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Modelling and control of an EV Charging Station with PV and Battery based on a Multiport Converter

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ABSTRACT

As an environmentally friendly vehicle, the increasing number of electrical vehicles (EVs) leads to a pressing need of widely distributed charging stations, especially due to the limited on-board battery capacity. 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 paper discusses the detailed modeling of a multiport converter-based EV charging station integrated with PV power generation, and battery energy storage system, by using ANSYS Twin Builder. In this paper, the 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. Simulation results are presented to confirm the benefits at different modes of this proposed multiport EV charging circuits with the PV-BES configuration. Furthermore, SiC devices are employed to the EV charging station to further improve the efficiency. For different modes and functions, power losses and efficiency are investigated and compared in simulation with conventional Si devices-based charging circuits.

Index Terms – EV charging station, PV, BES, power gap balancing, voltage sag compensation

I. INTRODUCTION

The substitution of electric vehicles (EVs) for conventional vehicles. gasoline-powered cars [1] because more people want to use less fossil fuels and cause less pollution. EVs need a lot of charging points because their batteries can only hold so much power. This is because more and more people are buying and using EVs. But a large The stability and dependability are hampered by the large number of grid-connected, directly-connected charging stations, with an emphasis on rapid and ultrafast charging. of the power system because of worries about voltage sag, power gaps, and peak demand overload [3EV charging infrastructure and photovoltaic (PV) generation have been connected by some academics [4], although PV integration continues viewed as a modest source of energy charging stations for EVs. PV generation has increased in response to the expanding demand for rapid charging throughout the day. is growing quickly. This makes the best use of power during peak times by making sure there is enough daytime generation. Because solar energy isn't always available, Battery energy storage (BES) can be used to stabilise PV output, fill in power gaps, and manage DC bus or load voltage [5]. owing to the high multiport efficiency and electricity density power converters, [6] the EV charge station in this study uses a multiport DC/DC rather than using three separate DC/DC converters. The above study [7] shows that charging station layouts include both AC bus and DC bus topologies. Since both the The DC bus charging station is similar in that it is similar to a battery energy storage system uses DC current to charge batteries. used in this case to get the most out of the solar energy while keeping the costs and losses of converters to a minimum [8]. Multiport converters that are not isolated from their input and output may be unsafe. have a smaller size, more power, and be more efficient [9, 10]. This study Utilises a SiC switch-equipped DC bus to increase performance and decrease power consumption. heat, cut down on power losses. Here is a summary of what this paper has contributed and what it has done. First, PV and BES combination is seen as the main source of power for charging EVs, instead of the power grid. In a case where PV is used a lot and EV charging stations are spread out, the link between PV, BES, the grid, and charging electric vehicles built and tested. A full comparison of how much power is lost and how well it is used is also looked into.

Due to Due to the high voltage, a multiport DC/DC converter was used The electric vehicle charging station does not need three individual DC/DC converters. uses a single unit. in this investigation. density and productivity of such devices.. According to the above study, charging station layouts have both AC bus and DC bus topologies. Considering that both the PV power and the BES can be considered DC current. sources:

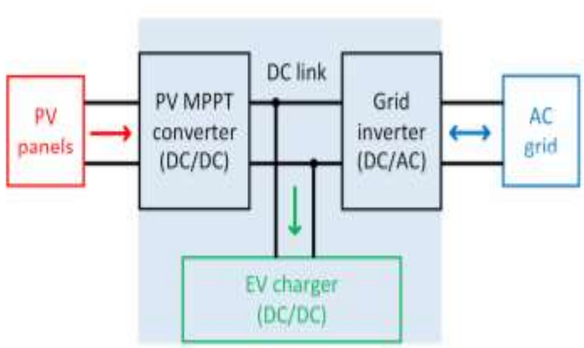

Fig.1. standard layout for PV integration in EV charging stations

In this case, Using a The DC bus recharge station enabled us to maximise the use of solar energy while minimising converter costs and losses. Isolated multiple port adapters may be larger, less efficient, and less space-efficient than their nonisolated counterparts, which are typically constructed from buck or boost converters. In this investigation, SiC switches are implemented on a nonisolated DC bus system. to improve efficiency and cut down on power losses. Here is a summary of what this paper has contributed and what it has done. First, PV and BES combination is seen as the main source of power for charging EVs, instead of the power grid. In a case where PV is used a lot and EV charging stations are spread out, the link between There is now PV, BES, the electricity grid, and EV charging in place. tested. There are more studies being done to find out how much power is lost and how different systems work.

In a typical In the integrated PV and DC bus charging station depicted in Fig. 1a, three separate converters link the PV, EV chargers, and the AC grid. a DC bus (Fig. 1b) is utilised by both the proposed DC bus and the existing DC bus. charging station and another bidirectional power source BES. The BES can be applied to make up for any extra or missing power and keep the DC link voltage fixed.

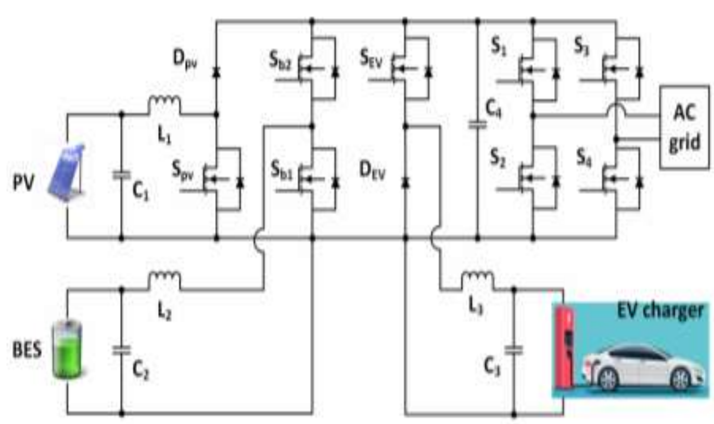

Fig.2. the proposed multiport converter-based EV charging station architecture integrated with PV and BES.

II. EXISTING MODE

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In this study, we look In a charging facility for PV-grids, where solar energy is prioritised and the grid or ESS is used as a backup power source, there isn't enough solar irradiation or when there is too much electricity [9]. This method lets the buffer connect while taking into account both energy transmission cost (ETC) and battery state of charge (SOC). The proposed solution aids the concept of a smart grid [10] by incorporating renewable energy sources into the existing electrical grid. V2G stands for "vehicle to grid." technology can also be used to make more money by letting owners of electric vehicles (EVs) find a balance between charging and releasing [11]. But this way would shorten the life of the batteries in electric cars and not solve other problems.

III. PROPOSED POWER CONVERTER

A. Buck–Boost Transformator

The term "buck boost converter" refers to a voltage-generating DC-to-DC converter. above or below the input voltage. By replacing a transformer with a single inductor, one can create a fly-back converter. Boost-buck converters have two different kinds of designs. Both can make output voltages that run from almost zero to magnitudes that are significantly greater than the voltage that goes in. The phases differences between the input and output voltages. This switched-mode power supply can function as both a boost and buck converter. The duty cycle can be changed to change the output voltage. of the switching transistor.. Make use of this change-o could be broken because the switch doesn't have a ground contact, which makes the driving circuits harder to understand.

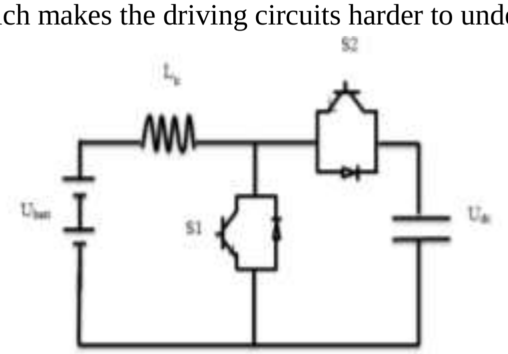

Fig.3. Proposed converter

But if the power source is separate from the load circuit, like a battery, it is easy to change the orientation of the power source and the diode. If they can be turned around, the switch can be on either the supply side or the ground side.

A combination of buck (step-down) and boost (step-up) converters

Most of the time, the direction is output voltage may be less than or greater than input voltage, or it may stay the same. One inductor can be used for both the buck and boost inductor modes in a non-inverting buck-boost converter, also referred as as "four-switch buck-boost converter," or numerous inductors can be used with just one switch, as in the SEPIC and Cuk designs.

C Principle of operation of Buck converter

In the input circuit, there is an inductor. allows the Buck-Boost converter to function by preventing rapid changes in the input current. The magnetic energy stored in the inductor is released when the switch is turned on. Output stage RC circuits benefit from a large output capacitor, which allows for a longer time constant. At steady state, the voltage across the load terminals is constant, so Vo(t) = Vo(constant). This is because the switching period is much less than the time constant..

IV. CONTROL MODES

The diagram displayed below depicts the Buck Boost converter's circuitry.

Buck-Boost converter operating modes

The two modes are that can be used with Buck to Boost converter.

a) **Continuous conduction mode** where Since the inductor's current is always nonzero, it follows that some of it goes away earlier than The alternation cycle starts.

b) **Discontinuous conduction mode** At the time of the inductor's operation, current goes to zero and it's completely empty, this marks the conclusion of the switching cycle.

Buck converter analysis circuit

Assume throughout the whole study that the voltage swing through the capacitor and the current swing through the inductor (from maximum to minimum value) are fairly small, allowing for linear change. This is done to make the research easier, and when the results are compared to the real numbers, they are pretty close.

A. Constant-current mode

case-1: If switch S is turned on

Since it stops currents from going from input to output in the opposite way, when the When the switch is activated, the diode becomes temporarily open. So, here's how to redo the Buck Enhance converter.

At this time, the inductor is being charged, and current is flowing. in it is going up. It is said how much current is going through the inductor.

$$I_L = (1/L) * \int V * dt$$

It is assumed that the inductor current prior to the transition is I'L, or off. switch opening. Taking into account the stability of the input voltage,

$$I_{L,on} = (1/L) * \int V_{in} * dt + I'_{L,on}$$

So, The number of seconds the switch is on is n if Ts is the transition duration, while D is the duty cycle. interval. Once the on time has elapsed, the inductor's current is determined as

$I_{L,\,on} = (1/L) * V_{in} * D * T_s + I'_{L,\,on}$ (equation 1)

Hence $\Delta I_{L,on} = (1/L) * V_{in} * D * T_s$.

case 2: In the off position

The diode will be biassed in the opposite way when the switch is off, allowing current to flow from the output (p-to-n terminal) to the input (n-to-p terminal).

Now, the inductor drains with the help of the RC and the diode. Let's pretend Before the switch is closed, the inductor's current is I'L, or off. The stream of an inductor is defined as:

$$I'''_{L,off} = -(1/L) * \int V_{out} * dt + I''_{L,off}$$

The inductor is discharging its charge, as indicated by the first negative sign in the equation. Under the assumption that tThe button is depressed for toff seconds., where Ts is the transition time interval, while Duty Cycle Denoted by the Letter "D" we get (1-D)*Ts. After the switch has been switched off, the current through the inductor can be read.

$I'''_{L,\,off} = -(1/L) * V_{out} * (1-D) * T_s + I''_{L,\,off}$ (equation 2)

For this reason, In this case, the currents the beginning of the "off" state and the end of the "on" state do not coincide. The discharge prevailing at the must not fluctuate. "Off" position of a switch. when everything is in a steady state. Also, the currents at the start of both the "off" and "on" states must be the same. Hence

$I'''_{L,\,off} = I_{L,\,on}$ also $I'_{L,\,off} = I''_{L,\,off}$

Using the equations 1 and 2 we get

$(1/L) * V_{in} * D * T_s = (1/L) * V_{out} * (1-D) * T_s$

$V_{in} * D = V_{out} * (1-D)$

$V_{out}/V_{in} = D/(1-D)$

As a result of D 1, Vout may be greater or less than Vin.When these conditions are met, the Buck boost converter is in use. D>0.5 and Vout >Vin. The Buck boost converter functions as a Buck converter with Vout greater than Vin. for D 0.

Using the rule of energy conservation and assuming there are no circuit losses

$V_{out} * I_{out} = V_{in} * I_{in}$

Since Iout > Iin for D 0.5, whereas Iout > Iin for D 0.5., it follows that Iout/Iin = (1-D)/D. As the duty cycle increases, the output voltage increases and the output current decreases. increases.

B. Discontinuous conduction mode

As was already said, when the converter is used in discontinuous mode, all of the energy saved in the inductor is used up before the toggling cycle is finished. In discontinuous modeThe figure below depicts the current and voltage waves produced by A Buck-Boost transformer..

In the "discontinuous" mode, the inductor releases all of the current it has stored during the "charging" part of the same "toggling" cycle. It is said how much current is going through the inductor.

$I_L = (1/L) \int V_L * dt$ = (1/L)* volume occupied by the voltage-time curve. Therefore, based on the wave shapes depicted,

$V_{out}*\delta*T_s = V_{in}*D*T_s$

$V_{out}/V_{in} = D/\delta$

and in accordance with the rule of conservation of energy, Iout/Iin = / D is the output to input current ratio.

V.RESULTS & DISCUSSION

An electronic charging station (ECS), also called an electric vehicle charging station (EVCS) or electric vehicle supply equipment (EVSE), is a type of infrastructure that provides electricity to charge plug- Electric autos, local electric vehicles, and plug-in hybrids that run on electricity.

The converters in some types of electric vehicles let them be charged at home or at the office by plugging them into a high-capacity appliance outlet or a regular electrical socket. Others may or may not need to use a charging station that can watch, protect, or convert electricity. When moving, these charging stations are also needed. Many of them can charge faster and at higher voltages and currents than EVSEs at home. On-street charging stations are either given by electric utility providers or are situated in privately owned public spaces including shopping centres, restaurants, and parking lots. companies.

Automakers have built in a standard battery charger that can charge up to 7.4 kW of power. It is hooked up to the power grid by a charge line that sends 230 volts of alternating current to it. Manufacturers have used two different ways to charge quickly (22 kW, 43 kW, and more):

- Use the car's built-in charger, which can provide between 3 kW and 43 kW of power at either 400 V in three phases or 230 V in one phase.
- You may charge a Nissan Leaf (which requires 50 kW) or a Tesla Model S (which requires 120-135 kW) using an external converter that transforms AC power into DC current. example).

Connecting To charge an electric car, simply plug it into a standard electrical outlet. device, but the charging system needs to take a lot of safety measures and talk to the vehicle to make sure the process is done safely.

Aside from Tesla, there are other charging networks for cars. There are both Level 2 and DC Fast Chargers in the Blink network, with different registration fees for each. Depending on where you live, members pay between \$0.39 and \$0.69 per kWh and non-members pay between \$0.49 and \$0.79 per kWh. Drivers on the Charge Point network can use both free and paid chargers as long as they obtain a badge of membership at no cost.Prices at commercial charging stations are as follows: set by city tariffs, just like Blink. Other networks have payment systems that work like regular gas stations, where you pay by the kWh and can use cash or a credit card.

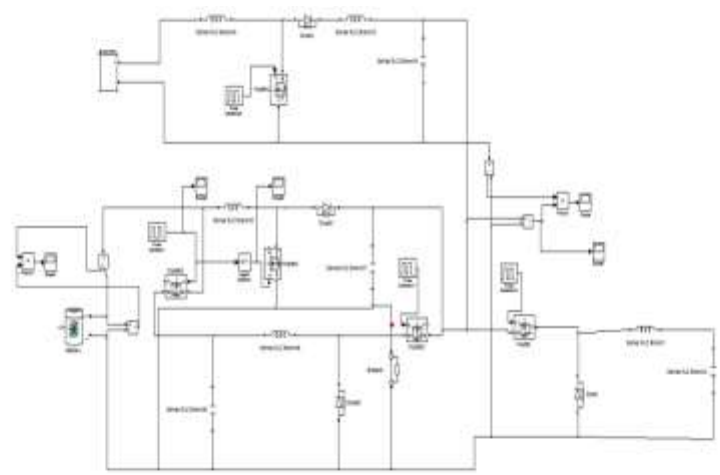

Fig 4: old circuit configuration

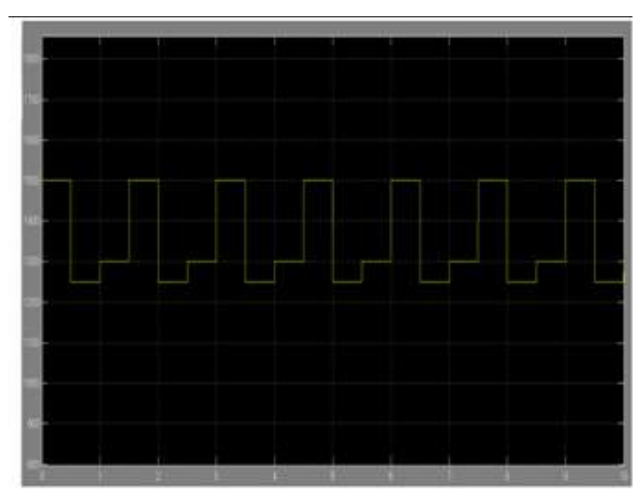

Fig .5. Irradiation on solar panel

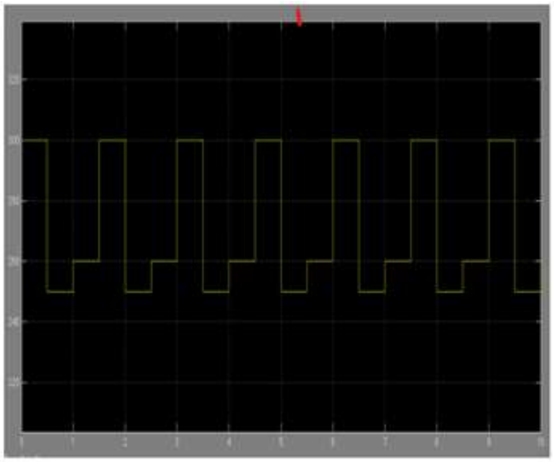

Fig .6. Solar output voltage

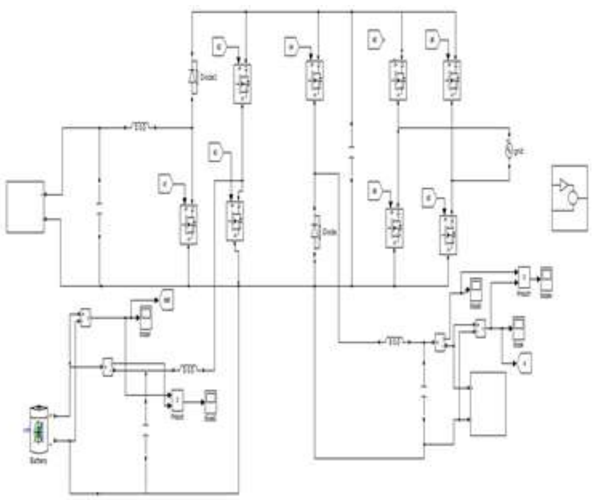

Fig .7. proposed simulation circuit

In reaction PV generation is a solution to the increasing demand for rapid charging at all times of the day. is growing quickly. This makes the best use of power during peak times by making sure there is enough daytime generation.

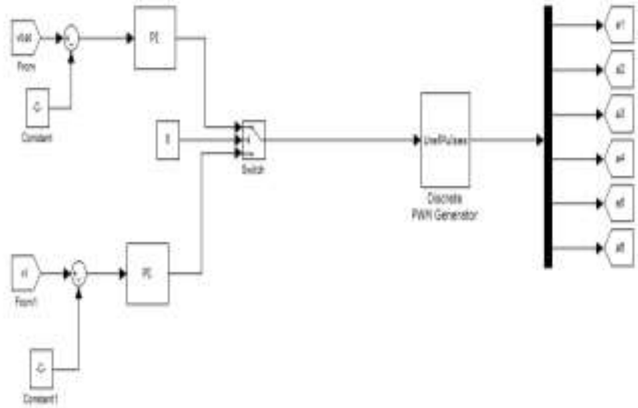

Fig. .8 proposed controller

Solar energy isn't always available, Therefore, BES can be used to maintain continuous PV power, fill in power gaps, and control DC bus or load voltage. In this investigation, a multiport The use of a DC/DC converter instead of three individual DC/DC converters to charge electric vehicles. Since multiport power supplies pack so much punch, converters, this is the case. and work well.

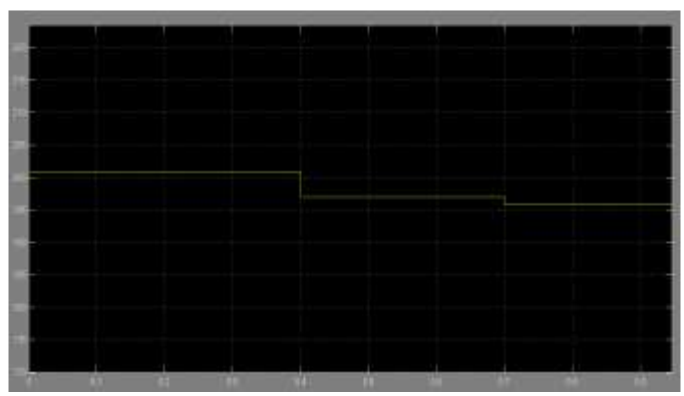

Fig .9. battery voltage

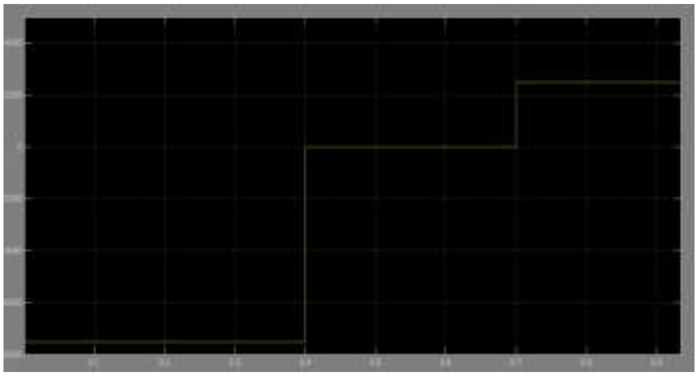

Fig.10. battery power

According to the above study, charging station layouts have both AC bus and DC bus topologies. Since the BES and the PV output can both be regarded as sources of DC current. In this case, solar energy is maximised while converter expenses and losses are kept to a minimum by using the DC bus charging station. Typically composed of buck or boost converters, non-isolated multiport converters can be utilised. smaller, have higher output power, and consume less energy. be more efficient than isolated multiport converters.

This study uses a non-isolated DC bus design with SiC switches to improve efficiency and reduce power losses. Here is a summary of what this paper has contributed and what it has done. First, PV and BES combination is seen as the main source of power for charging EVs, instead of the power grid. In a case where PV is used a lot and EV charging stations are spread out, the link between PV, BES, the electrical grid, and EV charging are constructed and tested. A DC bus recharge station incorporating PV is made up of the following parts:

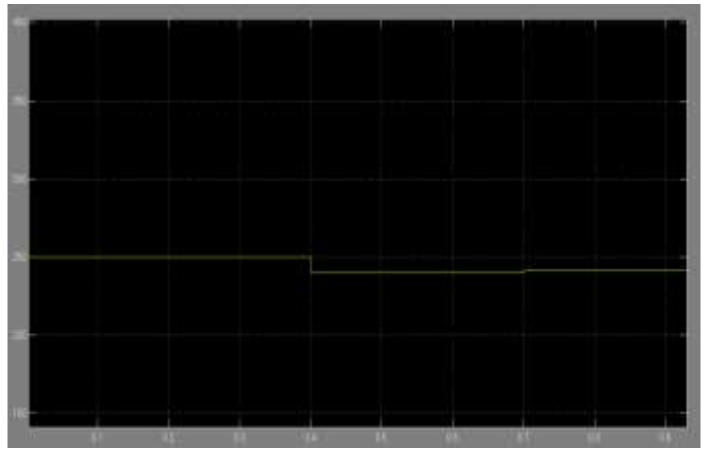

Fig .11. Terminal voltage

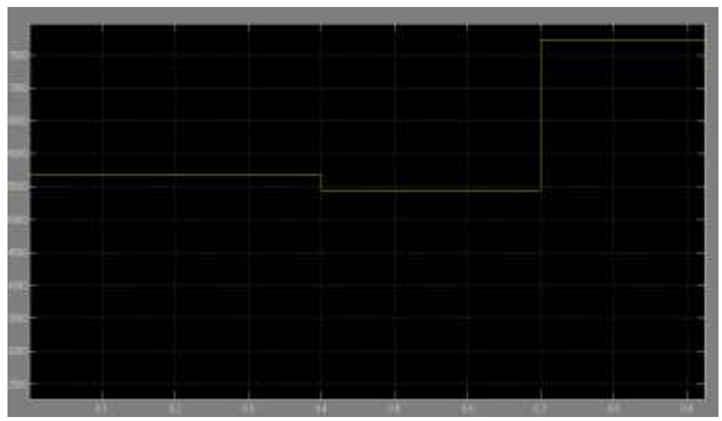

Fig.12. Terminal power

The three power sources, which include the bidirectional AC grid feed and the unidirectional sources for PV and EV chargers, are connected by three distinct converters. A DC bus is shared by the intended DC bus charging station and another bidirectional power source BES. (Fig. 1b). BES is utilised to make up for either too much or too little PV power and to keep the DC connection voltage fixed. With this setup, the following list of tasks and modes of operation are all possible.

VI. CONCLUSION

A multiport converter-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 nighttime. As a result, the combination of EV charging, PV generation and BES enhances the stability and reliability of the power grid. Different operating modes and their benefits are investigated and then, simulation and thermal models of the multiport converter based EV charging stations and the proposed SiC counterpart are developed in ANSYS Twin Builder. Simulation results show that the efficiency can be improved by 5.67%, 4.46%, and 6.00%, respectively, for PV-to-EV mode, PV-to-BES, and BES-to-EV mode at nominal operating condition, compared to Si based EV charging stations under the same operating conditions.

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