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Simulation and Implementation of Dynamic Voltage Restorer System

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Abstract: Dynamic Voltage Restorer (DVR) is a new concept of Flexible AC Transmission System (FACTS) controller with the unique capability for series compensation and power flow management among multi-line of a substation. The DVR employs a number of Voltage Sourced Converters (VSCs) linked at the same DC terminal, each of which can provide series compensation for the selected line of the transmission system. This study deals with simulation and implementation of DVR with open loop controlled systems. The hardware circuit of DVR was implemented.

Key words: FACTS, SSSC, DVR, PSPICE, power converter, India

INTRODUCTION

The basic design of the DVR is to inject a dynamically controlled voltage generated by a forced-commutated converter in series to the bus voltage by means of a booster transformer. The momentary amplitudes of the three injected phase voltages are controlled such as to eliminate any detrimental effects of a bus fault to the load voltage. This means that an equivalent voltage generated by the converter and injected on the medium voltage level through the booster transformer compensates any differential voltages caused by transient disturbances in the ac feeder.

In normal situation without short circuit in power system, a capacitor between rectifier and inverter (Fig. 1) will be charging. When voltage sag happened, this capacitor will discharge to maintain load voltage supply. Nominal voltage will be compared with voltage sag in order to get a difference voltage that will be injected by DVR system to maintain load voltage supply (Felce *et al*., 2004). PWM technique is using to control this variable voltage. In order to maintain load voltage supply, reactive power must be injected by DVR system. Practically, the capability of injection voltage by DVR system is 50% of nominal voltage. It is sufficient for mitigation voltage sag because from statistic shown that many voltage sag cases in power system involving <0.5 p.u. voltage drop. There are many ways in order to mitigate voltage sag problem. One of them is minimizing short circuits caused by utility directly which can be done such as with avoid feeder or cable overloading by correct configuration planning. Another alternative is using the Flexible AC Technology (FACTS) devices

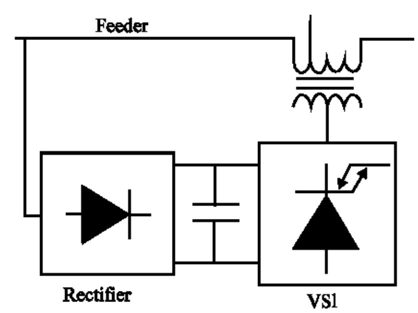

Fig. 1: Structure of DVR system

which have been used widely in power system now a days because of the reliability to maintain power quality condition includes for voltage sag mitigation. There are many devices have been created with purpose to enhance power quality such as Dynamic Voltage Restorer (DVR), Distribution Static Compensator (D-STATCOM) and Uninterruptible Power Supply (UPS) (Ghosh and Ledwich, 2008; Nguyen and Saha, 2004).

ANALYSIS OF THE DVR SYSTEM

The DVR is to maintain the magnitude of the appliance voltage phasor within a tolerable magnitude band. The basic circuit configuration is shown in Fig. 2. The converter generates a one-phase AC voltage is controllable in phase and magnitude.

By means of converter control is possible to create the appliance voltage phasor is as shown in the Fig. 3.

$$\overline{V}_a = \overline{V}_g - j\omega_s \times L_f \times \overline{I}_a - \overline{V}_c \quad (1)$$

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Presented DVR's control creates an appliance voltage phasor collinear with the grid voltage phasor. This strategy does not provide maximal converter voltage utilization because of inductor voltage drop however, current phasor evaluation is not required.

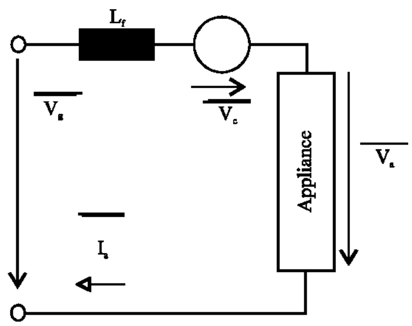

Fig. 2: Principle of proposed DVR

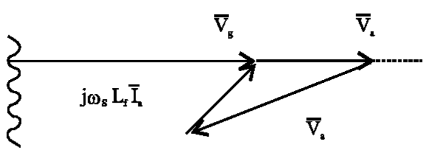

Fig. 3: Position of appliance voltage vector

SIMULATION OF DVR SYSTEM WITH DIFFERENT PHASE ANGLE

In this study, we considered two identical lines. Here, the two lines are interlinked using converter, capacitor and inverter arrangement. The simulation circuit as shown in Fig. 4. In which transmission line having more power flow that power will be draw by using converter and injected to the line which one is severely overloaded/more voltage sag by using inverter.

The capacitor to improve the stability of the input voltage to the inverters. In this different phase angle system the concept is based on the real power flow, the power flows from higher angle to lower angle (Heine and Lehtonen, 2004).

By using in this system, the real power will be controlled and to improve the stability of a transmission line. The various simulation results of real and reactive power flows is as shown in Fig. 5a and b, respectively.

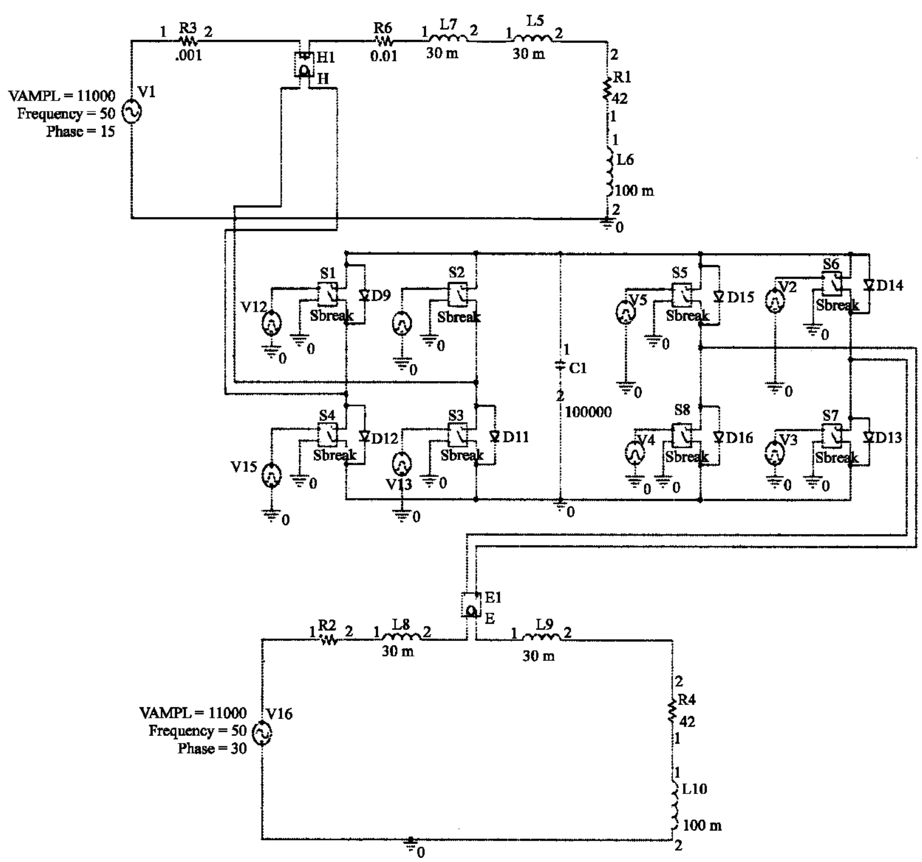

Fig. 4: Circuit diagram for DVR system with different phase angle

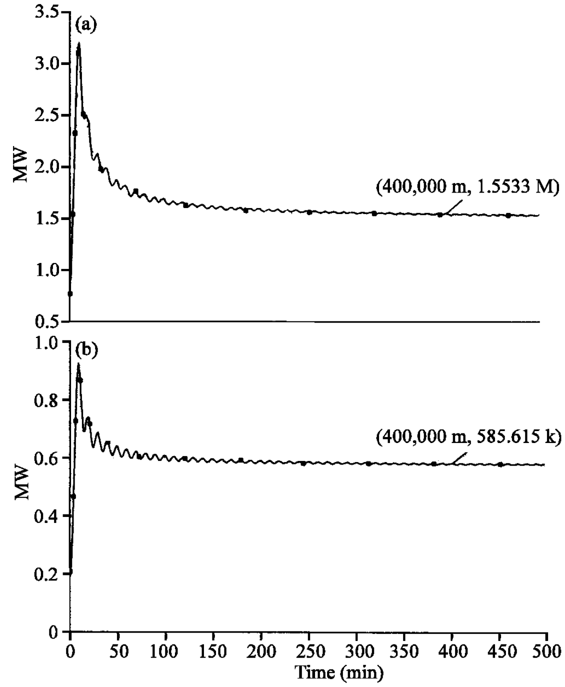

Fig. 5: a) Real power in line 1, avg. (W(R4)) b) real power in line 2, avg. (W(R1))

SIMULATION OF DVR SYSTEM WITH DIFFERENT VOLTAGE

In this study, we considered two non-identical lines. Here, the two lines are interlinked using converter, capacitor and inverter arrangement. The simulation circuit as shown in Fig. 6.

In which transmission line having more power flow, that power will be draw by using converter and injected to the line which one is severely overloaded/more voltage sag by using inverter (Chung *et al*., 2003). The capacitor to improve the stability of the input voltage to the inverters.

By increasing the injecting angle, the injecting voltage of the transmission line is increased. In this different voltage system the concept is based on the reactive power flow, the power flows from higher voltage to lower voltage.

By using in this system the reactive power will be controlled and to improve the stability of a transmission line. The various simulation results of real and reactive power flows is as shown in Fig. 7a-d, respectively.

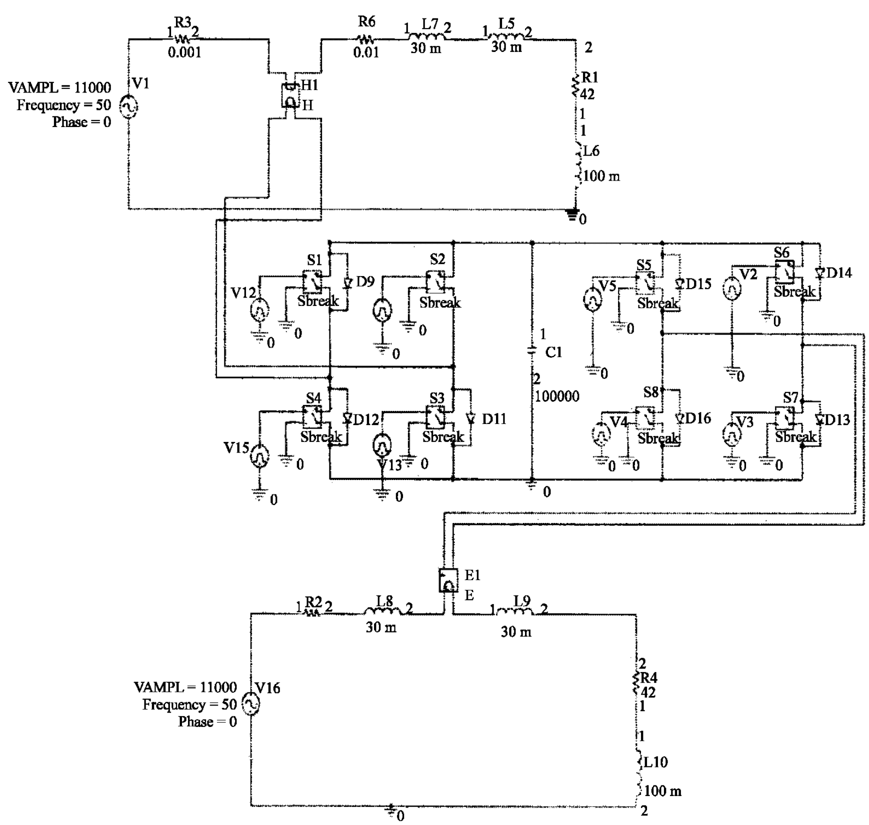

Fig. 6: Circuit diagram for DVR system with different voltage

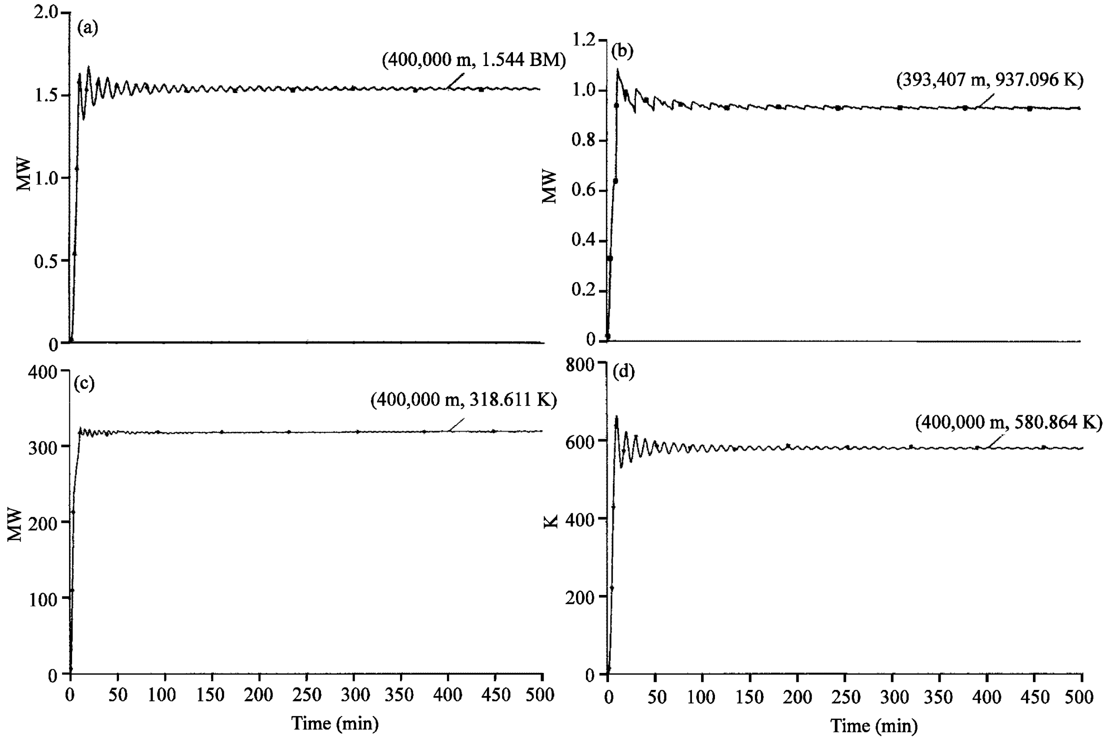

Fig. 7: a) RMS real power in the line 2, avg. (W (R4)), b) RMS reactive power of line 2, RMS (W(L10)), c) RMS real power in the line 1 (W (L6)), d) RMS reactive power line 1, avg. (W (R1))

HARDWARE IMPLEMENTATION OF DVR SYSTEM

This prototype DVR provides a charging of the DC bus capacitor up to the optimal voltage, stabilizing this when the voltage in the grid is normal and preventing DC capacitor overcharging during longer over voltages. The used voltage dips mitigation strategy corresponds to pre-sag compensation method as classified in dynamic voltage restorer system. In this method the appliance voltage can be ideally restored (Viktorin *et al*., 2003). When the DC bus voltage is optimal and the grid voltage is normal, almost no voltage is present across the DVR terminals. As such, the losses are minimal during the long period of the normal operation.

In this study, the dc link storage system is connected to VSI.The dc link capacitors to maintain the stability of the system. The IR2110 is a high voltage and high speed power MOSFET driver circuit system. The prototype configuration of DVR using micro controller is as shown in the Fig. 8. In the occurrence of a disturbance in the utility grid, the compensator injects the missing voltage supplying the protected load with voltages free from the disturbances. The energy injected by the equipment is

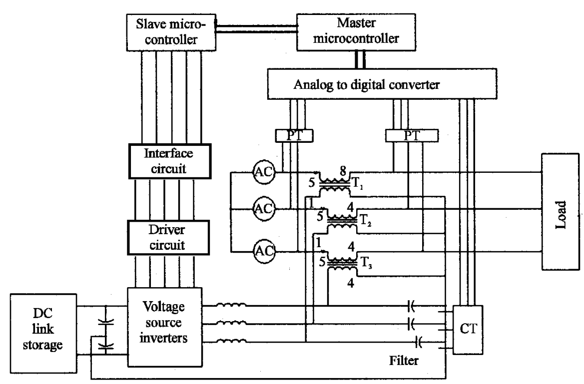

Fig. 8: Hardware prototype configuration of DVR system

extracted from the utility system through a diode bridge rectifier, which avoids using energy storage system, as battery banks, reducing implementation and maintenance cost. This driver circuit to gives the triggering pulse to MOSFET and the pulse propagation period is controlled by interface circuit. MOSFET output signals are given isolation to the controller circuit. This isolation transformer output is controlled by the master micro controller system. The power circuit and hardware design is as shown in the Fig. 9.

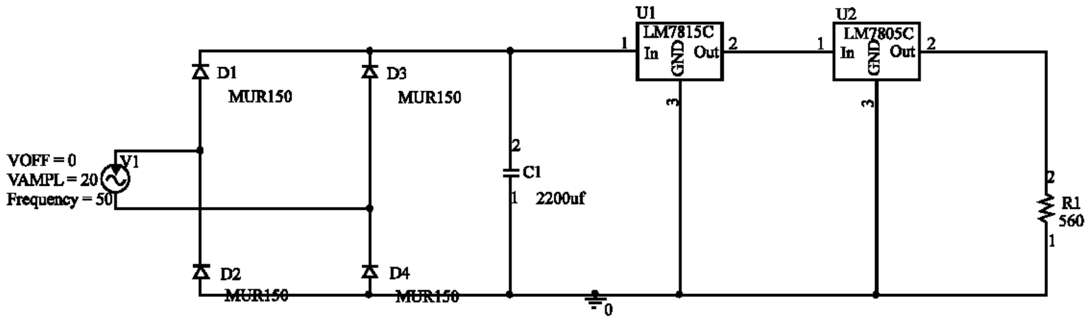

Fig. 9: Power circuit, hardware implementation

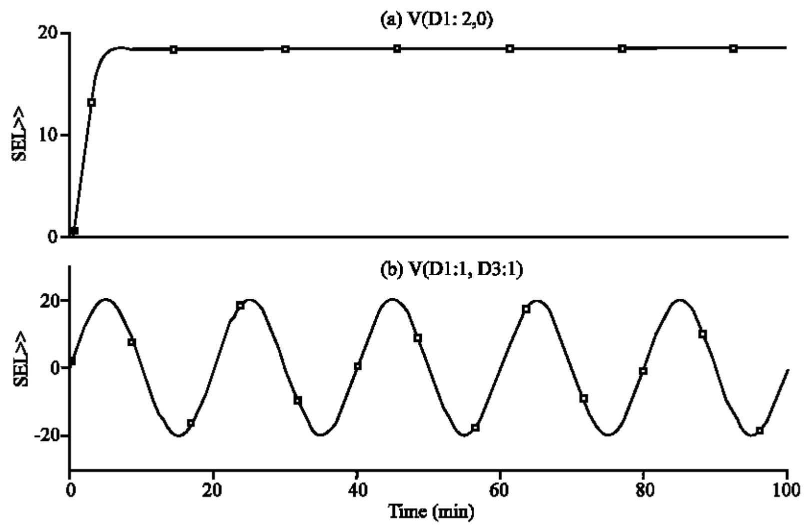

Fig. 10: Waveforms for rectifier output voltage and input voltage

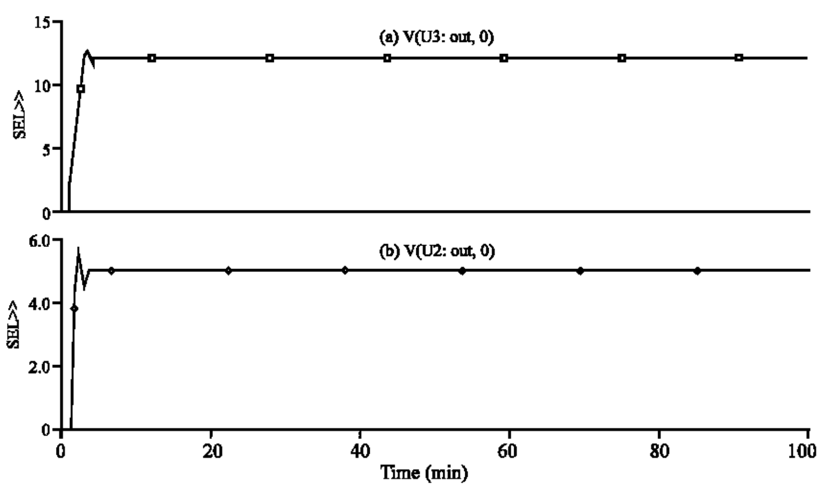

Fig. 11: Waveforms for output voltages of LM7812 and LM7805C

The waveforms for input and output voltage of rectifier are as shown in the Fig. 10. The sinusoidal voltage is given to the fully controlled rectifier circuit. The capacitor is to maintain the stability of the dc output voltage. The voltage across CM 7815 and CM7805 is as shown in the Fig. 11. The hardware implementation of

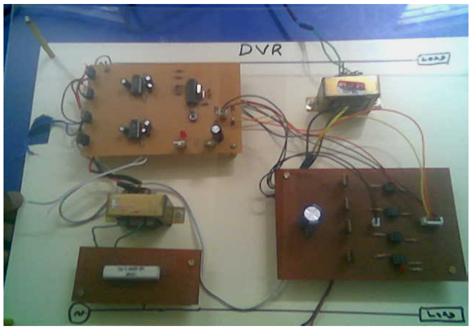

Fig. 12: Laboratory model of DVR system

DVR system is as shown in the Fig. 12. Hence, it maintains the voltage applied to the load during sags and swells by injecting a voltage of compensating amplitude and phase angle into the line. In this DVR to satisfy the stringent power quality demands of industrial and commercial customers.

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