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Comparison of Demand Side Management using Electric Spring and STATCOM

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ABSTRACT:

Along with nonlinear and unbalanced loads, the rising penetration of distributed generating into the power distribution network have various deteriorating effects, such as poor power quality and stability issues. The static synchronous compensator (STATCOM) and a new device electric spring (ES), can successfully address these challenges. This study compares STATCOM and ES' fundamental ideas and characteristics that improve power quality, like the ability to compensate for reactive power and regulate voltage.The MATLAB/SIMULINK software is used to simulate the ES Structure and STATCOM in the hybrid system and check the outputs. The results show that ES successfully offsets reactive power while controlling voltage and frequency.

Keywords: Electric Spring (ES), STATCOM, Smart Grid, Renewable Energy Sources (RES), Demand Side Management (DSM)

1. INTRODUCTION:

Since the past ten years, renewable energy sources (RES) like solar and wind have made significant contributions to our energy needs. Due to the scarcity of non-renewable resources and rising energy demand with decreasing operating costs, it keeps rising [1, 2]. It is impossible to establish the instantaneous generating power of the electricity grid due to the growing number of RES connected in distribution networks close to load centres. These sources may be aware or uninformed of the generating stations. Dynamic instability and fluctuation are the results of these causes resulting in unstable the mains voltage [3].The quality of the power produced by isolated generating stations that use renewable energy as their primary energy source is influenced by the weather. The frequency and stability of the mains voltage will be affected by changing weather conditions. It takes a novel control criterion to ensure that load demand follows power generation rather than the other way around in order to solve these issues [4].

In recent research, a number of methods for demand side management to ensure stabilised power generation have been presented and investigated. In [5], the use of storage devices during periods of peak demand is explored. The use of direct control is suggested for smart load controlling in [6]. Other techniques for demand side management (DSM) include real-time pricing and delay-tolerant power demand activities [7]. Using distributed resources, many researchers have offered alternative solutions to the voltage instability problem. It is suggested in[8] that battery energy storage systems can handle voltage increases during PV and wind peak production as well as voltage drops during high loads. However, it is not practical economically because of the expense of storage devices.

The Renewable energy penetration causes voltage and frequency instability and raises the probability of major load failures due to its sensitivity to weather factors. For enhancing voltage profiles and to satisfy the needs of important load customers, distributed voltage regulating and reactive compensating devices are becoming more and more common on the demand side.The STATCOM is a crucial custom power tool with a variety of benefits, including strong functionality, good performance, cost-effectiveness, and reduced space with high productivity [9,10]. By dynamically adjusting the grid with reactive power, STATCOM addresses power quality issues such improper power factor (PF), voltage fluctuation and flicker, current distortion, and three-phase unbalance. While an additional innovative power device called an electric spring (ES) has just been presented and has comparable functions. It is the electric regime's continued evolution of the Hook's low [11]. Despite the fluctuation brought on by the intermittent nature of wind power, it is discovered that the ES is effective at controlling the mains voltage and the ES provides an innovative approach to power system stability that allows for input-feedback control and makes noncritical loads' power to follow the profile of the power generation, both of which are essential for the development of a future smart power grid [12,13]. Water heaters, air conditioning units, public lighting systems, and freezers are examples of noncritical loads that can withstand a changing voltage supply.

2. FUNDAMENTALS OF STATCOM AND ES

2.1 STATCOM

A reactive power compensation device using a self-commutation variable current circuit is known as STATCOM, also known as Static Var Generator (SVG). The both inductive and capacitive reactive power can be continually compensated by altering the amplitude and phase of the inverter's AC-side voltage. The STATCOM is capable of stabilising rapid voltage changes, obstructing harmonic current, and inhibiting negative sequence reactive current brought on by unbalanced loads [10].As shown in Fig. 1, the two kinds of STATCOM's fundamental configurations are given voltage bridge topological structure and current bridge topological structure.

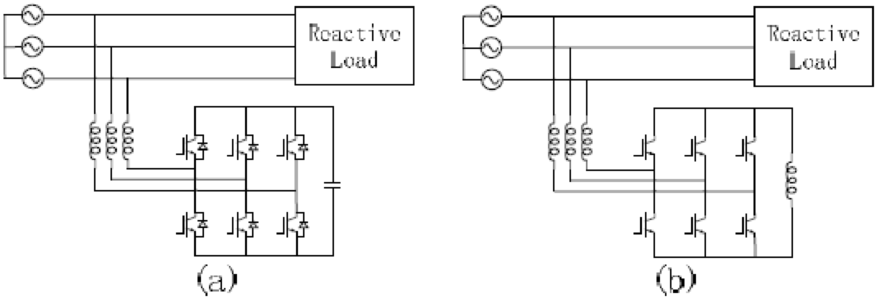

Fig.1. Topology structure a) voltage bridge b) current bridge [19]

In comparison to STATCOM with current bridge topological structure, STATCOM with voltage bridge topological structure has superior efficiency and a lower failure rate. As a result, the former form of STATCOM is more frequently utilised in real-world engineering applications [17].

2.2 The basic of ES

The restorative force of an ideal mechanical spring, according to Hooke's law, is inversely proportional to its deviation from the equilibrium position.

$F=-kx$ (1)

where, F is the restoring force of a spring that seeks to return to its equilibrium position, xis the displacement from the equilibrium position, and k is the spring constant.The mechanical spring's potential energy is expressed as

$P.E.=1/2\ kx^2$ (2)

Similar to a mechanical spring, an electric spring can support the required electric voltage, store electric energy, and dampen electric oscillations brought on by transient conditions. The expression for an electric spring (ES) is

$q=C$ a inductive mode (3)

$q=-C$ a capacitive mode (4)

$q=\int i_c\, dt$ (5)

The capacitor's current i_c, has an electric charge of q and a potential difference of Va.

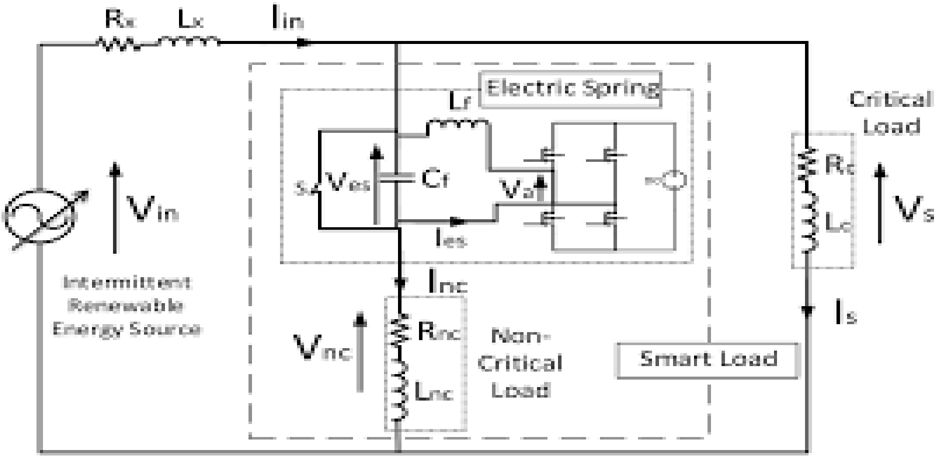

Fig. 2. Structure of power system with ES [20]

3. HYBRID POWER SYSTEM

A three phase grid power supply system, one PV generating units with DC/AC converter are used to feed the power to critical load and smart load (SL). The hybrid generation system using an electric spring for utility-side reactive power compensation and voltage regulation is shown in Fig.3.

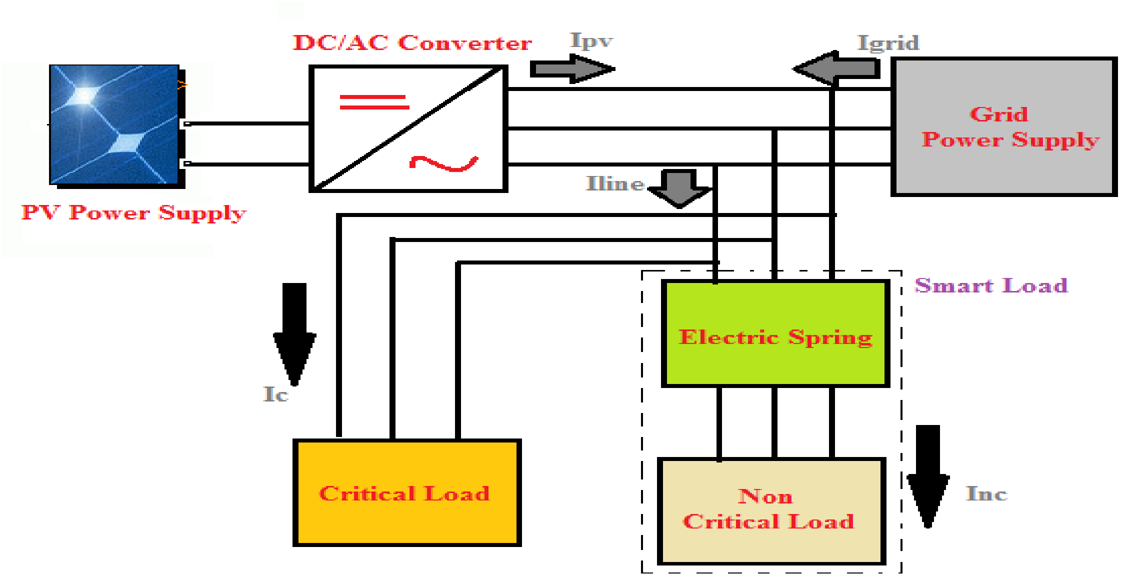

Fig.3. Block diagram of hybrid power system

3.1 PV power system

Numerous PV cells can be coupled in series or parallel to produce high voltage and power. The PV array with a DC/DC boost converter and Maximum power point tracking (MPPT) is shown in Fig. 4. To acquire the most power possible from a PV array, MPPT algorithm can regulate the output voltage of the DC/DC converter. The MPPT is achieved in this work using the Perturb and Observe technique. This method is a continuous process that looks for a voltage that boosts the PV array's power production.

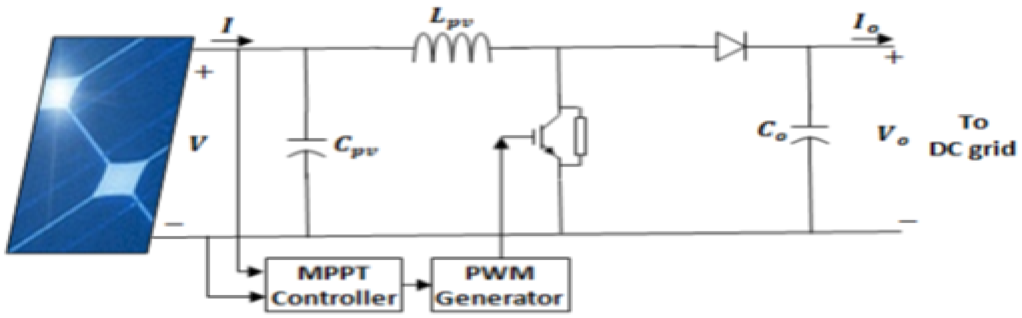

Fig. 4PV array with MPPT and DC/DC boost converter [18]

3.2 Grid power supply

The another power resource i.e. Three phase voltage source is connected to PV power generation system so it becomes hybrid power system as shown in Fig.3.

3.3 DC/AC Converter

In a PV power generation system, the inverter control should be set up so that load voltage and frequency can be maintained even in adverse weather. A synchronous reference frame-based control system is put into place to do this, as shown in Fig. 5. The switching transients generated by the inverter are decreased by an LC filter placed after it.

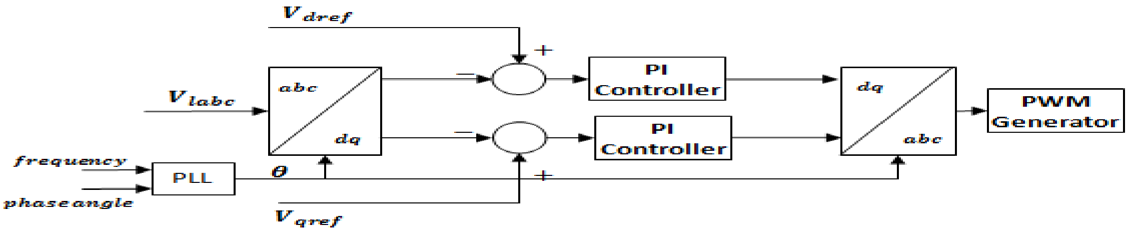

Fig. 5. Control Structure of Converter

4. SIMULATION OF DSM

The MATLAB/SIMULINK is used to model the hybrid power system with the ES as shown in Fig.6. and Table 1 illustrates the system's parameters. To lessen harmonics brought on by inverter switching transients, a harmonic filter is connected after the inverter. To control voltage magnitude and frequency as well as to account for reactive power by load, an ES is connected prior to the load in parallel with the critical load and in series with the non-critical load.

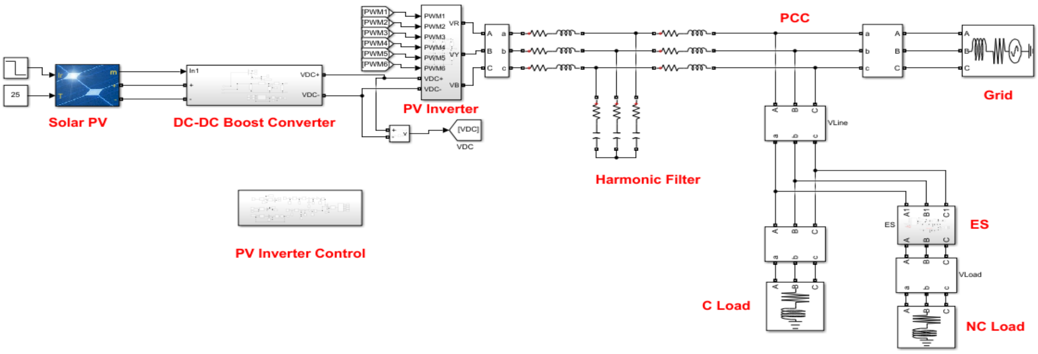

Fig. 6. Hybrid power system in MATLAB/SIMULINK

By using varied irradiation, the performance of the hybrid system and inverter is evaluated under adverse weather circumstances. In Fig.7, shows a variation in irradiance. PV array voltages are not constant as a result of these weather circumstances. The Fig.8, displays the inverter voltage, inverter current and DC-link voltage of inverter. The solar power generation systems use boost converters to maintain a steady voltage across the DC bus.

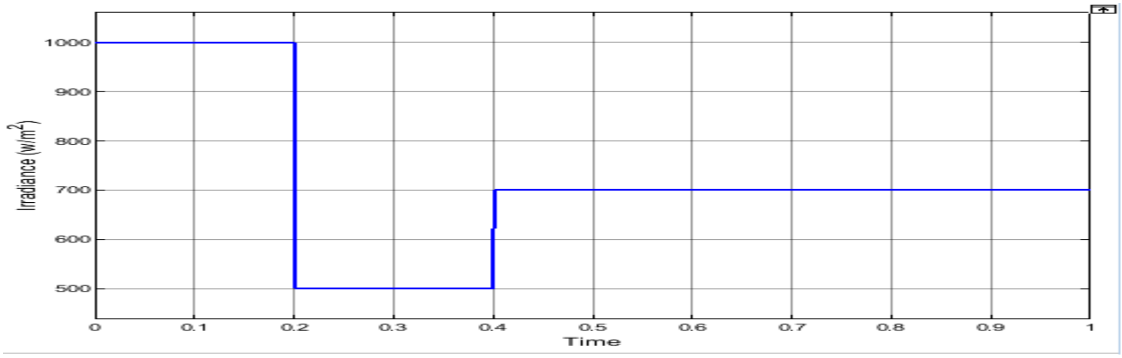

Fig. 7. Considering irradiance change

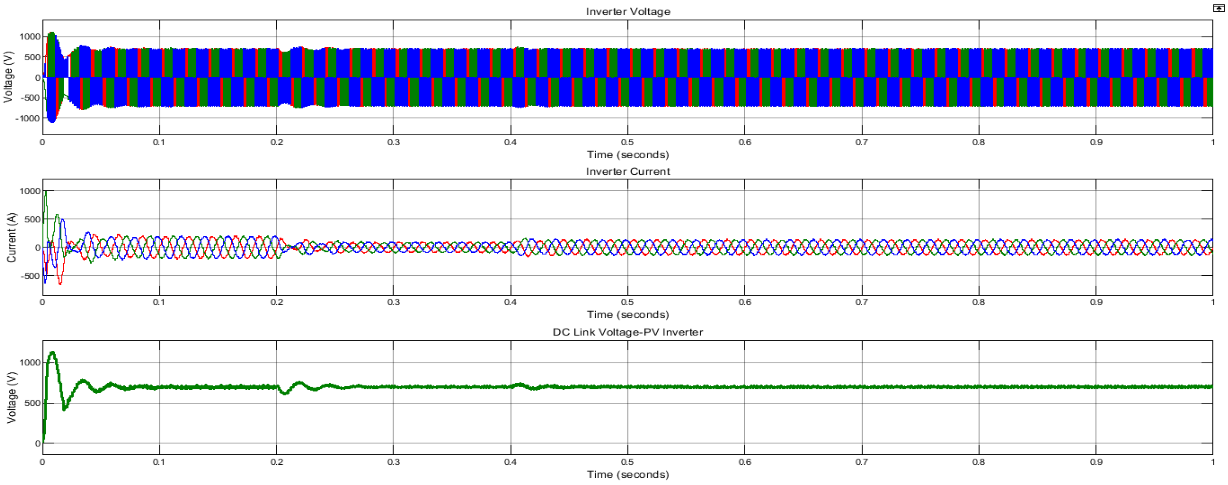

Fig. 8. Waveform of output inverter voltage, current and DC-link voltage.

4.1 Results

Case 1: Without ES having CL 150 W and 30 Var and NCL 150 W and 10 Var.

In this case not any compensating device is connected. The RMS voltage of critical load (CL) is shown in Fig. 9. (a) which shows large variation between 230.10 V to 231.50 V. The Fig. 9. (b) represents results of critical load (CL) frequency which changes at 0.2 sec and 0.4 sec. with respect to change in irradiation values.The critical load (CL) real power and critical load (CL) reactive power values are varies from 149.82 W to 150.44 Wand from 29.90 W to 30.33 W are shown in Fig.9 (c) and Fig. 9 (d) respectively.

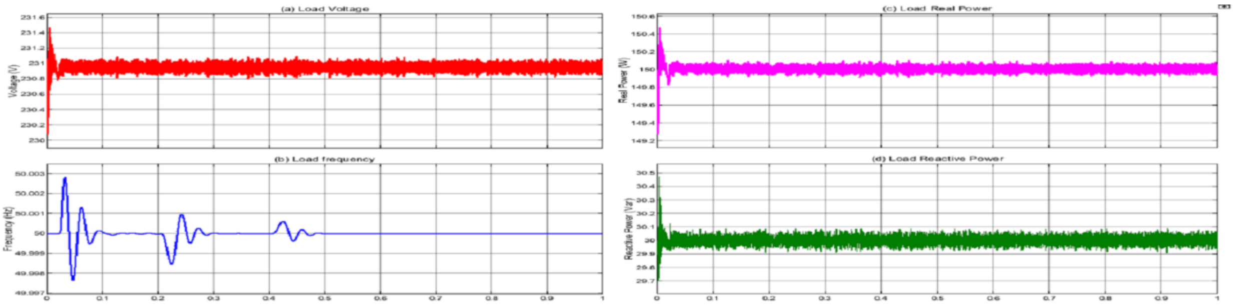

Fig.9 Results Critical Load Without ES (a) RMS voltage (b) Frequency (c) Real power (d) Reactive power

Case 2: With STATCOM having CL 150 W and 30 Var and NCL 150 W and 10 Var.

In this case STATCOM device is connected to the load side for power management. The Fig. 10.(a) shows results values of the RMS voltage of CL varies from 229.50 V to 325.50 V. The Fig. 10 (b) shows CL frequency values having better settling time while change in irradiation value. The result values of CL real power and CL reactive power is shown in Fig. 10 (a) and Fig. 10 (b). These value of power shows a better variation as compared to without compensating device for CL real power varies from 149.20 W to 151.20 W and CL reactive power varies from 29.60 Wto 31.20 W. There is not large change in power at 0.2 sec and 0.4 sec when irradiation occurs.

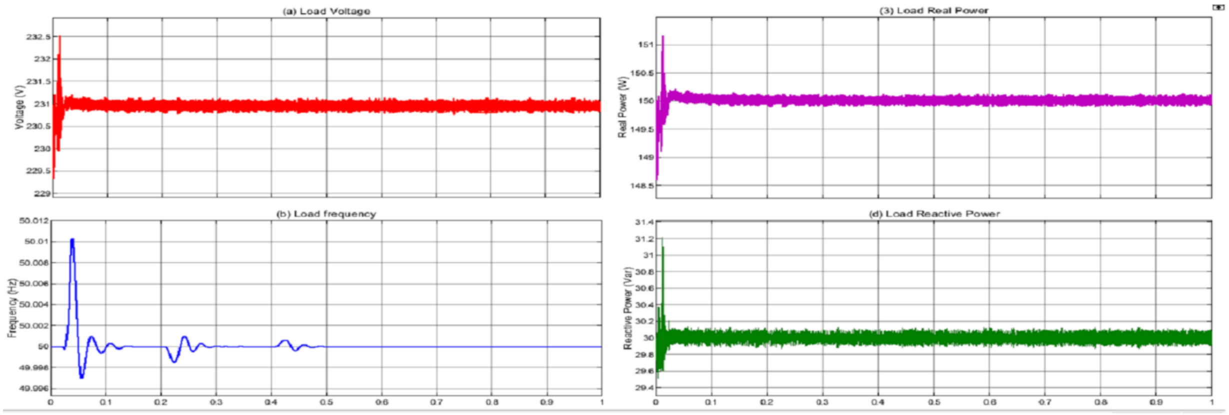

Fig.10 Results Critical Load With STATCOM (a) RMS voltage (b) Frequency (c) Real power (d) Reactive power

Case 3: With ES having CL 150 W and 30 Var and NCL 150 W and 10 Var.

The ES is connected between inverter and critical load and in series with non-critical load for this case. The Fig. 11 (a) represents RMS value of load voltage which 231 V. The Fig. 11 (b) shows response of CL frequency, no such effect when changing irradiation. The CL real power and CL reactive power values shows almost constant are about 150 Wand 30 W are shown in Fig.11 (c) and Fig. 11 (d) respectively. All the responses shown in Fig. 11 are having better results as compared to without ES and STATCOM.

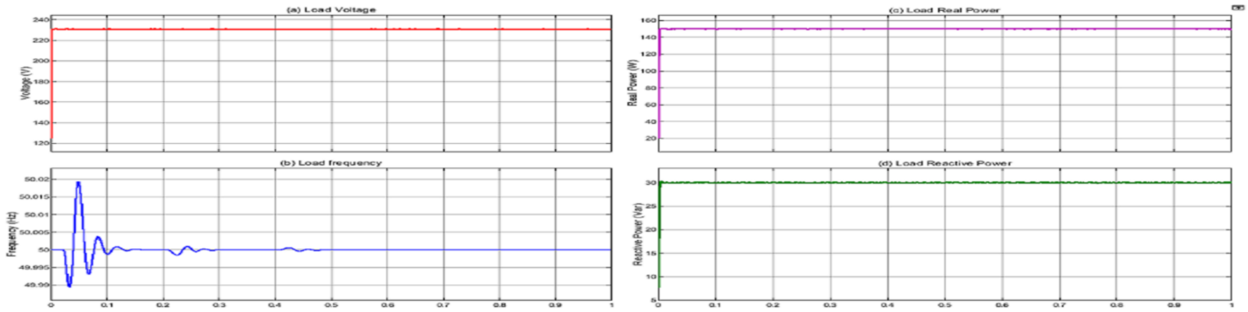

Fig.11. Results Critical Load With ES (a) RMS voltage (b) Frequency (c) Real power (d) Reactive power

5. CONCLUSION

A hybrid power system is coupled to an ES to increase voltage and frequency stability for essential loads and to account for reactive power. Energy from the sun is taken into consideration, because of this RES which is weather-dependent, their common DC bus voltage is unstable. So Critical and non-critical loads connected to the DC bus via the inverter will be less stable. Between the inverter and the important load, an ES is connected to increase voltage stability, frequency, and to correct reactive power. A control strategy is used for ES for better work.The output result of ES shows that the ESis effectively balances reactive power while stabilizing voltage and frequency. The ES is better suited for distribution networks with significant distributed generation penetration and important loads that have inflexible voltage and better power requirements.

The model of hybrid power generation system is tested in MATLAB/SIMULINK software with three different cases and their comparative results are given in Table 1. Table 1: Simulation results with and without ES

Parameters		**Without ES 150W,30Var (CL) and 150W,10Var (NCL)**	**With STATCOM 150W,30Var (CL) and 150W,10Var (NCL)**	**With ES 150W,30Var (CL) and 150W,10Var (NCL)**
Voltage Variation	Time (0.2sec. to 0.3 sec.)	230.80 V to231.10 V	230.95 V to231.05 V	231 V
	Time (0.4 sec. to 0.5sec.)	230.80 V to 231.15 V	230.97 V to 231.3 V	231 V
Frequency Variation	Time (0.2 sec. to 0.3 sec.)	49.9970 Hz to 50.0010 Hz	49.9980 Hz to 50.0010 HZ	49.998 Hz to 50.002 Hz
	Time (0.4 sec. to 0.5sec.)	49.9990 Hz to 50.0005 Hz	49.9995 Hz to 50.0005 Hz	49.999 Hz to 50.001 Hz
Real Power Variation	Time (0.2 sec. to 0.3 sec.)	149.90 W to 150.10 W	149.95 W to 150.05 W	150 W
	Time (0.4 sec. to 0.5sec.)	149.95 W to 150.05 W	149.97 W to 150.03 W	150 W
Reactive Power Variation	Time (0.2 sec. to 0.3 sec.)	29.90 W to 30.10 W	29.95 W to 30.05 W	30 W
	Time (0.4 sec. to 0.5sec.)	29.95 W to 30.05 W	29.97 W to 30.03 W	30 W

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