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Improvement of Voltage output for Distribution System under Transient Condition with Dynamic Voltage Restorer

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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. In this paper, the performance of voltage-source converter-based series compensators used for load voltage control in electrical power distribution network has been analyzed and compared, when a nonlinear load is connected across the load bus. Possible control schemes and their effects on the oscillation attenuation are also studied. Such studied control schemes include the commonly used single voltage loop control, voltage feedback plus reference feed forward control, and double-loop control with an outer voltage loop and an inner current loop. This research 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. The MATLAB simulation verification of the results derived has been obtained using a model of the three-phase DVR.**

***Keywords*— Dynamic voltage restorer (DVR), Flexible Alternating Current Transmission System, (FACTS), load voltage control, nonlinear load.**

I. Introduction

Power quality is certainly a major concern in the present era; it becomes especially important with the introduction of sophisticated devices, whose performance is very sensitive to the quality of power supply. Modern industrial processes are based a large amount of electronic devices such as programmable logic controllers and adjustable speed drives.

The main objective of this paper is to show that using Dynamic voltage restores (DVRs) are now becoming more established in industry to reduce the impact of voltage dips on sensitive loads. A voltage dip is commonly defined as any low voltage drop event between 10% and 90% of the nominal RMS voltage, Dynamic Voltage Restorer (DVR) it is possible to reduce the voltage fluctuations like sag and swell conditions in distribution systems.

DVR which is used for improving power quality is modelled and simulated using proposed control strategy and the performance is compared by applying it to a Single-machine infinite bus system with and without DVR. MATLAB R2009a version 7.8.0.347(64-bit) is used for Simulation of DVR and DSTATCOM model.

II. Sources And Effects Of Power Quality Problems

The distortion in the quality of supply power can be introduced /enhanced at various stages; however, some of the primary sources of distortion [3] can be identified as below:

i) Power Electronic Devices
ii) IT and Office Equipments
iii) Arcing Devices
iv) Load Switching
v) Large Motor Starting
vi) Embedded Generation
vii) Electromagnetic Radiations and Cables
viii) Storm and Environment Related Causes etc.

Some of the common power quality issues and their prominent impact are summarized below:

a) *Voltage sags:-* Devices /Process down time, effect on product quality, failure/malfunction of customer equipments and associated scrap cost, clean up costs, maintenance and repair costs etc.

b) *Transients:-* Tripping, components failures, flashover of instrument insulation hardware re booting, software glitches, poor product quality etc.

c) *Harmonics:-* Excessive losses and heating in motors, capacitors and transformers connected to the system

d) *Flicker:-* Visual irritation, introduction of many harmonic components in the supply power and their associated equipment.

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III. Dynamic Voltage Restorer (DVR): A Series Voltage Controller

A series compensator is a dual of the shunt compensator – it protects a sensitive load from the distortion in the supply side voltage. By inserting a voltage of required magnitude and frequency, the series compensator can restore the load side voltage to the desired amplitude and waveform even when the source voltage is unbalanced or distorted. Usually, a series compensator is used to protect sensitive loads during faults in the supply system. The series voltage controller is connected in series with the protected load as shown in Fig.1. Usually the connection is made via a transformer, but configurations with direct connection via power electronics also exist. The resulting voltage at the load bus bar equals the sum of the grid voltage and the injected voltage from the DVR. The converter generates the reactive power needed while the active power is taken from the energy storage.

A power electronic converter based series compensator that can protect critical loads from all supply side disturbances other than outages is called a dynamic voltage restorer (DVR).

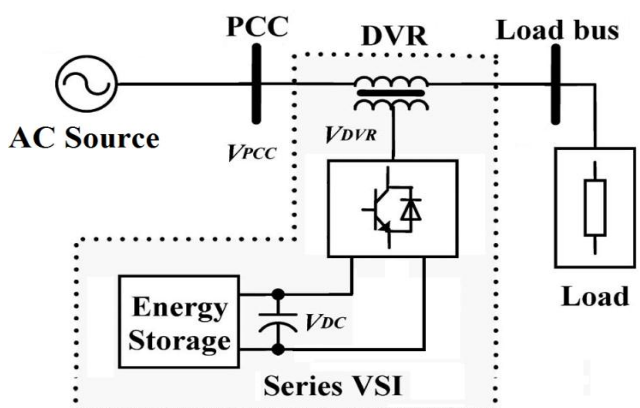

Fig. 1 Schematic diagram of DVR

The energy storage can be different depending on the need of compensation. The DVR often has limitations on the depth and duration of the voltage dip that it can compensate. In figure 1, the circuit on the left hand side of the DVR represents the Thevenin equivalent circuit of the system. The system impedance Z_{th} depends on the fault level of the load bus. When the system voltage (V_{th}) drops, the DVR injects a series voltage V_{dvr} through the injection transformer so that the desired load voltage magnitude V_L can be maintained.

$$V_{DVR} = V_L + Z_{th} I_L - V_{th}$$

Where V_L is the desired load voltage magnitude

Z_{Th} is the load impedance

I_L is the load current

V_{th} is the system voltage during fault condition

The load current I_L is given by,

$$I_L = \left(\frac{P_L + j \times Q_L}{V_L}\right)$$

When V_L is considered as a reference,

$$V_{DVR}\angle\alpha = V_L\angle 0 + Z_{th} \times I_L\angle(\beta - \theta) - V_{th}\angle\delta$$

Here α, β and δ are the angle of V_{DVR}, Z_{th} and V_{th}, respectively, and θ is the load power factor angle,

IV. Controller Scheme

To maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances we must introduce controller. The control system only measures the r.m.s voltage at the load point, i.e., no reactive power measurements are required. The VSC switching strategy is based on a sinusoidal PWM. This methods offer a more flexible option than the Fundamental Frequency Switching (FFS) methods favored in FACTS applications. The controller input is an error signal obtained from the reference voltage and the value rms of the terminal voltage measured. Such error is processed by a PI controller the output is the angle δ, which is provided to the PWM signal generator. The PI controller process the error signal generates the required angle to drive the error to zero, i.e., the load rms voltage is brought back to the reference voltage.

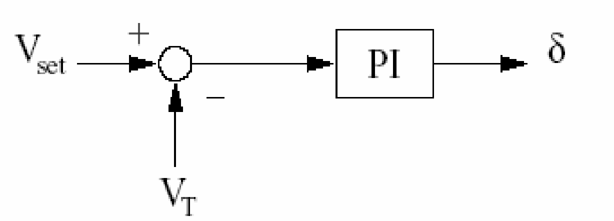

Fig. 2 Schematic diagram of PI controller

The sinusoidal signal $V_{control}$ is phase-modulated by means of the angle δ. i.e.,

$$V_a = \sin(\omega t + \delta)$$

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$$V_b = \sin\left(\omega t + \delta - {}^{2\pi}/_{3}\right)$$

$$V_c = \sin\left(\omega t + \delta + {}^{2\pi}/_{3}\right)$$

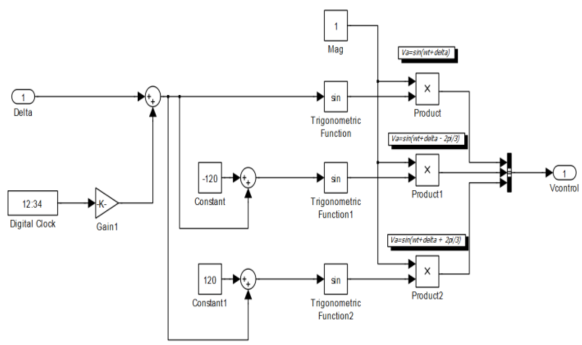

Fig. 3 Mathematical model of PWM generator

The modulating angle is applied to the PWM generators in phase A. The angles for phases B and C are shifted by 240° and 120°, respectively. It can be seen in that the control implementation is kept very simple by using only voltage measurements as the feedback variable in the control scheme.

The main parameters of the sinusoidal PWM scheme are the amplitude modulation indeed of signal and the frequency modulation index of the triangular signal. The amplitude index is kept fixed at 1 p.u., in order to obtain the highest fundamental voltage component at the controller output.The switching frequency is set at 1080 Hz. The frequency modulation index is given by,

$M_F = Fs/F_1 = 1080/50 = 21.6$

Where, F_1 is the fundamental frequency.

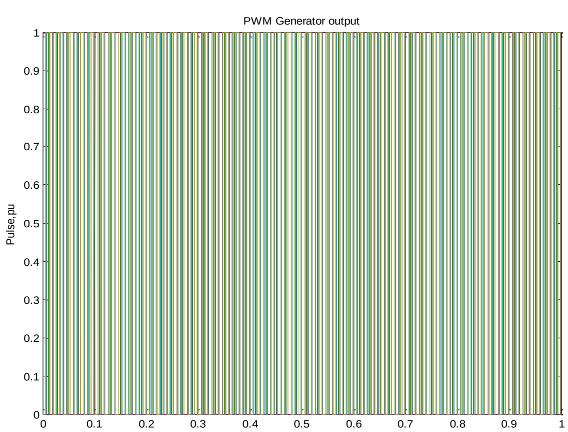

Fig. 4 Output of PWM generator

V. Results And Discussion Dvr: A Series Voltage Controller

Using the facilities available in MATLAB SIMULINK, the DVR is simulated to be in operation only for the duration of the fault, as it is expected to be the case in a practical situation. Power System Block set for use with Matlab/Simulink is based on state-variable analysis and employs either variable or fixed integration-step algorithms. Figure-9 shows the simulink model of DVR and Figure-8 shows the Simulink model of the test system for DVR.

A. Single line to ground fault Without DVR

The first simulation contains no DVR and a single line to ground fault is applied as shown in below Fig.3, via a fault resistance of 0.2 Ω during the period 300-600 ms. The voltage sag at the load point is 30% with respect to the reference voltage.

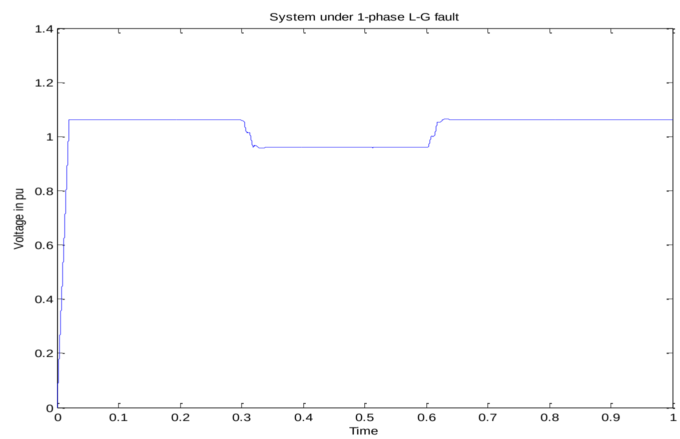

Fig. 5 Single line to ground fault Without DVR

B. Single line to ground fault With DVR

Now with the DVR in operation. The total simulation period is 1000 ms. When the DVR is in operation the voltage sag is mitigated almost completely and the r.m.s voltage at the sensitive load point is maintained at 98%, as shown in figure 4.

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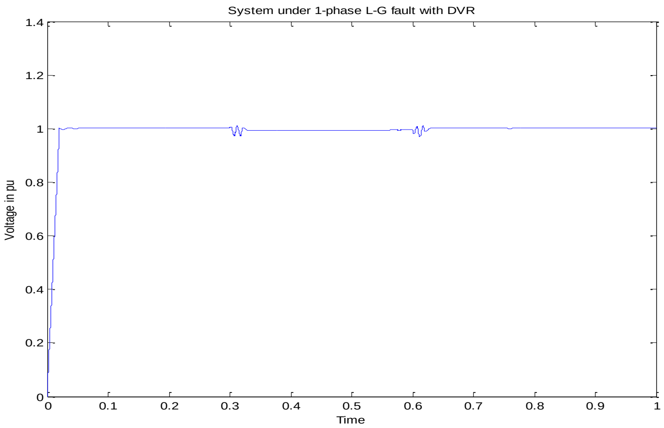

Fig. 6 Single line to ground fault With DVR

C. Three phase Line to Ground Fault Without DVR

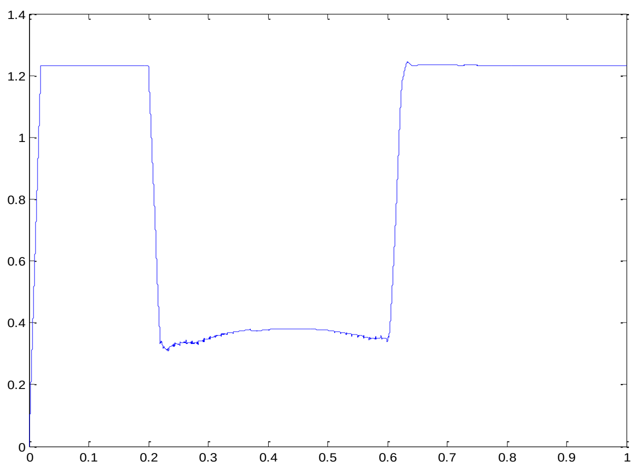

Fig. 7 Three phase Line to Ground Fault Without DVR

D. Three phase Line to Ground Fault With DVR

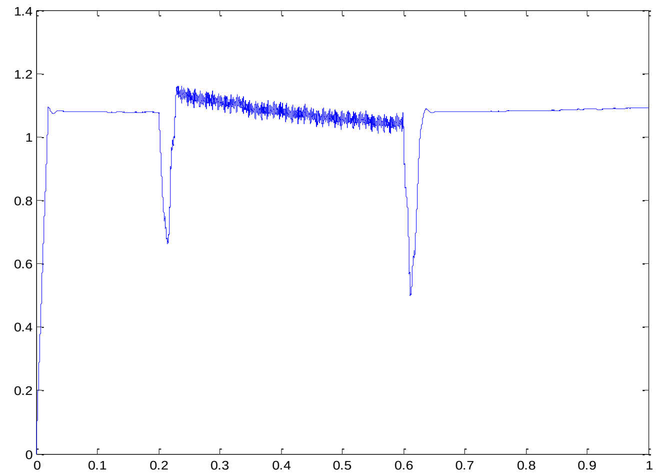

Fig. 8 Three phase Line to Ground Fault With DVR

VI. Conclusions

Since, from above comparison the basic difference of DVR to have overall superior functional characteristics, better performance with greater flexibility make more adoptable for low voltage distribution power network. A key feature of this control scheme is its simplicity; only one controller is required to eliminate three PQ disturbances, namely, voltage sags, harmonic voltages, and voltage imbalances. The controller can be implemented by using either a stationary reference frame or a rotating reference frame.This paper has presented the power quality problems such as voltage dips, and interruption, consequences and mitigation techniques of custom power electronic devices DVR. The design and applications of DVR for voltage sags, interruptions and swells and comprehensive results are presented. This characteristic makes it ideally suitable for low-voltage custom power applications.

Acknowledgment

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