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A Review on Dynamic Voltage Restorer (DVR) to Improve Power Quality

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Abstract

In distribution system the most common phenomena is voltage sag, in which will be effected on the different load mostly sensitive. Generally the custom power devices is An effective solution to mitigate The DVR is a powerful controller that is commonly used for voltage sags. It use with the four different compensation method to eliminate the voltage sag and reduce the voltage disturbance at load side. The paper provide a review on the DVR and discussion on four compensation method and different control Strategy

Keywords: Power quality, DVR, Compensation & Control Strategy

Introduction

In recently the use of the different load such as linear and nonlinear load so the purity of the wave form will be destroy and consequently the demand for high power quality and voltage stability has been increased. Sensitive loads such as medical equipment, factory automations, semiconductor-device manufacturer, are vulnerable to power-supply disturbances consequently, the demand for high power quality and voltage stability becomes a pressing issue. So now a days the power quality is big issue, the requirement for reducing losses and the behaviours of interconnected networks are some reasons which increase the importance of power quality concept.

There are many power quality problem such as sag, swell and harmonics, voltage sag is the most severe disturbance in distribution system. In order to overcome these problems the concept of custom power devices is introduced recently. Custom power is the power electronic or static controllers in medium voltage distribution systems for the purpose of supplying a level of reliability and/or power quality that is needed by electric power customers. Furthermore, there are custom power devices such as static synchronous compensator (STATCOM), distribution-STATCOM (DSTATCOM), unified power-quality conditioner (UPQC), and dynamic voltage restorer (DVR) as power electronics based solutions to minimize costly outcomes of voltage sags [12]. In comparison, DVR is more effective and direct solutions for “restoring” the quality of voltage at its load-side terminals when the quality of voltage at its source-side terminals is disturbed [14]-[19]. DVRs compensate voltage sags by injecting the proper amount of voltages in series with the supply voltage, in order to maintain the load side voltage within the specification [20]-[23]. Typically, a DVR consists of an energy storage device and an inverter which is coupled via a series transformer to the grid.

Configuration and Component of DVR

Basically DVR is the series connected FACTS device or it is voltage stability device which is able to protect the susceptible load against the normal, abnormal and transient disturbances in power system. Generally the DVR consist of two types of circuit one is power circuit and another one is control circuit. Control circuit is used to derive the parameters as like magnitude, frequency, phase shift, etc. of the control signal that has to be injected by the DVR [15] typically, a DVR consists of an energy storage device and an inverter which is coupled via a series transformer to the grid. The purpose of inverter is injecting the series voltage with a controlled magnitude and phase angle to restore the quality of load voltage and avoid load tripping [24]-[27]. The basic concept of DVR is depicted in Fig. 1. Moreover, there is a parallel switch to bypass and protect the DVR when the short circuit occurs in downstream power

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lines.

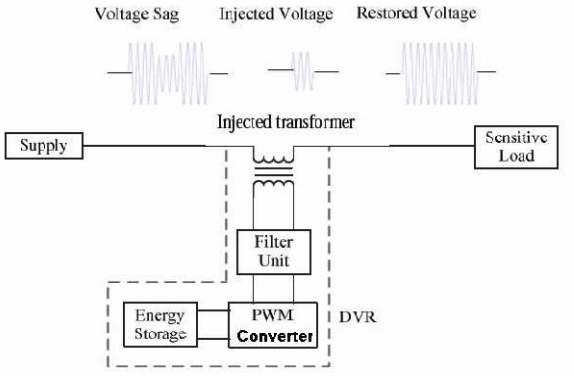

Fig. 1. Principle operation of DVR.

Principle of Operations

The basic principle of the dynamic voltage restorer is to inject a voltage of required magnitude and frequency, so that it can restore the load side voltage to the desired amplitude and waveform even when the source voltage is unbalanced or distorted. Generally, it employs a gate turn off thyristor (GTO) solid state power electronic switches in a pulse width modulated (PWM) inverter structure. The DVR can generate or absorb independently controllable real and reactive power at the load side. In other words, the DVR is made of a solid state DC to AC switching power converter that injects a set of three phase AC output voltages in series and synchronism with the distribution line voltages. The DVR has three modes of operation which are:

1. Protection mode
2. Standby mode and
3. Boost mode.

In protection mode scheme, a bypass switch is used as a protection device to protect the DVR. A large inrush current is flow at the load side if a short circuit is occurred on the load side [20].

In standby mode (*VDVR*=0), the low voltage winding of booster transformer is short circuited through the converter.So there are no switching of semiconductors occurs in this mode of operation. The DVR will be performing most of the time in this mode [21].

In boost mode (*VDVR*>0), the DVR is injecting a compensation voltage through the booster transformer due to a detection of a supply voltage interruptionThe power circuit of DVR consist of

A Voltage Source Converter (VSC):

Voltage Source Converter converts the dc voltage from the energy storage unit to a controllable three phase ac voltage. The inverter switches are normally fired using a sinusoidal Pulse Width Modulation scheme.

B. Injection Transformer:

Injection transformers used in the DVR plays a crucial role in ensuring the maximum reliability and effectiveness of the restoration scheme. It is connected in series with the distribution feeder.

C. Passive Filters:

Passive Filters are placed at the high voltage side of the DVR to filter the harmonics. These filters are placed at the high voltage side as placing the filters at the inverter side introduces phase angle shift which can disrupt the control algorithm.

D. Energy storage device/ Control system:

Examples of energy storage devices are dc capacitors, batteries, super-capacitors, superconducting magnetic energy Storage and flywheels. The capacity of energy storage device has a big impact on the compensation capability of the system. Compensation of real power is essential when large voltage sag occurs.

Voltage Injection Method

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 in magnitude and others are tolerant to these. Therefore the control strategies depend upon the type of load characteristics. There are four different methods of DVR voltage injection which are

I Pre-sag compensation method
II In-phase compensation method
III In-phase advanced compensation method
IV Voltage tolerance method with minimum energy Injection

A. Pre-Sag Compensation :

In this method the supply voltage continuously observed and if it detects any disturbances in supply voltage it will compensate the difference voltage between the sag or voltage at PCC and pre-fault condition, so that the load voltage can be restored back to the pre-fault condition. Compensation of voltage sags in the both phase angle and amplitude sensitive loads would be achieved by pre-sag compensation method. In this method the injected active power cannot be controlled and it is determined by conditions such as the type of faults and load conditions. Before a sag occur, V*S* = V*L* = V*0*.

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The DVR injects a voltage V*C1* such that the load voltage (V*L* = V*S1* + V*C1*) remains at V0 i.e. pre sag voltage (both in magnitude and phase).

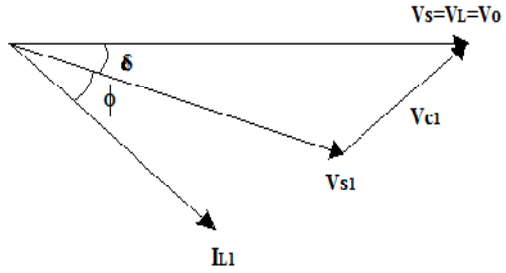

Fig.2 Pre-Sag Compensation

B. In phase Compensation method :

This method is very helpful over the pre-sag method because it can compensate unbalance voltage drop or unbalance phase jump but in this technique we can compensate voltage magnitude.

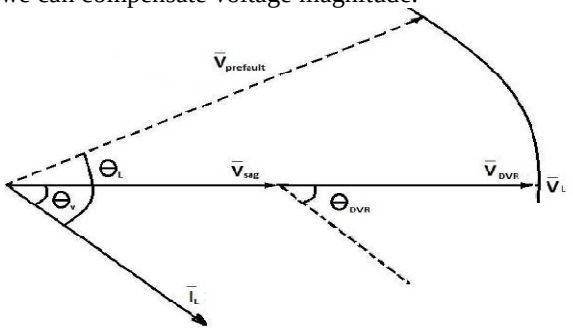

Fig.3 In phase Compensation

One of the advantages of this method is that the amplitude of DVR injection voltage is minimum for a certain voltage sag in comparison with other strategies. VDVR is in-phase with the left hand side voltage of DVR as shown in the figure 3[26] [27]. The injected voltage is in phase with supply voltage. Regarding exchanged power between DVR and power grid,this method injects both active and reactive power.

C. In Phase advanced compensation:

` The in-phase compensation strategy is the straightest forward method in which the injected DVR voltage is in phase with the supply side voltage regardless of pre-fault condition [1], [6], [8], [20]. In case of pre-sag and in-phase compensationmethod the active power is injected into the system during disturbances. The active power supplyis limited stored energy in the DC links and this part is one of the most expensive parts of DVR. it needs the active power to be supplied at dc link side otherwise this method can't compensate deep voltage sags for a long time. this method is only suitable for a limited range of sags.

D. Voltage tolerance method with minimum energy injection:

As mentioned and discussed in 2 previous sections, the inphase and pre-sag compensation methods injects active power during compensation time. Thus, the active power should be supported at the dc link; otherwise, the dc link voltage will drop continuously. However, there is another compensation method called energy minimized to avoid any exchange of active power in compensation process. The basic principle of this method is injecting to or absorbing from power grid as much reactive power as possible to compensate the voltage sag [1], [6], [20], [37], [38]. A small drop in voltage and small jump in phase angle can be tolerated by the load itself. If the voltage magnitude lies between 90%-110% of nominal voltage and 5%-10% of nominal state that will not disturb the operation characteristics of loads. Both magnitude and phase are the control parameter for this method which can be achieved by small energy injection.

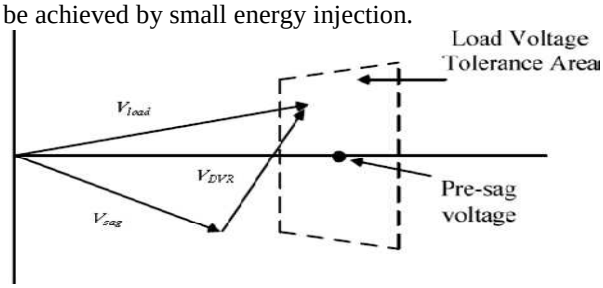

Fig.4 Minimum energy injction

Control Methods of DVR

There are several techniques to implement and control Methods of the DVR for power quality improvement. The Control of DVR is very important factor. Control method of DVR involves the detection of voltage sags by using the suitable detection algorithms. The control system only measures the r.m.s voltage at the load point. It means there are no reactive powers measurements are required. The performance of the DVR is directly affected to the control strategy of inverter, because the inverter is the most effective part of DVR [30] [31] [32]. The inverter control strategy comprises of following two types of control.

A Linear controllers :

The three main voltage controllers, which have been proposed in literature, are Feedforward (open loop), Feedback (closed loop) and Multi-loop controller [13]. The feed-forward voltage controller is the primary choice for the DVR, because of its

simplicity and fastness. The supply voltage is continuously monitored and compared with a reference voltage; if the difference exceeds a certain tolerance, the DVR injects the required voltage. The drawback of the open loop controller is the high steady state error. In the feedback control, the load voltage is measured and compared with the reference voltage, the missing voltage is supplied by the DVR at the supply bus in a feedback loop. This controller has the advantage of accurate response, but it is complex and time-delayed. Multi-loop control is used with an outer voltage loop to control the DVR voltage and an inner loop to control the load current. This method has the strengths of feed-forward and feedback control strategies, on the expense of complexity and time delay.

B. Non-linear

When the system is unstable, the model developed does not explicitly control target so all the linear control methods cannot work properly due to their limitation then we used the different types of non-linear controller in this literature as like the artificial neural networks, fuzzy logic and space vector pulse width modulation. Other non-linear controllers are also including in this are as sliding mode control, hysteresis control
and repetitive control [6].

Artificial Neural network Control (ANN)

ANN has inherent learning capability that can give improved precision by interpolation. ANN control can monitor the non linear relationship based on input and output without the detail mathematical model [8].

Fuzzy Control

When the mathematical formulations are not possible we used the fuzzy logic controllers. By using the fuzzy logic tracking error and transient overshoots of PWM can be considerably reduced [8].

SVPWM Control

SVPWM control strategy is to adopt a space vector of the inverter voltage to get better performance of the exchange is gained in low switching frequency conditions [9].

Other Control Modes

The sliding mode control no need of exact mathematical model but control modes offers the various advantages as like stability for large supply and load variations, robustness, and simple implementation [10]. The hysteresis voltage control is based on an error signal to produces the appropriate control signals. In this there is hysteresis band which is above and under the reference voltage. When the difference between the reference and inverter voltage reaches the upper (lower) limit,
the voltage is forced to decrease (increase) [9] [13].

Conclusion

A review of performance of DVR is presented in this paper. By the use of different control techniques it is viewed that DVR is suitable for voltage sag and swell mitigation. The basic structure of DVR, its operation, compensation methods and control techniques are discussed in detail. DVR has the advantage of low cost, require less computational efforts and its control is simple as compared to other methods. DVR provides simpler implementation for voltage profile improvement. Linear controllers provide simpler operation and less computational efforts when compared to other methods.

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