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Power Quality Improvement of Distribution Networks Using Dynamic Voltage Restorer

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ABSTRACT:The Dynamic voltage restorer is custom power device which is utilized to mitigate the voltage at load terminals. It has become important, especially, with the introduction of sophisticated devices, whose performance is very sensitive to the quality of power supply. Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure of end user equipment's. One of the major problems deal at here is the voltage sag. To solve this problem, custom power devices are used. One of those devices is the Dynamic Voltage Restorer (DVR), used in power distribution networks. In this paper DVR injects required voltage in series with supply voltage through injection transformer for correcting voltage amplitude, phase and harmonic component into line. This paper presents simulation and analysis of a Dynamic Voltage Restorer (DVR) with dynamic loading and RLC loading at fault condition(three phase fault) using MATLAB / SIMULINK. To enhance the voltage sagreconstruction capability of the DVR, this paper deals with the development of a control structure using a PI controller.

KEYWORDS: Dynamic Voltage Restorer (DVR),Battery Energy Storage Systems (BESS), Flexible AC Transmission Systems (FACTS), Insulated Gate Bipolar Transistors (IGBT), Unified power quality conditioner (UPQC).

I.INTRODUCTION

In modern industrial devices most of devices are based on electronic devices. The power electronic devices are very sensitive to create power quality issues such as voltage sags, swells and harmonics but voltage sags is one of the most severe issue to the industrial equipment The problem of poor power quality like voltage sag for sensitive loads can be better dealt or solved by power electronics based Dynamic Voltage Restorer. With the application of DVR, the power system can be operated without voltage sag and the power supply by flexibly changing the distribution configuration after the occurrence of a fault. The DVR is a series conditioner based on a pulse width modulated (PWM) voltage source inverter which could generate or absorb real or reactive power independently. [1] The condition of Voltage sags caused faults is, influenced in case of sensitive loads. The DVR injects the individual voltages to restore and maintained sensitive loads to its nominal value. The combination of the custom power devices DVR with PI controller for the power quality improvement in the distribution system is describe here for operation of DVR to improve the power quality in distribution system. [4]A new control strategy has been developed for achieving maximum benefits by eliminating or mitigating voltage sag / swell and power quality problem when abnormal condition occur in the distribution system, for this purpose the dynamic voltage restorer is proposed to improve the power quality and to reduce the sag and swell problem in the system.[16]

II. SYSTEM CONFIGURATION & EQUATIONS

Dynamic Voltage Restorer has two operating modes. In normal operation mode it is in standby mode in which voltage injection by DVR is zero. The primary function of DVR is to compensate voltage sags and swells but it can also perform the tasks such as harmonic compensation, reduction of transient in voltage and fault current limitation. The main parts of DVR are injection transformer, harmonic filter, a voltage source converter, energy storage device and control & protection system [3-4]. As soon as control circuit detects the any voltage disturbance, reference voltage is generated for required magnitude, duration and phase and is injected through injection transformer. This mode of DVR is known as injecting mode [1]. This injection should satisfy the equation (1) [2]

$$V_L=V_S+ V_{inj}......................... (1)$$

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Where V_S is the source voltage, V_{inj} is the injected voltage by DVR and V_L is the load voltage.Fig.1 shows the basic configuration and operation of DVR which consist of an injection transformer, Voltage Source Converter (VSC), harmonic filter, storage device and control system.

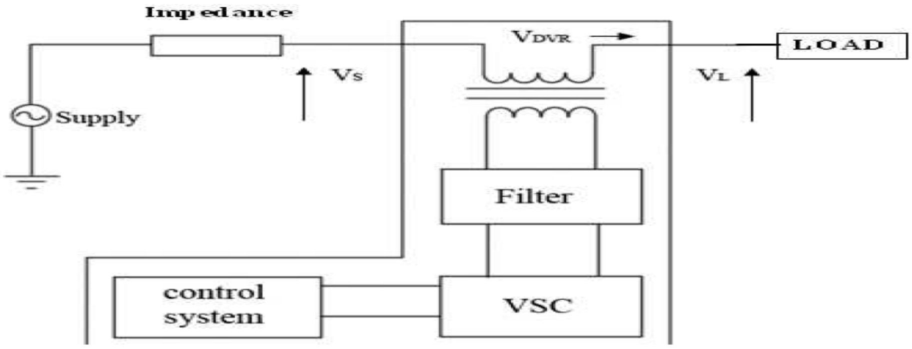

Fig. 1: Schematic diagram of DVR

Injection transformer is used to connect the DVR to the distribution network via High Voltage winding and injects the compensating voltage generated by VSC after the detection of any disturbance in supply voltage by control circuit. Another main task of injection transformer is that it will limit the coupling of noise and isolate VSC and control circuit from the system [5].VSC is a power electronic device consists of storage device and switching devices used to generate the compensating sinusoidal voltage of required magnitude, duration, in phase as that of system and instantaneously. In DVR voltage source converter provides the missing voltage during voltage sag [2].Output of VSC contains large content of harmonics. Harmonic filter is used to keep this harmonic content in Permissible limit [7].It is basically used to supply the necessary energy to VSC to generate the compensating voltage [2], [7].Control circuit continuously monitors the supply voltage. The function of control system is to detect the disturbance in the supply voltage, compare it with the set reference value and then generate the switching pulses to the VSC to generate the DVR output voltages which will compensate the voltage sag/swell [2], [7].

III.OPERATING METHOD OF DVR

The basic function of the DVR is to inject a dynamically controlled voltage V_{DVR} generated by a forced commutated converter in series to the bus voltage by means of a booster transformer. The momentary amplitudes of the three injected phase voltages are controlled such as to eliminate any detrimental effects of a bus fault to the load voltage V_L. This means that any differential voltages caused by transient disturbances in the ac feeder will be compensated by an equivalent voltage generated by the converter and injected on the medium voltage level through the booster transformer.

Voltage injection or compensation methods by means of a DVR depend upon the limiting factors such as; DVR power ratings, various conditions of load, and different types of voltage sags. Some loads are sensitive towards phase angel jump and some are sensitive towards change inmagnitude and others are tolerant to these. Therefore the control strategies depend upon the type of load characteristics. [10]

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IV.DEVELOPMENT TEST SYSTEM FOR DVR

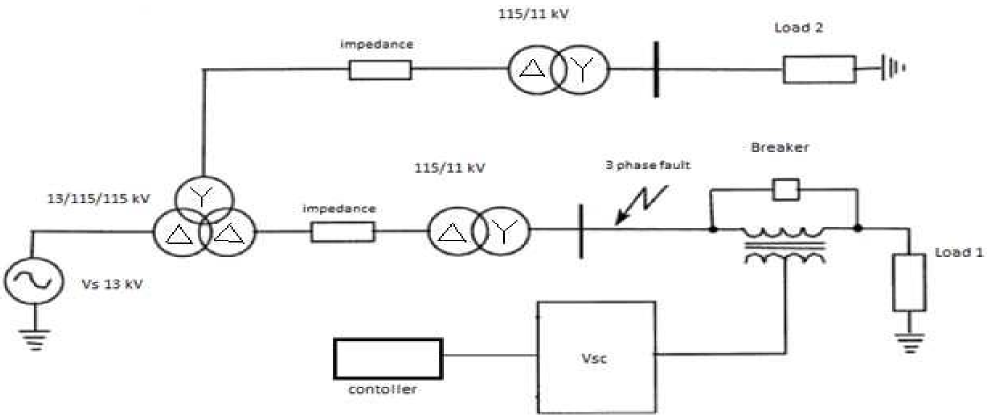

Fig. 2: Single line diagram of test system

Single line diagram of the test system for DVR is composed by a 13 kV, 50 Hz generation system, feeding two transmission lines through a 3- winding transformer connected in Y/Δ/Δ, 13/115/115 kV. Such transmission lines feed two distribution networks through two transformers connected in Δ/Y, 115/11 kV. To verify the working of DVR for voltage compensation, when fault is applied.

CASE: 1 SIMULINK MODEL OF DVR SYSTEM USING PI CONTROLLER WITH RLC LOAD

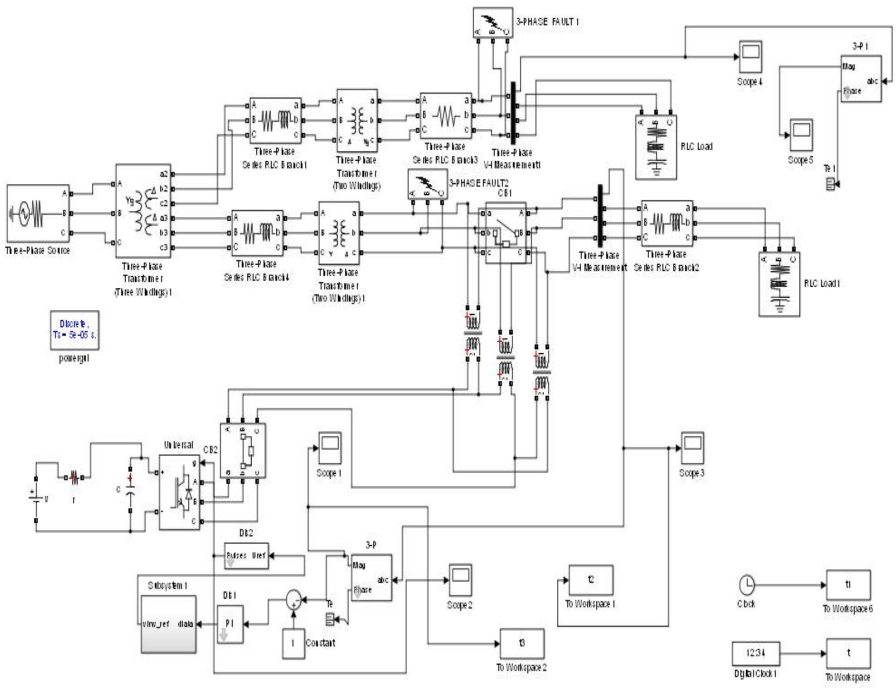

Figure 3: SIMULINK MODEL OF DVR with PI controller with RLC Load

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V. SIMULATIONS AND RESULTS

The first simulation was done without DVR and with RLC load a three phase fault is applied to the system. The second simulation is done at the same condition as above but here DVR is connected at the load side to compensate the voltage sag occurred due to the three phase fault applied.

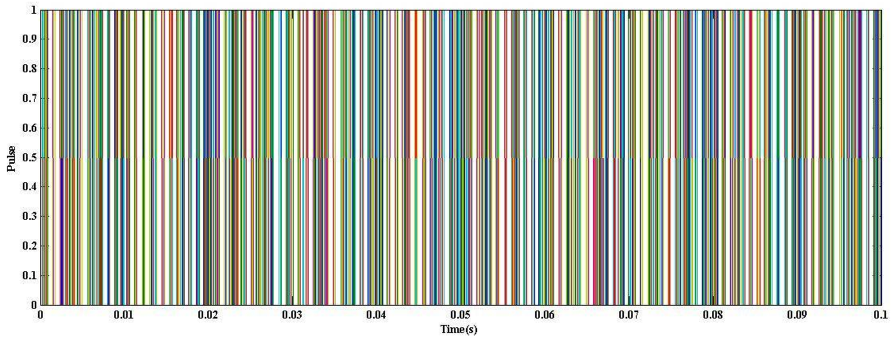

Figure 4: Firing pulse generated by discrete PWM generator

Fig. 4 shows the gate pulse for universal bridge with respect to time & fig. 5 shows the voltage magnitude at load point when the system operates without DVR and a three phase fault is applied to the system.

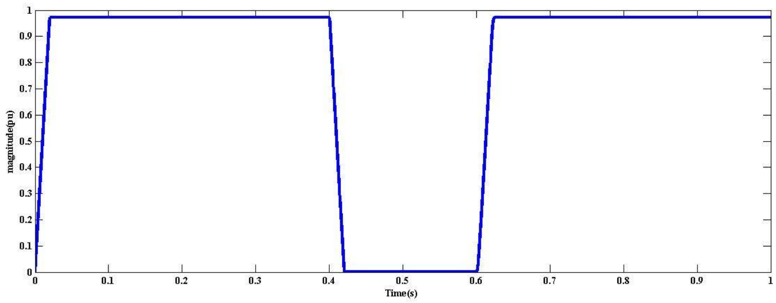

Figure 5: Voltage (pu) at load point, with 3-Φ fault, without DVR

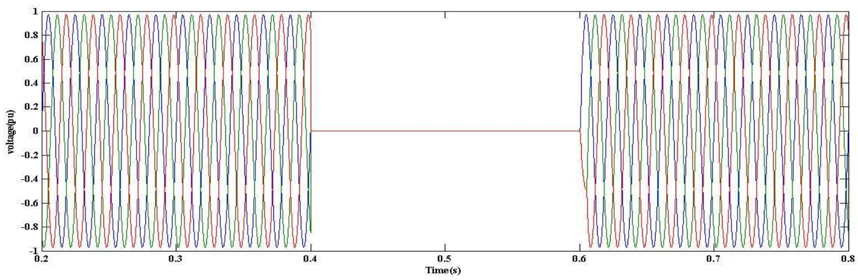

Figure 6: 3- Φ Voltage (pu) at load point with 3- Φ fault without DVR

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When the DVR is in operation the voltage sag is compensated almost completely shows in fig.8 and voltage at load point is maintained at almost normal condition. Fig. 6 shows that the three phase voltage at load point with three phase fault, without DVR. Fig. 7 shows that the three phase voltage at load point with three phase fault, with DVR.

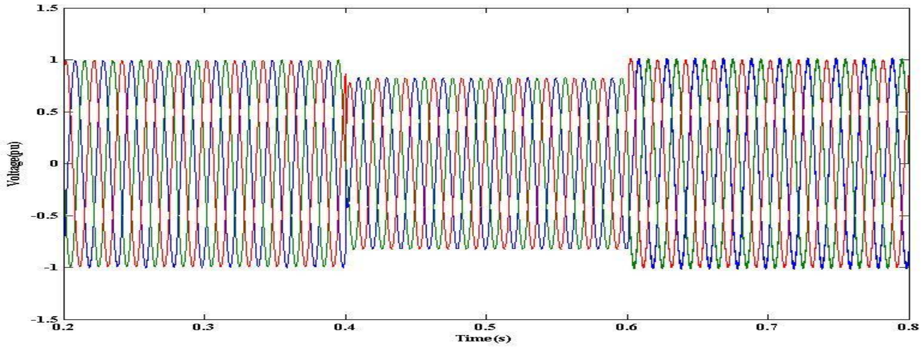

Figure 7: 3- Φ Voltage (pu) at load point with 3- Φ fault with DVR

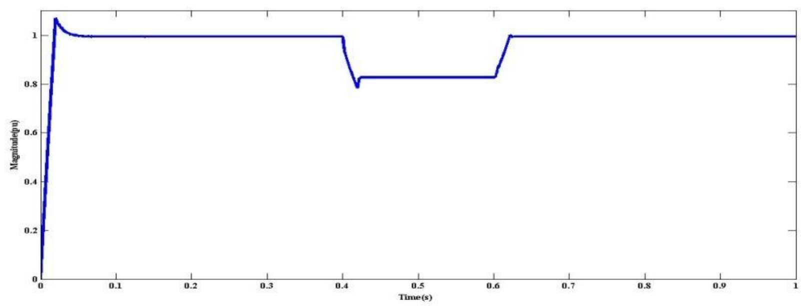

Figure 8: Voltage (pu) at load point with 3-Φ fault with DVR

CASE: 2 MATLAB MODEL OF DVR SYSTEM USING PI CONTROLLER WITH DYNAMIC LOADING

The Simulink model with the dynamic loading is also investigated three phase\ fault conditions are considered for this loading. There is inherent problem of starting dip in case of dynamic loading and effectiveness of DVR to reduce this problem is investigated in this work. Voltage sag condition is created in the proposed SIMULINK model and effectiveness of DVR for the same is investigated. Results for all these conditions are presented in the next section.

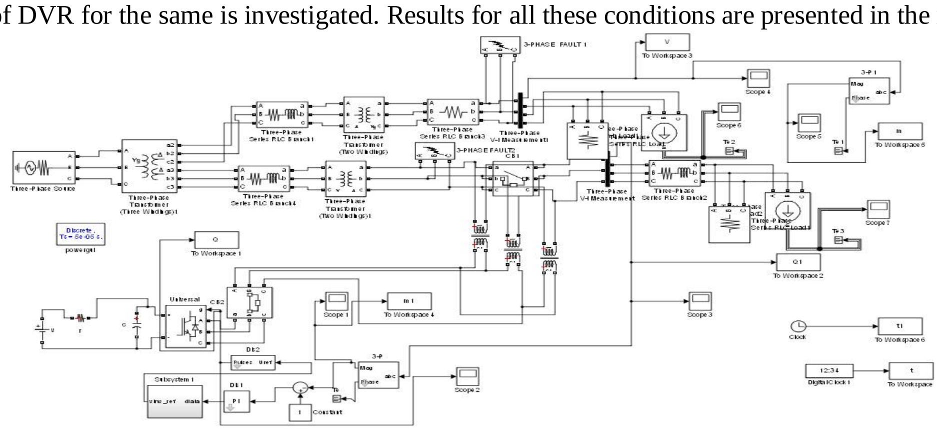

Figure 9: SIMULINK block diagram of DVR with PI controller with DYNAMIC Loading

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VI. SIMULATIONS AND RESULTS

The first simulation was done without DVR and with Dynamic Loading a three phase fault is applied to the system. The second simulation is done at the same condition as above but here DVR is connected at the load side to compensate the voltage sag occurred due to the three phase fault applied.

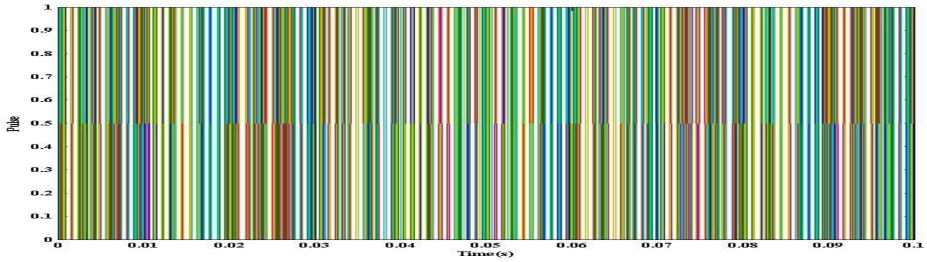

Figure 10: Firing pulse generated by discrete PWM generator

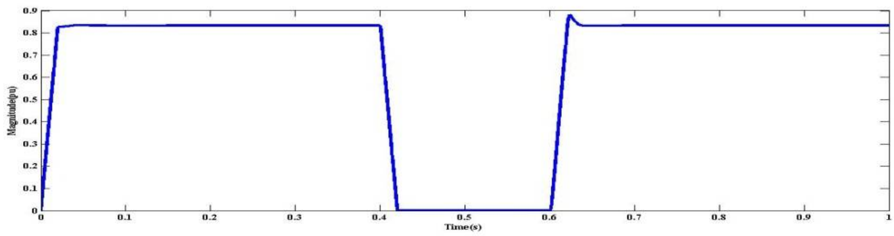

Figure 11: Voltage (pu) at load point with 3-Φ fault without DVR

Fig. 10 shows the gate pulse for universal bridge with respect to time & fig. 11 shows the voltage magnitude at load point when the system operates without DVR and a three phase fault is applied to the system.

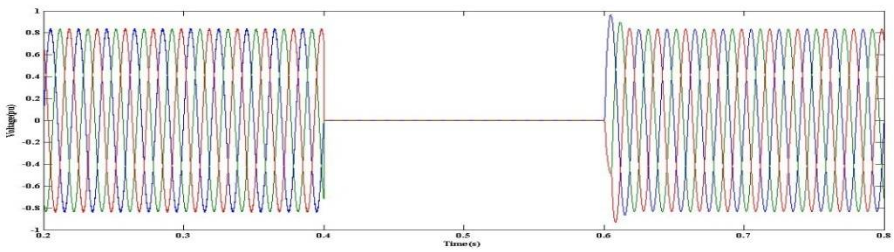

Figure 12: 3- Φ Voltage (pu) at load point with 3- Φ fault without DVR

When the DVR is in operation the voltage sag is compensated almost completely shows in fig.14 and voltage at load point is maintained at almost normal condition. Fig. 12 shows that the three phase voltage at load point with three phase fault, without DVR.

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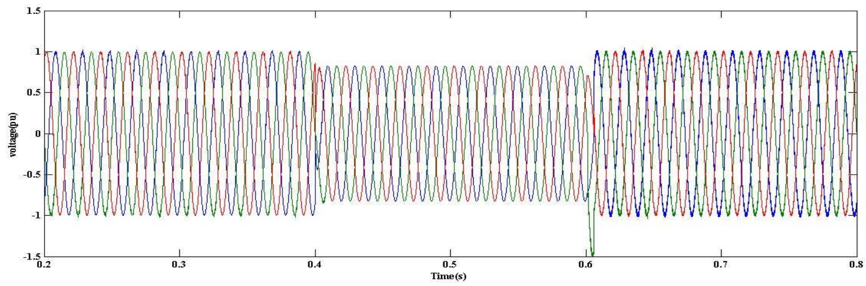

Figure 13: 3- Φ Voltage (pu) at load point with 3- Φ fault with DVR

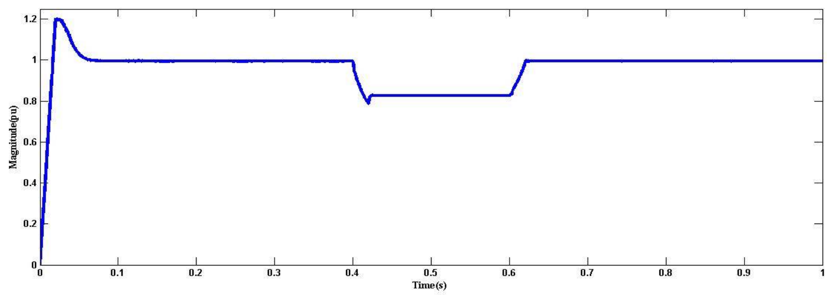

Figure 14: Voltage (pu) at load point with 3-Φ fault with DVR

VII. CONCLUSION

This paper has presented the power quality problems such as voltage dips, and mitigation techniques this problem by using DVR. The design and applications of DVR for voltage sags result is presented. The load side voltage (p.u) during a fault condition of DVR is presented, from this DVR deliver good compensation. Voltage magnitude (p.u.) of DVR before compensation is 0.01p.u. After compensation voltage magnitude of DVR becomes 0.86p.u and Improved Voltage is 0.85p.u.Results obtained shows that the developed DVR has good capability to increase the voltage level during voltage sag conditions.

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