Comprehensive Investigation on India's Solar Powered E-Mobility Sector: Charging the Future

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***Abstract*—The increasing environmental consciousness and adverse effects over climate alteration have partially successful to accomplish the attention over its disastrous consequences. Governments of India and Niti Ayog has taken several bilateral ingenuities for prioritizing zero-emission technology, in turn, promoting and nurturing the e-mobility sector for a sustainable future. To bring India's past glory back and to project in world platform it becomes very important to boost indigenous automobile sector which intern generate huge employment to our enthusiastic youth by supporting novel initiatives for the expansion of eco-friendly mobility solutions including solar-powered EVs. System performance is greatly impacting due to lack of suitable charging infrastructure, power management and Technological Innovation System (TIS). For stakeholders and other policy-makers, it becomes useful to understand the key factors which include social, economic and policies for vehicle adoption. This paper briefly discusses evolution, standards, features, economy, policy's, scope for growth of EV and finally systematically recognizes the role of various factors in promulgating new dimensions. This may turn out as the greenway to the future, by pleasing the sustainable goals.**

Keywords—Battery, energy, storages, EV, hybrid, dispatch

ABBREVIATIONS

PV: Photovoltaics
EV: Electric vehicle
DN: Distribution Networks
EPDS: Electric Power Distribution System

I. INTRODUCTION

Electrification in the mobility sector is one of the highlighting research areas for the past decade. Market share of conventional combustion i.e. CI and SI engine are shifting towards hybrid electric vehicles. EVs are capable of converts a greater percentage of the electricity provided to it into useful work. Due to cheaper running costs and future sustainability, EVs are likely to be the best-suited way of the future. Recently there has been immense research and development (R&D) work reported in both industry and academic on techno-economic aspects of EVs. Government has introduced a new scheme under which taxation benefit, subsidies and easy testing are being conducted to promote the use of solar-based electric vehicles (SBEV). National Institute of Labour Economics Research and Development (NERD) an autonomous body under Government of India on Global Mobility Summit has prepared and published a Policy Framework on Zero-Emission Vehicles (ZEVs) and Program Management to encourage the use of smart solar-based electric vehicles in the global platform.

II. LITERATURE SURVEY

The author has undergone a detail literature review of various international publication and research reports to understand recent trends in e-vehicle. Liu, K. T. Chau et al [1] in 2013 has presented a brief study on opportunities and challenges of (V2V), (V2H) and Vehicle-to-Grid (V2G) technologies. In the same year [2] S. Rezaee et al have undergone detail probabilistic analysis of plug-in, hybrid and standalone EVs to have a clear understanding. Thermal examination of permanent magnet motor for the EVs application [3] has been proposed by j. fan et al on 2010. A. emadi et al [4] has offered an all-new sophisticated power electronics and motor drives in plug-in hybrid electric vehicles (PHEV) in June 2008. A brief overview of permanent-magnet based DC brushless drives for all-new Hybrid Electric Vehicles (HEV) [5] has been accomplished by K. T. Chau et al in the year 2008. J. Ni et al [6] has designed revolutionary portable control configured vehicle on May 2018. Besides, antilock braking of hybrid electric vehicles by iterative learning control has been systematized [7] by Chanting Mi et al on March 2005. A. Rezaei et al (2018) for the first time has demonstrated Efficient catch energy-saving opportunity in charge-depletion mode for a real-time intelligent controller in plug-in hybrid electric vehicles [8]. Power-electronic module based prognostic warning system [9] has been incorporated for hybrid fuel-cell vehicles by Y. Xiong, X. Cheng et al on June 2008. An all-new innovative development and control technique [10] was projected for automatic transmission-based hybrid electric vehicle by Y. Kim et al on Jun 2011. Four-wheel independently driven EVs by adaptive sliding mode fault-tolerant coordination control (2018) was modified by D. Zhang. K. J. Dyke et al [11]. K. J. Dyke et al has identified the influence of transport electrification on electrical networks and itensure security and prevents accident to occur [12]. In 2017 J. Zhu et al, has designed divided teeth for EVs for switched reluctance motor with new enhanced torque in-wheel. Authors previously have made an effort to diagnose the performance characteristics of microgrid under numerous conditions. Increasing energy demand for EVs and its future projection has motivated the Authors to investigate on different social, technological, economical and Policies related to electric vehicles.

III. CONVENTIONAL TO RENEWABLE: TRANSITION IN INDIAN E-MOBILITY SECTOR

Global statistics represent 15 out of 20 most imperative cities in the world are in India with the highest atmospheric air pollution index. Pollution act as an active social catalyst in

humiliating environment regularly. It has been found that Industry and Automobile are one of the two largest sectors to enhance harmful gaseous emission which leads to air pollution. With the passage of time mobility has given speed to our daily activities, and now it seems quite impossible to turn down the vehicles. The whole automotive sector has been revolutionaries with the arrival of the electric vehicle during this crisis hour. An electric vehicle uses green energy which may further beneficial in maintaining greater stability in the energy ecosystem. Centre for Science and Environment has framed master plans for most urban cities in India to target 60-80% public transport ridership by 2025-2030. On the other hand, with ever-increasing in energy demand, the Government of India has aimed to produce 100 GW of solar power by 2022.

Electric vehicles are autonomous thus improves reliability, system performance and utilization of green renewable by acting as storage. Large scale penetration of EVs will require mutually demand-side incentives as well as integrated planning for distributed Grid management. EVs offer the finest opportunity to act as disseminated storage in the urban energy ecosystem which could further help in better integration of renewables. Smart Grid implementation with improved charging infrastructures is of great importance from the future perspective.

IV. KEY COMPONENTS OF EV

To improve fuel efficiency and emission regulation the best option would the adoption of Electric Vehicles (EVs). To understand physics, we need to go through important parts which constitute the EV. Electric vehicles are far simpler in construction as compare to conventional vehicles.

A. ***Battery Pack***

*1) Lead Acid Batteries:*It was first introduced in 1859 by a French scientist and among the ancient type of rechargeable batteries. It is prepared by dipping inside diluted Sulfuric acid. It has high charge to discharge and power to weight ratio. It is very less expensive and involve periodic maintenance with safety concern. Unfortunately, despite of having several advantages it suffers very low energy-to-weight/volume ratio.

*2) Nickel Metal Hydride (NiMH):*Recent research and development has successfully resolve and extended normal life span to 3000 charge cycles. High self-discharge rate, less tolerant to overcharging and memory effect has seriously affected its application. Chemist are still finding use in automotive applications for powering hybrid electric vehicles as it offers trouble free service.

*3) Lithium-Ion Batteries:*A typical lithium-ion battery are capable to store almost 150 watt-hours of electricity in 1 kilogram of battery. It is rechargeable and frequently used for portable circuits and devices. It is highly efficient as its discharge loss and charging time is very less as compare to other batteries. Now it has been popularly used in power bank, aerospace, and electric vehicles. And most importantly it is maintenance free, and it can sustain 300-500 charge cycles.

4) Fuel cell: Fuel cell technology are powered by hydrogen and emit only water vapors and thermal energy to environment. FC are the most advanced storage device with high energy efficient management. This technology poses enormous potential in various dimensions which include size reduction, good reliability and maintenance free operation to drive the future.

B. ***Electric Drive i.e. Motor***

1) Brushless DC Motor: BLDC motor feature high efficiency, simple design, high durability, excellent controllability, power-saving advantages and found wide application in short duty Drives.

2) Induction Motor: This type of motor is extensively used in all dimension of electrical engineering because of its unique natures. It is characterized by less maintenance, high durability and robustness which make it suitable to employed as a consistent drive for heavy continuous duty.

C. ***Power Electronics based Charge Controller:***

The advanced charge controller administers complete operation, energy management and the distribution of power at any given instant, It also acts as a media between the motor and batteries. Semiconductor devices are used to fabricate the controller which intern are responsible to monitor and regulates all key performance which include battery charging, indication and monitoring the battery voltage, cutting off the supply to the load switch to remove the load connection.

D. ***DC/DC power converter:***

DC-to-DC switching converters are broadly used to efficiently produce and regulate voltage from a source that may or may not be well controlled and are mostly used in portable devices such as EVs. They effectually produce various regulated supply voltages for different sub-blocks within the EVs. Featured components like indicator, horn, navigator, sound system is power by Battery or Solar panel through converter. Four common topologies that commonly find useful are the buck, boost, buck-boost, and special converters.

E. ***Mechanical Fabrication:***

The mechanical fabrication mostly comprised of Chassis, vehicle body and top. A chassis has been defined as the basic framework or canvas in which the final construction of the vehicle is placed upon and most often made of carbon steel. Chassis is one of the most imperative components of a vehicle, without which the car would have no mechanical structure. More recently, some chassis have been made with aluminium to create more inexpensive vehicles.

F. ***Mechanical transmission system:***

From the design point of view, it becomes very important to consider mechanical transmission elements. The entire system in the assembly consists of a differential axle, gear box, hydraulic controls, lubricating chamber and finally braking system which often require to undergo maintenance.

G. *Smart Intelligent Charger:*

They are commonly referred to as Electric Vehicle Supply Equipment (EVSE). This is incorporated to use electricity as fuel to charge the batteries. Charging can be facilitated both in-home as well as public places. They are configured with AI sensing module to monitor the real-time health parameters of the battery in order to ensure appropriate charging.

H. *Charging Technique*

1) Wired Charging: It comprises typically of 3 charging mode which includes Rapid, Fast and Slow based on the basis of effective power output and charging time.

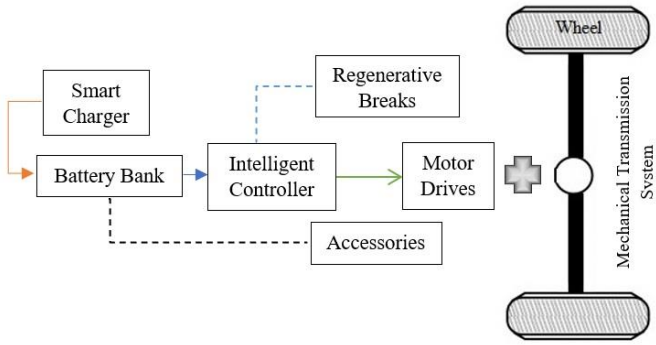
2) Wireless Inductive Charging: electrified embeded roadway (EER) leads to successful convergence of new charging technologies. Normally two wide-ranging approaches are found to deliver energy wirelessly which include employing high inductive coils and capacitive plates.

I. *Solar PV module:*

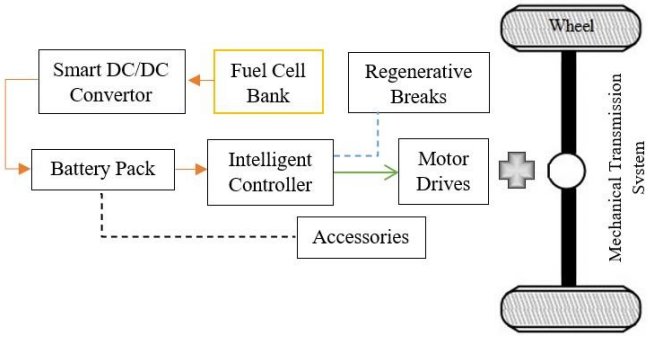
Solar energy is the cleanest and most accessible renewable energy source. The modern technology can harness clean environment-friendly energy to ensure power autonomy by installing PV modules. Sun's radiant energy is being utilized to produce real-time electric power and moreover incorporating the ability to save and store unused energy in the battery pack.

V. DIFFERNET CONFIGURATION OF EVS

A. *Battery Powered Electric Vehicle (BPEV)*



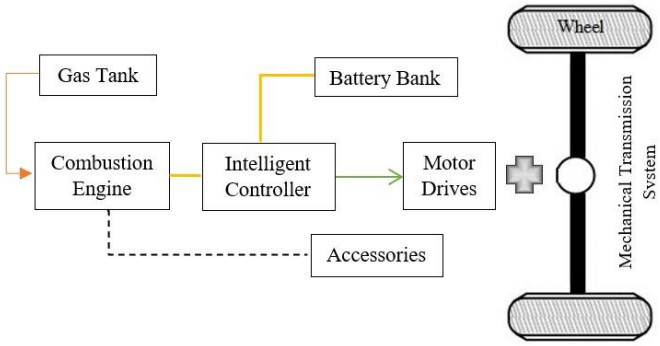
Battery Power EV is the most common and comprises rechargeable batteries equipped with charging circuit. State of the art technologies has now been adopted in the design and development of efficient energy storage devices.



B. *Fuel Cell Electric Vehicle (FCEV)*

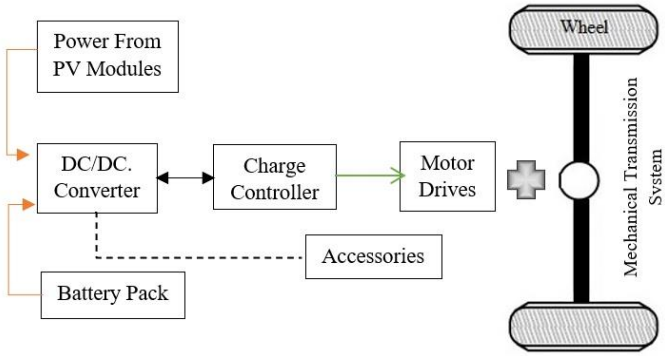
The fuel cell is one of the most promising technology in the coming era, and are being popularly been adapted to increase the reliability, power autonomy and compatibility of the EVs.

C. *Hybrid Electric Vehicle (HEV)*



HEV has the unique capability to drive using both combustion engine as well as electric heavy-duty motor. In circumstances when the battery fails to provide required input to the motor then mechanical engine act as a dynamic backup to attain the destination. Most of the car manufacturer worldwide emphasizing its R&D for better viability.

D. *Solar Powered Electric Vehicle (SPEV)*



With the passage of time and growing awareness among people, SPEV has gained enormous popularity globally for its extraordinary contribution towardssustainable green society by providing energy-efficient e-mobility alternative.

VI. CLEAN ENERGY ECONOMY

The Vehicle-2-grid (V2G) technology empowering bidirectional charging between EVs and the Grid system for frequency regulation and load balancing, which in turn has the significant potential to improve the financial viability of the EV sector. Electric mobility has unlocked a new dimension of business models, which primarily focus on providing stability services to the energy grid and optimizing the economic benefits of owning an EV. V2G encourages and promotes the amalgamation of intermittent renewable energy into the grid, charging optimization,reduction of peak load and regulation of participating capacity. Reduction in fossil fuel production has forced the entire automotive sector to adopt a sustainable clean energy economy, moreover, it possesses a unique perception to create a profitable business.The author has made an effort to bring out future growth projection and transition of EV in context to Indian Market. The estimate has been made by exploring numerous data, information and record from trusted sources which

include 'Bloomberg-New Energy Finance' and 'Society for India Automobile Manufacturer'

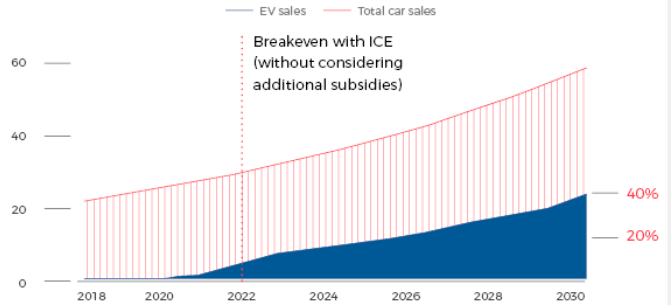


Fig1. EV sales in India (millions) vs time frame

As per the recent detailed report published by CRISIL, all nature of vehicle has been individually assessed and tentative prediction has been made for coming years and scientific strategy to accelerate its adoption in general masses.

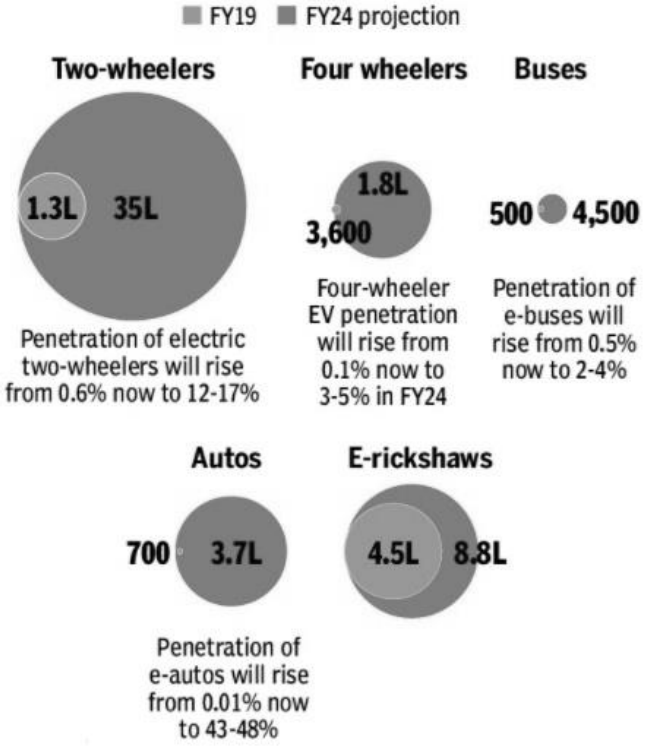


Fig 2. Market occupancy prediction of EVs in context to India

VII. Smart Technologies Revolutionizing EVs

Internet of Things (IoT) and Blockchain are advanced cutting-edge tools to bring rapid transformation in the Automotive sector. Vehicle safety, security, smart insurance, charging infrastructure and supply chain management can be modernized by the suitable application of above cutting-edge technologies. Blockchain may prove beneficial to drive electric vehicle infrastructure in various aspects. With an open blockchain-oriented platform, access to the complete tamper-free data can be ensured, therefore it allows to establish communication between EV owners and charging station. Internet of Things (IoT) technology has possessed the immense potential for application in distributed generation, grid infrastructure and development of Smart Grid. Some of the unique out of the box sophisticated future advancements which shall modernize the present scenario of EVs

- Augmented/virtual Reality (AR)
- IoT configured anti-theft protection
- Peer-to-Peer (P2P) smart EV charging
- Enhanced gesture control and automation
- Vehicle-to-vehicle (V2V) communication
- Battery optimization i.e. smart power saving
- Blockchainbased secure insurance marketplace
- Charging station management using IoT solutions
- stabilizingsmart grid by vehicle-to-grid technology

VIII. EV Standards and Infrastructure Codes

There are several renowned international agencies or laboratory which has a set of scientific standardization which are needed to be followed by Government, manufacturer, DISCOMS and sometimes the customer for uniformity and to safeguard intellectual property rights. Author has made an effort to shortlist some of the most significant standards by NREL, ISO and IEC, which are as follows:

TABLE I. National Renewable Energy Laboratory

NREL Codes	Title/ Explanation
SAE J-1634	EV Energy Consumption and Range Test
SAE J-2344	Safety guidelines for EV
SAE J-2894	Power Quality Index for Plug-In EV Chargers
SAE J-1798	Recommended Practice for Performance Rating of Electric Vehicle
SAE J-2288	EV Battery Modules Life Cycle Testing
SAE J-1772	Electric Vehicle Conductive Charge Coupler

TABLE II. International Organization for Standardization

ISO Codes	Title/ Explanation
ISO 6469-2:2018	Electric vehicle Operational Safety
ISO/TR 11954:2008	Fuel cell road vehicle, maximum speed detection
ISO/TR 11955:2008	Guidelines for balance charging in EVs
ISO 15118-1:2019	Grid communication interface with EV
ISO 19363	Magnetic field and wireless power charger
ISO 23274-1:2019	Fuel consumption and exhaust emissions measurements

TABLE III. International Electrotechnical Commission

IEC Codes	Title/ Explanation
IEC TC 69	Electric industrial trucks and road vehicles
IEC SC 23H	Socket-outlets, Plugs and couplers for EV
IEC/TC 77	LV surge protecting devices for plug-in EVs
IEC/SC 37 A	Electromagnetic compatibility (EMC)

IX. EV Policies in India

India has revised and adopted EV policies issued by the International Council on Clean Transportation (ICCT). India is gradually moving towards formulating an effective EV policy. On focusing the technological development and demand creation, the Government of India has launched 'Faster Adoption and Manufacturing of Hybrid Electric Vehicles' (FAME) scheme. Under phase II there will be a larger emphasis on the design, development and transformation of public transport, in this context 64 cities have been identified throughout the nation. With this policy government is planning to priorities shared mobility and two-wheeler by preferential treatment i.e. free parking and concessional tolls. In a recent move, Energy Efficient Charging Station needs to establish in order to promote people to use them.

X. SCOPE FOR GROWTH OF ELECTRIC VEHICLES IN INDIA

Recent survey resembles the world population to be 7.8 billion and India is equivalent to 17.4% of the total world population as of March 2020. India has the third-largest road network with a 350 million active vehicles on 2019-2020 as per the report published by Ministry of Statistics and Programme Implementation, Government of India. Global economist has projected India's Automobile sector of total worth to reach Rs 20 trillion by 2026, and it has also been anticipated that India may rise as the largest manufacturing hub for the whole world. The automobile sector plays a significant driver of economic advancement of India and also with high participation in global value chains. India has the largest youth which may play a vital role by raising the demand for mobility. Unfortunately, India seems to be moving with no Aim. Despite several serious challenges India has enormous potential to rise by shifting the entire industry into hybrid electric vehicles which in turn also fulfil global sustainable goals. This can only be achieved if Industry/ Manufacturer, Government and customer come forward and move synchronously. EVs is characterized to facilitate customer adoption and employment growth with a reduction in oil consumption with improved transportation qualities.

XI. FORTHCOMING CHALLENGES FOR EVS

- Installation and commissioning of intelligent hybrid charging Infrastructure with lessening in charge-time
- Assortment of appropriate battery chemistries for better charging and safe recycling
- Prepare qualified and dynamic skilled workforce
- Smart grid interface, communication & management
- Setting up of specific lucrative electric tariff policies
- Lucrative Import Duties and Taxation of vehicles
- Improvement of driving range of EVs
- Fixing vehicle servicing unit, testing and certification roadmap

XII. SPECIFIC OUTCOME

As a result, there are certain physical factor i.e. rapid climate change, advances in green energy, swift urbanization, energy security which lead to the adoption of all new smart solar-based electric vehicles (SSEVs) for a developing economy like India. In India, a particular set of circumstances which are conducive to a sustainable mobility paradigm vision have created a prospect for fast-tracked adoption of Electric Vehicles over conventional IC vehicles. India has a lot to gain by transforming its automobile sector at the earliest. Besides, there would be a considerable reduction in the oil import bill which might boost our economy by reducing non-performing asset (NPAs*)*. Besides government need to establish a governing body such as the national nodal e-mobility agency with an autonomous research institute or laboratory to flourish strategic organized development activities. Moreover, there is a need for Non-Banking Financial Institution to promote and encourage subsidized EV with minimal interest. Green corridor projects need to be triggered for the world-class road network and resolve connectivity issues.There are positive Potential areas where the application of EVs can be introduced which may be extended to Rural transportation and Critical ambulances.

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