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Integration of EVs through RES with Controlled Interfacing

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Abstract **– Electric cars have a lot of promise in future energy markets as a manageable load. A popular vehicle-to-grid control interface, which enables the aggregation of the charging mechanism for energy management in the distribution grid, is one of the most significant road blocks to realize this opportunity. Understanding the ecology of electric transportation and integrating it in local communities to alleviate the energy shortage at peak hours is very complicated. In this research paper, recent standardization initiatives aimed at overcoming obstacles such as the integration of electric cars into smart grids are discussed. A charge control scheme focused on vehicle-to-grid connectivity is implemented. It is observed that the rise of environmentally sustainable energy sources, such as photovoltaic (PV) and wind energy, is straining the power network and their infrequent power generation is causing problems in power system operation, regulation and planning. The introduction of electric vehicles (EVs) into the electricity grid has been proposed to overcome grid load variations. Finally, the article discusses the incorporation of renewable energy sources and latest potential solutions involving electric vehicles.**

Keywords **– Communication systems, electric vehicles, energy conversion, microgrids, power system interconnection, smart grids.**

I. Introduction

In today's world, fossil fuels are leading power sources for power generation and transportation. Reduction in fossil fuel reserves leads to a search for alternative energy sources in these sectors. More than 60 % of the global primary energy is consumed by the power generation and transportation sectors. The major portion of the liquid fuel requirement is for transportation and most of the solid fossil fuel requirement is for power generation [1]. Developing electric vehicles (EVs) to cut the global dependency on oil used in vehicles and to reduce the associated CO_2 emissions is an increasing prospect of industry in the past decade. Most EVs possess a definitive edge over conventional power storage technologies for their easy application and assurance of an eco-friendly environment. Integration of renewable energy sources (RES) into power system has grown in recent years. There are many hurdles to inject huge-scale renewable integration into the electricity system [2]. Larger energy storage systems (ESS) will be required with RES integration in the power system to fluently favour the power grids so that electrical power operational standards and demand are matched at all times. Vehicles are operational for about 95 % of their lives; this enforces the concept that they can continue being connected to the grid and are available to supply the power gathered in their batteries as an idea of V2G. Although EVs are delivering these facilities by continuous charge and discharge cycles, several problems are enforced on the power grid because of this process. These problems enforce the changes in the operation, control and planning of the grid [3]. Integration of the electrical sector with EVs and RES gives the capability to considerably lower the global dependency on oil and the associated emission of greenhouse gases (GHG). The EVs can be a part of the electric grid as a dynamic distributed energy storage system. EVs can facilitate the grid by providing services such as spinning reserve, frequency and voltage regulations also being able to smoothen the load demand curve. V2G technology is mainly classified into unidirectional and bidirectional. Bidirectional V2G employs this concept to enable power interchange between the grid and battery of the EV for grid support or EV charging. Bidirectional V2G allows many capabilities to regulate the energy of an EV battery and enhance the durability and reliability of the power system [4].

Pakistan is experiencing a power shortage due to a variety of factors, including transmission line failures. We run out of electricity during peak hours so we use scheduled blackouts to compensate the consumption. Load shedding is a technique used in information systems especially web services to prevent overloading and slowing down the system. In Pakistan, the peak hour is typically between 6 PM and 10 PM and this issue can be solved by using smart grid vehicles as a power source in vehicle-to-grid (V2G) mode. Electric vehicles provide electricity as an external generator allowing us to avoid load shedding and control the energy needed during peak hours. There have been notable studies that show how the introduction of electric batteries, whether on or off board chargers can help

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to solve existing energy shortages [5]. Large-scale integration of EVs also enhances stress over the grid. It is mandatory to integrate an alternative source such as a photovoltaics (PV) power generation source to reduce stress over the grid through a common busbar. Electrical sources to keep the power system alive, namely the smart grids, guide a new way to supply and control electricity after a power outage mobility with the aid of a power bank. This helps the industry to moderate them, add new life style items and this initiative also provides a good point for companies such as car manufacturers, electric chargeable batteries and labourer group value [6]. Individual mobility impacts between the grid and the plug-in electric vehicle (PEV) must be analysed by using the smart grid.The cost of fossil fuels is rising every day, which has a significant impact on the cost and availability of electricity to the customers. The automobile industry is transforming from fossil fuels vehicles to EVs. However, we will eliminate the energy shortage and overcrowding situations by using hybrid vehicles [7].

II. Challenges of the EVs in the Smart Grid

Because of the increased demand from the power supply, the primary challenge of the smart grid is to ensure stable and efficient service. The smart grid is made up of a mix of centralised and decentralised power generating units, as well as an increasing percentage of renewable energy sources, various loads and their delivery over power transmission and distribution lines and cables. For a single charge, electric vehicles need between 10 and 40 kWh of electrical storage [8]. In addition to electric cars, we need inverters and connectors for proper charging and discharging whose power groups can be distinguished according to the IEC 61851-1 specification [9].

Batteries are classified according to their content and charging time. Based on the battery size, these various classes of batteries result in different least charging durations. The charging times for common battery capacities are described in Table I.

TABLE I
Specifications of IEC 61851-1

Charging/ Phase	Type	Voltage (V)	Current (A)	Power (kW)
Three phase charging	AC	400	32	22/43
Single phase charging	AC	230	16	3.7
Fast charging	AC	500	250	220
	DC	600	400	240

We compare three electric vehicle characteristics across a wide spectrum of driving and transportation as well as integration criteria and electric utility demand constraints to examine the different schemes for tapping electrical energy from vehicle to grid V2G [10]. The expenses and life span of batteries over a large variety of utility of tapping electrical storage outweigh the cost and shorter battery life of vehicles. Law on the viability and practical use of automobiles is discussed in [11] which clearly shows that regulations are used for battery electric cars. Fast-response variations in power above and below a baseline are involved. EVs come in a variety of power configurations, including base load, max, spinning reserves and control (up and down). V2G has ample cost assumptions for base load which we do not need, and drive train designs expect a low running time structure (average 1 hour per day) [11].

TABLE II
Various Battery Capacities

Battery Power (kWh)	A	B
10	About 3 h	25–30 min
20	About 5.5 h	30–60 min
40	About 11 h	60–120 min

A variety of electric cars are compared with various aspects, such as driving criteria and electric utility demand conditions to examine vehicle battery storage in greater depth [12]. We also create different algorithms to quantify grid power potential. These calculations are used to estimate the costs and income of these vehicles that have energy. Two storage electric vehicles are evaluated to supply capacity for a particular energy sector. The typical values of battery capcacities for types A and B are shown in Table II. We look at both the plug-in hybrid electric vehicles (PHEV) and the vehicle-to-grid (V2G) concepts based on their technological capabilities [13].

For unit commitment (UC) with V2G, we suggested a flow map between cost and pollution reductions. Particle swarm optimization (PSO) correctly solves this problem and has a high level of viability in solving optimization problems efficiently and effectively. The only drawback is that electric cars are temporarily incorporated into the smart grid resulting in high replacement costs for electric vehicles. The provider must meet the EV mobility criteria for the customer and as close to the grid as possible. We propose a conceptual basis for effectively integrating electric cars with electric power systems [14].

The proposed study covers a wide range of topics, including grid technological activity and the development of a business landscape in electrical markets. We discuss the possible and reliable conditions for integrating electric vehicles into smart grids. The optimistic specifications are developed on an EV test bed using real-world EV components [12]. Electric vehicles are used to tap electricity to have a clean atmosphere by reducing pollution and saving fuel. The EV establishes a foundation which offers a variety of activities based on the amount of energy used each day at peak hours. When electricity supply is insufficient to meet demand, the power grid suffers. The benefit of this delivery is that it is low-cost and covers a large region [15].

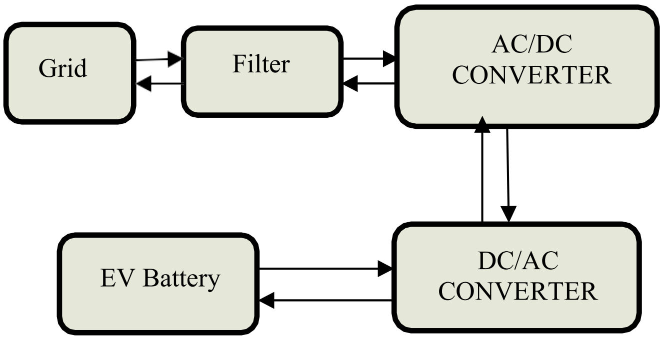

Fig. 1. Block diagram of DC charger.

We investigate the impact of reactive power on the operation and configuration of single-phase on-board chargers for electric vehicle integration. On-board PEV chargers use single-phase ac-dc converters as shown in Fig. 1. We paid close attention to topics such as new EV charging systems and tech solutions for smart charging [16].

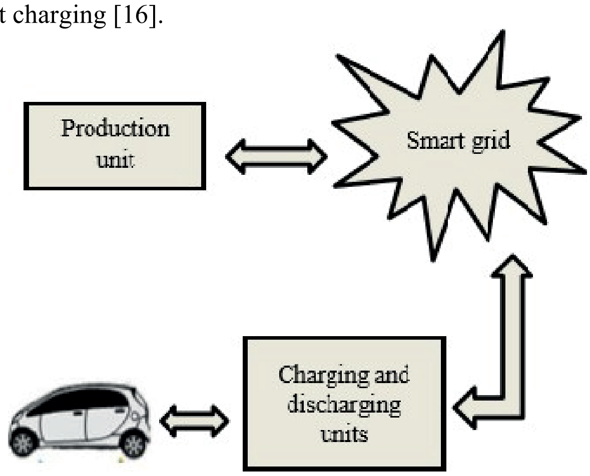

Fig. 2. Block diagram of V2G systems.

Figure 2 shows that, through the integration of electric vehicles, the smart grid is supposed to be more upgraded and ventilated, potentially reshaping the way electric power is generated and distributed without causing shortage.

In the future, a large amount of electricity will be produced from renewable energy sources and certain loads such as electric vehicles, electric boats and electric ships will be mobile [7]. We can move energy and carry it to various locations using electric vehicles. The maintenance of electric vehicles is discussed in this paper in order to increase system reliability and prevent load shedding. By the internet, we can track the electric vehicles and handle according to the peak hour demand and make all the vehicles accessible for peak hours [17].

A two-way communication between smart grid and electric vehicle enables a number of distributed energy services over a vast market region. The significant approach for V2G implementations is to distribute energy over a long distance using wireless networking. We refer to a common request in the convergence of electric vehicles with smart grids [18].

III. Electric Vehicles

A vehicle in which a part of or complete driving power comes from a battery is called an electric vehicle. Diesel fuel or gasoline is burnt to make mechanical energy that drives the vehicle. Different EV technologies that are either under development or in practice nowadays are explained in [19].

In a hybrid electric vehicle (HEV), a mini battery is used to improve operating performance of a combustion engine by supplying electricity. Battery charging of an HEV is done with engine kinetic energy. In terms of efficiency, HEVs are better than internal combustion EVs (ICEVs); however, liquid fuels are used to entirely power the vehicle.

Plug-in hybrid electric vehicle (PHEV) resembles HEV in theory, though it has a grid link and a bigger battery. The battery is charged with electricity allowed by the grid connection. The car can drive a substantial distance due to a bigger battery size. PHEV-20 represents the ability of the vehicle to travel twenty miles in all-electric mode. Similarly, PHEV-40 denotes a travel distance of forty miles in all- electric mode. A big onboard battery stores grid electricity to power a battery electric vehicle (BEV). EVs are more energy efficient than ICEVs, BEV efficiency is 60–70 %; on the other hand, typical ICEV efficiency is 15–18 % [20].

The findings show that the peak time for week days is between 7:30 AM and 9:00 AM and also between 4:45 PM and 18:40 PM [21]. Very notably for the purposes of this study, calculations suggest that typical peak hours account for 5.2 % of the day making them potentially usable as receptive load for the remaining 94.8 %. The battery output is expressed in ampere hours, watt hours, or kilowatt hours. The state of charge (SOC) is a critical parameter in battery control whose mathematical form is given in (1).

$$\mathrm{SOC} = \frac{\text{Remaining capacity}}{\text{Rated capacity}} \tag{1}$$

The improvement in the battery state of charge (SOC) is expressed in (2) as follows.

$$\mathrm{SOC} = \frac{1}{\text{Ah capacity}} \int_{t_0}^{t} i(t)\,\mathrm{d}t \tag{2}$$

IV. EV Technologies

EV technology is under the consideration of the public and government because of the increasing prices of fossil fuels and environmental changes. Gridable EVs (GEVs) are those EVs that can take power from the grid through a plug-in feature and can also supply power to the grid through a bidirectional charger. Following are the main EV technologies that are being used [22].

Vehicle-to-home (V2H) technology explains that, for charging or discharging, GEV can be linked to the home grid through a bidirectional charger. GEV is capable to send or receive power from home corresponding to the control system.

Vehicle-to-vehicle (V2V) technology explains that GEVs can send power via bidirectional chargers through a local grid circulating power between GEVs by a controller named aggregator [23]. The aggregator is accountable for gathering GEVs to establish a connection between vehicles or connection with the grid for power needs.

V2G technology explains that power can be received or supplied to the grid by connection with GEVs. As the power of each GEV is quite finite, the aggregator forms a group of vehicles for grid regulation or charging and discharging.

We can get benefits from BEVs or PHEVs by using both approaches V2G and G2V for the power system. By using G2V, we can charge BEVs or PHEVs at a lower cost at the time when generation ability is at large and load is decreased in a power system [24]. V2G can be utilized when load requirement is more or unexpectedly power is dropped. In that case, reserved power can be discharged from BEVs or PHEVs. This will give significant services in terms of regulation, load shedding prevention and spinning reserves.

V. Bidirectional Flow of V2G and G2V

The AC source is directly attached to the power grid. To complete the process of electric vehicle integration, we must transform the AC voltage into DC voltage and supply it to the vehicle using a converter [24]. At peak hours, an inverter is used to transform the DC source into an AC source to power the AC load. Following that, a converter is used to transform AC voltage to DC for use with a DC load. For contact, the source is transformed back to an AC source to supply signals to the control block as shown in Fig. 3.

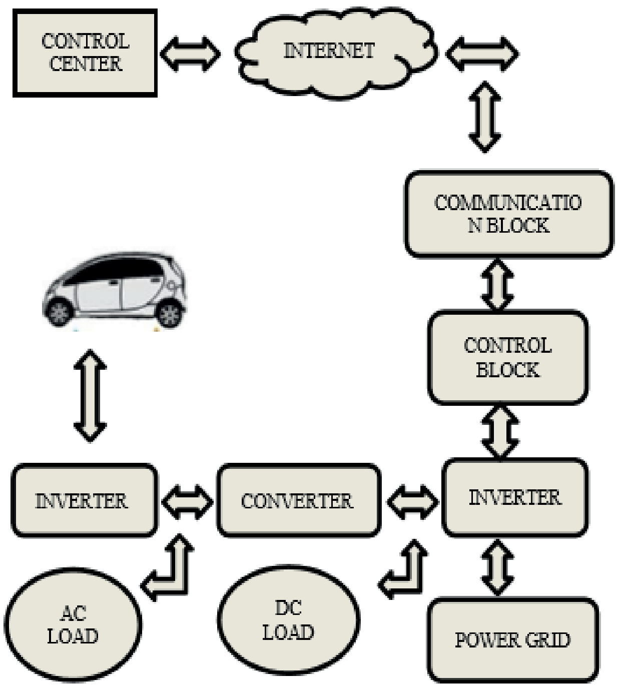

Fig. 3. Block diagram of V2G and G2V systems.

For easier connectivity, the whole device is wired to the internet. The power grid becomes a smart grid as a result of this contact [25].

We would use real time tracking to connect smart grid vehicles with the grid. Many of the parameters in a smart grid are wired to the internet for power. As the number of cars involved in the charging process grows, we face a serious energy shortage. Different charging stations with secure connectivity carry out the charging and discharging operation. As a result, the grid divides the vehicles into separate classes in order to charge them properly turn by turn. The aggregator is incharge of communicating with the vehicle and control center as well as sending and receiving data through the smart grid [8]. In a key study of an integrated test bed system, we smartly link electric cars to the electric grid and we use the left grid to manage peak hours through energy supply.

VI. EVs Integration with RES

Electricity generation from renewable energy sources such as wind and solar can be low (less than demand) or high (more than demand) depending on the availability of energy sources such as solar radiation and wind speed.

Figure 4 shows that EV batteries that have been assembled and can be used as energy storage systems (ESS) would allow us to use RES as dynamic energy storage systems in the energy industry. EVs may use a variety of charging schemes to absorb excess power produced by renewable energy sources.

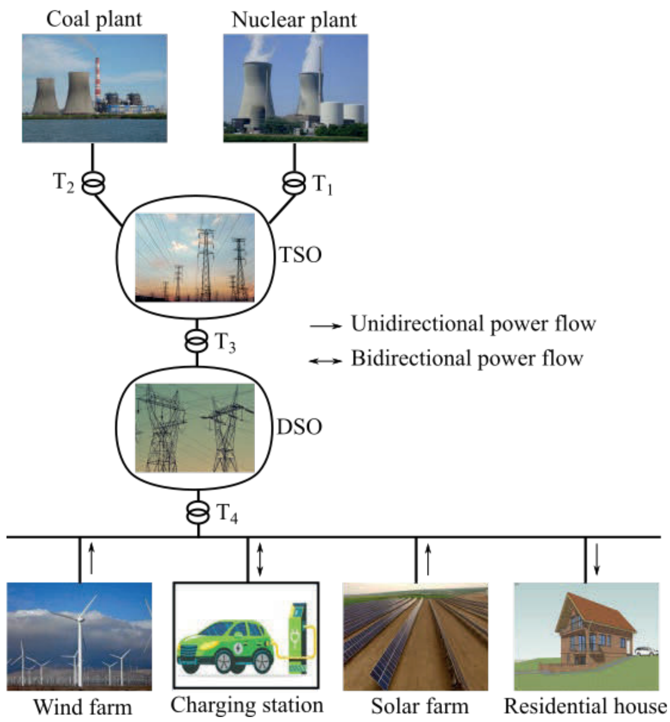

Fig. 4. Integration of EVs with PV and wind energysources.

EVs can supply electricity back to the grid in low power generation conditions and by using the V2G facility, they can help to smooth grid operations [26].

For maintaining energy stability by using EVs with the capability of providing V2G services with distributed RES (wind and PV solar) and maximizing the use of both RES and EVs, a strategy is required to reduce greenhouse gas (GHG) emissions while still lowering costs [27].

VII. Wind Energy

For EVs that have a V2G plant, which allows them to store non-uniform energy and eject it back to the grid as required, it has been discovered that adding renewable energy into the system will increase capability by 30–75 % [28]. In [28], the energy grid is examined for the integration of electric vehicles and wind power both separately and in combination.Without the use of electric vehicles, 4 GW of wind power can be installed without difficulty. This number is increased to 10 GW by inserting 1 million EVs [29].

A hybrid wind-PEV scheme is presented in this strategy which increases the useful jobs of these energy sources. In the absence of PEVs, it has been discovered that energy produced by wind energy systems and matching use in microgrids improves as surplus wind energy can be consumed by EVs which would otherwise be wasted. The higher the collective EV storage capacity, the more wind energy can be injected into the grid, which can be accomplished by either larger batteries or a larger number of vehicles [30]. Furthermore, EVs with a V2G facility will return this electricity to the grid allowing for greater incorporation of wind power into the generation system

VIII. PV Energy

PV solar energy has emerged as a new and plentiful source of electricity. Normally, PV solar arrays are clustered to supply electricity to the grid. Due to higher EV usage, PV solar energy would most likely be used for grid support and charging. Various experiments have been conducted to examine PV solar charging EVs on parking lot roofs [31], and also workplace charging stations built on PV solar systems.

It has been discovered that using solar charging at work saves about 544 kg of CO_2 emissions per year which is almost a 55 % reduction in emissions whereas using a home charging scheme (night charging) saves 326 kg of CO_2 emissions, which is almost 85 % reduction in emissions if the best home charging system is used. The impact of rooftop PV arrays of the workplace parking lot to provide a charging facility for a commuter during the day is also of paramount importance.

IX. Simulation

A. PV Integration

Figure 5 shows the first part of simulation in which we design the PV array panel with MPPT algorithm. The output from the PV panel is boosted with the help of boost converter to send power to the other end for the integration with the battery. The MPPT algorithm is the MATLAB function that operates the PV panel. We used a parallel combination of 5 PVs in a single array. The max power of each PV panel is 213.15 W, open circuit voltage is 36.3 V and it draws max voltage of 29 V. Since the PV panels are dependent on temperature and irradiation, by changing the irradiation, the efficiency of PV cell is affected greatly. These values are summarised in Table III.

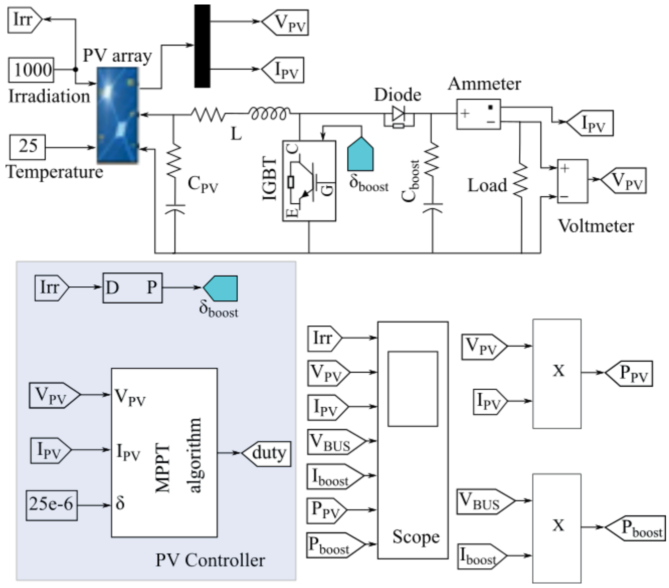

Fig. 5. Simulation of PV array with MPPT algorithm.

TABLE III

Parameters of Solar Module

Parameter	Value	Parameter	Value
# strings	5	Max. power	213.15 W
Series mod/str	1	V_{OC}	36.3 V
V_{MPP}	29 V	I_{SC}	7.84 A
I_{MPP}	7.35 A	$I_{Light\ generated}$	7.8649 A
I_0	2.9×10^{-10}A	Ideality factor	0.98117
R_{sh}	313.4 Ω	R_s	0.3938 Ω

Figure 6 shows the output efficiency of PV panel at two different temperatures of 45 °C and 25 °C. The graph shows that the PV panel gives max output at a temperature of 25 °C. The rate of electrons emitted increases too much at 45 °C because they start collide with one another. Hence, internal resistance increases due to which the output decreases. Therefore, the simulation was performed at 25 °C.

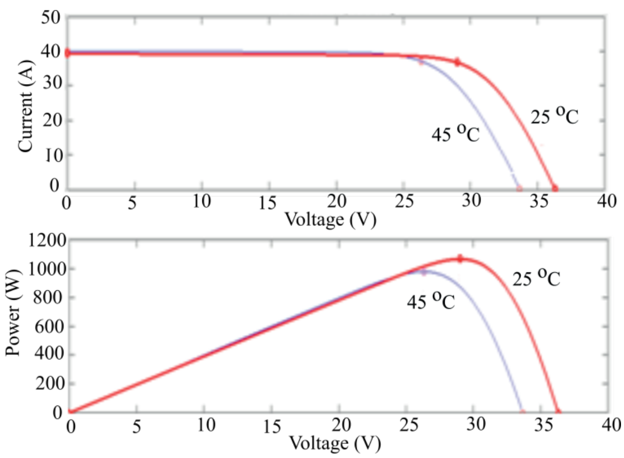

Fig. 6. Output efficiency of PV panel.

B. Battery Integration

We used Lithium ion battery in simulation with nominal voltage of 24 V and 50 Ah capacity. State of charge (SOC) plays a vital role in the integration of battery. Actually, this is the discharging limit of battery. When the battery is discharged up to SOC level, then it automatically cuts off and charging of battery is started.

The output of battery depends on its nominal voltage. Since the nominal voltage is 24 V; therefore, the output voltage is 27 V and nominal discharge current is 21 A with maximum output capacity of 45 Ah as tabulated in Table IV.

TABLE IV
PARAMETERS OF BATTERY

Parameter	Value	Parameter	Value
$V_{cut\text{-}off}$	18 V	$V_{fully\ charged}$	27.94 V
$I_{discharge}$	21.74 A	$R_{internal}$	0.0048 Ω
Capacity	45.22 Ah	Exp. Zone	25.93 V
Exp. Zone (Ah)	2.46 Ah	$I_{discharge\ (i1,\ i2,\ i3)}$	[6.5 13 32.5] A
$V_{nominal}$	24 V	Capacity_{rated}	50 Ah
Initial SOC	45 %	$\text{Time}_{response}$	1 s

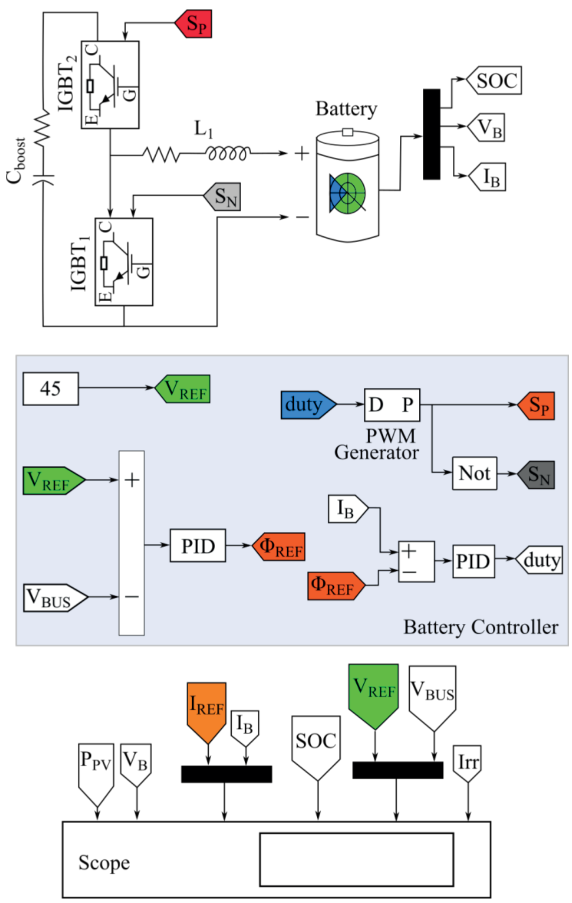

Fig. 7. Simulation of battery with a battery controller.

Figure 7 shows the simulation of battery with a battery controller. The output voltage of battery is passed through filters to make output smooth. Proportional integrals (PI) algorithm are used in the battery controller to produce reference current, which then gathers with battery current and produces a duty cycle. This duty cycle is fed into PWM generator that produces two outputs. These outputs are then fed into IGBTS as a gate signal. The reference voltage signal used in the controller is 48 V.

Figure 8 shows the output of the whole system at 0 irradiation (Fig. 8a) with 25.82 V across the battery. Figure 8b shows that the load current is approximately 20 A, which is supplied solely by the battery. Due to nonlinearities in the load, battery current is not a straight line instead, it undergoes fluctuations. At 0 irradiation, it means there is no output by PV farm, so V_{PV} = 0 V and voltage across the DC bus (V_{BUS}) = 47 V as shown in Fig. 8c. This indicates night time, so the battery discharges and supplies power to load. Figure 8d clearly shows that battery is discharging due to the fact that its voltage is decreasing. V_{DC} is also decreasing from 45 V which is taken as the reference due to the discharging battery (Fig. 8e). Finally, the PV power waveform undergoes weak oscillations around the 0 value meaning there is no output by PV farm as shown in Fig. 8f. Figure 9 shows the output at 600 irradiation (Fig. 9a) with 25.82 V across battery. Figure 9b shows the load current which is supplied solely by the PV farm. In this case, $I_{battery}$ is –ve since the battery is absorbing current to get charged as shown in Fig. 8b. At 600 irradiation, V_{PV} = 47 V and voltage across the DC bus (V_{BUS}) = 47 V as shown in Fig. 8c. Figure 8d clearly shows that battery is charging and settles at the voltage of 25.82 V. Voltage across the DC bus is also increasing and power delivered by the PV panel is around 580 W (Figs. 8e and 8f, respectively), which was 0 W in the previous case.

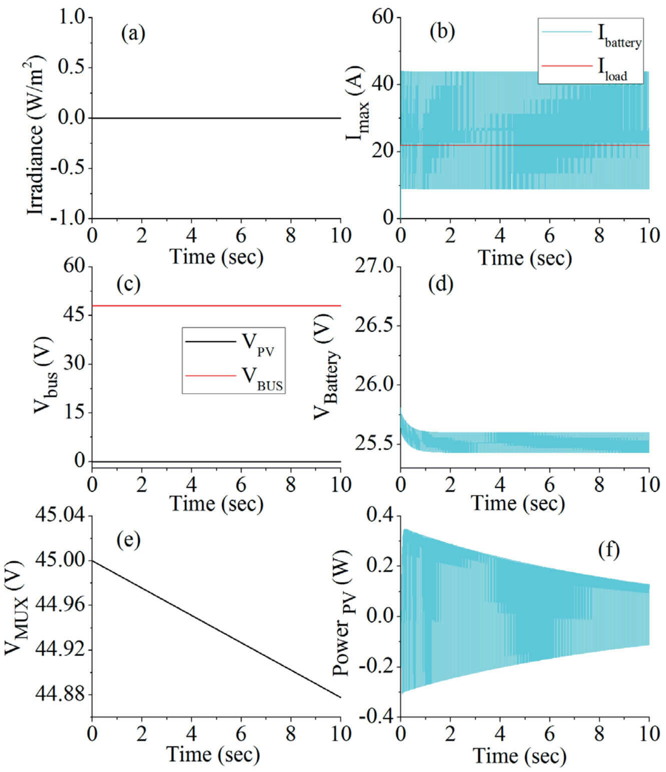

Fig. 8. Simulation results at zero irradiation.

V_{DC} is also decreasing from 45 V which is taken as the reference due to the discharging battery (Fig. 8e). Finally, the PV power waveform undergoes weak oscillations around the 0 value meaning there is no output by PV farm as shown in Fig. 9f. Figure 9 shows graph at 600 kWh/m^2 irradiation. Now the PV farm is producing power in bulk amount of about 600 W. At this time SOC is increasing showing that the battery is in the state of charging and the power is being supplied by the battery to the load. This process continues until the radiation exceeds beyond its limit or decreases from limit.

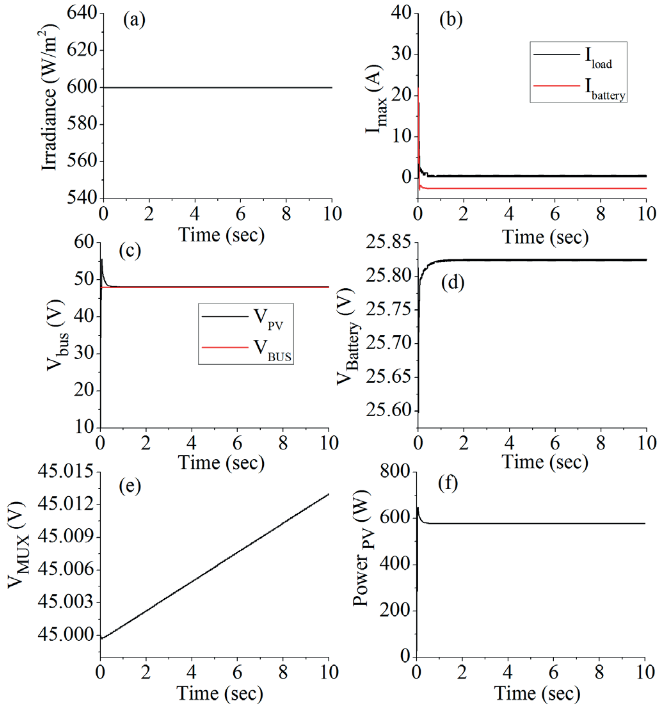

Fig. 9. Simulation resultsat 600 kWh/m^2 irradiation.

C. DC to DC Charging

Figure 10 shows the charging of one battery to another. In this procedure, the nominal voltage and Ah of one battery is kept high and considered as a source while the other acts as a load. Both of these batteries have specific SOC values on which charging and discharging depends.

Figure 11a shows that initially the battery is discharging and supplying power to load so its SOC graph is decreasing. When the SOC reaches 40 % of battery voltage, the load disconnects and the battery begins to charge itself that is why its SOC is also increasing as shown in Fig. 11a. Similarly, when the battery is supplying power to load, the current is positive but as the battery stops and begins to charge, it becomes negative for a moment (Fig. 11b). Figure 11c shows voltage across the battery which decreases when it supplies current to the load and increases when the battery gets charged.

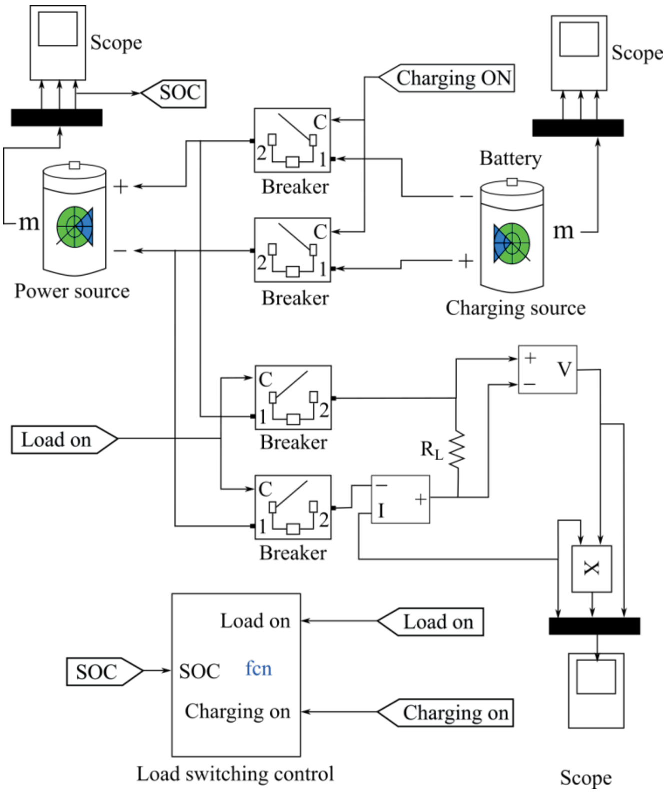

Fig. 10. Simulation of DC to DC charging system.

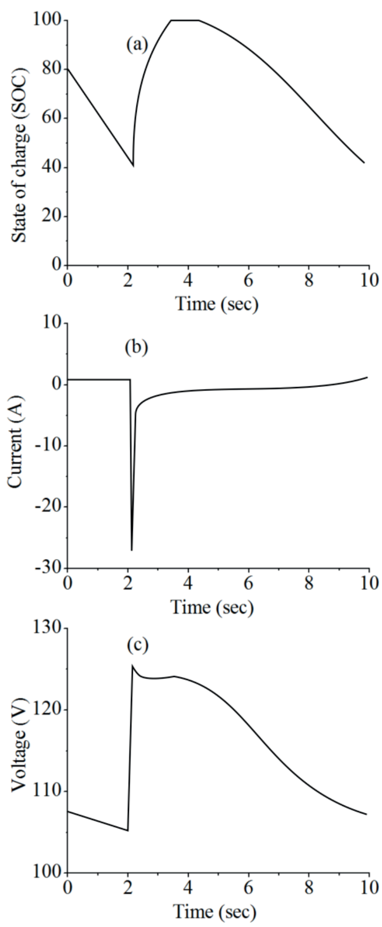

Fig. 11. Simulation results of DC to DCcharging system.

X. Conclusion

The range, power and energy density of electric vehicle batteries are expected to increase in the coming decades. With the rapidly rising costs of batteries, the utilities are facing challenges to install batteries for the individual grid task. In developing countries, the use of electro-volt batteries which are built in the vehicles would allow them to meet their goals. Through the incorporation of electric cars into the smart grid, it is possible to solve the energy shortage and provide energy to far flung towns without causing any distortions, thus dramatically improving our entire infrastructure.

The convergence of EVs with RES has also been considered in this study which reveals that the grid incorporation of electric vehicles (EVs) needs upgrade. A state-of-the-art schematic framework has been developed in this study, which implies better charging capability, long operating duration and minimum power loss through the storage devices. Various benefits can be achieved by EVs to include low operating expense, the reduced CO_2 emissions and services to the grid by using the proper infrastructure. The grid and electric vehicles will exchange power using V2G technologies. V2G technologies can provide a variety of services to the grid, including support for clean energy sources, load balancing and other ancillary services. Implementing V2G technologies will eliminate a number of problems, including vehicle battery loss and effects on delivery parameters.

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