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PWM Controller for Dynamic Voltage Restorer in the Voltage Grid

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Abstract
Dynamic voltage restorers (DVRs) are used to protect sensitive loads from the effects of voltage sags on the distribution feeder. In all cases it is necessary for the DVR control system to not only detect the start and end of a voltage sag but also to determine the sag depth and any associated phase shift. The DVR, which is placed in series with a sensitive load, must be able to respond quickly to a voltage sag if end users of sensitive equipment are to experience no voltage sags. With the loads, the stability of voltage for appearing voltage sag is placed on top of avoiding damaging the device. The voltage sag phenomenon is a change in voltage in a short time but can cause the machine to stop at some important loads, affecting the normal operation of the entire electric power system. The voltage sag can be overcome by the application of Dynamic Voltage Restorer (DVR) built on the basis of a power electronic converter with advanced features such as fast impact and very high accuracy.

Keywords: Dynamic Voltage Restorer, PWM, FACTS

1. Introduction

Voltage sag is a common and undesirable power quality phenomenon in the distribution systems which puts sensitive loads under the risk. An effective solution to mitigate this phenomenon is to use dynamic voltage restorers and consequently, protect sensitive loads. Sensitive loads such as factory automations, semiconductor-device manufacturer, and paper manufacturer are vulnerable to power-supply disturbances [1-5]. Voltage sag is a phenomenon of reducing, unbalancing of voltage, phase angle jump or transient voltage, interrupting power supply in the short term [6-18]. These disturbances occur due to, e.g., short circuits in upstream power transmission line or parallel power distribution line connected to the point of common coupling (PCC), inrush currents involved with the starting of large machines, sudden changes of load, energizing of transformers or switching operations in the grid [19-21].

The voltage step-ups are less important than voltage sags because they are less common in distribution system. The causes of the voltage sag are short-circuit failures in the electric power system, the voltage sag due to the starting of the large-capacity motors, or the impacts of switching on or off of transformers or the compensate capacitor system and may be due to remote operating errors. To overcome the voltage sag in the electric power system, there are many solutions such as raising the capacity of the substation, using compensates capacitors, operating properly to minimize incidents, but the use of Dynamic Voltage Restoration system (DVR)), using a multilevel inverter or a Voltage Source Converter (VSC) is more effective. In this research, we present a method of designing a PWM controller for the VSC of the DVR for the voltage grid.

2. Mathematical model of the DVR Dynamic Voltage Restorer system

The DVR consists of a series devices designed to maintain constant voltage values for loads. The diagram of the DVR in boost mode is shown in Fig 1.

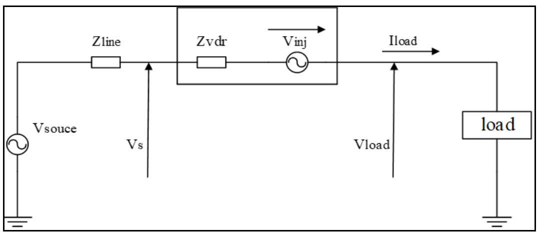

Fig 1: System of voltage balancing circuit using DVR

The equivalent circuit of the system with the participation of DVR shows that when the voltage source is dropped or stepped up, the DVR will pump the amount of V_{inj} voltage through the voltage pump converter so that the required load voltage value can be maintained. The amount of voltage pumped by DVR can be written as follows:

$$V_{inj} = V_{load} + V_S \quad (1)$$

In which:

V_{load}: is the required load voltage value (required)

V_S: is the source voltage in the condition of sag/step-up

The high frequency converter can be used to improve conversion efficiency without incurring significant damage, is shown in the Fig 2.

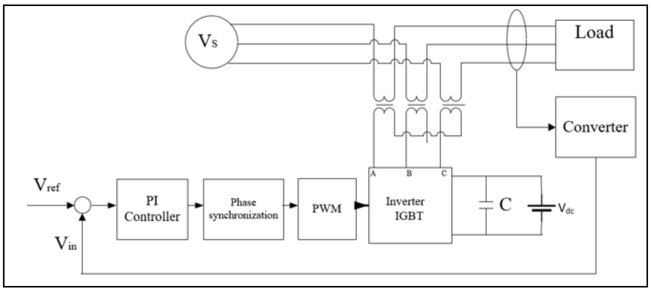

Fig 2: The DVR system structure uses PWM controller

It is important to concern that in this case, indirectly control the converter, which has the reactive power and the active power exchanged with the system at the same time: the error signal is obtained by comparing the reference voltage with the rms voltage measured at the load point. The process of controlling signal failures creates the angle necessary to control faults to zero, i.e., the rms load voltage is returned to the reference voltage. $V_{control}$ consists of 3 sinusoidal control signals which calculated by the following formula:

$$\begin{cases} V_R = \sin(\omega t + \delta) \\ V_Y = \sin\left(\omega t + \delta - \frac{2\pi}{3}\right) \\ V_B = \sin\left(\omega t + \delta + \frac{2\pi}{3}\right) \end{cases} \quad (2)$$

3. Simulation results

To investigate the performance of the DVR using to avoid voltage sag during short circuit, a ground short-circuit fault is located at a distance of 200 km from the generating source athrough a 0.4 Ω resistor, in a period of 200ms. The voltage recovery ability of the DVR system to protect the load in Medium voltage grid before the incidents. The results of the system construction in Matlab - Simulink software is shown in Fig 3 as follows:

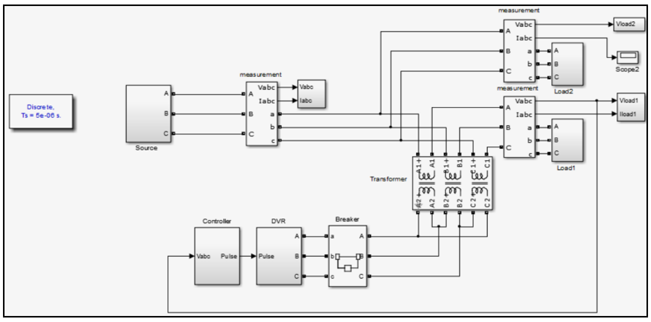

Fig 3: Model of the DVR system connected grid

Considering the incident of a 3-phase short circuit through a resistor of 0.4 ohm in the period of 400-600 ms. When short circuit occurs, it affects the voltage and current across the grid.

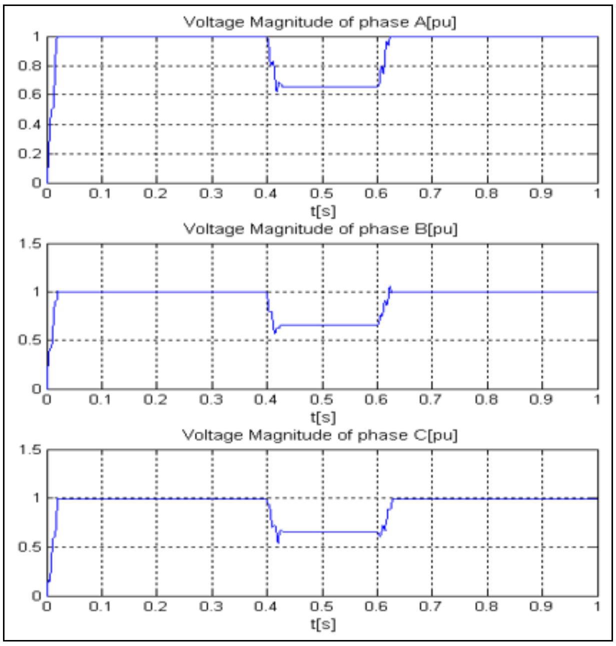

Fig 4: Voltage magnitude of each phase near the source during a three-phase voltage sag without the DVR

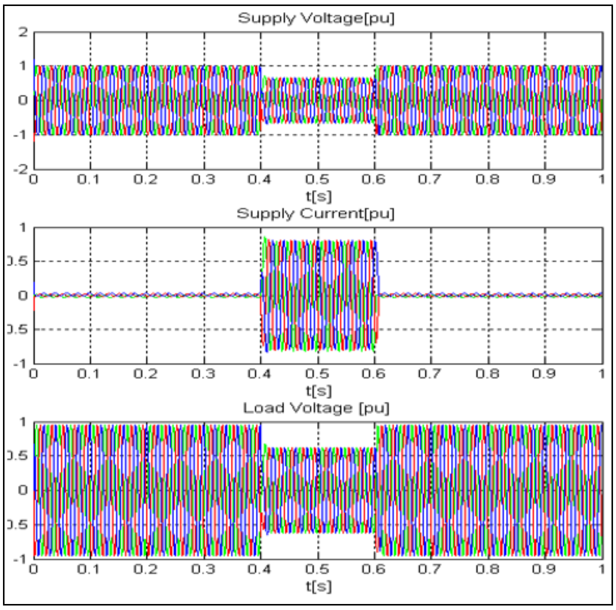

Fig 5: Voltage, current of the source and load during a three-phase voltage sag without the DVR

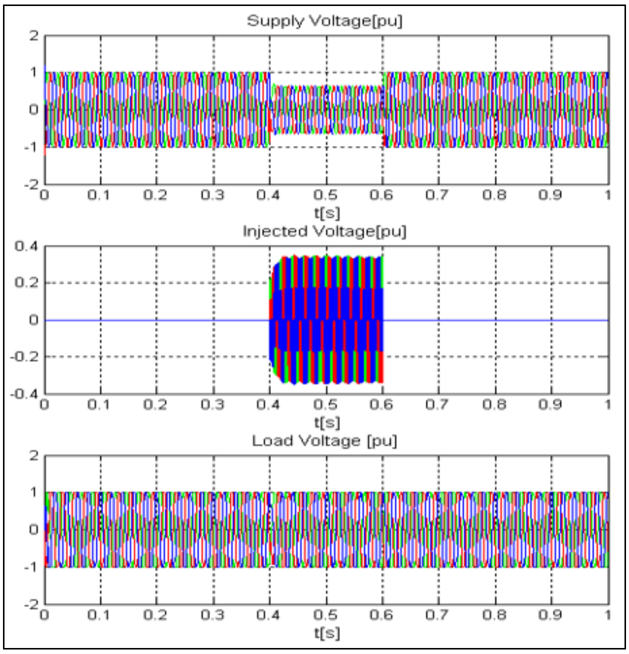

Fig 6: Voltage, current of the supply source and load when using the DVR system during a three-phase voltage sag with the DVR

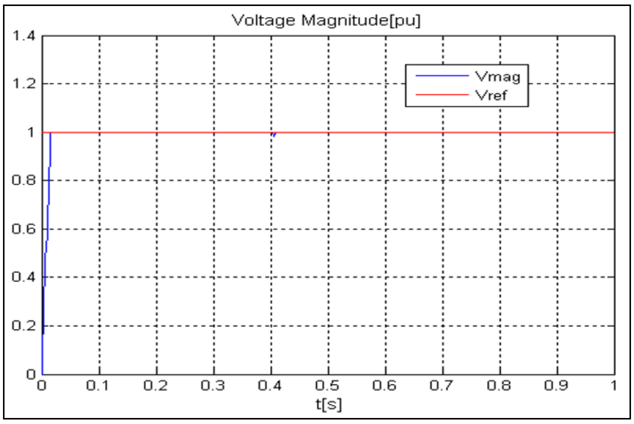

Fig 7: Load voltage magnitude when using the DVR system during a three-phase voltage sag with the DVR

When a short-circuit problem occurs, thanks to the DVR system, the phenomenon of voltage sag is almost completely reduced and the AC load voltage remains at 96% as shown in Fig 7 When using the DVR system, the load voltage magnitude closely follows the setting values. This helps DVR to ensure the supply of voltage to compensate for the voltage sag of the grid, improving electric power quality, ensuring quick restorer for the grid.

4. Conclusion

The paper presents a method of designing voltage stability for loads by DVR with the application of PWM controller. The results of system simulation when using the DVR with the application of PWM controller show the accuracy of the effectiveness of the proposed method. The application of PWM controller to the DVR increases the voltage quality, stabilizes the voltage, helps loads to operate normally when the incidents of transmitting or unstable power supply arise. With the design and simulation results for the DVR system model, the voltage sag on voltage line has been maintained.

5. Acknowledgment

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