

Power Quality Improvement using Z-Source based DVR

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Abstract— This paper proposes a photovoltaic (PV) system, which exhibits a set of benefits when draw parallels to conventional stand-alone PV system. In the present system, the generated energy by the PV arrays is managed by multi-string step-up converters. Voltage swell and sag is big brain-teasers in power system. Sensitive load has a serious effect on itself due to voltage swell and sag. Dynamic Voltage Restorer (DVR) is a power conventional appliance used in power distribution network. Various equivalent circuit models of a PV cell have been proposed. For obtaining high power, numerous PV cells are connected in series and parallel on a panel, which is a PV module. Power quality is one of the considerable attentions in the existing power system environment. Dynamic Voltage Restorer (DVR) is a modified power apparatus that is utilized to enhance voltage. The suggested control scheme is elementary to model and has outstanding voltage compensation capabilities, through the hysteresis voltage control technique are efficacious of proposed technique is examined through computer simulation. To felicitously control the control objectives for compensation voltage control, primarily the power circuit of a DVR system is analyzed with PV system. The model is humble. The Simulation results are fetched out by Simulink/Mat lab to verify the performance of the present method.

Key words: Dynamic Voltage Restorer (DVR), Photovoltaic (PV) system, Voltage Sags, Voltage Swells, Sensitive Load, VSI

I. INTRODUCTION

Today's automated industrial processes are based on a large amount of electronic devices. Consequently, industrial loads become more vulnerable to power-supply disturbances. Voltage sags are generally accepted as the most common and costly powerquality (PQ) problems affecting sensitive loads. They are mainly caused by the upstream transmission system faults or distribution system faults at the parallel feeder associated to the summit of frequent coupling (PCC). But voltage sag exceeds even two or three cycles, it may cause heavy production and quality losses. A dynamic voltage restorer (DVR) be able to abolish the majority sags and reduce the threat of load tripping throughout sags. It introduce suitable three-phase ac voltages within series with the supply, while PCC voltage sag is detected.

The transient response of any usual system is the mode in which the response of the system behaves as a purpose of time. Electromagnetic transient studies had forever played an necessary performance of the system in the occasion of diddimilar forms of transient phenomenon, which can scarcely be achieved by other means. This project address the transient studies of electrical networks with power electronics-based, embedded, Custom Power (CP) controllers and FACTS. The FACTS regulates task in the scrutiny of electrical power systems. A substantial

proportion of power system studies rely on electromagnetic transient simulations. These afford considerable information concerning to the measured here is the essential Static Var Compensator (SVC) with FCTCR composition. The CP controllers consists of Dynamic Voltage Restorer (DVR) and Distribution Static Compensator (DSTATCOM). The paper is organized as follows: the FC-TCR collection of SVC is discussed, the theory behind Voltage Source Converter (VSC) – Based Controllers namely, DVR and D-STATCOM, the PWM proposal adopted in this paper for DVR and D-STATCOM is described. Then the test belongings are existing and the simulation results are discussed and, finally, a few certain clarification are drained.

II. FACTS CONTROLLERS

With the breakneck growth of power electronics, Flexible AC Transmission Systems (FACTS) apparatus had been recommend and achieved in power systems. FACTS apparatus could be used to control power flow and improve system stability. Particularly with the restrictions from the electricity auction, here is an escalating attention in using FACTS appliances in the process and control of power systems through new loading and power flow situations. A best use of the keep going power systems to boost their controllability and capacities by installing FACTS appliances became vital important. Due to the present conditions, there are two main attributes that might be examine in using FACTS apparatus: The primary attribute is the adaptable power system process according to the power flow control accomplished of FACTS apparatus. The second attribute is the advancement of steady-state stability and transient of power systems. FACTS apparatus are the right apparatus to meet these confronts.

According to IEEE, FACTS, which is the truncate of Flexible Alternating Current Transmission Systems, is explain as follows:

Flexible alternating Current Transmission Systems consists of power electronics based and other static controllers to improve controllability and power transfer accomplishment.

A. Types of facts controllers:

In common, FACTS Controllers can be classified into four kinds:

- 1) Shunt controllers
- 2) Series controllers
- 3) Combined series-shunt controllers
- 4) Combined series-series controllers

III. DYNAMIC VOLTAGE RESTORER

The basic idea of a DVR is to inject the missing voltage cycles into the system through series injection transformer whenever voltage sags are present in the system supply voltage. As a consequence, sag is unseen by the loads. During normal operation, the capacitor receives energy from the main supply source. When voltage dip or sags are

detected, the capacitor delivers dc supply to the inverter. The inverter ensures that only the missing voltage is injected to the transformer. A relatively small capacitor is present on dc side of the PWM solid state inverter and the voltage over this capacitor is kept constant, by exchanging energy with the energy storage reservoir. The required output voltage is obtained by using pulse-width modulation switching pattern. As the controller will have to supply active as well as reactive power, some kind of energy storage is needed. In the DVRs that are commercially available now large capacitors are used as a source of energy. Other potential sources are being considered are: battery banks, super conducting coils, and flywheel.

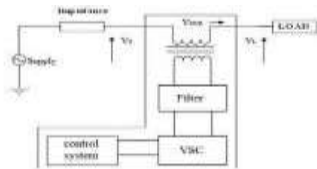


Fig. 1: Basic block diagram of DVR

With reference to Fig.1 the main components of DVR are

- 1) Energy Storage Unit: The required energy for compensation of load voltage during sag can be taken either from an external energy storage unit (batteries) or from the supply line feeder through a rectifier and a capacitor.
- 2) Inverter Circuit: Since the vast majority of voltage sags seen on utility systems are unbalanced, mostly due to single-phase events, the VSC will often be required to operate with unbalanced switching functions for the three phases, and must therefore treat each phase independently. Mitigation of Voltage Sags in a Refinery with Induction Motors Using Dynamic Voltage Restorer (DVR) 121 Moreover, sag on one phase may result in a swell on another phase, so the VSC must be capable of handling both sags and swells simultaneously. The variable output voltage of the inverter is achieved using PWM scheme.
- 3) Filter Unit: The nonlinear characteristics of semiconductor devices cause distorted waveforms associated with high frequency harmonics at the inverter output. To overcome this problem and provide high quality energy supply, a harmonic filtering unit is used. This can cause voltage drop and phase shift in the fundamental component of the inverter output, and has to be accounted for in the compensation voltage.
- 4) Series Injection Transformers: Three single phase injection transformers are used to inject the missing voltage to the system at the load bus. To integrate the injection transformer correctly into the DVR, the MVA rating, the primary winding voltage and current ratings, the turn-ratio and the short-circuit impedance values of transformers are required. The existence of the transformers allow for the design of the DVR in a lower voltage level, depending upon the stepping up ratio. In such case, the limiting factor will be the ability of the inverter switches to withstand higher currents.
- 5) Controller and auxiliary circuits: By-Pass switches, breakers, measuring and protection relays are some auxiliaries to the DVR block, in addition to the controller of the DVR.

The Dynamic Voltage Restorer (DVR) is a promising and effective device for power quality enhancement due to its quick response and high reliability. The conclusion is that the DVR is an effective apparatus to protect sensitive loads from short duration voltage dips. The DVR can be inserted both at the low voltage level and at medium voltage level. The series connection with the existing supply voltages makes it effective at locations where voltage dips are the primary problem. However, the series connection makes the protection equipment more complex as well as the continuous conduction losses and voltage drop. The role of a DVR in mitigating the power quality problems in terms of voltage sag, swell and interruptions is explained. The equations for calculating the voltages and power injected from each of the three DVR phases are given. The results obtained for a single phase dip to zero volts on the red phase are presented to design the PWM Inverter rating of the DVR.

IV. PHOTOVOLTAIC CELL

PV or Photovoltaic devices or “solar cells” – changes the sunlight directly into the electrical energy. The PV cell was exposed in 1954 by researchers of Bell Telephone by examining the properly prepared silicon sensitivity of a wafer to sunlight. Initiation in the late 1950s, PV cells were used for powering space satellites of U.S. The success of using Photo voltaic in space satellites in space generates industrial applications for this expertise. The easiest photo voltaic (PV) systems powering many of the wrist watches and small calculators used every day. More problematic systems generate electricity to power communications equipment, pump water and even supply electricity to our houses.

Photovoltaic cell working principle:

A photovoltaic cell, commonly called a solar cell or PV, is the technology used to convert solar energy directly into electrical power. A photovoltaic cell is a non mechanical device usually made from silicon alloys. Sunlight is composed of photons, or particles of solar energy. These photons contain various amounts of energy corresponding to the different wavelengths of the solarspectrum. When photons strike a photovoltaic cell, they may be reflected, pass right through, or be absorbed. Only the absorbed photons provide energy to generate electricity.

Crystals of Silicon are all neutral electrically. In Si of n-type our additional electrons are balanced out by the further phosphorous protons. In Si p-type the electrons missing (holes) were stabilized out by the protons missing in the boron. When the electrons and holes mix at the **junction** b/w P-type and N-type silicon, moreover, that neutrality is disrupted. Does all the free electrons fill all the free holes? Never. If they does, then the whole arrangement couldn't be most useful. Exact at the junction, though, they do mix and forms a barrier, making it even harder and harder for the electrons on the N side to go across to the P side. Ultimately, balance is reached, and we had separated the two sides with an electric field.

V. Z-SOURCE INVERTER

Z-source inverter has X-shaped impedance network on its DC side, which interfaces the source and inverter Hbridge. It facilitates both voltage-buck and boost capabilities. The Impedance network composed of split inductors and two capacitors. The supply can be DC voltage source or DC

current source or AC source. Zsource inverter can be of current source type or voltage source type. Fig. 2 shows the general block diagram of Z-Source inverter.

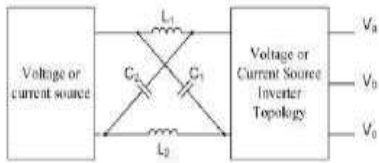


Fig. 2: Block diagram of Z-Source inverter

Z-source inverter operation is controlled by multiple pulse-width modulation. The output of the Z-Source inverter is controlled by using pulse width modulation, generated by comparing a triangular wave signal with an adjustable DC reference and hence the duty cycle of the switching pulse could be varied to synthesize the required conversion. A stream of pulse width modulation is produced to control the switch as shown in the Fig. 3.

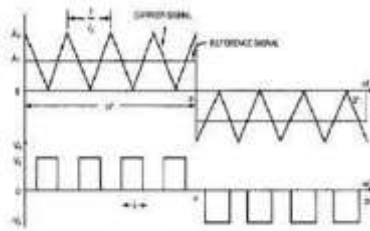


Fig. 3: Pulse width modulation

As shown in Table I, the single-phase Z-Source inverter has five switching modes. Two active modes in which the dc source, voltage is applied to load, two zero modes in which the inverter's output terminals are short circuited by $S1$ and $S3$ or $S2$ and $S4$ switches and a shoot-through mode which occurs as two switches on a single leg are turned on.

TABLE I Switching Modes

S_4	S_3	S_2	S_1	Switching mode
1	0	0	1	Active mode
0	1	1	0	
0	1	0	1	Zero mode
1	0	1	0	
0 or 1	0 or 1	1	1	Shoot-through mode

VI. DVR SYSTEM

The Simulink model of voltage compensation in a DVR system is shown in the Fig. 4. Initially the system was subjected to 25% voltage Sag at $t=0.6s$ and remains up to $t=0.9s$ with the total voltage Sag duration of 0.3s, in a run time of 1.2s.

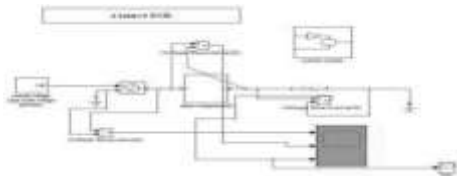


Fig. 4: Simulation circuit of Voltage compensation using DVR

Fig.5 shows simulation results of voltage sag compensation using DVR. It is shown clearly that a Sag is created at $t=0.6s$ and it is maintained up to $t=0.9s$ in a run time of 1.2s. The second part of the figure indicates the DVR voltage which is compensating voltage of system. The third part of figure indicates the load voltage of system which is maintained constant through the fault/ Sag is occurred in the system. A small jerk in voltage is observed in load current when the DVR comes to play.

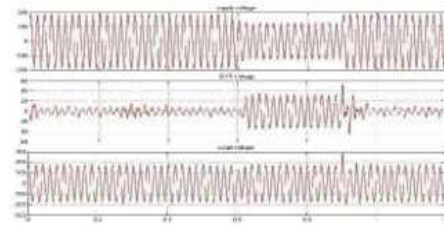


Fig. 5: Simulation results of Voltage sag compensation using DVR

Fig.6 shows the simulation result of voltage swell compensation of DVR. The swell is created at $t=0.1s$ and it is carried until $t=0.4s$ in a total run time of 1s. The first part of figure indicates the supply voltage in which voltage swell is indicated. The second part indicates the DVR compensating voltage. The third part indicates the unchanged load voltage during swell condition. A small jerk is observed due to quick action of DVR.

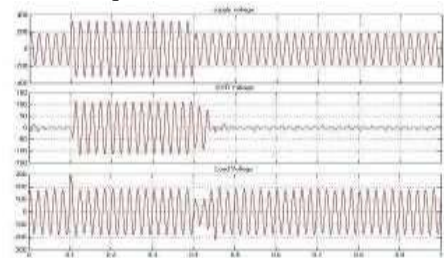


Fig. 6: Simulation results of Voltage swell compensation using DVR

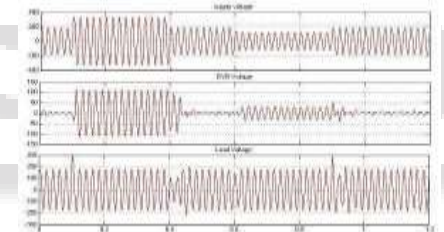


Fig. 7: Simulation results of voltage sag/swell compensation using DVR

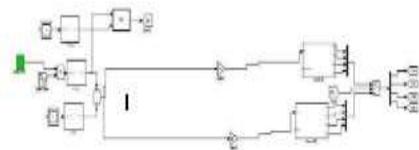


Fig. 8: Control circuit of DVR

Fig.7 indicates the simulation result of voltage sag and swell compensation of DVR. The swell is created at $t=0.1s$ and maintained up to $t=0.4s$ and sag is created at $t=0.6s$ and maintained up to $t=0.9s$. The first part of figure indicates supply voltage in which voltage sag and swell are created. The second part indicates the DVR voltage and the third part indicates the unchanged load voltage. Fig.8 indicates the control circuit of the DVR.

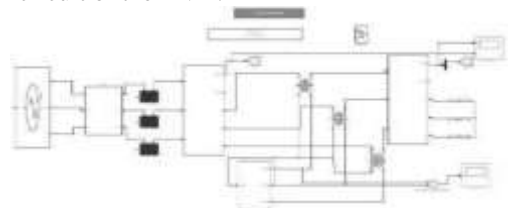


Fig. 9: MATLAB/Simulink model of three phase Z-Source inverter.

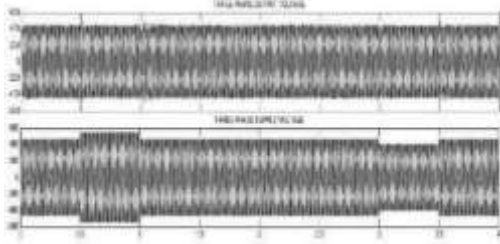


Fig. 10: Simulation results of three phase Z-Source Inverter

VII. CONCLUSION

In this paper voltage sag/swell compensation using three phase Z-Source inverter based Dynamic Voltage Restorer is considered. It is observed that throughout fault condition the power factor at input side is maintained unity and the system output voltage is maintained constant throughout the fault condition. The simulation results show that the developed control technique with proposed single phase DVR is simple and efficient. From the simulation results it was observed that dynamic voltage restorer compensates 25% of voltage sag and 30% of voltage swell. The control technique is designed using in-phase compensation and used a closed loop control system to detect the magnitude error between voltages during presage and sag periods. The modeling and simulation of closed loop control of voltage sag/swell mitigation were carried out using MATLAB software.

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