Modeling and Simulation of DVR Based On Dual Voltage Source Converter by a Super Capacitor Bank

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***Abstract*---The dynamic voltage restorer (DVR) has become popular as a cost effective solution for the protection of sensitive loads from voltage sags and swells It provides technically advanced and economic solution to compensate voltage sag and reactive power in both transmission and distribution systems. The proposed design dual voltage source converter based dynamic voltage restorer using super capacitor bank. The DVR is a power electronics device that is able to compensate voltage sags on critical loads dynamically. The developed dual converter based DVR can effectively compensate the voltage sag and to compensate reactive power for the sensitive load, such as computer, communication equipment, and automation equipment. A Dynamic Voltage Restorer (DVR) is a recently proposed shunt connected solid state device that injects voltage into the system in order to regulate the load side voltage**

Index Terms—Dynamic voltage restorer (DVR), emergency control, voltage sag, voltage swell.

I.INTRODUCTION

VOLTAGE sag and voltage swell are two of the most important power-quality (PQ) problems that encompass almost 80% of the distribution system PQ problems. Voltage sag is the decrease of 0.1 to 0.9 p.u. in the rms voltage level at system frequency and with the duration of half a cycle to 1 min. Short circuits, starting large motors, sudden changes of load, and energization of transformers are the main causes of voltage sags[1],[2]. According to the definition and nature of voltage sag, it can be found that this is a transient phenomenon whose causes are classified as low- or medium-frequency transient events. In recent years, considering the use of sensitive devices in modern industries, different methods of compensation of voltage sags have been used. One of these methods is using the DVR to improve the PQ and compensate the load voltage. Previous works have been done on different aspects of DVR performance, and different control strategies have been found.

Recently, power quality problems become a major concern of industries due to massive loss in terms of time and money. Hence, there are always demands for good power quality, which positively resulting in reduction of power quality problems like voltage sag, harmonic and flicker, interruptions, harmonic distortion. Preventing such phenomena is particularly important because of the increasing heavy automation in almost all the industrial processes. High quality in the power supply is needed, since failures due to such disturbances usually have a high impact on production costs[5]. There are number of methods to overcome voltage sags. One approach is to use Dynamic Voltage Restorers with energy storage. The DVR is a power electronics device that is able to compensate voltage sags on critical loads dynamically. By injecting an appropriate voltage, the DVR restores a voltage waveform and ensures constant load voltage. The DVR consists of Voltage Source Converter (VSC), injection transformers, passive filters and energy storage (lead acid battery). The Dynamic Voltage Restorer (DVR) with the lead acid battery is an attractive way to provide excellent dynamic voltage compensation capability as well as being economical when compared to shunt-connected devices. The DVR is a custom power device that is connected in series with the distribution system. The DVR employs IGBTs to maintain the voltage applied to the load by injecting single-phase output voltages whose magnitude, phase and frequency can be controlled [3].

The basic function of DVR is to inject dynamically voltage required, V_{DVR} to compensate sagging occurrence. Generally, the operation of DVR can be categorized into two modes; standby mode and injection mode. In standby mode, DVR either in short circuited operation or inject small voltage to cover voltage drop due to transformer reactance losses. The DVR is turn into injection mode as soon as sagging is detected. V_{DVR} is injected in series with load with required magnitude and phase for compensation. The common causes of voltage sag are faults or short circuit in the system, starting of large loads and faulty wiring. This will lead to increase in both production and financial loss for industries. Therefore, it is vital to mitigate voltage sag[8]. Two main characteristics that explain the voltage sag are depth/magnitude and duration of voltage sag itself. The depth/magnitude and duration of voltage drop that said to be voltage sag is between 0.1 to 0.9 p.u with time interval, about 0.5 cycles to 1 minute. This classification is based on IEEE standard 1159-1995.

There are various types of voltage sag mitigation equipment that available nowadays such as Uninterrupted Power Supply (UPS), flywheel, and the flexible ac transmission system (FACTS) devices which have been widely used in the power system due to the reliability to maintain power quality control[4]. One of the most FACTS devices that have been created in improvement the performance of power quality is Dynamic Voltage Restorer (DVR) also known as custom power devices.

In this paper, DVR which consists of the injection transformer, filter unit, PWM inverter, energy storage and control system is used to mitigate the voltage sag in the power distribution system. Control unit is the heart of the DVR where its main function is to detect the presence of voltage sags in the system, calculating the required compensating voltage for the DVR and generate the reference voltage for SPWM generator to trigger on the PWM inverter. The components of control system unit are the dq0-transformation, Phase-lock-loop (PLL) and the PI Controller. PI Controller is a feedback controller which drives the plant to be controlled with a weighted sum of the error (difference between output and desired set-point) and the integral of that value[11]

II. DYNAMIC VOLTAGE RESTORERS

Among the power quality problems like sag, swell, harmonic etc, voltage sag is the most severe disturbances in the distribution system. To overcome these problems the concept of custom power devices is introduced lately. One of those devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks[6]-[8].

DVR 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 generally installed in a distribution system between the supply and the critical load feeder at the point of common coupling (PCC). Other than voltage sags and swells compensation, DVR can also added other features like line voltage harmonics compensation, reduction of transients in voltage and fault current limitations[6].

A. Principle of DVR Operation

A DVR is a solid state power electronics switching device consisting of either GTO or IGBT, a capacitor bank as an energy storage device and injection transformers[9]. It is linked in series between a distribution system and a load that shown in Figure 1. The basic idea of the DVR is to inject a controlled voltage generated by a forced commuted converter in a series to the bus voltage by means of an injecting transformer. A DC to AC inverter regulates this voltage by sinusoidal PWM technique. All through normal operating condition, the DVR injects only a small voltage to compensate for the voltage drop of the injection transformer and device losses. However, when voltage sag occurs in the distribution system, the DVR control system calculates and synthesizes the voltage required to preserve output voltage to the load by injecting a controlled voltage with a certain magnitude and phase angle into the distribution system to the critical load[10].

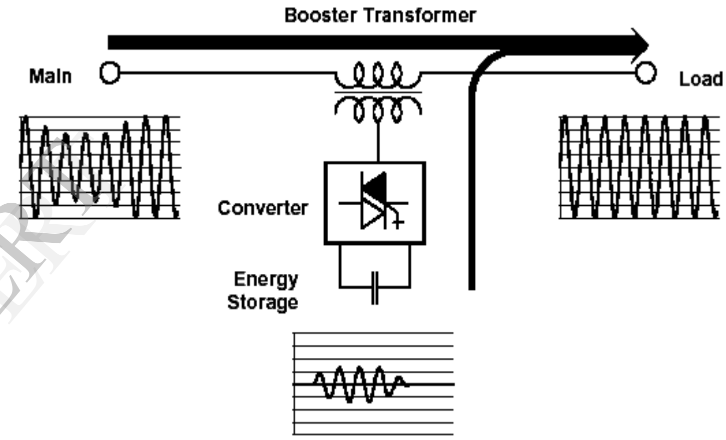

Fig1. Principle of DVR System

Note that the DVR capable of generating or absorbing reactive power but the active power injection of the device must be provided by an external energy source or energy storage system. The response time of DVR is very short and is limited by the power electronics devices and the voltage sag detection time. The predictable response time is about 25 milliseconds, and which is much less than some of the traditional methods of voltage correction such as tap-changing transformers.

B. Basic Arrangement of DVR

The DVR mainly consists of the following components:

(a) An Injection transformer
(b) DC charging unit
(c) Storage Devices
(d) A Voltage Source Converter (VSC)
(e) Harmonic filter
(f) A Control and Protection system

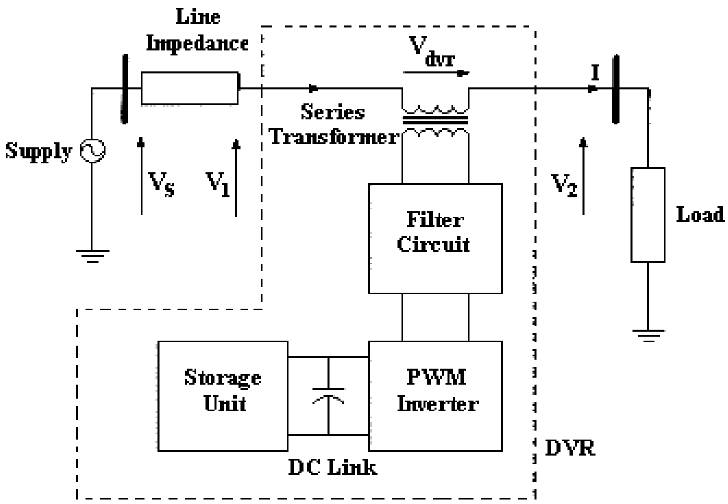

Fig 2. Schematic Diagram of DVR

A. Injection Transformer

Three single phase transformers are connected in series with the distribution feeder to couple the VSC (at the lower voltage level) to the higher distribution voltage level. It links the DVR system to the distribution network via the HV-windings and transforms and couples the injected compensating voltages generated by the voltage source converters to the incoming supply voltage. In addition, the Injection transformer also serves the purpose of isolating the load from the DVR system (VSC and control mechanism).

B. DC Charging Unit

The dc charging circuit is used after sag compensation event the energy source is charged again through dc charging unit. It is also used to maintain dc link voltage at the nominal dc link voltage.

C. Voltage Source Converter

A VSC is a power electronic system consists of a storage device and switching devices, which can generate a sinusoidal voltage at any required frequency, magnitude, and phase angle. It could be a 3 phase - 3 wires VSC or 3 phases - 4 wires VSC. Either a conventional two level converter or a three level converter is used. For DVR application, the VSC is used to momentarily replace the supply voltage or to generate the part of the supply voltage which is absent. There are four main types of switching devices: Metal Oxide Semiconductor Field Effect Transistors (MOSFET), Gate Turn-Off thyristors (GTO), Insulated Gate Bipolar Transistors (IGBT), and Integrated Gate Commutated thyristors (IGCT). Each type has its own benefits and drawbacks. The IGCT is a recent compact device with enhanced performance and consistency that allows building VSC with very large power ratings. The function of storage devices is to supply the required energy to the VSC via a dc link for the generation of injected voltages. The different kinds of energy storage devices are Superconductive magnetic energy storage (SMES), batteries and capacitance[7].

III.SIMULATIONDIAGRAMS

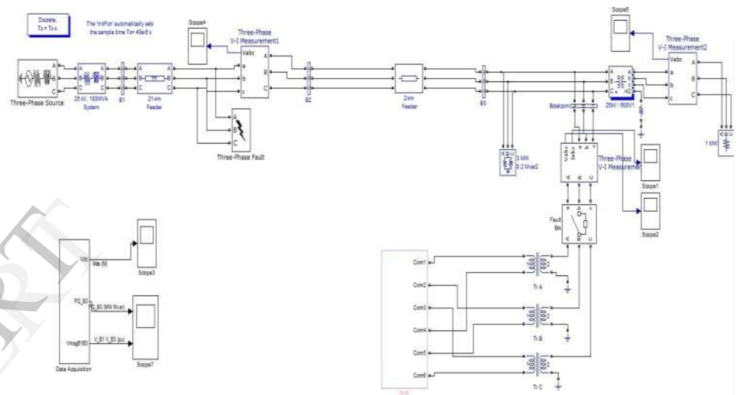

Fig 3. Simulink Model of DVR

IV.SIMULATION RESULTS

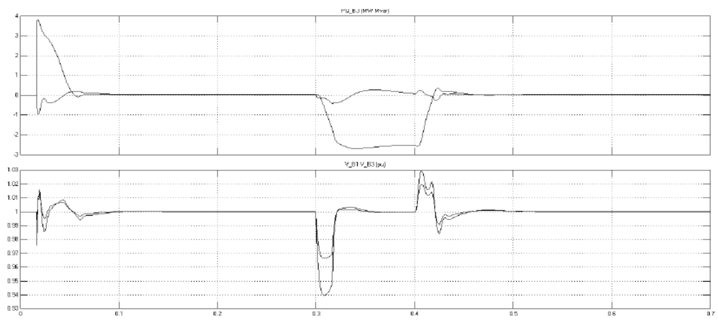

Fig 4. PQ with Fault without DVR

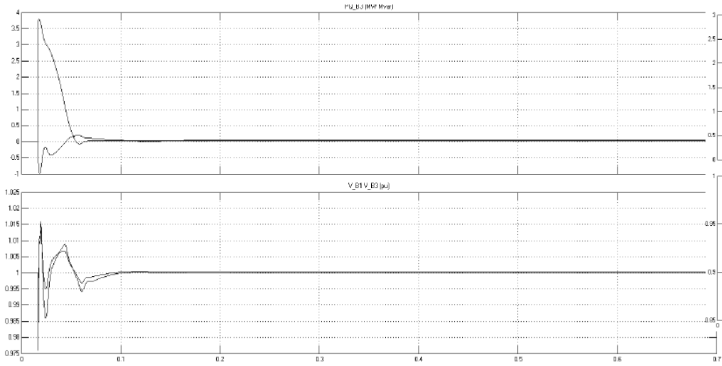

Fig 5. PQ without Fault With DVR

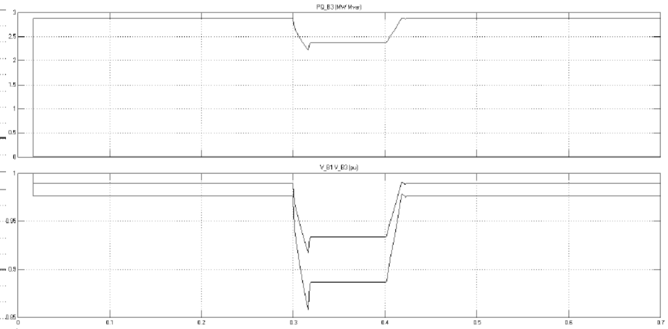

Fig 8. PQ With Fault and With DVR Not Connected

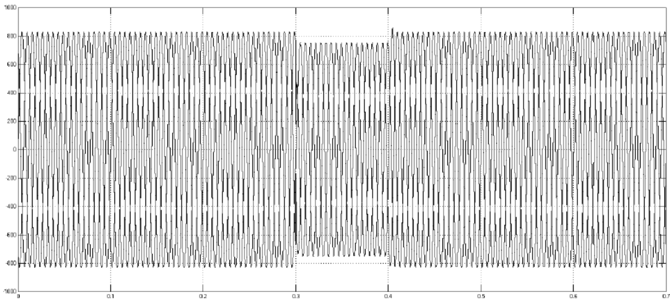

Fig 6. Voltage during fault condition without DVR

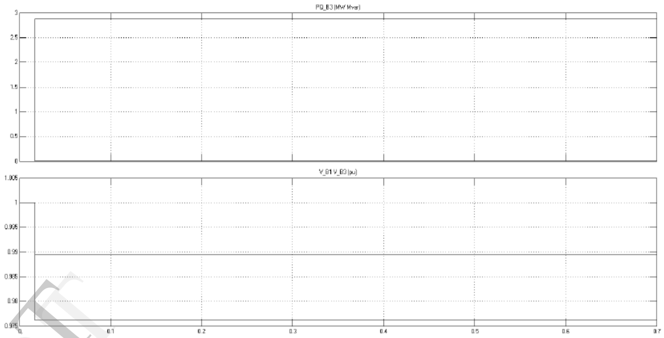

Fig 9. PQ With Fault and With DVR Connected

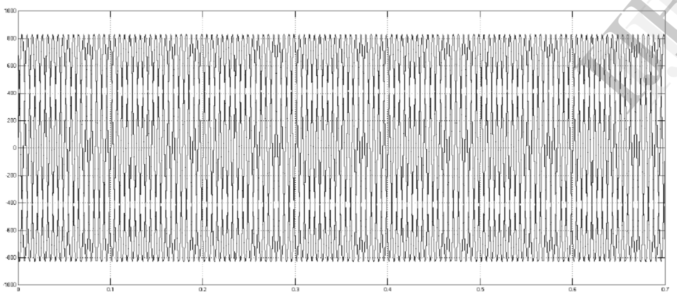

Fig 7. Voltage Improved in fault condition with DVR

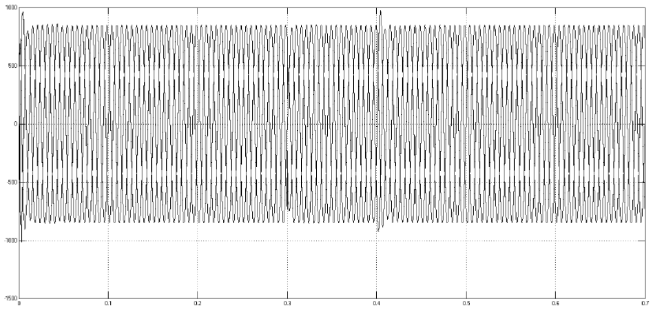

Fig 10. Voltage with DVR

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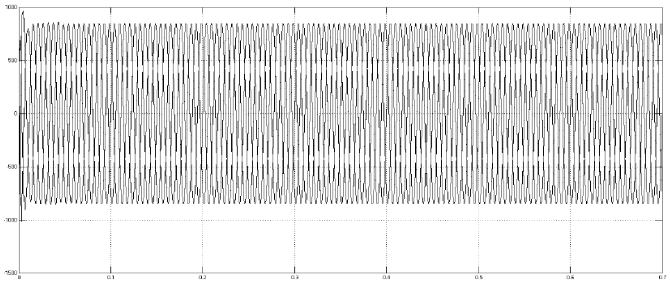

Fig 11. Voltage with DVR Without Fault

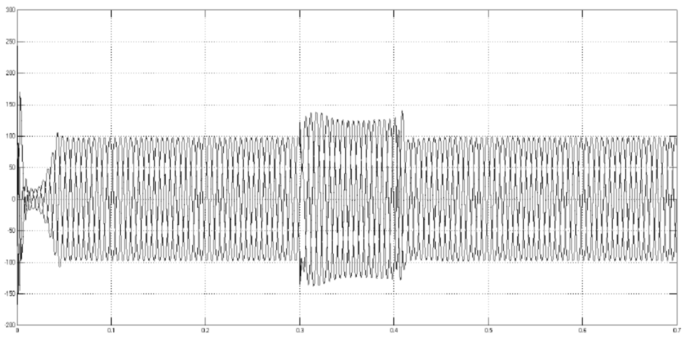

Fig 12. Current in Fault Condition

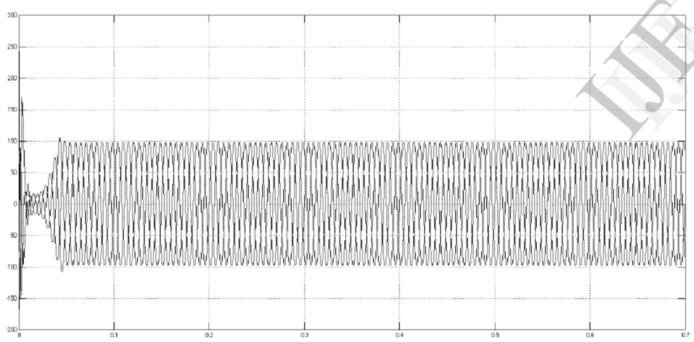

Fig 13. Current Improved in Fault Condition With DVR

V. CONCLUSION

In this paper an overview of DVR is presented. DVR is an effective custom power device for voltage sags and swells mitigation. The impact of voltage sags on sensitive equipment is severe. Therefore, DVR is considered to be an efficient solution due to its relatively low cost and small size, also it has a fast dynamic response. The simulation results show clearly the performance of a DVR in mitigating voltage sags. The DVR handles both balanced and unbalanced situations without any difficulties and injects the appropriate voltage component to correct rapidly any anomaly in the supply voltage to keep the load voltage balanced and constant at the nominal value.

REFERENCES

[1] Pedro Roncero-Sánchez, Enrique Acha “A Versatile Control Scheme for a Dynamic Voltage Restorer for Power-Quality Improvement” IEEE TRANSACTIONS ON POWER DELIVERY, JANUARY 2009

[2] Rosli Omar Nasrudin Abd Rahim “New Control Technique Applied in Dynamic Voltage Restorer for Voltage Sag Mitigation” 2009 IEEE

[3] J. Jeong, B. Han “Development of Line-Interactive Dynamic Voltage Restorer with Hybrid Sag Detection” 2010 IEEE

[4] J. Jeong1, B. Han “Development of Three-Phase Line-Interactive Dynamic Voltage Restorer with New Sag Detection Algorithm” 8th International Conference on Power Electronics - ECCE Asia May 30-June 3, 2011

[5] Alfonso Parre˜no Torres, Pedro Roncero-S´anchez “Generalized Proportional-Integral Control for Voltage-Sag Compensation in Dynamic Voltage Restorers” 2011 IEEE.

[6] Jingying Hu, Anthony D. Sagneri “High Frequency Resonant SEPIC Converter with Wide Input and Output Voltage Ranges” IEEE TRANSACTIONS ON POWER ELECTRONICS.

[7] B. Bae, J. Jeong “Novel Sag Detection Method for Line-Interactive Dynamic Voltage Restorer” IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 25, NO. 2, APRIL 2010

[8] J. W. Plastino, and W. G. Morsi, “On the Modeling of Dynamic Voltage Restorer for Voltage Sag Mitigation in Stand Alone Power System” 2011 IEEE Eletrical Power and Energy Conference

[9] R. H. Salimin, M. S. A. Rahim “Simulation Analysis of DVR Performance for Voltage Sag Mitigation” The 5th International Power Engineering and Optimization Conference (PEOCO2011), Shah Alam, Selangor, Malaysia : 6-7 June2011

[10] Hyun-Lark Do “Soft-Switching SEPIC Converter With Ripple-Free Input Current” IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 27, NO. 6, JUNE 2012

[11] Usha Rani P. Dr. S. Rama Reddy “Voltage Sag/Swell Compensation in an Interline Dynamic Voltage Restorer” PROCEEDINGS OF ICETECT 2011