Power Quality Improvment Using DVR (Dynamic Voltage Restorer)

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Abstract— A Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure or a mis-operation of end user equipments. In order to maintain the power system quality some devices are used (stated below) which will absorb and provide reactive power to mitigate voltage sag, swell, interruption and improve power factor in various conditions. Utility distribution networks, sensitive industrial loads and critical commercial operations suffer from various types of outages and service interruptions which can cost significant financial losses. With the restructuring of power systems and with shifting trend towards distributed and dispersed generation, the issue of power quality is going to take newer dimensions. Thus improvement of power quality is a serious question, it is very vital to take positive steps in this direction. There are various which can be used to improve the power quality for the transmission line like, SVC (static var compensator), DSTATCOM (distributed static compensator), DVR (dynamic voltage restorer). Dynamic Voltage Restorer can provide the most cost effective solution to mitigate voltage sags and swells that is required by customer. The Dynamic Voltage Restorer (DVR) is a rapid, flexible and resourceful solution to power quality problems.

Keywords: Power Quality, DVR, voltage sags/swells, VSI

I. INTRODUCTION

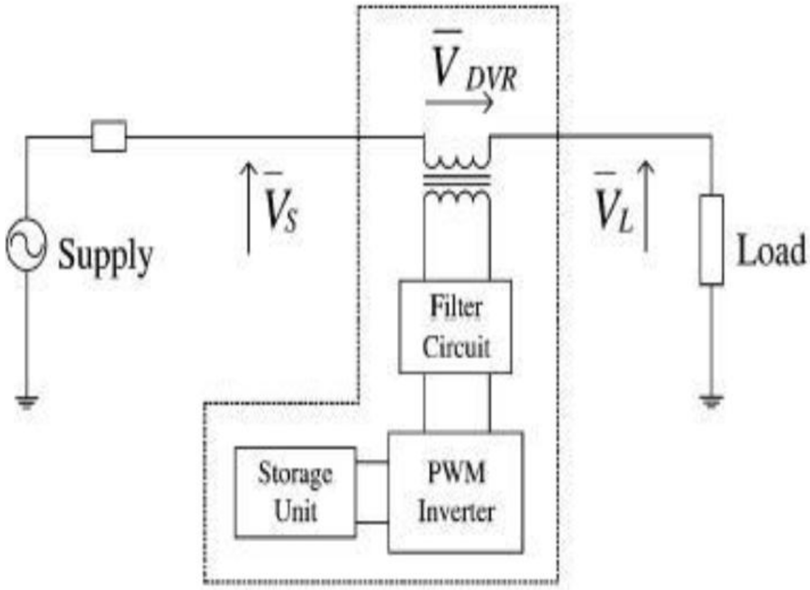
Power distribution systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency [1] however, in practice, power systems, especially the distribution systems, have numerous nonlinear loads, which significantly affect the quality of power supplies. As a result of the nonlinear loads, the purity of the waveform of supplies is lost. This ends up producing many power quality problems. Apart from nonlinear loads, some system events, both usual (e.g. capacitor switching, motor starting) and unusual (e.g. faults) could also inflict power quality problems[2].Power quality phenomenon or power quality disturbance can be defined as the deviation of the voltage and the current from its ideal waveform. Faults at either the transmission or distribution level may cause voltage sag or swell in the entire system or a large part of it. Also, under heavy load conditions, a significant voltage drop may occur in the system. Voltagesag and swell can cause sensitive equipment to fail, shutdown and create a large current unbalance. These effects can incur a lot of expensive from the customer and cause equipment damage [1]. The voltage dip magnitude is ranged from 10% to 90% of nominal voltage and with duration from half a cycle to 1 min and swell is defined as an increase in rms voltage or current at the power frequency for durations from 0.5 cycles to 1 min. Typical magnitudes are between 1.1 and 1.8 p.u[2].

There are many different methods to mitigate voltage sags and swells, but the use of a custom power device is considered to be the most efficient method, e.g. FACTS for transmission systems which improve the power transfer capabilities and stability margins. The term custom power pertains to the use of power electronics controller in a distribution system [10], especially, to deal with various power quality problems. Custom power assures customers to get pre-specified quality and reliability of supply. This pre-specified quality may contain a combination of specifications of the following: low phase unbalance, no power interruptions, low flicker at the load voltage, and low harmonic distortion in load voltage, magnitude and duration of over voltages and under voltages within specified limits, acceptance of fluctuations, and poor factor loads without significant effect on the terminal voltage.

There are different types of Custom Power devices used in electrical network to improve power quality problems. Each of the devices has its own benefits and limitations. A few of these reasons are as follows. The SVC pre-dates the DVR, butthe DVR is still preferred because the SVC has no ability to control active power flow [3]. Another reason include that the DVR has a higher energy capacity compared to the SMES and UPS devices. Furthermore, the DVR is smaller in size and cost is less compared to the DSTATCOM and other custom power devices. Based on these reasons, it is no surprise that the DVR is widely considered as an effective custom power device in mitigating voltage sags. In addition to voltage sags and swells compensation, DVR can also add other features such as harmonics and Power Factor correction. Compared to the other devices, the DVR is clearly considered to be one of the best economic solutions for its size and capabilities [4].

II. DYNAMIC VOLTAGE RESTORER (DVR)

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.



DVR series connected topology

The power circuit of the DVR is shown in Figure. The DVR consists of 6 major parts:-

A. Voltage Source Inverter (VSI)

These inverters have low voltage ratings and high current ratings as step up transformers are used to boost up the injected voltage

B. Injection Transformers

Three single phase injection transformers are connected in delta/open winding to the distribution line. These transformers can be also connected in star/open winding. The star/open winding allows injection of positive, negative and zero sequence voltages whereas delta/open winding only allows positive and negative sequence voltage injection.

C. Passive Filters

Passive filters are placed at the high voltage side of the DVR to filter the harmonics. These filters are placed at the high voltage side as placing the filters at the inverter side introduces phase angle shift which can disrupt the control algorithm.

D. Energy storage

Batteries, flywheels or SMEs can be used to provide real power for compensation. Compensation using real power is essential when large voltage sag occurs

E. Capacitor

DVR has a large DC capacitor to ensure stiff DC voltage input to inverter

F. By-Pass Switch

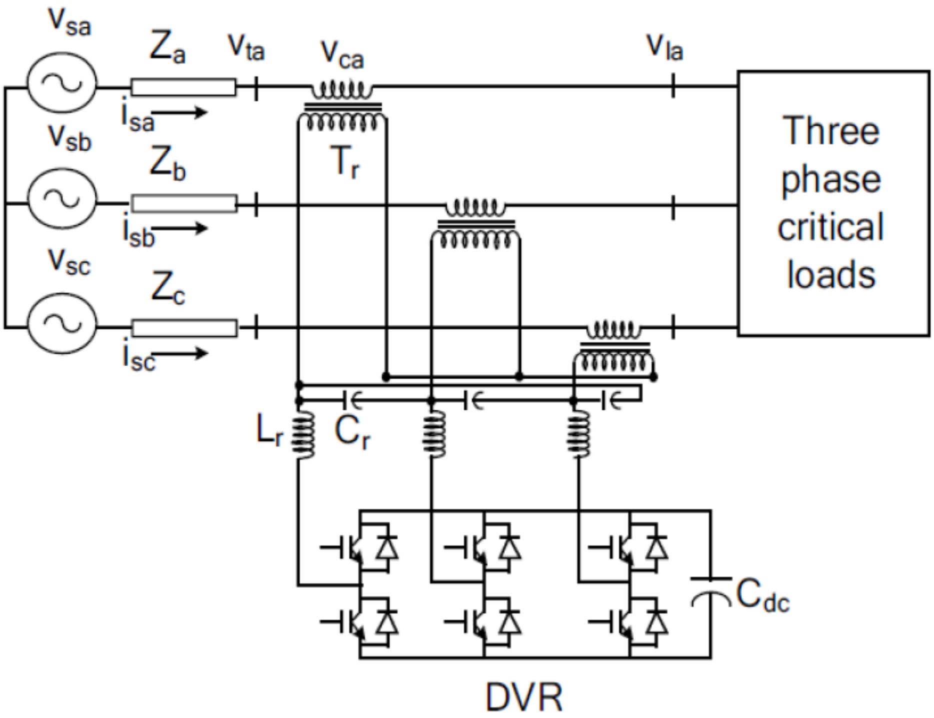
If the over current on the load side exceeds a permissible limit due to short circuit on the load or large inrush current, the DVR will be isolated from the system by using the bypass switches and supplying another path for current[6].

III. LOCATION OF DVR

The intention is only to protect one consumer or a group of consumers with value added power. Applying a DVR in the medium or low voltage distribution system would often be possible and a radial grid structure is the only type of system Considered here. In Europe three wire systems are common in the medium voltage systems and four wires in low voltage systems. In both systems the main purpose is to inject synchronous voltages during symmetrical faults and in some cases inject an inverse voltage component during non-symmetrical faults

A main difference between a Low Voltage (LV) connection and a Medium Voltage (MV) connection is the flow of zero sequence currents and the generation of zero sequence voltages. In the four-wire system, the DVR must secure low impedance for zero sequence currents and the zero sequence must either flow in the power converter or in a delta winding of the injection transformer.

IV. CONTROL & OPERATION OF DVR USING 3 PHASE TRANSMISSION LINE



DVR connected 3 phase line

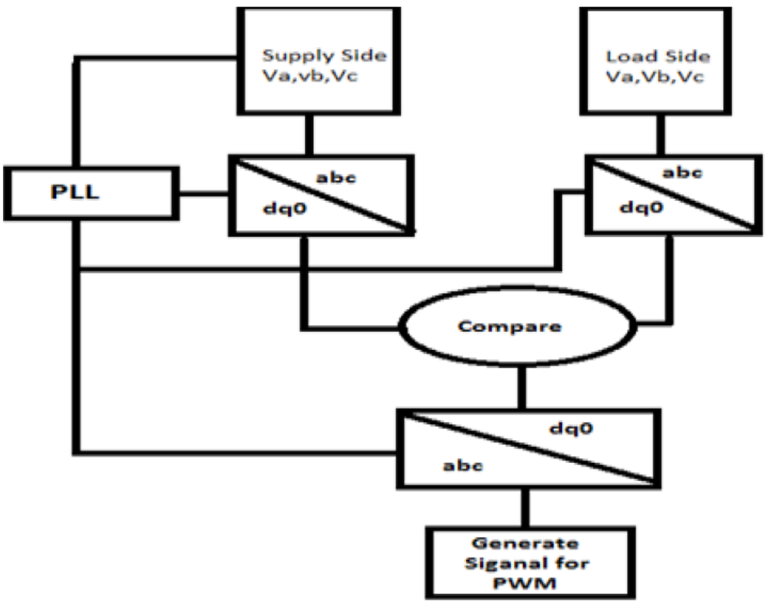
The compensation for voltage sags using a DVR can be performed by injecting/absorbing reactive power or real power. When the injected voltage is in quadrature with the current at the fundamental frequency, compensation is achieved by injecting reactive power and the DVR is self-supported with dc bus. But, if the injected voltage is in phase with the current, DVR injects real power and hence a battery is required at the dc side of VSI. The control technique adopted should consider the limitations such as the voltage injection capability (inverter and transformer rating) and optimization of the size of energy storage.

Figure shows the control block of the DVR in which the synchronous reference frame (SRF) theory is used for the control of self-supported DVR. The voltages at PCC (Vt) are converted to the rotating reference frame using the abc-dqo conversion. The harmonics and the oscillatory components of voltages are eliminated using low pass filters (LPF). The components of voltages in d-axis and q-axis are,

Vsd = Vsd dc + Vsd ac

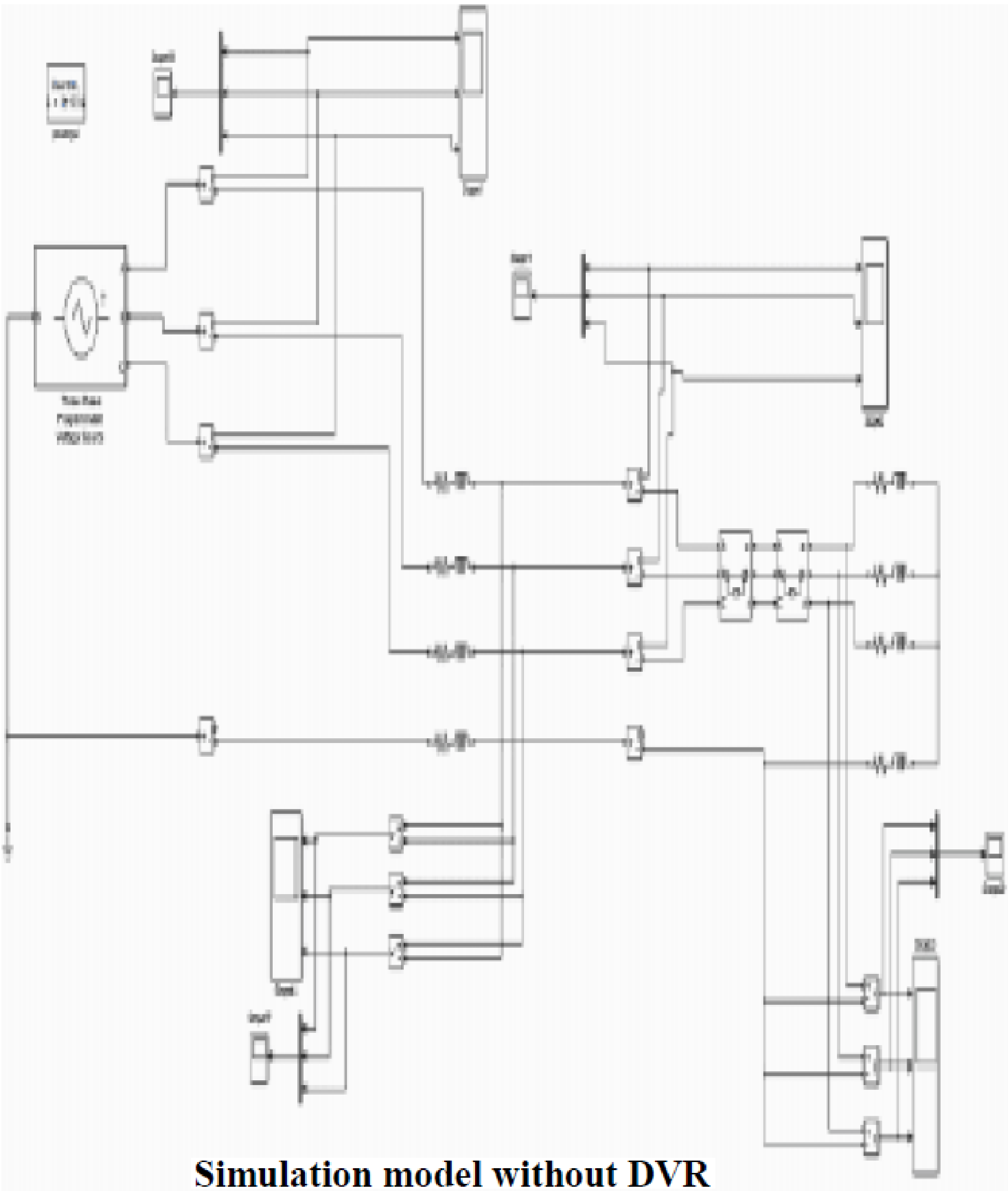
Vsq = Vsq dc + Vsq ac

The compensating strategy for compensation of voltage quality problems considers that the load terminal voltage should be of rated magnitude and undistorted.

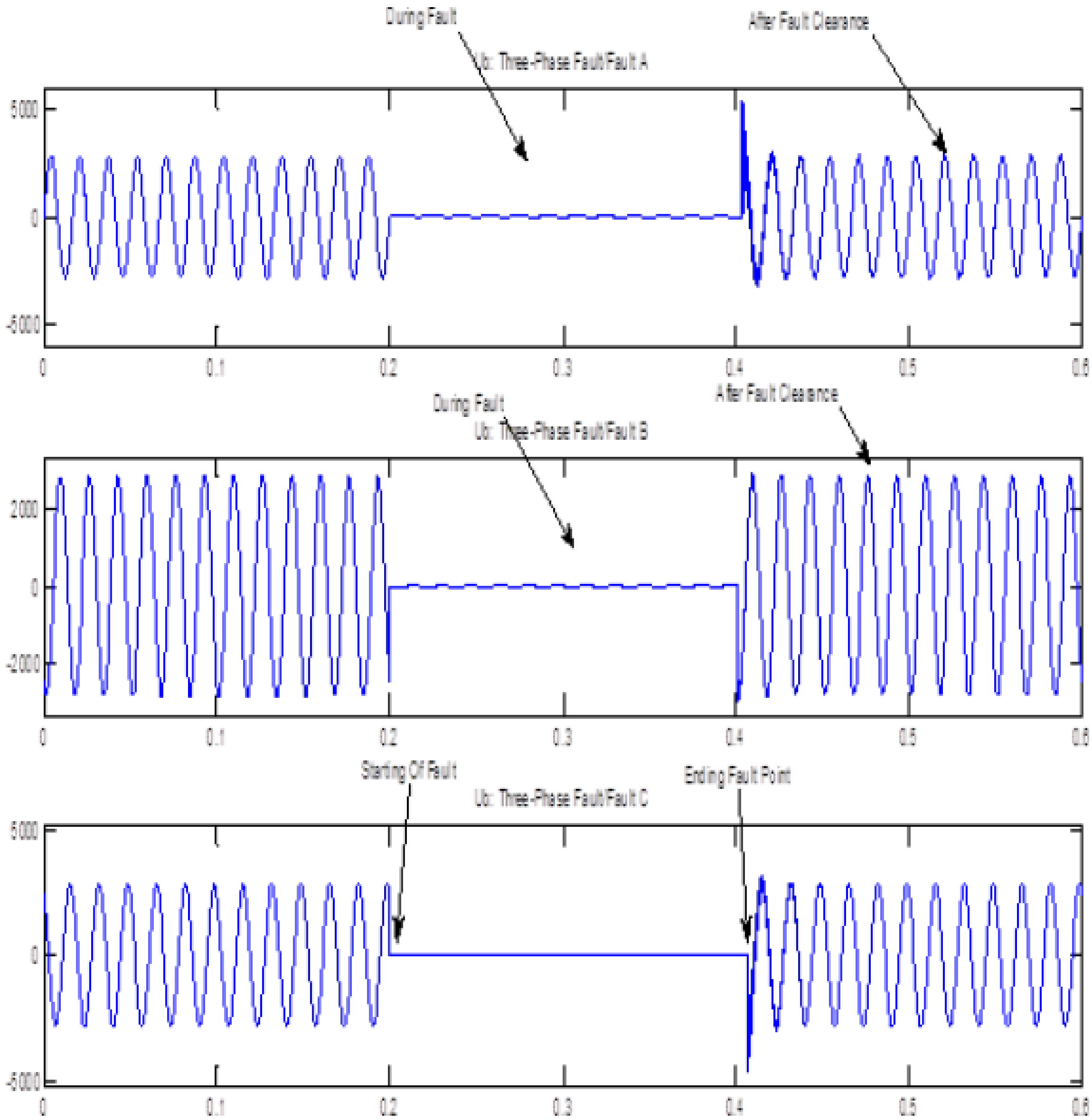


Control Block of DVR

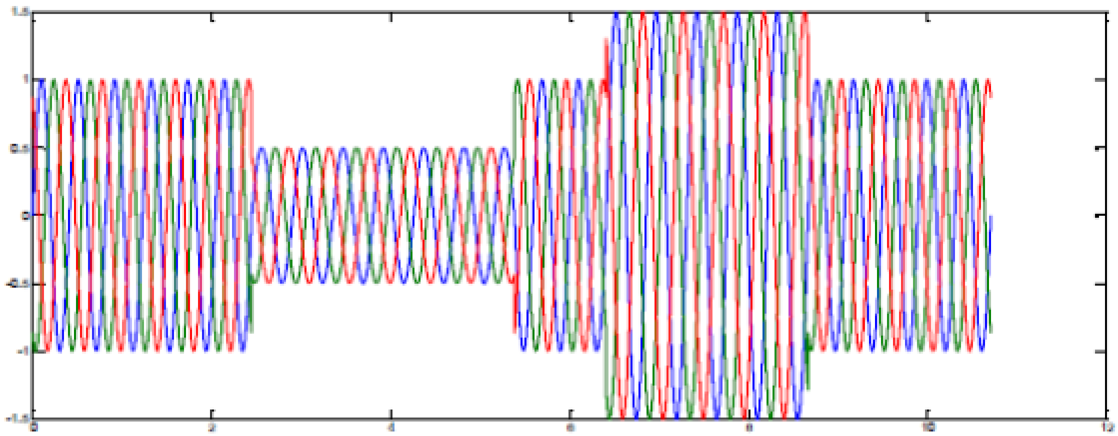
V. CONTROL & OPERATION OF DVR USING 3 PHASE TRANSMISSION LINE



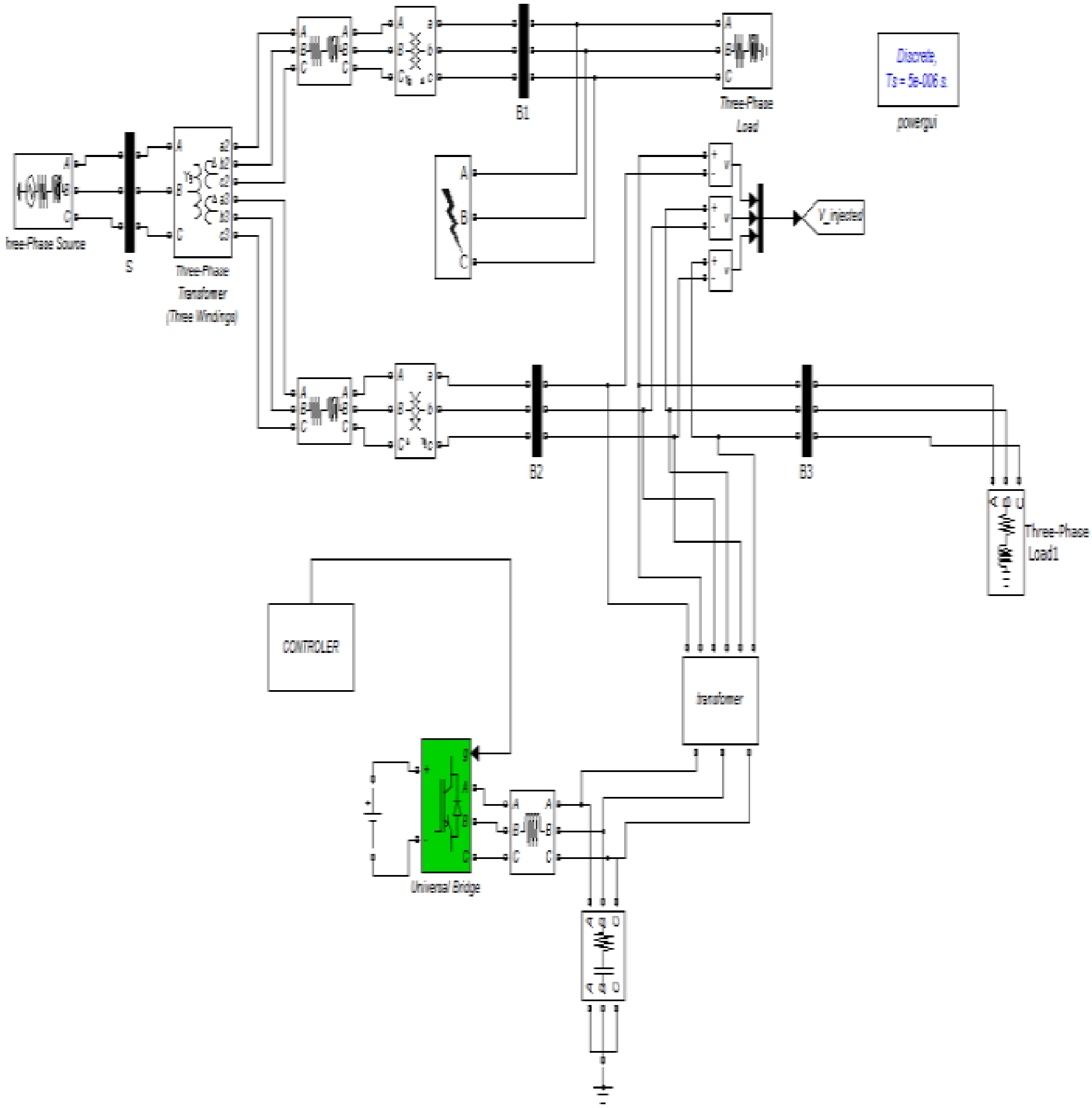
Simulation model without DVR



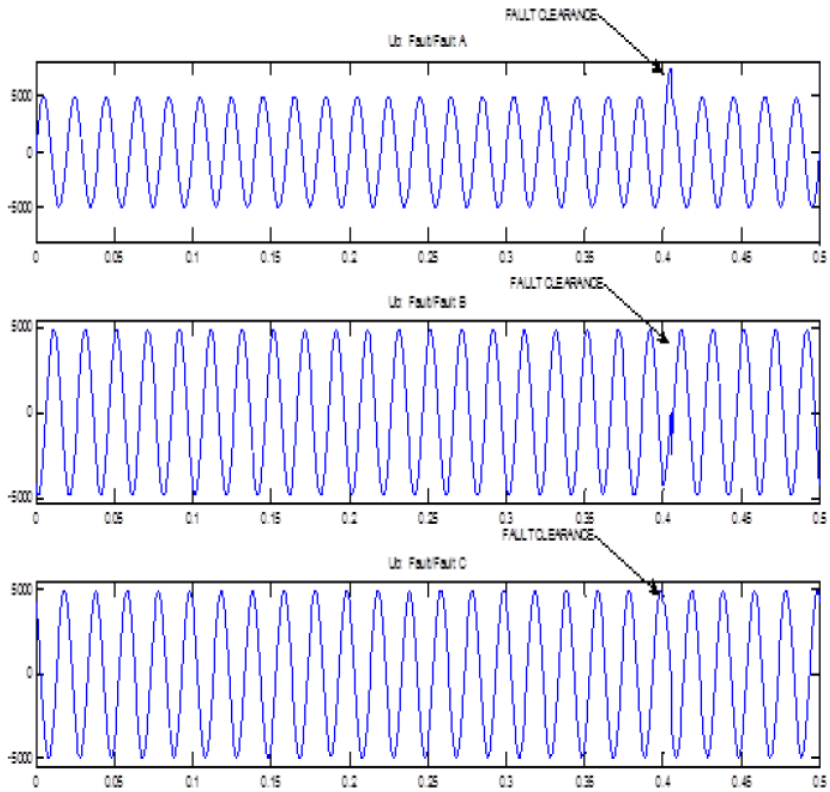
Three phase fault without DVR with a 3 phase fault



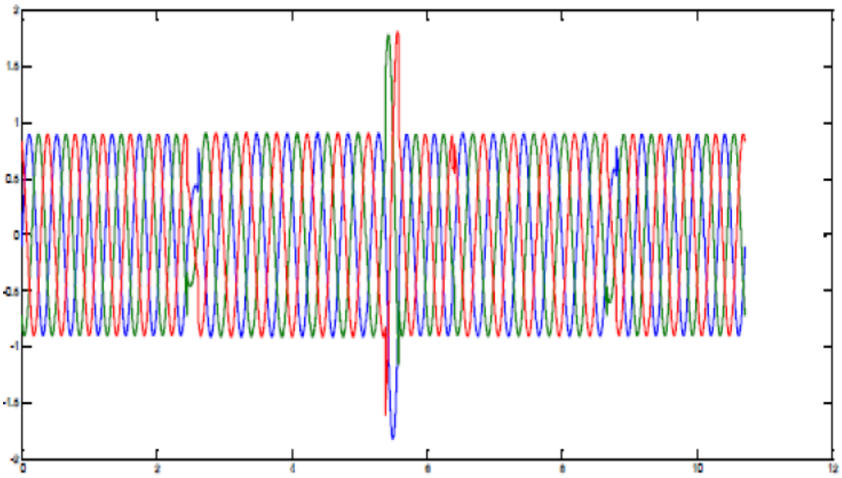
Three phase Current waveform without DVR with 3 phase fault with 50% voltage Sag and 50% voltage Swell



Simulation model with DVR



Three phase fault with DVR with a 3 phase fault



Three phase Current waveform with DVR with 3 phase fault after clearing the Voltage Sag and Swell

Figure shows the first simulation was done with no DVR and a three phase fault is applied to the system at point with fault resistance of 0.66 Ω for a time duration of 200 ms. Figure shows the second simulation is carried out at the same scenario as above but a DVR is now introduced at the load side to compensate the voltage sag occurred due to the three phase fault applied.

VI. CONCLUSION

From the above two waveforms we have studied that the clearing of sags and swells in the 3 phase system (by taking a faulty condition as an example) is very much clean and approx completely removed by using DVR. And also it has the ability to control the active power flow. So from the above study we can say that DVR is clearly considered to be one of the best economic solutions for its size and capabilities.

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