Improving The Power Quality In the Transmission Systems Using SMES & PV-DVR By Elimination Of Voltage Sag And Swells

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Abstract. Due to smart grids various energy storage technologies emerged and their integration into smart grids became cost effective. Dynamic Voltage restorer is one of the products which provides compensation for voltage sag and swell in power systems with energy storage integration technologies. In this work Ultra Capacitors (UACP), Superconducting Magnetic Energy Storage (SMES) & PV Cell is integrated to compensate for the sag and swell in power systems. The main purpose of integration is that UACP have lower energy densities, mostly used for low voltage applications. With SMES-PV Cell integration sag and swell can be compensated even for high voltage applications. This integration improves power quality by compensation sag and swell without depending on the grid. UACP, SMES are integrated to the DVR through the bi-directional converter which provides steady DC voltage at the DC link. In this work operation of SMES, UACP, DC-DC converter are discussed. All the simulation work has been carried out using the MATLAB software, the voltage sag and the swell has been maintained in the stable condition.

Keywords: UCAP, SMES and DVR.

1 Introduction

DVR became most popular in maintaining power quality for the first use itself by compensation for temporary voltage sag and swell. During voltage disturbances active power requirements at the grid are met by DVR with energy storage devices (rechargeable) at its DC terminals. In the past many of the researchers proposed a compensation technique for the voltage sag by inserting voltage (lagging) in quadrature with line current this technique also reduces the injection of active power to the grid. But rechargeable energy storage devices are not cost effective hence various other types of control strategies have been developed in order to reduce active power output (injection into grid) from DVR. Due to technological developments in auxiliary energy storage for DERs (Distributed Energy Storages) the cost of rechargeable energy storage has been drastically decreased. This situation led to the integration of DC terminals of DVR, STATCOM and other power quality products to the rechargeable energy storage systems.

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Integration of SMES, UCAP, FESS and other energy storage systems with DVR will make the system with active power capability and makes the system independent of the grid during voltage disturbances. In this work IGBT based DVR is proposed to reduce voltage disturbances in the transmission lines (High Voltage applications). UCAPs require active power to mitigate voltage disturbances but they have low energy densities i.e., applicable for low voltage applications. In order to integrate DVR with the transmission lines a renewable energy source and SMES are integrated to the DC terminal of DVR along with UCAP. This technology makes integration easier and it is possible to address various voltage disturbances in the system. By this technology DVR can independently compensate voltage sag and swell in the transmission line. The unique property of SMES is that it can work with its own magnetic field once it is recharged with the PV Cell. Moreover, SMES is able to mitigate high voltage disturbances, UCAP is able to mitigate low voltage disturbances, and ripples.

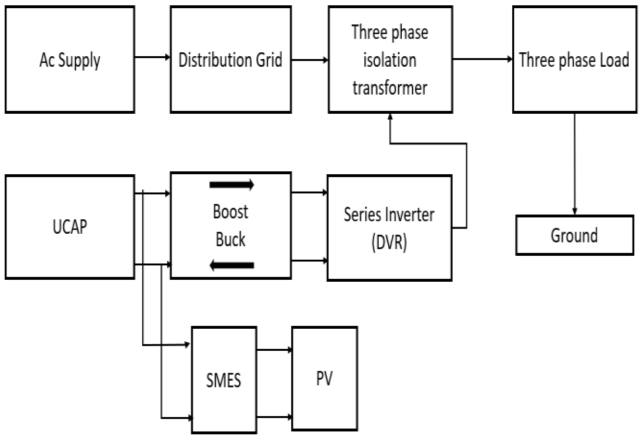


Fig. 1. Proposed Block Diagram

2 Control Strategy

In this work a DC reference voltage of 300V is compared with line voltage of the system using PI Controller. The output of this controller is used to trigger the pulses which activate the DVR. In this parks transformation is used to convert the currents from stationary reference frame to rotating reference frame. Praks transformation is used to eliminate inductances which are time varying by referring to a fixed frame of reference. An inverse transformation is used to determine the stationary reference frame. The required triggering pulses for DVR is generated from the stationary orthogonal reference frame voltages (Inverse Praks Transformation) through a comparator using pulse width modulation technique in the system.

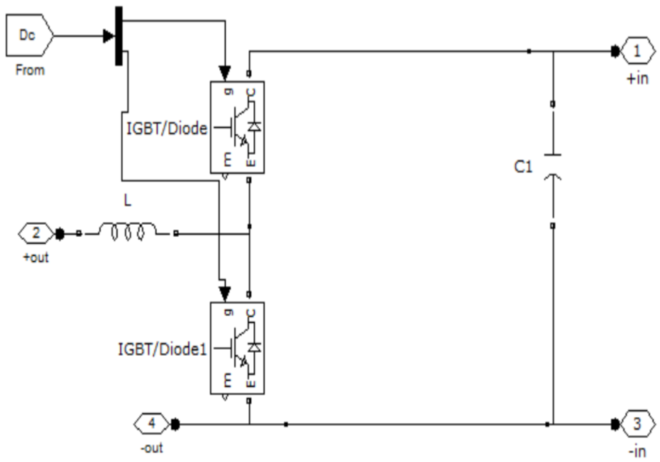


Fig. 2. Bi-directional converter

3 Bi-directional DC-DC Converter

The voltage profile of SMES, UCAP varies rapidly as its energy is discharging, so these energy storage devices cannot be connected to the inverter directly like a battery Here we required bi-directional dc-dc converter. This will maintain the voltage stable at the DC-Link. The voltage at the UCAP will be decreasing and increasing mode, i.e., while discharging and charging respectively. During voltage sag the required active power injections is provided by this converter during discharge mode. During voltage swell it operates in the charge mode in order to absorb the extra amount of voltage i.e., this converter is undergoing bi-directional mode of operation. Overall, this bi-directional dc-dc converter is operating as buck converter during charging and boost converter during discharging. Bi-directional dc-dc converter is operated in the buck mode when the voltage at the UCAP is below the specified value and the converter is able to take required energy from the grid. Bi-directional dc-dc converter is operated in the boost mode when the voltage at the UCAP is more than the specified voltage. On similar analysis during high voltage applications if the SMES voltage is below the specified value the converter is able to operate in buck mode. If the SMES voltage is above the specified value the converter is able to operate in the boost mode. In this work bi-directional dc-dc converter is constructed using IGBTs. In this only one IGBT will be in charging mode other will be acting as discharging mode. Average current mode control strategy is widely used by many researchers in order to regulate the voltage during buck and boost modes while discharging and charging of SMES, UCAP. This control strategy is stable, compared with other control strategies like peak current control strategy and voltage mode control strategy.

4 Simulation and Results

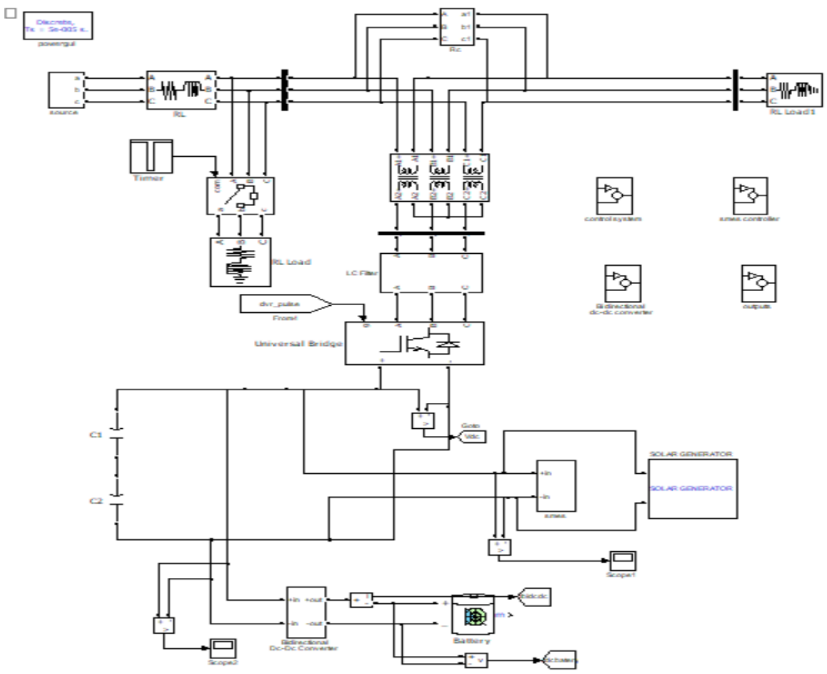
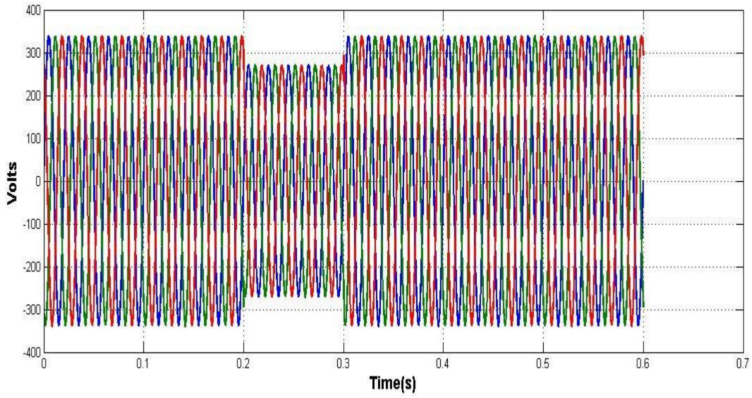


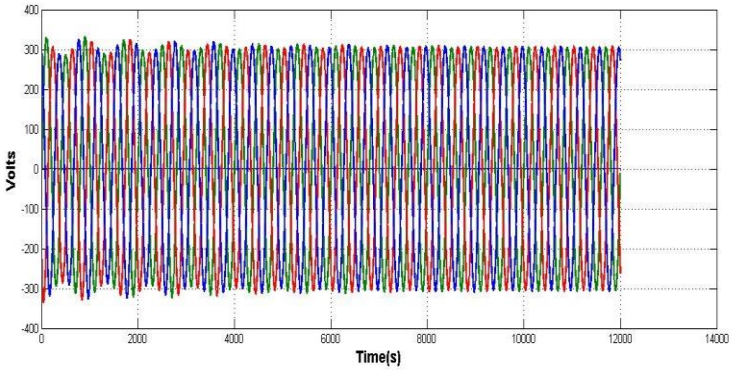
Fig. 3. Simulation Diagram

In this proposed system the source voltage is taken as 3 phase 415V AC is connected to the non linear load through medium transmission lines. In between the source and load DVR system is connected. DVR System consists of two energy storage devices UCAP and SMES. UCAP is powered by a battery and it is used to mitigate low voltage disturbances for the low voltage applications. On other hand SMES is powered by PV and this is used to mitigate the high voltage disturbances. Whenever there is voltage disturbance in the system then there is an error voltage generated through the voltage difference in the control unit. This error voltage through the PI Controller moved to the comparator and through the pulse width modulation technique required triggering pulses were generated. These pulses were sent to the DVR. If the voltage disturbance is either (Sag/Swell) UCAP will activate the converter. And the converter is operated in the buck mode and boost mode respectively. when the voltage at the UCAP is low or high depending upon the specified voltage respectively. On similar analysis SMES will activate the converter and enable the converter to operate in the buck and boost modes for high voltage disturbances and low voltage disturbances respectively. Here RC filter is used to remove the minute ripples in the system before sending to the load this helps in adding the strength to increase in the power quality. Moreover, in the control unit park‘s transformation is proposed to eliminate the time-based inductive currents. In this converter IGBTs are proposed since they are used for high voltage applications and have more switching frequency. MOSFETs are used to design the SMES, because it has a high switching frequency. The output of solar cells (V=1000V, I= 10A) is given to SMES input terminals which enables the system to act as a renewable energy-based DVR.



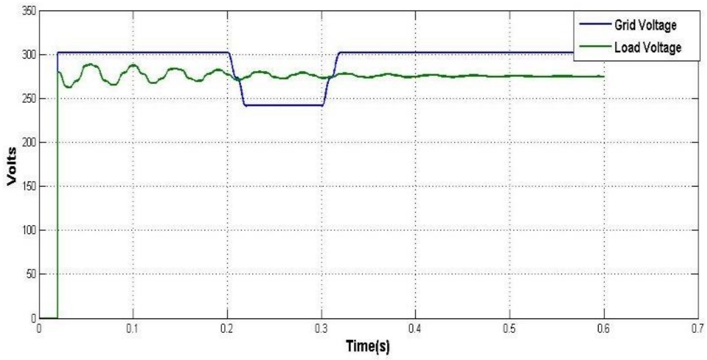
Volts
Time(s)

(a)



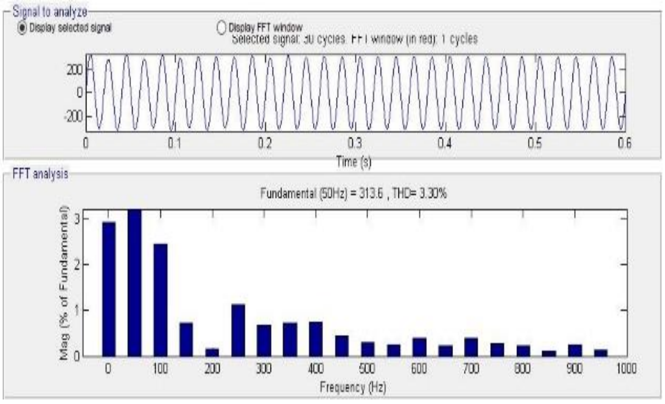
Volts
Time(s)

(b)



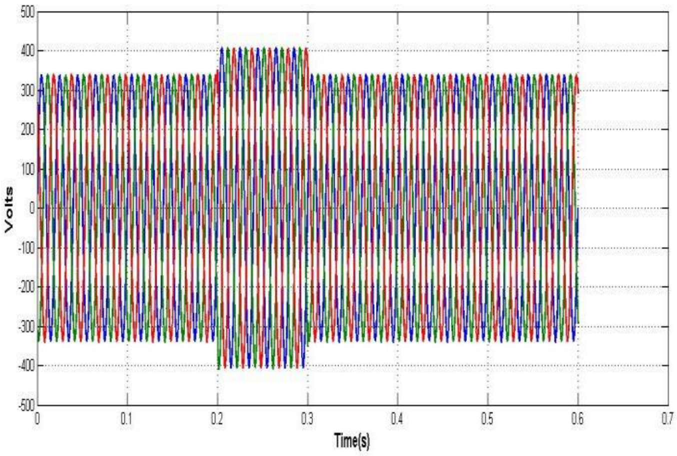
Grid Voltage
Load Voltage
Volts
Time(s)

(c)



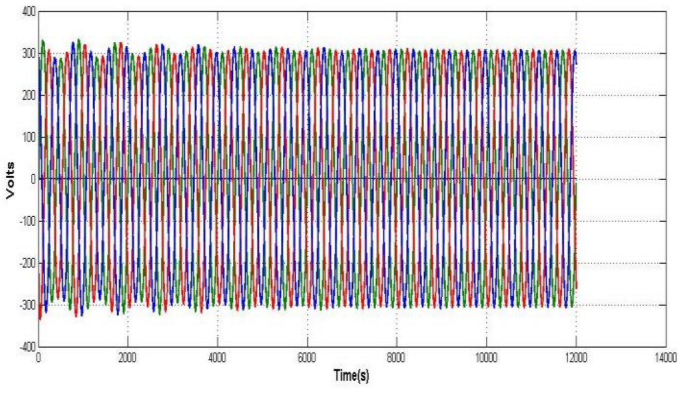
Signal to analyze
Display selected signal
Display FFT window
Selected signal: 30 cycles. FFT window (in red): 1 cycles
Time (s)
FFT analysis
Fundamental (50Hz) = 313.6 , THD= 3.30%
Mag (% of Fundamental)
Frequency (Hz)

(d)



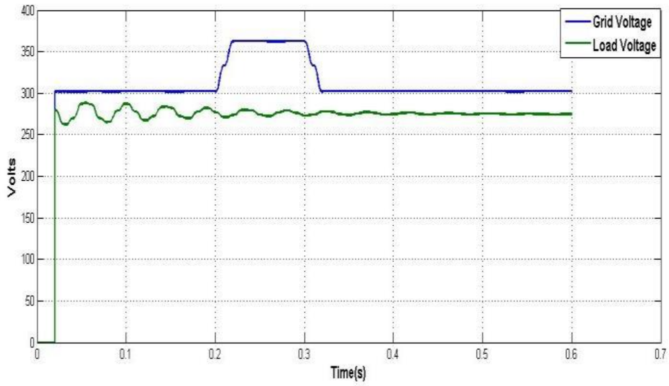
Volts
Time(s)

(e)

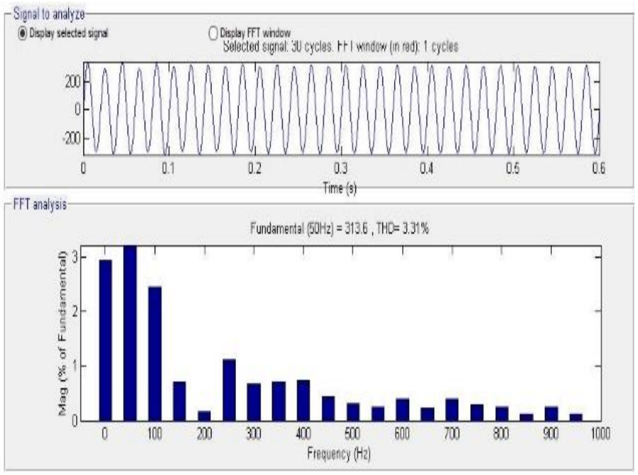


Volts
Time(s)

(f)



(g)



(h)

Fig's. 4. (a) Voltage Sag condition (b) Voltage sag after mitigation (c) Source and load rms voltage after the sag condition (d) THD After mitigating Sag (e) Voltage Swell condition (f) Voltage swell after mitigation (g) Source and load rms voltage after the swell condition. (h) THD After mitigating Swell

5 Conclusion

DVRs maintain power quality by preventing the users from the voltage disturbances from the utility side. In order to reduce the active power injection into the grid, here we have used a DVR device and DVR is integrated with the energy storage device UCAP. Due to some disadvantages of UCAP, mainly this can handle low voltage applications, we have newly implemented the SMES with PV is also used as back up to mitigate all kinds of voltage disturbance and that enables the power system to maintain quality power. In this work IGBTs were used in the design of bi-directional dc-dc converter which enables it to operate at the high switching frequencies and less switching losses. SMES based DVR enhances the power quality compared with UCAP based DVR. In the future A comparative analysis can be drawn in future by designing other energy storage systems like flywheel (FESS) and batteries (BESS) based DVR in mitigating sag and swell. In this work triggering pulses were generated using PI Controller, parks transformation technique but much accuracy can be obtained by using AI technology in future.

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