Power Quality Improvement Using DVR

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Abstract- Voltage sags and swells in the medium and low voltage distribution grid are considered to be the most frequent type of power quality problems based on recent power quality studies. Their impact on sensitive loads is severe. The impact ranges from load disruptions to substantial economic losses up to millions of dollars. Different solutions have been developed to protect sensitive loads against such disturbances but the DVR is considered to be the most efficient and effective solution. Its appeal includes lower cost, smaller size and its dynamic response to the disturbance. This paper described DVR principles and voltage restoration methods for balanced and/or unbalanced voltage sags and swells in a distribution system. Simulation results were presented to illustrate and understand the performances of DVR under voltage sags/swells conditions.

Key words: Dynamic Voltage Restorer (DVR), voltage sags, voltage swells, power quality.

I. Introduction

In the early days of power transmission in the late 19th century problems like voltage deviation during load changes and power transfer limitation were observed due to reactive power unbalances. Today these Problems have even higher impact on reliable and secure power supply in the world of Globalization and Privatization of electrical systems and energy transfer. The development in fast and reliable semiconductors devices (GTO and IGBT) allowed new power electronic Configurations to be introduced to the tasks of power Transmission and load flow control. The FACTS devices offer a fast and reliable control over the transmission parameters, i.e. Voltage, line impedance, and phase angle between the sending end voltage and receiving end voltage. On the other hand the custom power is for low voltage distribution, and improving the poor quality and reliability of supply affecting sensitive loads. Custom power devices are very similar to the FACTS. Most widely known custom power devices are DSTATCOM, UPQC, DVR among them DSTATCOM is very well known and can provide cost effective solution for the compensation of reactive power and unbalance loading in distribution system [3].

The performance of the DSTATCOM depends on the control algorithm i.e. the extraction of the current components. For this purpose there are many control schemes which are reported in the literature and some of these are instantaneous reactive power (IRP) theory, instantaneous compensation, instantaneous symmetrical components, synchronous reference frame (SRF) theory, computation based on per phase basis, and scheme based on neural network [4- 10]. Among these control schemes instantaneous reactive power theory and synchronous rotating reference frame are most widely used. This paper focuses on the compensating the voltage sag, swells and momentary interruptions. The dynamic performance is analyzed and verified through simulation.

II. Dynamic Voltage Restorer (DVR)

A dynamic voltage restorer is a PE converter-based D-SSSC, which can protect sensitive loads from all supply side disturbances other than outages. It is connected in series with a distribution feeder and also is capable of generating or absorbing real and reactive power at its AC terminals. The basic principle of a DVR is simple: by inserting a voltage of the required magnitude and frequency, the DVR can restore the load-side voltage up to the desired amplitude and waveform even when the source voltage is either unbalanced or distorted. Usually, a DVR, as a cost-effective solution when compared to very costly UPS agreements, is connected in order to protect loads and can be implemented at both a LV level and a MV level; which gives an opportunity to protect high-power applications from voltage sags during faults in the supply system.

A typical location in the distribution system and the operation principle of the DVR is shown in Fig. 1 [7], where UT – terminal supply voltage, U'L – the load side voltage after restore; UC – the inserted voltage by the DVR, IL and IS are the load and feeder currents, PC – the real power generated or absorbed by the D-SSSC. DVR was commercially introduced in 1994 for the first time, and its first important installation was in North Carolina, for the rug manufacturing industry [8]. Since then, the number of installed DVR has increased continuously. Obviously, it is implemented especially in those industry branches where supply-side disturbances can lead to dangerous situations personnel or serious production losses.

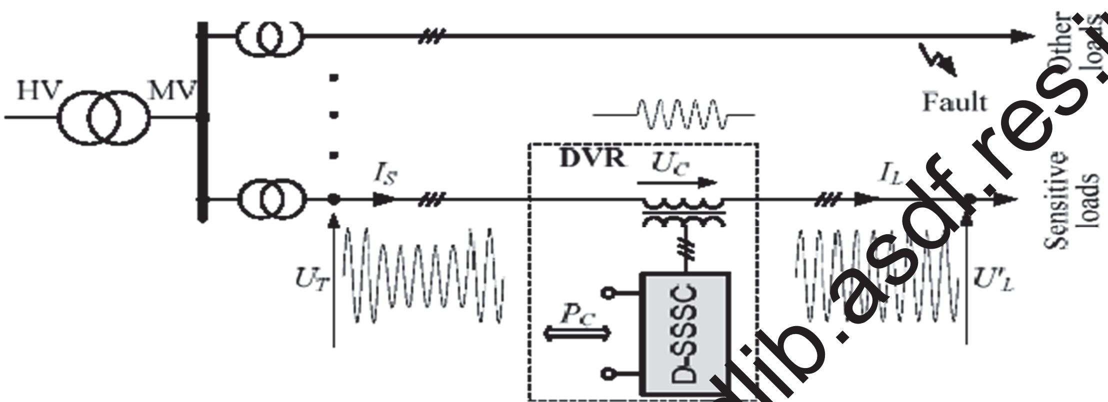
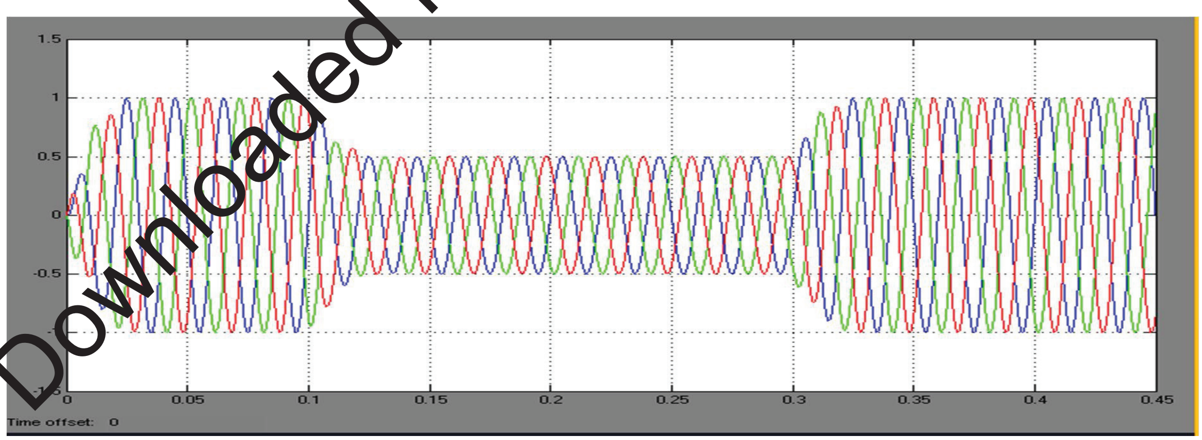


Figure 1 . A typical location and operation principle of the DVR

III. Results and Analysis

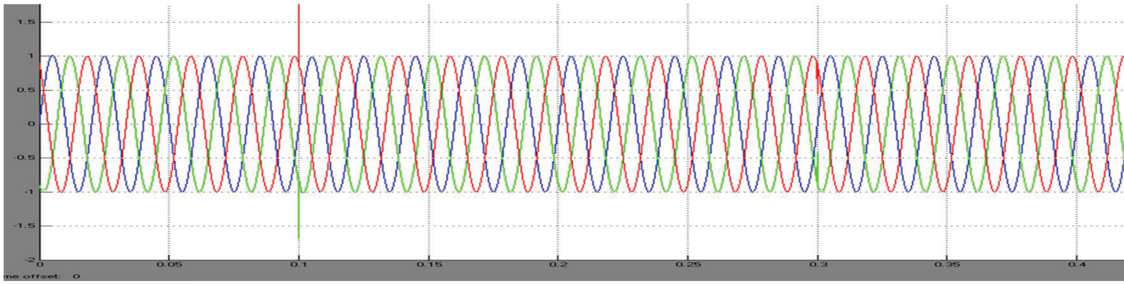
In order to show the performance of the DVR in voltage sags and swells mitigation, a simple distribution network was simulated using MATLAB. A DVR was connected to the system through a series transformer with a capability to insert a maximum voltage of 50% of the phase to ground system nominal voltage. In this simulation the In-Phase Compensation (IPC) method was used. The load considered in the study is a 5.5 MVA capacity with 0.92 p.f, lagging.

Voltage sags:



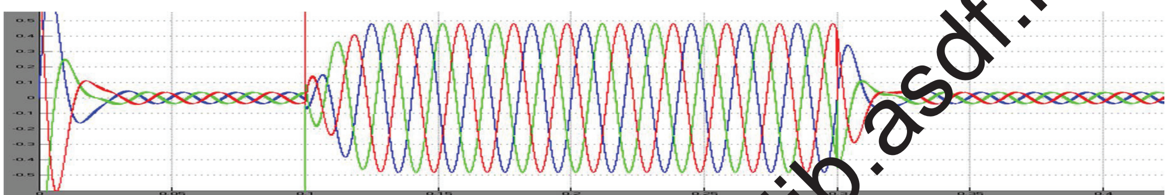
Time in Seconds

A case of Three-phase voltage sag was simulated and the results are shown in voltage sag initiated at 100 ms and it is kept until 300 ms, with total voltage sag duration of 200 ms. voltage injected by the DVR and the compensated load voltage, respectively. It quickly injects necessary voltage components to smooth the load voltage upon detecting voltage sag.



Time in Seconds

As a result of DVR, the load voltage is kept at 1 p.u. throughout the simulation, including the voltage sag period



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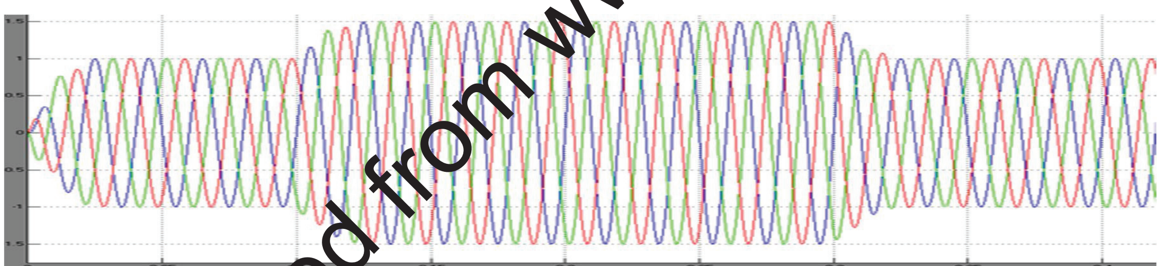
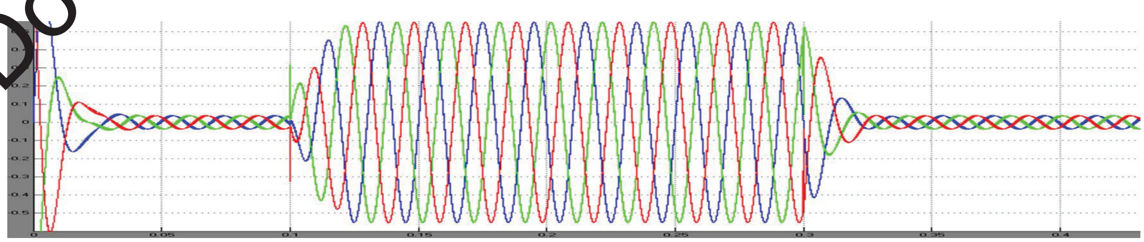
Voltage Swells:

The performance of DVR for a voltage swell condition was investigated. Here, the supply voltage swell was generated as shown in below.

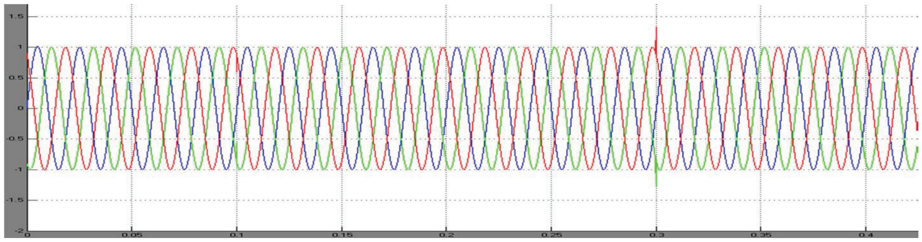


Time in Seconds

The supply three-phase voltage amplitudes were increased about 125% of nominal voltage. The injected threes phase voltage that was produced by DVR in order to correct the load voltage and the load voltage are shown below respectively. As can be seen from the results, the load voltage was kept at the nominal value with the help of the DVR. Similar to the case of voltage sag, the DVR reacted quickly to inject the appropriate voltage component (negative voltage magnitude) to correct the supply voltage.

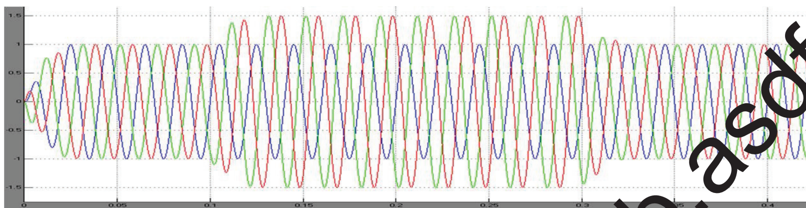


Time in Seconds



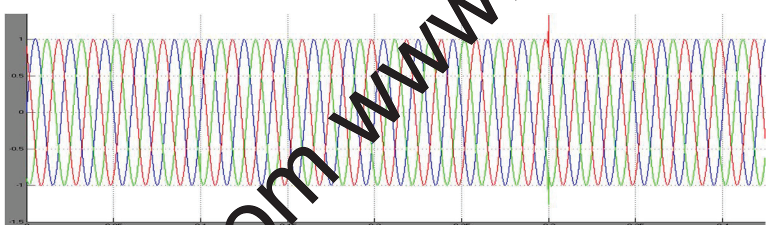
Time in Seconds

The performance of the DVR with an unbalanced voltage swell is shown. In this case, two of the three phases are higher by 25% than the third phase as shown.



Time in Seconds

The injected voltage that was produced by DVR in order to correct the load voltage and the load voltage are shown.



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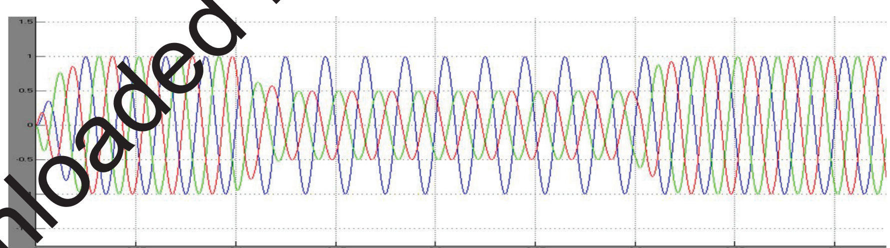

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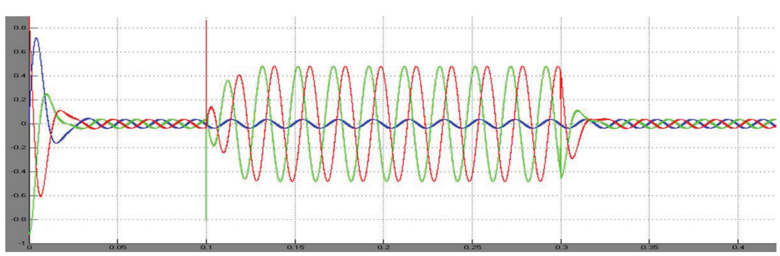

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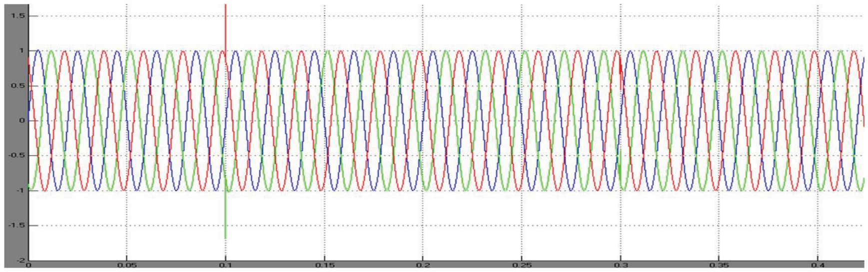

Time in Seconds

Two-phase voltage sag; (a): Source voltages;(b): Injected voltages; (c): Load voltages

IV. Conclusions

The simulation results showed clearly the performance of the DVR in mitigating voltage sags and swells. The DVR handled both balanced and unbalanced situations without any difficulties and injected 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. The efficiency and the effectiveness in voltage sags/swells compensation showed by the DVR makes him an interesting power quality device compared to other custom power devices

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