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Dynamic Voltage Restorer (Dvr) A Solution to Voltage Sag Mitigation in Power System

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Abstract
In this paper, we illustrate the power quality problem of voltage sag and its impact on non linear loads or sensitive loads. This paper also aims for improvement power quality by using Dynamic Voltage Restorer (DVR). Voltage sag is short reduction of voltage from normal voltage or healthy value of voltage. It is due to abnormalities which are occurring in power system for a short duration like voltage flicker, harmonic distortion, impulse transients etc..which can cause damage and loss of production especially in industrial sector. Custom power devices have been developed to improve voltage quality such as dynamic voltage restorer, distribution static compensator, uninterruptible power supply. Dynamic voltage restorer is fast, flexible and efficient solution to voltage sag/swell problem. Our project focuses mainly on DVR system which will be simulated using MATLAB simulink.
Keywords: Power Quality, Voltage Sag, Dynamic Voltage Restorer (DVR), , MATLAB

I. INTRODUCTION

Generally a healthy voltage waveform is sinusoidal with a constant or fixed frequency any deviation or disturbance in sinusoidal wave can result in abnormal operation of electrical or electronic device “Power quality is described as the deviation of voltage, current from its ideal waveforms. It refers to a wide variety of electromagnetic phenomena such as voltage sag, flicker, harmonic distortion transients etc.. that characterize the voltage and current at a given time and at a given location in the power system”. Voltage Sag (dip) is a momentary decrease in the root mean square (RMS) voltage magnitude in the range of 0.1 to 0.9 per unit, with a duration ranging from half cycle up to 1 min. It is considered as the most serious problem of power quality. It is often caused by balanced or unbalanced faults in the distribution system or by the starting of large induction motors. Voltage swell is defined as an increase in rms voltage or current at the power frequency for durations from 0.5 cycles to 1 min. typical magnitudes are between 1.1 and 1.8 up.Voltage swells are not as important as voltage sags because they are less common in distribution systems .There are different methods to mitigate voltage sags and swells, use of a custom Power device is considered to be the most efficient method. One of the most important custom power devices that has been created to improve the performance of power quality is Dynamic Voltage Restorer (DVR). The DVR maintains the load voltage at a nominal magnitude and phase by compensating the voltage sag/swell, voltage unbalance and voltage harmonics, DVR compensate voltage sags by increasing the appropriate voltages in series with the supply voltage, and therefore prevent loss of power.

II. DYNAMIC VOLTAGE RESTORER

Among the power quality problems (sags, swells, harmonics…) voltage sags are the most severe disturbances. In order to overcome these problems the concept of custom power devices is introduced recently. 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. 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 isnormally 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.

A. Basic Configuration of DVR:

The general configuration of the DVR consists of an 1.Injection / Booster transformer, 2. Harmonic filter, 3.Voltage Source Converter (VSC), 4.Battery,5.Control and auxiliary circuits.

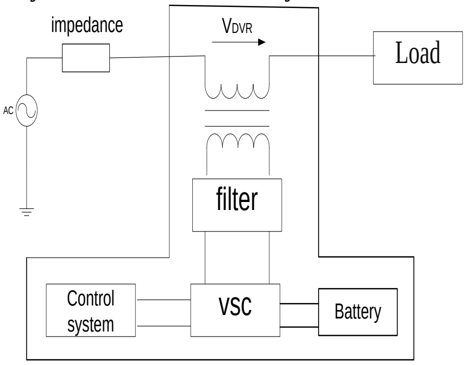


Fig 1: Schematic block diagram of DVR

1) SeriesInjectionTransformers: Three single-phase injection transformers are used to inject the missing voltage to the system at the load bus. To integrate the injection transformer correctly into the DVR, the MVA rating, the primary winding voltage and current ratings, the turn-ratio and the short-circuit impedance values of transformers are required. The existence of the transformers allow for the design of the DVR in a lower voltage level, depending upon the stepping up ratio. In such case, the limiting factor will be the ability of the inverter switches to withstand higher currents.

2) Harmonic Filter:The main task of harmonic filter is to keep the harmonic voltage content generated by the VSC to the permissible level.

3) Inverter Circuit:The primary function of a voltage source inverter is to convert a fixed dc voltage to a three –phase ac voltage with variable magnitude and frequency. Either a conventional two level converter or a three level converter is used. The increased number of levels has the main advantage of a decrease in the line filter size. For the relative simple two and three level topologies the main voltage drop are expected to be caused by the line-filter and the injection transformers, but by increasing the number of levels the line-filter can be reduced and the voltage drop across the semiconductor devices will have a greater importance.

4) Energy StorageUnit: The required energy for compensation of load voltage during sag can be taken either from an external energy storage unit (batteries) or from the supply line feederThrough a rectifier and capacitor.

5) Controller and auxiliary circuits: By-Pass switches, breakers, measuring and protection relays are some auxiliaries to the DVR block, in addition to the controller of the DVR.

B. Equations related to DVR

The system impedance Zth depends on the fault level of the load bus. When the system voltage (Vth) drops, the DVR injects a series voltage VDVR through the injection transformer so that the desired load voltage magnitude VL can be maintained. The series injected voltage of the DVR can be written as

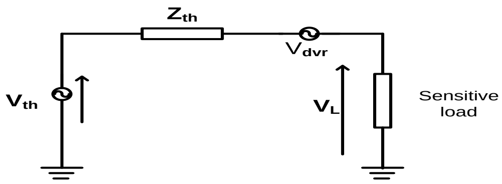


Fig 2 : Equivalent circuit diagram

$$V_{DVR} = V_L + Z_{TH} * I_L - V_{TH}$$

Where,

V_L:The desired load voltage magnitude

Z_{TH} :The load impedance.

I_L: The load current.

V_{TH}: The system voltage during fault condition.

The load current IL is given by,

$$IL = \frac{[PL + jQL]}{V}$$

When VL is considered as a reference equation can be rewritten as,

$$V_{DVR}\angle 0 = V_L\angle 0 + Z_{TH}\angle(\beta - \theta) - V_{TH}\angle\delta$$

α, β, δ are angles of VDVR, Z_{TH}, V_{TH} respectively and θ is Load power angle

$$\theta = \tan^{-1}(\theta L/PL)$$

The complex power injection of the DVR can be written as,

$$S_{DVR} = V_{DVR}\ I_L^*$$

It requires the injection of only reactive power and the DVR itself is capable of generating the reactive power.

C. Operating modes

The DVR has three operating modes :

1) *Standby mode*(also termed as short circuit operation mode) : Where the voltage injected has zero magnitude i.e. it is short circuited or bypassed by the switch.

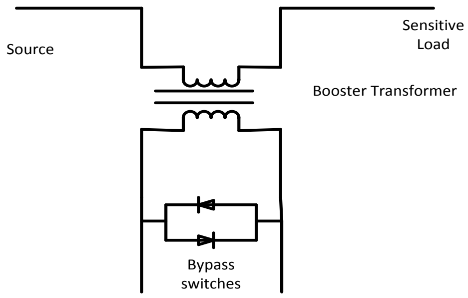


Fig 3 : Standby Mode

2) Boost mode: where the DVR injects a required voltage of appropriate magnitude and phase to restore the prefault load bus voltage by injecting the missing voltage.

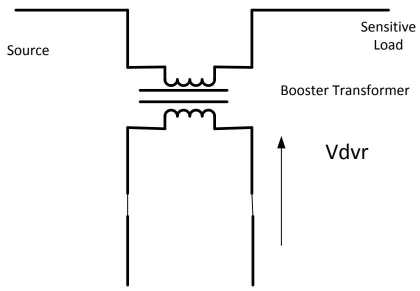


Fig 4 : Boost Mode

3) Protection mode:If the over current on the load side exceeds a permissible limit due to short circuit on theload or large inrush current, the DVR will be isolated from the systems by using the bypassswitches (S2 and S3 will open) and supplying another path for current (S1 will be closed).

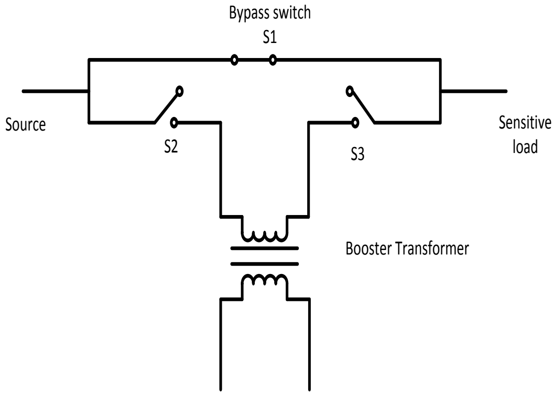


Fig 5 : Protection Mode

III. COMPENSATION STRATEGY

There are three basic control strategies as follows

1) Pre-Sag Compensation:

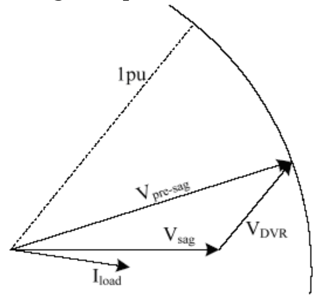


Fig.6 Phasor diagram for Pre-Sag compensation

The supply voltage is continuously tracked and the load voltage is compensated to the pre-sag condition. This method results in undisturbed load voltage, but generally requires higher rating of the DVR Before a sag occurs, Vs $=V_L=V_0$.The sag results in drop in the magnitude of the supply voltage to V_{s1}. The phase angle of the supply also may shift. The DVR injects a voltage V_{c1} such that the load voltage remains at V_0 .

$$V_{DVR} = V_{presag} - V_{sag}$$

2) In-Phase Compensation:

The voltage injected by the DVR is always in phase with the supply voltage regardless of the load current and the pre-sag voltage (V_0).

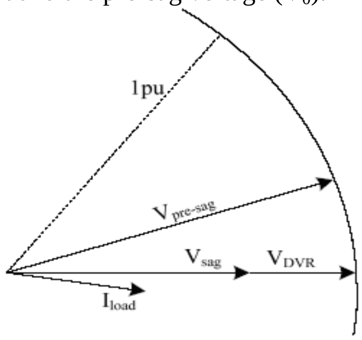
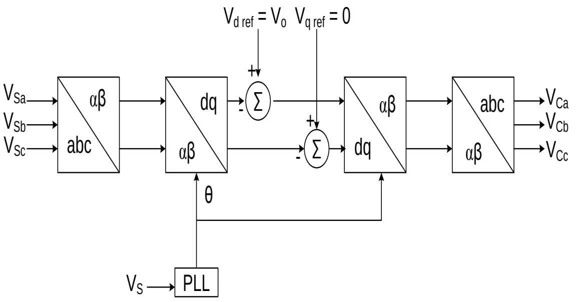


Fig.6 Phasor diagram for In-Phase compensation

This control strategy results in minimum value of the injected voltage (magnitude) as shown in fig . However, the phase of the load voltage is disturbed. For loads which are not sensitive to the phase jumps, this control strategy results in optimum utilisation of the voltage rating of the DVR.

IV. CONTROL SCHEME FOR DVR



In our project the DVR is realized by incorporating open loop control for the sag mitigation as shown in Fig. The three phase supply voltages are measured and transformed into d-q component through α - β components. The transformation to d-q components requires a PLL with inputs from the supply voltage. The d-q components of the supply voltage are subtracted from the reference values of the (desired) load bus voltage d-q components to give the required values of the injected voltages (d-q components). These are transformed to the required three phase injected voltages.

V. SIMULATION RESULTS

Initially the mitigation process of the faulted system is carried out with a conventional two-level inverter based DVR.

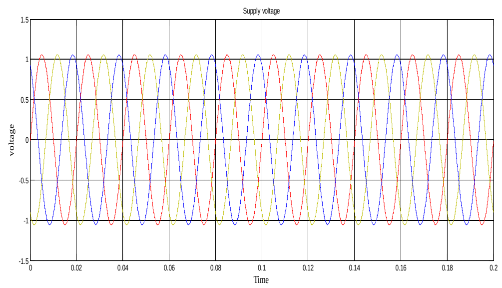


Fig 7 : Supply voltage

The resultant waveform indicates a healthy and undisturbed supply voltage with an rms value of 1 PU. This is the condition before the occurance of fault.

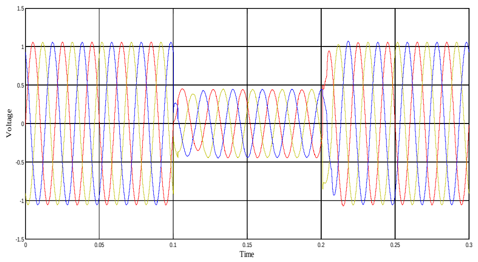


Fig 8 : Load voltage when fault occurs

This is the voltage when fault occurs. A SAG is developed. The sag magnitude after the three phase fault of fault impedance 1 Ω duration (0.1-0.2sec) is 0.395 p.u. as show in the fig above i.e. there is 60.5% sag from the prefault voltage, which was 1 p.u.

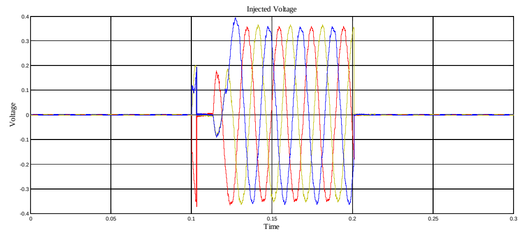


Fig 9:Injected voltage by the DVR

The waveform indicates compensation voltage which is required to repair the sag. . The DVR with a dc voltage of 375V gets connected into the system for the duration of sag and injects a voltage of 0.4 p.u. with a sag compensation of 40%. The injected three phase voltage is of two level while that of line voltage is three-level.

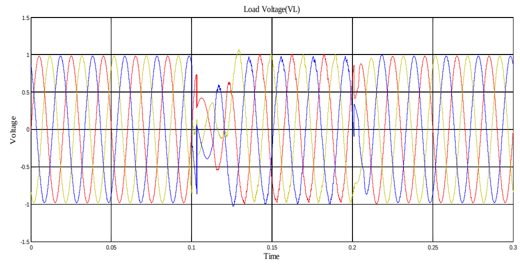


Fig 10:Compensated voltage after sag mitigation

The above waveform indicates the suppy voltage after removal of sag i.e. after compensation.

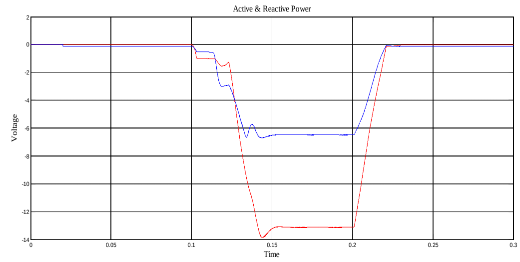


Fig11:Active & Reactive Power during sag.

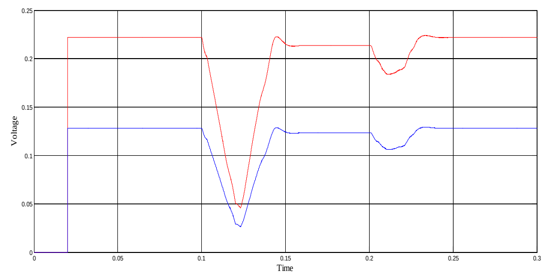


Fig12:Active & Reactive Power after sag mitigation.

For the duration of sag there is a drop in active and reactive power, as shown in the above figures, at the bus by 85%. Hence the DVR also compensate for the power by 60% restoring its value close to prefault condition.

VI. CONCLUSION

The DVR simulation has been shown by the aid of MATLAB/Simulink. The control system is based on SPWM technique The simulation shows that the performance of DVR is not only efficient in mitigating the voltage sags but also improves the quality of power in the system. According to the simulation results, the DVR is able to compensate the sags during single line to ground (SLG) fault and three-phase fault. The DVR handles both balanced and unbalanced situations without any difficulties. It injects an appropriate voltage component to correct any anomaly rapidly in the supply voltage; in addition, it keeps the load voltage balanced and constant at the nominal value. This characteristic makes it ideally suitable for low-voltage custom power applications.

REFERENCES

[1] Yash Pal, A. Swarup, Senior Member, IEEE, And Bhim Singh, Senior Member, IEEE ,A Review Of Compensation Type Custem Power Devices For Power Quality Improvement , C2008 IEEE

[2] Hilmy Awad, Student Member. IEEE, Jan Svensson, Member, IEEE And Math Bollen, Senior Member, IEEE,Mitigation Of Unbalance Voltage Dips Using Series Compensator, 2003 IEEE,Pp2672- 2675.

[3] M.H. Haque Voltage Sag Correction By Dynamic Voltage Restorer With Minimum Power Injector, 2001 IEEE May 2010pp55-58.

[4] Chellali BENACHAIBA, Brahim FERDI, Voltage Quality Improvement Using DVR, *Electrical Power Quality And Utilisation, Journal Vol. XIV, No. 1, 2008,* Pp39-45.

[5] ROSLI OMAR, NASRUDIN ABD RAHIM, MARIZAN SULAIMAN, Modeling And Simulation For Voltage Sag/Swell Mitigation Using DVR,Journal Of Theoretical And Applied Information Technology Pp465-470

[6] Shazly A. Mohammed1, Abdel-Moamen M. A. And B. Hasanin, Analysis, Modeling And Simulation Of Dynamic Voltage Restorer (DVR) For Compensation Of Voltage-Quality Disturbances, INTERNATIONAL JOURNAL OF CONTROL, AUTOMATION AND SYSTEMS, Vol1 No2,Pp23-29.