Voltage Sag Mitigation Due To Short Circuit Current Using Dynamic Voltage Restorer Based On Hysteresis Controller

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***Abstract*—Voltage sag is a major problem in power system that must be solved. To overcome the occurrence of the voltage sag, a system that well known as Dynamic Voltage Restorer (DVR) is needed. In an electrical power system, DVR is positioned in series between a source and load. There are several DVR voltage compensating methods,such as pre-sag method, in-phase method and in-phase advance compensation. DVR need synchronization time for equals phase injection voltage so it can compensate voltage sag due to short circuit current. This work employs Discrete Fourier Transform (DFT) for phase detection and hysteresis voltage control. This paper presents modeling, analysis and simulation of DVR by using MATLAB.**

***Keywords—* electric power quality; voltage sag; dynamic voltage restorer; hysteresis voltage control.**

I. Introduction

Many developing countries require increased productivity in industry, to achieve high productivity, industry requires power electronics components, where power electronics component is a sensitive device that must be supplied by a voltage that has frequency and magnitude at constant conditions [1]. Power electronics components are required high-power quality[2],[3], because electronics components are very sensitive to electromagnetic fault [4]. Such a fault causes problems of power quality, failure in providing high power quality can cause failure of equipment operation or even shutdown on a system, power quality problems are: voltage sag, flicker, voltage unbalance, interruption and harmonic. Voltage sag is one factor causing the diminished electrical power quality, one of causes of voltage sag is short circuit current. To mitigate the voltage sag, one can use Dynamic Voltage Restorer (DVR) [5], [6].DVR placed at point of common coupling, at customer side. So that DVR can protect load by injecting voltage for mitigation voltage sag.

II. Dynamic Voltage Restorer

A. Principle of DVR Operation

Fig. 1 shows the block diagram of DVR. The basic idea of DVR is to inject voltage from injection transformer, wherein voltage of injection transformer comes from inverter, in this work, the inverter is controlled using hysteresis control with phase detection .

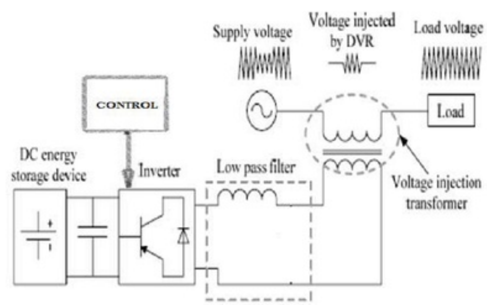

Fig. 1. Basic Circuit of DVR [7]

B. Basic Configuration of DVR

- An Injection/ Booster transformer: The main task of injection transformer is to connect DVR to distribution network via the HV-windings and transforms and couples injected compensating voltages generated by voltage source converters to the incoming supply voltage.
- Filter Unit: The main task of harmonic filter is to keep the harmonic voltage content generated by voltage source converter (inverter). Non-linear characteristics of semiconductor devices cause distorted waveforms associated with harmonics. To overcome this problem and providing clean electrical supply filter unit is used.
- Voltage Source Inverter Circuit: Inverter circuits convert DC voltage to AC voltage. Solid-state semiconductor devices with turn-off capability are used in inverter circuits. In DVR application, VSC is used to generate voltage for mitigation voltage sag.
- Energy Storage Unit: Purpose is to supply necessary energy to inverter via a dc link for the generation of injected voltages. Batteries and Ultracapacitors are most common types of energy storage devices. In fact, capacity

of the stored energy directly determines the duration of sag which can be mitigating by DVR.

C. Control scheme of DVR

Fig. 2 shows the flowchart of DVR operation, the first step of the control technique is phase detection by Discrete Fourier Transform (DFT) that used for reference voltage. the control output of the DVR to generate switching signal for inverter is generate based on error between reference and actual voltage.

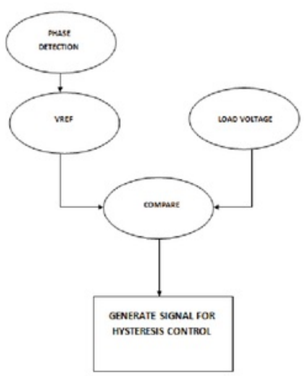

Fig. 2. Flowchart of Control Technique DVR based on phase detection

III. HYSTERESIS VOLTAGE CONTROL WITH DETECTION PHASE

Hysteresis control is a feedback controller that compares two statements that produce a switching signal from difference of two statements.

As in Fig. 3 (a) hysteresis control generally consists of a 3-phase IGBT inverter, battery for energy storage, injection transformer and hysteresis controller. Hysteresis controller requires two voltage signals, which are from supply voltage side and from injection transformer where voltage is injected by DVR. Hysteresis controller will compare two signals, and produce an error signal that is forwarded to hysteresis switching pattern according to fig. (b). This hysteresis controller uses bands (VH (upper) and VL (lower)), where if error signal is between upper and lower there is no switching signal and when signal errors≥upper, switching signal will decrease and vice versa, as in fig. (b) and (c).

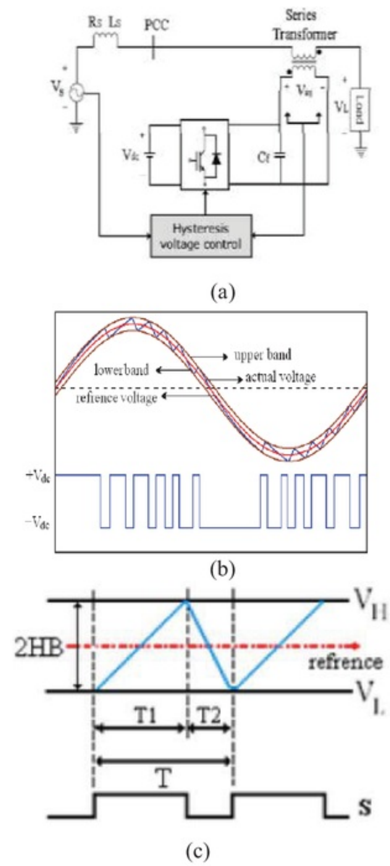

Fig. 3. (a). DVR circuit with hysteresis control[8]: (b). Hysteresis switching pattern[8], (c). hysteresis band control[9]

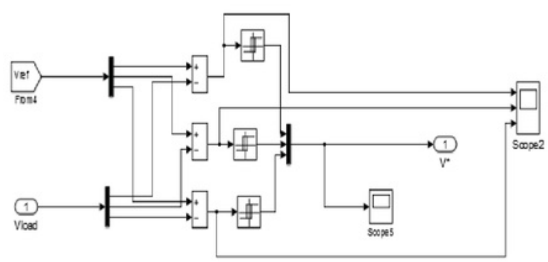

Fig. 4. Simulink model of Hysteresis Voltage Controller

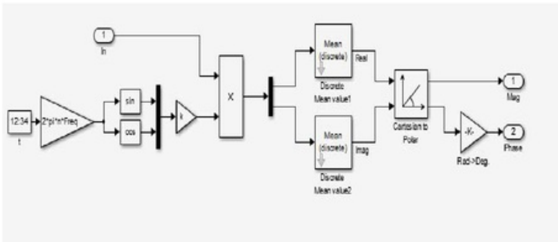

Fig. 5. Discrete Fourier Transform (DFT) Block.

Fig. 5 shows the DFT block for phase detection, the explanation of the DFT operation could be explainedas follow.

$$X(k) = \sum_{n=0}^{N=1} X(n)\, e^{\frac{-j2\pi nk}{N}} \quad (1)$$

where: k = 0, 1, 2,…, N-1.

n = 0, 1, 2,…, N-1.

$$b = {}^{2\pi k}/_{N} \quad (2)$$

By Substitute (1) to (2), then we get :

$$X(k) = \sum_{n=0}^{N=1} X(n)\, e^{-jb} \quad (3)$$

Based on Euler Cauchy relation below:

$$e^{jx} = cosx + jsinx \quad (4)$$

Then (3) could be represented by (5):

$$Xk = Xo(\cos(-bo) + jsin(-bo) + \cdots + Xn(\cos(-bn) + jsin(-bn) \quad (5)$$

Where the real part of the signal is :

$$Xo(\cos(-bo) + .. + Xn(\cos(-bn) \quad (6)$$

Whereas Imaginary part is :

$$jsin(-bo) + \cdots + jsin(-bn) \quad (7)$$

By simplication, (6) and (7)could be writen :

$$Xk = Ak + jBk \quad (8)$$

From (8), the magnitude and phase could be calculated as shown in (9) :

$$magnitude = \sqrt{Ak^2 + Bk^2} \quad (9)$$

$$\theta = tan^{-1}\frac{Bk}{Ak} \quad (10)$$

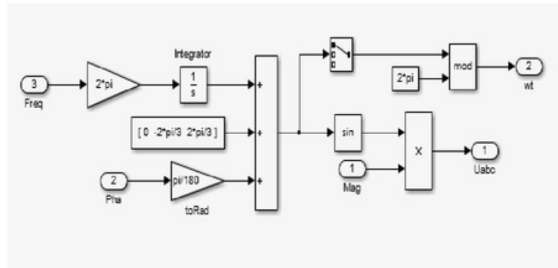

Fig. 6. Generating reference voltage block

From Fig. 6,the voltage of the grid are.

$$Vsa = Vm\sin(wt + \varphi) \quad (11)$$

$$Vsb = Vm\sin(wt + \varphi - 120^0) \quad (12)$$

$$Vsc = Vm\sin(wt + \varphi + 120^0) \quad (13)$$

where:
Vsa = Voltage A phase (V), Vsb = Voltage B phase (V), Vsc = Voltage C phase (V), Vm = Voltage Max (V), Wt = 2πf, φ = phase shift (^{0})

IV. SIMULATION RESULT AND DISCUSSION

Table 1 show parameters that used for simulaiton purposes.

TABLE I. . SYSTEM PARAMETER [5]

No	Parameter	Value
1	Supply 3 fasa	11KV, 50 Hz
2	Trafo *step up*	Y/Δ/Δ, 11/115/115 KV
3	Impedance	R= 0.001Ω L=1.33 μH
4	Trafo *step down*	Δ/Y 115/11 KV Y/Y 11 KV/440 V
5	Load	R=14 Ω, L=1mH

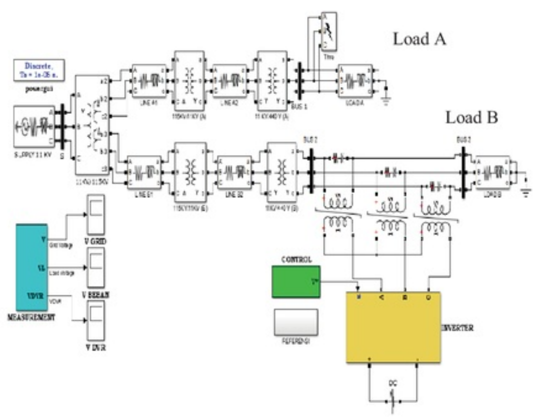

Fig 7.Simulink block diagram of the DVR

DVR in this research designed for protect LOAD B from voltage sag, voltage sag in this research caused by short circuit current. Simulated short-circuit currentsare one phase fault to ground (L-G), two phase fault (L-L), two phase to ground fault (L-L-G), and three phase fault (L-L-L).

To test the control design of the DVR, in this work we have simulate the DVR model by using Simulink.

Fig. 8.a and Fig.8.b respectively show the normal grid voltage and the output voltage control of the DVR. As shown at Fig. 8.b. in the first 0.02 second of simulation, synchronization process of the DVR will take placed.

Fig. 9 (10-11).aand Fig.9(10-11).b respectively show the faulted grid voltage caused by short circuit between line to line voltage and the output voltage control of the DVR. As shown at Fig. 9.b. to mitigate the voltage sag, the DVR will automatically generate voltage that coresponding with the depth of the sag.

Fig 12. Show the grid voltage after voltage compensation of the DVR for any faulted.

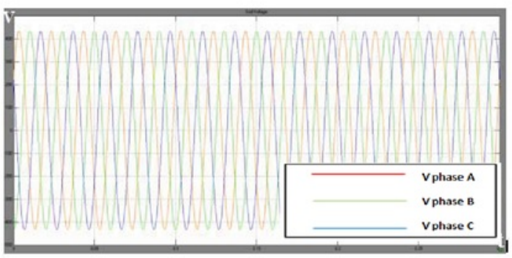

Fig.8 (a) Normal Voltage

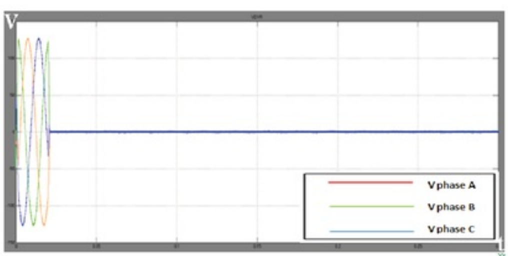

Fig. 8 (b) DVR output

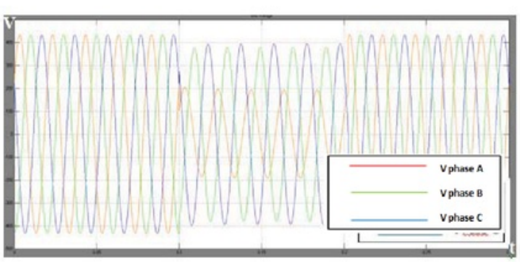

Fig. 9(a) Voltage sag caused by L-L fault

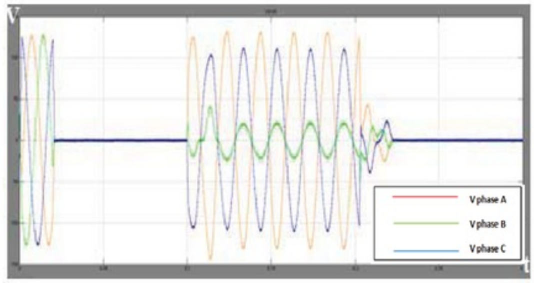

Fig.9 (b) Injection voltage for mitigation voltage sag L-L fault

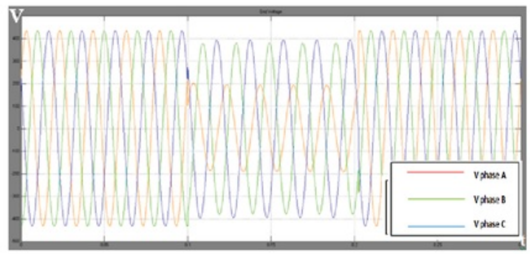

Fig.10(a) Voltage sag caused by L-L-G fault

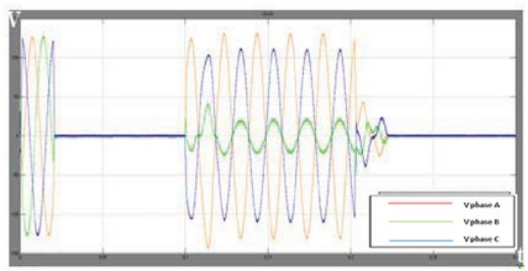

Fig.10 (b) Injection voltage for mitigation voltage sag L-L-G fault

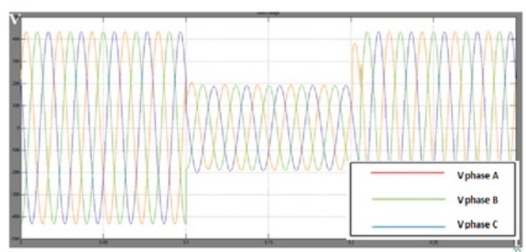

Fig. 6. Fig. 11(a) Voltage sag caused by L-L-L fault

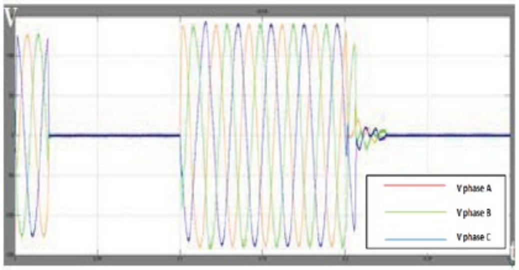

Fig. 11 (b) Injection voltage for mitigation voltage sag L-L-L fault

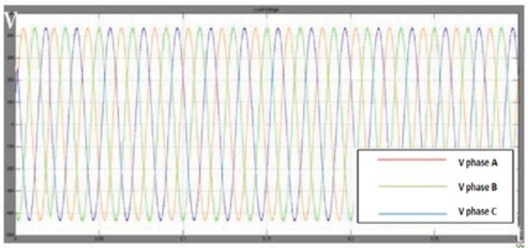

Fig. 12 Voltage at load B after compensation

V. CONCLUSION

In this work, we have built DVR model with hysteresis control phase detection method. Based on simulation result, DVR need synchronization time for equals phase injection voltage it can compensate voltage sag due to short circuit current L-G, L-L, L-L-G and L-L-L.

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