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MITIGATION OF VOLTAGE SAG BY USING SINGLE PHASE DYNAMIC VOLTAGE RESTORER

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Abstract — *Voltage sag disturbances are the most frequently occurring Power Quality problems in the distribution system. Dynamic Voltage Restorer is normally employed as a solution for mitigation of voltage sag. The proposed system has less number of switching devices and has good compensating capability in comparison with commonly used compensators. The Static Series Compensator (SSC), commercially known as Dynamic Voltage Restorer (DVR), is best suited to protect Sensitive loads against such incoming supply disturbances. This project presents the hardware implementation of single phase Dynamic voltage restorer in mitigating voltage sag and swell. A simple fault generated is created which intentionally creates four levels of Voltage disturbances .Single phase inverter based on MOSFET was designed and firing pulse to the device using micro controller based PWM generation. Energy storage device used in this work is Battery which acts as input to the inverter. DVR model compensates the voltage sag and swell with efficient and effective manner, because of its lower cost, smaller size, and fast dynamic response to the disturbance.*

Keywords- *Dynamic voltage restorer (DVR), Battery energy storage –MOSFET, sag, swell and harmonic voltages generater-microcontroller*

I. INTRODUCTION.

The power quality problems in industrial applications concern a wide range of disturbances such as voltage sag and swell. Preventing such phenomena is particularly important because of increasing heavy automation in almost all the industrial processes. The use of important electrical and electronic equipments, such as computers, programmable logic controllers, variable speed drives industrial motors etc, very often requires interruption free of power supplies with very high quality. The voltage sag as defined by IEEE standard 1159, IEEE recommended practice for monitoring electric power quality is: “a decrease in RMS voltage or current at the power frequency for durations from 0.5 cycles to 1 min, reported as the remaining voltage”. Typical values are between 0.1 and 0.9 per unit and typical fault clearing times range from three to thirty cycles depending on the fault current Power quality problems challenging the utility industry can be compensated and power is injected into the distribution system. Voltage deviations, commonly in the form of voltage sag and swell can cause severe process disruptions result in substantial production loss. Several recent surveys attribute that 92% of the disturbances in electrical power distribution systems are due to voltage sag and swell. These system- equipment interface devices are commonly known as custom power devices which DVR is a powerful one for short duration voltage compensation. The filter parameters are designed according to certain design aspects such as depth of the sag and swell mitigated and load voltage**.**

a. A Simple Sag Generator Using SSRs

Significant deviations from the nominal voltage are a problem for sensitive consumers in the grid system. Interruptions are generally considered to be the worst case with the load disconnected from the supply. Voltage sag are characterized by a reduction in voltage, but the load is still connected to the supply. Sag are in most cases considered less critical compared to interruptions, but they typically occur more frequently.

b. The System Research and Implementation of Dynamic Voltage Restorer

Sag are impossible to avoid because of the finite clearing time of the faults causing the voltage sag. The wide propagation of sag from the equipment can be made more tolerant of sag either via more intelligent control of the equipment or by storing more energy in equipment. Instead of modifying each component, for instance, a factory to be very tolerant to voltage sag, a better solution might be to install one Dynamic Voltage Restorer (DVR) to mitigate voltage sag. A DVR can eliminate severe sag and minimize the risk of load tripping at very deep sag.

c. Design and analysis of dynamic voltage restorer for deep voltage sag and harmonic compensation

Studies have shown that transmission faults, while relatively rare, can cause wide spread sag that may constitute major process interruptions for very long distances from the faulted point. The DVR can correct sag resulting from faults in either transmission or distribution system.

Power distribution system should ideally provide their customers an uninterrupted flow of energy with smooth sinusoidal voltage at the contracted magnitude and frequency. However, in practice power system especially the distribution system, have numerous non linear loads, which are significantly affect the quality of power supply. As a result, the purity of waveform of supply lost.

d. Effects of Voltage Sag, Swell and other disturbance on Electrical Equipment and their Economic Implications.

Voltage sag is defined as a sudden reduction in supply voltage to between 90% and 10% of the nominal value, followed by a recovery after a short interval. The standard duration of sag is between 10 milliseconds and 1minute.Voltage sag can cause loss in production in auto mated processes since voltage sag can trip a motor or cause its controller malfunction. Voltage swell is defined as sudden increase in supply between 110% and 180% of the nominal value of the duration of 10milliseconds to 1 minute. Switching off a large inductive load or energizing large capacitor bank is a typical system event that causes swell. To compensate the sag/swell in a system, appropriate devices need to be installed at suitable locations.

e. Sensitive load voltage compensation against voltage sag/swell and harmonics in the grid voltage and limit down stream fault currents using DVR

Power quality (PQ) is an issue which is now a days gaining significant interest to both electric utilities and end-users . Lack of PQ causes huge economical losses all over the world which makes it more important. Voltage quality is the most important part of PQ from the viewpoint of sensitive load. Voltage disturbances mainly include voltage sag, voltages well and voltage harmonics.
Different power-electronic based techniques can be used to mitigate PQ problems . They can be divided into two groups, series and shunt compensators. Series compensators are usually used for voltage quality improvement where shunt compensators are well suited for current quality improvement.

II. PRINCIPLE OF DVR.

Dynamic voltage restorer (DVR) protects the load from voltage disturbances. DVR maintains the load voltage at a predetermined level during any source voltage abnormal conditions such as voltage sags/swells or distortion.Under normal operating conditions, let the three phase voltage phasors Va1, Vb1and Vc1. During abnormal conditions, the phase voltage vectors may be altered toVa2, Vb2 and Vc2. DVR does not supply any real power in the steady state. This implies that the phase angle difference between DVR voltage phasor and current phasor must be 90° in the steady state.

How to Find the Injected voltage

Here I would like to mention that the maximum voltage we can get at primary side of injection transformer is 24V if we generate or apply 12VAC. Here we take1:10 transformer ratio so we can get 240 volt at secondary. injected voltage is 230– 200 =30 volt at secondary side. So at primary side required generated voltage is 3Volt Primary connection are in parallel so required voltage from battery is 3/2 equal to 1.5 Volt.

Pulse Width Modulation Calculation

PWM Frequency = 2 kHz

Oscillator Frequency = 8 MHz

PWM Resolution(max) = $\frac{\log(\frac{8\ MHz}{2\ KHz})}{\log 2}$

=11.96 bits > 10 bits

So 2 KHz frequency is valid frequency. In PIC next cycle is increment only when timer TMR2 is equal to the period register PR2. And TMR2 and PR2 both are 8 bits registers. And this registers are prescale by through software in 1:1, 1:4 and 1:16.

PWM period = $\frac{1}{2\ KHz}$ = 0.5 msec…………………(1)

$T_{0\ sc} = \frac{1}{8\ MHz}$ =0.125 µsec……………………………(2)

PWM period = [(PR2) + 1]*4*$T_{0\ sc}$*(TMR2 prescale value)……..(3)

If we take TMR2 = 4 ……………………………(4)

By putting value of equation 1,2,4 in equation 3 PR2 = 249 Which is equal to 8 bits so the TMR2 is valid.

How The PWM Cycle Is Generated

In thefigure 1 sine wave is shown. It is required wave which is want to produce.

Here 0 = X*sin 0°…………..(5)

1 = X*sin 9° ………………..(6)

2 = X*sin 18°………………..(7)

.

.

40 = X*sin360°

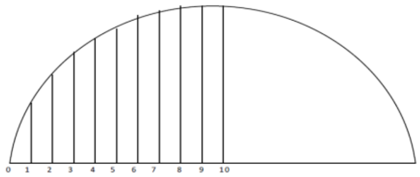

Figure. 1 Sine wave

Continue with the example (given in 4.4) our required voltage is 1.5 volt.

0 = 0 volt

1 = 0.23 V

When PWM duty cycle is full it generate 12 volt and 1024 count.To generate 0.23V. PWM duty cycle is 20.

So first 20 count PWM is generated or we can say that it is 1 and remaining time it is 0.

This logic is shown in figure 2

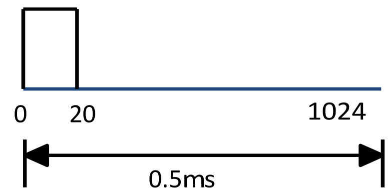

Figure 2. PWM cycle

III. BLOCK DIAGRAM OF DVR MODEL

As shown in fig.3 it is a single line diagram of DVR. Here we want to maintain 230 V at load side. Zero detector unit which is continuously measure the positive cycle and negative cycle at each 10ms. The other signal which is goes to controller and convert analog signal to digital signal. And generate the PWM signal according to the reference signal. Which is goes to OPTO-coupler MCT 2E to MOSFET. According the PWM MOSFET will trigger and generates the sine wave which is goes to series injection transformer through filter which purifies the sine wave.

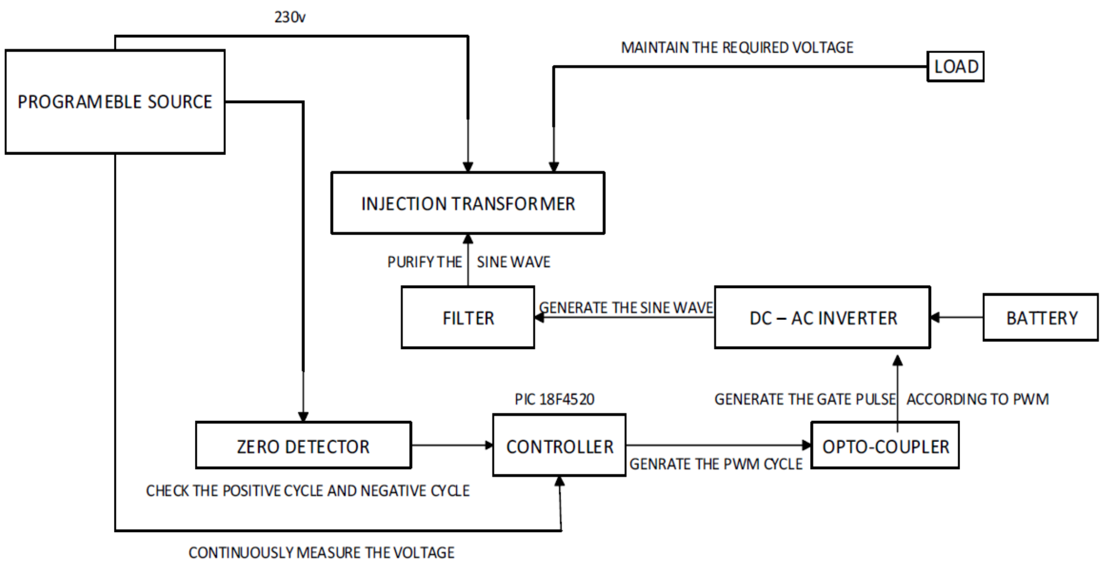

Figure-3 Single Line Diagram of Dynamic Voltage Restorer

IV. D-Q TRANSFORMATION.

The d-q Transformation is a transform that maps balanced three phase voltages to a synchronous rotating frame in order to extract a set of three-phase voltages with special frequency and to represent them as a DC component.

abc to dq0 trannsformation:

By using the following equation we can transform the three phase voltage into the dqo component.

$$\begin{bmatrix} v_d \\ v_q \end{bmatrix} = \frac{2}{3}\begin{bmatrix} sinwt & sin\left(wt-\frac{2\pi}{3}\right) & sin\left(wt+\frac{2\pi}{3}\right) \\ coswt & cos\left(wt-\frac{2\pi}{3}\right) & cos\left(wt+\frac{2\pi}{3}\right) \end{bmatrix}\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$

dqo to abc transformation:

By using the following equation we can transform the dq0 component into the three phase abc component.

$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \sin wt & \cos wt \\ \sin\left(wt-\frac{2\pi}{3}\right) & \cos\left(wt-\frac{2\pi}{3}\right) \\ \sin\left(wt+\frac{2\pi}{3}\right) & \cos\left(wt+\frac{2\pi}{3}\right) \end{bmatrix}\begin{bmatrix} v_d \\ v_q \end{bmatrix}$$

Where w is the d-q transformation frequency, and are synchronous rotating frame parameters, are abc parameters of coordinate system. If d-q Transformation frequency(w) is equal to frequency of the phase voltage(Wc), d-q synchronous rotating frame lock to abc synchronous rotating frame. Under this condition relation between balanced three phase voltages as given in the following equation and d-q synchronous rotating frame parameters have been given in the equation**.**

$$v_a = V_c\cos(w_c t + \theta_c)$$
$$v_b = V_c\cos\left(w_c t + \theta_c - \frac{2\pi}{3}\right)$$
$$v_c = V_c\cos\left(w_c t + \theta_c + \frac{2\pi}{3}\right)$$

Where Vc, Wc, c are amplitude , frequency, phase angle of the phase voltage.

V. SIMULATION OF FINAL DVR MODEL

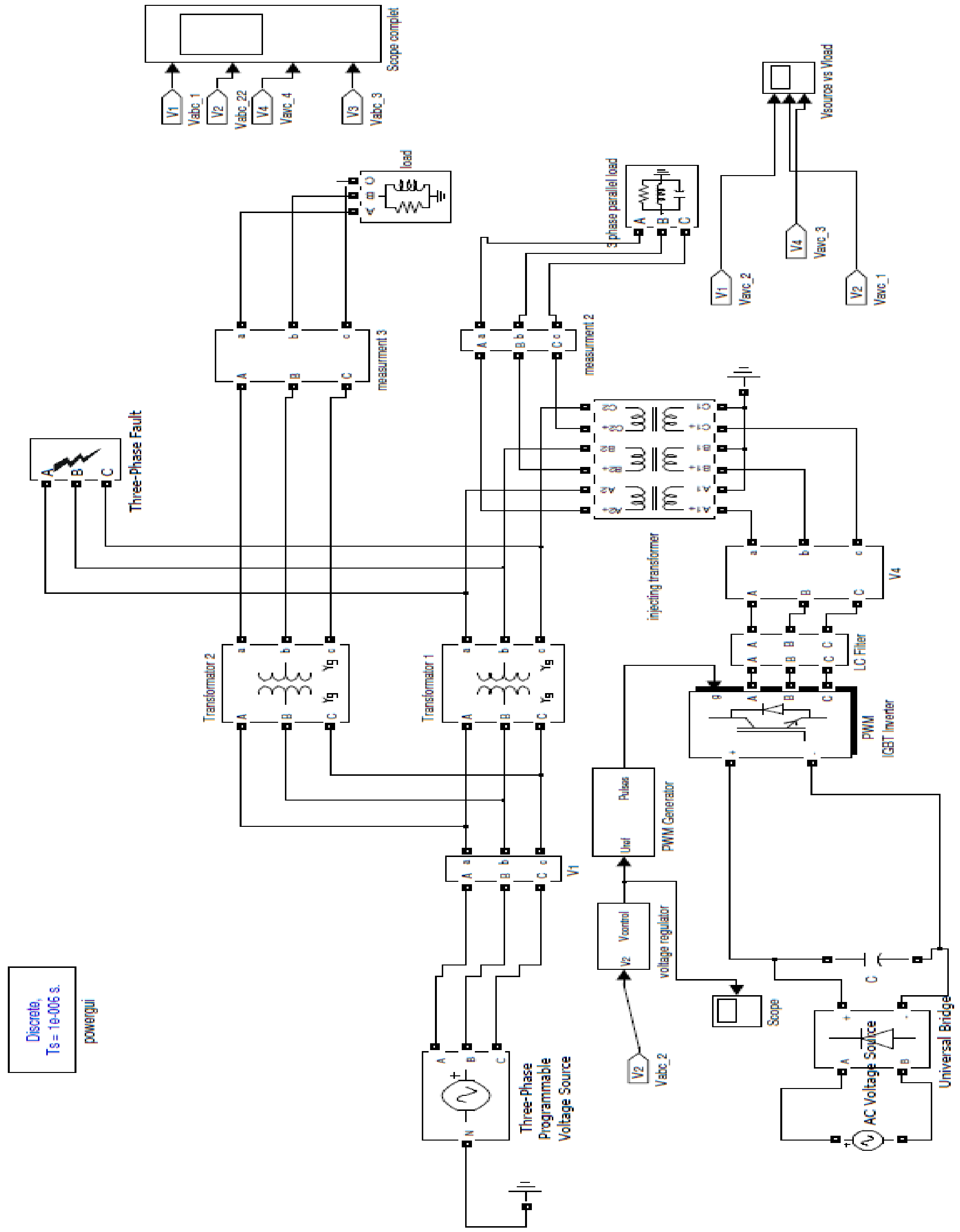

Figure 4. Simulation of DVR model

Simulation of voltage Regulator

For finding the Amplitude of voltage sag/swell Voltage regulator take the feedback from the load voltage for finding the amount of sag and compare with the source voltage and by using the D-Q theory this voltage is converted into the 2-phase and then error should be corrected by the controller and then the control voltage is generated which is given to the PWM generator which generate the appropriate gate pulse and the voltage correction action should be performed by the Inverter.

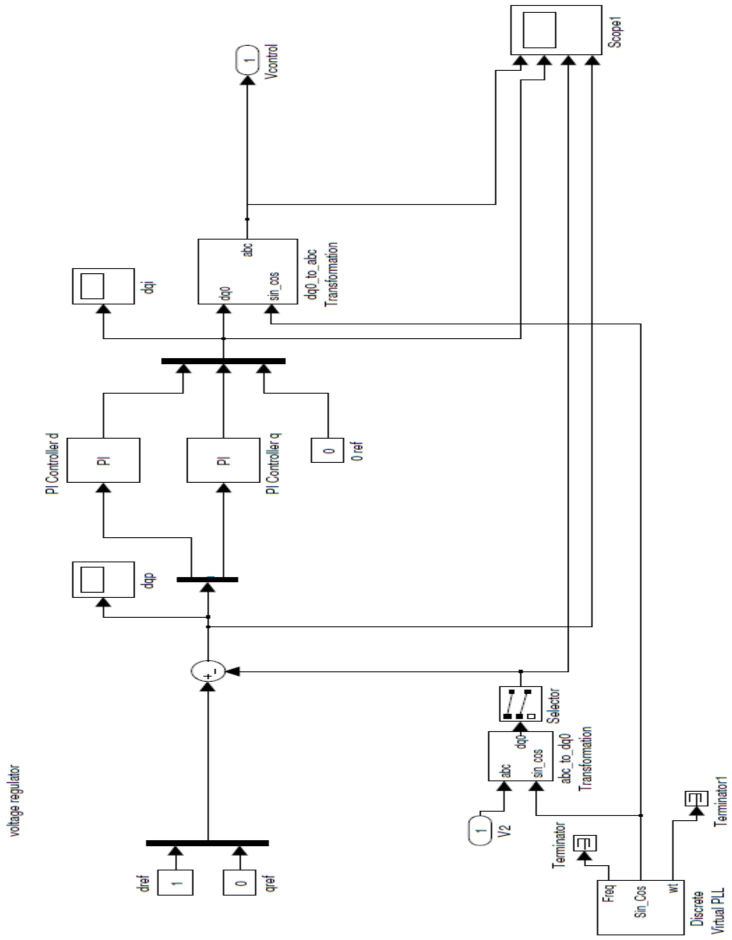

Figure 5. Simulation of voltage Regulator

Simulation Results of DVR model

As shown in Fig.6 the voltage sag is of the amplitude 0.8pu is introduced in the system at 0.02sec and the another sag is of the amplitude 0.6pu is introduced in the system at 0.04sec. Due to this sag in the system DVR comes in to action and it will start generating the compensating voltage in the system by the pulse received from the PWM generator. and compensate the load voltage as shown Fig 8. the compensating voltage Waveform is shown in the Fig 7..and DVR takes the voltage to the original amplitude of 1pu.

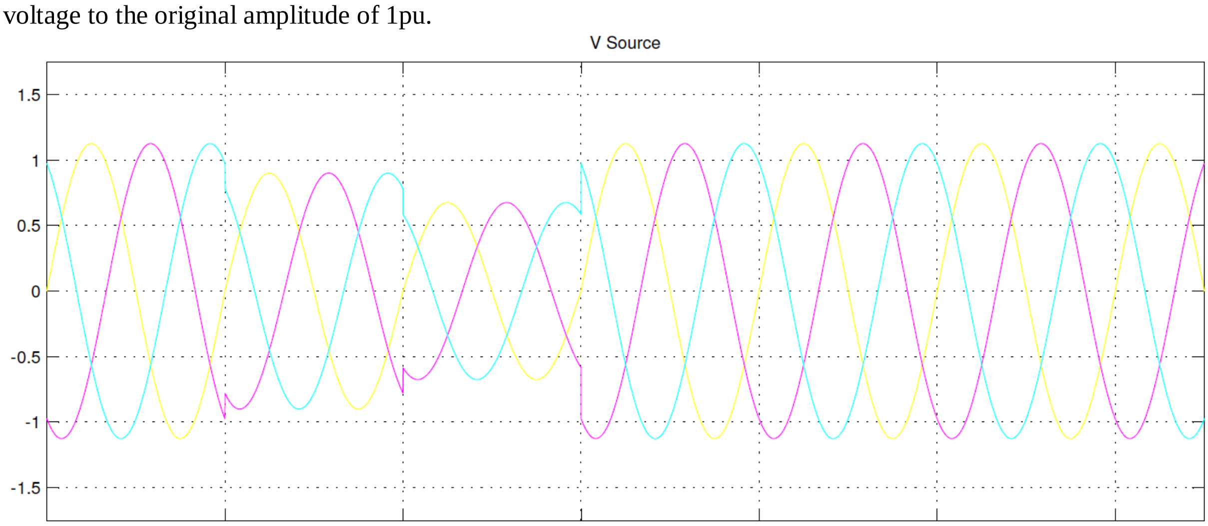

Figure 6. Source voltage Waveform

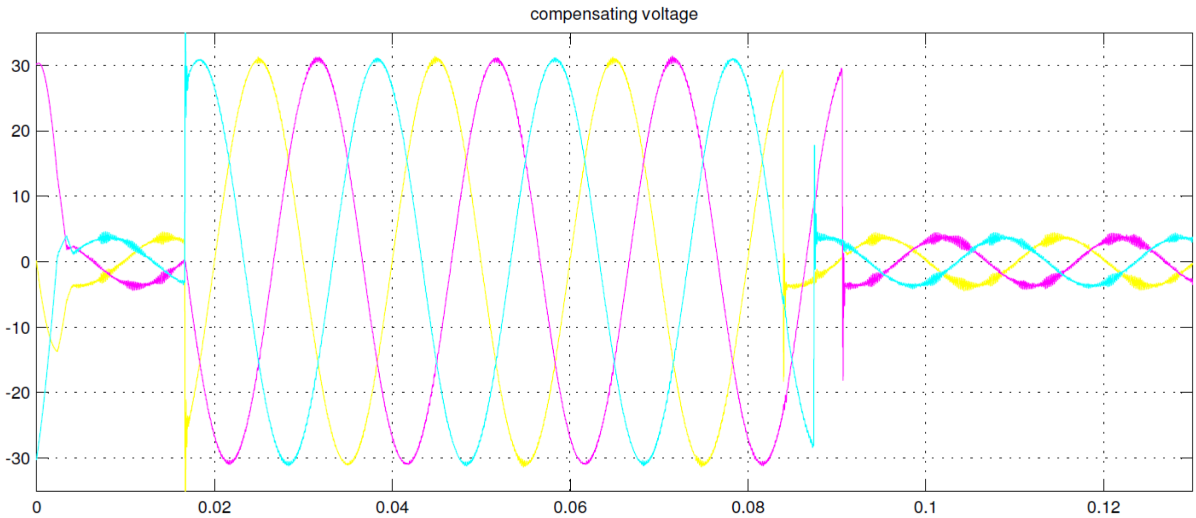

Figure 7. Compensating voltage Waveform

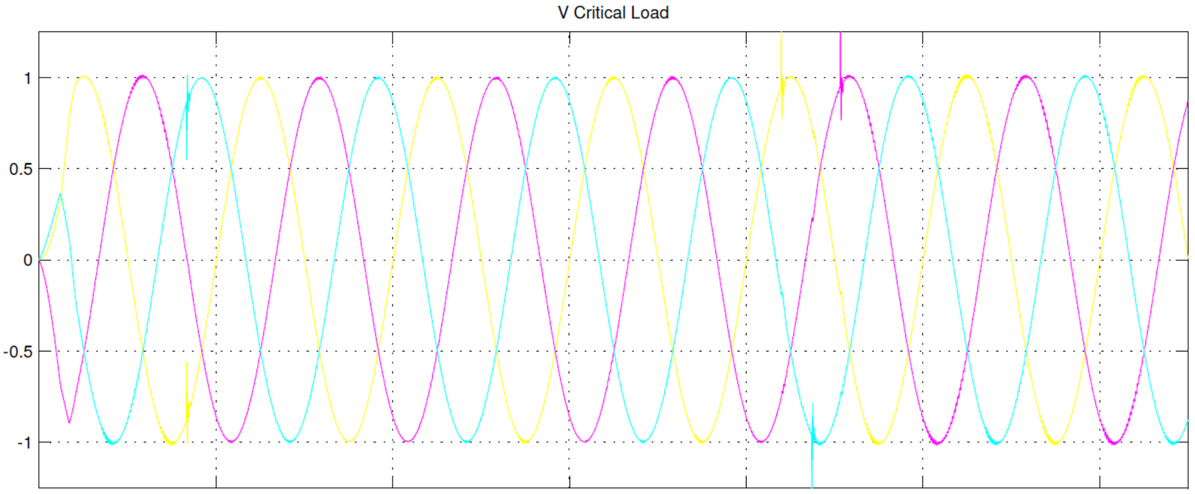

Figure 8. Ultimate load Waveform

Fig. 9 shows the voltage generated from the voltage controller which given to the PWM generator to generate the pulse required for the compensating the voltage sag.

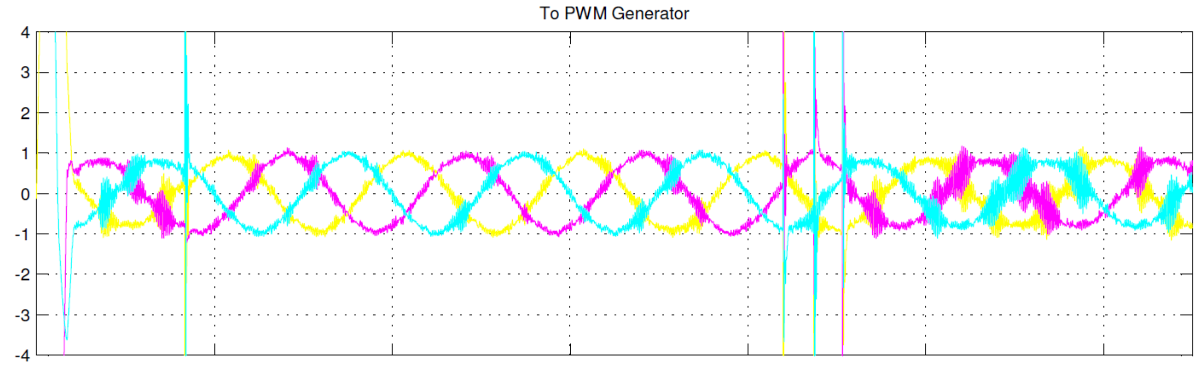

Figure 9. Voltage given to the PWM Generator

VI. CONCLUSION

In this project, the MATLAB Simulation of a DVR has been presented. The Simulation results showed clearly the performance of the DVR in mitigating voltage sag. The DVR handles the situation without any difficulties and injection or absorption the appropriate voltage component to correct rapidly any changes in the supply voltage thereby keeping the load voltage balanced and constant at the nominal value. In this study, the DVR has shown the ability to compensate for voltage sag; this has been proved through MATLAB simulation. The efficiency and effectiveness on voltage sag compensation showed by the DVR makes it an interesting power quality device compared to other custom power devices. It is planned to implementation of DSP based for the Dynamic Voltage Restorer in future work.

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