Smart Hybrid Next Generation Charging Infrastructure for EVs

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Abstract- *Nowadays, Vehicles used for transport purposes in India rely primarily on traditional sources of energy. In the various surveys, it has been observed that the automobile sector is the largest contributor of pollutants due to eminent co2 emissions resulting in the continuous degradation of the ecosystem and environment. Besides, the petroleum products usually used in automobiles are depleting promptly at a very alarming rate which is a matter of great concern. In view of that, the future lies in the more accelerated adoption of electric vehicles (EVs), which have been proved to be more energy-efficient, much higher than conventional petrol or diesel-based vehicles. This paper proposes an all-new innovative, integrated hybrid power module involving both renewable and conventional power sources fundamentally to feed the EVs. A smart integrated controller circuit has been designed for the efficient utilization of multiple energy sources and storage. Health monitoring of the whole system is taken care of to avoid disruption to the services. The scheme proposed is aimed towards reliable and affordable e-charging. Moreover, this scheme will also promote the local electricity supply's self-reliance and reduce the conventional energy flow burden. To become a critical imperative global player in the energy sector, India needs a rapid transformation by emphasizing and strengthening energy-efficient green technologies to support & nurture the ambitious goal, i.e., 'Atmanirbhar Bharat,' and to move towards a sustainable, vibrant society. The newly proposed scheme, cost optimization strategy, mathematical tools and the necessary outcome has been explained, explored, and highlighted in the subsequent sections.*

Keywords- Charging, distributed generation (DGs), electric vehicle, hybrid module, energy efficiency, solar PV

I. INTRODUCTION

In recent times there has been significant development in the field of e-mobility for energy-efficient operation and to make it a popular choice between the consumers. Moreover, new storage technology introduces a reliable power supply with a compact and attractive design. Researchers and scientists worldwide are continuously making an effort to study various optimization techniques to explore and unlock hidden potentials. Although there are several challenges, including design, production, reliability, efficiency, etc., an innovative approach with new cutting-edge technology has made it possible to convert it into opportunity. The quick deterioration of traditional power resources makes an urgent call for systematic replacement with alternative sustainable renewable sources. Several developmental challenges have been optimized in recent times, which have a remarkable contribution to the EVs sector's exponential growth. By early 2003, India witnessed a considerable shortage in the electric supply-demand, and non-renewable sources like coal and fossil fuels cannot meet the growing energy demand. This may also cause a problem in supplying adequate charge to the EV charging station from time to time. So, renewable energy sources are adapted to meet the growing demand and minimize the shortage of electric supply from the grid because of the above situation. Hence the EV charging station can be facilitated. India is among the elite class countries to have the largest growing economy, and this can further be strengthened by emphasizing energy-efficient green technologies, which also help to maintain a sustainable environment with better energy security. The recent global warming and energy crisis has unlocked the exploration and intense research for the most trustworthy sustainable alternative, which has paved the path towards the systematic adoption of Electric Vehicle (EV) with improvised technologies and shall be beneficial in minimizing co2 emissions and safeguard our environment to a great extent. Nevertheless, the challenges of the availability of infrastructural support for Electric Vehicles' smooth operation in large volumes do not exist, and this work aims to address those issues with an amicable solution. Moreover, introducing new storage technology leads to a reliable power supply with a compact design. However, several challenges include design, production, reliability, efficiency, the evolution of new cutting-edge technology, and innovation has made it possible to convert it into a golden opportunity. Apart from hydropower and likely wind power, non-conventional energy supplies are not accessible in abundance, rendering them incompetent and inefficient for mass-level energy production. Therefore, the widely fragmented complexity of their distribution and lack of reliability would preclude the likelihood of organized output. However, the decentralization of the current network and the emergence of distributed generation (DGs) would undoubtedly shed light on a viable Alternative. The acceptance of EV over fuel-powered vehicles has been debated in the automobile industries for years. In theory, EV's perform fantastic with instant torque, easy maintenance, carbon-free emission, less moving part, but unfortunately, in reality, there are prominent barriers that predominantly affect its future. The significant challenges lie in charging infrastructure, which has been cultivated as follows:

- **Range of cars:** EVs have less range than ICV. However, there have been claims of EV providing a range of 300 miles under safe parameters.
- **Charging Time:** It usually takes around 20 hrs to charge through 120V supply and almost 7hrs through 240V supply. With fast charging configuration, it hardly takes around 30 minutes to 1 hr.
- **Infrastructure:** A study carried out by Nielsen in 2017 showed that the gas charging station is almost three times the EV charging station. There is only one charging station for 16 EV.

II. LITERATURE SURVEY

In this paper, an extensive review of the literature was undertaken to systematically address this article's theory. [1] C. Liu et al. in 2013, launched an excellent solution to the benefits and problems of vehicle-to-home, vehicle-to-vehicle, and vehicle-to-grid technology. Plug-in Electric Vehicles' probabilistic study in 2013 and their effect was evaluated on the traditional grid in various implementation areas. In the year 2010, J. In the sense of the standard driving operating cycle, Fan et [3] al. Have carried out a thermal examination of the Permanent Magnet Motor in the area of electronic motoring. [4] J. Ni et al. in 2018 also planned and introduced an all-new control scheme optimized for an electric vehicle X-by-Wire. A. Rezaei [5] Capture Energy Saving Scheme in Power-Depletion mode programmed the plug-in hybrid electric vehicle automated charging management system remotely in the same year. In 2011, Y. Kim et al. introduced a revolutionary Automated Hybrid Electric Vehicle Transmitting Control feature [6], a major state-of-the-art technology. The effect of transport electrification upon electrical networks was excellent research undertaken by K.J. Dyke et al. in 2010 [7]. Zhang et al. Suggested in 2018 a groundbreaking Four Wheels Independently Powered Electric Vehicles Adaptive Sliding Mode Controlling Technique Fault-Tolerant Synchronization Control [8]. B. In 2010 Wang et al. [9] discussed numerous facets of electrical protection and various concerns at large-scale charging stations for electric vehicles. J. Zhu et al. made tremendous strides in developing the latest Improved Torque In-Wheel Shifted Reluctance Motor with Split Teeth for Electric Vehicles in 2017 [10]. Authors in their previous work have attempted to investigate and explore numerous varied fields of EVs [11].

III. PROPOSED SCHEME

An all-new Smart Hybrid Renewable Energy Hub with energy-efficient intelligent charging for EVs has been introduced and discussed. Numerous popular renewable energy generation units have been conceded in the scope, including solar PV, Windmill, and waste to energy generation unit and the conventional electric grid. This proposed model allows less electric stress to the grid infrastructure, in turn, encourages renewable co-generations. Under the typical scenario, the EV charging station is being powered by DISCOMs. Initially, the power from DERs is fed to 3-phase invertors, which further conditioned the output power by eliminating unwanted harmonics in the power regulation unit. The switching circuit operates to choose power from DERs or the grid by systematic analysis of load demand. Intelligent load scheduling has been employed to predict load demand under several physical constraints. The switching unit's output power is then fed to the charge controller kit with a smart protective feature installed. Now the power is ready to be used in the power hub to meet the current energy demand. EV charging station receives power from the hub, and under no need, it automatically eliminates contact losses. Besides, special provision has been developed to harness extra power to the community and allied activities and can further be stored in batteries for future sustainability.

The proposed scheme enables charging infrastructure to assure electric power from both sources, which in turn, restricts massive usage of fossil fuel energy and, on the other hand, encourages the use of renewable energy resources. The scope of the work includes two renewable power sources with one existing AC grid supply. The renewable sources, namely Solar (Principal source) and Wind (Secondary source if necessary), have been considered. An AC grid provision has been made available to ensure backup emergency supply if the solar power supply fails or unable to meet the EV charging station's current demand. Energy-saving and higher output equipment have been prioritized in the proposed model. The non-renewable energy sources which are on the verge of getting depleted can be prevented, and the new form of energy sources, i.e., solar, wind, biomass, etc., shall be harnessed, which provide greater energy security. The smart Electric Vehicle charging infrastructure capable of producing enough electricity and balances varying load demand in the local grid, in turn, ensure green energy round the year. This scheme mainly focuses on Solar power for providing charge to the charging station for EV charging purposes. With the current scenario, solar power is growing at a hefty pace these days in India, enabling us to utilize the solar scheme as a primary charge supplier for the charging station. The most essential and integral part of the scheme is the Intelligent Smart hybrid charging system, the PLC-based automated controllers. The controllers are placed at different places where autoregulation of the charge and switching are required. The controllers will control the amount of charge entering the storage unit so that the overflow of charge does not occur. The controller will also be used at the charging junction of the electric vehicles and so on. The controller is designed to keep Siemens SIMATIC PCS7 PLC in mind and control the charge's total flow to the EV or the energy storage unit. The other parts of the system include the Charging components alongside power electronic devices, i.e., rectifier, chopper, inverter, etc. A DC link to accumulate all the DC charges from the chopper or rectifier. AC grid system will be used as an emergency backup supply if the solar is unable to meet the total charging infrastructure, and hence the power shortage can be eliminated.

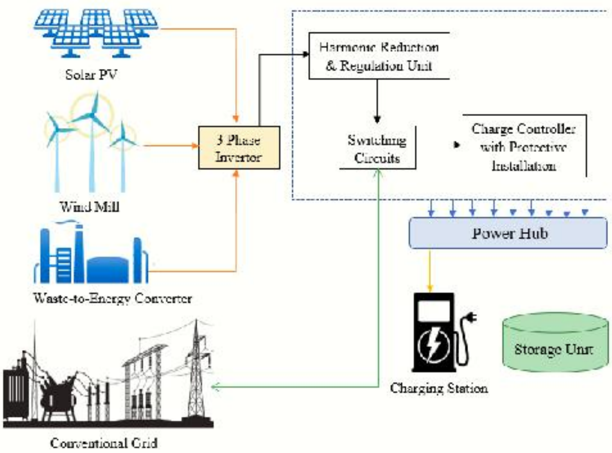


Fig. 1: Schematic view of the proposed model

IV. SCHEME AT A GLANCE

An effort has been made to present the simplified scheme for a better understanding of the model. A large number of energy-efficient power electronics-based equipment, PLC, and digital sensors, has been employed for better execution.

- A cluster of power feeding hubs, i.e., the input supply, is going to be from multiple reliable sources, may it be the renewable or conventional grid.
- The sources would be managed by smart PLC-based switching to maintain the desired output at all times. The controllers would also act as a protection device in case of any unwanted faults or transient conditions.
- A Lightning Arrester has to be installed at this point to protect the system components and accessories from a sudden surge.
- Combination of Isolated & Smart Grid system. Partnership mode of operation with the conventional system, as and when required.
- Intelligent Regulator and Protection device will be used, which will comprise of DC/DC Chopper, Buck Converters, and filters.
- The power will be used to charge EVs as well as a backup storage unit.
- The backup storage unit will be controlled by a smart regulator for safe charging and discharging.
- During peak hours, this unit can be utilized as well as can be used as a supply for the area the overall system is installed.
- Load scheduling shall be done during low-demand times, and the excess power will be utilized for provisional supply to other systems.
- The present status and health conditions can be tracked and monitored in real-time.

This proposed model accepts energy from sources readily available, i.e., preferably Green Energy exists in abundance for that specific Geographic Location. The overall system is Sub-Divided into the following parts for convenience:

A. *Hybrid Renewable Sources with PLC Controlled Switching*

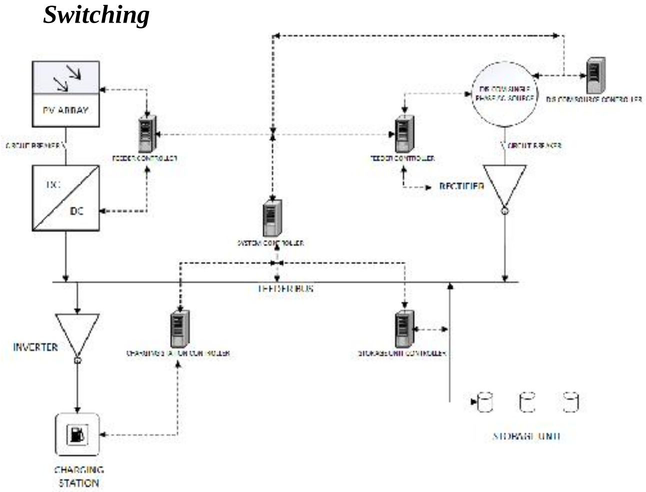


Fig.2: PLC Controlled System

This very power architecture comprises essentially solar and other grass-roots conventional resources from the supply utility. A PLC-based controller has been introduced for better efficacy and reliability, in turn, enhance system-performance. Compared to the reference parameter PLC shall sense for uninterrupted sources' available at that moment and shall quickly switch over to the standby power automatically. The working controller algorithm has been discussed underneath:

- The voltage of the source is sensed and checked with the reference voltage at every instant of time
- There might be instances like the weather is over-casted all day long, and the Optimum amount of voltage over the PV Arrays are not received
- There might be situations when the system is heavily loaded and not getting optimum voltage to supply.
- In such cases, the PLC controller will automatically switch over to the other power source for uninterrupted services
- If the reference voltage is attained, the system will check for clearance and wait to supply to the nearby charging station
- An appropriate automated relay with Circuit Breakers is in place to avoid any unwanted damage to the system and other delicate accessories
- A sophisticated temperature-based sensor module is installed to monitor the real-time system's overall temperature to avoid any overheating situation

B. Smart Automated Stationary Charging Station for Electric Vehicles

Power from either of the sources is fed to the Sinusoidal Pulse Width Modulated Inverter and LC Filters. The PLC controller monitors the overall system. An effort has been made to fix a reference load and has the mechanism of overload protection. We have used solid-state CBs connected with relays and PLCs for automation. The load will be monitored and placed with appropriate Circuit Breakers to avoid damages caused by faults.

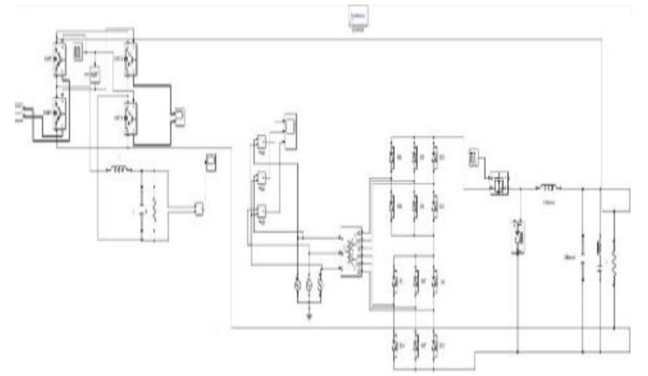


Fig.3: Circuit Diagram

C. Backup or Standby Unit

A situation might arise at any different time when there is a high demand for charging. To cope with the unusual circumstance, provisions have been made for the standby storage unit, i.e., lithium-ion battery *bank [10-15% of the rated capacity],* which can additionally be used as a power backup for local needs at power cut or emergency events.

V. RESULTS AND OBSERVATIONS

The proposed system's output mostly focuses on two parts, i.e., charging and discharging at the battery end & inverter output signal under-charging.

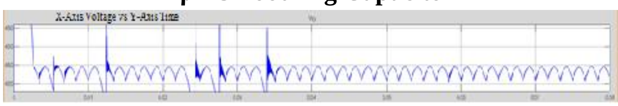
A. Charging and discharging at the Battery End

The Input to the device is fed from a 220V supply, and varying output DC voltage is obtained by varying the smoothing capacitor connected parallel with the circuit. The output voltage graph changes with the variation in the capacitor value.

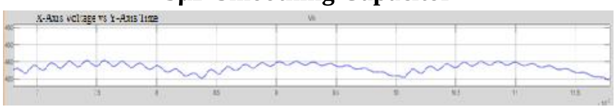
Table 1: Capacitor rating vs Output Voltage

Parameter	Ratings in (Farad)	Output Voltage in (Volts)
Capacitor	1 μF	423.4
Capacitor	5 μF	422.7
Capacitor	10 μF	424.0
Capacitor	50 μF	427.2
Capacitor	100 μF	438.0

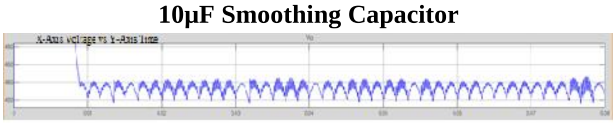
1μF Smoothing Capacitor



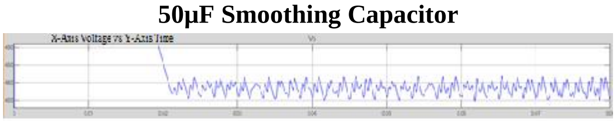
5μF Smoothing Capacitor



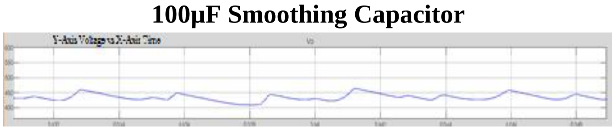
10μF Smoothing Capacitor



50μF Smoothing Capacitor



100μF Smoothing Capacitor



The output voltage smoothens by increasing the capacitor value. The output voltage and current harmonics of the output waveform is given by,

$$(Is)_n = \Sigma_{n=1, 3, 5}^{\infty} (4I_O/n\pi) \cos(\alpha n/2) \sin(n\omega t-n\alpha/2)$$

It, therefore, becomes inversely proportional to the value of the capacitor, the increment of which decreases the harmonic performance. There are two factors to remember when selecting a smoothing capacitor, firstly, its Operating Voltage, which must be greater than the No-load output value of the rectifier, and secondly, its Power Value, which specifies the volume of ripple that tends to be superimposed above the DC voltage. The capacitance value is too poor, and the capacitor has no impact on the waveform performance, as in the case of the 1microphate capacitor. However, if the smoothing capacitor is high enough and the final load current is not too high, the output voltage would be almost as smooth as pure DC waveform nature.

B. Inverter output Signal for charging

The Inverter is fed from a 220V DC supply, keeping the value of LC elements fixed; output voltage, output current, and source current are obtained. The output hence obtained is filtered using an LC filter, and the harmonics are eliminated. Specifications under standard testing conditions.

Frequency: 50Hz, Inductor: 36mH, Capacitor: 470µF

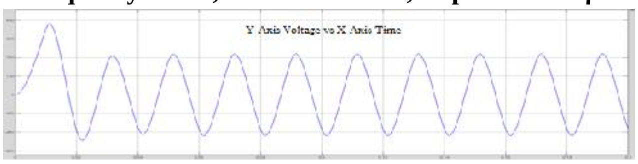


Fig 4: Output Voltage of the Inverter (V vs T)

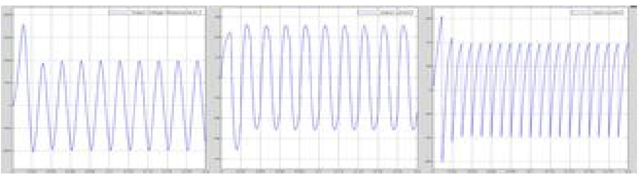


Fig 5: Output Voltage, Output Current, Input Current of the Inverter

By fixing the Capacitor and Inductor's value, the frequency of the output current and voltage can be adjusted. From the above Simulink results, it has been observed that the output voltage increases while the output current decreases guided by harmonics governed by the LC filter. It is known that the increase in the capacitor value decreases the output waveform harmonics, and hence the LC filter alongside the inverted produces a close by ideal AC input for the charging station hub. The IGBT switching is controlled using regulated pulse modulation.

C. Final Output

A standard EV charging station is of three types. Level 1 and level 2 charging is on AC, while Level 3/Fast charging is DC-based charging mainly implemented in European countries.

Table 2: Charging Station Readings

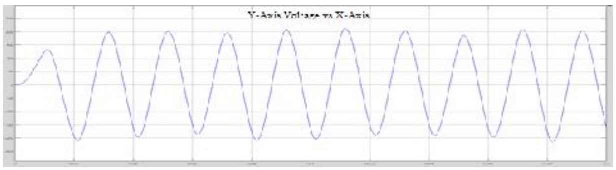
Parameters	Level 1	Level 2	Fast Charging
Voltage	120 V	220-240 V	200-450 V
Maximum Current	16 A	80 A	200 A
Current Type	AC	AC	DC
Power	1.4 kW	7.2 kW	50 kW
Maximum Output	1.9 kW	19 kW	150 kW
Charging Time	12 hrs.	3 hrs.	20 mins

Special emphasis has been given to Level 2 charging type

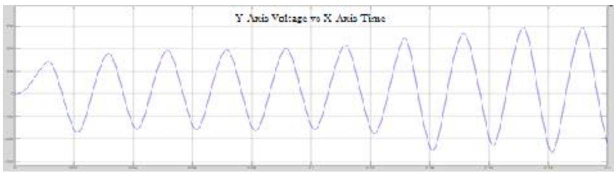
Location	Home	Store	Restaurant	Convention Centre	Workplace
Power	3.6 kW	7.2 kW	10 kW	12 kW	15 kW

The load requirement variation is maintained by changing the firing angle (α), and the values of L & C govern the harmonics and output frequency alongside the inverter. The output voltage waveforms for different loads have been demonstrated as follows:

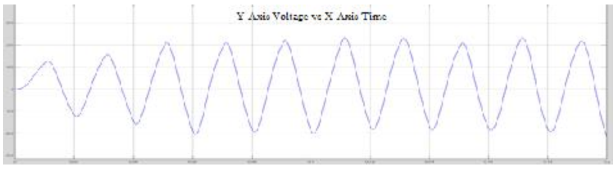
3.6 kW Load



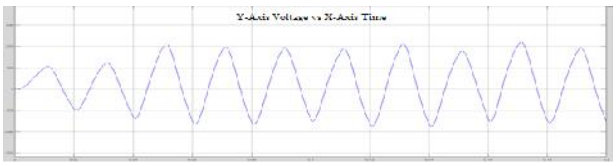
7.2 kW Load



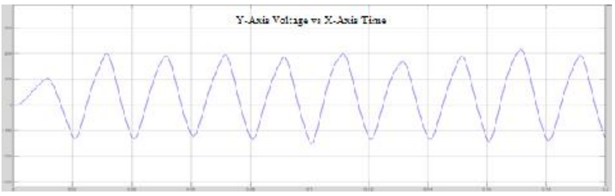
10 kW Load



12 kW Load



15 kW Load



VI. EQUIPMENTS AND COMPONENTS

The Design and fabrication unit has been split into 4 significant stages with the corresponding equipment used which have been listed chronologically.

Stage 1.0: Solar Panel to DC Link components

- *Solar Panel with MPPT controller*
- *DC-DC Buck Chopper*
- *Filter circuit*
- *Charge Controller*

Stage 2.0: AC grid to DC link components

- *AC grid power supple source*
- *Single Phase Controlled Rectifier*
- *L filter*

Stage 3.0: DC link to Storage unit components

- *Filter*
- *Controller*

Stage 4.0: DC Link to Charging Station components

- *Inverter (VSI) with Sinusoidal PWM*
- *Controller Circuit*
- *Charging station requirements and cables*

VII. SOCIAL IMPLICATION

In India, most motor vehicles commonly used for transport purposes are fueled by petrol, diesel, and natural gas, which are known to be important sources of pollutants due to high carbon dioxide emissions. Furthermore, the petroleum fuels used in cars are being exhausted at a very concerning level. There seems to be a worldwide need to pursue an acceptable solution to operating motor vehicles. The latest breakthroughs in electric vehicle (EV) technologies and inexpensive battery storage have shown promise for the widespread acceptance of EVs. However, various challenges may play a negative impression and large impact over-penetration of EVs. Indian electric power distribution system (EPDS) and charging infrastructure need to be modernized and focus on moving towards green transportation. The authors have done extensive analysis to understand technological opportunities and feasible real-time solutions by the proposed scheme. The proposed model has been fabricated by addressing various physical factors, including the environment, clean energy technology, and sustainability. Research shows that the emission of harmful gases through the automobile sector results in headaches, stress, and many significant respiratory diseases. The above-discussed difficulties can be converted into opportunities by the use of energy-efficient green e-vehicle. In the proposed scheme, a plan of action and framework has been discussed to set up an all-new Smart Hybrid Renewable Energy Charging Hub and e-mobile charging vehicle to ensure a prosperous green future in the automobile sector in coming years. Improvement in charging infrastructure leads to encouraging more masses of people to shift towards e-mobility. The entire system would involve business tycoon, government, and industry which can significantly contribute towards countries GDP and help in Nation building. This specific sector can open a new employment generation dimension to unemployed youth to strengthen their lives and families. Rural electrification and grid connectivity can be established conclusively, which helps build a strong nation and sustain the possibility of becoming 'Atmanirbhar' in the energy sector. The growth engine of the electric vehicle market would be fuelled by various drivers, of which strong governmental push and affordability would play key roles. NITI Aayog is targeting 30% EV penetration in India by 2030. To make EV adoption easier for manufacturers and consumers, the Government of India has taken some keys steps in the last few years.

A. Salient Features of EV:

- Zero Carbon footprint as there is no significant use of conventional fossil fuels, in turn saving natural resources
- Energy-efficient with low maintenance as it replaces internal combustion (IC) engine, i.e., less complexity
- Less running cost involved because of reasonable electric price per unit, low noise emission, and smoother traveling experience with less vibration
- Enhance future energy security in an eco-friendly and most sustainable means.
- Maximizes Health benefit as there is reduced harmful toxic exhaust emission in the atmosphere
- The hybrid Renewable Energy model helps in providing partial power autonomy
- It is characterized by better speed regulation high torque & power density with impressive efficiency
- Smart load scheduling features enable to stop the misuse of generated power and moreover helps in community and other activities by providing free electricity to nearby locality or villages.
- Integration of IoT, 5 G communication, blockchain, AI, and cloud network makes it more intelligent

B. Forthcoming Challenges of EV:

- Lack of new edge electricity tariff policies
- Range anxiety among consumer/customer
- Inadequate testing and certification support
- Realtime grid interface & faults troubleshooting
- Reliance on battery imports and fewer recycling
- Much longer charging time with fewer durability
- Too low driving range after attaining full charge
- Primitive registration, taxation & licensing system
- Complex servicing due to sophisticated technologies
- Inadequate charging infrastructure & safety measure

VIII. FUTURE SCOPE

EV has an optimistic future in context to the automobile sector, not only in India but worldwide. Scientists and engineers worldwide have been involved in scientific research activities to eliminate or neutralize the modern-day drawbacks using sophisticated, cutting-edge technologies. Nowadays, most populace companies prefer to use EVs instead of motorized vehicles and continuously express their responsibility towards safeguarding nature. Positive Recommendation has been discussed, which can prove beneficial to boost India’s electric vehicle sector with a much-awaited vision of a greener and cleaner India. The government needs to focus more on planning and preparing a simple roadmap by introducing production quotas for auto manufacturers instead of unrealistic targets. Besides, synchronization must be established to efficiently operate different ministries to achieve a common goal with incentives to build modern state-of-the-art public charging stations based on specific requirements. Different prevalent thinktank throughout the world has estimated that EVs has extensively high potential to grow in Indian market in record time. Below a pictorial graph has been shown to understand the projected cumulative sales of EVs in better conceivable way

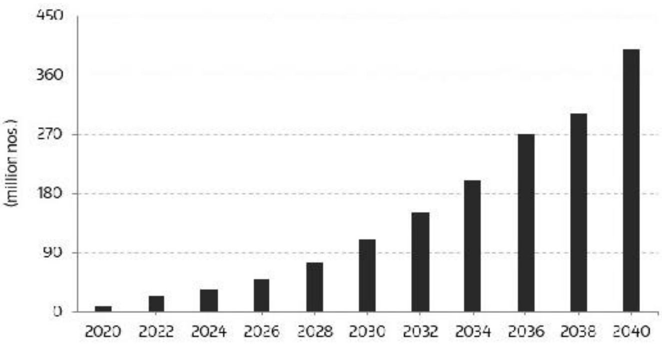


Fig. 3: Projected Cumulative Sales of EVs

IX. CONCLUSION

An all-new Smart Hybrid Renewable Energy Charging Hub has been introduced for energy-efficient charging of EVs. This proposed scheme has prioritized the use of Distributed Energy Resources with renewable energies. Besides, it is characterized by intelligent load scheduling features, which enable to unlock the hidden potential of technology innovatively. EVs are crucial for the green circular economy and need of the hour, which may boost India's indigenous economy and prove beneficial in upholding a sustainable environment. However, several technical issues strictly govern EVs' adoption in the market, which may be resolved by a strong configuration between analytical skills and cutting-edge technologies. The new intellectual strategy should be an advocate to grab a multidimensional opportunity in the EV sector. In this work, special effort has been made to minimize the ever-increasing challenges of electric vehicles' infrastructures, especially in distant suburban locations. Various technical-economic aspects have been considered, including design, planning, technical challenges, execution, and future scope. Green energy is the most suitable eco-friendly alternative to meet the prevailing energy demand and move towards a healthy, sustainable environment. The change in the contemporary scenario has led to the adaptation of e-mobility and its corresponding charging infrastructure. The growing environmental consciousness and adverse effects of climate change have partially attracted attention over its disastrous consequences. India's government has launched the Faster Adoption and Manufacturing of Electric Vehicles' scheme to endorse and provide subsidies for e-vehicle under the new India vision. The recent survey report by the Ministry of Road Transport and Highways, Government of India shows present charging infrastructure for e-vehicle and its background technology are outdated which does not allow features such as multiple and fast charging, which may seriously distress the nation goal towards energy-efficient green mobility. There is a considerable shortage of smart hybrid green charging stations in India, which has inspired authors to work in this domain to partially overcome technological limitations and partially provide intelligent features.

An effort has been made to introduce an all-new Smart Hybrid Renewable Energy Charging Hub with energy-efficient intelligent charging for EVs. Numerous popular renewable energy generation units have been conceded in the scope, including solar PV, Windmill, and waste to energy generation unit and the conventional electric grid. This proposed model allows less electric stress to the grid infrastructure and encourages renewable co-generation and Distributed Energy Resources. An intelligent load scheduling algorithm has been employed to predict load demand under several physical constraints. The charging station's electric power under no need automatically cut out to eliminate contact losses and reduce any unwanted accidental possibilities. MATLAB-based simulation has been done to understand the viability of the proposed scheme under various parameters. Complex mathematical tool and the robust algorithm has been employed for optimizing generated power effectively and efficiently. The specific outcome with the satisfactory result has been shown and discussed elaborately.

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