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MODELING AND SIMULATION OF SINGLE PHASE SENSITIVE LOAD TO VOLTAGE SAG COMPENSATION USING DYNAMIC VOLTAGE RESTORE

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Abstract: Recent year power quality is the most significant feature in the power system environment. Among all the power quality issues most commonly occurring disturbances, affecting the quality of power are voltage swells and sags. Convention power device, DVR (Dynamic Voltage Restorer) connected in series with a purpose to protect the loads from source side voltage disturbances. In this paper single phase Dynamic Voltage Restorer is adopted for single phase instead of using three phases Dynamic Voltage Restorer with sinusoidal pulse width modulation (SPWM) to compensate unbalanced sags. The proposed method allows flexibility in expenditure and simplicity in design. Simulation results are done using MATLAB/SIMULINK software and also illustrated to understand the performance of Dynamic Voltage Restorer under voltage sag fault condition.
Keyword: Power Quality, Dynamic Voltage Restorer (DVR), Sinusoidal Pulse Width Modulation

I. INTRODUCTION

With the fast technology advancements in control processes, electric utilities are experiencing more demanding requirements on the power quality from the huge industrial power consumers. The power quality issues in industrial applications concern a wide range of disturbances like voltage sags, voltage swells, flicker, interruptions, and harmonic distortion. Preventing such phenomena is mainly important since of the growing heavy automation in almost all the industrial processes. The use of urbane electronics and electrical equipments as computers, programmable logic controllers, variable speed drives and so forth, very often requires power supplies through very high quality because the failures due to such disturbances usually have a high impact on production costs [1]-[4]. IEEE standard (1159) the voltage sag as defined, IEEE suggested practice for monitoring electric power quality is: "a reduce in RMS current or voltage at the power frequency for durations from 0.5 cycles to 1 min, reported as the remaining voltage". Typical values are between values 0.1 and 0.9 per unit and typical range of fault clearing times from three to thirty cycles depending on the fault current magnitude and the type of over current detection and interruption [5,6]. Voltage deviations, commonly voltage sags can cause by severe process disruptions and result in large production loss. Several current surveys aspect that 92% of the disturbances in electrical power distribution systems are due to voltage sags [7]. Commonly these type of system-equipment interface devices are recognized as custom power devices [3,8], in which Dynamic Voltage Restorer is a powerful one for short-duration voltage compensation. Other than the D-STATCOM which connects to the load in parallel, where the DVR is connected in series with the sensitive load or distribution feeder and is able of injecting real and reactive power demanded by the load during voltage sag compensation. Though, a Dynamic Voltage Restorer cannot provide compensation during full power interruptions. In this paper, the simulation of Dynamic Voltage Restorer in MATLAB / SIMULINK environment is analyzed for voltage sag mitigation in a power system. The outputs are illustrated the effectiveness and efficiency of DVR in mitigating voltage sags in a voltage distribution system.

II. BASIC ARRANGEMENT OF DVR

The fundamental voltage control of series controller is termed as a series connected PWM regulator in, a static series regulator in and mostly the devices are termed DVR. If condition, the device only injects reactive power the device can be termed as series Var compensators. Captivating the same simplified model of load and supply, but now with a series controller inserted to support the load. If a 0.5 pu voltage sag can be restored a series device by a 0.5 pu DVR and only 0.5pu of the energy absorbed by the load has to be supplied by the DVR. The continues supply to be connected and no resynchronization is required as it is the case with a shunt connected converter [9].

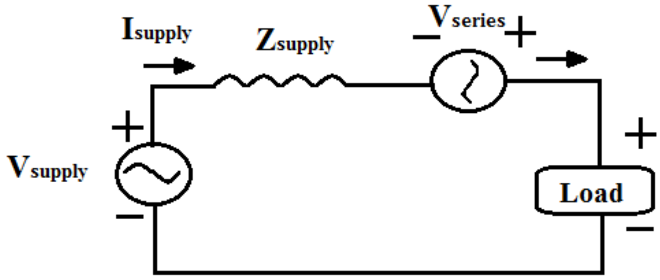

Figure 1 Circuit diagram of a system with series controller

The series voltage controller is connected in series with the secluded load as illustrate in figure 1. Frequently the connection is prepared via a transformer, but configurations with direct connection via power electronics too exist. The ensuing voltage at the load bus bar equals the sum of the injected voltage and the grid voltage from the DVR. The converter generates the reactive power desired while the active power is in use from the energy storage. The energy storage can be unusual depending on the needs of compensating. The dynamic voltage restorer frequently has limitations on the depth and duration of the voltage sag that it can compensate. Consequently right sized has to be used in order to get the desired protection. Available options for energy storage through voltage sags are conventional capacitors for very short durations but deep, batteries for longer but less severe magnitude drops and super capacitors in between. There are also other configurations and combinations possible.

III. BASIC PRINCIPLE OF DVR OPERATION

A Dynamic Voltage Restorer is a solid state power electronics switching device consisting of either IGBT or GTO, a capacitor bank like an energy storage device and injection transformers. It is connected in series between a distribution system and a load that illustrate in figure 2. The basic principle of the DVR is to inject a controlled voltage generated by a forced commuted converter in a series to the bus voltage by means of an injecting transformer. A inverter DC to AC regulates this voltage by SPWM (sinusoidal pulse width modulation) technique. All throughout normal operating condition, the Dynamic Voltage Restorer injects only a small voltage to compensate for the voltage drop of the injection transformer and device losses. Yet, if voltage sag occurs in the distribution system, the Dynamic Voltage Restorer control system synthesizes and calculates the voltage required preserving output voltage to the load by injecting a controlled voltage with a certain magnitude and phase angle into the distribution system to the critical load [7].

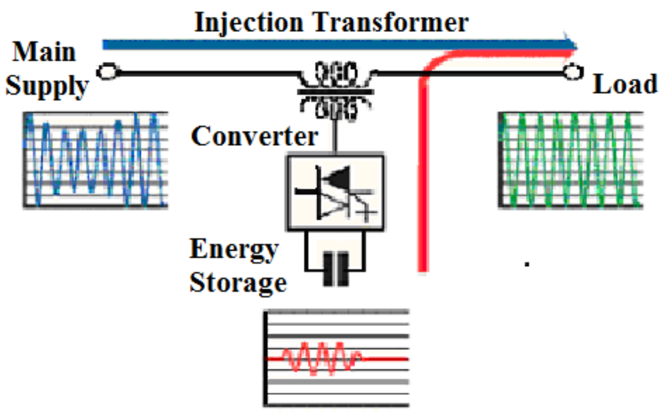

Figure 2 Basic Principle of DVR

The main components of DVR are explain below -

Energy Storage unit - The required energy by the voltage source inverter is supplied by the auxiliary supply (Energy source) which will be transformed to alternating quantity and then it is fed to injection transformer. Batteries are usually used for this purpose and sag duration which can be compensated is determined by the capacity of the battery.

Voltage Source Inverter (VSI) – Resultant Voltage which is changeable in nature is obtained by this unit. A voltage source inverter is a power electronic device consisting of a switching device such as battery. Sinusoidal voltage at any necessary magnitude, frequency and phase is generated by voltage source inverter. The voltage control is prepared by waveform modulation of output voltage within the inverter.

Injection Transformer– Series injection transformer consists of single phase transformers which are utilized to insert missing voltage to the system. The accurate choice of electrical parameters of series injection transformer ensures the maximum reliability and effectiveness. In this paper present single phase transformers instead of single three phase transformer are connected and transformer is connected in series with phase of the distribution level. The series injection transformer in addition ensures the isolation between DVR system and line.

Filter unit – The distortion in the waveform related with harmonic at the inverter output is caused due to non-linear characteristics of semiconducting devices. To decrease the effect of this issue and provide quality supply of energy, filter unit is used.

The inverter side filter is nearer to low voltage Side and harmonic source and thus it avoids the harmonic currents from penetrate into the injection transformer. This can cause drop in the voltage and phase shifting in basic component of inverter output. Higher rating of transformer is required because line side is nearer to high voltage side. Filter capacitor will basis improved inverter ratings. The better filter capacitor provides better harmonic attenuation but the rating of the inverter is connected with the capacitor value.

Auxiliary and controller circuits - By-pass switches, protection and breakers relays are some auxiliaries to the DVR block. In addition to all these, pulse width modulation controller is necessary to generate pulses to the inverter in accordance to the irregularity in load voltage.

IV. SIMULATION AND RESULT DISCUSSION

Single Phase Dynamic Voltage Restorer (DVR):

As illustrate in figure 3 it is a single line diagram of DVR. In this system, we want to maintain 230 V at load side. In zero detector units which is constantly measure the positive cycle and negative cycle at each 10ms. The other signal which is goes to controller and controller convert analog signal to digital signal. Consequently generate the pulse width modulation signal according to the reference signal. Which is goes to opto-coupler MCT 2E to MOSFET. According the pulse width modulation MOSFET will activate and generates the sine wave which is go to series injection transformer through filter which purifies the sine wave. Series injection transformer injects only the essential voltage so voltage of the sensitive voltage remains constant.

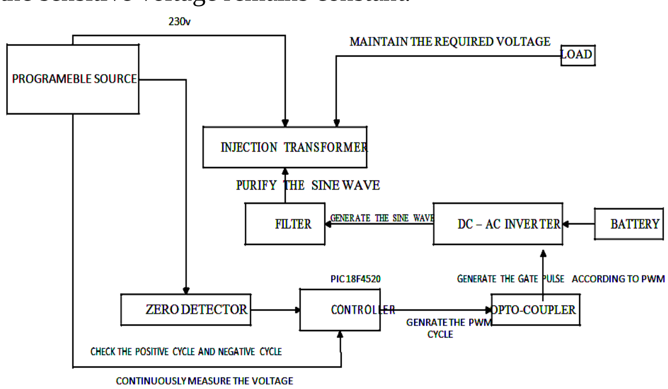

Figure 3 Single line diagram of Dynamic voltage restorer

Zero Detector:

Basically a zero-crossing is a point where the sign of a mathematical function changes, a crossing represented of the axis (zero value) in the graph of the function. It is a normally used term in mathematics, electronics, sound, and image processing.

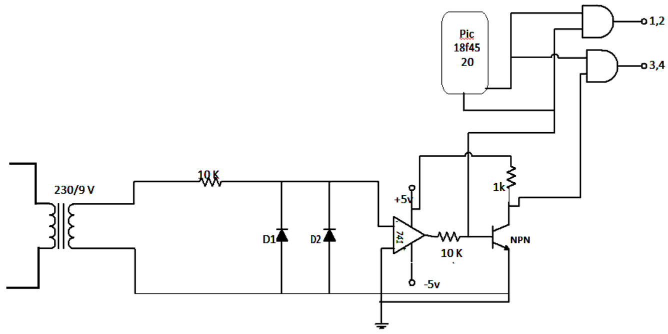

Figure 4 Zero Detector

Illustrate in figure when positive cycle comes diode D1 will be forward bias and op-amp generates +5 volt and it means that positive cycle is detected. As well as when negative cycle comes in diode D2 will be forward bias so Op-Amp generates -5V it means that negative cycle is generated. At this time signals are goes to AND gate to generate pulse width modulation signal according to that. Illustrate in fig NPN transistor will invert signal. Consequently when positive cycle occurs at that time 3, 4 have low signal and when negative occurs at that time 1, 2 have low signal and 3, 4 have high signal.

Simulation of Zero Detector:

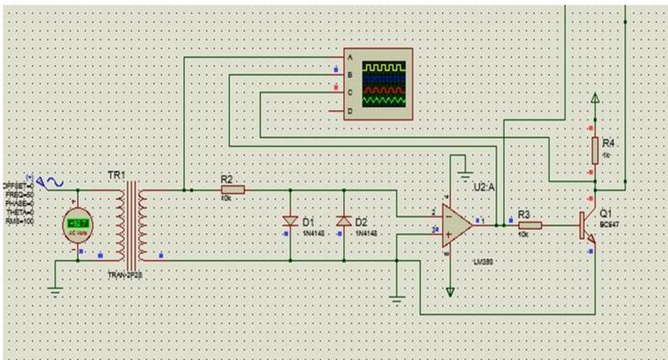

Figure 5 Simulation of Zero Detector

Illustrate in figure 5 it is a Zero Detector set up in proteus 8 software. If consider the positive cycle comes diode d1 is conduct and op-amp generates negative voltage and if consider the negative cycle comes op-amp generates positive voltage.

Result of Zero Detector:

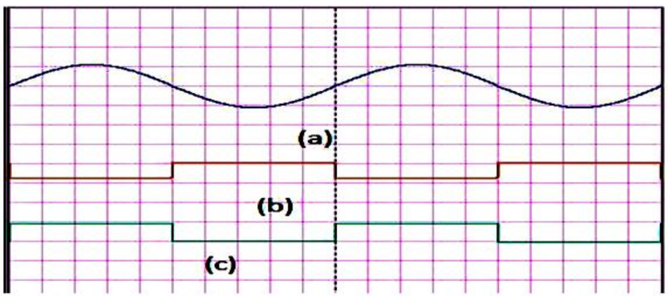

Figure 6 simulation result of the Zero Detector

(a) Output of the transformer (b)Output of the OP-AMP (c) Output of the transistor

In this above figure blue wave is the sinusoidal wave which is out from the transformer, red wave is the output of the op-amp and green wave is shows the NPN transistors value according the sine wave. It means that if negative cycle comes Op-amp sends the signal to controller and in positive cycle NPN transistor gives the signal to controller.

Simulation of AND gate and opto-coupler:

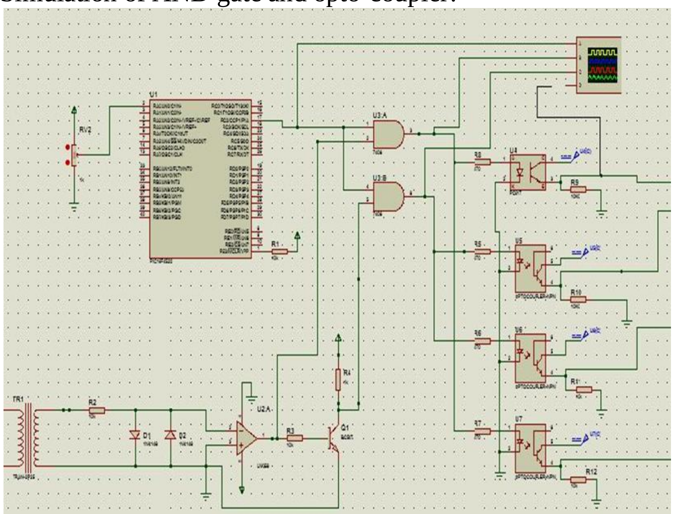

Figure 7 Simulation of AND gate and Opto-coupler

At this time present fixed pulse width modulation simulation. In the figure illustrated that controller continuously generates the PWM pulses and also Zero detector continuously measure the positive and negative cycle. If positive cycle comes below AND gate U 3 B and gate gets both input is high so S1 and S4 will turn on. Correspondingly for negative cycle comes U3A has both input is high so MOSFET S2 and S3 will turn on.

Result of AND gate and opto-coupler:

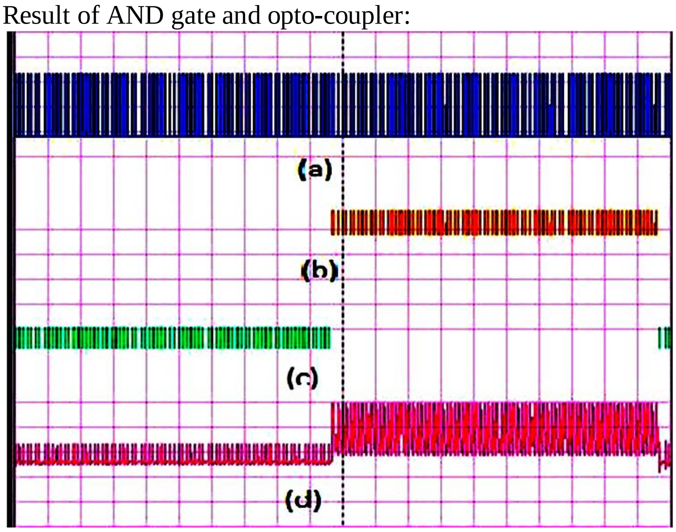

Figure 8 Result of opto-coupler and Controller
(a)Controller PWM (b) AND gate U3 A output
(c) AND gate U3 B output (d) Gate Pulse for the MOSFET S2 and S4

In figure 8 illustrated the controller PWM is continuously generated other than gate pulse is applied according to

positive cycle and negative cycle. Figure 8 (b) and (c) illustrate the output of the gate.
Simulation and Result of Gate Pulse:

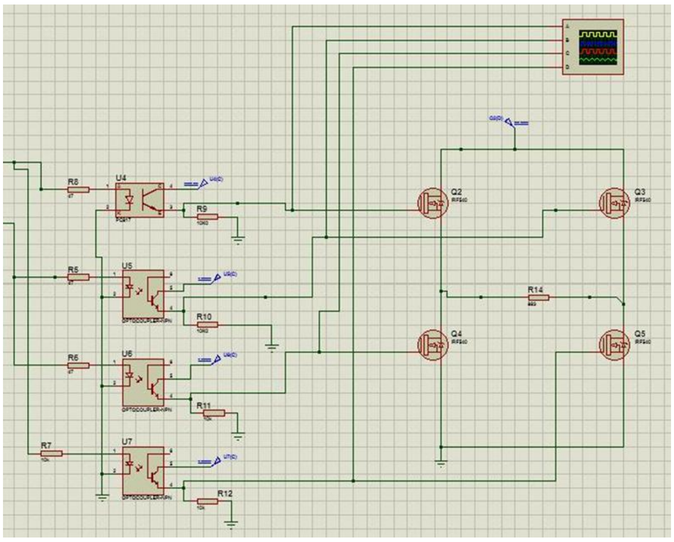

Figure 9 Simulation of Gate pulse measurement in oscilloscope

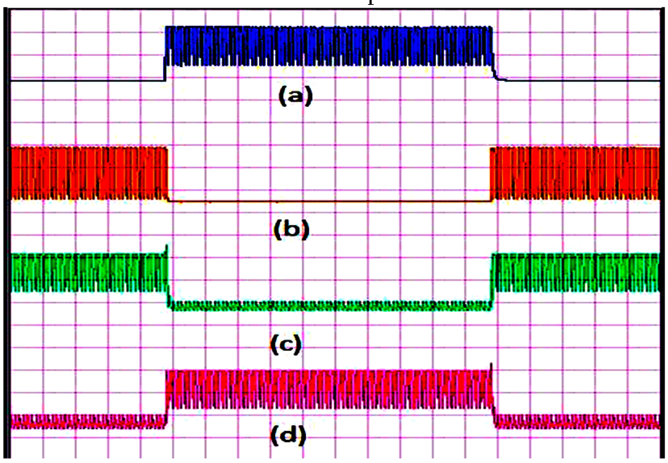

Figure 10 Gate Pulse of Oscilloscope
(a)Q2 MOSFET gate pulse (b)Q3 MOSFET gate pulse(c)Q4 MOSFET gate pulse (d)Q5 MOSFET gate pulse

V. CONCLUSION

In this paper, a fast and effective cost, Dynamic Voltage Restorer (DVR) is anticipated for mitigating the problem of voltage sag. Here an inverter using a Sinusoidal Pulse Width Modulation (SPWM) scheme. In this paper, the DVR has illustrate the ability to compensate for voltage sags at single phase sensitive load, this can be proved through hardware implementation. The effectiveness and the efficiency in voltage sags compensation showed by the DVR makes it an appealing quality device compared to other custom power devices. The DVR efficiency can be investigated and established for active loads.

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