

Compensation of Voltage Sags with Phase-Jumps through DVR with Minimum VA Rating Using PSO based ANFIS Controller

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ABSTRACT

Dynamic Voltage Restorer (DVR) restores the distribution system load voltage to a nominal balanced sinusoidal voltage, when the source voltage has distortions, sag/swell and unbalances. DVR has to inject a required amount of Volt-Amperes (VA) into the system to maintain a nominal balanced sinusoidal voltage at the load. Keeping the cost effectiveness of DVR, it is desirable to have a minimum VA rating of the DVR, for a given system without compromising compensation capability. In this regard, a methodology has been proposed in this work to minimize VA rating of DVR. The optimal angle at which DVR voltage has to be injected in series to the line impedance so as to have minimum VA loading on DVR as well as the removal of phase jumps in the three-phases is computed by the Particle Swarm Optimization (PSO) technique. The proposed method is able to compensate voltage sags with phase jumps by keeping the DVR voltage and power ratings minimum, effectively. The proposed PSO methodology together with adaptive neuro-fuzzy inference system used to make the DVR work online with minimum VA loading. The proposed method has been validated through detailed simulation studies.

Keywords: Dynamic Voltage Restorer, Particle Swarm Optimization, VA Rating, Voltage, Voltage Sags with Phase Jumps

INTRODUCTION

Now-a-days, the need of the electrical power is increasing and simultaneously the problems

while transmitting the power through the distribution system are also increasing. The consumers are ready to pay for a reliable and quality power. Majority of the problems occurring in the power system are due to the vagaries of the nature and switching on and off of the loads like induction motors connected (Bollen, 2001).

DOI: 10.4018/jsir.2010070102

The voltage related problems in a distribution network are harmonics, unbalances and sag/swell (Hingorani, 1995). The interest in voltage sags is mainly due to the problems they cause on several types of equipment i.e., adjustable-speed drives, process-control equipment and computers which are very sensitive for voltage. Any short circuit in a transmission system will cause a voltage dip (Nielsen & Blaabjerg, 2001). A short circuit in a power system not only causes a drop in voltage magnitude but also a change in the phase angle relation among the three-phases. This is referred to as phase-angle jump associated with the voltage sag. Phase-angle jumps during three-phase faults are due to the difference in X/R ratio between the source and the feeder. A second cause of phase-angle jumps is the transformation of sags to lower voltage levels (Ghosh & Ledwich, 2001). These problems will affect other sensitive loads of the distribution system. The problems in the distribution system are cleared using custom power devices. Dynamic Voltage Restorer (DVR) is a series connected; custom power device to mitigate the voltage sags with phase jumps. Some methodologies to compensate the voltage sags/swells with phase jumps using DVR are proposed by Nielsen and Blaabjerg (2001) and Ghosh and Ledwich (2001). VA rating minimization for economical operation was not addressed by these methods. In this work, a method is proposed to compensate, the voltage sag/swells with phase jumps by DVR with minimum VA rating. In order to compensate the voltage sag/swell with phase jumps, the DVR has to inject required amount of Volt-Amperes (VA) into the system. The DVR VA rating is minimized in this work without compromising its sag/swell compensating capability using particle swarm optimization technique. Since, particle swarm optimization (PSO) is an offline optimization technique; it cannot be used for online applications like DVR. Hence, a PSO based ANFIS is used to find the optimal voltage and angle of injection of DVR in real time for compensating sag/swell with phase-jumps, with minimum VA loading. The proposed methodol-

ogy is applied on a distribution system and the detailed simulation results are presented.

DYNAMIC VOLTAGE RESTORER

A DVR is a power electronic device, connected in series to the feeder, to protect the loads from typical voltage problems in distribution system. The schematic diagram of a series compensated distribution system is shown in Figure 1. In Figure 1, the source voltage is represented by v_s . The terms L_s and R_s represent feeder inductance and resistance. The terminal voltage and load voltage are represented by v_t and v_p , respectively. The DVR is realized by a voltage source inverter with DC capacitor voltage V_{dc} and power electronic switches S_1, S_2, S_3, S_4 . The term L_{is} represents the leakage inductance of the injection transformer and C_f represents the capacitance of the capacitor filter. The operating principle of the DVR is to inject a voltage (v_{DVR}) of required magnitude and phase to compensate sag/swell and distortion in the terminal voltage (v_t) and provide a balanced sinusoidal voltage (v_l) at the load. The reference DVR voltage to be injected (v_{DVR}) is realized by switching S_1, S_2, S_3, S_4 through hysteresis control (Woodley, Morgan, & Sundaram, 1999).

In literature, three methods are proposed to compensate voltage sags (Quirl & Johnson, 2006). These methods are,

- (i) Pre-Sag compensation
- (ii) In-phase compensation
- (iii) Phase advance compensation.

The three methods of compensation of voltage sags can be explained by using the phasor diagram given in Figure 2. Here $V_{S-presag}$ and V_{S-sag} represent the pre-sag and sag voltages of the source respectively. θ represents the phase angle jump, V_l is the load voltage obtained after compensation. ϕ represents the angle between load voltage and source sag voltage. V_{pre} , V_{in} and V_{opt} are the voltages that are in-

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