ENERGY MANAGEMENT AND POWER QUALITY IMPROVEMENT OF HYBRID RENEWABLE ENERGY GENERATION SYSTEM USING COORDINATED CONTROL SCHEME.

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ABSTRACT :

Renewable energy-based smart grids are famous nowadays due to their high intellectual properties. The world is starting new inventions in renewable energy-based electrical power generation systems to reduce global warming. However, a single renewable energy source cannot maintain a proper energy management system and reliability of power towards loads. Hence, integrating two or more systems is very important and can form a smartgrid with an appropriate energy management system. Nowadays, renewable energy sources such as solar Photovoltaic (PV) and wind power systems play a significant part in the process of generating electricity. These systems are tremendously reliant on the present and forecasted weather conditions. The inconsistent behavior of the system has an impact on the production as well as the variances in the output. As a result, the requirement for energy transmission and distribution systems to compensate promptly is becoming crucial. This paper proposes a new smart grid application for power system operation. A Static Compensator (STATCOM) device is utilized to improve the power quality and power flow in the distribution system, reduce unwanted harmonics and compensate for reactive power in the power sources. A quasi-Z-Source Inverter (qZSI) based STATCOM is constructed in connection with a Three-Phase Four-Wire (3P4W) distribution system. The combination of a q Z-source and a PV system makes up the suggested compensator circuit that is employed here for switching. To control the suggested compensator, an Adaptive Frequency Fixed (AFF) - Second Order Generalized Integrator (SOGI) has been implemented. The Fuzzy Logic Controller (FLC) is used to optimize the parameters of the Proportional Integral (PI) controller, such as *K*p and *K*i. The MATLAB/Simulink simulation results demonstrate that the system effectively by different conditions.

***Keywords* –** Power Quality, RES, Fuzzy logic controller, quasi-Z source inverter.

INTRODUCTION

The high penetration of renewable energy resources (RES) poses significant challenges to grid frequency regulation (FR) in maintaining the stability and reliability of the power system. Thus, energy storage systems (ESSs) are considered as a promising technology to provide FR service for ensuring stability by balancing the power generation and load demand. The integration of energy storage device with RES to reduce the fluctuation of grid frequency has been widely conducted. The various types of ESS technology have been researched for FR such as battery ESSs (BESSs), SCs, superconducting magnetic energy storage (SMES), and flywheels. However, a battery is characterized as low power and high energy density, indicating that the battery has an adverse impact with a quick response in a transient instant. Therefore, numerous research efforts in regards to FR hybrid energy storage systems (HESSs) as the combination of batteries with high power density devices such as SCs, SMES, and flywheels have been conducted. In most cases, independent use of solar and wind power cannot meet the changing demands of the grid for their availability changes substantially throughout the day. To meet the energy needs of distant users, stand-alone solar and wind energy systems must have excessive storage capacity. It is possible to reduce the amount of energy storage needed in a system by using the complementary nature of wind and solar power.

For microgrid applications, several forms of distributed power production are commonly acknowledged. However, the interface power converter is critical to the microgrid's dependability. Thus, a stable and dependable distributed power generation system will be ensured by the interface power converter's effective power control. As a result, the emphasis of this study is on the development of an off-grid quasi-Z-source inverter, a new type of interfacing inverter. PV systems use a variety of power converter topologies, each with its own set of advantages and disadvantages, such as the use of a transformer or not, and the use of a two-level or multilevel inverter. Single-stage inverters are replacing more traditional two-stage models because of their small size, low price, and high reliability. The usual inverter, on the other hand, has to be larger to cope with the huge swings in PV array voltage that are brought on by the low output voltage of the PV panels as well as the wide range of variation that is based on irradiance and temperature, often at a ratio of 1: 2. Large low-frequency transformers are needed to link an inverter's low voltage output to the grid, however, these transformers come with several drawbacks, including larger size, lower efficiencies, greater acoustic noise, and higher overall costs. The two-stage inverter eliminates the need for a transformer by using a boost DC/DC converter to increase the input voltage from a wide range to the desired constant value. Due to a malfunctioning switch, the DC/DC converter ends up being both the system's most expensive and most efficient component. For greater safety, some solar-powered electricity generation systems include galvanic isolation, which may be installed either in the DC/DC boost converter that makes use of a high-frequency transformer or on the AC output side of a line frequency transformer. Additional galvanic isolations like this raise the total system cost and size, as well as reduce its overall effectiveness. Because of their superior efficiency, smaller size, and lower cost for the PV system, transformerless topologies deserve further investigation. The qZSI has been used in PV systems because of its single-stage power converter to step-up and step-down functions.

Additionally, the inverter does not need to be overpowered to manage a broad range of PV DC voltage variations. This reduces the overall cost of the system and reduces component count and costs while also increasing dependability and stability. PV systems may benefit from several unique and interesting benefits offered by qZSIs. The qZSI minimizes switching ripples and simplifies the PV system by drawing a steady current from the PV panel and eliminating the need for additional filtering capacitors. It also has a lower component (capacitor) rating and simplifies the PV system. For the isolated load scenario, this study used qZSI to interface the PV-generating system. The authors of this study explain the installation of an AFF-SOGI control scheme in conjunction with a PV array and a Wind Energy Conversion System (WECS)-supported qZSI-STATCOM in order to enhance the power quality of the distribution system. This is accomplished by using a combination of the two. These are the primary goals that this investigation aims to achieve. When there is a DC offset in the load currents as well as distorted and unbalanced voltages, it is possible to improve the power quality in the distribution system by managing the qZSI-STATCOM using an AFF-SOGI-based control algorithm. This may be done in the presence of both conditions with the aid of the multi-mode functionality of the qZSI-STATCOM.

SYSTEM MODELING :

Because of their low cost and flexible operation, power generators such as wind turbines and PV are employed to serve the load more effectively than any other power source. Because of this, the wind turbine is relied upon to provide both linear and non-linear loads. Compensation circuits are used to improve the power quality in the distribution network. To solve the power quality issues at the source, a STATCOM compensator based on a qZSI is built parallel with the distribution network. The qZSI and PV system have been combined into one in the planned compensator circuit, which uses STATCOM for switching. The qZSIbased STATCOM model that has been presented may be seen in Fig.1. The AFF-SOGI control technique directs the compensator to keep the wind energy system's voltage and frequency within acceptable ranges. This also helps to attenuate the harmonics that are present in the 3P4W distribution system. The fuzzy-tuned PI controller is used to optimize the parameters of the frequency controller. This approach controls the flow of power to the load by eliminating harmonics and compensating for the reactive power that is present in the power sources. Fig. 2 shows the flowchart for PV-qZSI-STATCOM operating mode selection. This PV-assisted qZSI-STATCOM is comprised of four different modes using coordinated control. Mode 1 (Production of PV power), Mode 2 (Battery backup), Mode 3 (Continuous supply), and Mode 4 (Flywheel energy storage) depict the closed or open state of the power electronic switches (S1–S7). The control system enters mode: 1 when the amount of power produced by the PV power producing system is more than the amount of power that is connected to the load (PLoad). In this mode, the switches are in the following positions: (S1, S2, S3 = On, S4 = On (If State of Charge (SOC) of battery ≤ 50%), S5 = Off, S6, S7 = On). When the PV power produced by the PV system drops to PPV < 10%, the control system switches to mode: 2. When Vsabc equals zero, the mode: 3 setting is activated, and the switch positions are set as follows: (S1, S2, S3 = On, S4 = On (If PPV < 10%), S5 = Off, S6, S7 = On). The control system will enter mode 4 after it has determined that the power produced by the wind energy system Pwind is more than the power generated by the load PLoad.

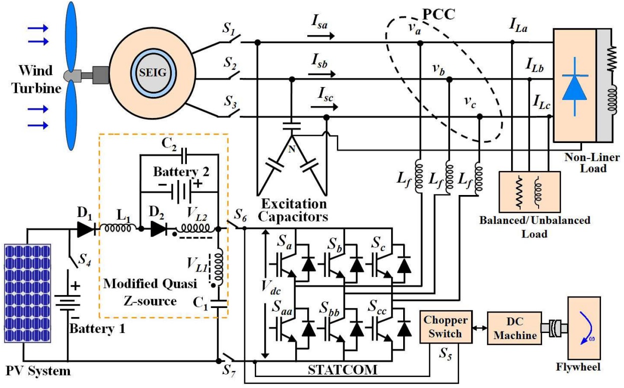


Fig.1. qZSI-STATCOM integrated with the wind energy conversion system.

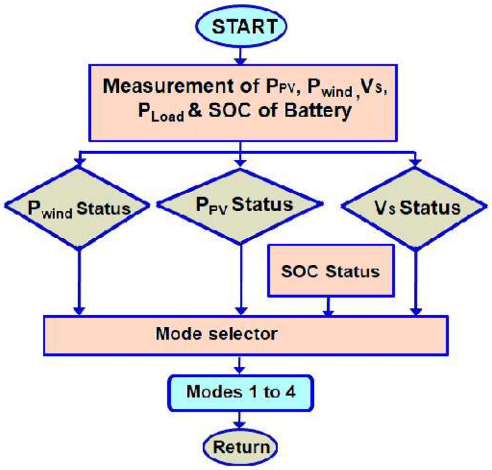


Fig.2. Flowchart for PV-qZSI-STATCOM operating mode selection.

Harmonics may be mitigated and reactive power consumption from connected loads can be compensated for with the help of the qZSI-STATCOM control, which works to enhance the reliability of the power grid in its entirety. Additionally, the goal is to make the grid currents pure sinusoids at distorted load currents and unbalanced voltages. It is thus possible to use the AFF-SOGI to estimate sinusoidal reference grid currents regardless of distorted load currents as well as unbalanced grid voltages. Fig. 3 depicts the AFF-SOGI control scheme for qZSI-STATCOM. AFF-SOGI takes solely the fundamental frequency currents into consideration. Where ZCD represents Zero Crossing Detector, S/H represents Sample and Hold circuit and Abs represents Absolute.

It does this by denying permission for the other frequency component to generate the currents in issue, which in turn stops those currents from entering the grid and allowing only those generated by the other frequency component. As a result, only active power from the source is drawn from the system. In addition to this, the controller makes use of unit voltage vectors that are computed based on the grid's positive sequence voltages. This assures that distortions and imbalances in the grid voltages do not have an impact on the reference currents. This method, which is developed from a SOGI algorithm based on a constant frequency, allows for the extraction of the fundamental current by replacing the damping factor and the resonant frequency with fractional order versions of these quantities. The AFF-SOGI has been significantly improved by the incorporation of a DC offset rejection loop. This loop guarantees that the fundamental current estimation is no longer impacted by DC offsets that are present in the load current. Fig. 4 depicts the AFF-SOGI schematic, which reveals the organization of its internal components.

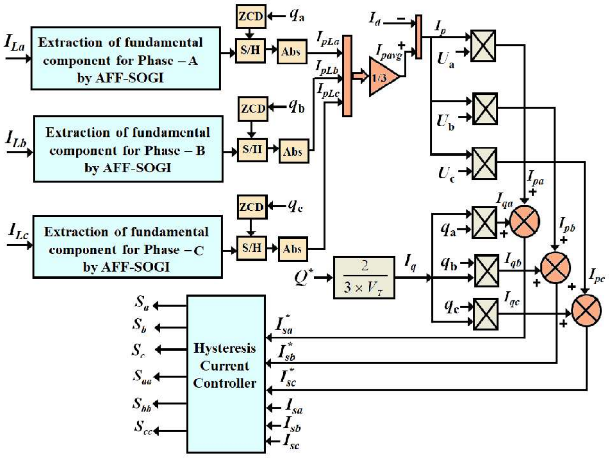


Fig.3. AFF-SOGI control scheme for qZSI-STATCOM.

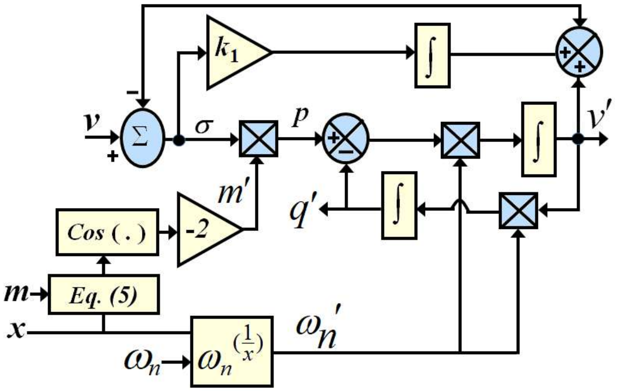


Fig.4. Internal structure of AFF-SOGI.

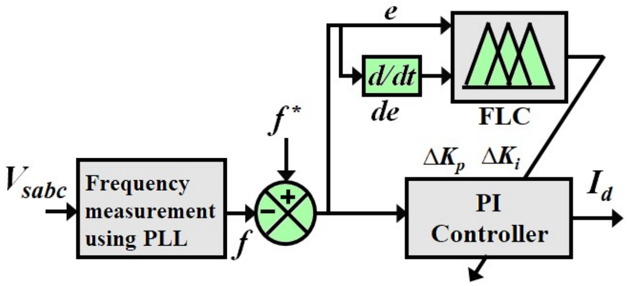


Fig.5. Fuzzy-tuned PI frequency controller.

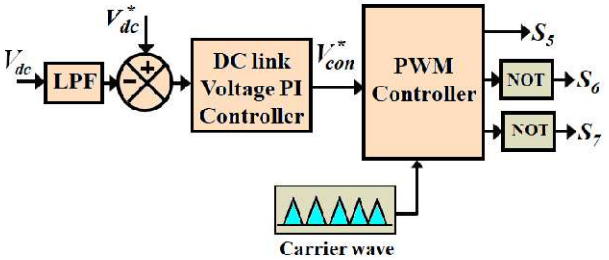


Fig.6. DC link voltage controller.

A ZCD is used to determine whether a signal has crossed zero. Grid voltage phase and frequency are carried in unit vectors enabling synchronization via these vectors. Since distortion and imbalanced voltages may deform vectors, they should be pure sinusoids of unit amplitude. The unit vectors are generated using positive sequence voltages for this purpose. The frequency of the system is determined by utilizing a Phase Locked Loop (PLL) using three-phase terminal voltages as input. A fuzzy-tuned PI controller is used to compare the estimated frequency to the reference frequency and to control the frequency error. The active current that is drawn by the compensator circuitry constitutes the output of the frequency PI controller. For the frequency PI controller, *K*pd and *K*id represent the proportional and integral gains, respectively. The fuzzy-tuned PI controller is utilized for tuning the PI controller gain parameters. The fuzzy-tuned PI frequency controller is shown in Fig. 5. Three-phase load requirements are evenly distributed due to average active currents. Regardless of the imbalance in voltage or the uneven demand for load, grid currents are always balanced as a consequence. Fig. 6 shows the DC-link voltage controller of qZSISTATCOM.

III. SIMULATION RESULTS

CASE 1: BALANCED NON-LINEAR LOADS AT CONSTANT WIND SPEED

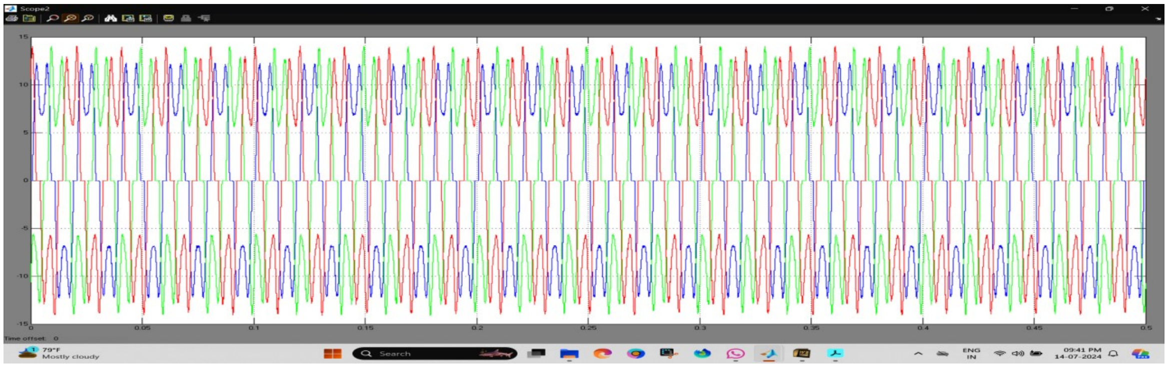


Fig.7 nonlinear load currents (Proposed system)

Fig.8 balanced load currents (Proposed system)

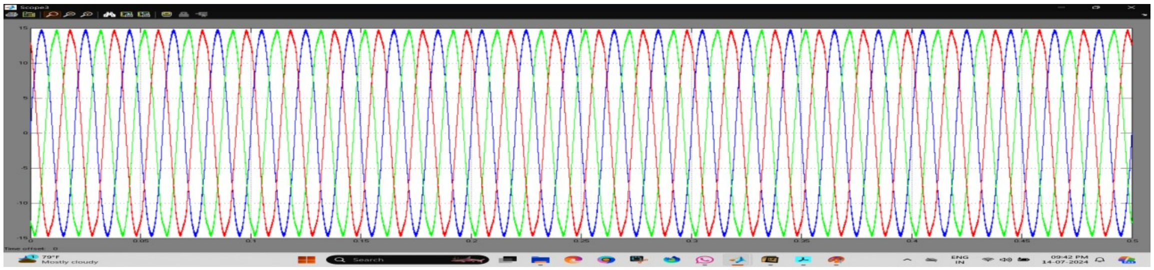


Fig.9 source currents (Proposed system)

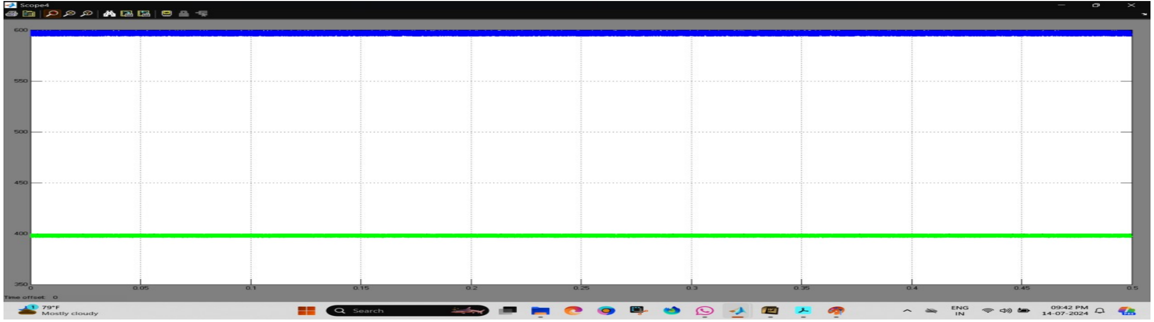


Fig.10 Voltage at DC link (Vdc), Voltage of PV array (VPV) (Proposed system)

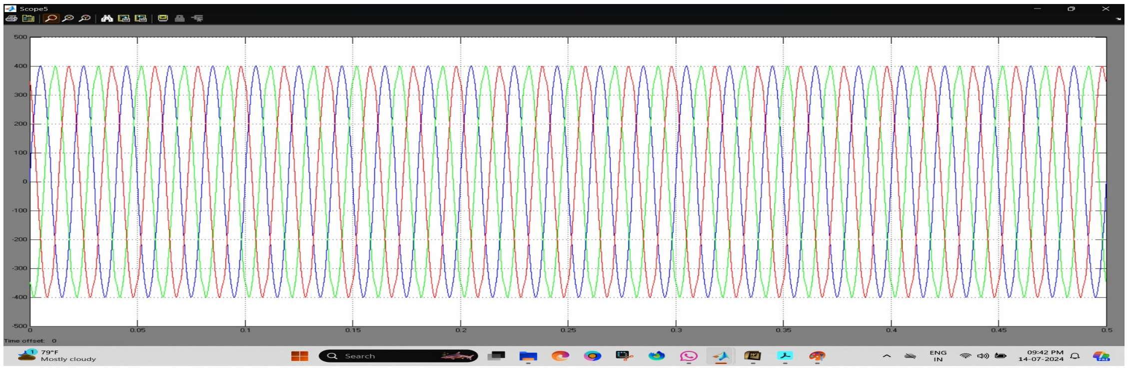


Fig.11 source voltages (Proposed system)

When the wind speed is held constant and the non-linear loads are balanced, PV-STATCOM is evaluated. As may be seen in Fig. 7, 8, 9, the present compensation experimental findings for Case 1 compensation are shown. Whereas the non-linear balanced load has an effect, the compensator circuit may be utilized to maintain a constant voltage and current. The experimental results of DC link voltage, PV array voltage, and Source voltage and Current are shown in Fig. 10, 11.

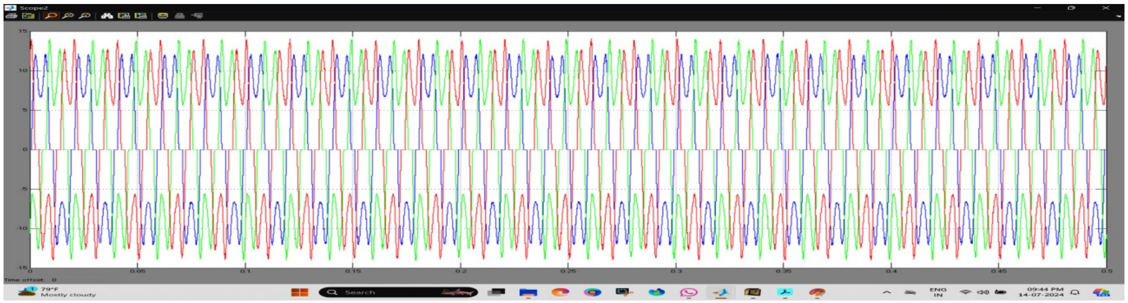


Fig.12 nonlinear load currents (Extension system)

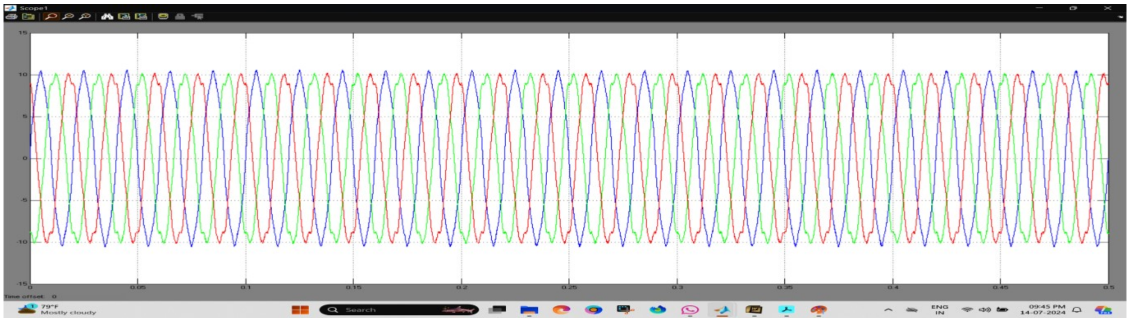


Fig.13 balanced load currents (Extension system)

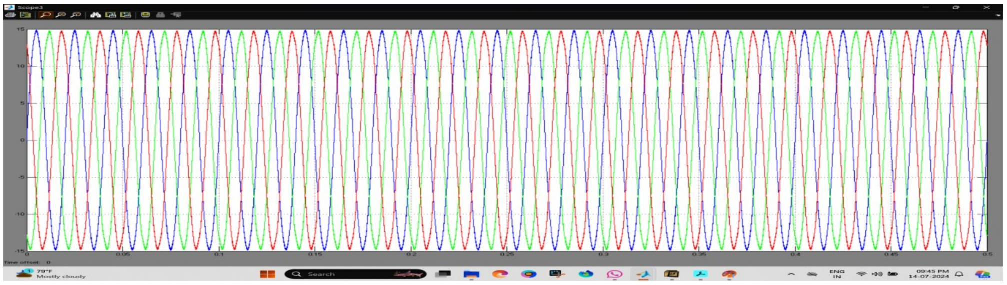


Fig.14 source currents (Extension system)

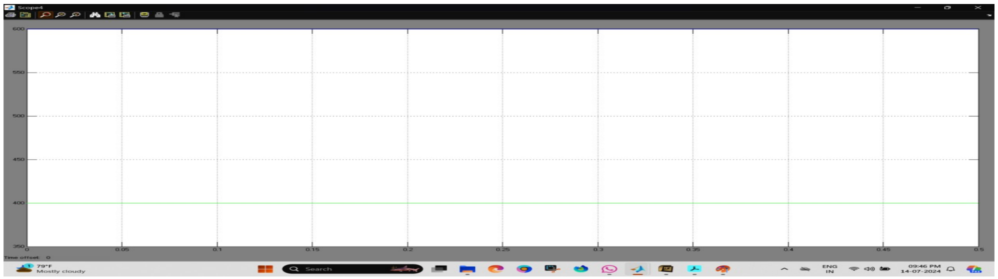


Fig.15 Voltage at DC link (Vdc), Voltage of PV array (VPV) (Extension system)

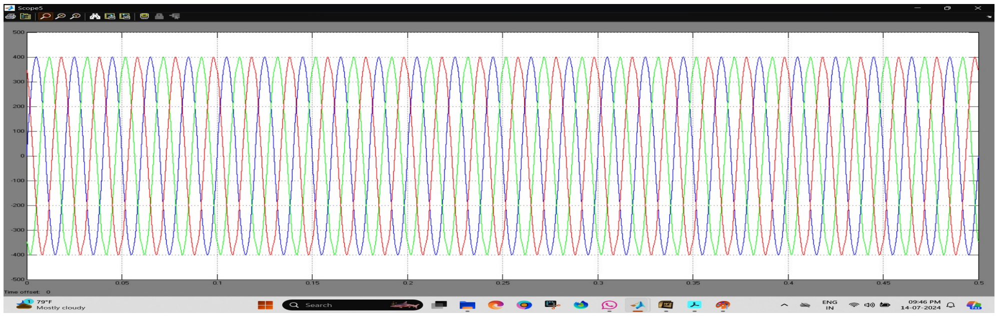


Fig.16 source voltages (Extension system)

CASE-2: UNBALANCED LOAD CURRENTS WITH VARYING WIND SPEED :

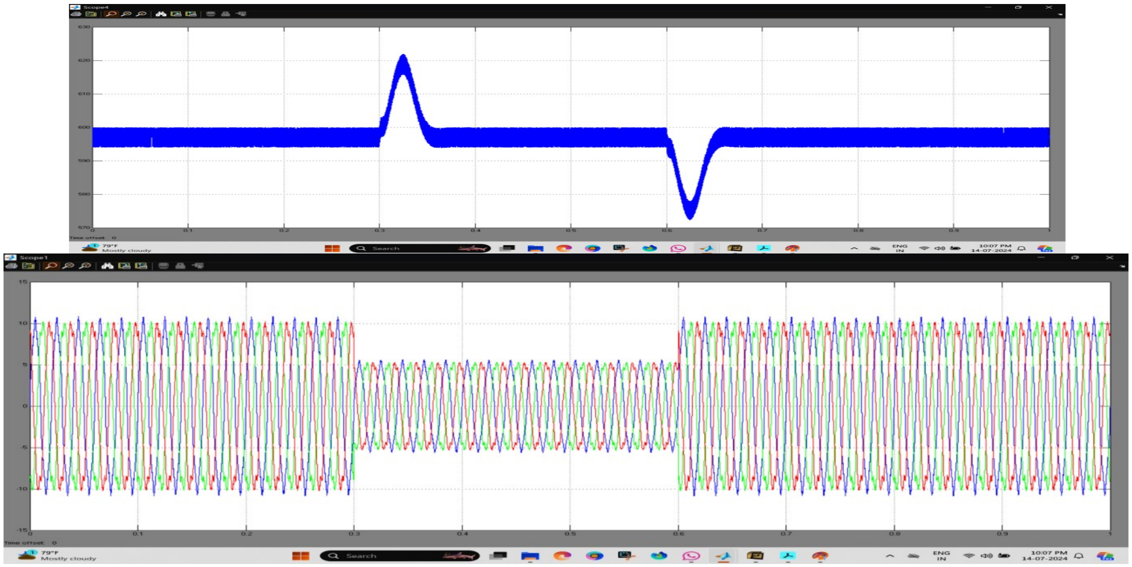
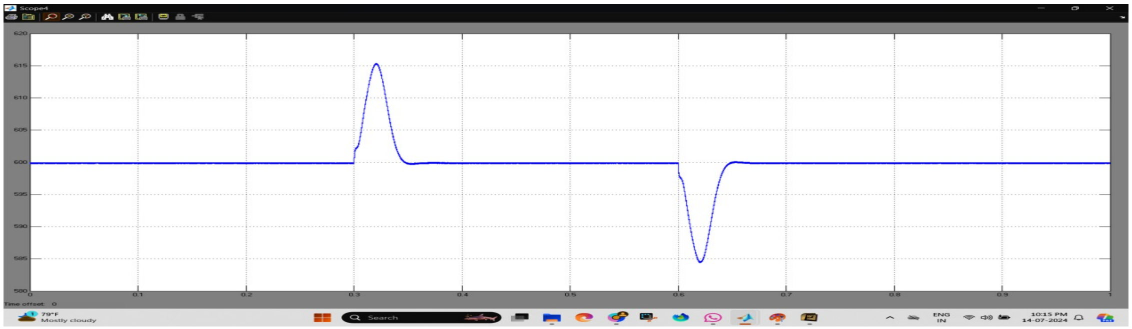


Fig.17 DC link voltage during step load changes. (Proposed system)

When step loads are applied, the results are shown in Fig. 17. When a nonlinear load is turned off, the actual power that was previously provided is transferred to the DC link until a new supply current reference is appropriate for the new load current is determined. As a result, the DC link voltage exceeds the reference value. When the nonlinear load is switched, the DC link voltage reduces by around 50V. The DC link voltage is stabilized after a few power cycles in both circumstances.



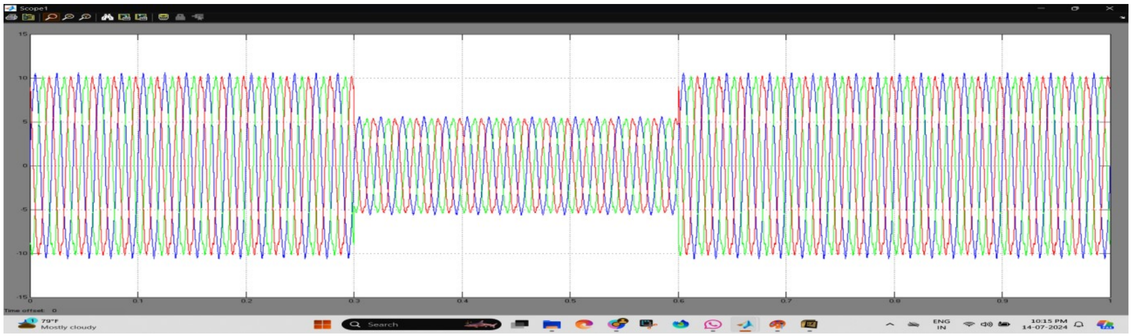


Fig.18 DC link voltage during step load changes. (Extension system)

CONCLUSION :

The important contribution that FACTS has made to the improvement of power system quality has been acknowledged by the major participants in the power industry. In addition, the incorporation of the integration of qZSI-STATCOM devices with renewable energy plants is possible due to the capabilities of STATCOM devices. These capabilities include enhancing transient stability, voltage trips, and power flow control, all of which are required in the operations of solar and wind power plants. These systems are profoundly affected by the climatic conditions in the surrounding area. The unpredictable behaviour of the system affects the range of production and output values. As a result, a new smart grid application has been developed for use in the management of power systems to regulate the flow of power, boost capacities, decrease harmonics in the distribution system, and compensate for voltage interruptions that are induced by power sources. When the fuzzy-tuned PI controller is used to make adjustments, the performance of the qZSI STATCOM is able to be enhanced due to the technique that is presented. The voltage fluctuation that was brought on by the change in reactive power has been eliminated, harmonics have been mitigated, and the ideal dynamic response has been accomplished as a result of finding the optimal values for the PI controller gains. In subsequent research, several different FACTS devices and optimization strategies may be compared to one another, to identify the one that is the most successful.

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