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Review of Control Techniques for Dynamic Voltage Restorer

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Abstract: ***DVR plays an important role in protecting sensitive loads at the time of voltage disturbances. DVR mostly deals with voltage sags and swells in distribution as well as in transmission systems. So DVR is applied for improvement of power quality and it presents solution which is cost effective. Review of proposed control strategies applied in DVR is discussed in this paper.***

Keywords: Controller, Harmonics, PLL

1. Introduction

Quality of power is concerning issue for electric utilities and end users of electric power. Main factor for such concern is invention of power electronic devices and controls based on micro processor are implemented for load equipments. Sensitivity of such load equipments is highly related to variations in voltage.

Power quality is defined as the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment [1]. Power quality problems which occur frequently are sag and swells and are considered as important because they have severe impact on sensitive loads. Application of custom power devices is one of the solutions for sags and swells. DVR is most efficient and suitable customer power device to sort out power quality problems.

DVR is series connected compensator **accompanied** by power electronics converter, placed in distribution system. It is connected between voltage source and load. Supply voltage disturbances such as sag and swell are mitigated with the help of DVR. DVR restores rated load voltage by injecting a voltage with required frequency magnitude and phase shift [2].

Basic control strategies for DVR are categorized as 1) Energy optimal compensation. 2) In-phase compensation 3) pre-sag compensation [3]. DVR must be able to compensate load voltages which can be linear, non-linear or distorted. As a result several control schemes has been introduced and proposed in the literature.

This paper is categorized into four sections. First section is introduction as discussed above. Second section presents different control schemes proposed for DVR. Third section explains conclusion and fourth section explains future scope.

2. Review of proposed control schemes for DVR

To find information about utility voltage frequency and phase angle phase locked loop (PLL) was introduced and was implemented for control scheme of custom power devices [5]. Under unbalanced voltage conditions, voltage flicker condition or harmonics frequency variation condition, PLL provide low distortion output by locking phase of utility voltage quickly. This PLL is hardware version that uses zero voltage crossing point detection method. Oscillation of output angle is the result of noise which in produced at zero voltage crossing point. Dynamic performance of this method is very poor.

In [6] 90^0 phase shifting of input voltage is implemented. In this method response to transients is very slow because of detection of zero crossing voltage during a half period. Adequate accuracy is also major limitation of this method.

Vector product phase locked loop (VP-PLL) concept is proposed in [7], for faster and accurate phase control. P-I controller, vector product phase detector, memory and timer is implemented in this proposed control scheme. Problems raised in hardware PLL because of comparator are avoided in VP-PLL software based method.

Filter for the measurement of positive sequence voltage is implemented in [8]. This was done under a voltage unbalance condition. Achieved phase angle of positive sequence is used further. But this control scheme introduced a phase delay because of insertion of filter in circuitry.

A phase delay introduced in above control scheme is eliminated in [9], and with this method we can achieve positive and negative sequence voltages without any phase delay. This proposed control scheme implements weighted least- squares estimation method for instantaneous phase angle detection algorithm under condition of voltage sag.

The software phased locked loop (SPLL) based on concept of space vector and dq-transformation is proposed in [5]. This SPLL along with digital signal processors (DSP) is combined in this control scheme method which is very robust, fast and simple. Root locus method and bode diagrams are used to analyze filtering characteristic and system performance. For this lead/lag loop controller is utilized by SPLL model.

Comparisons of various control methods are carried out in [10]. Voltage sag having phase jump compensation methods are proposed here. This control scheme utilizes open loop control for DVR. This scheme regulates load voltage but gives poorly damped response. Restorer harmonic filters are the reason behind the response mentioned above [11].

In [11] multi loop controller is proposed to improve damping effect caused by switching harmonic filter. Closer tracking of reference load voltage is essential and this proposed control scheme allows it under different load conditions. To improve stability margins current mode control techniques along with outer voltage feedback loop is incorporated into DVR control schemes. In this proposed control scheme two feedback loops using DVR load side voltage and currents of filter capacitor are added along with control scheme with open loop which already exists.

Control strategy for cascaded high voltage DVR is proposed in [12]. This control scheme uses a 2-DOF strategy that incorporates posicast and P + resonant compensator for control of cascaded high voltage DVR. Here transient voltage oscillations are effectively damped and tracking of reference voltage is perfectly achieved.

In [13] new matrix method is proposed for computing voltage sag and phase shift of supply voltage faster than other systems. This matrix vector control is utilized by main DVR control which considers only negative sequence and positive sequence information in the supply. Requirement of zero sequence control is eliminated in this proposed control scheme. Phase locked loop (PLL) is core of this control strategy which locks synchronous reference frame to positive sequence component of the supply. Generally this control type is called as space vector control and inverter pulse pattern strategy as space- vector pulse width modulation.

Harmonics play important role as a major power quality problem. To handle harmonics a novel controller is proposed in [14]. This proposed controller has two feedback loops and a single feed forward loop. For keeping output voltage over shoot with acceptable limits the damping component of LC filter system is actively increased with the help of first feedback loop. On the other hand decreasing voltage due to feedback loop is compensated by using feed forward loop. Source, non-linear load and power converter produces load voltage harmonics which are periodic in nature. This harmonics are compensated by second feedback loop which is incorporated with digital repetitive control algorithm.

In [15] proposed controller is based on analysis of physical limiters of the control bandwidth of DVR system that use LC output using filters. The control scheme gains maximum control bandwidth up to the cut off frequency of output filter. Better control dynamics are provided by this proposed voltage controller. This control schemes implements digital controller with processor.

Sliding mode control (SMC) strategy is summarized in [16]. Along with PI feedback control and feed forward control SMC strategy is used for DVR in current control strategies.

Hysteresis voltage control strategy for DVR is proposed in [17]. Discrete Fourier Transform (DFT) strategy is implemented for detection of phase jump and magnitude of voltage swell and sag. Two levels Hysteresis voltage control method which is conventional is applied in this proposed strategy. Such method is non-linear voltage control depending upon voltage error. Under condition of voltage variations such as sag and swells, the effect of Hysteresis band on DVR voltage and quality of load is analyzed in this control scheme.

A compensation voltage control scheme based on Clark-Concordia transformation and PLL is proposed in [18] for DVR. Due to qualities such as robustness, fast dynamic response and system order reduction, the SMC (sliding mode control) is used in PLL structure. Control strategy proposed for DVR power converter is input-output linearization.

Control strategy which deals with voltage sag, voltage imbalances, and harmonic voltages simultaneously within bandwidth is proposed in [19]. With the help of single controller the power quality disturbances mentioned above are eliminated is the important aspect of this control scheme. It consist feedback loop which enables zero error in steady state and feed forward loop for the improvement of transient response. Rotating or static reference frame may be implemented for such controller.

For achieving greater voltage boosting controllability in both time response and voltage, the control strategy is proposed in [4]. This scheme incorporates firing control strategy which reduces injecting voltage waveform harmonic contents on large extent.

In [20] voltage sag detection algorithm and control algorithm synthesis of DVR are proposed. The proposed control scheme includes grid synchronization algorithm based on reference compensation voltage generation, the shunt converter control algorithm, series inverter control algorithm and double synchronous reference frame PLL (DSRF-PLL).

3. Conclusion

Different control scheme for DVR are discussed in this paper.

4. Future prospectus of the study

By comparing mentioned control schemes, efficient controller for DVR can be modeled and studied.

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