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A Fast and Effective Control Scheme for the Dynamic Voltage Restorer

C. Shashidhar
Sr. Assistant Professor
Dept. of Electrical & Electronics Engg
Aurora's Scientific, Technological & Research Academy
Bandlaguda, Hyderabad, Telangana

P. Ramesh
Associate Professor
Dept. of Electrical & Electronics Engg
Aurora's Scientific, Technological & Research Academy
Bandlaguda, Hyderabad, Telangana

K. Narasimha
Assistant Professor
Dept. of Electrical & Electronics Engg
Aurora's Scientific, Technological & Research Academy
Bandlaguda, Hyderabad, Telangana

***Abstract*— The widespread use of power natural philosophy devices has semiconductor diode to a whole modification in electrical load nature, of these variations in load causes disturbances in voltage waveforms. The disturbance includes Voltage sag/ swell, interruption etc. the employment of custom power devices is taken into account to be the foremost economical methodology for restoration of system voltage. Dynamic Voltage refinisher (DVR) will offer the price effective resolution for mitigation of short length voltage disturbances in distribution system. Here during this paper, 3 section Dynamic voltage refinisher supported Neural Network controller with Levenberg-Marquardt Back propagation coaching formula square measure projected for mitigating voltage sag, swell and interruptions. Short length voltage disturbances square measure simulated on a 3 section system and also the comparative results has been conferred victimization MATLAB/SIMULINK.**

***Keywords*— Three Phase DVR, Voltage Sag, Voltage Swell, Interruptions, Back propagation feed forward network**

I. INTRODUCTION

In the recent era, because of the arrival of subtle devices, the standard of power equipped to the top users holds larger importance. The distortion within the quality of provide power could cause mis-operation or failure of finish use instrumentation. therefore the demand of prime quality of power is enhanced. the employment of custom power devices is taken into account to be the foremost economical methodology for restoration of the system voltage. Dynamic Voltage refinisher (DVR) could be a series custom power device wont to shield sensitive hundreds against short length voltage disturbances like Voltage Sag/Swell and interruptions. totally different management methods and configuration has been projected for the DVR in mitigation of Voltage Sag/Swell and interruptions. Here during this paper 3 multilayer perceptron is projected for mitigation of voltage sag, swell and unbalance. The projected controller provides optimum mitigation of disturbances. During this paper, reconciling neural network is projected for mitigation of voltage sag with minimum energy injection from DVR for compensation; here an easy feed forward structure is employed. Here during this paper, the benefits of each PI controller and neural network controller square measure mentioned and also the performance is analyzed. Here, high power DVR with neural network controller is projected. it's wont to observe the voltage disturbance and for regulation of output voltage, conjointly it compensates the voltage disturbances as quick as potential. Here the performance of each PI and mathematical logic controller based mostly DVR is analyzed. Proposes a generalized PI controller for mitigation of voltage sag with DVR. Proposes a unique management theme to mitigate the voltage disturbance effectively and to compensate the disturbance in terribly quicker rates. Here voltage sag, swell and harmonics square measure remunerated by victimization DVR. Now, here during this paper, feed forward Neural Network controller with Levenberg-Marquardt Back propagation formula is employed for the mitigation of 3 section Voltage Sag, Voltage Swell and interruptions within the system victimization DVR. The simulation result shows that the performance of Neural Network controller is taken into account to be smart when put next to the standard controllers. The results square measure conferred victimization MATLAB/SIMULINK.

II. SHORT DURATION VOLTAGE DISTURBANCES

Voltage sag is that the decrease within the traditional voltage level between ten and ninetieth of the nominal RMS voltage at the facility frequency for length of zero, five cycles to one minute. the most causes of voltage sag square measure, fuse (or) breaker operation, electrical device switch, faults on the transmission or distribution network, faults in consumer's installation, association of serious hundreds and start-up of huge motors.

Voltage Swell is outlined because the increase of voltage higher than the conventional tolerance lasting for length of few seconds. the most causes of voltage swell square measure begin and stop of serious hundreds, badly dimensioned power supply. Voltage interruptions square measure the entire interruptions of electrical provide for length of few milliseconds to at least one or 2 seconds. The higher than short length disturbances leads to malfunction of knowledge technology instrumentation, particularly microprocessor-based management systems (PC's, PLC's, ASD's) which will cause a method stoppage, tripping of contactors and mechanical device relays, disconnection and loss of potency in electrical rotating machines.

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III. DYNAMIC VOLTAGE RESTORER

Dynamic Voltage refinisher (DVR) could be a series connected voltage supply convertor based mostly compensator that has been designed to safeguard sensitive instrumentation like PLC, ASD from short length voltage disturbances. Its main perform is to observe the load voltage waveforms perpetually by injecting needed voltage within the case of disturbances. If a fault happens on any feeder, then DVR inserts series voltage and compensates load voltage to pre-fault voltage.

The basic configuration of DVR includes, AN injection/booster electrical device, a harmonic filter, a voltage supply convertor, AN unit of measurement and system

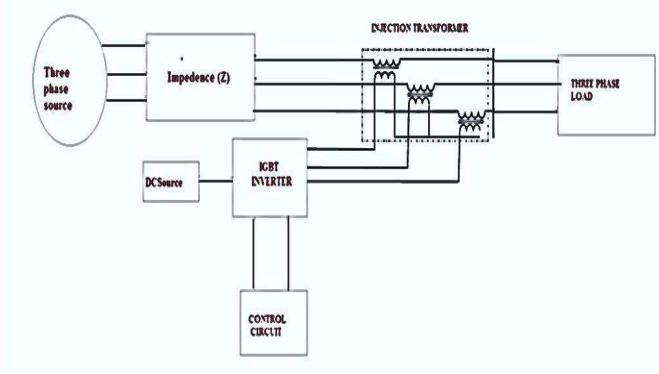

Fig.1. Three Phase Test System with DVR

An injection/booster transformer: An injection/booster electrical device connects the DVR to the distribution network via the high voltage windings and it's conjointly wont to couple the injected compensating voltage from DVR energy storage to the incoming provide voltage.A harmonic filter: A harmonic filter is employed to decrease the output harmonics that is generated by the VSC. A voltage supply convertor (VSC): A VSC consists of energy storage and switch device. It generates a curving voltage at any needed frequency, magnitude and phase. the main styles of switch devices used square measure MOSFET, GTO, and IGBT.

Energy storage: The DC energy memory device satisfies the important power demand of the DVR throughout Compensation. numerous storage technologies are projected which incorporates regulator energy storage, super-conducting magnetic energy storage (SMES) and super capacitors.

Flywheel: A regulator is AN mechanical device that couples a rotating electrical machine with rotating mass to store energy for brief durations. The motor/ generator draw power provided by the grid to stay the rotor of the regulator spinning. throughout an influence disturbance, the mechanical energy keep within the rotor is remodeled to DC electrical energy by the generator, and also the energy is delivered at a relentless frequency ANd voltage through an electrical converter and a bearing system. The regulator provides power throughout a amount between the loss of utility equipped power and either the come back of utility power or the beginning of a back-up installation.

Super capacitors: super capacitors conjointly called ultra-capacitors square measure DC energy sources and should be interfaced to the electrical grid with a static power conditioner, providing energy output at the grid frequency. an excellent electrical device provides power throughout short length interruptions or voltage sags. Medium size super capacitors square measure commercially accessible to implement ride-through capability in tiny equipment, however giant super capacitors square measure still in development, however could shortly become a viable element of the energy storage field.

SMES: A flux is formed by current a DC current in an exceedingly closed coil of superconducting wire. the trail of the coil current current will be opened with a solid state switch that is modulated on and off. because of the high inductance of the coil, once the switch is off the magnetic coil behaves as a current supply and can force current into the facility convertor which is able to charge to some voltage level. correct modulation of the solid state switch will hold the voltage inside the right in operation vary of the electrical converter, that converts the DC voltage into AC power.

Control System: The aim of the system is to take care of constant voltage magnitude at the purpose wherever a sensitive load is connected, below system disturbances; the system of the final configurations usually consists of a voltage correction methodology that determines the reference voltage that ought to be injected by DVR.

Operating Modes of DVR: The basic perform of the DVR is to inject a dynamically controlled voltage generated by a forced commutated convertor serial to the bus voltage by means that of a booster electrical device. The momentaneous amplitudes of the 3 injected section voltages square measure controlled like to eliminate any prejudicious effects of a bus fault to the load voltage. this implies that any differential voltage caused by transient disturbances within the ac feeder are going to be remunerated by the same voltage generated by the convertor and injected on the medium voltage level through the booster electrical device. The 3 modes of operation of DVR square measure Protection mode, Standby mode, Injection or boost mode

Protection mode: If the over current on the load facet exceeds a permissible limit because of short on the load or giant influx current. The DVR are going to be isolated from the systems by victimization the bypass switches and provision another path for current.

Standby mode: In standby mode the booster transformer's low voltage winding is shorted through the convertor. No switch of semiconductors happens during this mode of operation, as a result of the individual convertor legs square measure triggered like to determine a short-circuit path for the

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electrical device association. Therefore, the sole relatively low conductivity losses of the semiconductors during this current loop contribute to the losses. The DVR are going to be most of the time during this mode.

Boost mode: In boost mode, the DVR is injecting a compensating voltage through the booster electrical device because of a detection of a provide voltage disturbance.

The existing DVR management methods square measure the subsequent, in section voltage injection technique Phase advance compensation technique.

In section voltage injection technique: Here the voltage injected by the DVR is in section with the sag voltage. This methodology doesn't take into account the section shift of the voltage disturbances thus most power ought to be injected by the DVR energy storage unit into the distribution system. therefore this methodology doesn't minimize the energy needed for the compensation of voltage disturbances.

Phase advance compensation technique: In section advance compensation technique, the load voltage advance angle 'α' is adjusted in such some way that less real power has to be injected by the DVR energy storage into the distribution system. The advancement of load voltage advance angle 'α' at the start of the disturbance yet because the restoration of the phase at the top of the disturbance should be administrated while not interrupting the operation of sensitive hundreds. when put next to standard In-Phase compensation technique, the section advance compensation technique reduces the energy demand of the DVR energy storage unit.

IV. NEURAL NETWORK CONTROLLER

An artificial Neural Network (ANN) is AN information science paradigm that's impressed by the approach biological systema nervosum, like the brain, method data. AN ANN controller utilized in the system consists of 3 vegetative cell layer, i.e., the input layer, the hidden layer, the output layer.

In this paper, Neural Network managementler is projected for the control of DVR. the unreal neural network includes an outsized range of powerfully connected parts. The computer file flow through the colligation weight. These weights amplify or attenuate the input signals before the addition at the node. The summed knowledge flows through a transfer perform, f. the neurons square measure interconnected making totally different layers.

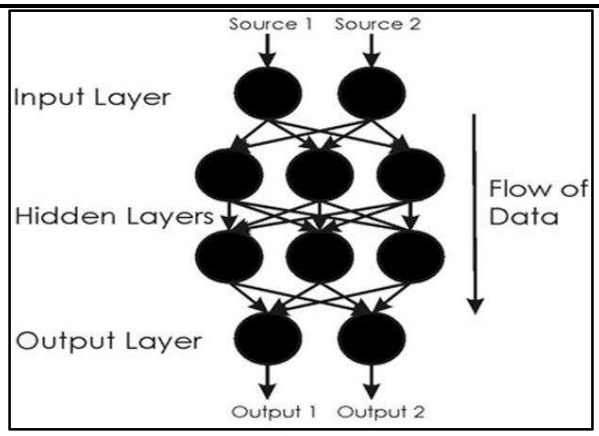

Fig.2.Architecture of simple Neural Network

The feed forward design is that the most typically adopted. In feed forward methodology, the knowledge moves in mere one direction forward from the input nodes through the hidden nodes and to the output nodes. Back propagation could be a style of supervised coaching. The network should be supplied with each sample inputs and anticipated outputs the anticipated outputs square measure compared against the particular outputs for a given inputs. It takes a calculated error and adjusts the load of the varied layers backwards from the output layer to the input layer.
The network has been trained to allow desired pattern at the output, once the corresponding computer file set is applied. This coaching method is administrated with sizable amount of input and output target knowledge. These knowledge will be obtained employing a simulation platform or AN experimental system. The initial output pattern is compared with the required output pattern and also the weights square measure adjusted by the formula to reduce the error. The repetitious method finishes once the error becomes close to null.

V. THREE PHASE DVR TEST SYSTEM

The 3 section DVR check system contains of 230V, 50HZ rating. once the short length voltage disturbances square measure detected, the DVR injects the specified real power specified it effectively compensates the voltage disturbance at load terminals. Here Neural Network managementler is employed for the control of DVR. The Input layer transmits the sign to the hidden layer. The Hidden layer uses TANSIG transfer perform whereas the output layer uses linear transfer perform.

The Input to the ANN is that the 3 section voltage errors of Dynamic Voltage refinisher (DVR). The Output of ANN is compared with the carrier signal and also the several output is triggered.

The neural network managementler is additionally wont to control the DVR. elaborate simulations square measure performed on the DVR check system victimization MATLAB/SIMULINK. System performance is analyzed for compensating voltage sag, swell and interruptions therefore on

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succeed rated voltage at a given load. The voltage magnitude of the load bus is maintained at 1pu throughout the short length voltage disturbances.

VI. CONVENTIONAL SYSTEM CONFIGURATION OF DVR

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, Further, they could be either balanced or unbalanced, depending on the type of fault and they could have unpredictable magnitudes, depending on factors such as distance from the fault and the transformer connections. 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. The concept of custom Power was introduced by N.G. Hingorani in 1995. Like Flexible AC Transmission Systems (FACTS) for transmission systems, the term custom power pertains to the use of power electronics controllers in a distribution system, especially, to deal with various power quality problems. Just as FACTS improves the power transfer capabilities and stability margins, custom power makes sure customers get prespecified quality and reliability of supply. This prespecified quality may contain a combination of specifications of the following: low phase unbalance, no power interruptions, low flicker at the load voltage, low harmonic distortion in load voltage, magnitude and duration of overvoltages and undervoltages within specified limits, acceptance of fluctuations, and poor factor loads without significant effect on the terminal voltage. Each of Custom Power devices has its own benefits and limitations.

Dynamic Voltage Restorer (DVR) is one of the most effective type of these devices. There are numerous reasons why the DVR is preferred over the others. A few of these reasons are presented as follows. The SVC pre-dates the DVR, but the DVR is still preferred because the SVC has no ability to control active power flow. Another reason is that the DVR costs less compared to the UPS. Other reasons include that the DVR has a higher energy capacity and lower costs compared to the SMES device. Further more, the DVR is smaller in size and costs less compared to the DSTATCOM. 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 added 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. This paper Introduced Dynamic Voltage Restorer (DVR) and its operating principle. Then, analyses of the voltage correction methods were presented. At the end, simulation results using MATLAB were illustrated and discussed.

The effects of voltage dips, over-voltages and voltage harmonics on electric loads can be mitigated using DVRs. The general structure of a DVR can be seen in figure 4.1 where the it is connected to the sensitive load through an injection transformer. The energy storage can be a group of batteries or a DC capacitor filtering the output of a diode rectifier conected to the electrical grid. The power converter switches at high frequency generating a PWM output voltage waveform which must be low-pass filtered (LF, RF and CF) before arrive to the injection transformer. Switches S1, S2 and S3 control the compensation status of the DVR.

The structure of the controllers applied to DVRs varies but in general, it can be divided in two fundamental blocks: the generation of the reference signal for the voltage injection, measuring the source (Vs) or the load voltage, and the control of the output voltage to ensure that it corresponds to the reference signal, which considers the state variables in the LPF (IF and VF).

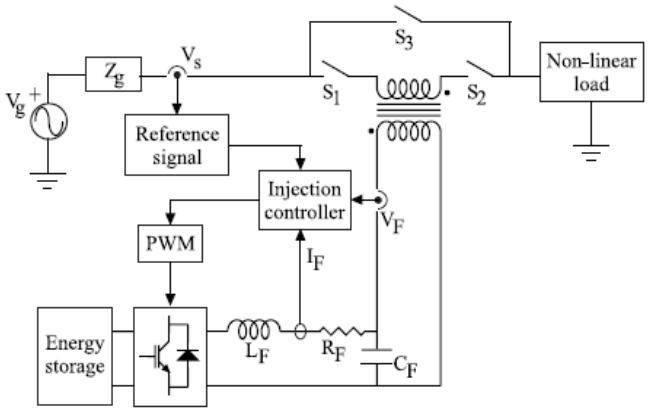

Fig. 3. Hardware structure of a DVR

The second block can be implemented in three ways. Feedback structures allow a good stationary response while forward structures generate quick responses during voltage transients. Feed-forward strutures allows both behaviours being more used. The generation of the reference signal depends strongly on the compensation objectives: voltage dips, over-voltages or voltage harmonics. The rms value of the grid voltage can be measured to detect voltage dips and over-voltages, once detected, the PLL used to synchronize the compensation signal must be frozen (not applied to the voltage signal) to maintain the previous phase. When the load voltage harmonics are the compensation objective, a repetitive controller can be applied to mitigate the effect of all voltage harmonics. In this case the reference signal is generated inside the voltage controller and doesn't allow selective harmonic compensation, both in harmonic order and harmonic magnitude.

Modeling of DVR: Power quality has a significant influence on high-technology equipments related to communication, advanced control, automation, precise manufacturing technique and on-line service. For example, voltage sag can have a bad influence on the products of semiconductor fabrication with considerable financial losses. Power quality problems include transients, sags, interruptions and other

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distortions to the sinusoidal waveform. One of the most important power quality issues is voltage sag that is a sudden short duration reduction in voltage magnitude between 10 and 90% compared to nominal voltage. Voltage sag is deemed as a momentary decrease in the rms voltage, with duration ranging from half a cycle up to one minute. Deep voltage sags, even of relatively short duration, can have significant costs because of the proliferation of voltage-sensitive computer-based and variable speed drive loads.

The fraction of load that is sensitive to low voltage is expected to grow rapidly in the coming decades. Studies have shown that transmission faults, while relatively rare, can cause widespread sags that may constitute a major source of process interruptions for very long distances from the faulted point. Distribution faults are considerably more common but the resulting sags are more limited in geographic extent. The majority of voltage sags are within 40%of the nominal voltage. Therefore, by designing drives and other critical loads capable of riding through sags with magnitude of up to 40%, interruption of processes can be reduced significantly. The DVR can correct sags resulting from faults in either the transmission or the distribution system.

Dynamic Voltage Restorer (DVR): A Dynamic Voltage Restorer (DVR) is a series connected solid state device that injects voltage into the system in order to regulate the load side voltage. The DVR was first installed in 1996. It is normally installed in a distribution system between the supply and the critical load feeder. Its primary function is to rapidly boost up the load-side voltage in the event of a disturbance in order to avoid any power disruption to that load. There are various circuit topologies and control schemes that can be used to implement a DVR. In addition to voltage sags and swells compensation, DVR can also added other features such as: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations.

The Dynamic Voltage Restorer (DVR), Fig 4.3, is designed to mitigate voltage sags on lines feeding sensitive equipment. A viable alternative to uninterruptible power systems (UPS's) and other utilization voltage solutions to the voltage sag problem, the DVR is specifically designed for large loads (2MVA and up) served at distribution voltage. A DVR is expected to be a lower cost alternative to UPS for applications at distribution voltage. A DVR typically requires less than one-third the nominal power rating of the UPS. Also, the DVR can be used to mitigate troublesome harmonic voltages on the distribution system. The DVR is available in 2 MVA increment sizes up to 10 MVA.

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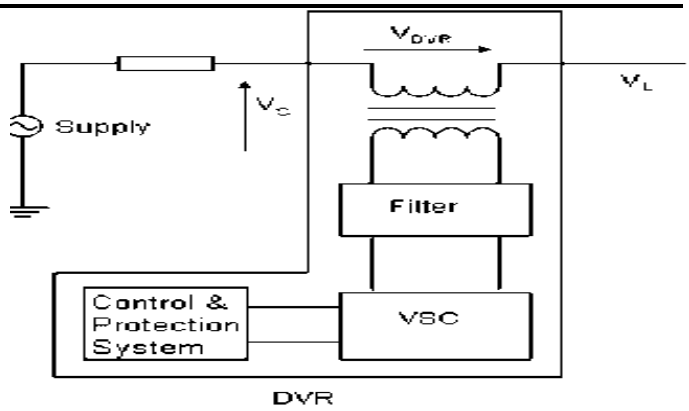

Fig. 5. Block diagram of DVR system

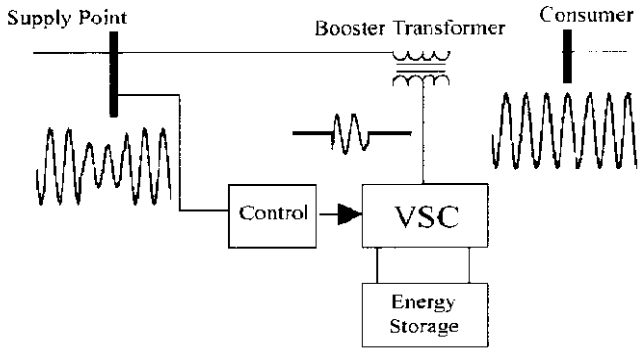

Fig.6. Schematic diagram of DVR System

Dynamic Voltage Restorer Is A Series Connected Device Designed To Maintain A Constant RMS Voltage Value Across A Sensitive Load.

Principle of operation of Series-connected VSC (DVR): The basic idea involved in principle of operation is to inject a voltage ec(t) of desired amplitude, frequency and phase between the PCC and the load in series with the grid voltage. A typical configuration of the DVR is shown in Figures shows a simplified single-line diagram of the system with DVR.The DVR can be represented as a voltage source with controllable amplitude, phase and frequency. The DVR is mainly used for voltage dip mitigation.

The device maintains the load voltage el(t) to the pre-fault condition by injecting a fundamental voltage of appropriate amplitude and phase. Figure 4.6 shows the phasor diagram of the series injection principle during voltage dip mitigation, where Ec is the phasor of the voltage injected by the compensator, Il is the phasor of the load current and where Ψ is the angle displacement between load voltage and current. In order to be able to restore both magnitude and phase of the load voltage to the pre-fault conditions, the DVR has to inject both active and reactive power. The voltage dip mitigation capability of this device depends on the rating of the energy storage and on the voltage ratings of the VSC and the injection transformer.

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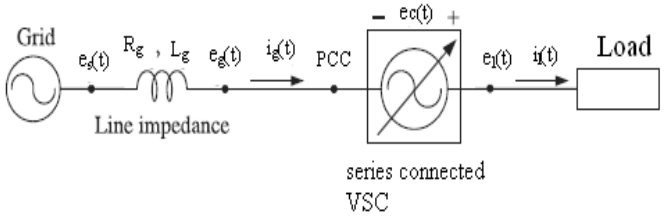

Fig.7. Simplified line diagram of series connected VSC

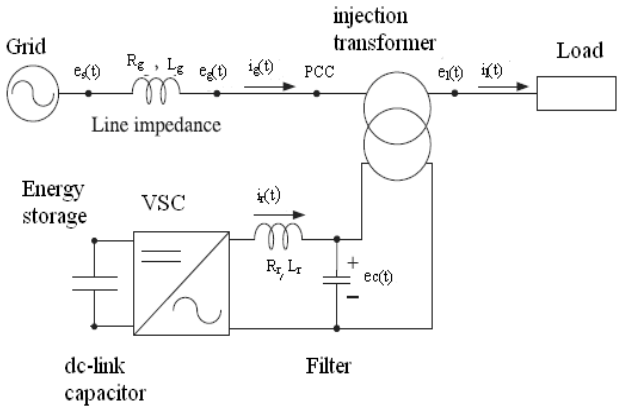

Fig.8. Single line diagram of series connected VSC

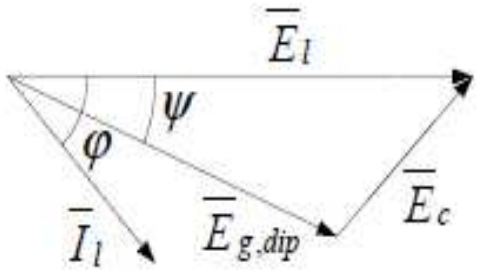

Fig.9. Phasor diagram of voltage mitigation using series VSC

The reactive power exchanged between the DVR and distribution system is internally generated by the DVR without any ac passive reactive components, i.e. reactors and capacitors. For large variations in the source voltage, the DVR supplies partial power to the load from a rechargeable energy source attached to the DVR dc terminal. The DVR, with its three single phase independent control and inverter design is able to restore line voltage to critical loads during sags caused by unsymmetrical L-G, LL, L-L-G, as well as symmetrical three phase faults on adjacent feeders or disturbances that may originate many miles away on the higher voltage interconnected transmission system. Connection to the distribution network is via three single-phase series transformers there by allowing the DVR to be applied to all classes of distribution voltages. At the point of connection the DVR will, within the limits of its inverter, provide a highly regulated clean output voltage.

VII. CONCLUSION

The Simulation results shows that the, the ANN based mostly controller provides higher performance when put next with the standard controllers. The ANN controller for DVR is incredibly effective and strong in compensation of Voltage Sag, swell and interruptions. The ANN controller has quick dynamic response when put next with the standard controllers. so the detection and elimination of voltage sag,swell and interruptions helps in improvement of power quality.

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About the authors:

Mr. C.Shashidhar at present is a Sr. Assistant Professor department of Electrical & Electronics Engineering, Aurora's Scientific, Technological & Research academy Hyderabad Andhra Pradesh, India. He received B.Tech. degree in Electrical and Electronics Engineering from J.N.T.U Hyderabad in 2006 , M.Tech Power Systems Engineering from Acharya Nagarjuna University, in 2009. He published several papers in various National, International Conferences and Journals. His research interests accumulate in the area of Power Systems, Power Quality Improvement, Renewable energy sources and Distribution system.

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Mr. P.Ramesh at present is a Associate Professor department of Electrical & Electronics Engineering, Aurora's Scientific, Technological & Research academy Hyderabad Andhra Pradesh, India. He received B.Tech. degree in Electrical and Electronics Engineering from J.N.T.U Hyderabad in2000 , M.Tech Power Systems Engineering J.N.T.U Hyderabad , in 2012. He published several papers in various National, International Conferences and Journals. His research interests accumulate in the area of Power Systems, Power Quality Improvement, Renewable energy sources and Distribution system

Mr. K. Narasimha at present is a Assistant Professor department of Electrical & Electronics Engineering, Aurora's Scientific, Technological & Research academy Hyderabad Andhra Pradesh, India. He received B.Tech. degree in Electrical and Electronics Engineering from J.N.T.U Hyderabad in2013 , He is currently pursuing M.Tech (Power Sya\stems) from J.N.T.U, Hyderabad India. His research interests accumulate in the area of Power Systems, Power Quality Improvement, Renewable energy sources and Distribution system