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Power Quality Improvement in Modified Solid State Transformer System Using Statcom

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Abstract— **Power quality is a major issue of loads in the distribution system used in industrial and domestical appliances. In this work, we proposed a modified solid state transformer system using statcom to improve the power quality of loads in the distribution system. The proposed model is used to eliminate voltage sag, and swell. The matrix converter is adopted in the proposed design of modified solid state transformer to reduce the power loss. The control strategy of matrix converter is done by sinusoidal pulse width modulation techniques. In addition to this, harmonics are reduced by using vector proportional integral controller. The simulation is done in MATLAB/SIMULINK software, the several case studies are carried out and the simulation results shows that the proposed system has better voltage regulation than that of conventional system.**

Key words— **PV, High frequency transformer, Matrix converter, statcom, MPPT, SPWM.**

I. INTRODUCTION

Power quality is a major aspect in power systems. The term power quality refers to voltage stability, frequency stability. The main objective of power quality is to deliver power with good quality. Harmonic distortion is the significant problem to maintain power quality [1]. The main reason for it is the majority of loads in the distribution system are linear lagging power factor loads and nonlinear loads such as AC drives and DC drives used in industries and domestic appliances. These loads draw the reactive power and inject the harmonics in the system which results in distorted supply and voltage drop at the load end. These kinds of power quality problems can be mitigated by the use of FACTS devices such as STATCOM connected at the PCC. For compensating the load and neutral current, there are many topologies in STATCOM such as single phase Voltage Source Converter, 3-leg VSC, 4-leg VSC with split capacitor. The proposed system uses 2-leg VSC with dc link capacitor.

Now-a-days the demand for electrical power has increased continuously day by day. So the usage of alternative renewable sources like PV, Wind, Fuel cell and tidal power has increased significantly [2].The microgrid is the new technique employed, which is used to reduce the power shortage problem. The research topics are mainly based on AC microgrid applications. But recently AC microgrid is integrated with the DC microgrid for reliable usage of power. The basic idea of DC microgrid consists of renewable energy sources. The power generated by renewable sources will supply power to the local load, or delivered to the utility. Comparing to AC microgrid, the DC microgrid has some advantages: 1) easily to integrate with the hybrid system in which different sources such as PV, supplying power to the Microgrid; 2) efficiency of the hybrid system gets increased because the power conversion stages are eliminated in the dc and the usage of filter is reduced; 3) there is no synchronization problem (frequency mismatching) in dc because the dc supply has no frequency.4) losses associated in the system is very low.

When the system is interface to an AC grid by using converter, and the conventional transformers. The transformer size gets higher and the efficiency gets reduced. The modified solid state transformer is used to interface the AC and DC microgrid. Comparing to conventional transformer, the MSST has reduced size and weight, oil free transformer and it is friendly to environment. The main function of the MSST is Protects load from power supply disturbances, Protection against output short circuit, Operates on distributed voltage level, Medium frequency isolation. Due to this a modified solid state transformer are used which improves efficiency and the size of the transformer gets reduced.

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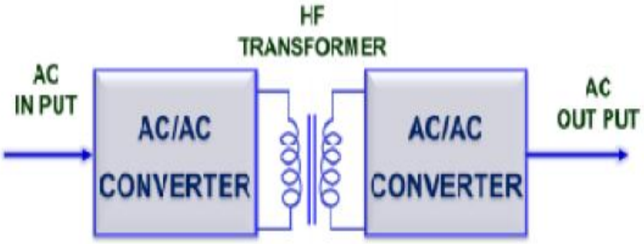
II.CONVENTIONAL SST MICROGRID SYSTEM

The Fig.1 shows the basic block diagram of the SST using high frequency (HF) or medium frequency (MF) AC link without DC link capacitor [3]. In this system, the line side



AC Waveform is modulated with a converter to a high frequency Square wave and passed through HF transformer.

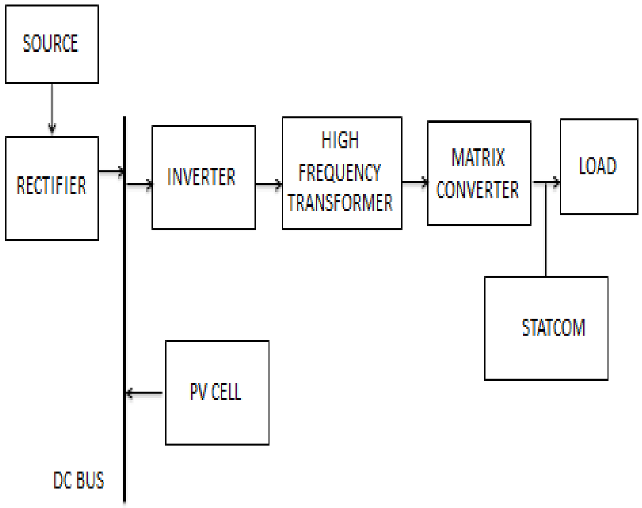
Fig.1. conventional design of solid state transformer

Then the square wave demodulated to alternating wave again by a converter. Since the frequency of the transformer is inversely proportional to its size. The HF/MF transformer is much smaller than the power-frequency transformer. So, the sizes of the transformer, weight and stress factors are reduced considerably.

Due to lack of energy storage system, the design of SST with high frequency AC link fails to protect the critical loads from instantaneous power interruptions. The Fig. 1 shows the basic block diagram of a SST with DC link capacitor which includes three stages. The first stage is an AC/DC converter which shapes the input current, corrects the input power factor and regulates the voltage of primary DC bus. The second stage is an isolation stage which provides the galvanic isolation. In this stage, the DC voltage is converted to a high frequency square wave voltage by DC/AC converter which is coupled to the primary side of the HF transformer. The secondary side voltage of HF transformer is rectified to DC by another AC/DC converter. The output stage is a voltage source inverter which produces the desired AC waveforms. In comparison to the first design, the voltage or current of this design can be flexibly controlled in either side of HF transformer. It is possible to add energy storage to enhance the ride-through capability of the SST. The use of too many converters and DC-link electrolytic capacitors reduces the efficiency of the SST. In this paper, a model of MSST is proposed which provides better efficiency and voltage regulation without any electrolytic storage.

III. PROPOSED DESIGN OF MSST

The proposed MSST is comprised of three sections which are input stage, isolation stage and output stage without any DC storage capacitor. The input stage comprises of PWM (pulse width modulation) converter, class C chopper which acts as boost regulator and low pass tuned filter. The isolation stage is comprised of PWM inverter, high frequency transformer with high insulation capability and tuned high pass filter. A matrix converter is used in the output stage of the proposed design. The Fig. 2 shows the block diagram of the proposed MSST. The matrix converter ensures power quality issues like sag correction and reactive power compensation. The three stages of SST can be controlled independently from the other one. The close loop control is required for overall operation of the system. The converter of the input stage controls the input current and power factor and keeps the DC link voltage at a desired reference value .The PWM maintains the synchronism between input and output as well as reduces harmonics. The dc chopper is used as boost regulator which regulates the



amplitude of output dc voltage with frequency operation.

Fig.2. Proposed design of modified solid state transformer

It is the single phase, three stages modified solid state transformer. It consists of rectifier section, inverter section and matrix converter section. Fig 3 shows the abc to dqo transformation In the rectifier section, the Single-phase d-q decoupled control is provided for the ac/dc Converter. Here abc coordinates with PLL loop are transformed into the dq0 frame for easy to control the required system. Then the direct axis current (Isd), direct axis voltage(Vsd) ,and quadrature axis current(Isq),quadrature axis voltage(Isq).

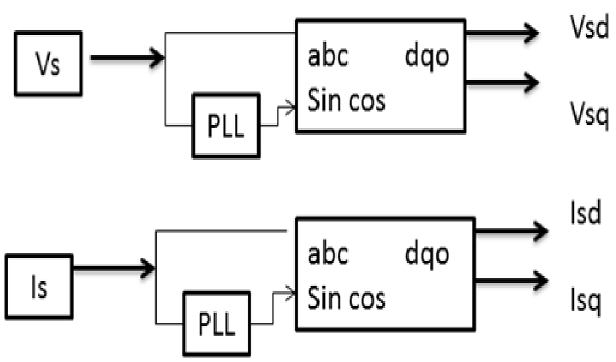


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Fig.3. abc to dqo transformation

Then the q-axis current are compared with the reference current and produces the output. Then the VPI controller is used for producing the error signal which in turns to add with the output signal. Then it is provided by the q-axis voltage and produces the required voltage for the dq0 to abc transformation.

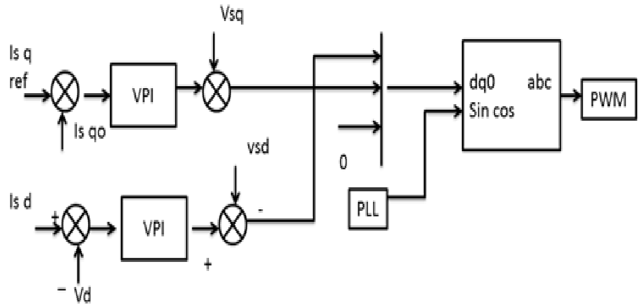

Fig.4. Rectifier section

Fig 4 shows the rectifier section. The d-axis current is compared with the d-axis voltage then produces the output, which is provided by the VPI controller is shown in Fig 5. It adds the error signal and compared with the d-axis voltage produces the voltage required for the abc transformation. The PLL loop is provided in the transformation block. It is used for generating the sine wave, cosine wave. Depending upon the output from abc frame, the pulse width modulation is used to generate the gate pulses. The gate pulses produced which is used for turn on and turn off the switching devices such as MOSFET, IGBT, SCR, etc.

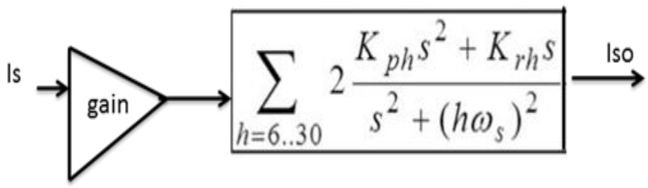

Fig.5. VPI controller block

IV. PHOTOVOLTAIC CELL

The radiation from the sun light falls on the PV panel, which is used to sense the voltage and the current. The optimum voltage and current can be obtained by PV control. The boost converter is used to connect the low dc voltage from the PV panel and high voltage dc bus. The boost converter which is used for increase the output voltage produced by the PV panel. There are two main operations in the boost converter. The first method is to operate the boost converter in the maximum power point tracking (MPPT) mode, it is normal mode of operation at that time system operates in the grid connection mode. Another method is to operate the PV panel in the power tracking mode which tends to supply the maximum power needed to the system [4].

Fig 6 shows the PV is operated in MPPT mode. Perturb and observe (P&O) method is applied here for finding the optimum operating voltage by using the MPPT technique it can be achieved. So, the dual control loop scheme is implemented here for absorb the voltage reference from the PV. The internal current loop is different from the external voltage loop.

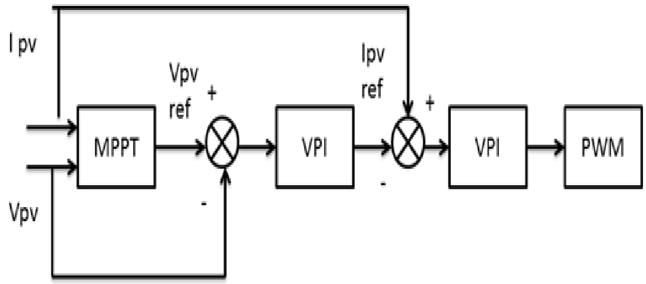

Fig.6. PV is operated in the MPPT mode

Then the second stage is inverter stage is shown in Fig 7. Dual loop controller is applied for conversion of dc/ac. The dc bus voltage is taken as reference and it is compared with the dc voltage. Then the comparator compares and produces the voltage, which is applied to the VPI controller adds the error signal into it. Then the PLL loop is provided for generating the sine wave, cosine wave. The product block is used to multiply the both the inputs and produces the combined output. Depending upon the output, PWM generator produces the gate pulse which is used to switch on/ off the power electronics devices.

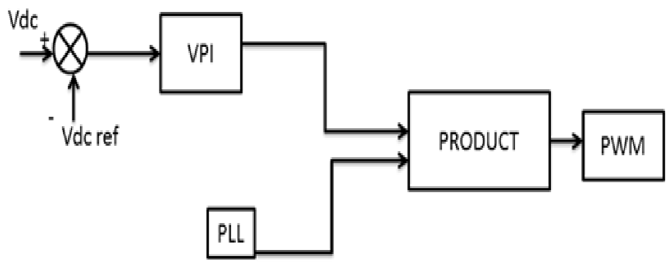

Fig.7. Inverter section

The third stage is high frequency transformer. The first step is the selection of core and the second step is the selection of turns in primary and secondary coils which determines the magnetic flux density within the core. The change is flux density of the transformer can be written by the following equation of the transformer. The change in flux density depends on the frequency, f= 1/T and the number of turns.
So, the Emf equation of the transformer is given by:

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E=4.44*f*N*A*B ---- (1)

V.MATRIX CONVERTER

The output stage consists of matrix converter is shown in Fig 8.The matrix converter directly converts AC to AC rather than AC- DC -AC as in existing voltage source PWM AC. The frequency input (5000Hz) to a power frequency output (50 Hz).The proposed converter produces required output voltage with suitable shape and frequency [5]. The matrix converter has ability to generate power and reduces input current harmonics and therefore it is considered as a suitable option for driving rotating machines. For the proposed design, the sinusoidal pulse width modulation (SPWM) is used for switching of the matrix converter. The advantages of using SPWM are simplified control mechanism and maximum voltage transfer ratio is obtained without considering third harmonic components. The SPWM manages each switching state of a two level converter as a point in space.

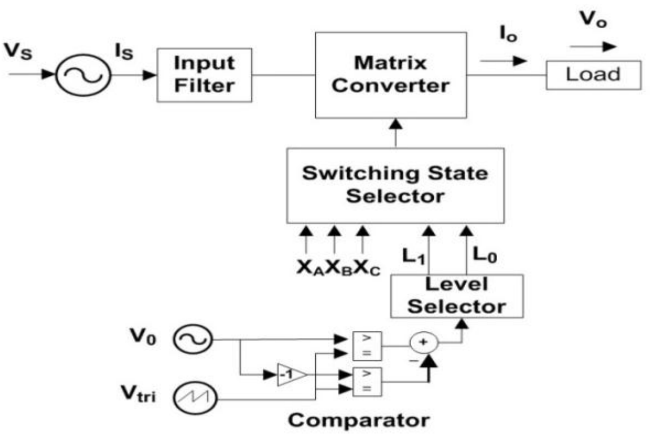


Fig.8. controller of matrix converter

A reference phase is rotating in the plane for each switching period, the fundamental frequency is sampled, and the switching states of the converter are selected with duty cycles calculated to achieve the same average as the sampled reference phase. It directly controls the line to line voltages of the converter as well as minimizes the THD of third harmonic distortion. However in comparison to conventional pulse width modulation based converter, the sinusoidal based matrix converter requires more switching devices [6]-[8]. The control block of the matrix converter is shown in Fig.8. The matrix converter is operated according to the switching topology which is determined according to the system requirement The level selector is used which determines the switching sequence of the switching devices of the converter. The comparator is used for generation of SPWM triggering pulses for switching. The output frequency of the matrix converter is controlled according to the switching topology and input signal frequency. The reliability and power quality of the overall system can be significantly improved by using proposed MSST.

VI.STATCOM

The voltage source converter is a one type of power electronics device, which converts a DC input voltage into AC output voltage which supplies the active and reactive power needed by the system and to mitigate voltage sag and swell. VSC can produce sinusoidal voltage with suitable frequency and phase angle. Fig 9 shows the STATCOM connected to a network. Capacitor is used to supply power to Voltage source converter. STATCOM controller is used for improving the power quality at the distribution level by making the voltage stable [9]. A voltage source converter at the distribution voltage level, the switching device is generally the MOSFET due to its lower switching losses and reduced size.

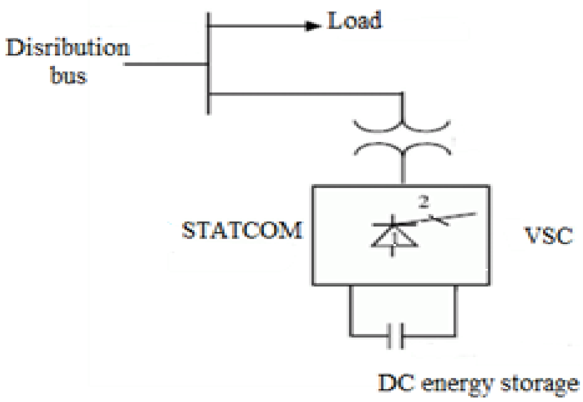


Fig.9. STATCOM connected to a network

The STATCOM operation depends upon reactive current generation, so I vary as,

$$I = \frac{V - V_0}{X} \qquad -(2)$$

Where Vo, V, X are the output voltage of the MOSFET based inverter, system voltage, and the transformer leakage reactance and system short circuit reactance respectively. When the voltage across secondary terminal (Vd) is lower than the bus voltage (Vb), the STATCOM absorbs reactive power from the bus. When the secondary terminal voltage (Vd) is higher than the bus voltage (Vb), the STATCOM acts like a capacitor generating reactive power to the bus. During steady state working condition, the voltage V_2 produced by VSC is in phase with V_1 no reactive power flow in system. If the magnitude of the voltage V_2 produced by the VSC is less than the magnitude of V_1, the reactive power is flows to VSC. (i.e absorbing the reactive power). If V_2 is greater than V_1 the reactive power is flows to power system (i.e STATCOM producing reactive power) and if the V_2 is equal to V_1,the exchange of reactive power is zero. The amount of reactive can be given as,

$$Q = \frac{V_1(V_1 - V_2)}{X} \qquad \text{--(3)}$$

The STATCOM connected in shunt with the ac system provides multiple functions which can be used for up to three quite distinct purposes such as Voltage regulation and compensation of reactive power, power factor Correction, reduction of current harmonics [10]-[13].

VII SIMULATION RESULTS

Voltage sag occurs when the rms voltage decreases between 0.1 to 0.9 p.u of nominal voltage. The main factor cause of voltage sag is sudden load changes or excessive loads. The Fig 10 shows that the voltage sag occurred at the time 0.2 to 0.4sec due to overloading of the system. Beyond 0.4 sec, overloading is disconnected, and the system resumes to steady state.

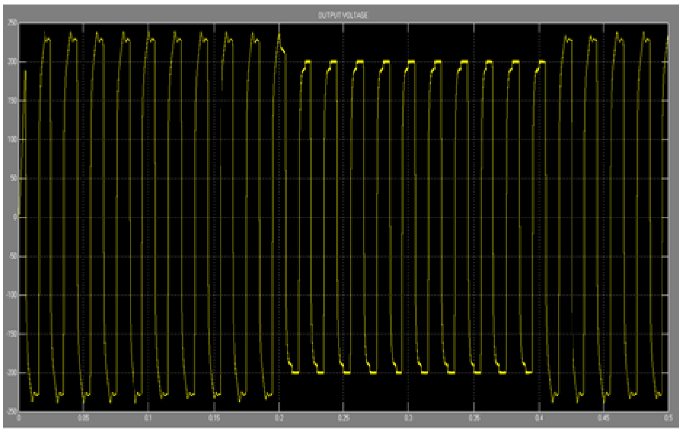


Fig.10. voltage sag

During the time 0.2 to 0.4sec the voltage sag occurred is shown in Fig 10. It can be compensated by connecting statcom parallel to the load. It supplies compensating voltage and makes the system to be steady state. So, the constant voltage is maintained throughout the system. Fig 11 shows the voltage sag compensation is done during 0.2 to 0.4sec.

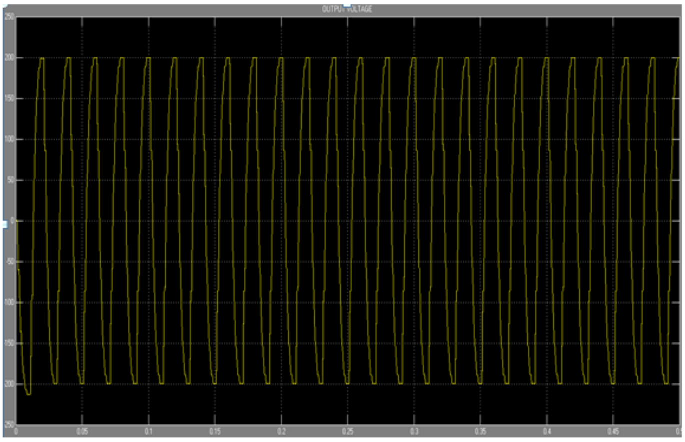
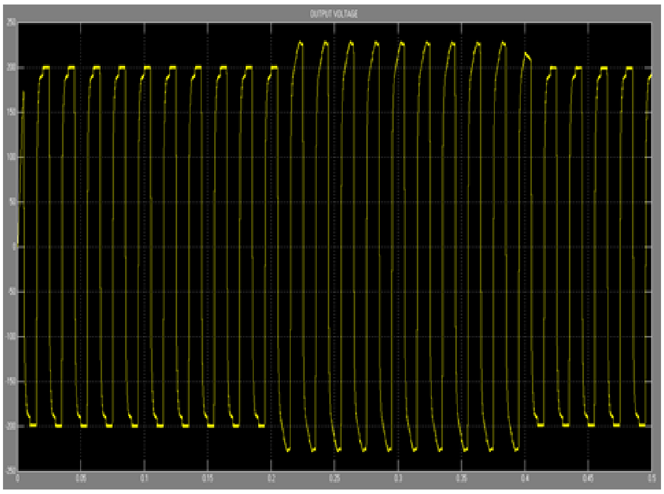


Fig.11.voltage sag compensation

Voltage swell occurs when the rms voltage increase between 0.1 to 0.9 p.u of nominal voltage It occurs due to disconnection of the loads in the system .The Fig 12 shows that the voltage swells occurring from 0.2 to 0.4sec. And beyond which, the normal load is connected and the system resumes to normal state.

Fig.12. voltage swell.

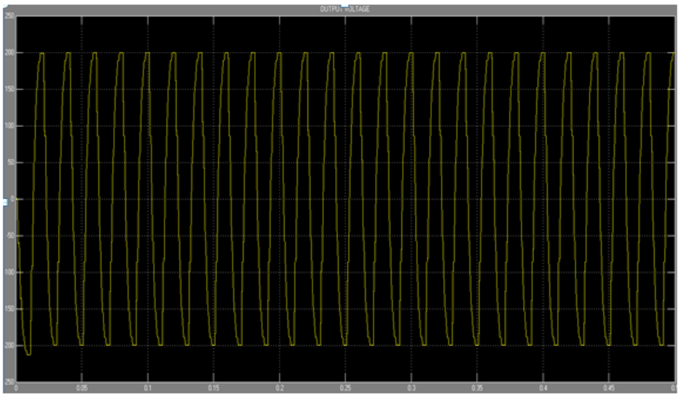
The mitigation of voltage swell is done by statcom is shown in Fig 13. During the time 0.2 to 0.4 sec, statcom absorbs the reactive power, thereby the voltage is to be maintained



constant throughout the system.

Fig.13.mitigation of voltage swell

While comparing to conventional system, the THD of the proposed system is improved by using vector proportional



integral controller.

	EXISTING	PROPOSED

	SYSTEM	SYSTEM
THD	37.91	13.47

Fig.14.THD for existing and proposed system

VIII CONCLUSION

In this paper, a new model for modified solid state transformer has been proposed. The advantages of this configuration are power factor correction, better voltage regulation. The proposed model eliminates voltage sag and voltage swell using statcom across the distribution system. The vector proportional integral controller eliminates the effects of harmonics in the output. The matrix converter in the proposed system reduces two conversion stages which reduces the power loss and improves the efficiency of the system. Thus the simulation model is designed and the result verifies the proposed system has better voltage regulation than that of conventional system.

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