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"A REVIEW ON RENEWABLE ENERGY INTEGRATION FOR ELECTRIC VEHICLES"

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ABSTRACT

Electric Vehicles (EVs) are gaining momentum due to several factors, including the price reduction as well as the climate and environmental awareness. This paper reviews the advances of EVs regarding battery technology trends, charging methods, as well as new research challenges and open opportunities. More specifically, an analysis of the worldwide market situation of EVs and their future prospects is carried out. Given that one of the fundamental aspects in EVs is the battery, the paper presents a thorough review of the battery technologies—from the Lead-acid batteries to the Lithium-ion. Moreover, we review the different standards that are available for EVs charging process, as well as the power control and battery energy management proposals. Finally, we conclude our work by presenting our vision about what is expected in the near future within this field, as well as the research aspects that are still open for both industry and academic communities. Electric vehicles (EVs) or renewable energy (RE) sources provide the potential to significantly reduce emissions of carbon as of the economy's transport & power generation sectors. There can be a range of impacts and benefits to the mass adoption of EVs, with the ability to aid in integrating renewable energy into current electricity grids. Present literature on EVs, power grid as well as the integration of RE is reviewed in this paper. Literature's main methods and assumptions are deliberated. Economic, environmental & the grid effects of EVs are studied. Several research studies have been conducted on the ability of EVs to integrate Res. literature indicates that excess RE generated on a power grid can be reduced significantly. In the Vehicle to grid (V2G) idea the Plug-in electric vehicle (PEVs) can be performed as the load or as the distribution energy source.

Key Words: *Electric Vehicles, Lithium-ion renewable energy, Vehicle to grid (V2G.*

I. INTRODUCTION

With the rapid depletion of fossil fuels and growing environmental concerns due to greenhouse gas emission, electric vehicles (EVs) have gained increased popularity. EVs utilize onboard or off-board chargers to charge the EV batteries from the electric grid [1]-[3]. The negative effects of EV charging on the power quality of low-voltage electricity distribution grids have been extensively studied in the technical literature, and it has been demonstrated that coordinated EV charging can mitigate adverse impacts such as increased peak load when large-scale EV grid integration is required [4]-[6]. Additionally, due to the energy storage capacity and vehicle to grid (V2G) operation capabilities, EVs can provide active and reactive power support to the electric grid either in battery-connected or disconnected mode [7]-[11]. The possibility of using EVs for reactive power support was extensively investigated in technical literature [10], [12]-[16]. Providing reactive power compensation using distributed energy storage devices such as EVs, reduces the installation and maintenance costs associated with dedicated reactive power compensators such as capacitor banks, static VAR compensators and static synchronous compensators.However, the use of EVs for V2G reactive power compensation leads to additional concerns such as discharging of the battery and exposure of the

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battery to undesirable ripple current components. A second-order harmonic ripple current component at the DC-side of single-phase onboard EV chargers increases with V2G reactive power operation as explained in [14]. The adverse effects of the low-frequency ripple current components on the EV batteries can be mitigated using two stage charger topologies. However, according to the analysis presented in [15], a larger DC link capacitor has to be employed to handle the increased second-order harmonic ripple power requirement. For single stage EV chargers, the second-order harmonic ripple current has to be supplied by the EV battery unless a ripple compensation method is employed. Such continuous low-frequency ripple current components adversely affect the lifetime of battery due to internal heating [16], and also increase the number of charge/discharge micro-cycles of the battery and hence deplete its lifetime more quickly [17],[18] In addition to the second-order harmonic ripple current component, the EV battery has to withstand an undesirable switching frequency ripple current component for a longer period with V2G reactive power operation. Another significant concern of V2G reactive power compensation is discharging of the battery due to the continuous operation of the power converter and associated power conversion losses [19]. In [20], the authors proposed to disconnect the EV battery from the charger, when it is not charging from the electric grid. The disconnection of the battery from the charger helps to avoid adverse impacts of V2G reactive power compensation on the EV battery. However, important effects related to the disconnection of the battery from the EV charger such as dynamic performance, capacitor sizing, and capacitor voltage control were not analyzed in [21]. Power electronic inverters play a key role in the EV battery storage systems. The boost inverter topology is a single-phase differential inverter topology which provides both boosting and inverting functions in a single power conversion stage.

PHEV and EV Technology-Today, there are three types of passenger vehicles available in the market operating with an electric traction motor powered by a battery: HEVs, PHEVs, and EVs or BEVs. HEVs have the smallest size battery pack, and therefore an electric motor is used to drive at very low cruise speeds or to assist the internal combustion engine (ICE) during higher power requirements. Therefore, HEVs offer customers a way to increase gasoline mileage by having batteries and electric drive systems work with the ICE. The most efficient hybrid vehicles reduce the gas consumption by around 40% compared to similar size conventional ICE vehicles. However, HEVs lack the availability to go for more than just short distances at low speeds with only electric power because the battery is not capable of storing enough energy to power the vehicle for a daily commute.

PHEVs, however, provide an all-electric range up to a pre-specified distance with a larger size battery pack, which is not inherent in HEVs. There are several definitions on how a PHEV is defined. According to [22], the battery pack capacity should be at least 4 kWh, and the PHEV must be rechargeable by an external source of electricity. Another definition adds the ability to drive the vehicle at least 10 miles in electric-only mode without consuming any gasoline as a requirement for a vehicle to be classified as a PHEV. By definition, an EV has only an electric motor in the traction drive which is powered by an on-board battery, and conventional vehicles have only combustion engines. The 2010 Toyota Prius HEV has only 1.3 kWh on-board traction battery capacities. As a comparison, the 2011 Chevrolet Volt PHEV has a 16 kWh battery capacity and 2011 Nissan Leaf EV has a capacity of 24 kWh on-board battery energy storage.PHEVs operate in charge-depleting (CD) mode when most/all of the energy comes from the battery during the all-electric mode; hence, the battery is in the deep cycle mode. If the battery reaches its minimum state of charge, the control system switches to the charge-sustaining (CS) mode where the battery experiences only shallow cycles. PHEVs are usually described as PHEV-X where X is the number of miles that a PHEV can go just with the electric energy.

Vehicular Traction Battery Technology Status-For years, the biggest hindrance of deployment of EVs has been the lack of a portable high-energy storage device. With recent developments in battery technology, it has been easier to overcome this obstacle. During this advancement of vehicle grade batteries, the main categories that the vehicle battery research has focused on are: energy, power, life span, safety, and cost.The energy stored in a battery determines the electric drive range and is measured in amp-hour (Ah) or watt-hour (Wh). The electric drive range of a PHEV is proportional to the amount of stored energy, as more energy is required to drive the vehicle in electric-only mode. Since the available space is limited in vehicles, researchers usually focus on the energy density (watt-hour per liter (Wh/l)) or specific energy (watt-hour per kilogram (Wh/kg)) of a battery. The amount of stored energy is more of a concern for EVs compared to PHEVs, since EVs do not have a gasoline tank to extend the driving range on a single charge. The battery power is measured in watt (W); however, as in the energy and energy density, battery researchers focus on power density (watt per liter (W/l)) or specific power (watt per kilogram (W/kg)) in battery terminology. Higher battery power translates into higher motor torque or vehicle acceleration. The power rating is also important to determine how fast a battery can be charged which is usually much slower compared to discharging. The battery life span includes two

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different cycle measurements; the first of which is the minimum calendar life. A vehicle battery is expected to operate above a specified capacity for the calendar life period of 15 years with limited degradation.The next important item for the battery lifetime is the cycle life which relates to the total number of charging-discharging cycles that the battery is exposed to during its lifetime. A battery experiences both deep and shallow charge-discharge cycles depending on its operation mode. A deep cycle means one complete charging and discharging of the battery usually between 20% and 90% of the SOC† . A shallow cycle usually occupies a very narrow SOC window, i.e. 40% - 60%. A shallow cycle is more battery friendly compared to a deep cycle since a smaller SOC window is used. In other words, a deep cycle affects the battery lifetime worse than a shallow cycle. Safety should always be kept as the number one priority for all of the operating conditions

II. Literature Review

Ananda Babu et.al. 2020- In this work, the performance of BLDC motor is evaluated by considering two different applications which are so realistic to real time systems such as Electric-Vehicle Transportation system and water-pumping system based irrigation applications. In general, BLDC motor is powered by either DC source or Renewable Energy Sources (RS) with a power-electronic inverter followed by high voltage-gain boost DC-DC converter. In this work, SPV system is considered and interfaced to two real-time applications with the help of power-conditioning systems, it consists of high-voltage gain DC-DC converter and DC-AC inverter with attractive control schemes. The evolution of DC-DC converters with greater voltage gain converter is required, it transforms low-level SPV voltage to high-level DC-bus voltage with attractive Maximum-Power Point-Tracker(MPPT) algorithm is placed to attain the pre-requisite efficiency. Unfortunately, formal DC-DC converters are not preferable because of extreme duty ratios. So as to implement a high voltage gain DC-DC converter, several types of converters are reviewed. A conventional DC-DC boost converter is selected for driving the PM-BLDC drive powered by Solar-PV system. The performance of PM-BLDC motor is evaluated under fixed speed and variable speed conditions by using Matlab/Simulink tool, results are presented.

Arnab Ghosh; et.al. 2018 -In this paper a very high gain step up DC-DC converter of multilevel output voltage is proposed. Maximum voltage gain in conventional Boost converter like, switched inductor converter, cascaded Boost converter, switched capacitor converter etc. are limited due to extreme duty cycle (i.e. duty cycle near to unity). Operation at extreme duty cycle leads to, serious reverse recovery problem at the switches, high conduction losses, high electromagnetic interference etc. Isolated converter such as fly-back converter, push-pull converter, forward converter, bridge converters etc. overcomes the above issues, where basically a transformer or coupled inductor is used to Boost the voltage. But, inclusion of transformer or coupled inductor introduces voltage spike at the main switch and power loss due to leakage inductance. Recently, DC micro-grid gets major importance because of the significant increase in DC loads and demand of high quality power. These DC loads require different voltage levels based on their power ratings. Photo voltaic source (PV) is one of the prime sources of energy in DC micro-grid. A very high voltage gain converter is the need for DC micro-grid because of low PV source voltage. In this regard, here a step up DC-DC converter topology is proposed, which possess a very high voltage gain characteristic. The proposed converter operates in continuous conduction mode.

Hossein Gholizadeh et.al. 2021 - In this study a transform-less high step-up converter has been proposed. The topology of the proposed converter has been built up based on the conventional boost converter and has been modified by two voltage multiplier cell. The mentioned converter has been designed for the continuous current mode. The voltage ratio of the proposed converter has been extracted for both ideal and non-ideal mode. The non-ideal voltage ratio of the proposed converter has been compared with other high step-up DC-DC converters. Moreover, the practical voltage ratio of the converter has been extracted and compared with the result of the relation of the non-ideal voltage gain. Finally, the simulation results have been extracted and compared with experimental results. The PLECS is the simulation engine which has been used in this study.

Hiroaki Matsumori et.al. 2021 -This paper presents an isolated step-sown DC-DC converter using GaN power device for automotive applications. The works for a power supply from a high voltage main battery with 200V to low voltage auxiliary battery with 13.6V in hybrid electric vehicle. A LLC converter is known as isolated DC-DC converter with high-efficiency. However, when input and/or output voltage considerably fluctuates, efficiency of a LLC resonant converter becomes worse. In order to solve this problem, a DC-DC boost-up converter to mitigate efficiency deterioration for the input and/or output voltage fluctuation is added to a LLC resonant converter. Generally speaking,

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an additional circuit, the boost-up chopper in this case, also deteriorates the total system efficiency. To avoid the efficiency degradation, discontinuous current mode control and GaN power devices are applied to the boost-up chopper. The DC-DC boost-up converter experimentally achieves 99.03% of conversion efficiency at nominal output so that it has no effect on the total system efficiency. Even though adding a DC-DC boost-up chopper to the LLC resonant converter, a power density expected to 10 W/cc.

M. Shahriman et.al. 2018 - This paper presents a new approach for generating the state-space averaged model of dc-dc converters in the basis of relative variables using the Lagrange theorems. Averaged mathematical models of boost, buck and buck-boost converters have been developed, allowing the analysis of steady-state processes in continuous conduction mode (CCM) and discontinuous conduction mode (DCM). It is shown that a new approach to obtaining averaged models makes it possible to calculate not only the constant components of the process, but also their pulsation components, as well as the duration of the time intervals of the steady-state process, which is an advantage over traditional averaging methods. Using the obtained models, the dependences of the current ripple of the storage choke relative to the load current and the voltage transfer coefficient of the converters were calculated in the entire range of regulation of the switchi

Tat-Thang et.al. 2021- With the improvement of the requirement on energy conversion and power transmission, the technology of DC-DC converter has developed rapidly. In order to realize the energy transmission between the high voltage side and the low voltage side, this paper proposes a novel DC-DC converter which is made up of modular multilevel converter (MMC) on the primary side and the full-bridge on the secondary side. When it comes to the control scheme, there is an improved carrier phase- shifted pulse width modulation (CPS-PWM), producing a five-level stair wave. The secondary side employs the single-phase- shift (SPS) control. In the meanwhile, the equations on MMC side are obtained, containing AC equivalent output voltage, AC output current and corresponding transient power. Moreover, the power characteristics are demonstrated apparently in MATLAB/simulink.ng duration.

Agasthya et.al. 2019 - With the improvement of the requirement on energy conversion and power transmission, the technology of DC-DC converter has developed rapidly. In order to realize the energy transmission between the high voltage side and the low voltage side, this paper proposes a novel DC-DC converter which is made up of modular multilevel converter (MMC) on the primary side and the full-bridge on the secondary side. When it comes to the control scheme, there is an improved carrier phase- shifted pulse width modulation (CPS-PWM), producing a five-level stair wave. The secondary side employs the single-phase- shift (SPS) control. In the meanwhile, the equations on MMC side are obtained, containing AC equivalent output voltage, AC output current and corresponding transient power. Moreover, the power characteristics are demonstrated apparently in MATLAB/simulink.

Evelyn-Astrid et.al. 2018 -Modeling, design and control of a DC-DC converter using state-space averaging approached are presented. A proposed DC-DC converter topology is based on two half-bridge DC-DC converters which control the power between the battery, energy storage system (ESS) of an ultra-capacitor, and an output load resistance. Two well-known control schemes based on AC equivalent circuit modeling are used to design converter control system. The average voltage mode control is used for the boost converter operation and the two-loop average current mode control for the bidirectional operation. Control schemes are modeled and designed, the performance and responses were analyzed using Matlab/Simulink. The simulation results show that the proposed control system is capable to regulate efficiently the power flow between two DC sources.

III. ELECTRICAL VEHICLE IMPACTS AND PERFORMANCE

The introduction of EVs, like a lower vehicle running costs, decreased CO2 emissions, as well as supporting and improving grid power and stability, may expect a certain range of positive impacts if appropriate technology is implemented. However, the potential of EVs to help incorporate RE sources into the power grid is perhaps important. This has the potential to reduce both energy generation or transport carbon emissions. It should be observed that while EVs can significantly reduce some adverse implications of large-scale RE, other methods & technologies are probably required to incorporate the high level of the RE penetration. EVs give several possible advantages to the grid, with the potential to add intermittent sources of RE. The capacity, limits, and that transport and the electricity industry can be combined through electricity and renewable energy must be understood. This will affect the policies and planning of infrastructure to optimize the environmental & economic gains of all innovations while reducing global greenhouse gas emissions and reliance on fossil fuels. System providers, vehicle owners as well as the environment benefit from PEV. PEV's can serve as stored energy tools & serve as a reservoir for the prevention of unexpected outages if they are

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provided with sufficient on-board power source, energy storage connections, and digital charger control hardware. It benefits the environment and accelerates the use of PEVs

A. Economic impacts (EI) EI of EVs is categorized into 2 parts. The first part is the vehicle owner and the second part is the electricity system. Better battery technology & mass production are expected to improve the lifecycle economy of EVs. BEV's cost is greater than PHEV's. Both are more costly than the traditional IC engine [23]. However, EVs are much less costly than IC motor vehicles as the electric motor is highly powerful. B. Environmental impacts The most frequently slow output applied to assess the environmental consequences of network-powered changes to EVs is CO2 emissions. Integrating electricity or transport sectors reduces emissions of carbon dioxide by 85% [24]. They are discussing the intensity of emissions (gCO2e/kWh) for energy used for charging by EV. The average grid intensity is used in most studies to represent a situation where EVs are usually followed and can be used as part of the daily demand profile. Other studies contend that marginal intensity [25] is used, where EV energy is allocated to the emissions of the marginal generation unit. In general, it can be found that even with electrical systems by high fossil fuel generation, EVs minimize overall CO2 emissions because the electric motor is highly powerful relative to internal combustion engines. C. Grid impacts EVs affect power, performance, or need grid power, especially when the vehicle is charged with restriction. When a basic recharge technique is applied [25], peak loads increase. It also calls for increased investment in capacity generation and transmission. When the vehicle uses an adaptive charging strategy, the vehicles raise the total load and use the base charging devices. And also it does not require any extra installed capacity [26, 27]. Other impacts of EVs on-grid include higher wear on transformers, overloading, or problems in terms of power quality [28]. The EVs and V2G are controlled to have very little effect on losses or voltage of the delivery system [29]. Even more, studies have established delivery charge level plans to preserve power quality or prevent congestion issues arising from the generally accepted use of EVs. [30, 31]. The effects of EVs at low EV penetrations are negligible on residential distribution transformer. But the effect is increased as no. of EVs increases. A high number of EVs leads to voltage limit violations, transformer overload & increase line losses [32]. To combine more EVs in distribution networks safely, these latest management approaches are necessary.

IV. Benefits & Challenges Of Vehicle-To-Grid (V2G)

Ancillary Services in PG, supply & demand must be maintained, supply & demand regulated, and electricity transfer from the seller to the buyer provided via Ancillary services. The two-way V2G paradigm offers better quality ancillary services than those offered at current. More PEVs must be obtained by the transistors in the community to provide a greater and needed load for utilities [33, 34].

• **Voltage & Frequency Regulation**- Regulation services represent the 1st phase for V2G since the vehicle power storage device is of high market demand and has low stress [35, 36]. To balance supply and demand, frequency regulation is used [37]. The frequency regulation is attained by cycling large generators that are expensive [38]. In its fast charging or discharging speeds, V2G is a good alternative to frequency change [39]. The voltage regulator is used for reactive power to balance supply & demand.

• **Load Levelling (Load Shifting)** By charging during high demand or charging during low demand, V2G can level power load. Local & global smart charging monitoring approaches were described by K. Mets [47]. By doing the smart charging, the peak load, as well as the load curve, would be reduced. For leveling the grid, PEVs should be paid at night. The design of the battery charger is regulated to minimize the overall load and to increase energy demand [48, 49]. Renewable Energy Supporting & Balancing The energy generated in the intermittent wind and solar energy plants can be used to combine PEV with renewable to buffer and store energy [39, 50, 51]. For instance, the sun is only available during the day and wind power due to the unpredictable wind speeds is more complex. This will lead to imbalance [52]. Kempton or Tomic [53] examine that this fluctuation would be resolved by V2G. If renewable grid capacity is very high, central power plants must either their output to reinstate equilibrium, or distributed generation components must be decreased. PEVs may be used by discharging or charging PEVs to match consumption or generation. Extra renewable can be processed by PEVs. This extra power can be used to drive the vehicle or later power the grid [42]. The V2G would also improve grid stability to make better use of intermittent renewable.

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V. Challenges Of V2G

V2G has many advantages, but the increased amount of PEV will influence the efficiency of the power delivery system, by overloading transformers, cables, and transducers. This decreases productivity and can require additional starts, producing voltage and harmonic variations [54, 55]. Battery infrastructure and high initial costs relative to IC engine vehicles are the biggest challenges in V2G. a) Battery Degradation The degradation of the battery relies on the energy recovered or based on the depth of the discharge or duration of cycling. For auxiliary networks, bidirectional V2G will slash battery life. The battery costs are very high as the technologies continue to grow. By using a battery in the middle of a state of charge (SOC) range is a good way to slow degradation [56]. Depending on the chemical composition or development process battery life cycle varies greatly. Currently, the Li-ion batteries are the best for V2G due to its long service life and high capacity. Li-ion batteries have around 2000 to 2400 deep cycles [57]. b) Effects on Distribution Equipment The impact of PEV charges on delivery equipment is considerable [58]. The battery charger will easily service charge the delivery facilities, depending on the PEVs penetration scenarios. This increases transformer distribution fails, fluctuation of voltage, harmonic distortion, and high demand [59]. This would increase additional investments in large underground wires, general lines, and more room for transformers [60]. Distribution transformer life will decrease and the quality of the insulation will also decrease. Large PEVs penetration with poor coordination of charging affects the power grid. By the uncontrolled indicting at 50% PEVs penetration the life of the transformer will decrease by around 200 to 300% [61]. To decrease the effect of PEVs charging on distribution by demand response. The problem of a voltage drop may be minimized by using a condenser bank or a load tap changer [62] or by reactive PEV charger control. c) Investment Costs & Energy Losses Based on the charging approach, energy losses of up to 15% of the average current network cost may increase to 40% during off-peak hours if 60 percent of total vehicles are PEVs.

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