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***Journal of Scientific and Engineering Research*, 2020, 7(6):127-133**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Application of PWM Controller for Dynamic Voltage Restorer

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Abstract The issue of voltage quality on the power grid is one of the issues worried to the electric power transmission system. 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. 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.

Keywords Voltage sag phenomenon, Dynamic Voltage Restorer, PWM controller

1. Introduction

Voltage sag is a phenomenon of reducing, unbalancing of voltage, phase angle jump or transient voltage, interrupting power supply in the short term [4-10]. This short-term interval usually ranges from 0.5 to 30 cycles. According to the survey [1, 8, 17], the voltage sag has the highest occurrence rate with 31% of the total of voltage events on the grid. 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 [2]. The phenomenon of voltage sag affecting each device in the system is different, depending on the sensitivity of the device in the system [2-3, 5-7, 11-16]. Devices used in modern industrial systems (e.g. programming logic controllers (PLCs), speed controllers (ASD), computers, and contactors) are sensitive to voltage sag [9]. 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. To control the VSC in the DVR, there are many different methods such as the PWM pulse width modulation method, basic Frequency Filtering System (FFS) method, etc. The controlling method of VSC as per PWM pulse width modulation not only has simple characteristics but also given good response. Therefore, in this paper, we present a method of designing a PWM controller for the VSC of the DVR for the medium voltage grid.

2. DVR Dynamic Voltage Restorer system

The DVR consists of a series devices designed to maintain constant voltage values for loads. The general structure of a DVR is shown in the Figure 1.

The configuration of the DVR is shown in Figure 3, including the following main components:

The Transformer: isolation between DVR and grid, coordinating voltage level.

The Frequency filter: improving the adding voltage waveform of the DVR.

The VSC in the DVR: that is a three-phase voltage inverter using IGBT modulation PWM.

Energy storage unit: storing energy, connecting to VSC to create the necessary AC voltage to compensate for a voltage sag event when it occurs.

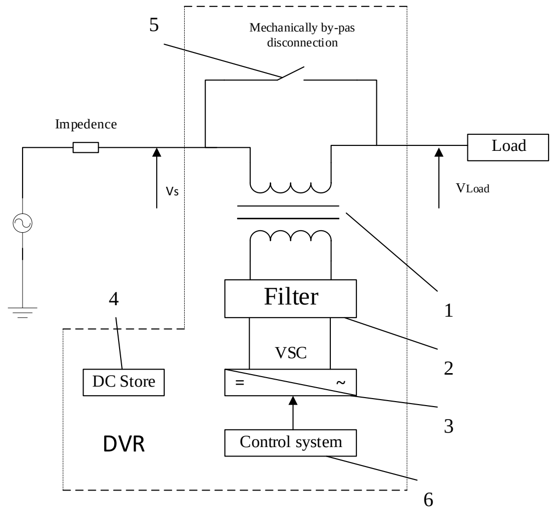


Figure 1: Structure diagram of the DVR

Disconnected device: Mechanical switch to completely isolate with DVR, provide electric power for loads or in the case of emergency.

VSC controller: The main function of the DVR is to protect loads due to voltage step-up / voltage sag from the grid. Therefore, the DVR is located on the line which connected to loads. If a problem occurs on the line, the DVR will add the voltage V_{DVR} and compensate the voltage so that the load voltage is equal to the voltage value before the incident. The instantaneous magnitude of pumped 3-phase voltage is controlled by eliminating any adverse effects of breakdown on the V_L load voltage.

The DVR set works independently with the types of incident or any event that occurs on the system, it provides voltage to the rest of the system connected to the reserve.

DVR has 2 operation modes as follows: standby mode and boost mode.

When the standby mode ($V_{DVR} = 0$) is used, the low voltage winding of the transformer is short-circuited via a voltage source converter (VSC). There is no switching when operating in this mode. DVR will work mainly in this mode.

When the boost mode ($V_{DVR} > 0$) is used, the DVR will pump the compensation voltage through the transformer when it detects unbalanced source voltage, the DVR will add the voltage as V_{DVR} so that the load voltage is equal to the value of voltage before the incidents. The instantaneous magnitude of 3-phase voltage is controlled by eliminating any adverse effects of breakdown on the V_L load voltage.

The diagram of the DVR in boost mode is shown in Figure 2.

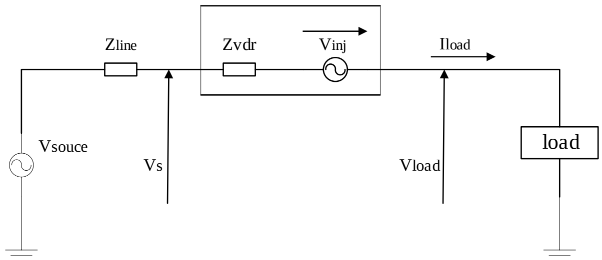


Figure 2: System of voltage balancing circuit using DVR

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:

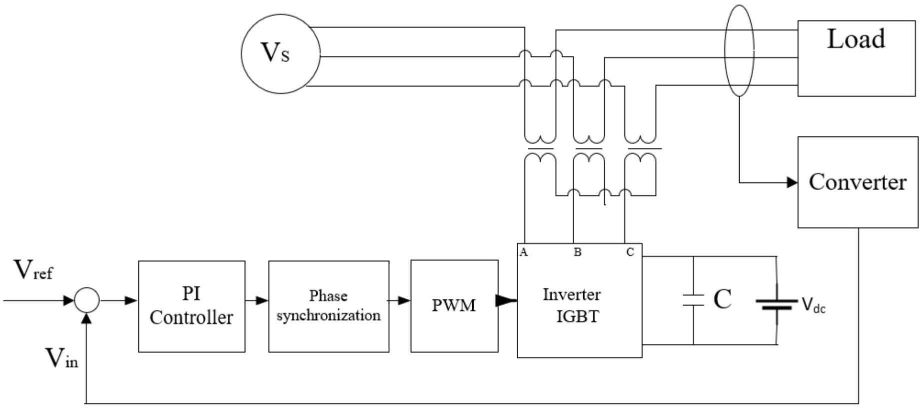
V_{load}: is the required load voltage value (required)

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

3. Application of PWM controller for the DVR

Structure of DVR with application of PWM controller

To control the VSC for the DVR, we use the PWM controller. The purpose of this method is to maintain the value of the continuous voltage at the point where the load is connectedin accordance with the system malfunction. The VSC converter based on sinusoidal PWM technology which is a simple system given a good response. The PWM offers a more flexible option than the basic Frequency Filtering System (FFS), a preferred method in FACTS applications. Besides, the high frequency converter can be used to improve conversion efficiency without incurring significant damage. The DVR system structure uses PWM controller is shown in the Figure 3.



Where:

V_S is the source voltage

V_{abc}: three-phase voltage of the medium voltage grid

V_{ref}: set voltage value (=1p.u)

V_{in}: magnitude of voltage in p.u

δ: the angle for PWM

The inputs of controller are the error signals obtained from the reference voltage and the rms value of the voltage at the pole to be measured. Such incident is handled by a controller which its outputs is theδ, providing to the PWM signal generator. 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, ie the rms load voltage is returned to the reference voltage.

$V_{control}$consists of 3 sinusoidal control signals which calculated by the following formula:

$$\begin{cases} V_R = \sin(wt + d) \\ V_Y = \sin\left(wt + d - \frac{2p}{3}\right) \\ V_B = \sin\left(wt + d + \frac{2p}{3}\right) \end{cases} \quad (2)$$

PI controller structure: $PI(s) = K_p + \frac{K_i}{s}$ T

4. The simulation results of the DVR system

To consider a transmission system with the following parameters: generator 13kV, 50Hz, rated power of 100MVA, providing for 2 transmission lines through a transformer of 3 coils of type Y / ▵ / ▵, 13kV / 115kV / 115kV. Such transmission line over 200 km is a source for two distribution networks through two transformers of type ▵ / Y, 115kV / 11kV.

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 as shown in Figure 4 through a 0.4 Ω resistor, in a period of 200ms. The apparent power of the reserve device is 650V.

he 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 Figure 5 as follows:

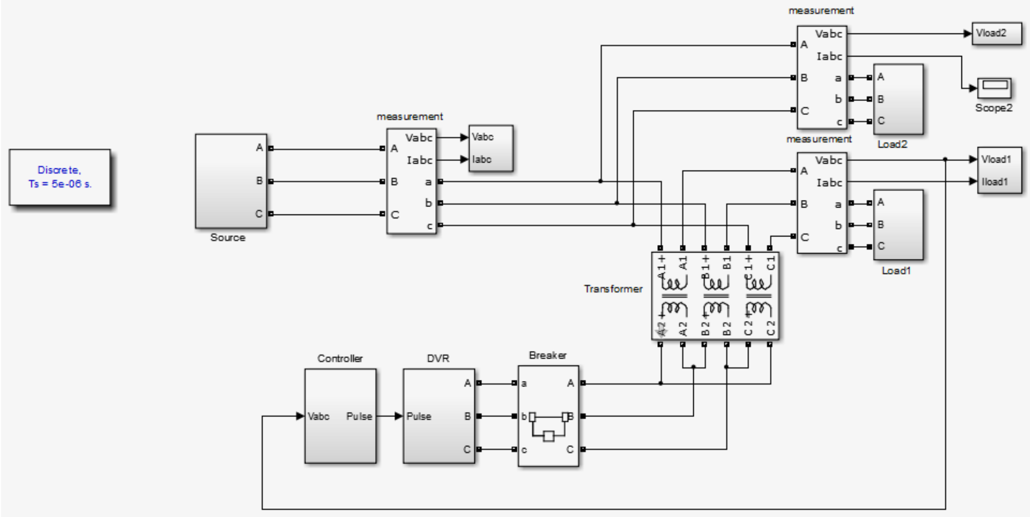


Figure 5: Model of the DVR system connected grid

The transfer function of the controller for DVR system is given by $G_R(\mathbf{z})$: $G_R(\mathbf{z}) = \dfrac{K_P + K_I z^{-1}}{1 + z^{-1}}$

The system without the DVR

Considering the incident of a 3-phase short circuit through a resistor of 0.4 ohm in the period of 400-600 (ms), from the simulation results we see, the value of the load voltage drops 35 - 40% compared to supply source voltage as shown in the figure below. The total simulation time is only 1s of setting.

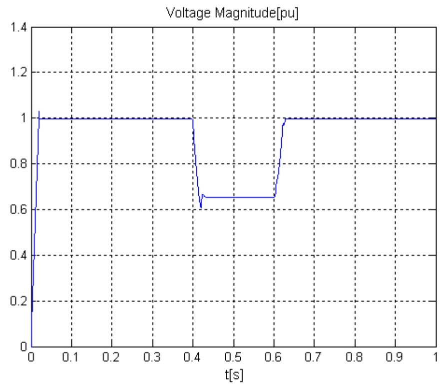


Figure 6: Load voltage magnitude without DVR system

The voltage sag of 35-40% occurs at the time of 400ms and lasts up to 600ms, the total time of the voltage drop is 0.2s. The phenomenon of voltage sag occurs on all 3 phases.

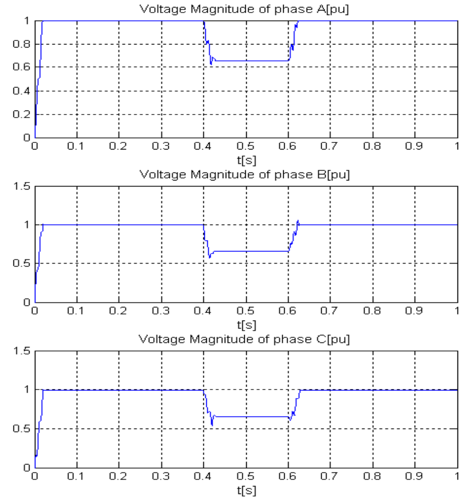


Figure 7: Voltage magnitude of each phase near the source during a three-phase voltage sag

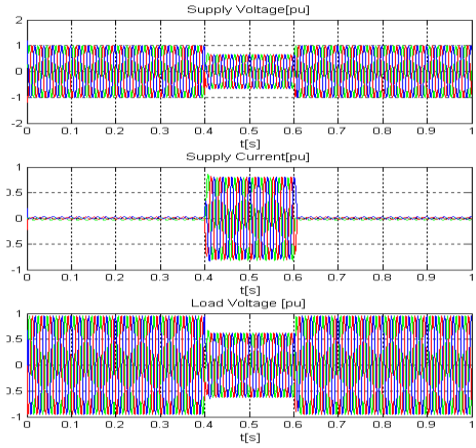


Figure 8: Voltage, current of the source and load during a three-phase voltage sag

When a 3-phase short circuit occurs, it affects the voltage and current across the grid

The system with the DVR

The results of the DVR system simulation in the Matlab Simulink are shown in the Figure 9 and 10.

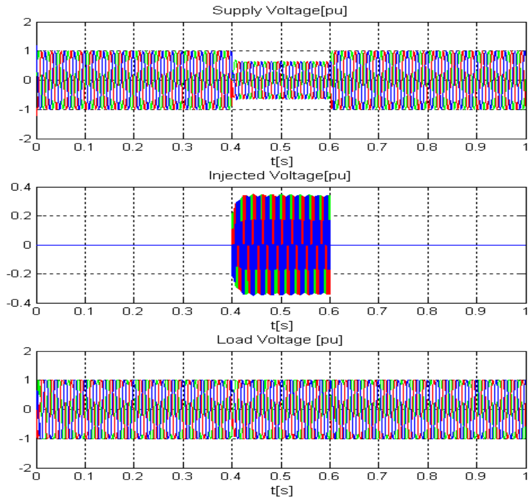


Figure 9: Voltage, current of the supply source and load when using the DVR system during a three-phase voltage sag

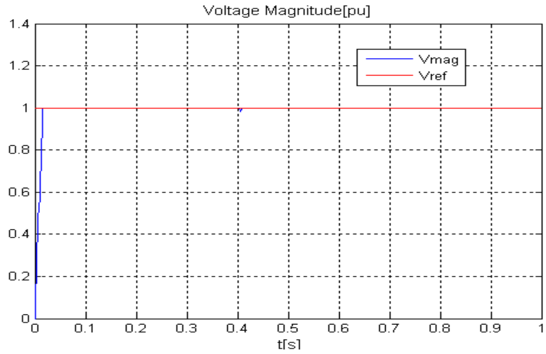


Figure 10: Load voltage magnitude when using the DVR system during a three-phase voltage sag

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 Figure 10. However, at the time of 400ms still causes the transient phenomenon within 4.5ms due to the control process of the DVR system. This period of time is quite short, ensuring fast restoration for medium voltage grid.

When using the PI controller in 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.

5. Conclusion

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 medium voltage line has been maintained. The proposed work identifies the indices regarding the goodness of the system quality.

Acknowledgment

This research was funded by Thai Nguyen University of Technology, No. 666, 3/2 street, Thai Nguyen City, Viet Nam.

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