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# Enhanced Electric Vehicle (EV) Battery Charging Based on Solar Photovoltaic (PV) with SOSMCC Disturbance Observer for Grid Integration with SABCAF Control

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**Abstract -** The proposed study proposes a state-of-the-art solar PV electric vehicle (EV) charging system based on intelligent control for improving grid stability, power quality and renewable energy utilisation. The system is designed to efficiently perform Grid to Vehicle (G2V) and Vehicle to Grid (V2G) activities for a wide range of load and climatic conditions. It consists of a solar PV array, a grid interface, batteries and a bi-directional DC-DC converter. A Second Order Sliding Mode Cascaded Control (SOSMCC) method is adopted to keep the DC-link voltage steady and the charging and discharging of electric car batteries smooth when the solar radiation is subject to unexpected fluctuations or variations. Moreover, a Linear Extended State Disturbance Observer (LESDO) is integrated to improve the dynamic performance by lowering the settling time, overshoot and undershoot under transient operating conditions.

Furthermore, the harmonic suppression is achieved via the Sparse-Aware Bias-Compensated Adaptive Filtering (SABCAF) method to eliminate the harmonics and accurately extract the fundamental current component as per the IEEE 519 standards, which enhances the power quality. Complete system analysis for evaluation of system stability, energy management and charging efficiency is performed using MATLAB/Simulink models. The simulation results show that the proposed technique has higher performance than the old method in convergence speed, mean square error, harmonic rejection and disturbance rejection ability. The suggested technology is dependable, efficient and ecologically benign and can be useful for a future smart electric vehicle charging infrastructure incorporating renewable energy sources.

***Key Words***: The terms SABCAF, electric vehicle, solar PV system, SOSMCC, and battery energy storage system.

## 1.INTRODUCTION

Rapid developments are taking place in electric vehicle (EV) technology due to the increasing need for renewable energy sources and sustainable transportation solutions. The rapid industrialisation, urbanisation, and transportation systems that rely on fossil fuels have all led to greenhouse gas emissions, depletion of traditional energy supplies, and serious pollution. These environmental issues have caused scientists and governments to work on the development of electrified transport systems and the integration of renewable energy sources. Solar photovoltaic (PV) technology is one of the most promising and widely used technology among several renewable energy sources due to its abundance of supply, low operating costs and environmentally friendly nature. Integration of solar PV systems with electric vehicle charging infrastructure is one of the possible long-term options to improve clean mobility and to decarbonise the transportation sector. PV-assisted EV charging is able to directly harness the solar energy to power EVs, and hence it is very desirable for both the utility grid and the environment. The intermittency of solar irradiation and the fluctuating electric vehicle charging load provide issues in terms of power quality, voltage control, energy management and system stability. Intelligent power management techniques and advanced control algorithms are needed to operate hybrid solar PV/electric car charging systems safely and reliably in a wide range of load conditions and situations.

The deployment of grid-connected solar EV charging stations has brought more choices for modern power systems, and also new technological obstacles. EVs are generally charged via the utility power grid, which raises peak demand and causes instability in the distribution network when a large number of EVs are charged at the same time. To tackle these difficulties, scientists have designed renewable-energy-based charging systems which include solar systems, smart grid technologies, bidirectional converters and battery energy storage systems (BESS). These integrated technologies enable G2V and V2G operations, which means electric cars may now both consume and generate energy. This bi-directional energy flow increases grid flexibility, efficiency and load balancing.

It is still tough to have a consistent DC-link voltage and a seamless power transfer regardless of mode changes, unanticipated changes in the load or fluctuations in the solar power output. The traditional methods of control seldom give the quick response and effective disturbance rejection that one is led to expect when working in an uncertain environment. The increasing use of power electronic converters in the electric car charging systems has a high impact on the reliability and quality of the electrical power delivered to the consumers due to harmonic distortion, low power factor and

voltage variations. So, advanced charging control strategies are required for the charging system to perform well in different grid and weather conditions and to achieve better power quality with lower harmonics. Recently developed electric vehicle charging systems based on renewable energy sources are based on adaptive filtering algorithms, disturbance observers and Second Order Sliding Mode Cascaded Control (SOSMCC) to overcome these difficulties. Among these methods, SOSMCC has been popular because of its better durability, fast convergence and good disturbance rejection capability.

This management approach is able to stabilise the charging and discharging operation of the EVs and can maintain the DC-link voltage even with the variation of solar irradiation and load. Disturbance observers have been widely used for estimation and compensation of uncertainty, overshoot, undershoot and external disturbances affecting the stability of the system. The Linear Extended State Disturbance Observer (LESDO) performance and settling time is enhanced for transient response characteristics under continually varying operational conditions. Another challenge is how to maintain good quality power in the PV-based EV charging systems. Harmonics from non-linear loads and switching devices can cause electromagnetic interference and reduce efficiency and increase loss in distribution networks.

This is solved by Sparse-Aware Bias-Compensated Adaptive Filtering (SABCAF) and other state-of-the-art adaptive filtering algorithms that accurately extract the fundamental component of the load current and successfully cancel higher order harmonic components. The SABCAF algorithm enhances the performance and reliability of power systems by reducing the Total Harmonic Distortion (THD) below the IEEE 519 limitations and by improving the convergence speed.

The aim is to develop a green and highly efficient solar charging infrastructure for next-generation smart grids. This system features renewable energy sources, smart energy management and innovative control technology. The system is mainly based on the renewable energy generation through the photovoltaic (PV) array, with the energy storage battery as a backup to allow operation in low sunlight periods. The PV system can be designed with maximum power point tracking (MPPT) techniques to maximise the output regardless of the environment conditions and sunshine levels.

The bidirectional DC-DC converters allow the seamless transfer to and from the G2V and V2G modes for controlled charging and draining of the electric vehicle batteries. The voltage source converter (VSC) and control circuits are synchronised to grid to improve the power quality and to limit the use of reactive power. Different circumstances like load changes, solar irradiation variations and grid outages can be included in modelling and simulation using MATLAB/Simulink to investigate the system performance. The simulation findings indicate that the combination of SOSMCC, LESDO and SABCAF results in a significant improvement of charging efficiency, voltage stability, decrease of harmonic distortion and system dynamics. The proposed strategy contributes to sustainable development goals through enhancing the use of renewable energy, reducing emissions of greenhouse gases, and boosting clean energy transportation systems.

Last but not least: PV systems charging electric vehicles give hope for sustainable and economical mobility. With renewable energy, intelligent power management and advanced converter technologies together with robust control algorithms, many of the challenges associated with electric vehicle charging applications can be effectively solved. Using solar power to charge electric autos has many advantages such as fewer pollution, lower running costs and much less dependency on fossil fuels.

Advanced control techniques such as SOSMCC, LESDO and SABCAF are employed to increase the system stability, power quality, disturbance rejection capabilities and harmonic control capability of your system in dynamic operating scenarios. bidirectional charging also enables efficient energy transfer between the utility grid and the EVs, leading to more energy management flexibility in smart grid applications. Although much of the study was done using MATLAB/Simulink for simulation analysis, the proposed method is a solid foundation for future smart charging infrastructure development and real-time hardware implementation. Solar PV charging solutions for electric vehicles are essential to a clean, reliable and environmentally conscious transportation future. That's because the PV technology, battery storage and advanced control systems are continually improving.

## 2. proposed configuration

The proposed system may provide efficient energy management, consistent power flow, and improved power quality in dynamic operating scenarios, by integrating intelligent control methods with an advanced solar-based electric vehicle (EV) charging infrastructure. The system consists of an interface with the utility grid, a voltage source converter (VSC), a bidirectional DC-DC converter, a battery energy storage system (BESS), and solar photovoltaic (PV) array that can permit charging activities between the grid and automobiles. The proposed strategy aims to efficiently charge the electric vehicles using the solar energy from renewable sources, thereby decreasing the dependency on the conventional sources of electricity from fossil fuels. The alternative proposed is better than most of the charging options today which are largely grid powered. It intelligently manages the flow of energy between the

electric car battery, the public grid and the solar PV system, in accordance with load demand and solar power generation. Modern control techniques provide a constant DC-link voltage, correct charging, low harmonic distortion and no problems in the mode changeover. The proposed plan promotes eco-friendly mobility, enhances the smart-grid, and minimises the emission of greenhouse gases. The full system is first simulated in MATLAB/Simulink and afterward the system dynamics are studied for different charging scenarios. load disturbances, and varying solar irradiation levels.

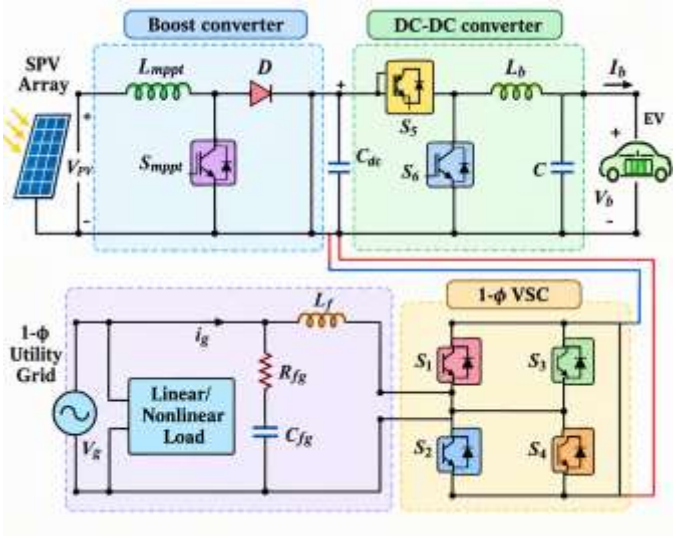



Fig.1.System configuration of PV-GEVBC

The charging plan would largely consist of solar photovoltaics (PV) for renewable energy utilisation. A number of solar photovoltaic ( PV ) cells are connected in series and parallel to convert the energy of the sun directly into electricity at a voltage and current specified . The generated electricity by the PV system is continuously changing because the solar irradiation and environmental temperatures are changing during the day. The proposed model adopts an efficient Maximum Power Point Tracking (MPPT) technique to extract the maximum power of the PV array under diverse weather conditions. The boost converter is fitted with a maximum power point tracking (MPPT) controller that operates at the maximum power point (MPP) of the PV system to achieve maximal efficiency. Hence, the solar array will be capable to accommodate the variations of temperature and irradiance effectively. The boost converter is connected with the PV array boost the voltage generated by the PV array from the low voltage to the suitable value of the DC-link. This enables voltage regulation. The MPPT controller is working effectively hence increasing the utilisation of renewable energy sources and minimising energy wastage. The overall efficiency of the EV charging infrastructure is increased.

A bidirectional DC-DC converter is proposed to control the charging and draining of the electric vehicle's battery from the DC-link bus. The bidirectional converter is necessary for functionalities such as Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G). A charging station is a piece of specialised equipment that charges an EV's battery, tapping into power from the grid or renewable energy sources like solar panels. However, should the battery need to provide extra power, it can be discharged back to the grid or connected loads. The bidirectional converter is equipped with an advanced control mechanism which maintains the charging current constant, thus protecting the battery against deep drain and overcharging. The suggested system continually monitors the battery State of Charge (SOC) so that it may adapt the charging and discharging process according to the battery operational conditions and the system needs. The use of bidirectional energy transfer capabilities increases the flexibility of energy management, reduces the stress on the grid during peak demand periods and maximises the usage of renewable energy sources. Battery storage can also offer backup power in case of short-term network outages or periods of low solar irradiation, hence boosting the durability of the system.

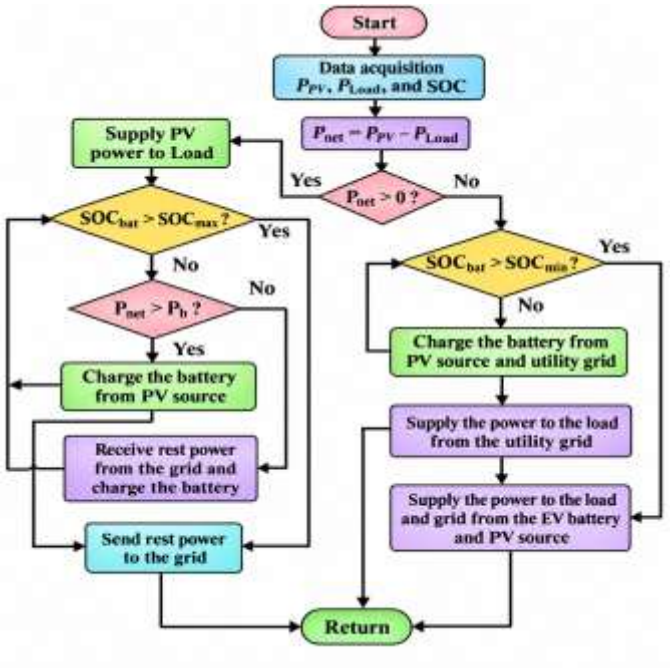



Fig. 2. Energy management flow chart.

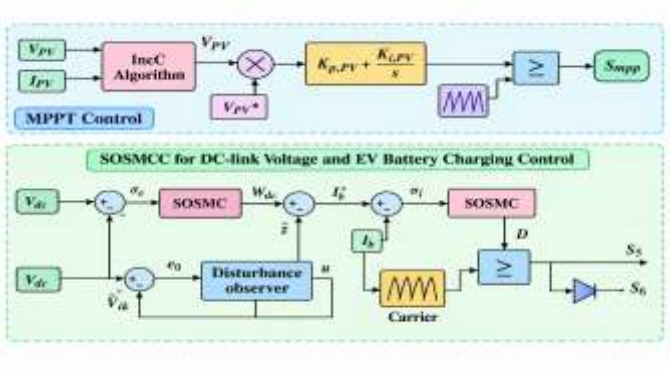



Fig.3. Block representation of MPPT and SOSMCC with observer

The proposed model improves the system stability and the dynamic performance by controlling the power flow in the charging infrastructure and controlling the DC-link voltage using an approach of Second Order Sliding Mode Cascaded Control (SOSMCC). It is expected that the SOSMCC technique provides better robustness to shocks, faster transients and higher control precision in case of intermittent operation. The conventional control procedures are slow and not very effective in case of abrupt change in load demand or solar irradiation. However, the proposed SOSMCC approach effectively alleviates the DC-link voltage fluctuations, overshoot and undershoot during transient operation situations. The cascaded structure of the controller allows the separate regulation of the voltage control loop and the current control loop to achieve the stability and the steady state error reduction.

The second order sliding mode mechanism can greatly reduce the chattering, which is more present in the older sliding mode control systems. It is observed from the simulation results that the SOSMCC controller is superior to the conventional proportional-integral control methods in terms of resilience, settling time and quality of the charging mode transition. Hence, the suggested controller boosts the overall efficiency and reliability of the solar EV charging system remarkably.

### 3.Simulation Results

To improve charging efficiency, power quality, and grid stability, the simulation results of the proposed photovoltaic-based electric vehicle (EV) charging system show how effective it is to integrate renewable energy generation, advanced control strategies, and intelligent power management techniques. The system overall was simulated and tested in MATLAB / Simulink in different scenarios including varying solar input, load perturbations, G2V and V2G operations and dynamic mode changes.

The proposed system includes solar panels, a bidirectional DC-DC converter, energy storage batteries, a voltage source converter (VSC), and an interface with the utility grid. The interface is driven by algorithms such as SABCAF, LESDO and Second Order Sliding Mode Cascaded Control. The voltage-regulation capability, disturbance-rejection performance, suppression features and overall stability of the charging system were determined through simulation analysis. Although climatic and electrical circumstances may change quickly, the findings show that the suggested design keeps the DC-link voltage steady and the charging process running smoothly. The proposed system offers improved dynamic responsiveness, reduced harmonic distortion and enhanced use of renewable energy than the conventional EV charging techniques. These results validate the performance and effectiveness of the proposed control architecture, which is essential for ensuring reliable and sustainable EV charging.

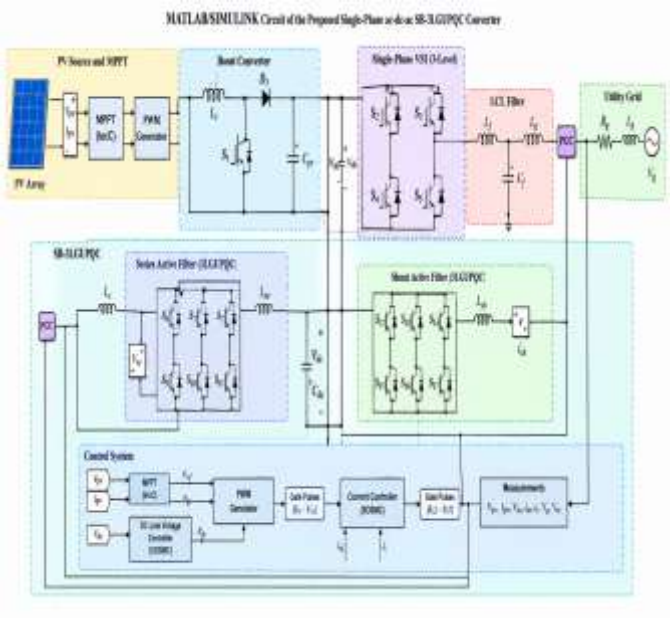


Fig.4. Schematic Circuit of the Proposed Single-Phase AC–DC–AC SB-3LGUPQC Converter

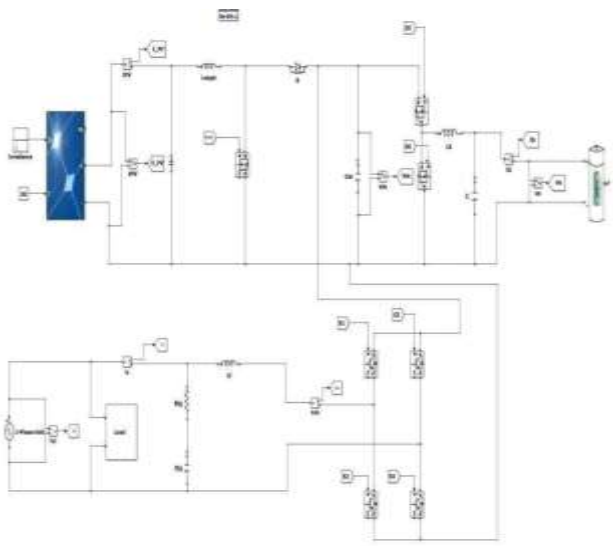


Fig.4.1 Digital-to-Analog-to-single-phase SB-3LGUPQC converter schematic in MATLAB/SIMULINK

The following point is an important result of the simulations performed using the proposed model; the operation of the PV system under different scenarios of solar radiation. Changes in irradiance may have a major impact on charging efficiency and DC-link voltage stability since the amount of electricity produced by solar panels is directly related to weather conditions like temperature and the amount of sunshine. Maximum Power Point Tracking (MPPT) algorithm is a continuous duty cycle optimization of the boost converter that makes the most out of the PV array. As seen from the waveforms of the simulation, the MPPT controller tracks the maximum power operating point with very little oscillations and is responsive to solar irradiation changes. Under low-irradiance conditions, the controller ensures optimal operation by efficiently utilizing the available solar energy, while during

high-irradiance periods, it supplies additional power to the EV charging system.

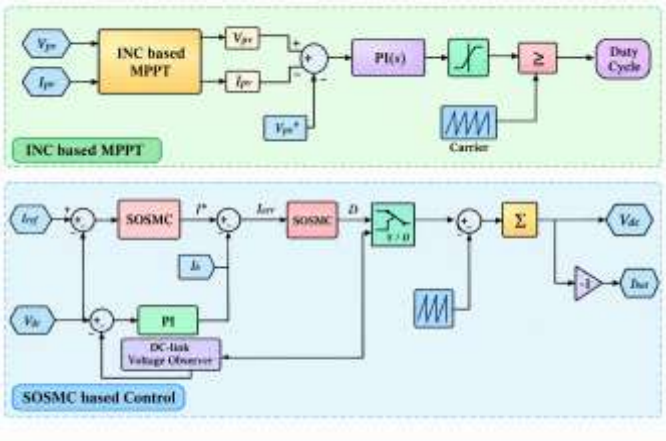



Fig.5. Schematic Circuit control strategy for DC/DC converter and boost

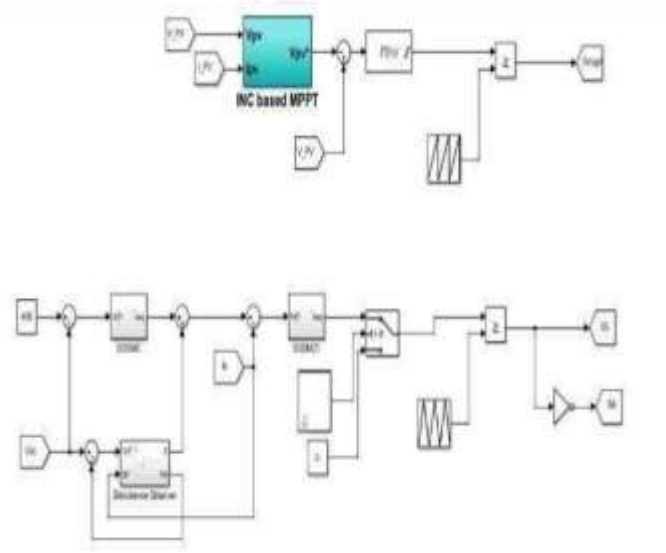



Fig.5.1 simulation circuit of control strategy for DC/DC converter and boost

The simulation results indicate that the proposed charging system can effectively realise the Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) functions corresponding to the bidirectional DC-DC converter operation. The G2V converter delivers electricity from the grid or solar PV to the electric car batteries at a fixed voltage and regulated current. The charging current waveform is smooth meaning there is a smooth charging process with little spikes or droops. This enhances the charging efficiency and allows the battery to last longer. V2G can provide energy to the grid or connected loads when demand is high. The converter may reverse the flow of power without disturbing the system or the utility network. Simulation findings show that the voltage of DC link bus is consistent and ripple free during charging and discharging. The State of Charge (SOC) of the battery is continuously monitored to avoid overcharging and over discharging. It can be seen that the bidirectional converter may improve the grid support capability in dynamic operation, transfer energy effectively and control power flexibly.

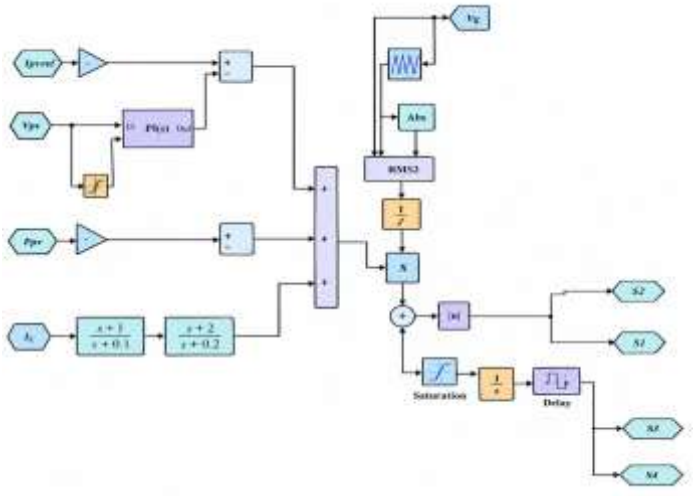


Fig.6. schematic Circuit Control system for VSC

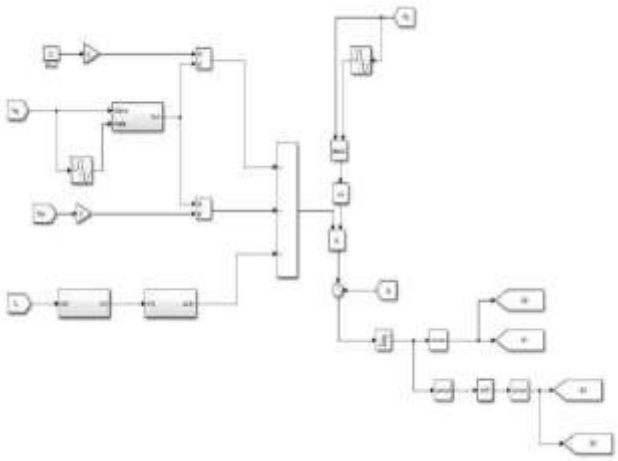


Fig.6.1. Simulation circuit of Control system for VSC

The SOSMCC strategy's efficacy in various transitory operational contexts was investigated through comprehensive simulation studies. No matter how fast the load changes modes, the results demonstrate that the SOSMCC controller can handle DC-link voltage regulation and maintain system smoothness. In some situations, such as when the load demand changes abruptly, conventional controllers might cause a long settling time and a large voltage overrun. The proposed SOSMCC method eliminates these shortcomings while ensuring fast dynamic response and disturbance rejection. Based on the modelling results, it is evident that the DC-link voltage waveform shows minimal voltage fluctuations and quickly stabilises after short disturbances. Its cascaded architecture improves the accuracy of regulating current and voltage while reducing steady-state inaccuracy.

The second-order sliding mode mechanism drastically reduces the chattering effects compared to conventional sliding mode controllers. Regardless of the operating conditions, the suggested SOSMCC method achieves better stability, settling time, and transient response than conventional control. The results demonstrate that the SOSMCC approach makes good use of RE sources to provide a steady and dependable power flow in the EV charging network.

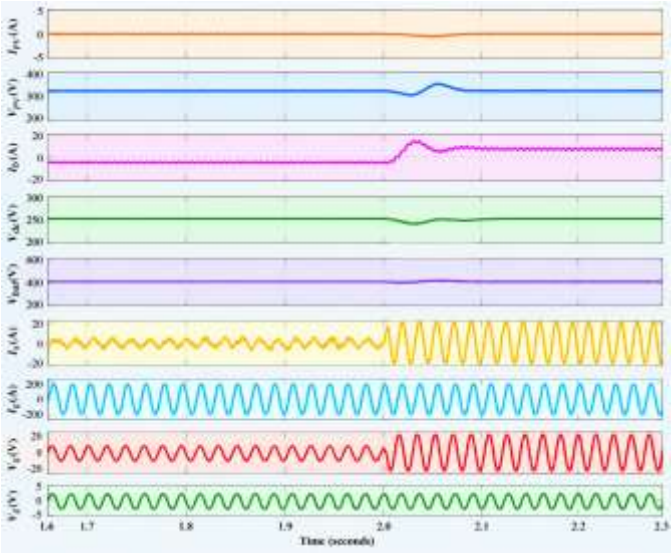


Fig.7. Transitioning performance from G2V to V2G

The incorporation of the Linear Extended State Disturbance Observer (LESDO) in the proposed system achieved outstanding results in the uncertainty and external disturbances. Disturbances such rapid changes in solar irradiation, switching loads or sudden mode changes (G2V / V2G) might impact the high voltage stability and the charging performance on DC-links. The LESDO continually creates adjustment signals to keep the charging system as undisturbed as possible by unknown disturbances affecting the system dynamics. Simulation results indicate that the disturbance observer can successfully suppress the transient voltage overshoot, undershoot and oscillations.

The LESDO has a higher transient response and a much faster settling time compared to the conventional disturbance observer systems. The results show that the proposed observer can improve the capacity of the system to keep charging even in the case of a power outage or rapid change in the weather. The coordinated operation of the SOSMCC controller and LESDO ensures the management of the power flow and a very consistent adjustment of the DC-link voltage. The results validate the efficiency of the suggested disturbance compensation method in enhancing the operational stability and overall dependability of electric vehicle charging infrastructure that relies on renewable energy sources in real-world settings

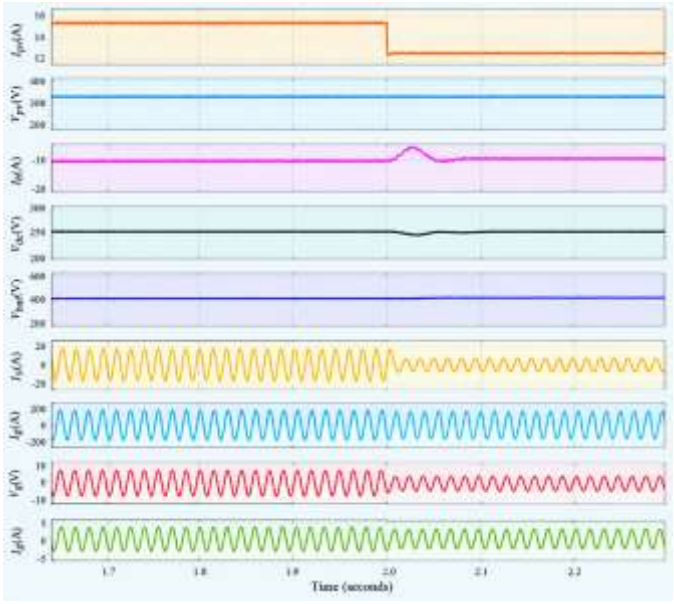


Fig.8 Performance during the change of solar irradiance

Another key conclusion of the study is the quality of switching between G2V and V2G modes of operation of the system. To be able to provide reliable electric vehicle charging infrastructure with the smart grid, charging and discharging have to be done together. Simulation results reveal that the suggested control approach can effectively control the mode switching without instability, large voltage spike and current surge. The bidirectional converter allows power to flow in both directions between G2V and V2G mode, while maintaining the DC-link voltage and battery current constant. The charging of the battery is uninterrupted and no transient oscillation is observed when the system switches from V2G to G2V mode. The cooperation between SOSMCC controller and LESDO observer reduces mode switching disturbances and consequently allows continuous power transmission between the grid, PV system, and battery. The results imply that the proposed technology can satisfy the demands of future smart-grids and distributed energy storage systems for bi-directional charging.

## 4. CONCLUSION

Finally, a reliable, efficient, and eco-friendly solar photovoltaic (PV) electric vehicle (EV) charging system will fuel the future of transportation and energy management. Charging EVs with renewable solar power is one way to minimise our dependence on polluting fossil fuels and other traditional energy sources. The proposed system includes a solar array, a bidirectional DC-DC converter, a battery energy storage system, a Voltage Source Converter (VSC) and improved charging control algorithms, designed to work consistently and efficiently under varied load and weather circumstances. Maximum Power Point Tracking (MPPT) is used to extract the maximum energy from PV systems.

In contrast, SOSMCC is good at managing the DC-link voltage and making the system more stable. Furthermore, the

Linear Extended State Disturbance Observer (LESDO) enhances the disturbance rejection capacity and transitory oscillation minimisation under dynamic operational settings. The SABCAF method further enhances the power quality by minimising the harmonic distortion and maintaining the Total Harmonic Distortion (THD) within the limits specified by the IEEE 519 standard. The efficiency of the charging process, the correctness of the voltage management, the elimination of harmonics, and the smoothness of G2V and V2G operations are simulated and verified by MATLAB/Simulink. To summarise, the proposed layout is an intelligent, practical and energy efficient electric vehicle charging network which can support renewable energy smart grid applications. This network has the potential to be an important constituent of sustainable development and environment friendly transportation.

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