International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 2 Issue 9, September-2013, pp: (1-5), Available online at: www.erpublications.com

Mitigation of voltage sag by using AC-AC PWM converter

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Abstract: The objective of this research is to develop a novel voltage control scheme that can compensate for voltage sag and swell conditions in three-phase power systems. In order to mitigate power interruptions, this research proposes a scheme called "Voltage Sag Supporter utilizing PWM (Pulse Width Modulation) Switched Autotransformer". The proposed scheme is able to quickly recognize the voltage sag or swell condition and it can correct the voltage by either boosting the input voltage during voltage sag events or reducing the input voltage during voltage swell events. Among existing methods, the scheme based on the inverter system such as dynamic voltage restorers (DVR) require an inverter, a rectifier, and a step-up down transformer, which makes the system expensive. AC converters can be used for the purpose of the research. However, they consist of two solid-state switches per one phase and include energy storage devices such as reactors and capacitors. . A design is presented for 440v, 50 hz, system.

Keywords: Power Quality, Voltage Sag, PWM AC-AC Converter.

INTRODUCTION

1. Voltage Sag: A voltage sag is a momentary decrease of the voltage RMS value with the duration of half a cycle up to many cycles. Voltage sags are given a great deal of attention because of the wide usage of voltage-sensitive loads such as adjustable speed drives (ASD), process control equipment, and computers. In case of sensitive loads, even a shallow voltage dip can cause malfunctions and a stoppage of operation, which results in the loss of production.

2. Causes of Voltage Sags: Faults in systems and starting large motors create voltage sags. In case of starting large motors, the voltage sags are usually shallow and last a relatively long time. Faults in the distribution or transmission line can be classified as single-line-to-ground (SLG), and line-to-line (L-L) faults. SLG faults often result from severe weather conditions such as lightning, ice, and wind. Animal or human activity such as construction or accidents also causes SLG faults. Lightning may cause flashover across conductor insulators and is the major source of SLG faults. Figure 2.1 shows a typical shape of voltage sag due to a short SLG fault. Many statistical power quality studies have been performed in various locations and show that most voltage sags are caused by SLG faults. SLG faults may occur at any place in the power system and are nuisance to industrial and commercial customers. The magnitude of voltage sag can be expressed by the voltage divider model of voltage sag events as shown in Figure 1.1.With ignoring the load current, the sag voltage V_{sag} can be expressed as (1)

$$V_{sag} = \frac{Z_s}{Z_s + Z_f} \times V_s \qquad (2.1)$$

Where, Z_S represents the source impedance at the point of common coupling (PCC) and Z_f represents impedance between the PCC to the location of the fault [8]. At the point of fault the voltage is almost zero. Therefore, the impedance of Z_S and Z_f determines the magnitude of voltage dip, and the duration of voltage sags is determined by the fault clearance time of the protection device. From (2.1), it can be known that the fault occurs near to PCC, which causes deeper voltage sag.

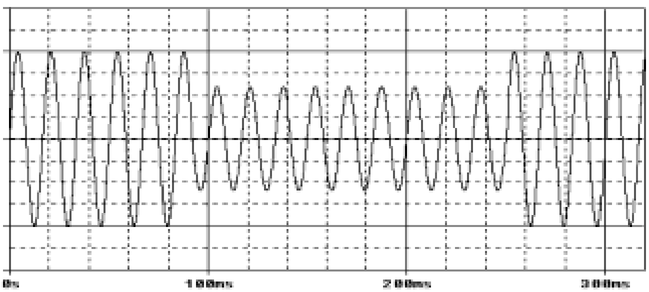

Figure 1.1: A shape of voltage sag due to SLG fault.

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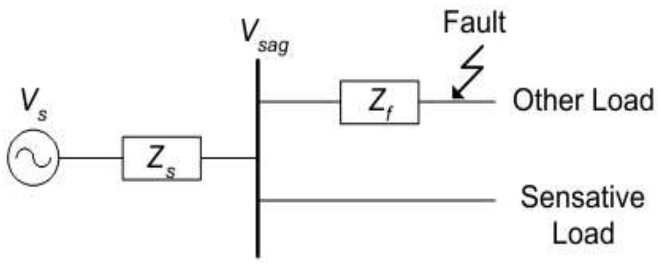

Figure 2.2. Voltage divider model for a voltage sag event.

PROPOSED SYSTEM CONFIGURATION

The proposed device for mitigating voltage sag and swell in the system consists of a PWM switched power electronic device connected to an autotransformer in series with the load.

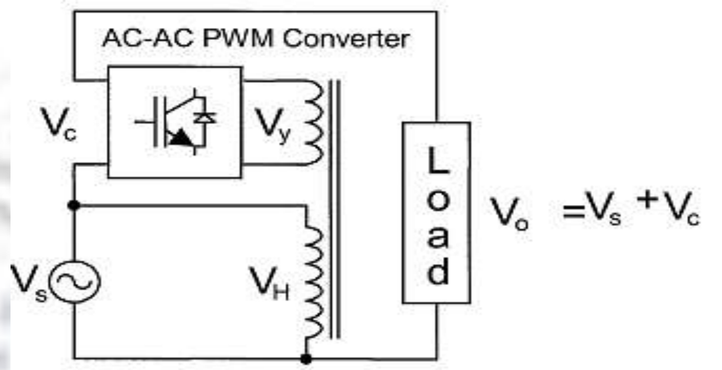

Fig. 3.3 shows the single phase circuit configuration of the mitigating device and the control circuit logic used in the system. It consists of a single PWM insulated gate bipolar transistor (IGBT) switch in a bridge configuration, a thyristor bypass switch, an autotransformer, and voltage controller.

AC TO AC PWM CONVERTER

Converter systems with either a voltage or a current DC-link are mainly used now a days for power conversion from a three-phase mains system to a three-phase load with an arbitrary voltage amplitude and frequency, as required, for example for variable-speed drives. In the case of a converter with a voltage DC-link, the mains coupling can, in the simplest case, be implemented by a diode bridge. A pulse-controlled braking resistor must be placed across the DC-link, or an antiparallel thyristor bridge must be inserted on the mains side to enable generator (braking) operation of the load. The disadvantages are the relatively high mains distortion and high reactive power requirements. A mains-friendly AC–AC converter with bidirectional power flow can be implemented by coupling the DC-link of a PWM rectifier and a PWM inverter. The DC-link quantity is then impressed by an energy storage element that is common to both stages, a capacitor *C*DC for the voltage DC-link back-to-back converter [V-BBC; cf., Fig. 4.4(a)] and an inductor *L*DC for the current DC-link back-to-back converter [C-BBC; cf., Fig. 4.4(b)]. The PWM rectifier is controlled in such a manner that a sinusoidal mains current is drawn, which is in-phase or antiphase with the corresponding mains line voltage. The implementation of the V-BBC and C-BBC requires 12 transistors (typically IGBTs) and 12 diodes or 12 reverse conduction IGBTs (RC-IGBTs) for the V-BBC and 12 reverse blocking IGBTs (RB-IGBTs) for the C-BBC. Due to the DC-link energy storage element, there is an advantage that both converter stages are, to a large extent, decoupled regarding their control for a typical sizing of the energy storage. Furthermore, a constant mains-independent input quantity exists for the PWM inverter stage, which results in a high utilization of the converter's power capability.

On the other hand, the DC-link energy storage element can have a relatively large physical volume compared with the total converter volume, and when electrolytic capacitors are used for the DC-link of the V-BBC, the service lifetime of the converter can potentially be reduced. Aiming for high power densities, it is hence obvious to consider the so-called matrix converter (MC) concepts that enable three-phase AC–AC conversion without any intermediate.

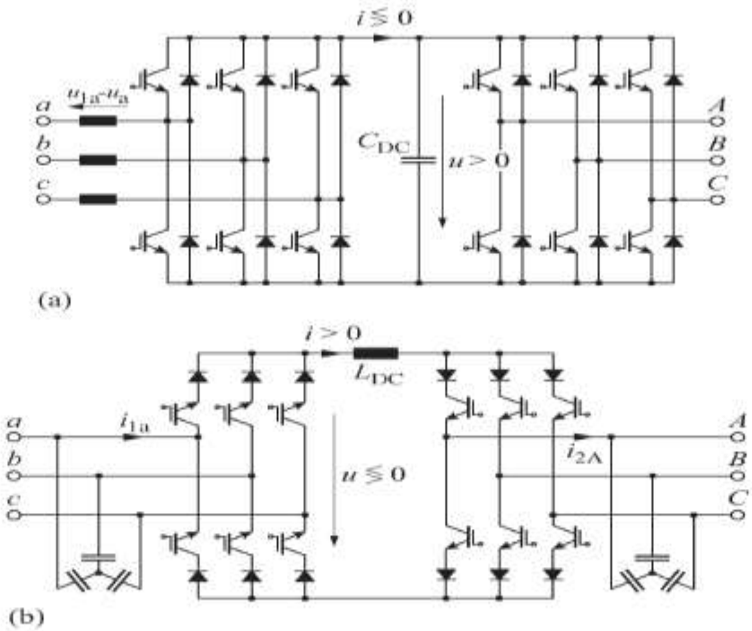

Fig. 4.4 basic three phase AC to AC converter topologies

SIMULATION AND DESIGN

Simulation analysis is performed on a three-phase 11 kV, 100 MVA, 50 Hz system to study the performance of the PWM switched autotransformer in mitigating the voltage sag and swell disturbances. The MATLAB/SIMULINK model of the system used for analysis is shown An RL load is considered as a sensitive load, which is to be supplied at constant voltage. Under normal condition, the power flow is through the antiparallel SCRs and the gate pulses are inhibited to IGBT. The load voltage and current are same as supply voltage and current. When a disturbance occurs, an error voltage which is the difference between the reference rms voltage and the load rms voltage is generated fig 5.5(a) shows the transmission line without AC to AC pwm converter and fig 5.5(b) shows the output response of the without AC to AC converter in this condition the voltage sag is clearly observed by the response at time 0.3 to 0.6 sec.

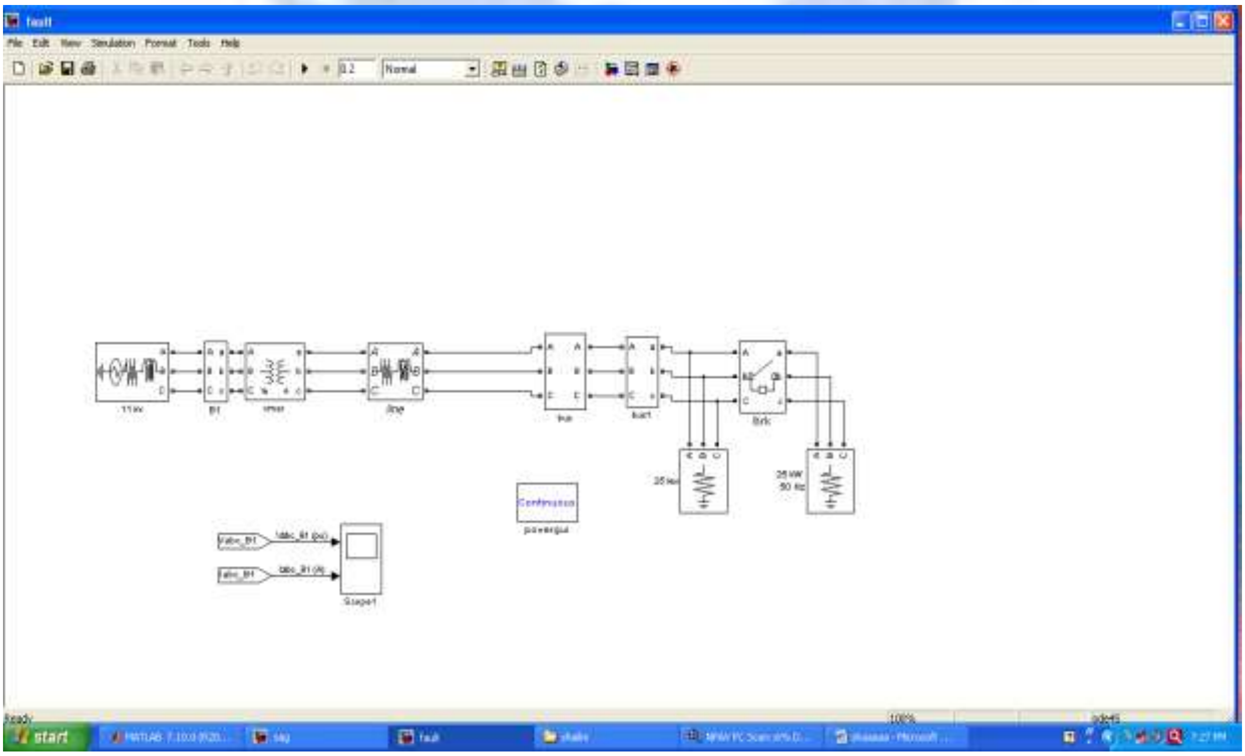

fig 5.5(a): Power system without compensating devices

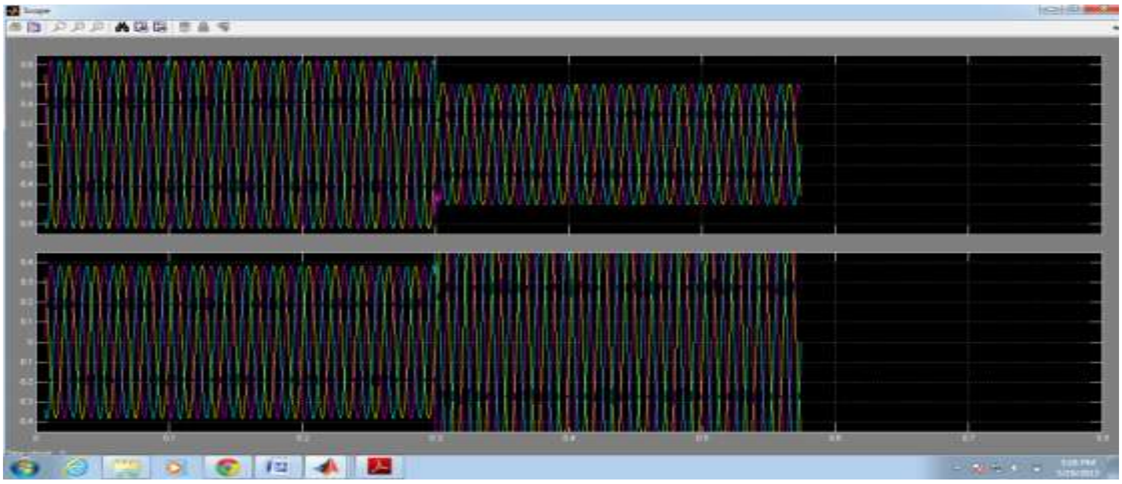

Fig. 5.5(b): output response of the system

The fig 5.5(c) shows the power system with AC to AC PWM Converter connected with the line and output response shows in fig 5.5(d) the response shows the mitigation of voltage sag at .3 sec to 0.6 sec period this period the AC to AC PWM Converter compensate the voltage sag.

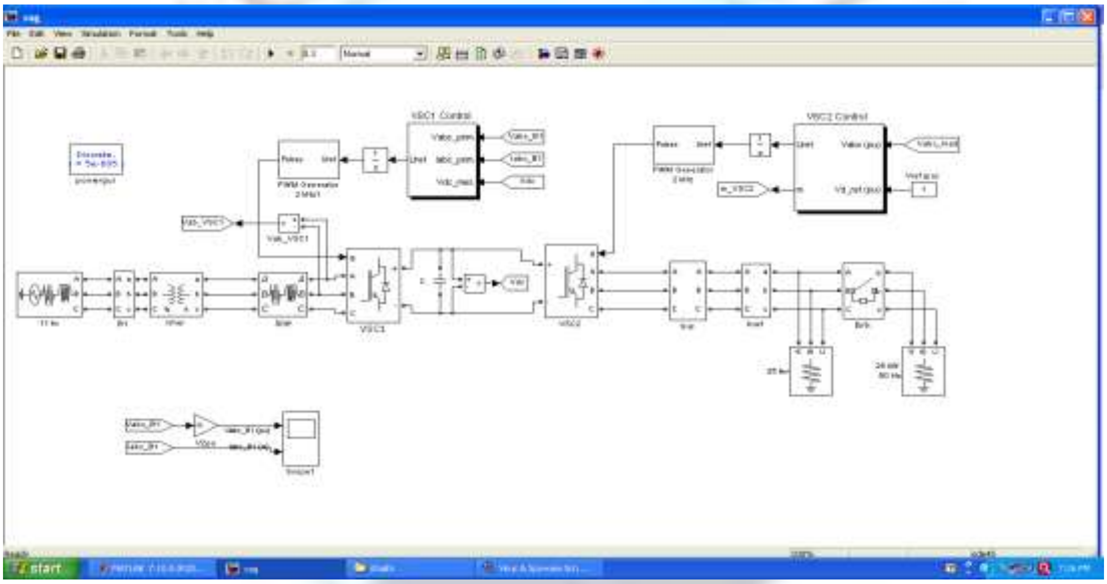

Fig 5.5(c): AC TO AC PWM CONVERTER

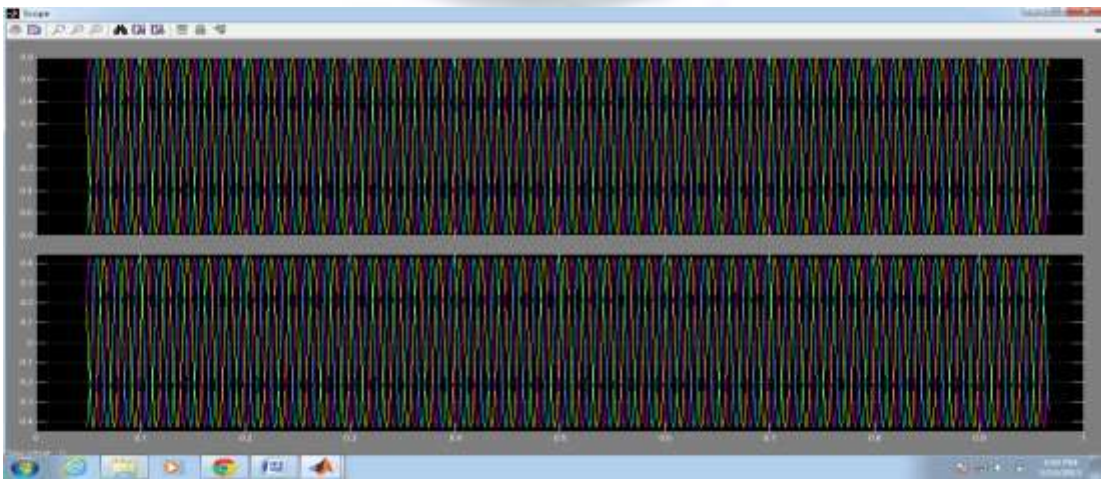

Fig 5.5(d): output response of the AC-AC PWM CONVERTER

CONCLUSION

A new voltage sag compensator based on PWM switched autotransformer has been presented in this paper. Control circuit based on rms voltage reference is discussed. The proposed technique could identify the disturbance and capable of mitigating the disturbance by maintaining the load voltage at desired magnitude within limits. The proposed technique is simple and only one IGBT switch per phase is required. Hence the system is more simple and economical compared to commonly used DVR or STATCOM. Simulation analysis is performed for 27% voltage sag for three phase system and simulation results verify that the proposed device is effective in compensating the voltage sag disturbances.

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