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Energy management of multiple resource charging station

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Abstract

Managing plug-in electric vehicles (PEVs) recharging with different capacities can achieve the optimum operation schedule. Otherwise, stability issues for the microgrid may occur. Therefore, Energy management becomes essential for charging stations to meet the complexity of bidirectional power flow and multiple resource availability. This paper presents an energy management system of PEVs based on multiple resources managed by a DC microgrid. Three main resources are used: the national grid, Photovoltaic cells (PV), and Battery. The grid and PV cells are centralized distributed, whereas Batteries are decentralized distributed. Balance options are defined to match the vehicle requirements based on power availability, even the surplus power between the connected vehicles. The aims are to optimize grid energy usage, long life of the storage devices, and improve resilient power to the load demand. Metaheuristic methods (PSO) are used to enhance the response to the charging station operator. The results show that electric vehicles are a promising solution to keep the voltage stability of the grid in a high-demand approach. The PV is a flexible and cheap resource to recharge electric vehicles and synergize the national grid. Sometimes, trading power from a high state of the charging PEV to a lower one is beneficial to maintain the stability of the charging station.

Keywords: microgrid, charging station, Electric vehicles, multiple resources, voltage stability.

1. Introduction:

Although electric vehicles are classified as a demand for an electrical grid, they could be a source for the grid in peak demand or at grid stability requirements [1], [2]. Plug-in electric vehicles may have two or more electric resources, such as a supercapacitor for fast charging and discharging and a battery for steady-state operation. PEVs should park at a charging station for a specific time while charging these resources. Managing power flow is essential to maintaining the resilient operation of the grid. Implementing specific policies between owners of electric EVs and charging stations could discharge part of the energy for EVs to the grid for a specific period [3], [4]. Therefore, PEVs could be vital in charging and discharging electricity within charging stations [5]. Furthermore, a high penetration level of renewable energy within the distribution system would help the resilience operation of the charging station system and lessen dependency on the national grid [6], [7]. However, the intermittent and random nature of renewable energy can provoke the stability of the charging station. Therefore, electric vehicles can help maintain the stability of charging stations using their resources in power fluctuation of either the intermittency of renewable energy or the independence of the national grid [6], [8].

This paper discusses managing multiple resources for charging station systems: photovoltaic cells and the national grid. The paper focuses on discharging the resources of plug-in electric vehicles in case of the lack of power from the charging station's resources. Electric vehicles with a high state of charge can charge the number of plugged-in electric vehicles or help the national grid in case of stability issues.

Charging station strategy:

Power flow in charging stations is not just from primary resources to electric vehicles but from electric vehicle resources to grid or other electric vehicles. Therefore, there should be a policy to manage the discharging of power from electric vehicles, which should be based mainly on the owner of electric vehicles. Since the electric vehicle is the owner's private property, some data should be collected from the owner before discharging or even charging starts. The information collected adequately regarding the reference of vehicles for cloud management desired to leave the state of charge, expected leaving time, and the authority of discharging power. Furthermore, the management system starts analyzing the information to decide the discharging percentage of electric vehicle resources and the discharge time based on the grid's state and discharge price. Moreover, the tariff price varies on time, whereas at high demand, the price is more than based on demand, which causes owners to discharge their electric vehicles at high demand for profit. The direction of the charging station could be based on either frequency variation or voltage variation. When multi-electric vehicles are connected to a charging station, then the less state-of-charge vehicles can charge from the high state-of-charge vehicles. The direction of power can be managed by either the voltage difference of angle between virtual induced EMF and the voltage of resources.

2. The research aims to:

1- design the electrical architecture of the charging station based on size and capacity, including photovoltaic panel and national grid

2- proposed management strategy for station and policy with owners for charging and discharging PEVs.

3- study the effect of PEVs in charging mode, discharging mode, and interflow power between them

3. System components:

As shown in Fig. 1, the system consists of a PV system and a national grid as part of the charging station topology and a battery for the electric vehicle. All of them are connected to the DC bus via converters and filters; the power balance for covering load demand is: $P_s = (P_{pv} + P_g \pm P_b) - P_l - P_{loss}$

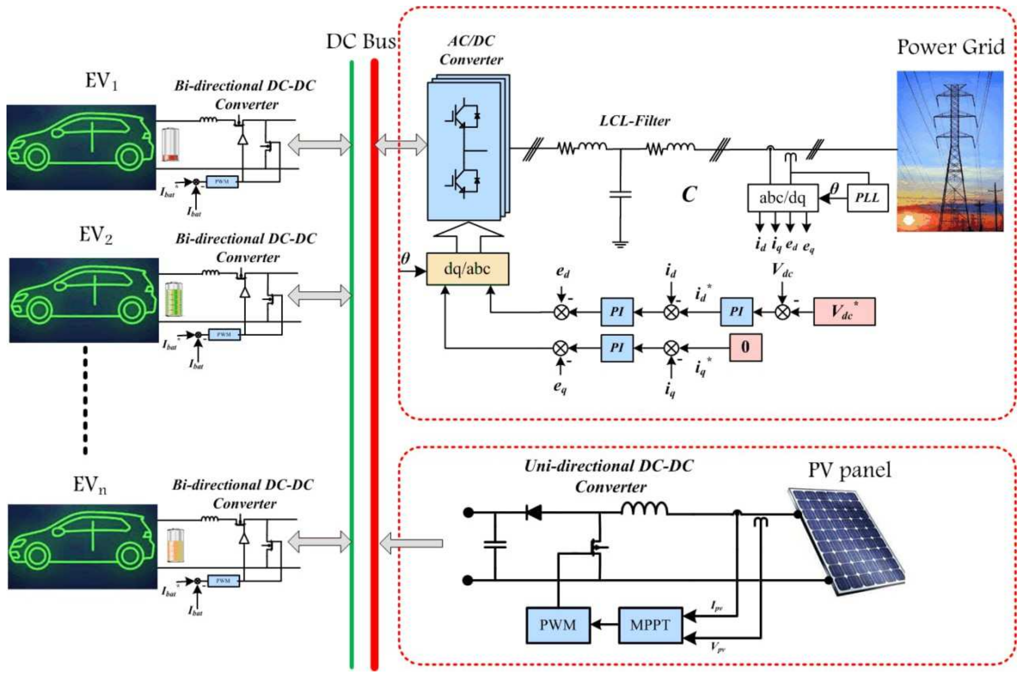

Fig. 1: The considered model

4. charging station model:

A linear power source was used to model the PV generator regarding ambient temperature and irradiance level [9]. The total generator's output power at the maximum power point (MPP) is calculated using equation (1) [10].

$$P_{pv} = \left[P_{pv,STC} \times \frac{G_T}{1000} \times \left[1 - \gamma \times (T_j - 25)\right]\right] \times N_s \times N_P \quad (1)$$

Where $P_{pv}, P_{pv,STC}, G_T, \gamma, T_j, N_s$ *and* N_P represent the output power of the generator, the power temperature coefficient and the rated PV power at MPP, and STC, the *irradiance* level at STC, the cell temperature, and the number of modules in series and parallel that made up the generator, respectively.

The temperature of cell is calculated using equation (2) [1].

$$T_j = T_{amb} + \frac{G_T}{1000} \times (NOCT - 20) \qquad (2)$$

NOCT measurement conditions is $T_{amb,NOCT} = 20\ {\circ}_C$.

The voltage-current characteristics of a battery system can be shown in equation 3:

$$V_{bat} = V_0 - k\frac{Q}{Q - \int I_{bat}\,dt} + A.\ e^{(-B\int I_{bat}\,dt)} - R_b I_{bat} \qquad (3)$$

where, R_b is the internal resistance of battery, B is the exponential area time constant inverse, A is an exponential area amplitude, and $\int I_{bat}\,dt$ is the capacity of the battery.

$$SOC(t) = SOC(t-1) - \frac{\int I_{bat}\,dt}{Q} \qquad (4)$$

The state of charge should be within limit of $SOC_{min} \le SOC \le SOC_{max}$

The droop control is used for synchronization between the resources and ignites the inverter switches as shown in Fig. 2. Two inner loops are used to control the actual voltage at the PCC sides.

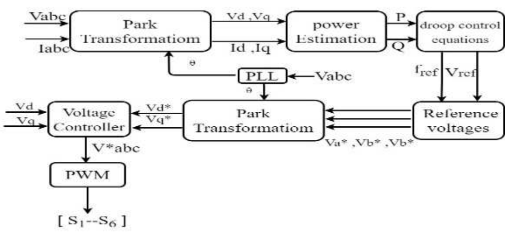

Fig. 2 Droop control method

5. Standardization and policy of charging stations

The charging station must be designed according to standardization to specify the power transfer to a vehicle, required protection, and communication protocol. either as a conductive (IEC62196), or (IEC 61851), wireless (IEC 61980), or battery-swapping charging station as well as Vehicle to Grid (V2G) protocol (ISO 15118) [8]

Key Trends Shaping the EV Charger Station Industry can be classified into:

1- Expansion of Charging Networks
2- Technological Advancements
3- Integration with Renewable Energy
4- Partnerships and Collaborations

However, some challenges of charging stations are infrastructure investment, charging Standardization, grid capacity and demand management, and user experience and accessibility.

The policy of discharging power is based on collecting data, analyzing them, and solving the optimization function periodically. When an EV is parked and connected to the charging station, the charging station operator records the connection time and collects some data from the owner of the EV as listed in the Fig. 3.

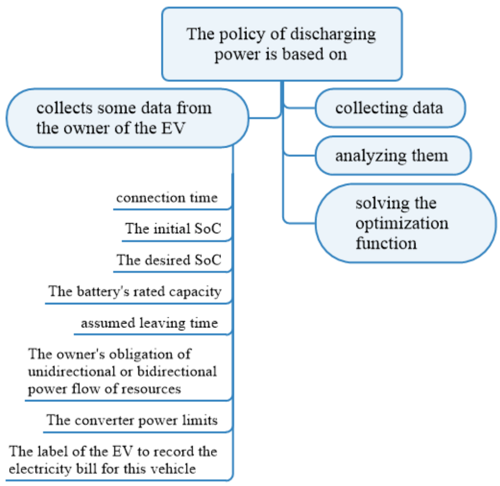

Fig. 3 The policy of discharging power

In general, charging stations operate in three modes which be classified in Fig. 4

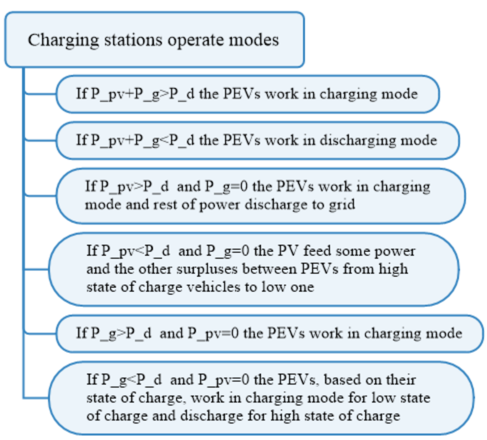

Fig. 4 modes of operation

6. Simulation results:

A. the proposed system

four modes are considered in this section to demonstrate the effectiveness of the proposed control strategy. The parameters of LR5-72HGD-590M PV panel that used in this paper are listed in table 1. The total power generated by the solar power plant to provide the demand load is 27kW. MATLAB software was used to conduct all simulation studies. The parameters of proposed system are tabulated in table 2

Table 1 Specifications of the proposed PV generator system.

Description	Symbol	Value	Unit
Max Power point	MPP	590	W
Open circuit Voltage	V_{OC}	51.63	V
Short circuit current	I_{SC}	14.38	A
Current at the maximum power point	I_{mpp}	13.59	A
The voltage at maximum power point	V_{mpp}	43.44	V
Number of parallel panels	N_p	3	-
Number of series panels	N_s	16	-
Total power of solar power plant	P_{total}	28	kW

Table 2 The calculated parameters of the proposed system of Fig. 1.

Parameters	Value	Parameters	Value
Rated power	36 kW	Boost capacitor	2.2 mF
Grid voltage (L-L)	400 V	Boost inductance	0.67 mH
Grid frequency	50 Hz	DC-link capacitor	7 mF
DC-Voltage	600 V	Filter capacitor	40 μF
Switching frequency	6 kHz	Filter inductance	81.47 mH
Bi-directional inductance	0.3 mH		

B. Case studies:

This study analyzed various scenarios, and each was individually examined.

1. Case one: Integrating PV System for EVs Charging

Both PV and grid share power to charge EVs. At 0.2 s, the grid outages, whereas the PV keeps the same power level. All plugged-in electric vehicles are charging at a high level from both sources of charging station until the second 0.2, the level of charging EVs is stepped down, as shown in Fig. 5 and Fig. 6.

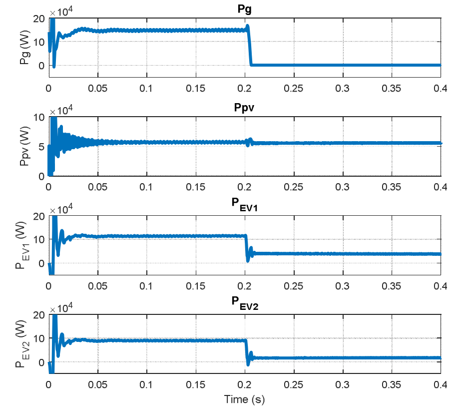

Fig. 5 power of resources at case 1

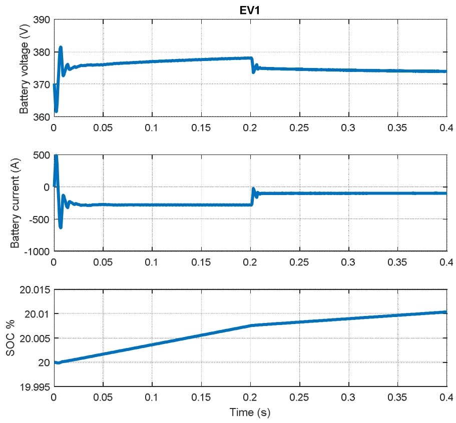

Fig. 6 states of EV1 at case 1

2. Case two: Integrating PV System and EV2 for Charging EV1

Both PV and grid are charging EVs. However, at 0.2 s grid outage of service therefore EVs with high SoC (EV2) start synergize PV for charging lower Soc's EVs (EV1) as shown in Fig. 7, Fig. 8, and Fig. 9

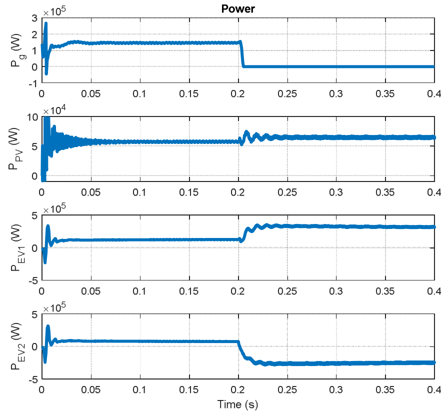

Fig. 7 power of resources at case 2

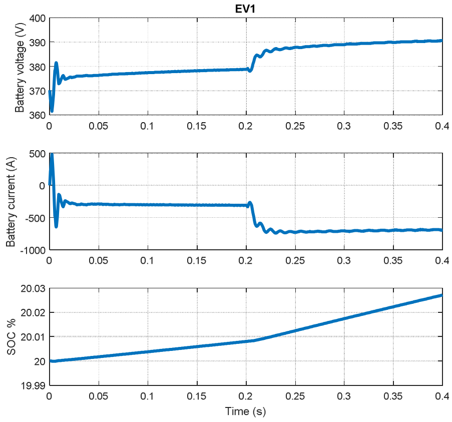

Fig. 8 states of EV1 at case 2

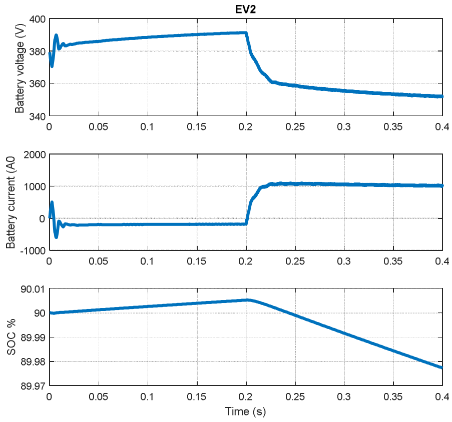

Fig. 9 states of EV2 at case 2

3. Case three: Integrating grid and EV2 for Charging EV1

Both PV and grid are charging EVs. However, at 0.2 s PV outage of service therefore, EVs with high SoC (EV2) start synergize grid for charging lower Soc's EVs (EV1) as shown in Fig. 10, Fig. 11, and Fig. 12

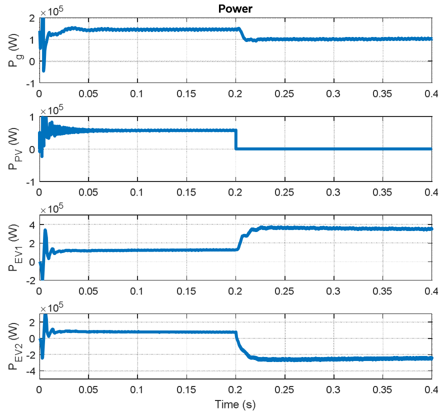

Fig. 10 power of resources at case 3

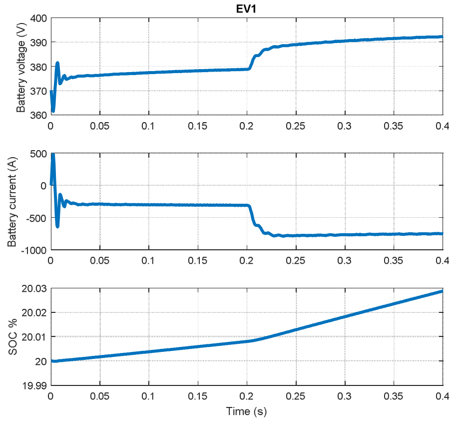

Fig. 11 states of EV1 at case 3

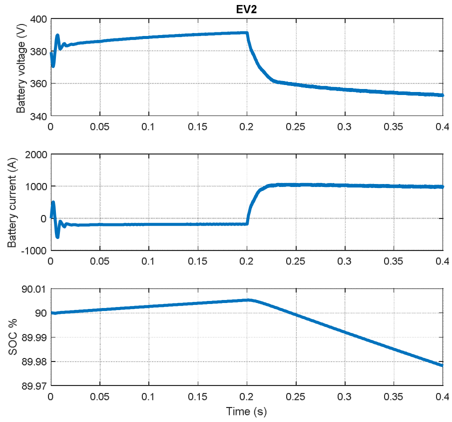

Fig. 12 states of EV2 at case 3

4. Case four: EV2 Charges EV1

Both PV and grid are outage at 0.2 s whereas EV2 charges EV1 as shown in Fig. 13, Fig. 14, and Fig. 15

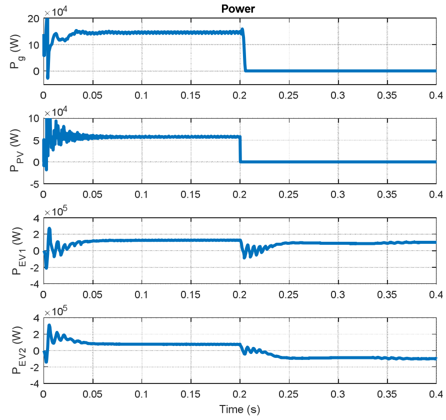

Fig. 13 power of resources at case 4

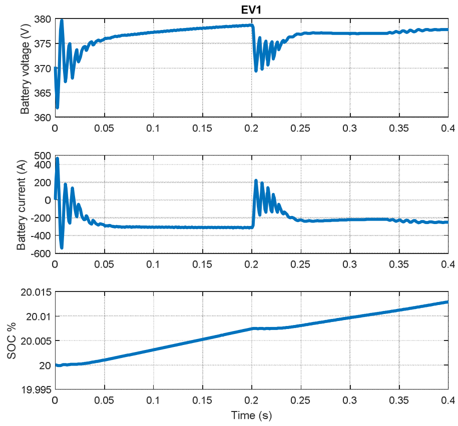

Fig. 14 states of EV1 at case 4

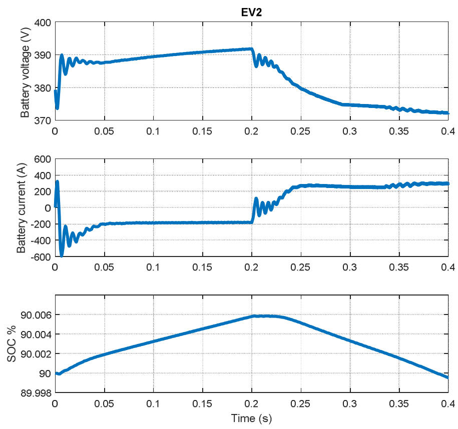

Fig. 15 states of EV2 at case 1

7. Conclusion

This paper presented the advantage of surplus power between PEVs within charging stations. The power can be transferred from high SoC vehicles to lower ones with revenue to the owner of the discharged PEV. Results are demonstrated when operating the system in different modes: battery charge or discharge. In charging mode, it acts as a load; in discharging mode, it acts as a source. Furthermore, the energy flows from the charging station's resources to the EVs until the desire to leave a state of charge is reached. Vehicles' batteries are synergized in discharging mode to provide the required power. PV is an effective and cheap source for charging EVs.

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