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Voltage Sag and Mitigation Using Dynamic Voltage Restorer (DVR) System for Power Quality Improvement

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Abstract:-This paper emphasizes voltage sag as one of a power quality concern and Dynamic Voltage Restorer (DVR) is using for mitigation of voltage sag. DVR is a custom power devices that most operative and efficient. Consequently, the determination of this project is to study how the DVR functions during compensating of voltage sag. The distribution network has been a selection of as a sample to study the DVR system. This network consists of two feeders, and each feeder connected to the balanced load. A fault has been applied to one of the feeders. Then, voltage sags occurred at another feeder. Matlab Simulink was chosen as the software to simulate the system. Mathematics model for calculation of voltage sag, and voltage injection by DVR System also labelled.The effect of power devices, different circuit topologies, and constraints of components was discussed. The result of the simulation was recorded and discussed while the conclusions and recommendations of this project were done.

Keywords: - Dynamic Voltage Restorer, Voltage Sag, Power Quality (PQ), Voltage Sag Compensation, Voltage Source Inverter (VSI).

I. INTRODUCTION

In many contemporary years, Power quality disturbances become a most issue which makes many scholarsinterested to find the best answers to solve it. There are numerous types of power quality which are transients, short duration voltage variation, long- duration variation, there are voltage sag, swell, and interruption .Based on archives by (TNEB). 80% of power quality grievances in India were outlined to be related to voltage sag [1]. Due to the growing of new technology, a lot of devices had been shaped and technologically advanced for mitigation of voltage sag.

This paper distresses two goals of this project which are a study on voltage sag phenomenon in power system and mitigation this phenomenon by using Dynamic voltage restorer (DVR) system. In order to carry out these objectives Productively, voltage sag characteristics and DVR system will be discussing tentatively in details. Simulations are divided into three parts which are a performance of DVR system. Simulation with and without DVR installation, the effects of voltage sag caused by a fault in power system connected to DVR system, and finally increasing recital of DVR system.

II. VOLTAGE SAG

Voltage sag is commonly acknowledged as one of the most important power quality disturbances. Voltage sag (figure 1) is a short reduction in r.m.s voltage from nominal voltage, occurred in a short duration, about 10ms to seconds. The voltage sag (dip) as a temporary reduction of the voltage at a point of the electrical system below a threshold , voltage sag as an r.m.s variation with a magnitude between 10% and 90% of nominal voltage and duration between 0.5 cycles and one minute.

Voltage sag is occurs at the head-to-head feeder with an unhealthy feeder. The unhealthy feeder always caused by two aspects which are short circuits due to faults in power system networks and starting motor which draw very large current. Both of these concerns are the main factor creating voltage sag as a power quality problem in a power system. Voltage sags are the most common power quality disturbance which definitely gives distressing especially in industrial and large commercial customers such as the damage of sensitivity equipment and loss of daily productions and finances.

There are many methods in order to mitigate voltage sag problem, One of them is decreasing short circuits caused by the utility directly which can be done such as with avoiding feeder or cable overloading by correct organization forecasting. Another auxiliary is using the flexible ac technology (FACTS) devices which have been used widely in a power system. There are many devices have been created with tenacity to boost power quality such as Dynamic Voltage Restorer (DVR), Distribution static compensator (D-STATCOM). All of these strategies are also known as custom power devices.

III. DVR SYSTEM

Rectifier, inverter, filter and coupling transformer comprises of DVR structure,to control variable voltage pulse width modulation technique is used besides. Harmonics can be eliminated by filter due to high switching frequency. Typically DVR system is connected in series with distribution feeder which supplies sensitive load in power system network.

IV. THE PRINCIPLE OPERATION OF DVR SYSTEM

To protect from high power application from voltage dip typically DVR is installed on both sides of medium and low voltage. It can inject missing voltage to the supply using injection transformer when sag has been detected by control unit. Injecting active power into distribution in sag correction technique during compensation. Actually for long duration sags DVR needs energy storage. DVR compensating voltage can be done by three methods.

A. Pre –Sag Compensation Method

During fault to the pre-fault condition, load voltage was reimbursed and this method also measured supply voltage continuously. In this method, the load voltage can be restored ideally, but injected active power cannot be controlled such as the type of faults and load condition

B. In-Phase Compensation

The added DVR voltage is in phase with measured supply voltage regardless of the load current and the pre-fault voltage. The magnitude of injected DVR voltage is minimized for constant load voltage magnitude is the advantage of this method.

C. Phase Advance Method

The injection voltage is in phase with the source voltage. For this method, the injection voltage magnitude of phase advanced method is larger than others method. Voltage phase shift might cause voltage waveform break, imprecise zero crossing, and load power swing. Thus phase advance method should be changed to the load that is tolerant to phase jump, or transition duration should take while phase angle is moved from pre-fault angle to advance angle.

V. MATHEMATICAL MODEL FORVOLTAGE SAG CALCULATION

Considered Figure 7, in a normal condition (no fault), current through load A and load B is equal (balance load). When there is fault on feeder 1, a high current (short circuit current) will flow on feeder 1. So, based on Kirchhoff's Law, currents flow to feeder 2 will be reduced. Subsequently, voltage will also drop in feeder 2this voltage drop will be defined as voltage sags.

Assume

Load A	$= Z_{LOAD}\_A$
Load B	$= Z_{LOAD}\_B$
Feeder 1 Reactance	$= x_1$
Feeder 2 Reactance	$=x_2$
Current from supply source	$= I$
Current in feeder 1	$= I_1$
Current in feeder 2	$= I_2$

Thus $I=I_1+I_2$

In normal condition (without fault in system)

$$I=\frac{V_2}{x_2+Z_{LOAD\_B}}+\frac{V_2}{x_1+Z_{LOAD\_A}}$$

When a fault happened (see Figure 7) in feeder 1, because of short circuit, a high current flow through feeder 1 as well as source current I.In the course of this time, voltage in feeder 2 reduced due to increasing of voltage drop across source reactance x_s, this makes sag happened.

$$I=\frac{V_2}{x_2+Z_{LOAD\_}B}+\frac{V_2}{x_1} \text{ (when fault happened)}$$

Hence,

$$V_2=V_{s.}-I\,x_s$$

And V_2 decreased from nominal value (V_2 become as voltage sag)

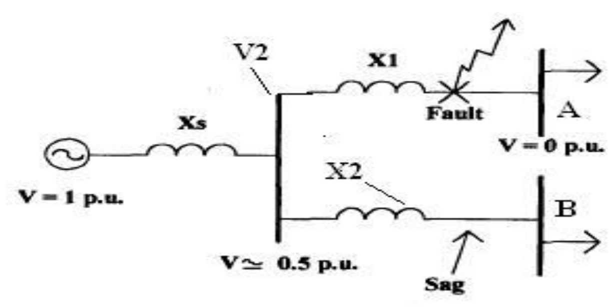

Fig. 1: Calculation of Voltage Sag.

VI. MATHEMATICAL MODEL FOR VOLTAGE INJECTION BY DVR SYSTEM

Consider the schematic diagram shown in Figure2.

$$Z_{th}=R_{th}+jX_{th}$$

$$V_{DVR}+V_{th}=V_L+Z_{th}I_L$$

When dropped voltage occurred at V_L, DVR inject a series voltage V_{DVR} through the injection transformer so that the desired load voltage magnitude $V_L$can be sustained. Hence

$$V_{DVR} = V_L+Z_{th}I_L-V_{th}$$

$$I_L=\left[\frac{P_L+jQ_L}{V_L}\right]^*$$

When V_L is considered as a reference, therefore;

$$V_{DVR}\angle\alpha=V_L\angle0^\circ+Z_{th}I_L\angle(\beta-\theta)-V_{th}\angle\delta$$

Here α, β and δ are the angle of V_{DVR} , Z_{th} and V_{th} , respectively and θ is the load power factor angle with

$$\theta=\tan^{-1}\left(\frac{Q_L}{P_L}\right)$$

The power injection of the DVR can be written as

$$S_{DVR}=V_{DVR}I_L$$

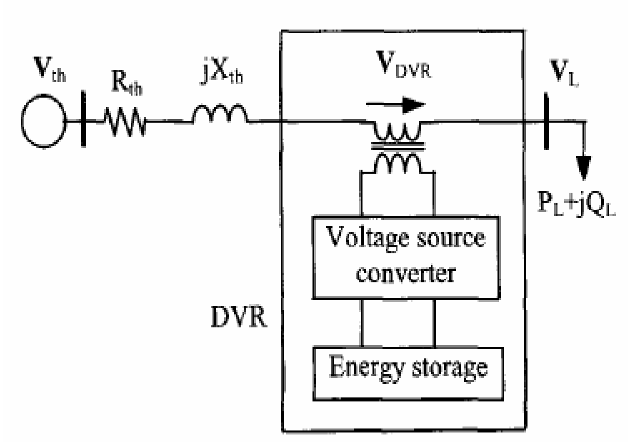

Fig 2: Calculation for DVR Voltage Injection

A. Power Circuit

Power circuit unit of DVR consists of DC Link or energy storage unit, DC/AC inverter, LC filter, injection transformer and system protection. Whereas the control unit of DVR consists of sag or swells detection, reference signal generation, and voltage injection strategies, the last one is generating of gating signal.

B. Inverter

The Inverter is a static circuit. In general, the function of the inverter is to convert DC power to AC power in other word, inverters transfer power from a DC source to AC load. There are two types of an inverter which are voltage source inverter and current source inverter. This project used VSI type of inverter. The difference between these two types is DC voltages are taken as a source for VSI while DC current as a source for CSI.

The switching component for the inverter to operate can be a thyristor, GTO, IGBT or any other power transistor. IGBT was selected in this project. The advantage of IGBT is low power loss and fast switching. In order to trigger the inverter, the gating signal comes from PWM is injected to the IGBT.

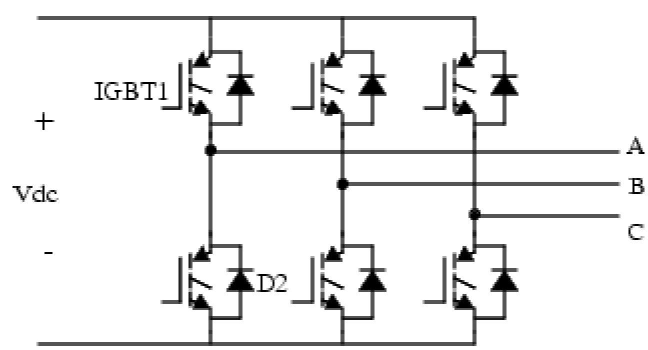

Fig 3: IGBT layout

C. Control Unit

The Control unit of DVR consists of sags or swell detection, reference signal generation and voltage injection strategies. This unit is the most important part in DVR system. It is the first to be operated to detect the voltage sag. Then, it will conduct the power unit to compensate for the voltage sag that occurred in the power system. If this unit is not operating properly, then the power unit cannot compensate the voltage sag, and the primary purpose DVR installation in the power system can be viewed as useless or not worth.

The sequence of the operation of a control unit is starting with sag and swell detection. When the sag occurred in the system installed with DVR, it will detect the sag. Then, the actual signal (sag) and reference signal will convert into dq0 form. After relating both of the signals, the error signal in dq0 form will produce. This signal will change back into VABC form. Because of inverter need pulse signal to operate, the VABC signal in sinusoidal form will convert into pulse signal via PWM control. This pulse will send to the inverter which is in the power unit. Thus, power unit will settle the rest of the operation.

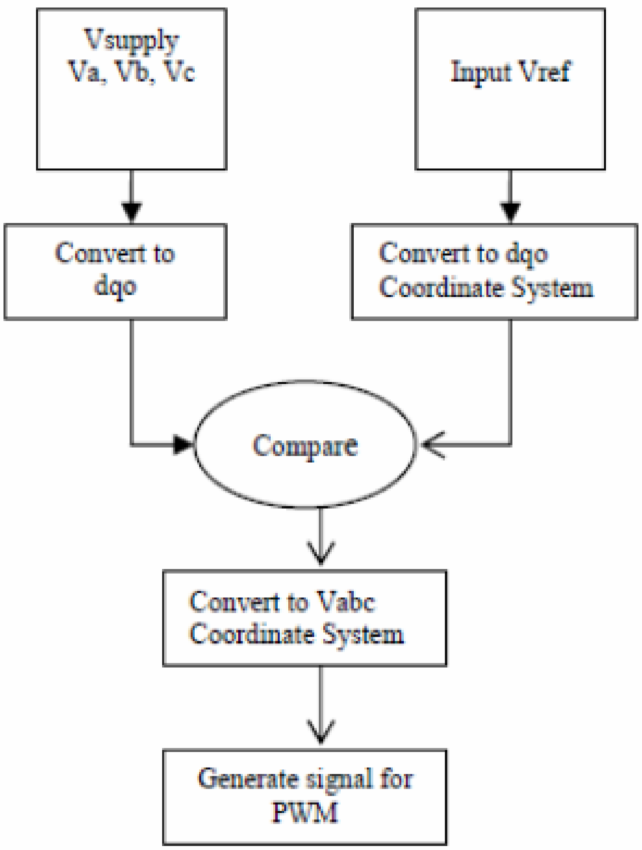

Fig. 4: Power Unit

VII. TECHNICAL ISSUE OF USING DVR

To improve the power quality traditional compensation methods such as passive filters, synchronous capacitors, phase advances were employed. However, traditional controllers include many disadvantages such as fixed compensation, bulkiness, electromagnetic interference and possible resonance. These disadvantages urged power system and power electronic engineers to develop adjustable and dynamic solutions using custom power devices.

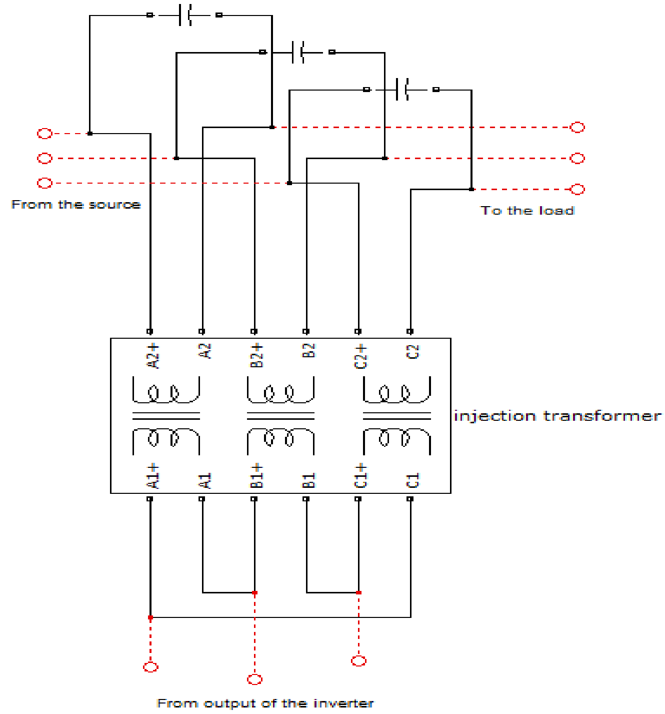

Fig.5: Injection Transformer

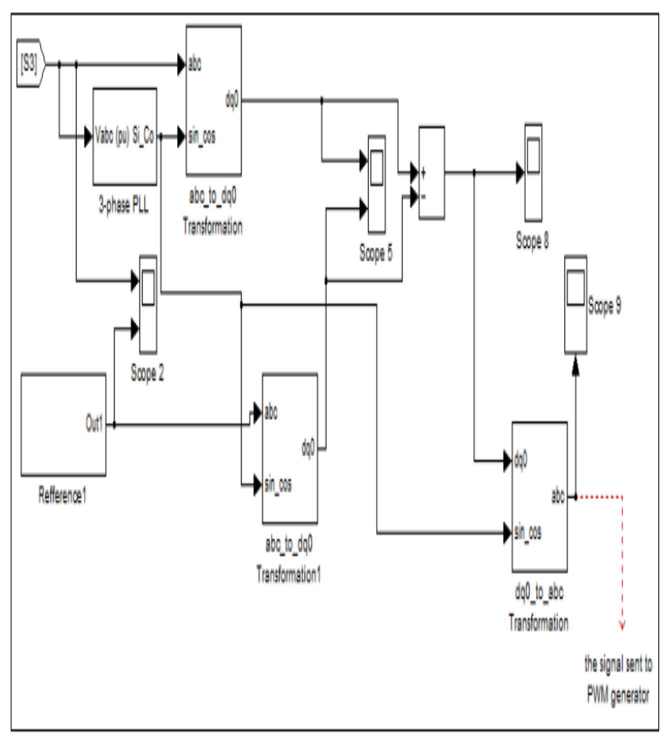

Fig.6: Sag Detector Circuit, Dq0 to ABC and ABC to Dq0 Circuit

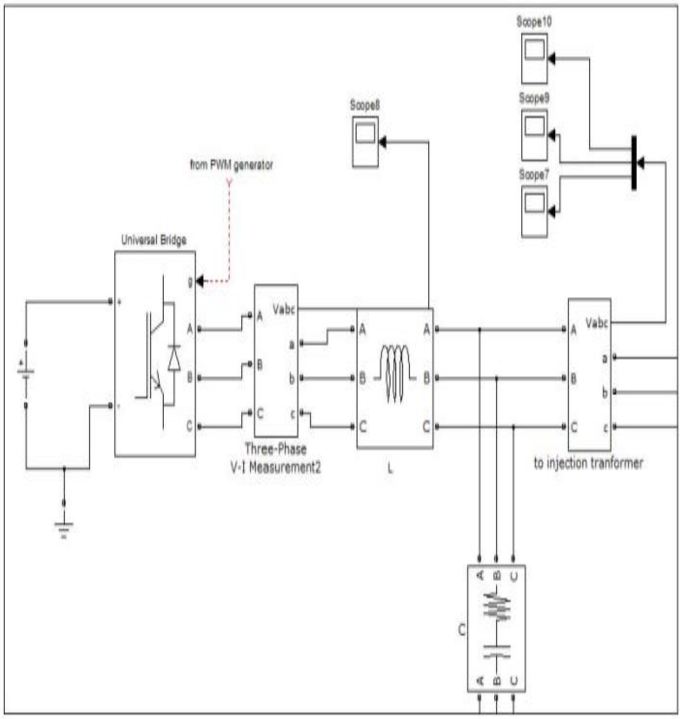

Fig 7: Inverter Circuit and Filter

A. Proposed System

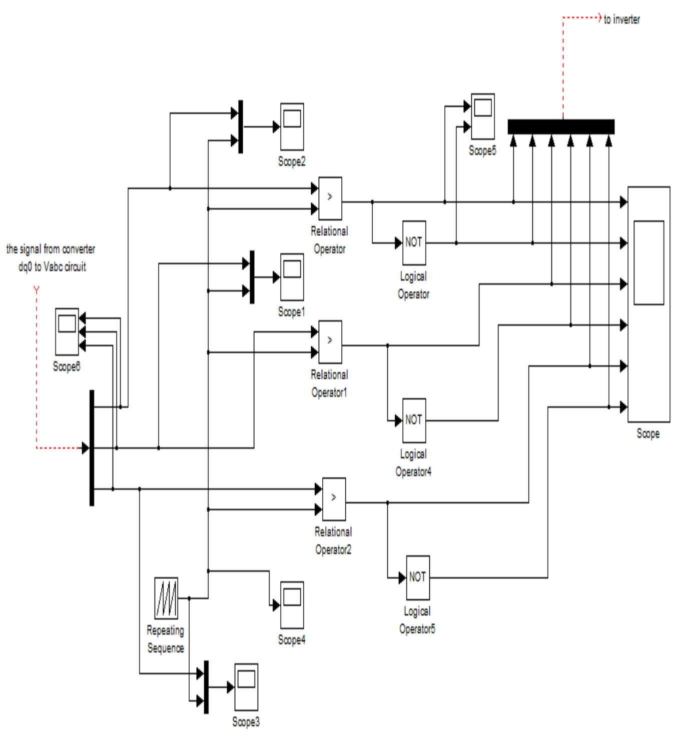

Fig. 8: SPWM

The circuit of the PWM generator was connected. The input of this circuit was an error signal in ABC form. The waveform of the input to this circuit was compared with the repeating sequence by a relational operator. Shows the configuration of repeating sequence in the circuit. Thus, the switching frequency will become 20 KHz.

VIII. SIMULATION

A. Simulation without DVR System

The simulation was tested on the distribution system which consists of two feeder and balance loads. In order to investigate the sags event, three lines to the ground fault was generated at feeder A. Then, automatically voltage sags will occur in feeder B. Thus, we can investigate the effect of using DVR and how DVR systems mitigate the sag. All of the process was done by using Matlab Simulink.

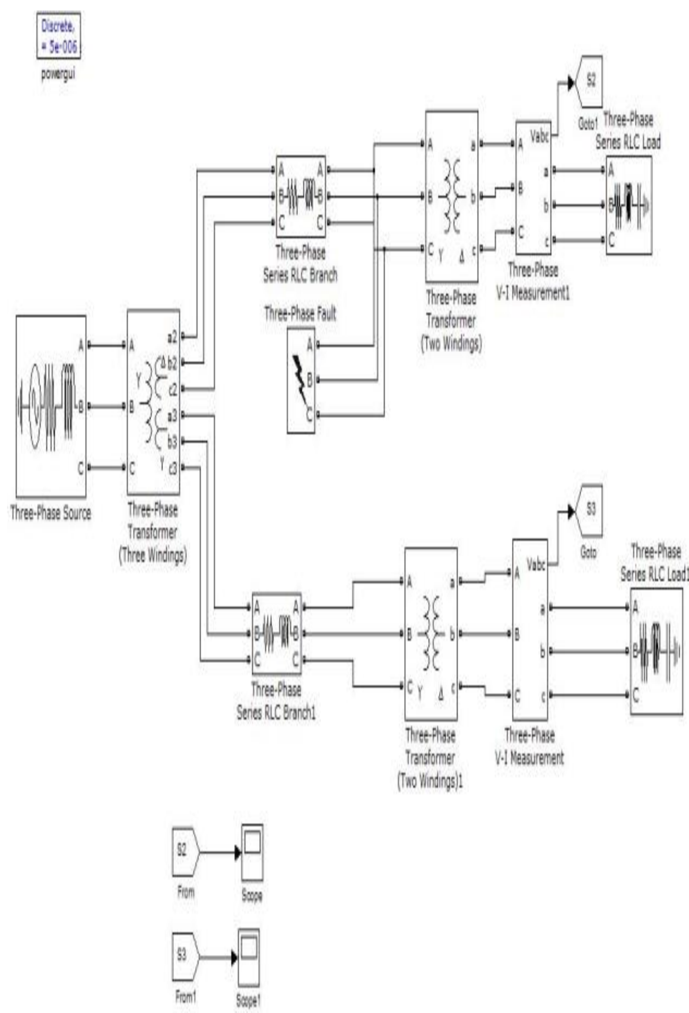

Fig. 9: Simulation without DVR System.

Shows the main circuit of distribution network without installation of DVR systems. The load connected to the system is balanced loads. The three phase fault generator was placed at feeder A. The run time for the whole system is 0.14 seconds where sags occur in feeder B during 0.04 second to 0.1 second. The fault generator was set to the three phase to the ground by check all three parameters and the transition times was set to (2/50) to (5/50) in order to produce sag for 0.06 seconds.

B. Simulation with Installation of DVR System

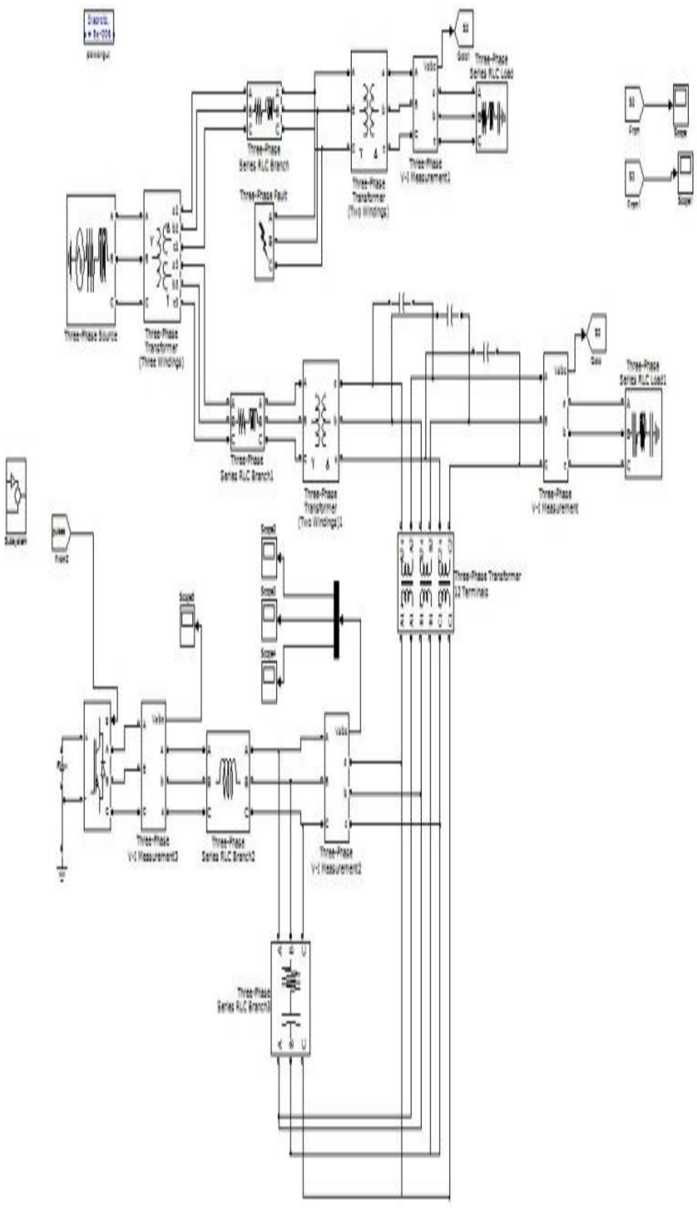

Fig. 10: DVR System Connected to the Power System.

IX. RESULTS AND DISCUSSION

The result of the simulation without installation of the DVR system from Scope 1. When the fault applied at feeder A, the voltage sags occurred in feeder B. The result obtained viewed from Scope 1 was as expected. Voltage sags occurred between 0.04s till 0.1s. During that time, the voltage dropped 5% from adnominal value. Therefore, the event occurred during the interval of time can be considered as voltage sag because the period of the voltage sag is between 0.5 cycles.

Until 1minute. From this result, it means the next simulation of distribution network installed with DVR system can proceed by using the same value and configuration of the fault occurred in the simulation.

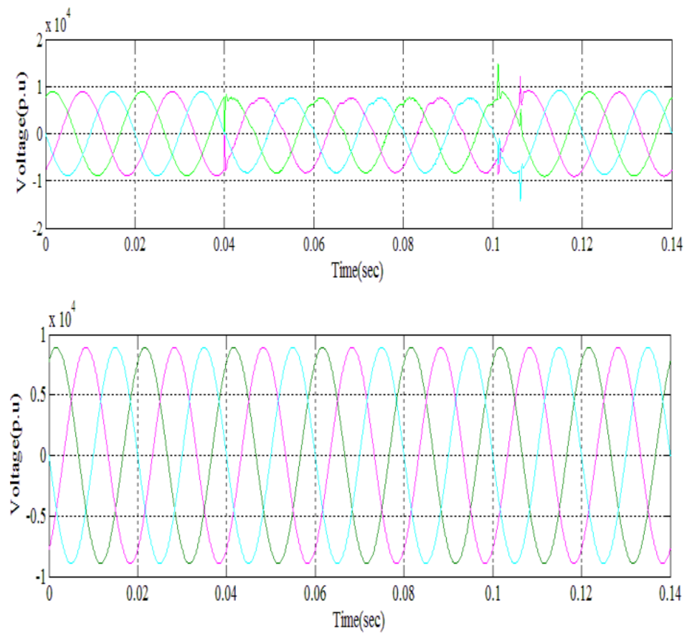

Fig. 11: Actual signal (sag) and reference signal

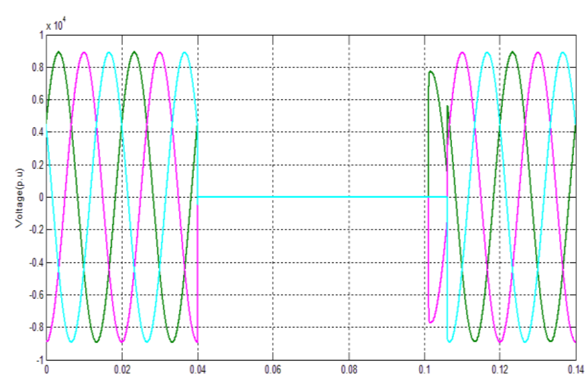

Fig 12: Voltage output at feeder A without DVR.

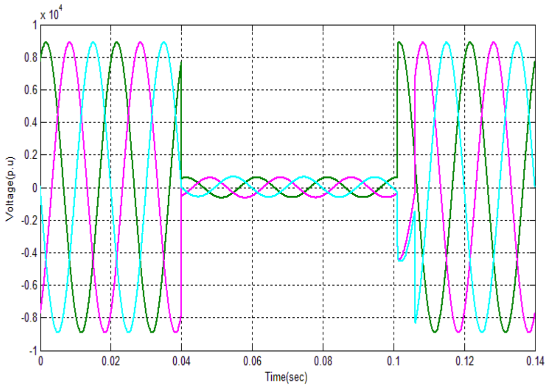

Fig 13: Voltage output at feeder B without DVR.

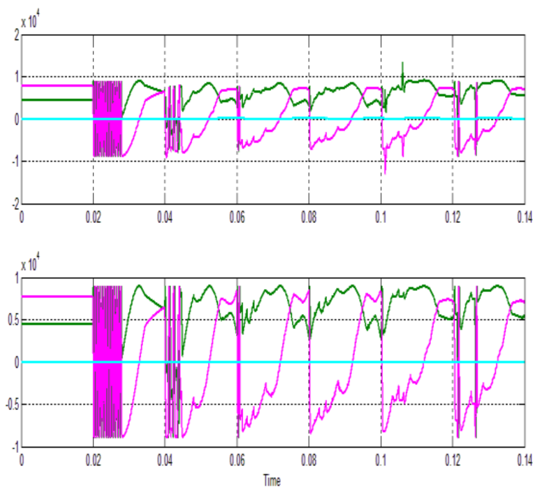

Fig 14: Actual Signal (sag) and Reference Signal Convert into Dq0 form Respectively.

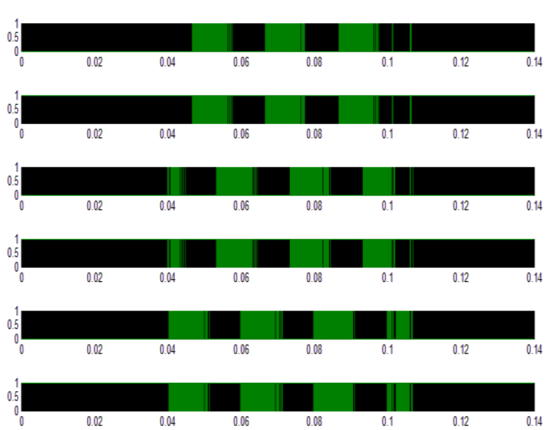

Fig. 15

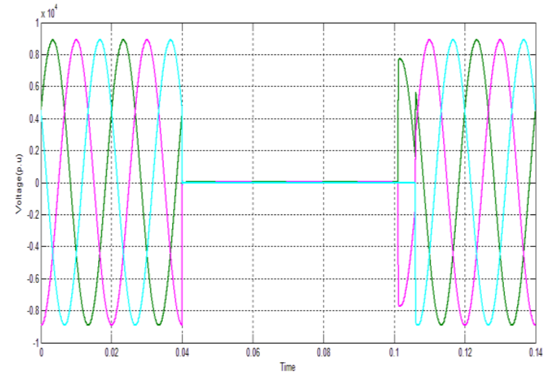

Fig 16: Output From Sinusoidal Pulse With Modulation (SPWM).

The final result of compensation DVR to the power system. It shows that the custom power devices successfully compensate the voltage sag. 85% of the voltage during the 0.04s to 0.1s back to the nominal value. However, the harmonic problems cannot be solved even though the line side filtering scheme was used. The main factor that distributed to the appearance of the harmonic is due to usage of converter or inverter, pulse width modulation, and transformer.

The results of the simulation double lines to ground are shown. As expected, DVR systems have no problems to handle voltage sag problems, but the appearance of harmonic and distortion in the system still cannot be avoided.

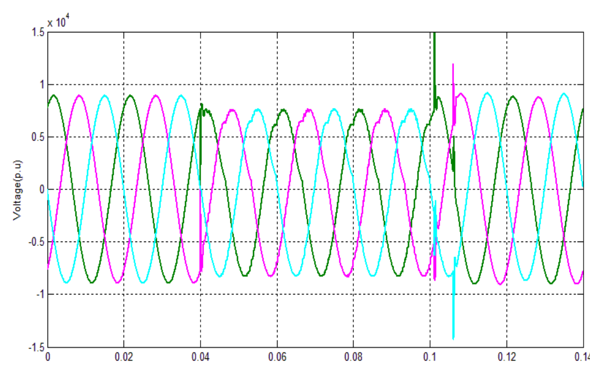

Fig 17: Output Voltage of Feeder B after Compensation.

X. CONCLUSION

Based on this project, one of the methods to mitigate the voltage sag is by using dynamic voltage restorer system. In order to investigate whether the DVR is able to deal with this problem, Matlab Simulink was selected in order to simulate the system and mitigate the voltage sag. Based on the simulation that had been done, it can be proved that DVR is the dynamic fast response devices that able to overcome the devices. Even though the system cannot compensate 100 percent of voltage during sag, it is an acceptable because the output voltage after compensation still in a range of the nominal value. The simulation was implemented by using the distribution network where the effectiveness of the DVR system is better compared to the transmission network.Since DVR is the custom power devices, there were so various combinations of the main component that can be combined in order to get better results. For example, using GTO as a switching device, using SVPWM as the device for generating gating signal or maybe can use the other type of filter in order to eliminate the harmonics.

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