Optimal Siting of DG for Voltage Improvement Using STATCOM and RES

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Abstract: *T Incorporating photovoltaic (PV) inverters into power distribution systems using static synchronous compensators (PV-STATCOM) during nighttime has recently been proposed to enhance network performance. The allocation of PV-STATCOM devices in distribution networks is formulated to simultaneously minimize electrical energy losses and improve the voltage profile while considering 24-hour load variations. The impact of different numbers of installed PV-STATCOM devices on distribution systems is analyzed. Virtual STATCOM is a widely used device for enhancing the voltage of weak buses in an eight-bus system. This work deals with modeling and simulation of closed loop controlled Three Phase voltage source inverter based VIRTUAL - STATCOM in eight bus system.*

Keywords: *STATCOM- Static compensator PV-Photo volatic*

I. INTRODUCTION

The increasing power demand due to urbanization, industrialization, and rising living standards places a significant burden on utilities. Traditional power sources are insufficient to meet global power demand, leading to electricity stability and security challenges, while large-scale pollutant emissions raise serious environmental concerns. Over the past few decades, renewable and distributed energy resources (DER) have emerged as viable alternatives to conventional energy sources, offering a solution to meet load demand while addressing power system issues effectively.A key advancement in renewable energy systems is Hybrid Renewable Energy Systems (HRES)-based Distributed Generation (DG), which has demonstrated high performance and reliability. Numerous proposals have been made to optimize the use of various renewable energy resources for electricity generation. Among developed renewable energy technologies, wind and solar energy sources are widely utilized in hybrid systems. Solar PV-Wind hybrid systems have gained significant attention from utility companies worldwide.

With the increasing integration of renewable energy and nonlinear loads, power quality has become a major concern. This issue primarily arises from nonlinear power electronic devices that distort the sinusoidal supply waveform by introducing frequency distortions into the grid. Studies indicate that integrating Renewable Energy Conversion (REC) systems into the power grid contributes to harmonic distortions at the Point of Common Coupling (PCC). This research employs the STATCOM converter as an active power filter to regulate voltage, reactive power, and power quality in grid-connected wind and solar farm

II. OVERIVIEW Of STATCOM

A Static synchronous compensator is a shunt-connected static var compensator whose capacitive or inductive output current can be controlled independent of the ac system voltage".The concept of STATCOM was proposed by Gyugyi in 1976. Power Converter employed in the STATCOM mainly of two types i.e. is Voltage Source Converter and Current Source Converter. In Current source Converter direct current always has one polarity and the power reversal takes place through reversal of dc voltage polarity while In Voltage Source Converter dc voltage always has one polarity, and the power reversal takes place through reversal of dc current polarity. The power semiconductor devices used in current source converter requires above reasons Voltage source converter is Preferred over Current source converter and now these days it act as a basic electronic block of a STATCOM that converts a dc voltage at its input terminals into a three-phase set of ac voltages at fundamental frequency with controllable magnitude and phase angle.In STATCOM different technologies used dependent upon the power ratings of STATCOM. For higher power STATCOMs GTO based technologies are used while for lower power STATCOMs IGBT based technologies used.

STATCOM is made up of a coupling transformer, a VSC and a dc energy storage device. STATCOM is capable of exchanging reactive power with the transmission line because of its small energy storage device i.e. small dc capacitor, if this dc capacitor is replaced with dc storage battery or other dc voltage source, the controller can exchange real and reactive power with the transmission system, extending its region of operation from two to four quadrants. A functional model of a STATCOM is shown in Figure 1.

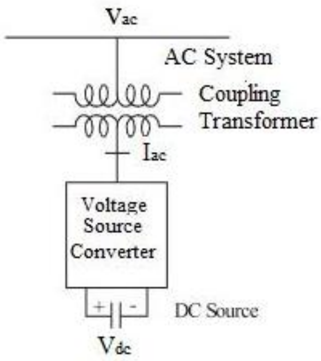

Fig.1 Functional model of STATCOM

The relationship between fundamental component of the converter ac output voltage and voltage across dc capacitor is given as Where *k* is coefficient, which depends upon on the converter configuration, number of switching pulses and the converter controls. The fundamental component of the converter output voltage i.e. V_{out} can be controlled by varying the dc voltage across capacitor which can be done by changing the phase angle α of the operation of the converter switches relative to the phase of the ac system bus voltage. The direction of flow of reactive power whether it is from coupling transformer to the system or from system to the coupling transformer depends upon the difference between the converter output voltage and the ac system bus voltage. The real power flowing into the converter supplies the converter losses due to switching and charges the dc capacitor to a satisfactory dc voltage level. The capacitor is charged and discharged during the course of each switching cycle but in steady state, the average capacitor voltage remains constant. If that were not the case, there would be real power flowing into or out of the converter, and the capacitor would gain or lose charge each cycle. In steady state, al1 of the power from the ac system is used to replenish the losses due to switching.

The STATCOM's ability to absorb/supply real power depends on the size of dc capacitor and the real power losses due to switching. Whenever the DC capacitor and the losses are relatively small. The amount of real power transfer is also relatively small. This implies that the STATCOM's output ac current I_{ac}, has to be approximately + 900 with respect to ac system voltage at its line terminals. Varying the amplitude of the converter three-phase output voltage V_{out} controls the reactive power generation/absorption of the STATCOM. If the amplitude of the converter output voltage V_{out} is increased above the amplitude of the ac system bus voltage V_{ac} then the ac current I_{ac}, flows through the transformer reactance from the converter to the ac system generating reactive power.

In this case, the ac system draws capacitive current that leads by an angle of 900 the ac system voltage, assuming that the converter losses are equal to zero. The ac current flows from the ac system to the voltage-sourced converter if the amplitude of the converter output voltage is decreased below that of the ac system, and consequently the converter absorbs reactive power. For an inductive operation, the current lags the ac voltage by an angle of 90^0. Assuming again that the converter losses are neglected. If the amplitudes of the ac system and converter output voltages are equal, there will be no ac current flow in/out of the converter and hence there will be no reactive power generation/absorption the ac current.

III. PROPOSED DIAGRAM

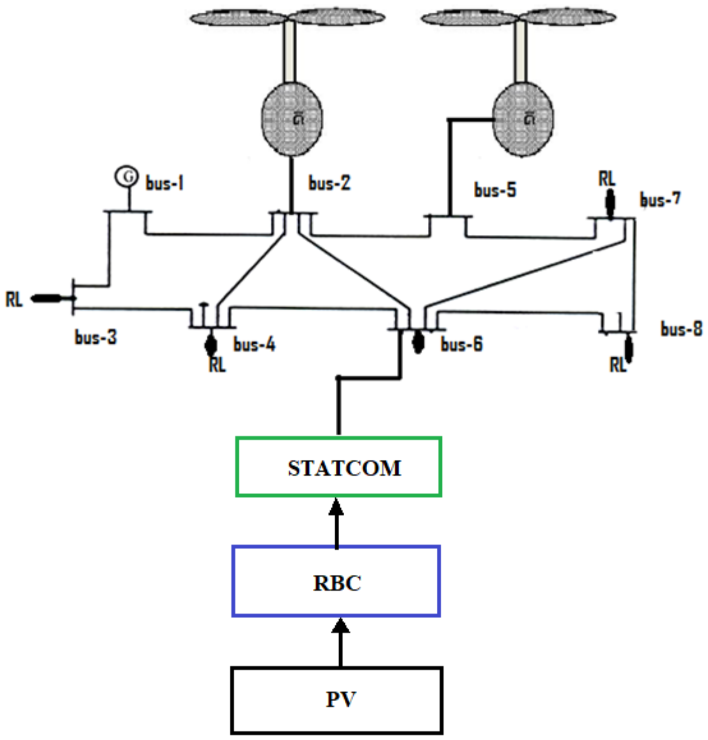

Fig.2 Views Of Smart Mirror.

This diagram represents an electrical distribution system integrated with a photovoltaic (PV) system and a static synchronous compensator (STATCOM) for voltage and power quality management. The key components and their roles are:

1. **Bus System**:
- The diagram shows multiple buses (bus-1 to bus-8) forming a distribution network.
- Loads (RL) are connected to various buses, indicating the presence of power consumers.
- Two wind turbines are connected at bus-2 and bus-5, indicating wind energy integration.

2. **PV System**:
- The PV system is placed at the bottom of the diagram, representing a renewable energy source.
- It supplies power to the system and is managed through a Renewable Battery Controller (RBC).

3. **Renewable Battery Controller (RBC)**:
- The RBC manages the power flow from the PV system and ensures stable operation.
- It helps in regulating voltage and energy storage.

4. **STATCOM (Static Synchronous Compensator)**:
- STATCOM is connected to regulate voltage levels and improve power quality.
- It compensates for reactive power and stabilizes the grid under varying load conditions.
- It plays a crucial role in mitigating voltage fluctuations caused by renewable energy sources like PV and wind.

Functionality
- The system integrates wind and solar power sources to support the grid.
- The PV system, controlled by RBC, supplies energy to the network.

- STATCOM enhances the voltage profile and power stability.
- The distribution network ensures proper energy flow to various buses, with loads connected at different points.
- This hybrid system improves power reliability by leveraging renewable energy sources while maintaining grid stability using STATCOM.

IV. SIMULATION RESULTS AND DISCUSSIONS

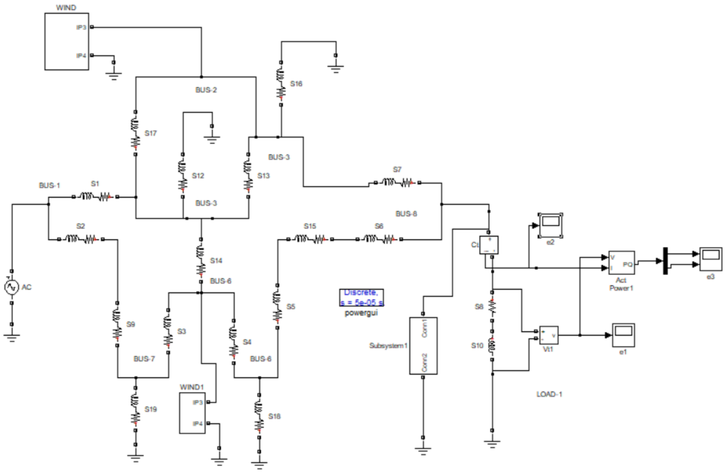

Fig.3 8 bus system without STATCOM model

Circuit diagram of 8 bus system without STATCOM model is shown in fig 3.2. Voltage at bus-8 is shown in fig 3.3 and its value is 650V. Current at bus-8 is shown in fig 3.4 and its value is 12A. Real and Reactive power at bus-8 are shown in fig 3.5 and its value are 4.25 MW and 800 VAR.

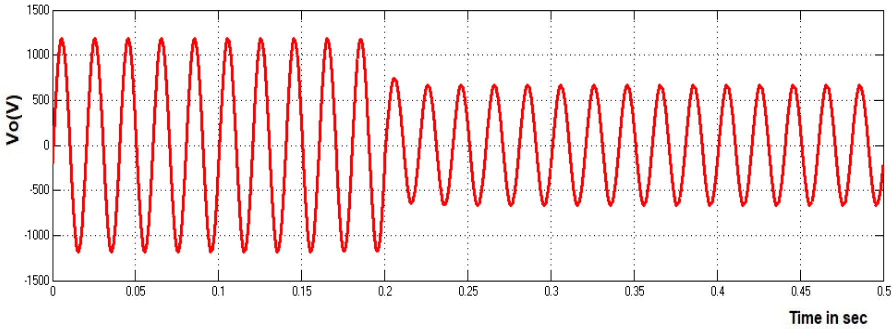

Fig.4 Voltage at bus-8

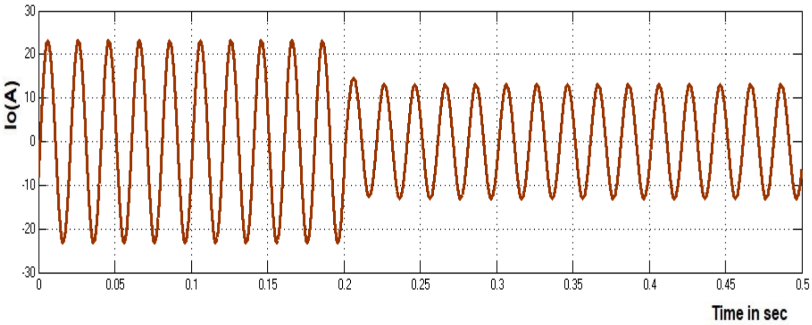

Fig.5 Current at bus-8

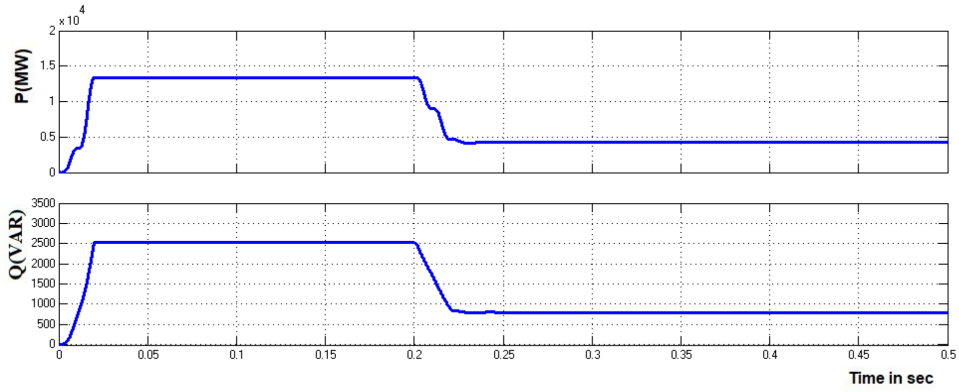

Fig.6 Real and reactive power at bus-8

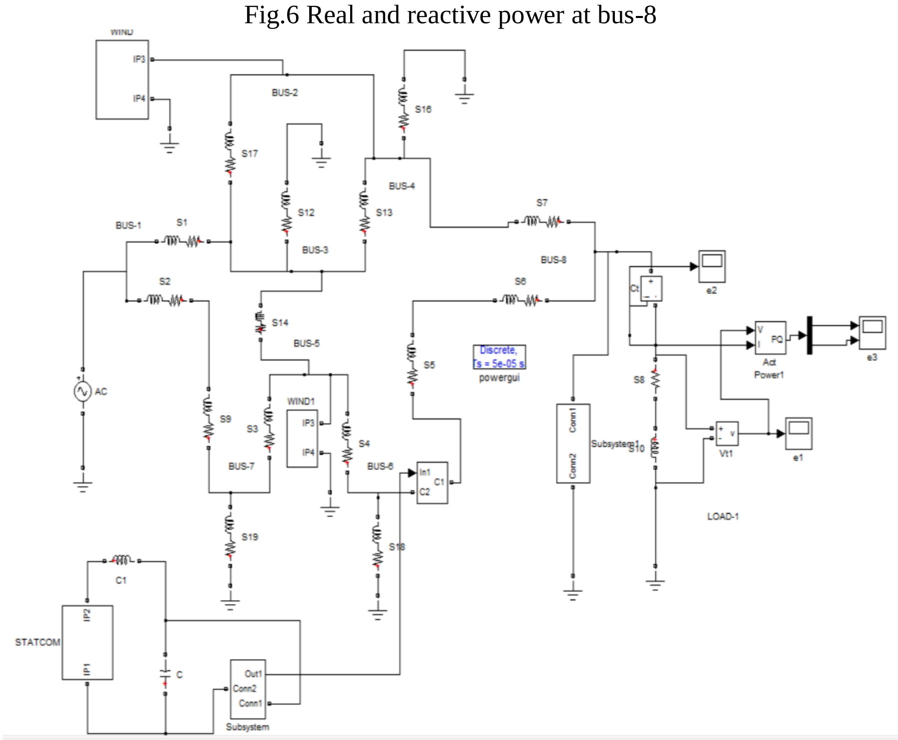

Fig.7 8 bus system with STATCOM model

Circuit diagram of 8 bus system with STATCOM model is shown in fig 3.6. PV & RBC FED STATCOM MODEL is shown in fig 3.7. Circuit diagram of Re-Boost Converter is shown in fig 3.8. Voltage at bus-8 is shown in fig 3.9 and its value is 1270V. Current at bus-8 is shown in fig 3.10 and its value is 24A. Real and Reactive power at bus-8 are shown in fig 3.11 and its value are 16.2 MW and 3000 VAR.

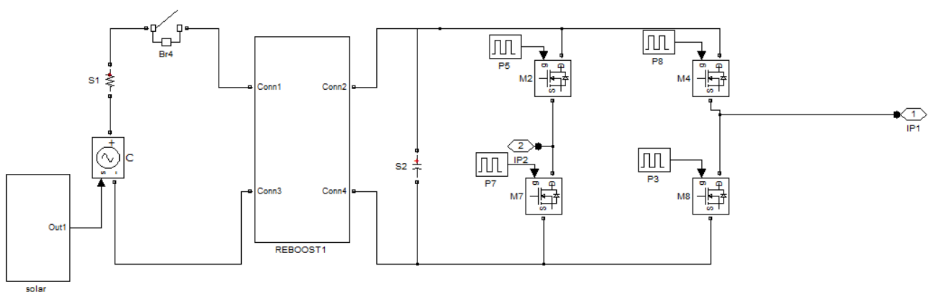

Fig.8 PV & RBC FED STATCOM MODEL

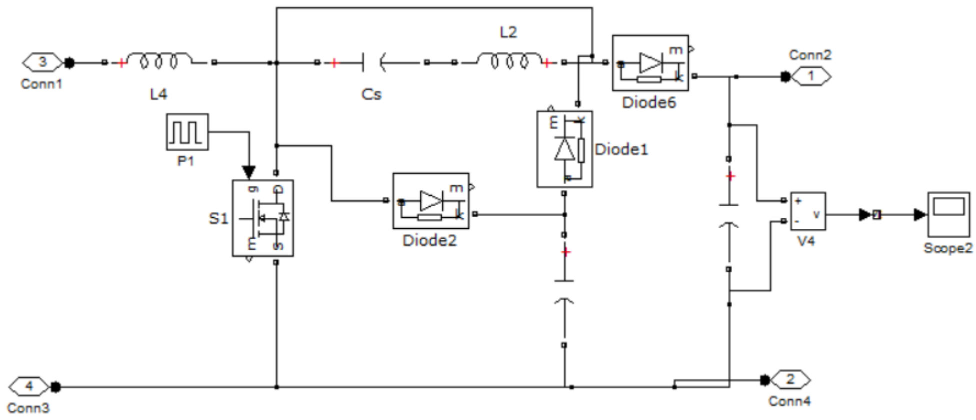

Fig.9 Circuit diagram of Re-Boost Converter

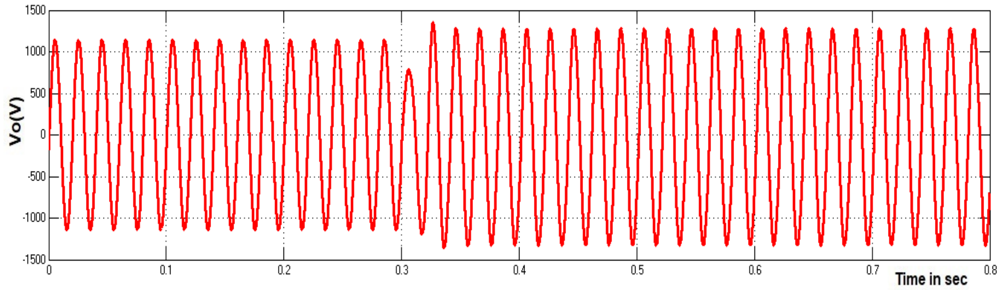

Fig.10 Voltage at bus-8

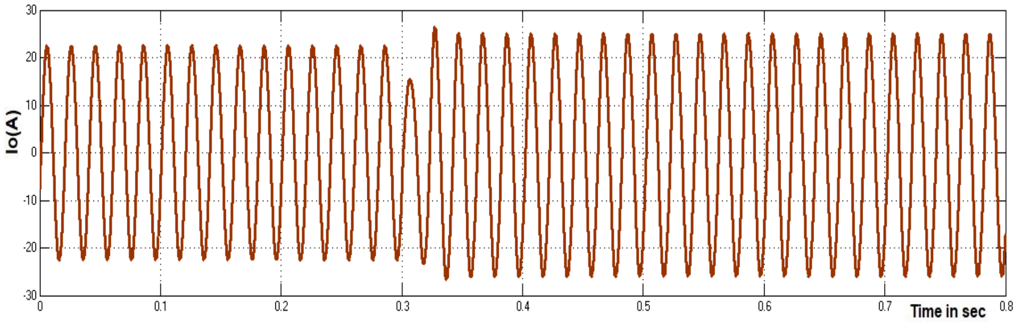

Fig.11 Current at bus-8

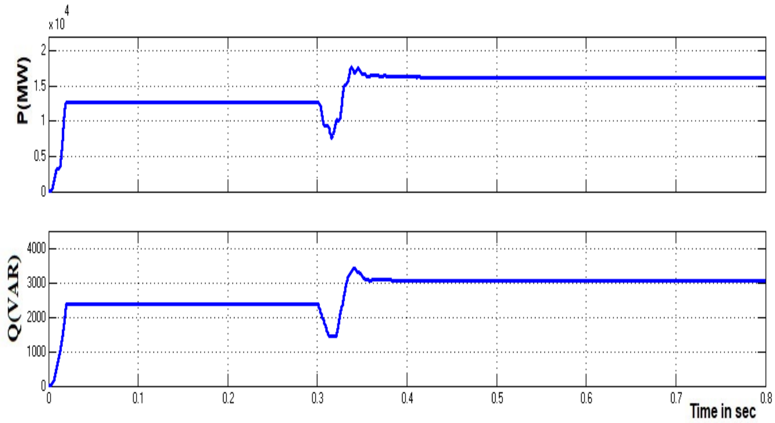

Fig.12 Real and reactive power at bus-8

TABLE-3.1 COMPARISON OF VOLTAGE, REAL POWER & REACTIVE POWER

8-bus system	Voltage at bus-8 (V)	Real power at bus-8 (MW)	Reactive Power at bus-8 (VAR)
Without STATCOM	**680**	**4.25**	**800**
With STATCOM	**1270**	**16.2**	**3000**

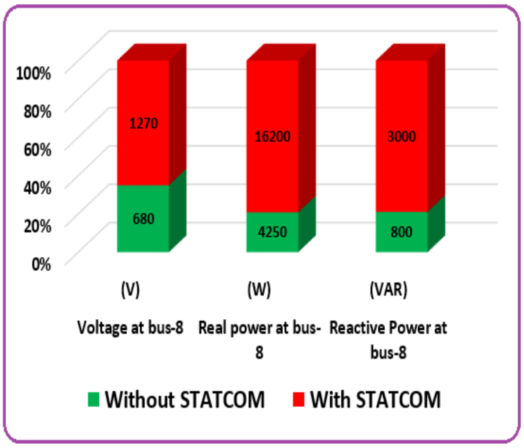

Fig.13 Bar chart Comparison of voltage, Real Power & Reactive Power

V. CONCLUSION

Circuit diagram of 8-bus system without STATCOM system is simulated. Circuit diagram of 8-bus system with STATCOM system is simulated. Above systems are compared. Without STATCOM, the voltage at bus-8 is quite low (680V), indicating instability.With STATCOM, the voltage increases to 1270V, showing better voltage regulation and stability.The real power at bus-8 significantly rises from 4.25 MW to 16.2 MW, demonstrating STATCOM's ability to support active power flow and reduce losses.STATCOM improves reactive power support from 800 VAR to 3000 VAR, ensuring better voltage regulation and power factor correction. The results clearly show that integrating STATCOM enhances voltage stability, increases real power delivery, and significantly boosts reactive power compensation. This leads to a more stable and efficient power distribution network.

VI. REFERENCES

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