International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 02 Issue: 03 | June-2015 www.irjet.net p-ISSN: 2395-0072

Application of DVR for Power Quality Improvement

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Abstract -*In this paper various power quality problem caused by voltage sag or swell on power system are discussed. These problems will create failure of end user equipments which are sensitive to power quality supply. By the introduction of Custom power devices namely DVR, DSTATCOM, UPQC various problems are reduced. Here an attempt is taken in this paper to review from its establishment to an up to date bibliography on DVR for power quality improvement. Basically the main function of DVR is to eliminate voltage sag. Various control strategies and its improvement is analyzed. Finally, the explorations on DVR incorporating with BESS, different voltage injection method have also been discussed. But PI controller with PWM technique provides good control for sag elimination with reduced voltage.*

Key Words: DVR, sensitive load, voltage injection technique,voltage sag

1. INTRODUCTION

Voltage sag due to fault has become one of the most important power quality problem facing industrial consumers. Any disturbance to the voltage waveform can result in problem related with the operation of electrical and electronics devices which uses need constant sine wave shape, constant frequency and symmetrical voltage with constant RMS value to continue production. This increasing interest to improve overall efficiency and eliminate variation in the industry have resulted more complex instrument that can sensitive to voltage disturbance.

Static Series Synchronous Compensator (SSSC) commercially known as Dynamic Voltage Restorer (DVR) inject voltage in series with the system voltage provides most cost effective solution to mitigate voltage sags by improving power quality level that is required by the customer When fault s in a distribution network sudden voltage sag will appear adjacent loads. DVR installed on sensitive load (critical load) resistors the line voltage to its normal value in few milliseconds.

The conception of custom power is to use static controller or power electronics devices in the medium voltage distribution system aim to supply reliable & high quality power to the user's sensitive load. Sensitive load on distribution side like semiconductor manufacturing plant, paper mil, food industries etc, uses DVR for eliminating voltage sag.

DVR as a custom power device could be means to overcome some major power quality problems such as voltage sag by the way of injecting active or/and reactive power into two system. .

DVR is connected in series with the transmission line which is shows in figure 1. When source supply voltage changes DVR connected in series injects dynamically controlled voltage in series with supply voltage through a series transformer correct the sag or swell present in system. However in control of DVR not only voltage magnitude (injection) but also active and or reactive power injection is needed.

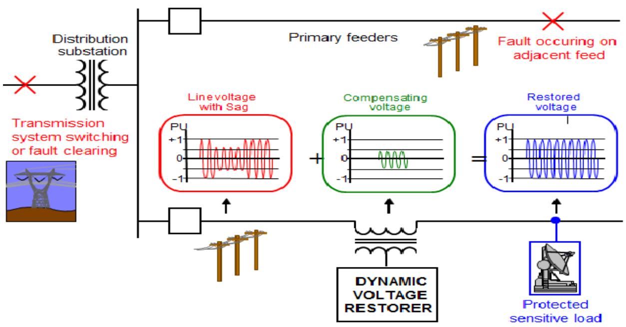

Fig -1: DVR Location

The rating of DVR as module is 2 MVA per module. It compensates 35% of voltage sag for a very less duration of time of half a second. If SLG (single line to ground) fault is occurs than it compensate voltage sag greater than 50%. For Energy storage device capacitor is used which requires 0.2 to 0.4 MJ per MW of load served through a transformer, connected in series with DVR.[6]

When the DVR is used as standby mode at that time no voltage is injected and converter is bypassed. At a instant when voltage sag is detected, DVR inject a series voltage of required value this is called as boost mode.

DVR can also be used as active filter for isolating harmonics current from source side to load side. In this operation IGBT or IGCT is used with it.

2. DYNAMIC VOLTAGE RESTORER

Shows the main component of DVR connected in series with the distribution system used for voltage correction. Typically DVR consist of energy storage system force commutated VSC, passive filters and series booster transformers.[6]

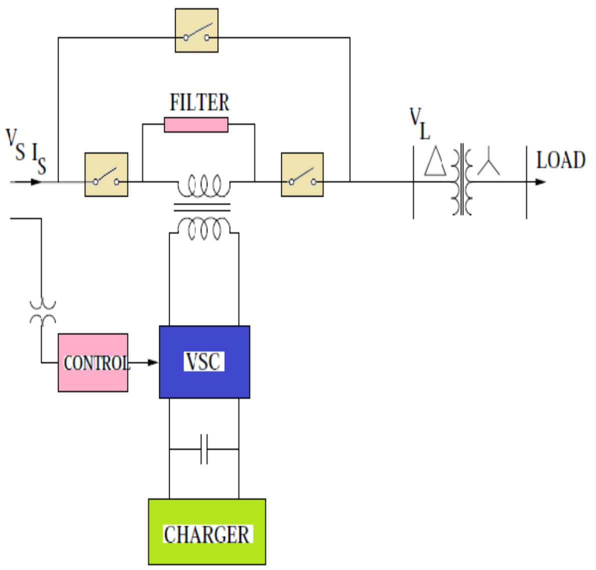

Fig -2: Main Component of DVR

Voltage source converter used is of 3 phase 3wire or 3phase 4 wire. The passive filter is connected on converter side or transformer side. When it is on converter side the higher order harmonics current doesn't flow through transformer winding.The ESS can be used to protect sensitive production equipments from shutdowns caused in voltage sags. These is usually DC storage systems such as UPS, batteries, superconducting magnetic energy storage (SMES) storage capacitor or even flywheels driving DC generators. The enough energy is feed to the system to compensate the energy that would be lost by voltage sag. A delta /open or star/ open winding can be used in series transformer. A delta/open winding Is preferably used since it prevents the third harmonic and zero sequence current entering into the system and also maximize the use of DC link compare to star/open winding.

The control apparatus of the general configuration typically consists of hardware with programmable logic. All protective functions of the DVR should be implemented in the software. Differential current protection of the transformer, or short circuit current on the customer load side are only two examples of many protection functions possibility.

3. OPERATION OF DVR

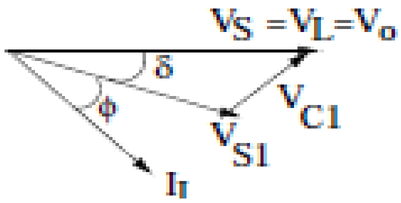

Fig-3: Voltage Injection

It shows that the initial voltage of DVR is V_S and as the sag occurs V_S reduces to V_{S1} DVR must supply voltage equal to V_{C1} in that case

$$V_L = V_{S1} + V_{C1}$$

When injected voltage is in phase with the supply voltage the desired injection (voltage correction) may be achieved with a minimum voltage injection, but it may require a considerable amount of active power injection into the system. When the injected voltage leads to supply voltage, same correction can be made with a lower value of active power injection. This is possible at an expense of high voltage injection. Such as operation requires careful determination of injected voltage and angle. In general the active and reactive power flow is controlled on the angle between the voltage that is injected in series with the line and the line current. When the injected voltage is in phase with the current only active power is changing with the line otherwise if the voltage is in quadrature with the current only reactive power will change with the line, with minimum active power injection will be required if the power factor of supply is unity.

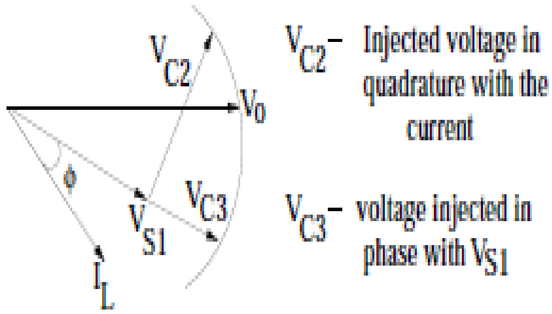

Fig-4: in-phase and quadrature voltage injection

Without energy storage system (ESS), the DVR can only inject voltage in quadrature with the load current to mitigate the voltage sag. In addition reactive power compensation is only effective for small voltage sag. ESS gives flexibility to inject voltage at any phase angle and compensate for deeper voltage sag, voltage sag with phase jumps and longer duration voltage sag. From fig 4.[6]

$V_s=V_L+I_LZ$ Where, V_s= supply voltage

Z = impedance

I_L = Line current

V_L= load voltage

A disturbance or fault in the system may reduce the supply voltage magnitude 'V_s' to a new value $V_{S.New}$. The supply voltage can be maintained by the injection of V_i

$$V_{S.New}+V_i = V_L+I_LZ$$

$$V_{S.New}= (V_L+I_Lz)-V_i$$

Where ,

$V_i = (V_L+I_LZ)-V_{S.New}$, V_i = injected voltage

α = phase angle of V_i

The ratio of ESS (Complex Apparent Power) is

$S_i = 3.V_i.I_L$

I_L = current representing complex conjugate.

$S_i = 3(V_L+I_LZ-V_{S.New}).I_L$

When $\alpha = S$, S_i will be minimum.

The direction of I_LZ depends on the power factor of load (lagging P.F in this case) and impedance of line. However injected complex power depends on the amplitude & phase of injected voltage V_i.

If V_d is % voltage dip then

$V_{S.New} = V_S - V_d.V_S$ {V_d is phaser quantity}

$= (1-V_d)V_s$

S_i is given by

$S_i =3 (|V_d|\ |V_s|.\ |I|e^{(\delta+\Phi)})$

The voltage deviation 'V_d' of the system is reffered as a voltage in the utility industry.

$V_D =(V_S - V_L)/\ V_L$

$V_S = V_D.V_L+V_L$

$V_S = V_L\ (1+V_D)$

The absolute value of KVA injected by ESS of DVR is given by the equation of power.

$|S_i| = 3\ (|V_d|.V_L(1+V_D).|I|{-\delta+\Phi})$

4. SIMULATION

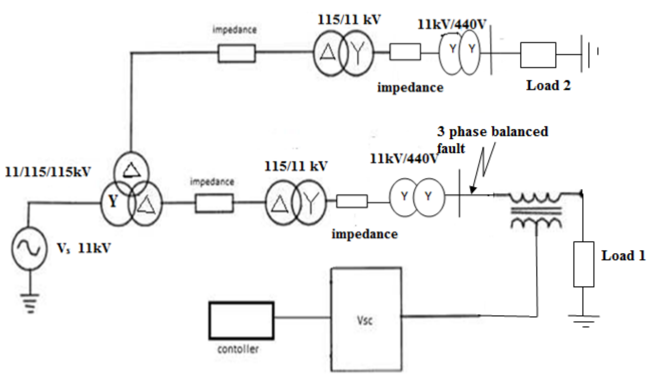

Fig -5: Single Line Diagram of Power System

Table -1: Parameter used in simulation

Sr.No	System Quantities	Standards
1.	Three phase source	11kV, 50Hz
2.	Step up transformer	Y/Δ/Δ, 11/115/115kV
3.	Transmission line parameters	R=0.001Ω, L=1.33μH
4.	Step down transformer	Δ/Y, 115/11 kV, Y/Y , 11kV/440V
5.	Distribution load parameters	R=20Ω, L=1mH
6.	Inverter	IGBT based, 3 arms, 6 pulse, Carrier frequency=1080Hz, Sample time=5μs
7.	PI controller	K_P=0.5,K_i=50,Sample time=50μs
8.	DC Voltage source	450V
9.	Injection/Linear/Isolation transformer	1:1 turns ratio, 440/440V

As shown in figure 5, single line diagram of power system feeing two parallel lines. The fault is occurring in second line for duration 0.1 to 0.2 second. All data taken for simulation are mentioned in table. First we are considering the system without fault.

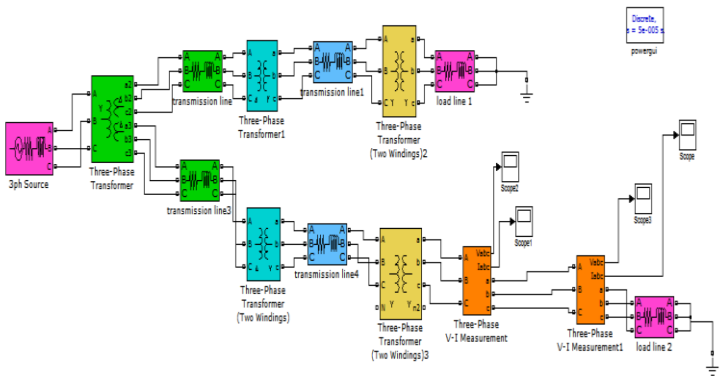

Fig-6: system without fault

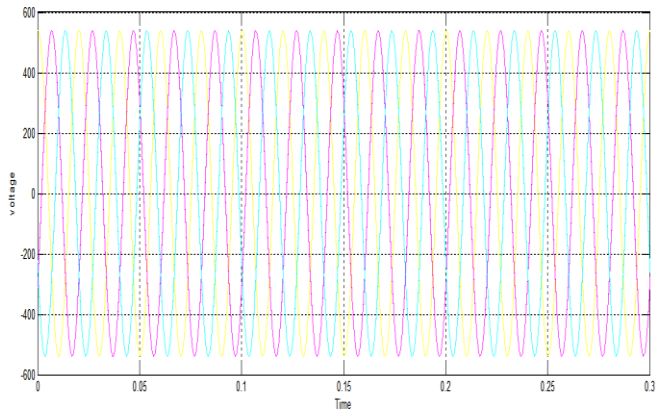

Fig-7: output voltage without fault

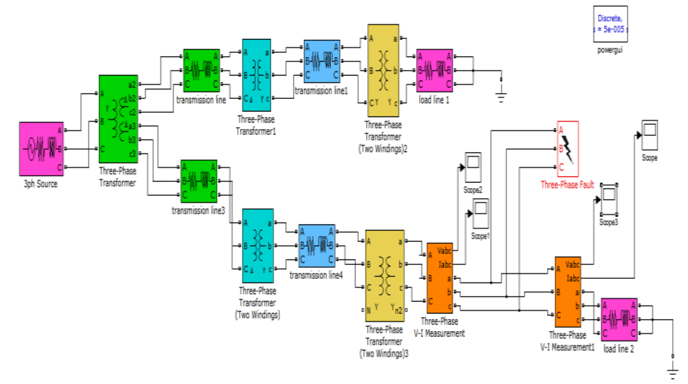

Fig-8: System with fault

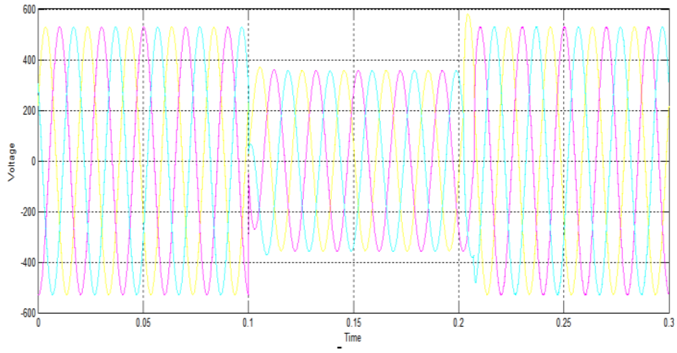

Fig-9: voltage sag

When fault occur the voltage sag is observe for duration 0.1 to 0.2 second. This sag is 75% of real voltage.

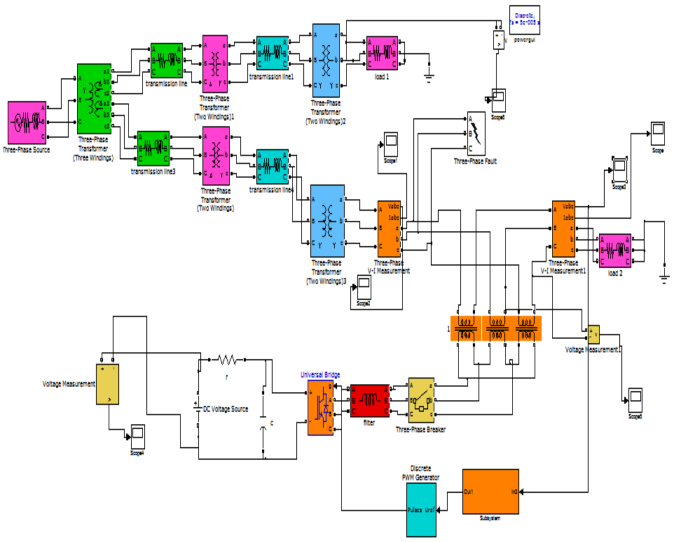

Fig-10: Voltage injection through DVR

When we connect DVR the required voltage is injected through linear transformer. PI Controller and PWM scheme is used for pulse generation.

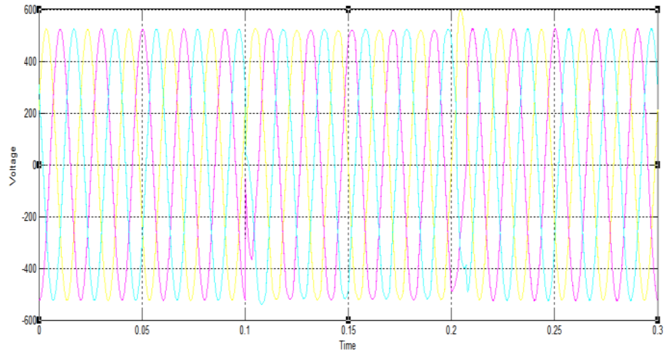

Fig-11: Sag elimination using DVR

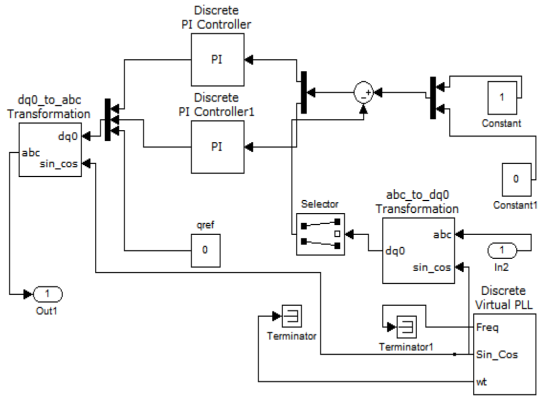

Fig-12: Control Circuit

This chart shows the reduced harmonics value. The THD=1.88% only. This is clear this scheme uses low harmonics frequency.

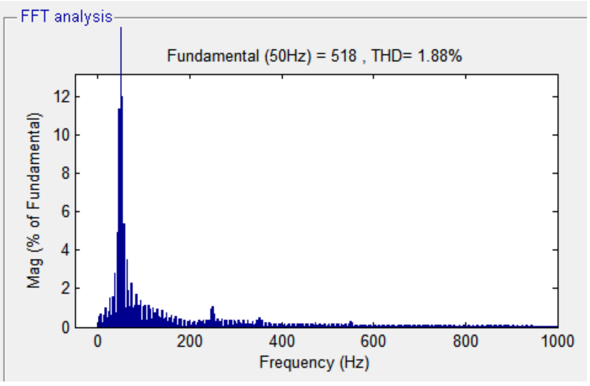

Chart -1: Harmonics analysis

When DVR is controlled by discrete PWM scheme using PI controller the three phase balanced fault is applied with a fault resistance. The fault condition is applied between the time period of 0.1 to 0.2s and voltage sag condition is created in the system. This control scheme based on PI controller is able to compensate 100% percentage of voltage sag value. [9]

5. CONCLUSIONS

In this paper we have analyzed the control of DVR based on discrete PWM technique using PI controller, The discrete PWM technique using PI controller work efficiently. The discrete PWM scheme using PI controller compensated 100% of the voltage sag condition. This is also analyzed that it reduces the harmonics contents, and required DC voltage Source is of reduced rating. The new technique with reduced rating VSC for sag compensation are errorless, provide 100 percentage compensation. [1]

ACKNOWLEDGEMENT

The authors thanks Dr.D.P. Kuthari for their support.

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BIOGRAPHIES

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