Fuzzy based Modelling and Control of a EV Charging Station with PV and Battery

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ABSTRACT

The prospective spread of electric vehicles (EV) and plug-in hybrid electric vehicles leads to the need for fast charging rates. Higher charging rates lead to high power demands, which cannot be supported by the electrical grid. Thus, the use of on-site sources alongside the electrical grid for EV charging is a rising area of interest. In this dissertation, a photovoltaic (PV) source is used to support high power EV charging. However, the PV output power has an intermittent nature that is dependent on the weather conditions. Thus, battery storage is combined with the PV in a grid-tied system, providing a steady source for on-site EV charging in a renewable energy based fast charging station. Renewable energy based fast charging stations should be cost effective, efficient, and reliable to support the high charging rates demanded when a large number of EVs are connected to the electrical grid. However, fast charging stations, especially super-fast charging stations may stress power grid with potential overload at peaking time, sudden power gap and voltage sag. This project discusses the detailed modelling of a multiport converter based EV charging station integrated with PV power generation and battery energy storage system with fuzzy control. In this project, fuzzy control scheme and combination of PV power generation, EV charging station and battery energy storage (BES) provides improved stabilization including power gap balancing, peak shaving and valley filling, and voltage sag compensation. As a result, the influence on power grid is reduced due to the matching between daily charging demand and adequate daytime PV generation. MATLAB/Simulink Simulation results are presented to confirm the benefits at different modes of this proposed multiport EV charging circuits with the PV-BES configuration.

I.INTRODUCTION

1.1 INTRODUCTION

Global demand for electricity, combined with both the economic and the environmental constraints of traditional sources of energy like fossil or nuclear power, places greater demand for alternative sources of energy. While green energies, renewable energy sources are of particular interest. The distributed generators (DGs) and intelligent grid technologies have been explosive.

The small size of DGs and their possible high penetration into future smart grids make it neither realistic nor economic to apply conventionally the optimal power flow. The organization in the form of microgrids is the feasible solution in order to monitor and manage these highly distributed and tiny generators. Microgrids are a smart grid innovation field, providing versatility and scalability to monitor DGs and achieve intelligent grid objectives. A microgrid is linked via the standard coupling to the main grid. Multiple buses can be linked to the microgrid via condenser banks, motors, generators and DGs. The growing demand for energy consumption and increasing environmental pressure on conventional, fossil fuel, coal and nuclear power generation are looking forward to a near-future use of cleaner, more efficient energy.

In spite of the fact that the way of using clean vitality changes, the general public and research has been continuously to grasp the new type of intensity age that uses the graphically scattered and clean generator – conveyed age. Contrasted with the ordinary top-down power foundation, the DG uses privately introduced and moderately little limit electrical age, which can incorporate sustainable power source assets for instance of sun oriented and wind vitality, little hydro force and biomass and so forth., and furthermore can include some non-inexhaustible sources, for example, little size gas and diesel turbines. Consequently, the DG a bit much alludes to utilize total sustainable power source. Or maybe, it shows a framework structure that the downstream or end of intensity framework utility inactively go about as force shopper, yet in addition effectively play the job as force maker.

The DG office brings the preferences, for example, I) deftly usage of the downstream privately introduced vitality sources (particularly sustainable power sources), ii) helpful putting away vitality in a scattered way and along these lines can be acknowledged in a lower scaled limit, iii) can be utilized to perform top shaving activity as far as financial advantages. This start to finish way of intensity age and utilization, comparable with the web structure, normally brings the guarantee of keen lattice round the corner together with the propelled correspondence innovation.

Be that as it may, because of the inalienable impediment and exacting prerequisite of intensity framework, the enormous use of DG office raises the accompanying test: I) The force electronic gadget interfaced DG units normally doesn't adds to the recurrence idleness, in this manner their attachment and-play trademark when the electrical shortcomings happens can acquaint the recurrence insecurity with upstream force framework. ii) The change from customary unidirectional to bidirectional force stream of these coolly found DG units takes the trouble of intensity dispatch and gadget assurance. iii) The enormous measure of scattered force electronic gear and aloof segments bring new force quality issue that symphonious can infiltrate among the system. In this manner, so as to keep up the value of deftly usage of these conveyed assets, and to lighten the potential mischief to the customary force framework by completely scattered DG foundation, scientists are looking for new ways that can shape these DG units into a littler size of matrix which can support the force utilization without anyone else, and simultaneously can collaborate with other little networks and upstream lattice, by methods for vitality the board frameworks.

1.2 LITERATURE REVIEW

V. Rallabandi, D. Lawhorn, J. He, and D. M. Ionel[1], Solar race vehicles require minimized parts working at high productivity. This undertaking proposes the utilization of a coreless hub transition lasting magnet machine, which has the qualities of low stator mass, irrelevant center misfortune and for all intents and purposes zero cogging torque, as the impetus engine. A three-stage inverter with its dc transport took care of from a three-port DC/DC converter, which acknowledges contributions from a sun based board and battery controls the drive engine. Galium nitride gadgets are utilized in the three-port converter, permitting high exchanging frequencies in this manner decreasing the size of the transformer which gives galvanic separation between the two sources and yield. The three-port converter guarantees activity of the sunlight based board at its most extreme force point and furthermore permits bi- directional force stream between the impetus engine and battery relying upon working conditions. Activity over a wide scope of velocities, which is required by the sun powered race vehicle application, is accomplished by the new methodology of current debilitating. This technique includes raising the dc transport voltage of the engine side inverter at speeds surpassing the appraised.

Y. Liu, Y. Tang, J. Shi, X. Shi, J. Deng, and K. Gong[2], As little estimated superconducting attractive vitality stockpiling framework is economically accessible at present, the capacity and impact of a little measured SMES in an EV charging station including photovoltaic (PV) age framework is concentrated in this task, which gives a viable utilization of little measured SMES. The examination of three speedy reaction vitality stockpiling frameworks including flywheel, capacitor (super- capacitor) and SMES is likewise introduced to explain the highlights of SMES. SMES, PV age framework, and EV battery are associated with a typical dc transport with comparing converters individually. Voltage source converter (VSC) is utilized for network association. With normal for brisk force reaction, SMES is used to keep up the dc transport consistent. During the drawn out activity of EV charging station, a vitality the executives methodology is intended to control the vitality move among PV units, SMES, EV battery, and force framework.

II.DISTRIBUTION SYSTEM

2.1 TRADITIONAL CONCEPT OF POWER SYSTEMS

The bulk of electricity systems produce and supply the following considerations

- For large electricity plants generated electricity is typically located near the primary source of power (e.g. spiral mines) and far from the consumption centres.

- Electricity is supplied by a large passive distribution network of high voltage, medium-voltage and low-voltage grids to consumers.
- Such delivery networks are intended for radiological service. The power only flows from the upper voltage to the customers on the radial feeders.
- Three steps have to be taken in this cycle, i.e. output, transmission and distribution, before power comes to the end consumer.

The first step is to produce electricity in large-scale power plants located outside of demand in non-populated areas to cope with economic size and environmental problems.

The second step comes with multiple transformers, overhead lines and subterranean cables from various equipment. The final step is the distribution, the partnership between the services and end users. The most important part of the power system is this point because its reliability is the final power quality.

The demand for electricity is continuously increasing. Therefore, in order to fulfill demand requirements, electricity production needs to increase. This growth is confronted by conventional power systems that add new levels 1 support systems (see Figure 2.1). At the same time, additional rates are less usual in transmission and distribution.

MULTIPORT INTEGRATED CONVERTER WITH HYBRID SYSTEM

Agreeable control enables singular operators in a framework to utilize a common correspondence system and make the general framework go about as a gathering. Framework is malleable to arrange disengagement, topology changes, inactivity and irregularities. Helpful control initially was presented for the control of self-ruling robots and vehicles. For example, the shows a gathering of robots that is following a pioneer robot. The gatherings of robots utilize the correspondence system and attempt to be situated by the pioneer. Another model is demonstrated where a gathering of submarines speak with one another to follow the pioneer and be composed likewise.

In the two instances of the correspondence system may experience genuine abruptions, discontinuities and not all the modules approach the pioneer. Additionally the pioneer may change during the time. Agreeable control helps the operators in any gathering, where the pioneer is liable to change, use the accessible non-steady correspondence organize and act as a vigorous and joined gathering. This encourages the general gathering understand the ideal destinations. In a brilliant network, DGs ought to be controlled appropriately to agreeably fulfill different targets. In this part, from the start the ideal force destinations are examined. At that point, the agreeable control law, in light of the inverter demonstrating, is presented. It is demonstrated that the framework is steady and the recreation results show the viability of this method, contrasted and the best in class.

III.ELECTRIC VEHICLE TECHNOLOGY

A general definition for the four delineated classifications is as per the following:

1) Battery electric vehicle (BEV) – A BEV is an electric vehicle that is fueled exclusively by power put away in locally available batteries; Figure 3.1 (d). A BEV doesn't include a burning motor and is charged by connecting to the power matrix or, on a set number of models, swapping the battery pack. In the BEV class, the drive

framework is acknowledged utilizing an electric engine (eMotor) and an engine inverter. The coupling to the wheels is acknowledged by means of a technician coupler and a transmission shaft. Some portion of the vitality drawn from the battery during driving can be recuperated by regenerative breaking. The main wellspring of vitality is the battery pack which is intended to satisfy a specific range.

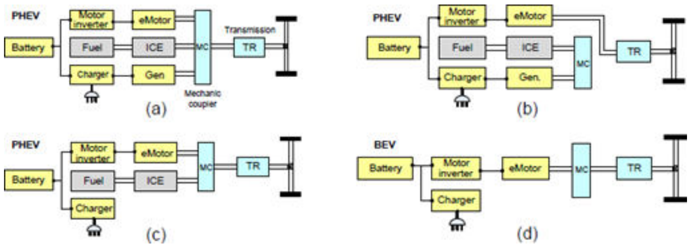

Figure 3.1:Plug-in vehicle architectures.

Figure 3.1 speaks to the coordination of EV load depends on the current EV innovation. An intensive portrayal of the genuine vehicle models is given by Chen et al. A typical component is that all module vehicle ideas utilize the lattice to energize the battery to the full charge state. Two vehicle classes can be recognized: module mixture EV (PHEV), with various classifications, and battery EVs (BEV).

Plug-in cross breed electric vehicle (PHEV) – A PHEV is a consolidated electric and inward burning motor (ICE) vehicle competent to charge utilizing the lattice and to work over a short separation in electric-just mode and it can highlight regenerative breaking. The battery in a PHEV has a littler size than a BEV battery, accordingly a traditional motor and fuel tank are utilized to broaden the range. The three classifications of arrangement equal cross breed, serried half and half and equal mixture have a place with the PHEV class and these are portrayed in Figure 3.1(a), (b) and (c), separately. All things considered, the vitality substance of a BEV is higher than a PHEV. Be that as it may, a typical part of the two classes is the utilization of a state of association in the low-voltage (LV) dispersion matrix to understand the charging reason. For the extent of this venture, the two classes introduced will be essentially viewed as "EV". Ordinary electric force frameworks are confronting consistent and quick changes to lighten ecological concerns, address legislative motivators, and react to the shopper requests.

The thought of the savvy matrix has as of late developed to present a smart electric system. Improved dependability and supportability are among wanted attributes of shrewd matrix influencing the dissemination level.

3.1 FUZZY LOGIC CONTROLLER

Lofti A. Zadeh put-forth the fuzzy logic, which is utterly different from Boolean algebra. The inherent characteristics of fuzzy logic are the values state has to be either 1 (ON) or 0 (OFF). The fuzzy logic varies from the Boolean logic due to its ability to accept two or more values between the true and false. Unlike the Boolean logic it accepts only true or false. Fuzzy logic helps in obtaining fixed conclusions from ambiguous, vague and imprecise information. The structure of the Fuzzy Logic Controller (FLC) used for performing VR in a solar PV fed cascaded H bridge multilevel inverter is exposed in Figure 1. Here, the output voltage (Vo) obtained from a fifteen level inverter output is then compared with the reference voltage (Vref), which is the preferred voltage to be achieved for the inverter in accordance with the grid requirements. The subsequent error, e = Vref−Vo and the rate of error change de/dt serves as input attributes for the FLC. The FLC consists of five major block set. They are fuzzifier, defuzzifier, inference system, rule base and database. Fuzzification in membership functions converts input data into degrees of membership. The commanding signal (or control signal) Cs obtained by the FLC is then contrasted with Vef to generate the modulating signal Ms required for PWM (pulse width modulation) generation, thereby afford the suitable gating signals to the semiconductor switches in the inverter power circuit.

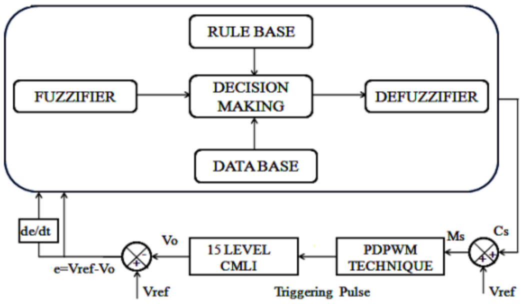

FIGURE 3.2. Fuzzy logic Control Structure

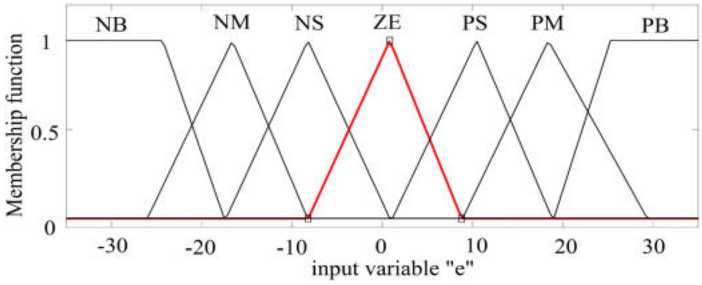

FIGURE 3.3. Membership function for error signal

The problem is formulated with an error and its derivative MF (membership function). The MF for the error signal is illustrated in Figure 6.2. In this figure, N indicates Negative, P for Positive and Z indicate Zero. Similarly, B indicates Big, M indicates Medium and S indicates small and E indicates the error. The derivative of the error signal for the fuzzy logic controller input and its MF is given in Figure.

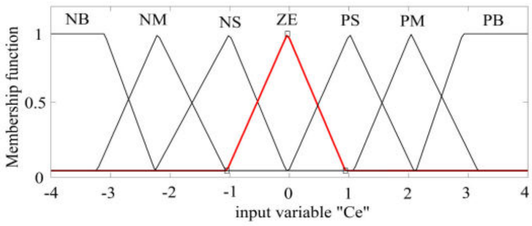

FIGURE3.4. MF for the change in an error signal

PI-BASED CONTROLLER: As similar to the FLC, the role of PI (Proportional-Integral) controller is to maintain the output voltage of the inverter constant in accordance with the grid requirements. The PID controller has been widely used in all types of feedback system as shown in Figure 6. While the rules formulation and MF parameterization is the major task in FLC, in PI based controller, the tuning of controller gains is the major task to meet the required objective. The PI controller gain is tuned for various error signals concerning the variable irradiance. The PI controller

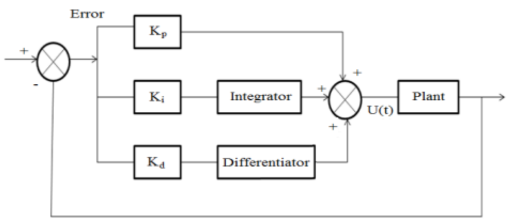

Fig3.5: Structure of PID Controller

ARTIFICIAL NEURAL NETWORK BASED CONTROLLER

Neural networks collectively perform functions and by the units parallelly, rather than there being a clear delineation of subtasks to which various units are assigned. Pertaining to the input-output dataset, the neural networks based controller provides the required voltage regulation. The voltage error values are calculated using this equation Verror = Vref – Vactual. These error values are used to train the ANN. For the appropriate values of error signals the ANN can provide the optimal switching angles for the inverter circuit to maintain the constant voltage at its output end. The training procedure of ANN consists of the following steps: 1) Provide the inputoutput data set, 2) Calculate the weights and 3) Update the weights based on the input changes. The neural network is trained for various samples at different intervals to process the error signal.

V.PROPOSED SYSTEM

The BES is utilized to maintain the DC link voltage and balance power surplus/insufficiency from the PV. With this configuration, the function and operating modes can be discussed as follows in detail.

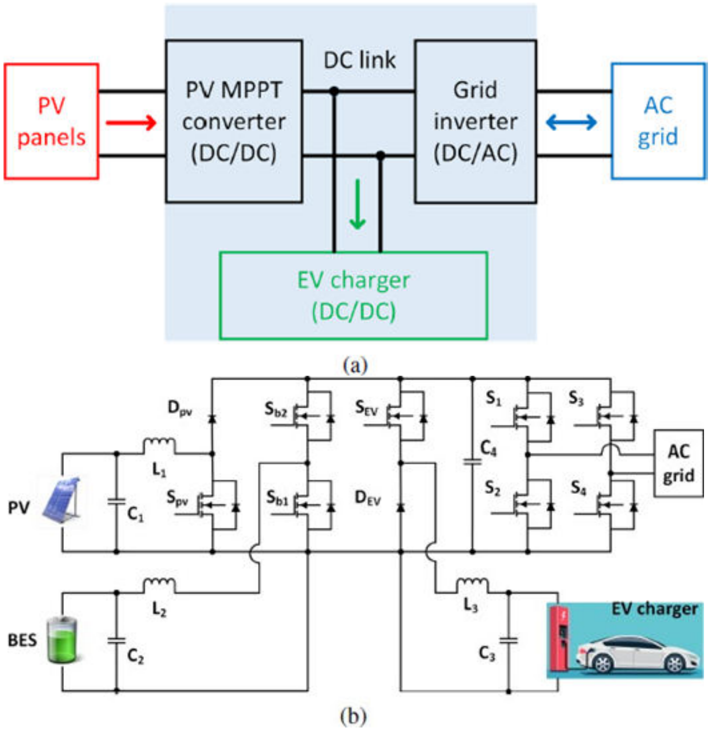

Figure 4.1 Multiport converter architectures, (a) the conventional architecture of EV charging stations integrated with PV, and (b) the proposed multiport converter based EV charging station architecture integrated with PV and BES.

Figure 4.1 (a) represents the conventional architecture of DC bus charging station with PV integration, all the three power sources, including PV and EV charger unidirectional sources, and AC grid bi-directional source, are all connected through three separate converters.

Figure 4.1(b) shows the proposed DC bus charging station, consists of one more bi-directional power source BES sharing the same DC bus.

A. Mode 1: PV to EV

In this mode, the switches Spv, Sb1, and Sb2 are turned off while SEV is turned on (Fig. 4.2a). Therefore, PV directly delivers power to the load, as shown in Fig. 4.2a. The differential equations in this stage can be expressed as follows:

$$i_{PV} = C_1 \frac{dv_{C1}}{dt} + i_{EV} \quad \text{———} \quad 4.1$$

$$C_2 \frac{dv_{C2}}{dt} = \frac{v_{Bat} - v_{C2}}{r_b} - i_{L2} \quad \text{———} \quad 4.2$$

$$i_{EV} = C_3 \frac{dv_{C3}}{dt} + \frac{v_{EV}}{R_{EV}} \quad \text{———} \quad 4.3$$

$$v_{C1} - v_{C3} = L_3 \frac{i_{L3}}{dt} \quad \text{———} \quad 4.4$$

$$L_2 \frac{i_{L2}}{dt} = -v_{C2} \quad \text{———} \quad 4.5$$

where C1, C2, C3, L1, L2, L3, and rb speak to the capacitance of the PV port capacitor, the capacitance of the BES port capacitor, the capacitance of the EV port capacitor, the inductance of the PV port inductor, the inductance of the BES port inductor, the inductance of the EV load port inductor, and the proportional obstruction among vBat and C2, respectively, as appeared in Fig. 1b; iPV , iEV , iL2, and iL3 speak to the output current from PV boards, the current of EV load, the current through inductor L2, and the current through inductorL3, individually; vC1, vC2, vC3, vBat, and vEV speak to the voltage across capacitor C1, the voltage across C2, the voltage across C3, yield voltage from BES, and the charger voltage, respectively. The obligation cycle for the switch Spv can be gotten with,

$$\frac{V_{DC}}{V_{PV}} = \frac{1}{1 - D_{pv}} \qquad \text{———} \qquad 4.6$$

where VDC, VPV , and Dpv represent the DC link voltage,voltage of PV array, and duty cycle of switch Spv, respectively.

B. Mode 2: BES to EV

When Spv and SEV are turned on while Sb1 and Sb2 areturned off, BES is discharged to the EV load, as shown in Fig.4.2b. The differential equations in this mode can be expressed as follows:

$$i_{PV} = C_1 \frac{dv_{C1}}{dt} \qquad \text{———} \qquad 4.7$$

$$L_2 \frac{i_{L2}}{dt} = v_{DC} - v_{C2} \qquad \text{———} \qquad 4.8$$

$$v_{DC} - v_{C3} = L_3 \frac{i_{L_3}}{dt} \qquad \text{———} \qquad 4.9$$

$$C_2 \frac{dv_{C2}}{dt} = \frac{v_{Bat} - v_{C2}}{r_b} - i_{L2} \qquad \text{———} \qquad 4.10$$

$$i_{EV} = C_3 \frac{dv_{C3}}{dt} + \frac{v_{EV}}{R_{EV}} \qquad \text{———} \qquad 4.11$$

where vDC refers to DC link voltage, which equals to thevoltage across capacitor C4. The duty cycle for switch Sb1can be obtained with:

$$\frac{V_{DC}}{V_{Bat}} = \frac{1}{1 - D_{b1}} \qquad \text{———} \qquad 4.12$$

where VDC, VBat, and Db1 represent the DC link voltage, voltage of BES, and duty cycle of switch Sb1, respectively.

C. Mode 3: PV to BES

When Sb2 is turned on while Sb1, Spv and SEV are turned off, BES is charged from the PV surplus energy, as shown in Fig. 4.2c. The differential equations in this mode can be expressed as follows:

$$i_{PV} = C_1 \frac{dv_{C1}}{dt} - i_{L2} \quad \text{———} \quad 4.13$$

$$L_2 \frac{i_{L2}}{dt} = v_{C1} + v_{DC} - v_{C2} \quad \text{———} \quad 4.14$$

$$L_3 \frac{i_{L3}}{dt} = v_{DC} - v_{C3} \quad \text{———} \quad 4.15$$

$$C_2 \frac{dv_{C2}}{dt} = \frac{v_{Bat} - v_{C2}}{r_b} - i_{L2} \quad \text{———} \quad 4.16$$

$$i_{EV} = C_3 \frac{dv_{C3}}{dt} + \frac{v_{EV}}{R_{EV}} \quad \text{———} \quad 4.17$$

The duty cycle for the switch Sb2 can be obtained with:

$$\frac{V_{Bat}}{V_{DC}} = D_{b2} \quad \text{———} \quad 4.18$$

where Db2 represents the duty cycle of the switch Sb2.

D. Other Modes:

PV to BES, Grid to EV, and PV to Grid The operating principle of other modes including PV toBES, grid to EV, and PV to grid. Besides, the differential equations can be similarly expressed with the same analysis method in Modes 1 to 3. The detailed simulation analysis will be provided in the following section.

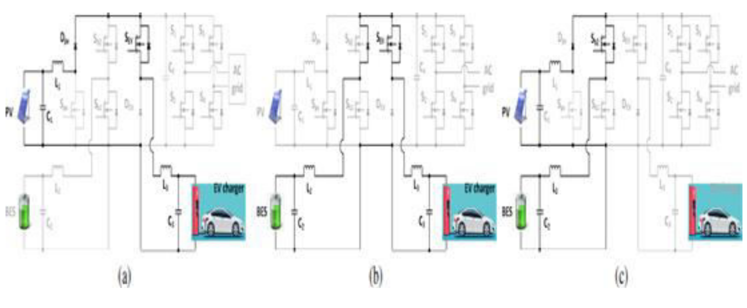

Figure 4.2. Multiport converter operating modes, (a) PV supplies EV charging when solar energy is sufficient, (b) BES supplies EV charging during PVintermittent, and
(c) PV charges BES when solar generation is surplus.

V.SIMULATION RESULTS

CASE-1: EV CHARGING:

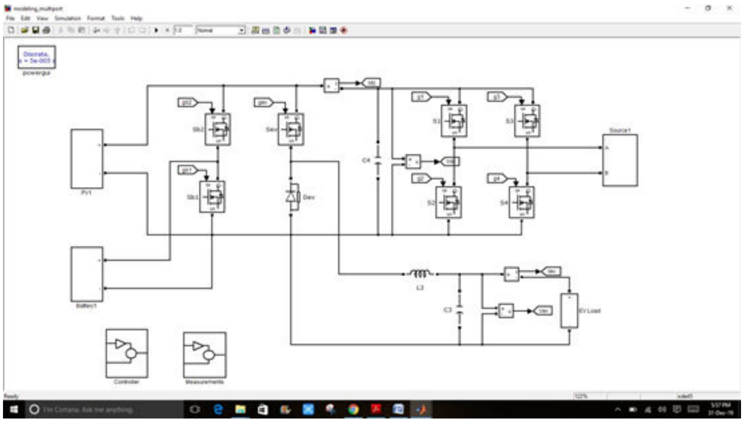

Fig:5.1- The simulation diagram of EV charging.

Figure 5.1 represents the simulation results of EV charging in which it shows the EV charges with the output of the PV panel.

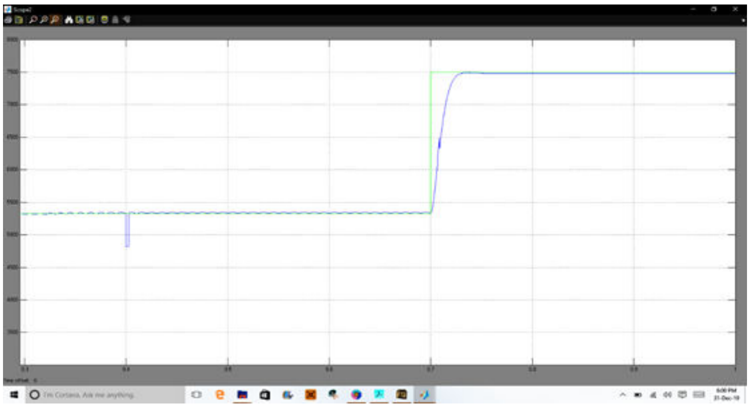

Fig 5.2 demand and consumed power of EV charging.

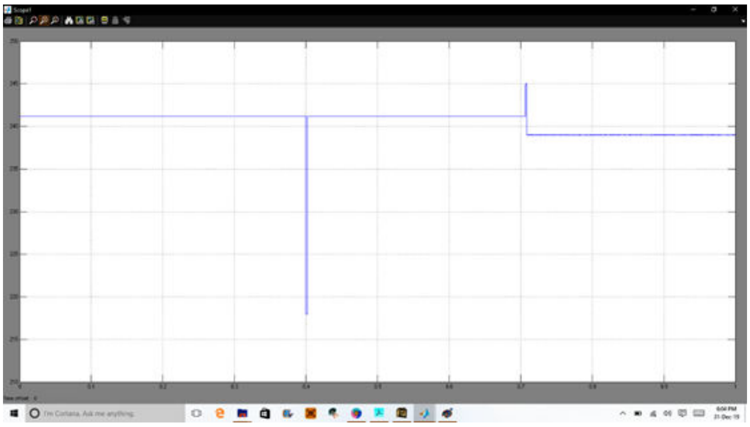

Fig 5.3 Terminal voltage of the EV charger.

Figure 5.1 shows the control scheme is simulated with MATLAB/Simulink. At 0.4ms of the simulation time, the irradiance drops from 700k/W^2 to 600k/W^2, and at 0.7ms of the simulation time, the load should be varied. At 700ms of the simulation time, EV charging demand suddenly goes up from 5.7kW to 7.7kW.

CASE:2- BATTERY ENERGY STORAGE:

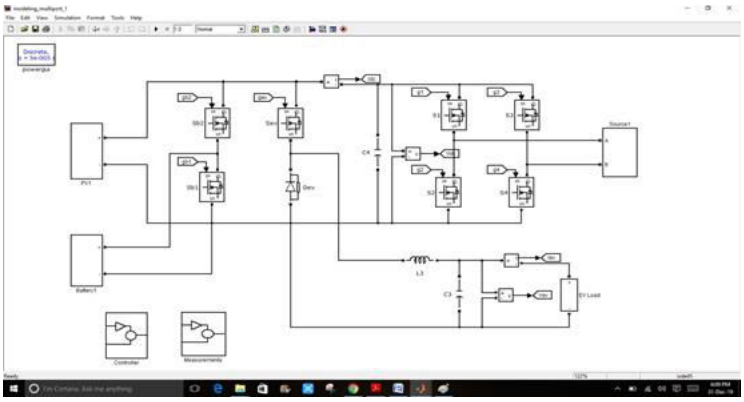

Fig:5.4- The simulation results of the BES.

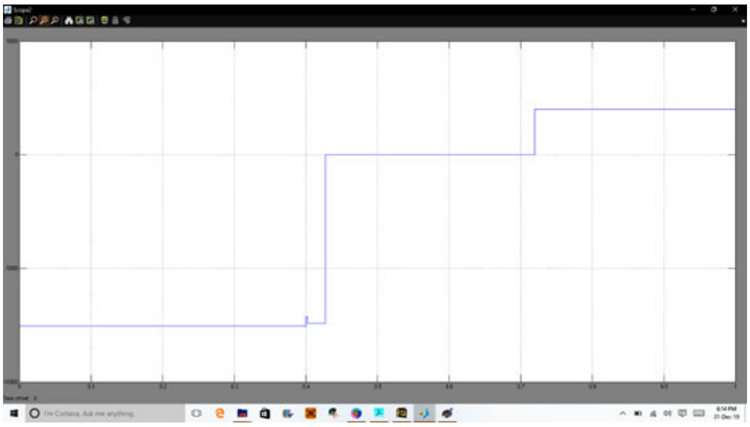

Fig 5.4(a) Output power from BES.

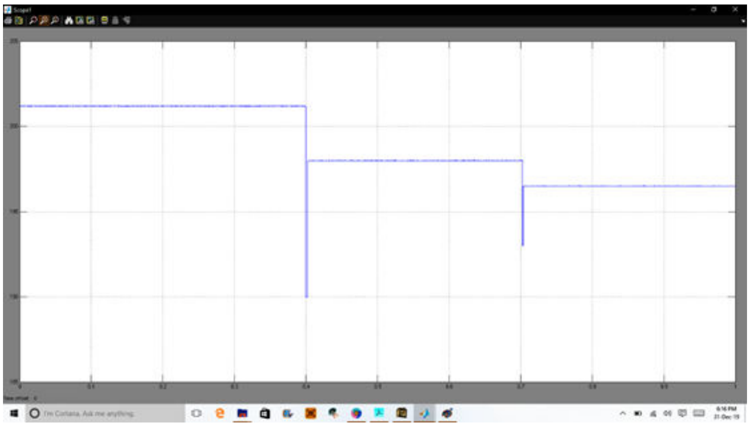

Fig 5.4(b) Terminal voltage of the BES.

Figure 5.4 shows the simulation results of the BES.In this case, between the simulation time of 0 to 0.4ms, the EV charging demand is low while the PV generation is sufficient. Therefore, both PV-to-EV and PV-to-BES modes are triggered, and the surplus PV generation charges the BES. Between the simulation time of 0.4ms to 0.7ms, the PV panels can provide 5.7kW which meets the EV charging amount.

As a result, the system is operated in PV-to-EV mode and no BES charging/discharging is required. After the charging demand increase at 0.7ms, the PV panels are not able to supply all the required 7.7kW charging power under the condition of 400k/W^2 irradiance. Therefore, the BES starts to discharge and supply EV charging with 2kW and provides voltage support.

VI.CONCLUSION

In this project, a multiport converter with fuzzy control based EV charging station with PV and BES is proposed. A BES controller is developed to regulate the voltage sag, and balance the power gap between PV generation and EV charging demand. With the proposed control design, BES starts to discharge when PV is insufficient for local EV charging, and starts to charge when PV generation is surplus or power grid is at valley demand, such as during night time. As a result, the combination of EV charging, PV generation, fuzzy and BES.

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