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Comparison of Different Control Schemes Used In DVR for Power Quality Improvement

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Article Info
Volume 83
Page Number: 1184 - 1190
Publication Issue:
March - April 2020

Article History
***Article Received**: 24 July 2019*
***Revised**: 12 September 2019*
***Accepted**: 15 February 2020*
***Publication**: 14 March 2020*

Abstract

Voltage dip can be compensating by using the Dynamic Voltage restorer (DVR). DVR works on the basis of the series mitigation technique and power electronics based devices are used in the technique. The required amount of voltage, for power quality mitigation is supplied by DVR and the supplied amount in the DVR is controlled by various controlled technique. In this paper various control techniques for a DVR circuit is discussed. The various control techniques such are; energy optimization technique, hybrid technique, in-phase compensation techniques, phase shift method, advanced phase shift and Pre-Sag compensation technique are compared for voltage sag compensation and suggested better technique.

Keywords— *Control Technique, Dynamic voltage restorer (DVR), Power Quality*

I. INTRODUCTION

Power quality (PQ) is a major problem for the sensitive load or problems now days. It is important as well as essential requirement in today's world. Highly stable and reliable electrical power supplies are needed in modern society where so many microelectronic machines are used. For a microelectronic machine, not only a power failure, but also a short-term (few cycles) voltage variations may cause serious problems. Personal computers may lose important data in a momentary voltage disturbance.

Permanent availability of power supply is a crucial prerequisite for an enormous number of modern procedures. The interference of basic procedure because of power failure [1], voltage sags or interruptions can bring about loss of profitability, harm of gear and items, delay in conveyance [2], costs for cleaning and restart and in worst case damage to individuals and pollution of environment. Thus, power quality (PQ) is a precise significant problem for utilities and industrial market. Uninterrupted Power Supply (UPS) is a prime factor in deciding steady industrial growth [3].

Voltage sags are well-investigated as unexpected reduce in the voltage many or one phases to an amount between 90% to 1% of the reference voltage. The most sensitive load can be protected by DVR during the voltage sag condition [2]. Presently various control algorithms are used based on the phase shift method, advanced phase shift method, energy optimization technique, hybrid technique in-phase compensation and Pre-Sag compensation.

II. DVR CONFIGURATION

The Fig. 1 is shown the basic configuration of DVR System. It comprises of in the six parts which is connected in a proper manner as given Fig. 1. The six parts are energy storage unit in the form of DC, capacitor bank, voltage injection transformer, low pass filter and voltage source inverter (VSI),.

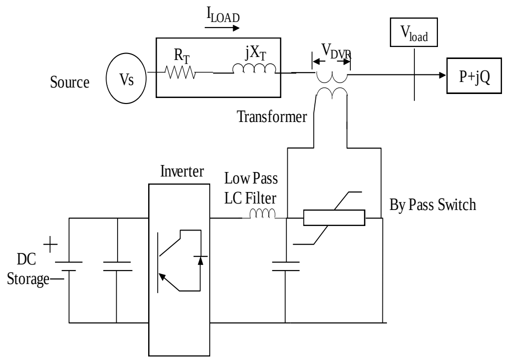

Fig.1. Configuration of Dynamic Voltage Restorer

A. Energy Storage Unit: It is a storage part of DVR, where the DC energy is stored. Present time different storage gadgets are utilized for energy storage in the DC Form like: Flywheels, Lead acid batteries, Super-Capacitors and Superconducting attractive energy storage (SMES). These unit deliveries the real power of the framework requirements, when DVR is utilized for voltage sag mitigation [6].

B. Capacitor: In this unit large numbers of capacitor components are used for constant input supply to the inverter. Aluminum electrolytic capacitors can be used for this purpose. The harmonics fed back to the source is reduced by capacitor bank [4-6].

C. Inverter: the purpose of inverter is converting DC into AC. In the Configuration of DVR, high current and low voltage ratings are used. Outputs of the inverter through filters are which is low voltage ratings are given to the input of the step up injection transformer in the DVR based mitigate system and output of this injection transform are feed to the power system line [7-9].

D. Passive Filters: The unnecessary higher order harmonics component can be reduced by the filter which is generated during the conversion process from DC to AC [10].

E. By-Pass Switch: A by pass switch can be used for the purpose to secure the voltage source inverter from high currents in the DVR circuit [2-4].

F. Voltage Injection Transformers: for three phase systems, a voltage transformer (3 Phase) can be used for voltage addition purpose or three single phase units can be used in star or delta mode for a three phase connection [10].

III. SERIES VOLTAGE CONTROLLER

Single line diagram of DVR application in Power System is shown in Fig. 2 which can be used for voltage sag compensation.

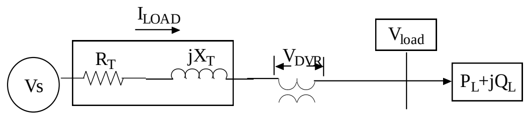

Fig.2. Single Line Diagram of DVR application in Power System

This is based on the series injection voltage compensation. The mathematical equation for Single line diagram can be [5-10].

$$V_{s*fault} + V_{DVR} = V_{load} + (R_{T+}jX_T)\, I_{Load} \qquad (1)$$

or $$V_{DVR} = V_{load} + (R_{T+}jX_T)\, I_{Load} - V_s \qquad (2)$$

Where:

Vs*fault =is the system voltage during fault condition,

V_{DVR} = Voltage supply by the DVR,

V_{Load} = Load voltage magnitude (desired),

Load impedance = $(R_{T+j}\, X_T)$

I_{Load} = Load current,

Current is the load side can be calculated as

$$V_{load}\ \ I_{Load} = P_L + j\, Q_L \qquad (3)$$

$$I_{Load} = \left(\frac{(P_L + j * Q_L)}{V_{Load}}\right) \qquad (4)$$

Where load voltage consider as a reference, P_L is active power of load, and Q_L is reactive power load.

Then voltage equation of DVR can be descried as

$$V_{DVR}\angle\alpha = V_L\angle 0^o + Z_T I_{Load}\angle(\beta - \theta) - V_{sf}\angle\delta \qquad (5)$$

Where α, β and δ are the angles of V_{DVR}, Z_T, and V_{sf} respectively

$$\theta = \tan^{-1}\left(\frac{Q_L}{P_L}\right)$$

Where θ = load power factor angle of load.

The DVR injected apparent power by shown by

$S = V_{DVR} * I_L$ (6)

III. COMPENSATION TECHNIQUE

DVR is used numerous sag compensation techniques for mitigate the voltage sag. This compensation technique is based on the series voltage compensation. It is used as a real and reactive power injector or absorber during voltage sags and swells conditions. In this section five compensation technique is discuss; pre-sag compensation, in-phase compensation, energy optimization technique.

I. Pre-Sag Compensation: This type of mitigation technique is used the difference between the pre sag voltage and sag voltage supplied by the DVR.

i $V_{DVR}=V_{presag}-V_{sag}$ (7)

It gives a direct solution, it means the line voltage is continuously traced and the load voltage is compensated during sag period [2-5]. This compensation technique is used polar form ($M<\theta$) at the time of compensation i.e. M is the magnitude and θ is the phase angle.

In this technique the phase angle and reference voltage never changed. These techniques have drawbacks: (1) higher voltage injection transformers

(2) Large capacity DC storage device [3-6]. This type of compensation always suggested for nonlinear load. At the load side, voltage never changed due to voltage sag and its result it leads to the lowest distortion at the load side [2-8]. This strategy is desired for load that is controlled with power electronics device [2-6]. In this technique need both the real and reactive power compensation [1-3].

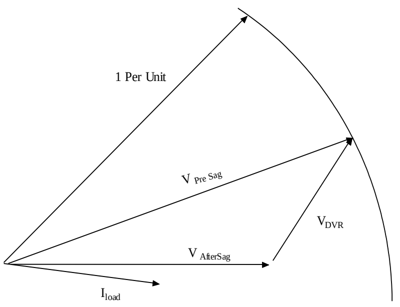

Fig.2. Pre-Sag Compensation Technique

DVR is supplied voltage in pre sag compensation is calculated by the (8) [1-8].

$$V_{DVR} = \sqrt{\frac{2}{3}}V_N\sqrt{1-2(1-\varepsilon)COS\delta+(1-\varepsilon)^2} \quad (8)$$

With: V_N = Nominal grid voltage

ε =Sag depth

and

DVR power is given by (9) & (10)

$$P_{DVR} = 3(P_{LOAD}-P_{GRID}) \quad (9)$$

$$P_{DVR} = \left(\sqrt{3}\right)V_N I_N (COS\varphi-(1-\varepsilon)COS(\phi-\delta)) \quad (10)$$

δ is represent the Phase jump during the short circuit

II. *In-Phase Compensation*: It is used for compensation in the structure of voltage magnitude (M). In this technique both active and real power compensation are needed. This technique has one drawback it cannot be used for sensible load because it would lead to a loss of power supply. The extent of injected voltage is a distinction between the supply and the load voltage [6]. Which need not to be compensated for the phase angle [1-3].

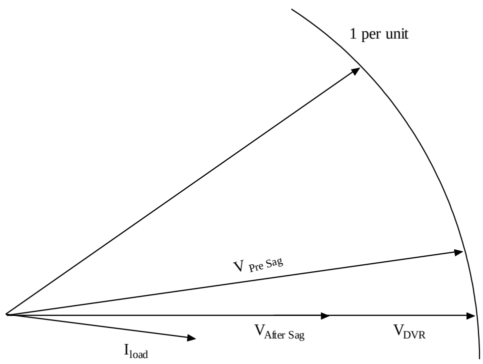

Fig. 3.In-Phase Compensation Technique

Supplied voltage by the DVR in-phase compensation is calculate by the [1-6]

$$V_{DVR} = \sqrt{\frac{2}{3}}V_N\varepsilon \quad (11)$$

and the DVR power is calculated in phase compensation by (12)

$$P_{DVR} = \sqrt{3}V_N I_N \varepsilon Cos\phi \quad (12)$$

In this method, continues real power is supplied during voltage sag period this results large energy storage is required. This method also propose for the reduce the system volume and it gives the

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guarantees of the minimum magnitude of the compensating [4-7].

III. *Energy Optimization Technique*: In this technique the amount of injected during the voltage sag compensation will be high as compare to in-phase compensation technique. Advantage of this technique; the real power requirement is reduced because voltage is injected at 90^0 phase angle to supply current. [3-5]. The real power is provided by the DVR and this can be take infinite time [2-6]. The depletion of the energy storage device minimize in this technique by collect information about the load current [1-8].Voltage amplitude and phase distortion are two main disadvantage with this technique [1-6].Due to reason reactive power supplied by the DVR high rating inverter and injected transformer are required for voltage sag compensation [11].

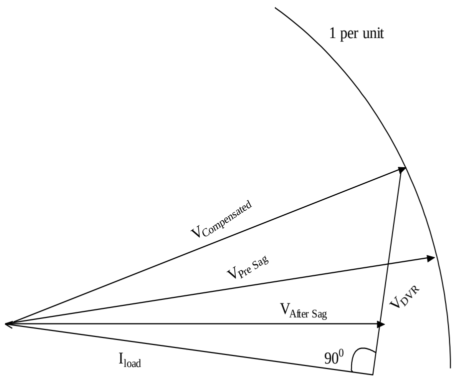


Fig.4. Energy Optimization Technique

Following condition is essential to mitigate the voltage sag without using active Power [3-5].

$$|V_S| \geq |V_L COS\Phi| \quad (13)$$

Supplied voltage by the DVR in energy optimization voltage sag compensation technique is calculated by the (14) [1-6]

$$V_{DVR} = \sqrt{\frac{2}{3}} V_N (\sin\phi - \sqrt{(1-\varepsilon)^2 - Cos^2\varphi}) \quad (14)$$

ϕ = phase angle in between load voltage and current

DVR power in energy optimization technique is given by given by (15)

$$P_{DVR} = \sqrt{3} V_N I_N (Cos\phi - 1 + \varepsilon) \quad (15)$$

It is increasingly complex. As indicated by the profundities of the voltage sage and the load impedance point, the DVR could work in two distinct states: zero power infusion and least energy infusion. A complex case-sensitive calculation is proposed for over two diverse two states and the entire framework cost expanded. It is for generally looked into ease capacitor upheld plot [1-8].

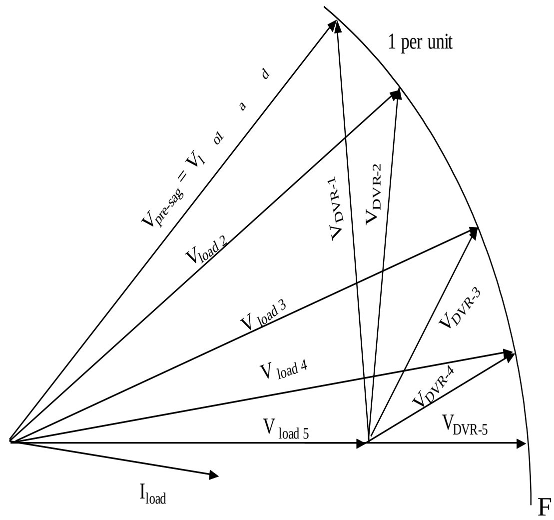
IV. HYBRID TECHNIQUE: In the hybrid technique two compensation techniques are combined i.e in-phase as well pre-sag compensation. It is achieved effectiveness voltage sag compensation and easy to control.

This procedure is pertinent where the voltage is reestablished in the polar structure for example extent with phase. At the present time is steadily moved to be in phase with the post-sag voltage vector, right now the voltage mixture essential [1-7].

Hybrid controlled technique is presented in Fig.5; at the time of voltage sag compensation the system is used pre-sag compensation and DVR is supplied V_{DVR-1} voltage and system involve pre sag compensation, and gradually injected voltage pharos is moves toward via.V_{DVR2} to V_{DVR3} and V_{DVR3} to V_{DVR4} and finally V_{DVR4} to V_{DVR5} according to Fig 5.

$$V_{DVR5} + V_{LOAD5} = Vpre\text{-}sag \quad (16)$$

Equation (16) represents the in-phase compensation.



ig. 5. Hybrid Compensation

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V. *ADVANCED* PHASE SHIFT METHOD

But the algorithm complexity and the relating, above both the problem are reduced by using a phase shift method. A phase move technique is proposed with basic execution. It gives an additional control degree to profit more. The fundamental thought of phase move control is to control the edge between source voltage and load voltage if the edge is appropriately controlled.

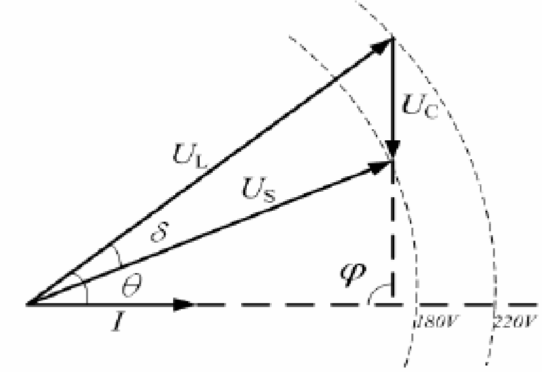

Fig.6. Phasor Diagram for Phase Shift Method

Phase shift controlled technique graphical representation is shown in fig. 6. It shows when the $\varphi < 90^o$, DVR supplies the active power, vice-versa. Where δ influences the edge φ.

The suggested technique doesn't influence the consistent state remuneration execution yet accomplishes the best transient reaction because of the best possible determination of the points of confinement. When the δ arrives at as far as possible, the DVR could assimilate the greatest active power from the utility source, so the DC voltage arrives at the quickest lift speed, and the other way around. Since the δ is obliged in a monotonic range, the framework stability is ensured [8-11].

VI. COMPARISON OF DIFFERENT VOLTAGE SAG COMPENSATION TECHNIQUES

Different Compensation technique like energy optimization technique, hybrid technique, phase shift method and advance phase shift method, in-phase compensation and pre-sag compensation are compared for DVR compensation technique in Table.1 on the basis of magnitude, phase angle, advantage and disadvantage.

Table.1 Voltage Sag Compensation Comparison

S. No.	Compensation Technique	Remark	Advantage	Disadvantage
1	Pre-Sag Compensation	Magnitude and phase angle is Used	(i) It is Suggested for The Non-linear Loads	(i)Requires a Large Capacity DC Storage Device
2	In-Phase Compensation	Magnitude is Used	(ii)It is Used For Sensible Load	(i)In This Technique Need Both the Real and Reactive Power Compensation
3	Energy Optimization Technique	Voltage is Injected at 90^0 Phase Angle	(i)It is Minimize The Use Of Real Power Injection. (ii)The DVR Provides Only Reactive Power Compensation.	(i)Voltage Amplitude and Phase Distortion
4	Hybrid Technique	Both Magnitude and Phase Angle is Used	(i)Effectiveness Voltage Sag Compensation and Easy to control (i)Decreasing the Voltage Injection Requirement	(i) Requires A DC Storage Device (ii) Need Both The Real and Reactive Power For Compensation
5	Phase Shift Method	Phase angle is used in the form of δ and angle φ	(i) Simple Implementation	(i) Potential Stability issue
6.	Advanced Phase Shift Method	Phase angle is used in the form of δ and angle φ	(i) Performance: High Steady State (ii) Response : Rapid Transient (iii) Tolerable & result is achieved Robust	(i) No Dis-advantage

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Various curves from Fig.7 to Fig.12 is shown in comparison of performance of pre-sag, in phase and energy optimized technique in the various parameter like; comparison time & voltage amplitude both are depended on sag depth, voltage amplitude & compensation time depended on displacement factor, the amount of voltage amplitude is a also depend on the depth of the phase jump [7-11] .

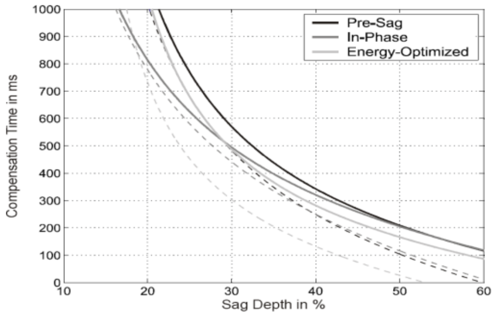

Fig. 7. Sag Depth V/s Compensation Time

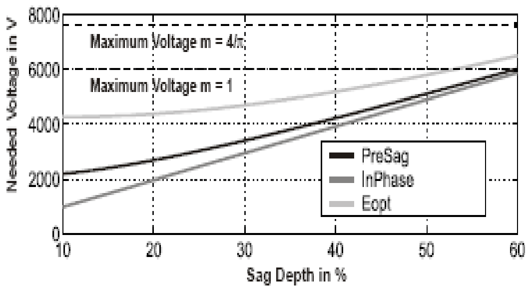

Fig. 8. Sag Depth V/s Voltage Amplitude

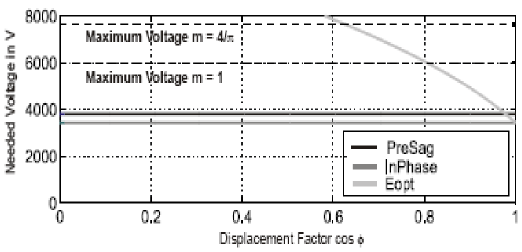

Fig. 9. Displacement Factor V/s Voltage Amplitude

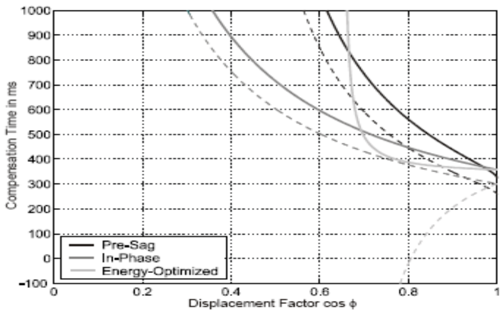

Fig.10. Displacement Factor V/s Compensation time

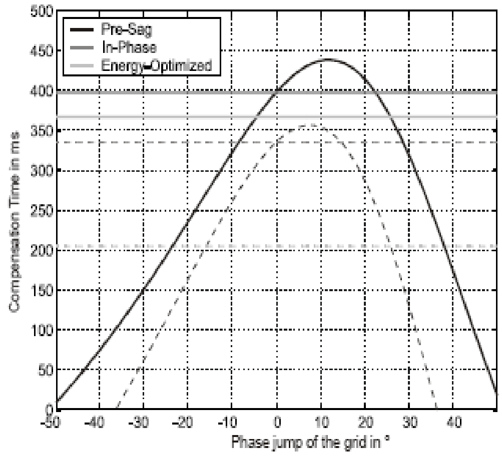

Fig.11 Phase jump V/s Compensation time

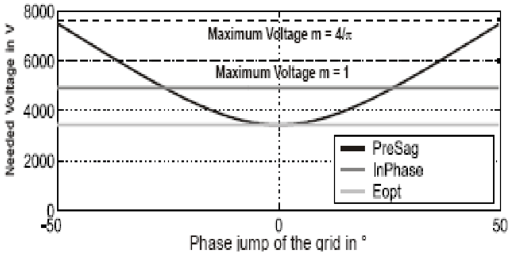

Fig.12 Phase jump V/s Voltage amplitude

VII. LIMITATIONS OF CONTROL STRATEGIES

Before a selection of a particular control technique it is necessary to know about the various issues of each scheme, DVR has its individual restricted capabilities. Voltage sag is compensate by DVR in series based compensation technique.

Various issues of Dynamic Voltage Restorer is classified into three categories [3-9]

(i) Voltage limit -A DVR has the ability to insert voltage up to a certain threshold; this is due to design economics and voltage drop across the device during nominal conditions.

(ii) Power limit – The power limit is carried out by converter, converter is used in the DVR circuit in the mitigation process.

(iii) Energy limit- The size is used as low as possible due to energy reserve. It gives huge amount for large energy.

VIII.CONCLUSION

In this paper comparison is shown in between various controlled techniques, which is used for voltage sag compensation. On basis of comparison, it is recommended that two techniques in-phase and energy optimization looks to be better for voltage sag compensation in DVR systems. Both techniques provided more than 90% efficiency for achieving the voltage sag compensation and both are owing to minimal requirement of real power injection: above mentioned both techniques are reduced the DC storage capacity in the DVR circuit. Advanced phase shift method is used for fast transient response together with high steady state compensation performance. It is a robust technique.

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