces unsymmetrical sag.

Fault on the system can also causes swell i.e. increase in voltage than input side voltage. Time duration for swell is switching of large capacitor bank. And it is observed only in three phase fault.

In order to improve power quality problem with fault analysis, DVR is used with new control strategy for achieving maximum benefit by eliminating or mitigating sag/ swell with the application of DVR. There is maximum utilization of distribution voltage, and power supply by flexibly changing distribution configuration after the clearance of fault.

1.1 Objectives

The various objectives formulated and positioned for observation in the paper are:
1) To study and analyze the complete distribution system and their problem.
2) To develop mathematical model, DVR system, voltage sag, swell, controller with output.
3) To examine and analyze proposed model with and without DVR system using MATLAB Simulink.
4) To study the condition of developed DVR system for different case like voltage sag, swell, during Fault and clearing fault

II. DYNAMIC VOLTAGE RESTORER

2.1 Propitious choice of DVR

There are numerous reasons why DVR is preferred over other devices:
1)Although ,SVC predominates the DVR but the latter is still preferred because the SVC has no ability to control active power flow.

2) DVR is less expensive compared to the UPS.
3) UPS also needs high level of maintenance because it has problem of battery leak and have to be replace as often as five years.
4) DVR has a relatively higher energy capacity and costs less compared to SMES device.
5) DVR is smaller in size and cost less compared to DSTATCOM
6) DVR is power efficient device compared to the UPS

2.2 Location of DVR

DVR is generally installed in the utility primary distribution system between the supply and critical load feeder at the point of common coupling (PCC*)*.It is a series connected solid state device.DVR was first built in US for the Electric Power Research Institute (ERPI) by Westinghouse. To protect an automated yarn manufacturing and weaving factory. It was first installed in 1996 on 12.47 KV Duke power company grid system located in Anderson, South Carolina. Fig 2 shows DVR location.

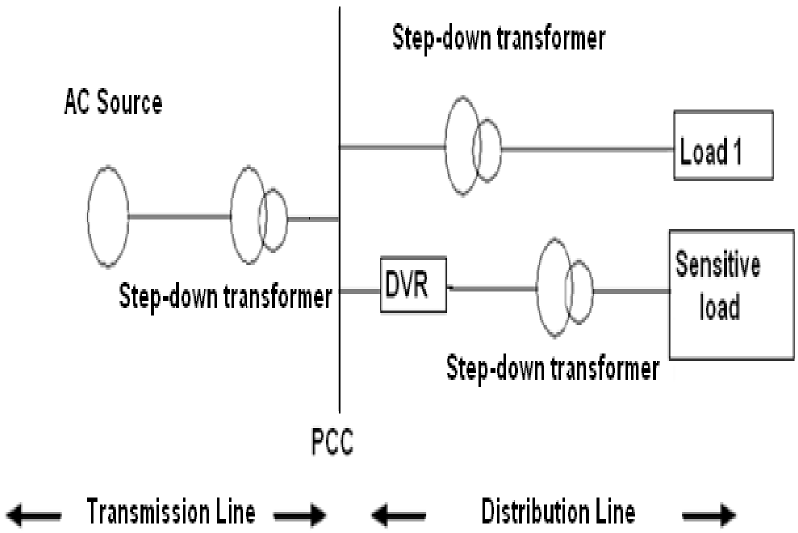


Fig. 1 *Location of DVR*

2.2 Basic Principle of DVR

DVR is a method of overcoming voltage sags and swell that occur in electrical power distribution. These are a problem because spikes consume power and sags reduce efficiency of some devices. DVR saves energy through voltage injections that can affect the phase and wave shape of power being supplied.

The basic principle of dynamic voltage restorer is to inject a voltage of the magnitude and frequency necessary to restore the load side voltage to the desired amplitude and waveform, even when the source voltage is unbalanced or distorted. The DVR can generate or absorb independently controllable real and reactive power at the load side. In other words, the DVR is a solid state DC to AC switching power converter that injects a set of three phase AC output voltages in series and synchronicity with the distribution and transmission line voltages.

The source of the injected voltage is the commutation process for reactive power demand and an energy source may vary according to the design and manufacturer of the DVR, but DC capacitors and batteries drawn from the line through a rectifier are frequently used.

The amplitude and phase angle of the injected voltages are variable, thereby allowing control of the real and reactive power exchange between the dynamic voltage restorer and the distribution system. DVR is linked in series between a distribution and a load that shown in fig 2

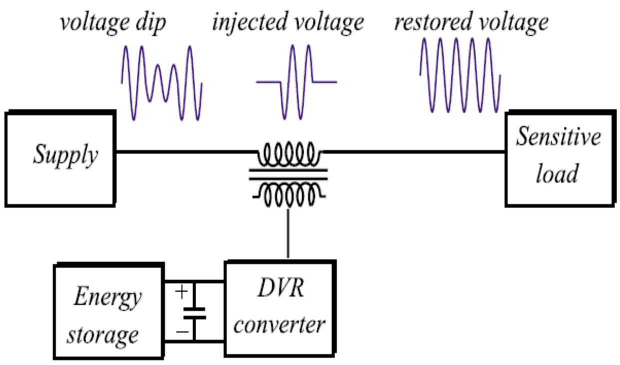


Fig.2 Operating principle of DVR

2.3 Basic configuration of DVR

The general arrangement of DVR is composition of transformer, filter, storage devices, voltage source converter, DC charging unit. Control scheme which is shown in fig 3

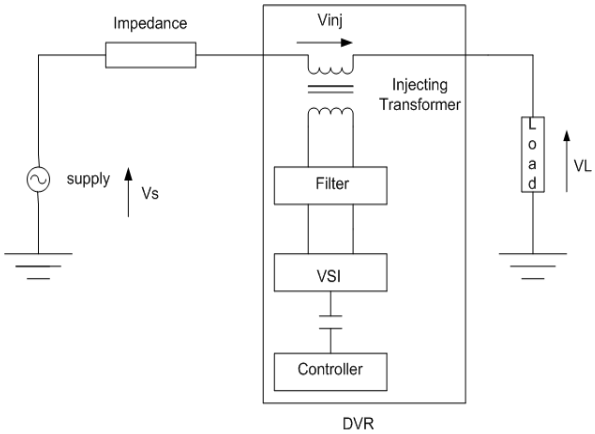


Fig .3 Schematic of DVR

The conventional DVR consist of:
1.Series injection transformer: Basic function of injection transformer is to increases voltage supplied by filtered VSI output to desired level while isolating DVR circuit from distribution network.
2. Energy storage device: The energy storage such as capacitor, battery is responsible to supply energy source in DC form .Energy source may vary according to design and manufacturer of DVR. Energy storage consist of two type form. One using stored energy to supply the delivered power and other having no significant internal energy storage nut instead energy is taken from faulted grid supply during sag.
3.Filter: Filter is used to eliminate unwanted harmonics components generated in VSI section.
4. Inverter: The variable output voltage is achieved by voltage source inverter (VSI). Solid state semiconductor devices with turn on capability are used in inverter circuit.

2.4 Compensation Techniques

Voltage injection methods depend on DVR power ratings, various conditions of load, and different types of voltage sag and swell. There are 4 types of DVR voltage injection methods are as follow
1) Pre sag compensation method
2) In phase compensation method
3) Phase advanced compensation method
4) Energy optimization method

II. Mathematical Modelling Of Dvr System

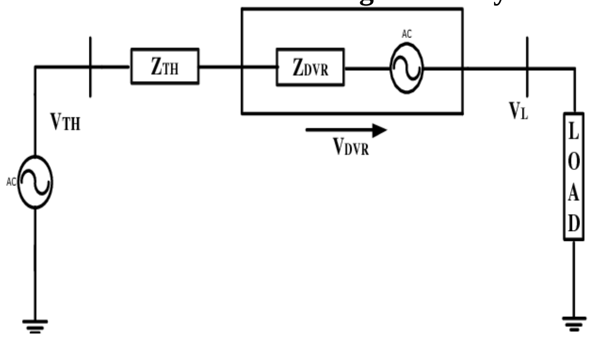


Fig.4 Equivalent circuit of DVR

Fig 4 shows equivalent circuit of DVR.The system impedance Z_{TH} depends on the fault level of the load bus.When the system voltage V_{TH} drops , the DVR injects a series voltage V_{DVR} through the injection transformer so that the desired load voltage magnitude V_L can be maintained. The series injected voltage of the DVR can be written as

$$V_{DVR}=V_L+Z_{TH}\ I_L-V_{TH} \qquad (1)$$

Where

V_L :The desired load voltage magnitude

Z_{TH} :The load impedance

I_L:The load current

V_{TH} : The system voltage voltage during fault condition

The load current I_L is given by,

$I_L=[\frac{PL+J*QL}{VL}]$ (2)

When V_L is considered as a ref equation can be written as,$V_{DVR}<\alpha= V_L<\Theta+Z_{TH}\ I_L< (\beta-\Theta)- V_{TH}<\delta$ (3)

Here, α,β,δ are angles of V_{DVR}, Z_{TH}, V_{TH}, respectively and ϴ is the load power angle

$$\Theta= \tan^{-1}(\frac{QL}{PL})(4)$$

The complex power injection of the DVR can be written as

$$S_{DVR} = V_{DVR}\ I_L^*(5)$$

III. Proposed Methodology

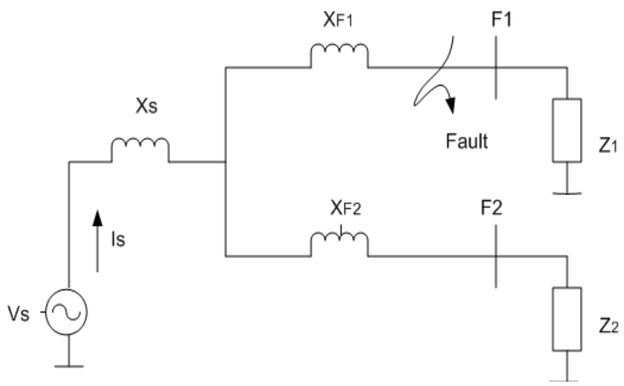


Fig.5 proposed system circuit without DVR

Fig 5 shows the equivalent circuit of the system represented by voltage source Vs and source reactance Xs. It is feeding two equal loads represented by$Z_1$and Z_2 through feeder F_1 and F_2 ,where Z represents the load impedance and X_F the magnitude of feeder reactance. Is is the supply current. In normal operation , the pre sag voltage at the point of common coupling(Vpresag-sag) and the supply current are given as follows

$$Vpresag=Vs- IsXs \quad (6)$$

$$Is = I_1+I_2= \frac{Vpresag}{Z1+XF1}+ \frac{Vpresag}{Z2+XF2} \quad (7)$$

When the fault occur on F_1 ,a high current will flow through it as well as the supply current.During such a case, the supply current Is,fault and the voltage at the point of common coupling during sag (Vsag) will be given as follow

$$Vsag = Vs - I_{s,fault}Xs$$

$$I_{s,fault} = \frac{Vsag}{XF1} + \frac{Vsag}{Z2+XF2} \quad (8)$$

Accordingly , the voltage across the adjacent feeder F_2 will be reduced due to the excesive voltage drop that will appear across the source reactance Xs. Hence, a DVR represented by a controlled voltage source V_{DVR} will be inserted between the point of common coupling and the sensitive load Z_2, as shown in fig 6

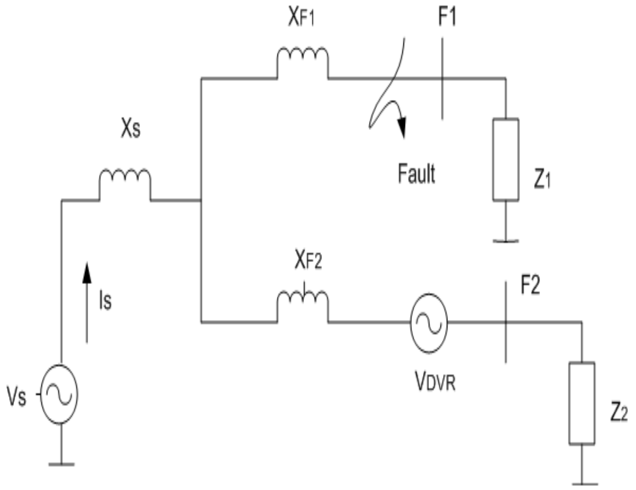
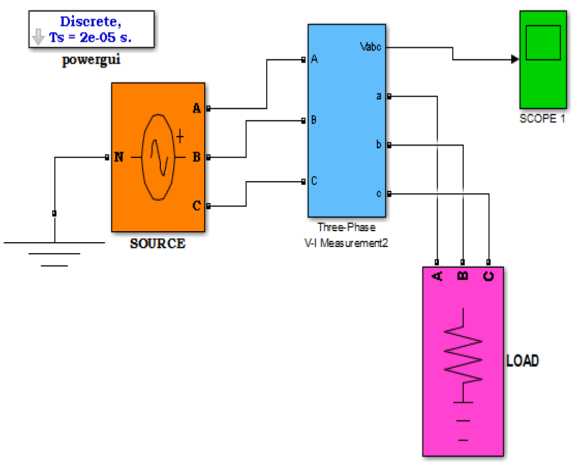


Fig.6 DVR injection circuit with fault

IV. Simulation Modelling For Sag And Swell Without Dvr



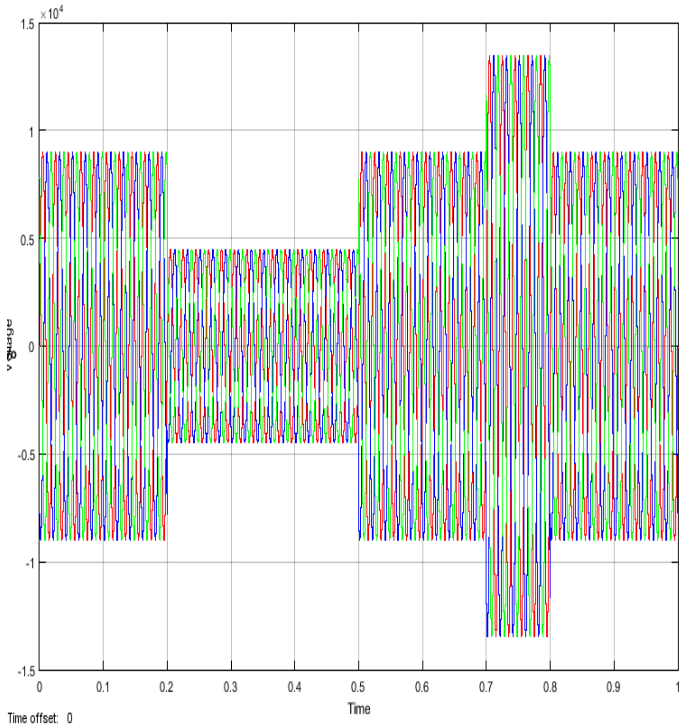


Fig. 8 simulation results for voltage sag and swell without DVR

V. Modelling Of Proposed System Configuration

Fig. 9 shows MATLAB model of DVR Connected in Distribution System with the occurance of faiult. The Test system consist of source feeding two parallel feeders or two transmission lines through a two windind transformer.

Under normal condition load voltage is same as source voltage.Voltage disturbance is created by aplying fault on first feeder at the load side .Due to this voltage dip with swell is occur on the source as well as load side. To overcome this sag swell DVR is inserted in second feeder.SRF controller is used for control purpose. Here DVR ic connected to distribution system using injection transformer.The injected voltage that is produced by DVR in order to correct the load voltgaes and the load voltages maintain at the constant level.
Fig.7 Simulation circuit for voltage sag and swell without DVR

The system consist of voltage of 1 PU, 50Hz source with 2 MW 3 phase 1KV Resistive load which is shown in fig.7

Fig8 shows three phase voltage waveform under fault condition without DVR. From the fig. 8 it is observed the sag is created for a time duration of 0.2 to 0.5 sec. and swell is occur at 0.7 to 0.8 sec. Now the function of DVR would be to inject compensating voltage, which would result in fairly constant voltage across the load terminal, with the use of fast acting power electronics converters, DVR is capable to inject voltage for such a small duration of few cycles.

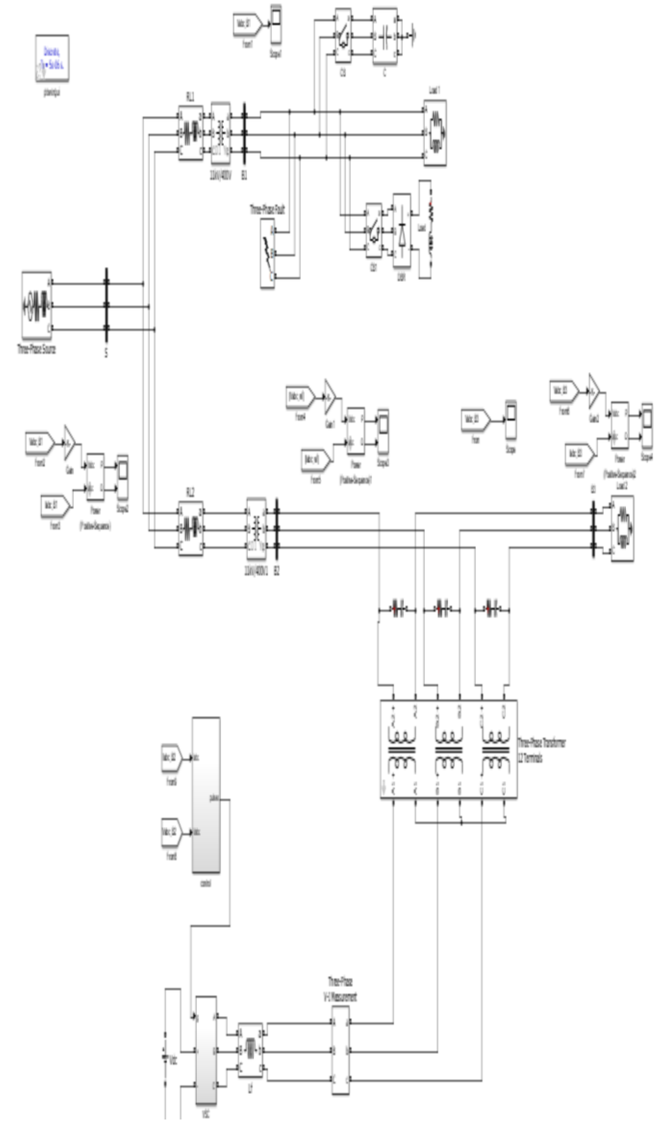


Fig.9 MATLAB Model of System Configuration of DVR with Fault

VI. Control Scheme Of Dvr

The control strategy of DVR is as shown in fig 10. SRF theory is used for control of DVR. Volatge at PCC are converted to rotating reference frame using parks transformation .The dqo frame express voltage error and phase shift information as instantaneous space vector with start and end times.Voltage is converted from abc reference frame to dqo reference.The harmonic and ocillatory componenets are elimanated using low pass filter. In order maintain DC bus volatge of capacitor,a PI controller is used at DC bus voltage. The ampliude of load voltage terminal V_L is controlled to its reference voltage V_L* using another PI controller. The output of PI controller is considered as a reactive componenet for voltage regulation of load terminal voltages. Amplitude of load voltage V_L at PCC is calculated from AC voltages. Reference load voltages in abc frame are obtained from reverse parks transformation.The error between sensed load voltages and reference load voltages are used over a controller to generate gating pulses to VSI of DVR

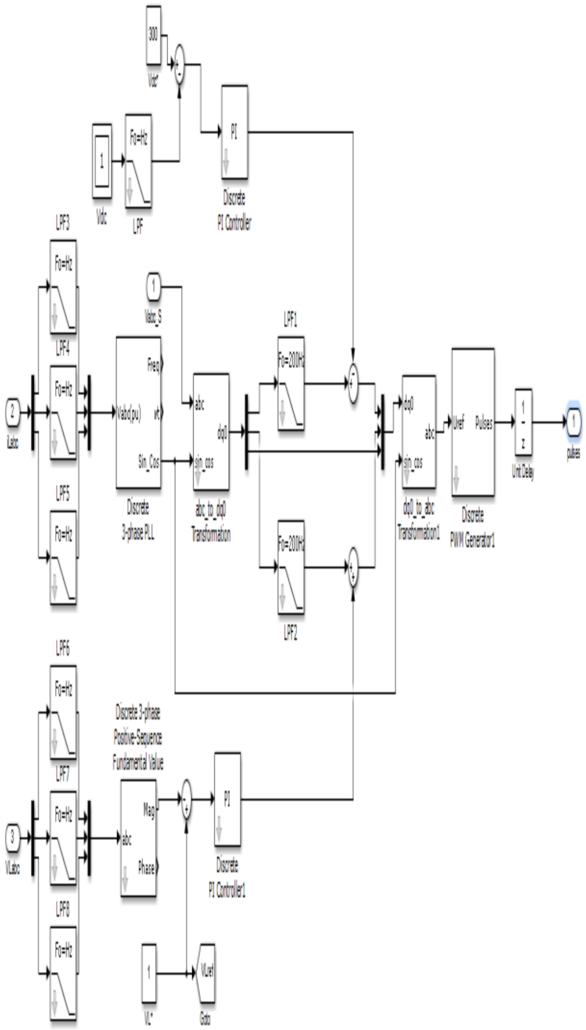


Fig 10. Control Scheme

VII. Simulation Results Of Proposed System

6.1 Three Phase Fault

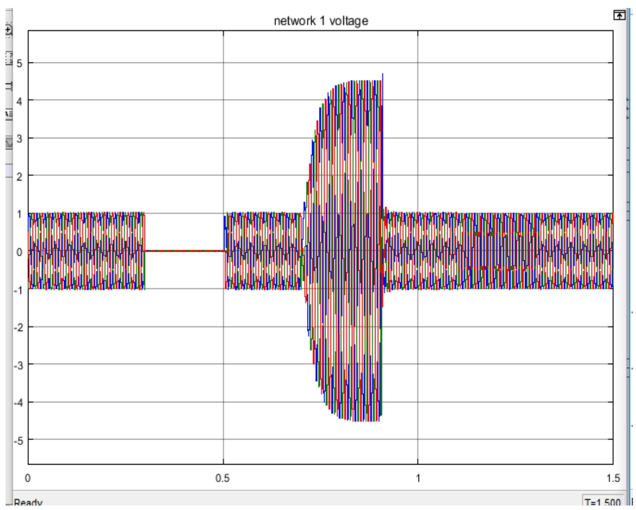


Fig.11. Three phase sag swell a) source voltage with Fault

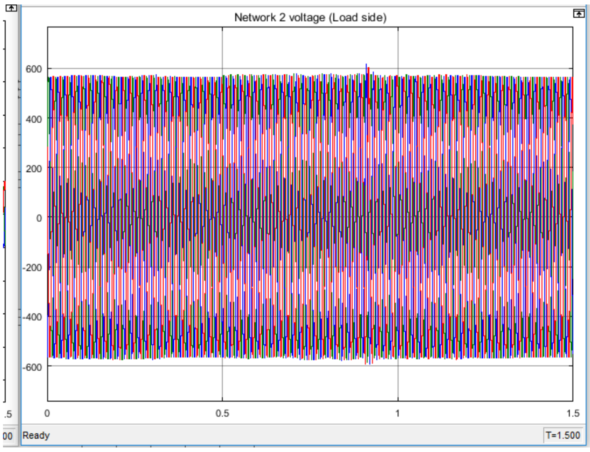


Fig. 11 Three phase sag swell b) Load voltage with DVR

6.2 Single Line to Ground Fault

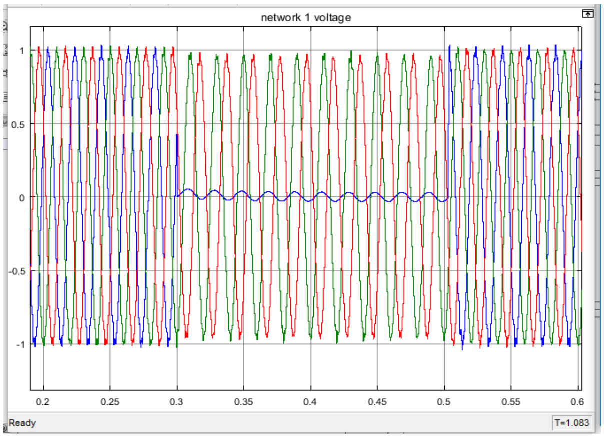


Fig.12 Single phase sag a) source voltage with Fault

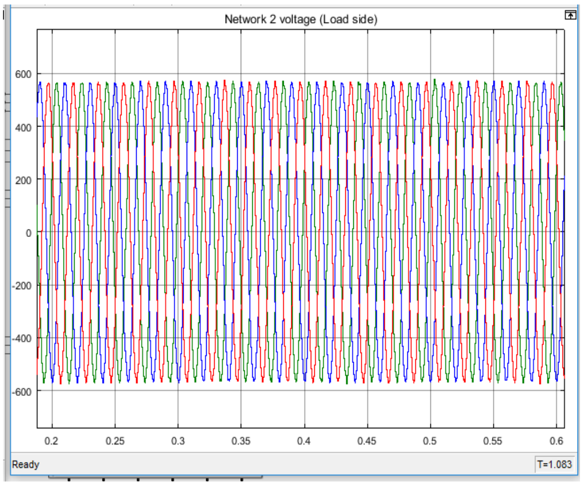


Fig. 12 Single phase sag b) load voltage with DVR

6.3 Double Line to Ground Fault

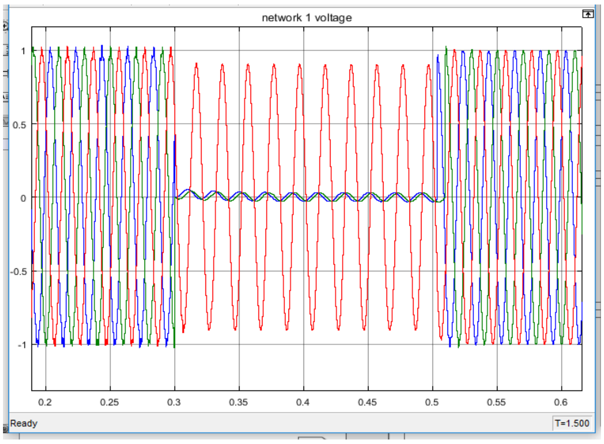


Fig. 13 Double Phase sag a) Source voltage wit Fault

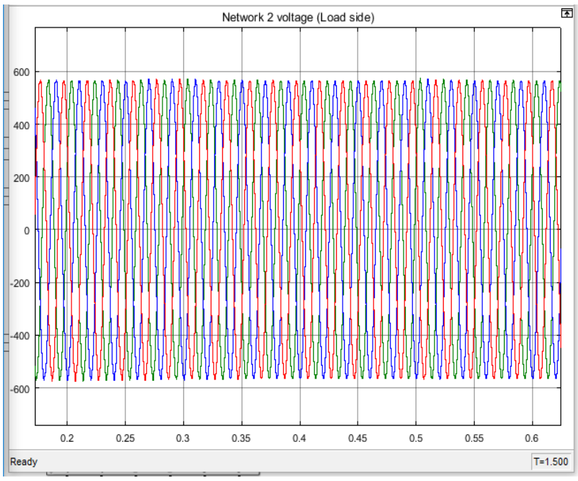


Fig.13 Double Phase sag b) Load Voltage with DVR

Fig11 (a) showswaveform of three phase sag swell source voltage with fault.During the fault period the magnitude of voltage decreases causes sag and due to energization of capacitor bank voltage is increses causes swell.This voltages are needed to be compensated to get the desired voltage at the load or to get proper operation of load connected to system.

The simulation results of fig 11 (b) shows the load voltage waveform when DVR is introduced at the load side to compensate the voltage sag and swell occur due to three phase fault. From this it is clearly observed that voltage waveform obtained after compensation is constant.

Fig 12(a) shows the source voltage when single line to ground fault applied on phase ‘A’.Fig (b) shows the load voltage after compensation.It is seen from the fig 13 during SLG fault, voltage at the faulted line reduces to 200 V from 600V i.e. voltage sag occurs at phase ‘A’.When DVR is connected to the line, the load voltage becomes equal to desired voltage.

Fig 13 (a)Show source voltage when double line to ground fault is applied on phase ‘A’ and’B’ When the fault is occur voltage dip is observed in two phases of the system. Fig. 13 (b) shows that load voltage is compensated to greater extent.

It is observed tfrom the above figures that due to fault the load voltage reduces to a very low value.If we compare the waveforms of source voltage with fault and load voltage with DVR, we observed that when the DVR is in operation the Voltage dip is compensated almost completely and the RMS voltage at the sensitive load is maintained at desired value.i.e. near about 900 v.The DVR is designed to supply or difference in voltage under different fault conditions i.e. until the fault is removed from the network.

VIII. Conclusion

It is concluded that it became easier to construct the large distribution network and analyze the performance of DVR under different fault conditions. The controlling of DVR is done with SRF controller. The simulation results clearly showed the performance of DVR in improving the quality of voltage due to fault in distribution system. DVR is one of the fast and effective custom power device has shown an efficiency and effectiveness on voltage sag and swell compensation, hence it makes DVR to be effective power quality improvement device. This has been proved through simulation implementation. The proposed work showed that in case of SLG and three phase fault voltage compensation took place for almost 95%

Besides SRF controller, fuzzy controller can also be used as a DVR controller. In future, the multilevel concept of inverter will be prominent choice for power electronic system mainly for medium voltage operation.

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