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Power Electronic Transformer based DVR for Load Side Protection

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Abstract: Now a day's electrical equipment's are more receptive to power quality problems. In power system there may be oscillation in power quality at the sensitive load due to faults and switching operation of breakers. This interruption results in breakdown of the equipment which connected at load side. In this paper, a bidirectional power electronic transformer based three phases four wires Dynamic Voltage Restorer (DVR) structure is projected to inject required series voltage to the electric power system in such a way that continuous sinusoidal voltage is seen at load side at heavy fault occurrences also main power quality problems like voltage sag and swell are deliberate. The PET- Power Electronic Transformer is a power transformer which has the advantage of increasing the frequency to reduce the overall size of transformer and hence this system delivers the extreme cost effective solution to alleviate the above problems which required by customer. So in MATLAB simulation model, this PET based DVR for load side protection against voltage disturbance is investigated which shows that power quality at load side improved with greater controllability and reliability**.**

Keywords: PET, DVR, SPS, PQ.

I. INTRODUCTION

A. Introduction

This Today, lots of attention on Power Quality problems as they affect lots of sensitive end-users including industrial and commercial electrical consumers. From Studies it is clear that voltage sags, transients and momentary interruptions constitute 92% of all the PQ problems occurring in the distribution power system. In fact, voltage sags always have a huge threat to the industry and still 0.25s voltage sag is long enough to interrupt a manufacture process resulting in enormous financial losses. According to depth and duration time, voltage sags are commonly classified. Typical sag can be a drop to between 10% and 90% of the rated RMS voltage and has the time duration of half cycles to 1 min. According to the data presented in majority of the sags recorded are of depth no less than 50%. But deeper sags with long duration time obviously cannot be ignored as they are more unbearable than shallow and short-duration sags to the sensitive electrical consumers. Power distribution systems; ideally provide their customers with a continuous flow of energy at pure sinusoidal voltage at the tapered magnitude level and frequency. But in practice, power systems specially the distribution systems, have numerous nonlinear loads which considerably affect the quality of power supplies. As a result of the nonlinear loads at the utility, the pureness of the waveform of supplies is lost and hence this starts producing many power quality problems. With the increasing use of non-linear loads and complexity of the network, the power system network faces challenges to deliver quality power to the consumers. In this paper we describe the effectiveness of dynamic voltage restorer (DVR) in order to alleviate voltage sags and swells in low voltage distribution systems, required by customer. DVR is a rapid, flexible and resourceful solution to power quality problems which has great importance today in all modern environments. One of the major concerns in electricity industry today is power quality troubles. So, Dynamic voltage restorer (DVR) can provide the worthwhile solution to mitigate voltage sag by establishing the appropriate voltage quality level, necessary.

B. Problem Definition

Electric power which delivered is affected by many different factors at the distribution network which has to be compensated to improve the quality as well as quantity of power been delivered.

C. Objectives of the work

1. Detection of voltage sag/swell in the power system network.
2. To mitigate the power quality issue using DVR and its behavioral study.
3. To select the best suitable control technique for DVR.

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4. To control the device in order to obtain desired performance. [9]

D. Outline of paper

This paper is arranged in following diverse sections. In section 1 we give a brief introduction of the system with problem definition and objectives. The Section 2 gives explanations of various reviews of different research papers. In section 3 we explained Dynamic Voltage Restorer (DVR) with its various components in detail. Then in section 4 we give simulation work with its results and finally we conclude and lay out the future work.

II. LITERATURE REVIEW

A vast number of publications have been addressed the voltage sag compensation. The numerous researchers have investigated all the topics associated to Dynamic Voltage Restorer (DVR) by including the compensation strategy, the circuit topology, the components design, the control circuit, the filter design and the detection of the sag. So in this below paragraphs we gave a brief literature review on the mitigation of voltage sag and its associated scheme.
In this paper [1] author explain reviews of various articles with advantages and disadvantages of each possible configuration and control techniques pertaining to DVR are presented. As, power quality requirement is one of the most essential issues for power companies and to their customers. For an industrial customer, the voltage sag and swell is very rigorous problem which requires attention for its compensation. So, there are various methods for the compensation of voltage sag and swell in which one of the most popular methods of sag and swell compensation is DVR- Dynamic Voltage Restorer, which is used in both low voltage and medium voltage applications. Also, compensation strategies and controllers have been presented in this literature, which aims at fast response, accurate compensation and low costs. Finally it's clear that this review help the researchers to select the optimum control strategy and power circuit configuration for DVR applications

In this paper [2] discuss and proposed a new control algorithm for the DVR to regulate the load terminal voltage during sag, swell in the voltage at the Point of Common Coupling. This proposed work is based on Synchronous Reference Frame theory along with PI controller which is used for the generation of reference voltages for a Dynamic Voltage Restorer (DVR). Also, the control of the DVR is implemented through used of derived reference load terminal voltages. Finally, it concludes that the proposed control scheme is simple to design. The simulation results are taken by MATLAB as its Simulink and Sim Power System (SPS) toolboxes to verify the performance of the proposed scheme.

As DVR-Dynamic Voltage Restorer is a convention power device used to correct the voltage sag by injecting voltage as well as power into the system. The mitigation capability of these devices is mainly influence by the maximum load; power factor and maximum voltage dip to be compensated. Voltage Dips on a feeder is significant assignment for DVR system operation and appropriate desired voltage sag compensation. So in this paper [6] main focus is projected to incorporate the amount of DC energy storage depends on voltage dip, which available in a convenient manner for DVR power circuit.

In this paper [7] author described DVR principles and voltage restoration methods for balanced and unbalanced voltage sags and swells in a distribution system. Voltage sags and swells in the medium and low voltage distribution grid are considered as most frequent type of power quality problems based on studies of power quality. This impact on sensitive loads which ranges from load disruptions to substantial economic losses up to millions of dollars. For this purpose, different solutions developed to protect sensitive loads against such disturbances but among them the DVR is the most efficient and effective solution that includes lower cost, smaller size and its dynamic response to the disturbance. Finally, simulation results present illustration and understanding of the performance of DVR under voltage sags/swells conditions.

The DVR is a power electronic based device which is fast, flexible and efficient solution to voltage sag problem. In this paper [8] author give an overview of the DVR and its functions, configurations, components, compensating strategies and control methods are reviewed as well as the device capabilities and limitations. The DVR offers a three- phase controllable voltage source, whose voltage vector adds to the source voltage during sag event to restore the load voltage to pre-sag conditions.

III. DYNAMIC VOLTAGE RESTORER (DVR)

A Dynamic Voltage Restorer is a recently proposed series connected solid state device that injects voltage into the system in order to regulate the load side voltage. It is normally installed in a distribution system between the supply and critical load feeder. The basic structure and Circuit diagram of a DVR is shown in below fig.1. And fig.2. Respectively as,

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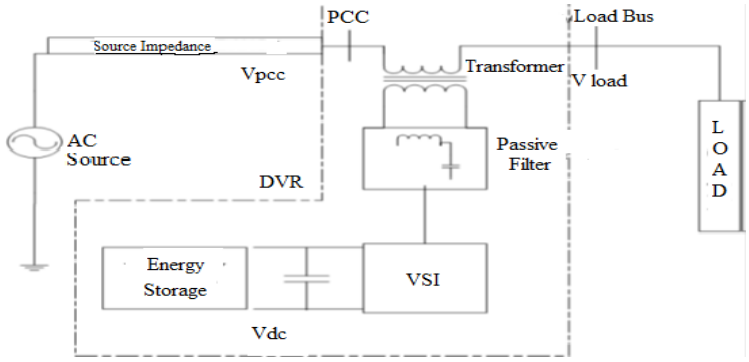

Fig. 1. Basic Structure of DVR

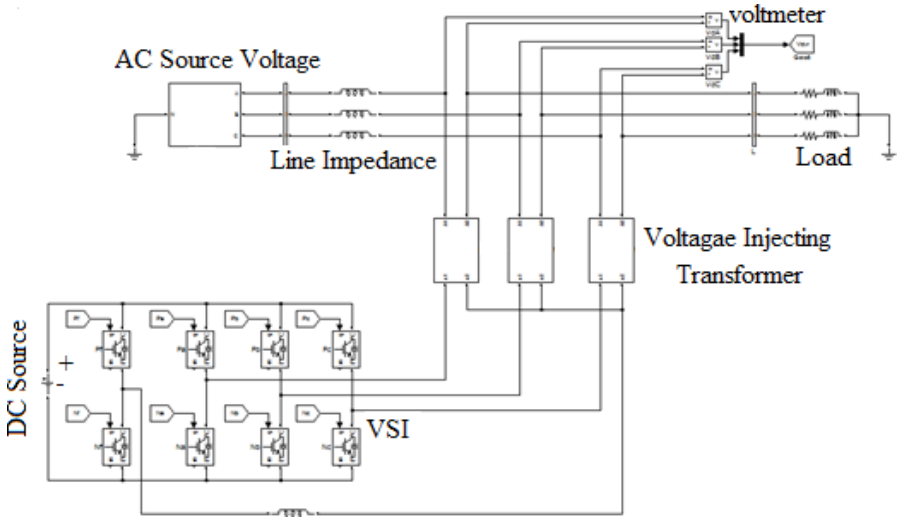

Fig. 2.Circuit Diagram of A DVR

The various components constitute by DVR are,

i) **Energy Storage Unit**: Energy stored in DC form. Super capacitors, Flywheels, superconducting magnetic energy storage and Batteries can be used as energy storage devices. Main Purpose-To supply necessary energy to the VSI via a DC link for the generation of injected voltages.

ii) **Capacitor**: A large DC capacitor is used in DVR to ensure a proper input DC voltage to Inverter.

iii) **Voltage Source Inverter** (VSI): Inverter system is used to convert dc storage into ac. It is a power electronic system which consists of a storage device and switching device, which can generate a sinusoidal voltage at any required frequency, magnitude and phase angle from dc storage.

iv) **Voltage Injection Transformers**: The AC voltage supplied by VSI is stepped up by using injection transformer to the desired voltage level. It is a specially designed transformer that attempts to limit the coupling of noise and also transforms energy from the primary side to the secondary side.

v) **Passive Filters**: It converts the inverted pulse width modulation (PWM) waveform into a sinusoidal waveform. It is achieved by eliminating the unwanted harmonic components generated VSI action. Higher orders harmonic components distort the compensated output voltage. Also it filters out the harmonics present in the output of the VSI which kept either at the inverter side or at the HV side of the transformer.

vi) **By-Pass Switch**: It is used to protect the inverter from High current in the presence of unwanted conditions. At a time of a fault or a short circuit, DVR changes it into the bypass condition where the VSI inverter is protected against over current flowing through the power semiconductor switches.

vii) **Control circuit**: It steadily observe the system and its function is to detect any disturbance in the system done by comparing the supply voltage with reference voltage and based on that generate the switching command signals for VSI in order to generate the compensating voltage by DVR.

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IV. SIMULATION & RESULTS

A. Simulation work

In the simulation model, the DVR is connected in series with the load which is supplied by the source voltage VRMS. The injecting transformer is connected in each line to insert the compensating voltage in the line. Injecting transformer is fed by voltage source inverter with DC bus voltage Vdc. The scope is connected at output to show the results waveforms. The below fig. 3. Shows the simulation model of DVR as,

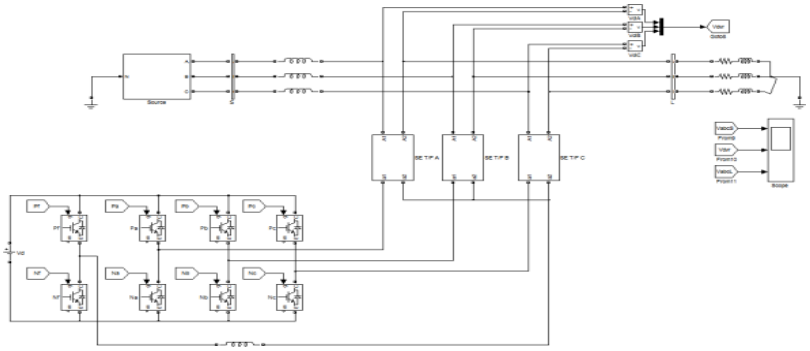

Fig.3. Simulation model of DVR

In this controlling circuit as shown in below fig. 4. Three Dimensional Space Vector Pulse Width Modulation (3DSVPWM) techniques are used. Here value at load side and reference value get compared and proportional to the above deference the pulse get generated by this modulation technique. The deferent blocks are used like abc to dq0 transformation, three phases PLL, alpha beta to abc.

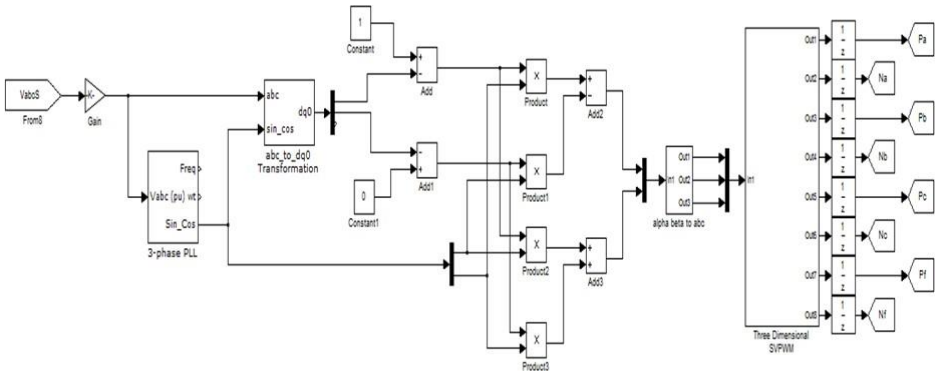

Fig.4. Control System Diagram

B. Simulation Results

Fig.5. shows the simulation results under balanced voltage sag condition. In this case, 50% voltage sag has been considered for each phases. Utility voltage, injected voltage & load voltage is restored to the nominal condition (before sag occurrence) after a time lower than a half cycle.

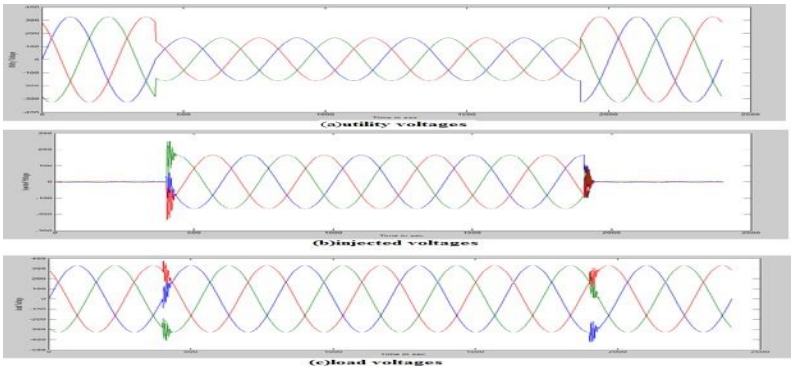

Fig.5. Simulation results under Balanced Sag

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Fig.6. shows the simulation results under unbalanced voltage sag condition with the values of 60%, 50% & 40% on phases a,b&c respectively.

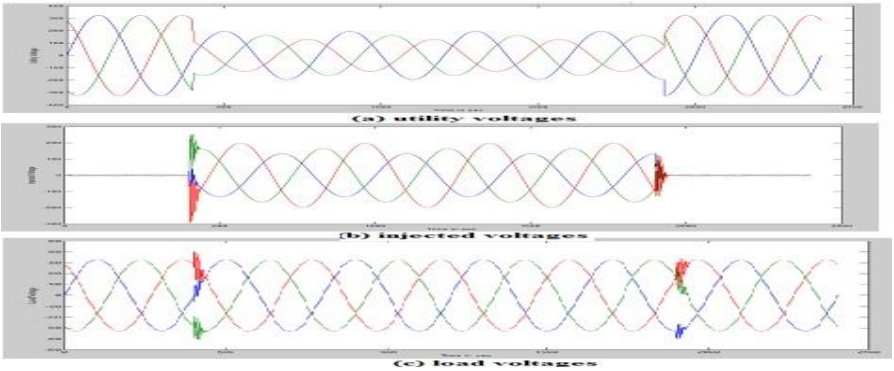

Fig.6. Simulation results under Un-balanced Sag

In other case the DVR performance is investigated under balanced & Unbalanced Voltage Swell. Fig.7. shows the performance of DVR under 50% Balance Voltage Swell conditions.

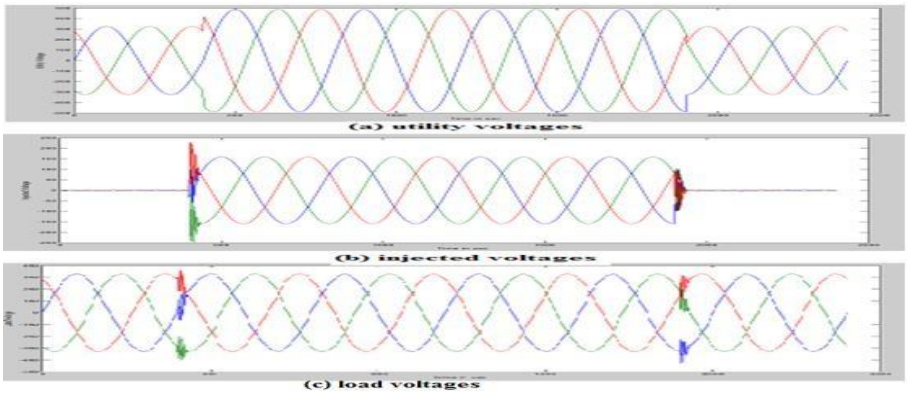

Fig.7 Simulation results under Balanced Swell

The result of un-balanced swell is shown in fig.8. In this case the three phase terminal voltages with unbalanced swell of 60%, 50% & 40% on phase a, b& c is considered, respectively. As can be seen, also under swell condition, the load voltage is restored to its nominal value. Fig. 9. Shows the simulation results of the proposed DVR under harmonic polluted utility voltage. It is clear that the load voltage remains balanced & sinusoidal even when such condition is occurred for utility voltage.

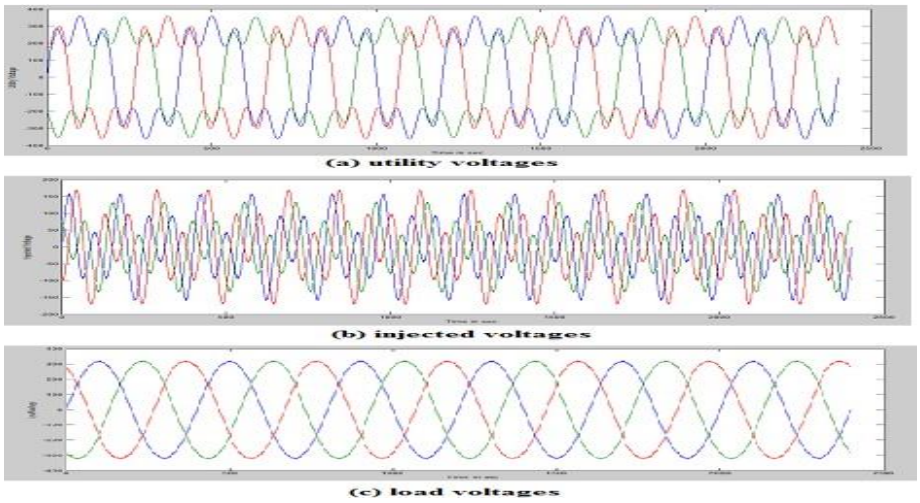

Fig.8. Simulation result of un-balanced swell

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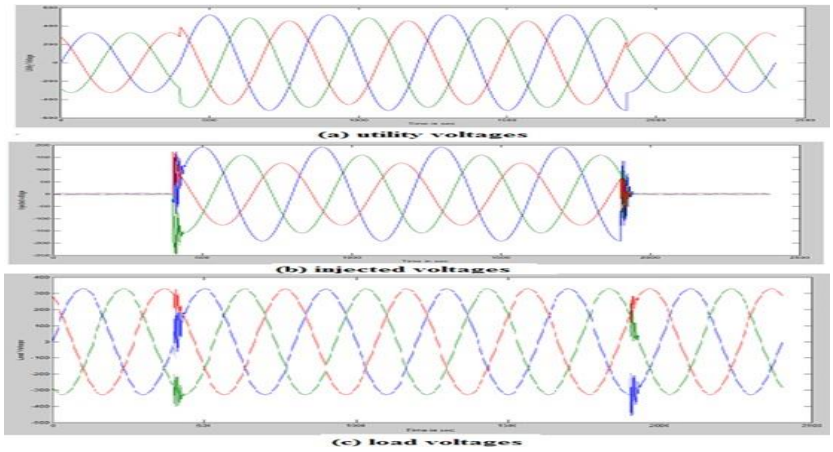

Fig.9. Simulation results under Harmonic Polluted utility Voltage

The below table 1 shows utility voltage with or without PET base DVR is given as TABLE I: OBSERVATION TABLE

	Without PET base DVR	With PET base DVR
Utility Voltage Before Fault (At 0.02 sec)	420 volt	420 volt
Utility Voltage at the time of Fault (At 0.05 sec)	250 volt	420 volt
Utility Voltage at the time of Fault (At 0.04 sec)	560 volt	420 volt

V. CONCLUSION

To improve power quality at utility side, there are some effective methods. In this paper, the voltage sag and swell mitigation using a device called power electronic transformer based DVR is presented. Voltage unbalance under both balanced and unbalanced condition is considered and Simulation results are shown. Modeling and compensating technique used by DVR for compensating such unbalance are also presented. The 33kv/11kv Distribution Substation was taken for study of system. The simulation result shows that DVR compensate sag and swell effectively and provide good voltage regulation. From this structure point of view, the main advantage of the proposed DVR is low volume & weight due to use PET. In future by considering the enhanced functionality and flexibility of PET, the added cost can be easily justified.

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