Hybrid Solar and Wind Residential EV Charging System with Price-Adaptive Energy Management

C.Radhacharan[1], K.Anusha[2]

[1]Associate Professor & Department of Electrical and Electronics Engineering, JNTUH University College of Engineering (Autonomous) Jagtial ,Telangana, India.

[2]PG, M.Tech (Electrical Power System), Department of Electrical and Electronics Engineering, JNTUH University College of Engineering (Autonomous) Jagtial ,Telangana, India.

Abstract: ***The study presents a price-adaptive energy management solution that incorporates a single-phase household system, electric vehicles (EVs), and hybrid solar photovoltaic (PV) and wind generation. The suggested method deftly incorporates electric car charging and discharging, grid interaction, and renewable power production to mitigate power price volatility. When the cost of electricity reaches a user-configurable daily threshold, the system shifts to discharge mode to assist residential loads, and it prioritises rapid EV charging when the cost of electricity is low and renewables are plentiful. Another way electric vehicles may save money on electricity and reduce their grid reliance is by driving in vehicle-to-home (V2H) mode during peak tariff times. Our innovative minimum lncosh-based voltage source converter (VSC) management strategy ensures dependable operation regardless of external factors such as price fluctuations, rapid changes in demand, or intermittent renewable production. The suggested controller improves system stability and lessens the effect of outliers compared to more traditional control approaches. By lowering harmonics and maintaining a power factor of unity at the point of common connection, it enhances the grid-side power quality. Power quality, economic advantages, and utilisation of renewable energy sources are three areas where the suggested hybrid system outperforms current techniques, according to comprehensive simulation tests.***

Keywords: ***PV systems, electric vehicles, residential energy systems, power quality improvement, harmonic mitigation, reactive power compensation, unity power factor, price-adaptive energy management.***

I. INTRODUCTION

A shift towards renewable energy sources and electric vehicles is underway, propelled by worries about climate change and the exhaustion of fossil fuels [1]. A lot of people are interested in using hybrid RESs, such as wind power and solar photovoltaic (PV), to charge electric vehicles (EVs) here because of the environmental advantages and the possibility that they may minimise grid dependence [2]-[5]. For household EV charging applications, hybrid solar-wind combinations are better than solo PV systems because of the enhanced energy availability and dependability. There are a number of technical and economic issues that arise with the increasing use of home EV charging systems. These include managing grid congestion, power pricing, and peak demand [6]-[9]. Applications such as grid-to-vehicle (G2V), vehicle-to-grid (V2G), and vehicle-to-home (V2H) are discovering more and more methods to use EVs as multifunctional energy storage devices. This adaptability, when combined with renewable energy production and dynamic power pricing, allows for intelligent scheduling of power use and generation. As the use of power electronic converters continues to rise and nonlinear loads are produced by charging electric cars, there is a growing worry about grid power quality (PQ) deterioration and related energy management difficulties. These causes lead to harmonic distortions, reactive power imbalance, and a lower power factor at the point of common coupling. Conventional approaches based on mean square error (MSE) criteria have difficulty handling non-Gaussian noise, such as intermittent renewable power or unexpected changes in demand, despite the fact that many adaptive filtering techniques aim to reduce harmonics and extract critical components. Fuzzy logic and higher-order adaptive controllers are two alternatives that have come under fire for allegedly being too complicated or too slow to respond dynamically.

To get beyond these restrictions, adaptive control design has investigated resilient cost functions. Its remarkable handling of both big and tiny faults sets the lncosh cost function apart from others. An adjustment parameter enables the lncosh-based

ISSN:3049-0952
www.jsetms.com

method to seamlessly switch between MSE and MAE characteristics, making it more resilient to disturbances, outliers, and uncertainties linked to fluctuations in renewable energy and dynamic pricing signals.

Researchers have looked at approaches to make electric car charging stations more economically viable using price-responsive energy management techniques and PQ enhancement [19]-[22]. Home systems that combine renewable energy sources with real-time price signals are noticeably understudied compared to commercial or large-scale charging infrastructures, which have amassed an abundance of research. Many studies also make the assumption that tariffs are static or fail to account for the potential for electric vehicle and renewable power coordination in their scenarios for dynamic pricing.
This study suggests a price-adaptive approach to energy management for home EV charging systems that use solar and wind power, taking into consideration the aforementioned constraints. The suggested method enhances the coordination of renewable energy utilisation, grid interaction, and EV charging/discharging processes via the use of dynamic electricity price signals. By adjusting its operation to price changes and system circumstances, the EV may move between G2V, V2G, and V2H modes to control power expenditures and relieve grid stress during periods of high demand. Reduce harmonics, control reactive power, and guarantee unity power factor using an innovative least lncosh-based voltage source converter (VSC) management strategy; improve power quality and system resilience. Here is a synopsis of the key arguments:
• Utilise dynamic power pricing to create a price-adaptive energy management system for charging home solar-wind hybrid electric vehicles.
• How to integrate renewable power sources into EV driving modes (G2V, V2G, and V2H) in the most efficient and cost-effective way possible.
• Electric vehicles' ability to charge and discharge themselves adaptively aids the grid and allows for more effective management of peak demand. Reduce harmonic distortion, take reactive power into consideration, and maintain power strength during outages by improving power quality using a least lncosh-based control algorithm.

II. SYSTEM CONSIDERING PV

Here is the system topology shown in Figure 1. At its core, the system is comprised of electric car charging stations, solar panels, and a single-phase electrical infrastructure. Along with the first electric vehicle, a bidirectional DC/DC converter links the second.

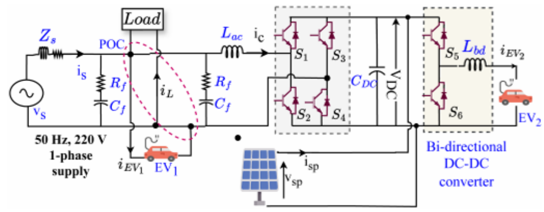

Fig.1. Topology of the system considering PV.

III. SYSTEM CONSIDERING PV AND WIND

One possible solution is a home EV charging architecture that uses a combination of renewable energy sources, including wind power, solar photovoltaics (PV), the utility grid, electric vehicles (EVs), and a single DC-link to improve power management and power quality.
A 50 Hz, 220 V single-phase AC utility supply is linked to the system on the input side via source impedance (Z_s). Points of common connection (POC) are where the grid and residential loads are linked. With the use of a shunt passive filter made of (R_f, C_f), harmonic mitigation and ripples in high-frequency switching may be reduced. The input current to the converter is further smoothed down by using the inductor (L_ac).
The S_1-S_4 full-bridge voltage source converter (VSC) forms the backbone of the system. The DC-link and the AC grid are connected via this converter, which controls the power in both directions. It controls the DC-link voltage (V DC), which is crucial for reducing grid-side harmonics and achieving unity power factor. The DC-link capacitor (C_DC) acts as an energy buffer, preventing voltage fluctuations caused by renewable power sources' intermittency and other transient events.

In contrast to wind energy systems, which need an AC/DC converter to transform AC power into DC power before transmitting it to the DC-link, the DC power for the DC-link is immediately supplied by a PV array. This hybrid configuration guarantees a constant supply of electricity in all weather circumstances and increases the system's dependability.
There are two distinct modes that make up the electric car charging system: Typical charging behaviour is seen by electric cars with an AC side connection, which connect to the grid directly at the consumption location.

When connected via a bidirectional DC-DC converter (S_5-S_6, L_bd), the procedures of charging and discharging electric cars are regulated. This solution is compatible with all three modes: grid-to-vehicle (G2V), vehicle-to-grid (V2G), and vehicle-to-home (V2H).

ISSN:3049-0952
www.jsetms.com

In response to signals from the power price and system demands, the bidirectional DC-DC converter controls the electric vehicle battery current (i_EV2) and enables energy transfer between the electric vehicle battery and the DC chain.
A strategy for managing energy expenses is mostly followed by the system, where:
When renewable energy sources are abundant and power rates are cheap, charging electric cars becomes an important concern.
By releasing power into the grid (in V2H mode), EVs may reduce household loads when tariffs are high.
The VSC control, which is based on the least lncosh algorithm, maintains good power quality (low total harmonic distortion, reactive power correction, and UPF operation) and is resilient against interruptions such as renewable variability and unexpected changes in demand.

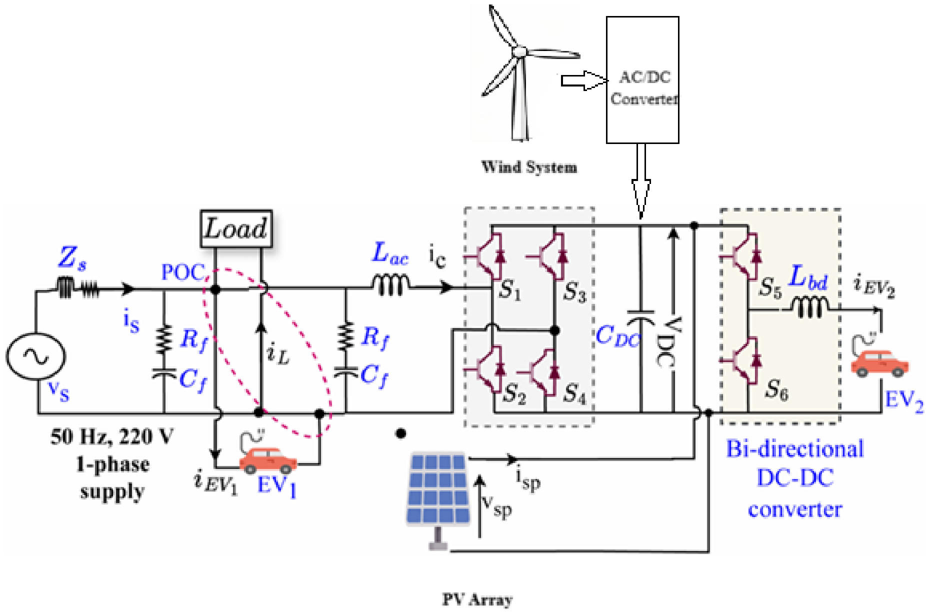

Fig.2. Topology of the system considering PV and Wind

IV. CONTROL STRATEGIES

The solar-assisted electric car charging system's overall control method is described in this section. Exceptional power quality at the grid interface, cost-effective charging of electric cars, efficient utilisation of photovoltaic (PV) electricity, and steady DC-link voltage are all goals of the management plan. The control system coordinates the photovoltaic system, electric vehicle charging unit, home loads, and grid-interfacing converter. Power pricing, home load demand, energy vehicle state of charge (SOC), PV output power, and DC-link voltage are some of the real-time signals that may be triggered in a hierarchical control system. The DC-link voltage is the primary indicator of the system's power balance. If the DC-link voltage changes, the system will adapt its operation to compensate for the imbalance between generation and consumption.

To optimise energy harvesting in solar systems under changing irradiance circumstances, a method called maximum power point tracking (MPPT) is used. During the day, PV power supply is given priority for electric vehicle charging demands and residential loads. Depending on the state of the system and energy prices, owners of electric vehicles have the option of storing surplus PV power in the battery or sending it back to the grid via the voltage source converter (VSC).

A constant current and price adaptive logic are the building blocks of the CC-CV approach, which is used for electric vehicle charging management. When power is cheap, more and more people are charging their electric vehicle (EV) batteries via the grid or solar panels. As long as the state of charge (SOC) stays within acceptable limits, electric vehicle (EV) charging may be limited or enabled in vehicle-to-home (V2H) or vehicle-to-grid (V2G) mode during periods of high power costs or peak demand. By using this method, we may decrease charging costs and peak grid demand while ensuring customer satisfaction.
A two-loop control structure is used by the grid-interfacing VSC. The outer loop regulates the DC-link voltage to keep the system stable and balanced, while the inner loop regulates the grid current to suppress harmonics and make the power factor one. System resilience against price-dependent mode

ISSN:3049-0952
www.jsetms.com

switching, PV intermittency, and unexpected demand shifts is enhanced via adaptive control systems.

A supervisory controller keeps a close eye on the system to make sure the electric vehicle charger and grid link are working properly. To prevent voltage or current transients, there are smooth transitions during idle, discharging, and charging. To further enhance power quality and reduce switching ripple, filters should be used on both the AC and DC sides. An intelligent and coordinated operation of the solar-assisted electric car charging system is made possible by the suggested control mechanism. No long-term energy storage is required to accomplish grid compatibility, consistent power balance, maximisation of renewable energy sources, and decrease of power costs.

A Cosh Algorithm Requiring Minimal Input

Isolating the basic frequency component of the EV1 current and local loads may be accomplished using the least lncosh method. The lncosh cost function, Flncosh, may be expressed as follows:

$$lncosh(e_n) = \begin{cases} 0 & e_n \leq \epsilon \\ \frac{1}{\psi} ln(\cosh(\psi e_n)), & \text{otherwise} \end{cases} \quad (1)$$

In this way, we may say that the cost function is,

$$F_{lncosh} = (1/\psi) ln(\cosh(\psi e_n)) \quad (2)$$

precisely identify the source of the system error signal. If ψ is a tiny positive integer between zero and infinity, then the cosine function with a hyperbolic form is cosh(ψen). The following procedure may to get the amplitude of the voltage at PCC:

$$V_t = \sqrt{v_{s1}^2 + v_{s2}^2} \quad (3)$$

in where vs1 denotes the in-phase signal and vs2 the quadrature signal. The distortion-free unit template Ut is made available by

$$U_t = \frac{v_{s1}}{V_t} \quad (4)$$

By using the stochastic gradient approach, one may express the derivative of the lncosh cost function with regard to the load current weight vector wn−1.

$$\begin{aligned} \nabla_{w_{n-1}} F_{lncosh} &= \frac{\partial F_{lncosh}}{\partial w_{n-1}} \\ &= (1/\psi) \frac{\partial ln(\cosh(\psi e_n))}{\partial w_{n-1}} \\ &= (1/\psi) \frac{\partial ln(\cosh(\psi e_n))}{\partial \cosh(\psi e_n)} \frac{\partial \cosh(\psi e_n)}{\partial \psi e_n} \frac{\partial \psi e_n}{\partial w_{n-1}} \\ &= (1/\psi) \frac{1}{\cosh(\psi e_n)} \sinh(\psi e_n)(-\psi U_t) \\ &= -\tanh(\psi e_n) U_t \end{aligned}$$

$$\nabla_{w_{n-1}} F_{lncosh} = -\tanh(\psi e_n) U_t \quad (5)$$

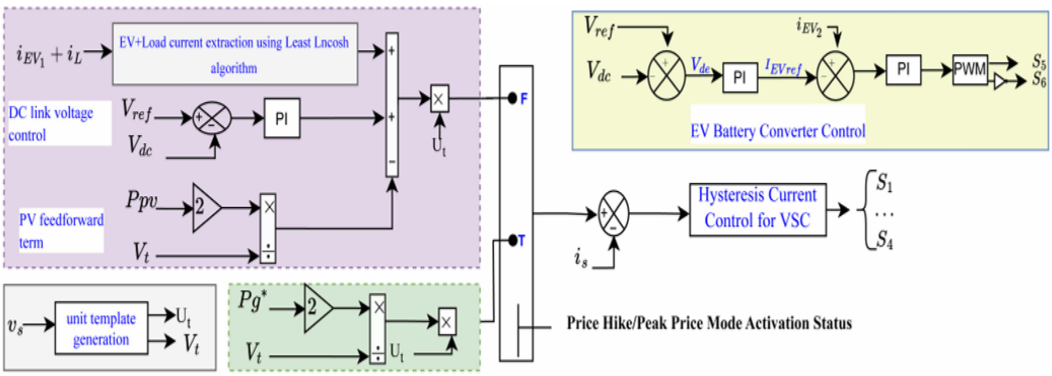

Fig.3 Figure out how the system is controlled.

The control architecture schematic for the proposed home EV charging system with solar help and price adaptive control is presented in Figure.3. The control system seamlessly integrates grid current control, DC-link voltage regulation, PV power management, and electric car battery charging control. In order to achieve unity power factor functioning and precise harmonic suppression, the least lncosh method may be used to extract the major active component of the combined residential load and EV current. A DC-link voltage control loop keeps the power supply constant by comparing the current DC voltage to a reference value and then adjusting the voltage via a signal. To do this, a PI controller is used. Adding a PV feedforward term increases the controller's dynamic responsiveness and maximises the utilisation of renewable energy sources, making it easier for it to react quickly to fluctuations in solar output. In order to modify the grid current, a distortion-free sinusoidal reference is derived from the grid voltage using a unit template generator. By controlling the hysteresis current, the grid-side voltage source converter can maintain low current tracking speeds and low harmonic distortion. Using a series of cascaded PI controllers, an electric vehicle's DC-DC converter regulates the charging and discharging power according to the DC-link voltage requirements. For efficient and cost-effective charging of electric vehicles and grid assistance at peak and low prices, a supervisory price-adaptive logic block determines the operating mode. Affordable electric vehicle charging, efficient PV utilisation, excellent power quality, and steady DC-link voltage are all achieved via the coordinated efforts of these control loops, which do not need permanent energy storage. When there is sudden significant outlier noise, ψen gets extremely big and tanh(ψen) approaches sign(ψen), but the lncosh function acts as the LMS strategy otherwise. The net feedforward is impacted by PV generation in the following ways:

$$W_{SPV} = \frac{2P_{PV}}{V_t} \tag{6}$$

Here is the formula for the maximum value of the reference current:

$$W_{pg} = W_{EV_1} + w_L - W_{SPV} \quad (VPM) \tag{7}$$

The utility grid threatens to cut off power supply or demand a certain amount from the system if the cost of energy above a set daily threshold. This usually happens in the late afternoon, when both power prices and residential load demand are at their highest. Due to the system's inability to handle unrestrained power exchange in these overloaded conditions, only a limited and regulated quantity of energy is allowed. The voltage source converter (VSC) is able to overcome these restrictions in regulated power exchange mode by sustaining consistent power transfers between the DC-link and the utility grid. Turning the VSC control knob to this position makes it put system stability and grid support ahead of flexible power balancing. Whatever temporary swings there may be in demand or PV production, the fixed power reference will remain unchanged. Utilisation of PV and charging or discharging of electric vehicle batteries solve any power imbalance locally. This technology ensures dependable operation during price and demand peaks and allows home EV charging devices to actively participate in demand-side management. It also reduces burden on the grid. The following equation describes the VSC power reference under high-price operating circumstances and expresses the governing relationship for this continuous power exchange.

$$W_{pg} = \frac{2P_G^*}{V_t} \quad (FPM) \tag{8}$$

wherein P∗ G is the reference grid power. The resultant grid reference current which is generated as follows

$$W_{pg}^* = W_{pg} * U_t \tag{9}$$

With no utility grid needs for price-induced power exchange, the DC-link voltage of the system is regulated by the BDCC that comes with EV2. As a result of system circumstances and power cost signals, the BDCC provides EV battery management, enabling the vehicle to switch between charging and discharging modes. With the BDCC, the EV2 battery may reduce charging costs by drawing electricity from the grid or PV system when energy rates are low. But with BDCC, EV2s may maintain home loads (V2H) or release electricity to the grid (V2G) at times of peak pricing or unexpected price hikes. Due to its bidirectional functionality, the electric vehicle's battery can maintain power balance even when no permanent energy storage is available.

Vde=Vref−Vdc (10)

The difference between the reference DC-link voltage (V_{ref}) and the observed DC-link voltage (V_{dc}) is used to determine the control course. This voltage inaccuracy reveals the current power imbalance in the system.

V.PRICE ADAPTIVE CONTROL

Morning, afternoon, and night are the three main parts of an average workday. This grouping is based on today's happenings and the current trend in energy costs. Various tariff levels are intrinsically linked to these time segments. Electric vehicles (EVs) are most efficiently charged from the utility during off-peak hours, such as late at night or first thing in the morning, when demand is low and rates are low. During the day, the system may lower electricity tariffs and give preference to renewable energy sources like photovoltaic (PV) generating. Unfortunately, power bills are at their greatest in the evenings due to the system's extreme strain from business and residential use during this time. The several modes of operation of the proposed price-adaptive management system for each of these

ISSN: 3049-0952
www.jsetms.com

time periods are shown in Figure 3. The control algorithm then obtains tariff information for the next day on an hourly or sub-hourly basis, after the acquisition of the day-ahead energy pricing schedule. Figure 4 shows the result of using data from [29] to generate a sample pricing profile. In order to get a more precise level of control, the 24-hour day is split into 15-minute intervals, represented as (t_m), where (m) is an integer between 1 and 96. Because of this fine-grained separation, the controller can react quickly to changes in load and pricing. The final 20 of 96 time slots that are deemed peak pricing periods fall after 19:00 hours, which is also when power prices are at their highest. Importing huge quantities of electricity becomes expensive and unattractive when the system is under a lot of stress. Accordingly, the suggested method of management prioritises regulated EV battery draining and local PV production while limiting grid power interchange in order to fulfil load demand. The suggested method efficiently lowers energy costs, minimises peak grid demand, and improves overall system efficiency without the need for physical energy storage by dynamically categorising time periods and adjusting system operation in response to signals from power pricing.

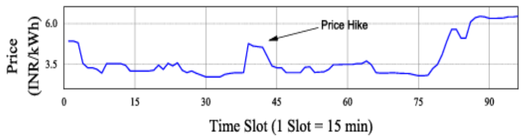

Figure 4: Grid price as shown by the day-ahead schedule of the Indian Energy Exchange Limited

Shown in (11) is the computation for the threshold.

$$Price_{threshold} = \frac{\sum_{m=1}^{n} M_{t_m}}{n}$$

$$n = 76 \quad (11)$$

With respect to the calculation of the price threshold, Mtm denotes the power price for the thirteenth time slot, where n is the number of slots. with respect to the absolute and relative constraints.

$$\min C = M_{t_m} \times P_G^*;$$

$$P_G^* = \lambda^g \left\{P_L - P_{PV} - \lambda^{EV} P_{EV}\right\} \quad (12)$$

The system guarantees accurate control over power import and export between the utility grid and the household energy system by setting a constant value for the grid power reference (P_G^{*}). As a result of efficient functioning and reduced excessive energy buying during tariff times, customers are able to keep their electricity rates down thanks to this controlled power exchange.

A) Low Price Mode

From midnight until seven in the morning, the system experiences its lowest overall loads and power prices are at their lowest in the low price mode. Currently, the weather is ideal for quick and cheap electric vehicle charging. Even though morning solar photovoltaic (PV) output was low, the utility system was able to fulfil all demands, including those of homes and electric vehicle charging stations.

The controller permits charging the electric vehicle battery with the highest current allowed by law in this mode, taking into account the limitations of the battery and converter. The voltage source converter (VSC) is able to obtain the necessary quantity of power from the grid thanks to the precise adjustment of the grid power reference (P_G^{*}). This makes the system efficient and allows it to capitalise on the current drop in power prices. The total power consumption by homes plus the amount of power supplied by the grid to charge EVs is the power balance of the system in low-price mode. While this operational plan is in place, electric car batteries are quickly and cheaply charged during times of renewable power outages, reducing dependency on that source of energy and making them ready to be discharged later in the day during peak-load or high-price periods.

B) Service Durations

During the day, the system is operational when the amount of photovoltaic (PV) production is enough to power homes and, if necessary, charge EVs. By actively using the price-adaptive control strategy and comparing the real-time energy price signal with a predetermined price threshold (Price_{threshold}), the operating mode of the system is now chosen, as shown in equation (13).

C) Coordinated Universal Time (UTC)

The system is running in its normal daytime mode, which means that power prices are below the price threshold. When the EV's battery state of charge (SOC) is within acceptable limits, the PV array will prioritise supplying loads for homes and assisting the EV's charging. The primary goal of this operating mode is to maximise self-consumption of

PV energy in order to decrease power consumption and dependence on the utility grid. When the PV generating capacity is at its maximum, the system returns any excess electricity to the grid, and it meets all load demands, including electric vehicle charging. On the other side, the utility grid will step in to fill the gap if the PV power generated isn't enough to meet the whole demand. By managing the power exchange via the grid-interfacing converter, power factor and DC-link voltage stability are maintained throughout the process. Keeping the electricity on continuously throughout the day provides several advantages, such as reducing the cost of charging electric vehicles, making the most of renewable energy sources, and guaranteeing a consistent supply of power.

D) Grid Back-Up Mode (Daytime Running with Price Increases)

At its most efficient, a photovoltaic (PV) system will harness the sun's energy all day long by running at full blast during the MPPT. Assuming no unforeseen circumstances, this PV output, in conjunction with grid assistance when needed, more than covers the load demand for homes and the EV charging needs. An increase in residential usage or congestion in the regional system can cause power demand to rise unexpectedly at specific periods of the day. Figure 4 shows the pricing trend for the next day, showing that when demand surges, power costs often rise quickly.

The system notifies users of a grid stress or price-hike event when the current power price exceeds the daily adaptive price threshold. On rare circumstances, increasing power generation might overwhelm the electrical system, leading to congestion and voltage fluctuations. The suggested pricing-adaptive control method allows the EV to run vehicle-to-grid (V2G) and take part in grid assistance, which is one way to fix this issue. With the battery in Grid Support Mode, the electric car may safely use grid power. The DC-link voltage control loop and price-adaptive supervisory logic drive a bidirectional DC-DC converter to regulate this discharge power. Discharging EVs lowers peak loads and flattens the demand curve by decreasing net grid power use. Avoiding overdischarge, which may harm the usefulness and health of batteries, requires careful management of the amount of electricity released into the grid to meet battery state-of-charge (SOC) regulations.

All the while, the PV system is still delivering its peak power to the DC-link and residential loads. In addition to the electric vehicle, any extra solar power may be used to power the system. During peak price times, the grid will see decreased net demand due to a combination of inadequate photovoltaic (PV) power, electric vehicle (EV) discharge, and PV production. Constantly regulating grid current, the VSC keeps harmonic distortion to a minimum and the power factor at one, guaranteeing that the power meets all quality criteria. Enabling demand response programmes allows a home's electric car charging equipment to function while in Grid Support Mode. The strategy boosts grid resilience, reduces consumer electricity prices, and encourages effective use of distributed energy resources without requiring permanent energy storage by providing regulated system assistance during price-hike moments.

E) V2H Mode at End-Use Pricing Points

During the late hours of the night, power prices tend to spike since most people are home and equipment such as stoves, lights, and heaters require a lot of energy. Due to the significant demand on the electrical system, power tariffs peak at this time. Solar power is an impractical green option as PV output drops to almost nothing after the sun goes down. Importing power from the grid without restrictions during load shedding is not feasible from a financial and technical perspective. By letting the EV go into vehicle-to-home (V2H) mode when expenses are high, the suggested price-adaptive management system takes care of these problems. Here, each home receives electricity straight from the battery of an electric vehicle, which functions as a distributed power plant. The system can only provide a certain amount of power; going over this limit would lead to the grid being unstable and energy prices to increase. The voltage control mechanism of the DC-link handles the orchestration of the V2H operation. The DC-link voltage drops below its reference value when grid import is limited and home load demand is high. Upon detection of this disparity, the control system instructs the bidirectional DC-DC converter to disconnect the electric vehicle's battery and transfer its power to the DC-link. Home loads get the injected power via the VSC and the local distribution network thereafter.

Limitations on the battery's charge level are crucial for tasks involving transportation from the car to the house. The electric car may let its battery die as long as it's still over a certain threshold.

ISSN:3049-0952
www.jsetms.com

It will make sure that enough energy is stored for when we require transportation in the future. When the state of charge (SOC) of an electric vehicle gets close to this minimum level and the grid can satisfy the remaining demand within its permissible limitations, the rate of discharge is lowered or stopped. In addition to ensuring a secure and dependable power source, this technology is also very user-friendly.

Hydrogen cars are economically viable because they decrease grid energy consumption during peak tariff times, which in turn lowers electricity rates. The grid benefits from this mode because it reduces congestion, peak demand, voltage failure, and loadshedding.

VI. SIMULATION RESULTS

A) RESULTS OF THE SYSTEM CONSIDERING PV

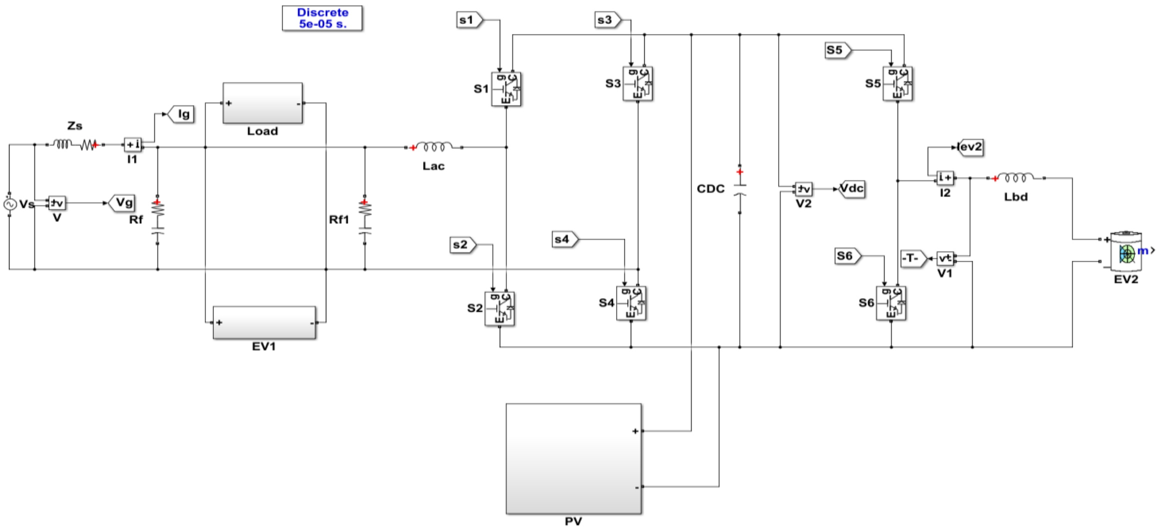

Fig. 5. System topology considering PV.

The electric vehicle charging system (EVCS) is vulnerable to disruptions caused by changes in demand, weather, and power prices. The PV array can power EV1, EV2, and nonlinear loads with 5.2 kW at 1000 watts per square metre at its maximum power point (MPP). Powering down EV2 to satisfy load demand, EV1 charging, and grid needs occurs when real-time power costs above the adaptive threshold; however, EV1 and nonlinear loads are unaffected. Because the electric vehicle battery can manage higher demand without putting additional strain on the grid, reliability is maintained even when solar irradiance drops significantly (from 1000 W/m² to 600 W/m²) and peak demands are high throughout the night. Fig.6 summarises the dynamic performance, which includes grid interaction, PV production, load supply, electric vehicle charging and discharging, and more. This demonstrates that the demand is constant, costs are manageable, and the grid is steady.

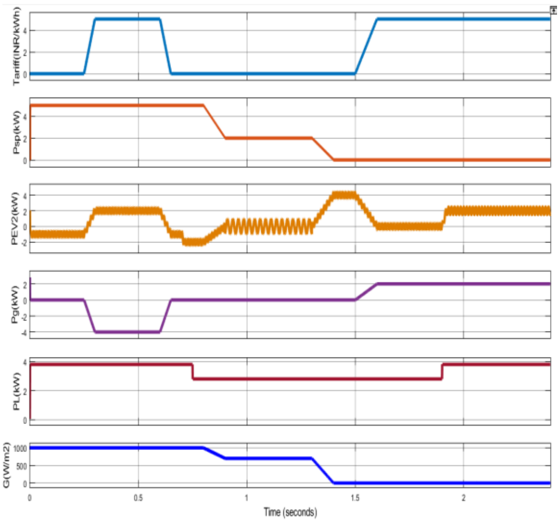

Fig.6 Results from the simulation showing different dynamic fluctuations

ISSN:3049-0952
www.jsetms.com

B) RESULTS OF THE SYSTEM CONSIDERING PV AND WIND

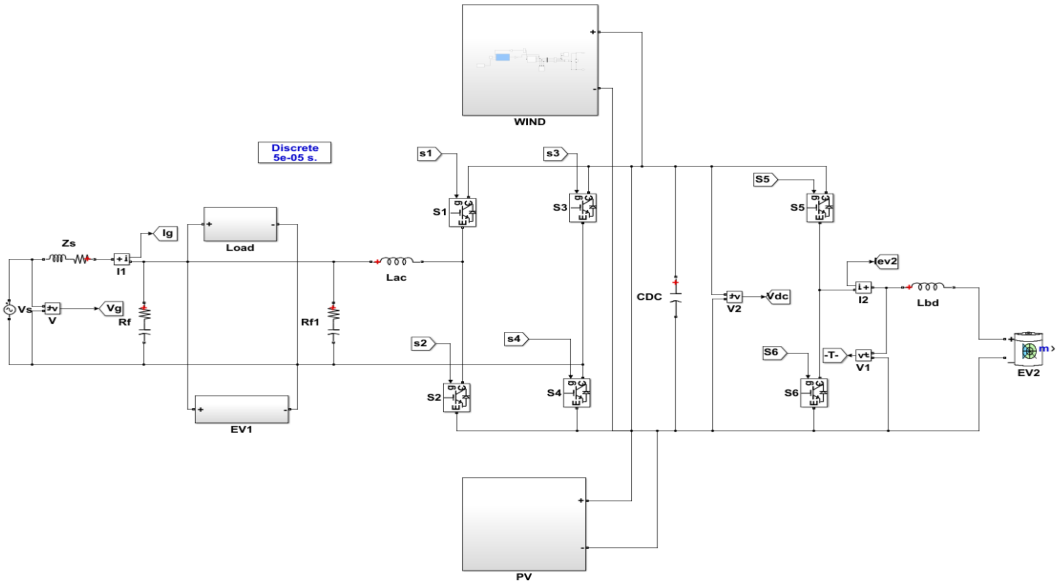

Fig. 7. System topology considering PV and Wind.

The hybrid electric vehicle charging system (EVCS) is susceptible to disturbances including changing energy costs, unexpected weather, and changes in demand due to its mix of wind and solar photovoltaic (PV) electricity. The PV array can produce around 5.2 kW at its maximum power point (MPP) when exposed to 1000 W/m² of irradiance; the wind energy conversion system (WECS) may supplement this power output based on the available wind speed. It is possible to power electric vehicles (numbers 1, 2) and nonlinear loads using a mix of solar and wind generators. V2G mode is engaged by EV2 to help with load demand, EV1 charging, and grid needs when real-time energy prices beyond the adaptive threshold; however, EV1 and nonlinear loads are unaffected by this.

Designed to reliably operate in unpredictable weather circumstances, such as a rapid reduction in solar irradiation from 1000 W/m² to 600 W/m², variable wind speeds, and a high nighttime energy demand, the system is resilient. It is possible that electric vehicle batteries and wind power would more than make up for the power shortfall, easing the strain on the utility grid and preventing it from becoming worse. The system's dynamic performance enhances load dependability, cost management, and grid support via its integration of hybrid PV-wind production, load supply, grid interaction, electric vehicle charging/discharging, and more (Fig. 8).

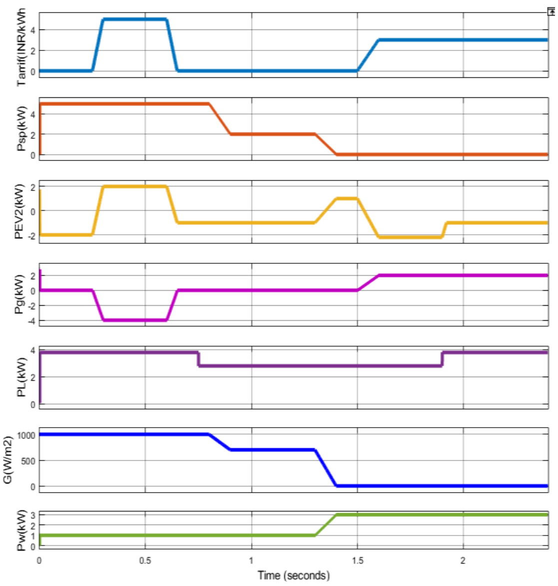

Fig 8. The outcomes of the simulation showing several dynamic fluctuations

VII. COMPARISION TABLE

Parameter	System with only PV	System with PV + Wind
Efficiency (%)	90%	98%
Power Quality	Average	Improved
Stability	Moderate	High
Tariff Type	Fixed Tariff	Dynamic / Price-Adaptive Tariff
Electricity Cost (₹/kWh)	Higher (₹6–₹8/kWh)	Lower (₹4–₹6/kWh)
Peak Hour Cost	High (No Scheduling)	Reduced through Smart Energy Management
Off-Peak Utilization	Not Utilized	Effectively Utilized
Energy Cost Saving	Low	20–35% Savings

VIII. CONCLUSION

To maximise utility grid energy utilisation in residential electric vehicle charging systems that use hybrid photovoltaic (PV) and wind power, a real-time price-adaptive management method was devised. Electricity prices and maximum sanctioned limitations are considered in real-time by this technique. The suggested system is very resilient and can easily endure fluctuations in demand, price, and the intermittent nature of renewable power sources that are hybrid. To guarantee the most cost-effective operation, it is possible to specify an adaptive daily price threshold that relies on the power plan for the next day. At low-price times, the least lncosh approach effectively extracts the major components of nonlinear load and EV currents, resulting in a ripple reduction of the load current to 0.2 A. This is an improvement of roughly 60% compared to the usual SRF methodology. It is more reliable to combine PV output with wind energy conversion in situations when solar irradiation is weak or when wind is unexpected. The control strategy converges rapidly in reaction to changes in loads and environmental conditions, with little peak-to-peak ripple and consistent dynamic performance. Adaptations to demand swings, source availability changes, shifts in EV charging and discharging protocols, and intermittent power outages caused by wind and PV all fell under this heading. The suggested hybrid price-adaptive control system not only boosts grid support and overall efficiency of energy management, but it also saves a lot of money, according to economic research.

REFERENCES

[1] J. A. P. Lopes, C. L. Moreira, and A. G. Madureira, "Defining control strategies for microgrids islanded operation," IEEE Trans. Power Syst., vol. 21, no. 2, pp. 916–924, May 2006.

[2] R. H. Lasseter, "Microgrids," in Proc. IEEE Power Eng. Soc. Winter Meeting, 2002, pp. 305–308.

[3] N. Hatziargyriou et al., "Microgrids: An overview of ongoing research, development, and demonstration projects," IEEE Power Energy Mag., vol. 5, no. 4, pp. 78–94, Jul./Aug. 2007.

[4] M. E. Baran and I. M. El-Markaby, "Fault analysis on distribution feeders with distributed generators," IEEE Trans. Power Syst., vol. 20, no. 4, pp. 1757–1764, Nov. 2005.

[5] H. T. Nguyen and J. B. Song, "Optimal charging and discharging for multiple PHEVs with demand side management in vehicle-to-building," IEEE Trans. Power Syst., vol. 27, no. 3, pp. 1713–1722, Aug. 2012.

[6] S. Deilami, A. S. Masoum, P. S. Moses, and M. A. S. Masoum, "Real-time coordination of plug-in electric vehicle charging in smart grids," IEEE Trans. Smart Grid, vol. 2, no. 3, pp. 456–467, Sep. 2011.

[7] W. Kempton and J. Tomić, "Vehicle-to-grid power fundamentals: Calculating capacity and net revenue," J. Power Sources, vol. 144, no. 1, pp. 268–279, Jun. 2005.

[8] C. Jin, J. Tang, and P. Ghosh, "Optimizing electric vehicle charging with energy storage in the electricity market," IEEE Trans. Smart Grid, vol. 4, no. 1, pp. 311–320, Mar. 2013.

[9] Y. He, B. Venkatesh, and L. Guan, "Optimal scheduling for charging and discharging of electric vehicles," IEEE Trans. Smart Grid, vol. 3, no. 3, pp. 1095–1105, Sep. 2012.

[10] A. Y. Saber and G. K. Venayagamoorthy, "Plug-in vehicles and renewable energy sources for cost and emission reductions," IEEE Trans. Ind. Electron., vol. 58, no. 4, pp. 1229–1238, Apr. 2011.

[11] M. Yilmaz and P. T. Krein, "Review of battery charger topologies, charging power levels, and infrastructure for plug-in electric vehicles," IEEE

Trans. Power Electron., vol. 28, no. 5, pp. 2151–2169, May 2013.

[12] S. Dusmez and A. Khaligh, "A compact and integrated multifunctional power electronic interface for plug-in electric vehicles," IEEE Trans. Power Electron., vol. 28, no. 12, pp. 5690–5701, Dec. 2013.

[13] H. Akagi, "Active harmonic filters," Proc. IEEE, vol. 93, no. 12, pp. 2128–2141, Dec. 2005.

[14] B. Singh, K. Al-Haddad, and A. Chandra, "A review of active filters for power quality improvement," IEEE Trans. Ind. Electron., vol. 46, no. 5, pp. 960–971, Oct. 1999.

[15] M. Karimi-Ghartemani and M. R. Iravani, "A method for synchronization of power electronic converters in polluted and variable-frequency environments," IEEE Trans. Power Syst., vol. 19, no. 3, pp. 1263–1270, Aug. 2004.

[16] P. Rodriguez et al., "Decoupled double synchronous reference frame PLL for power converters control," IEEE Trans. Power Electron., vol. 22, no. 2, pp. 584–592, Mar. 2007.

[17] S. Kouro et al., "Recent advances and industrial applications of multilevel converters," IEEE Trans. Ind. Electron., vol. 57, no. 8, pp. 2553–2580, Aug. 2010.

[18] T. Esram and P. L. Chapman, "Comparison of photovoltaic array maximum power point tracking techniques," IEEE Trans. Energy Convers., vol. 22, no. 2, pp. 439–449, Jun. 2007.

[19] R. Teodorescu, M. Liserre, and P. Rodriguez, Grid Converters for Photovoltaic and Wind Power Systems. Hoboken, NJ, USA: Wiley, 2011.

[20] S. Heier, Grid Integration of Wind Energy Systems, 2nd ed. Chichester, U.K.: Wiley, 2006.

[21] Z. Chen, J. M. Guerrero, and F. Blaabjerg, "A review of the state of the art of power electronics for wind turbines," IEEE Trans. Power Electron., vol. 24, no. 8, pp. 1859–1875, Aug. 2009.

[22] J. M. Guerrero et al., "Hierarchical control of droop-controlled AC and DC microgrids," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 158–172, Jan. 2011.

[23] X. Liu, A. Aichhorn, L. Liu, and H. Li, "Coordinated control of distributed energy storage system with tap changer transformers for voltage rise mitigation," IEEE Trans. Smart Grid, vol. 3, no. 2, pp. 897–906, Jun. 2012.

[24] M. Savaghebi et al., "Secondary control for voltage quality enhancement in microgrids," IEEE Trans. Smart Grid, vol. 3, no. 4, pp. 1893–1902, Dec. 2012.

[25] A. Bidram and A. Davoudi, "Hierarchical structure of microgrids control system," IEEE Trans. Smart Grid, vol. 3, no. 4, pp. 1963–1976, Dec. 2012.