



International Journal of Science, Architecture, Technology and Environment

Smart Topology of EVs Charging Station by PV System and Wind Energy Conversion System Based Grid Tied Control Strategies

Ms. Shabnam yunus sheikh^{1*}, Prof. Miss Alfiya A. Mahat²

¹PG Scholar, Matsyodari shikshan Sanstha College of Engineering and Technology, Jalna

²Assistant Professor, Matsyodari shikshan Sanstha College of Engineering and Technology, Jalna

*Corresponding author, shaikhshabnam0119@gmail.com

DOI: <https://doi.org/10.63680/ijstate092529.15>

Abstract

In this paper, control strategies of a smart topology of EV charging station based on grid tied renewable energy sources and battery are designed and analyzed. The renewable energy sources (RES) that power EV charging station are composed by photovoltaic system and wind energy conversion system (WECS). Thus, a dc/dc boost converter based on a maximum power tracking controller is connected to the photovoltaic array, the WECS is tied to the DC link through a single ended primary inductor converter (SEPIC), and four charging points are associated to four dc/dc converters in order to secure a large scale of power to charge electric vehicles battery. However, the PV/WECS is tied both to the grid and to the battery storage buffer (BSB) of the charging station via a three-phase bidirectional inverter and a bidirectional dc/dc converter respectively. The aim of this work is to achieve an improved power management approach, that consists of an optimization algorithm set to mind the gap of energy deficiencies of a multi sources system, for instance an unfavorable weather conditions for RES, an overloading phenomenon of the grid and a limited capacity of the BSB. Simulation results in Matlab/Simulink have shown the effectiveness of the proposed power management strategy via seven operating modes.

Keywords: Electric Vehicle Charging Station, Optimization Algorithm, Power Management, Photovoltaic Array, Wind Energy Conversion System

I. INTRODUCTION

During the last two decades, the fossil fuel emissions and the petrol consumption in the transport sector have increased at a higher pace. According to the International Energy Agency, over 70% of global energy demand growth has been fulfilled by natural gas, coal and oil, while renewable sources accounted all the rest [1]. Alongside electricity production, renewable energy sources are ensuring new solutions for mobility and energy security worldwide. Furthermore, the industrial development in mobility sector provides new challenges for researchers and industrials to keep developing the charging infrastructures of electric vehicles (EVs). Besides, numerous energy constraints are listed in the recent The concept of smart grid allows the electricity distribution systems to respond digitally to the quick changes of load demand, and to set a smooth

integration of renewable energy sources (RES) into the electricity network [4]. Unlike conventional power sources at standalone mode, a multi sources system provides reliable findings e.g., the improvement of its efficiency and performance over a huge power demand, and also the low operating cost in favorable climatic conditions [3].

The electric vehicle charging station (EVCS) is presented as one of the possible applications of a multi-source system, where the EVs power demand is usually causing an inconvenient burden on the grid during peak hours, hence the intervention of solar and wind energy is paramount in multiple levels. In order to get more revenues for the charging station utility, V2G (Vehicle to Grid) technology could also be combined in the topology if the EV is equipped with bidirectional charger [5]. The main factor underlying this trend is the profitability that EV owners would achieve via charging/discharging process i.e., charging during non peak hours and discharging during peak hours. Yet, this approach may cause a short lifetime of the batteries and other unsolved issues [6]. Both solar and wind source have drawn much attention by their inherent benefits of power complementary along the year [7]. Several authors in literature suggest PV integration as one of the best alternatives among all RES to be combined into the CS system due to its efficiency property and its low investment cost [8]. However, its power may still struggle from discontinuity and instability over a day. In order to achieve the regulated goals from a robust hybrid electrical system, the intervention of wind energy conversion system (WECS) is also appreciated due to the enormous improvement in power electronics technology, mostly, for the small wind turbine controls [9].

In fact, high required charging rates from EVs would lead up to high power demand, which may not be supported by one of the RES in a standalone mode. In order to promote electrification of the transportation system, the grid and the battery storage buffer (BSB) would compensate the lack of energy. Meanwhile, some criteria are necessary to maintain the effectiveness of the system e.g., operating the BSB within a safety margin of state of charge (SOC) and taking into account a low voltage alternative current (LVAC) load, which is tied to the grid via AC link [10].

Typically, a LVAC load (residential, commercial and industrial customer) has the high priority to be powered up from the grid which causes an extra burden to the supply system and limited power to feed the CS. However, the grid overload and the intermittent power of the PV/Wind are eventual energy constraints related to climatic changes and to LVAC as well. In these cases, the control would adopt the available stored energy in the BSB as a potential solution in the compensation mode for charging plugged in EVs [11]. The contribution of this work is based on the power sensing of DC link, where the WECS, the PV, and the BSB are tied. The strategies aim to achieve an energy equilibrium between demand and supply at any interval of time and to reduce the consumption of grid power in order to achieve gainful financial findings.

However, in terms of rapidity and stability, the CS performance would be improved using an optimization algorithm of seven operating modes implemented in a fore castes power model. This paper is divided as follows. First, a proposed CS topology is provided in Section II, then, Section III describes the power predictive algorithm. Section IV defines the operating modes. Section V provides the simulation results of the architecture. Finally, a conclusion is presented in Section VI. Proposed EVs Charging

Station System Diagram Fig. 1 depicts the complete scheme of the adopted approach, that consists of grid tied RES/BSB. The PV system is connected to DC link via MPPT algorithm based on dc/dc boost converter in order to extract the maximum power from solar irradiance.

The BSB is also tied to the group using a bidirectional dc/dc converter, that adapts the medium battery voltage to a reference voltage of DC link. Transferring electricity at high power level during each operation mode of charging scenarios would require a sophisticated CS system that should fulfill the customer specifications.

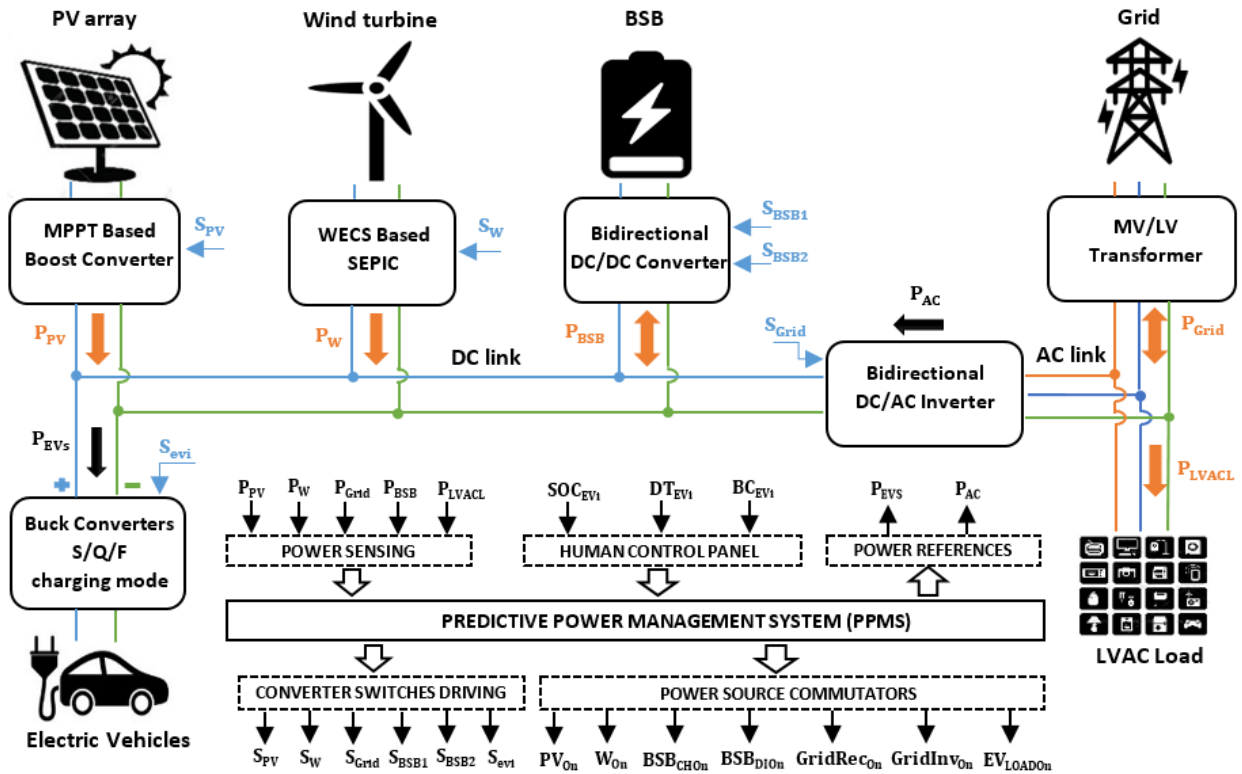


Fig. 1. Detailed scheme of different blocks of EVCS

In order to meet the selected power demand from plugged in EVs, dc/dc buck converters are used to settle the DC voltage and the current by which the charging requirements will be achieved [12]. Moreover, all charging points are tied in parallel configuration to PV/Wind and BSB; each point contains a human control panel (HCP) to provide a full data via two-way communication protocol to be processed by the CS main controller. For instance, the required SOC of the plugged in EV battery and the duration time since the vehicle is connected. Other data is immediately sensed by the HCP e.g., the battery capacity and the vehicle company/model.

The main control unit is based on a predictive power management system (PPMS), that gathers all the data so that it can select the optimal charging mode for the plugged EVs. The PPMS applies a smart scheduling of power on the system via a decision-making process of multiple optimization algorithms

PV Array and MPPT Process

Solar photovoltaic cells are modeled in detail in separate subsystems in order to match the exact parameters of a typical PV panel. The output power (PPV) of the PV array is obtained as:

$$PPV = VPV * IPV \text{--- (1)}$$

The PV voltage is boosted to the DC link reference via unidirectional dc/dc converter controlled by MPPT algorithm, which extracts the maximum power from a solar irradiance profile. The boost converter is characterized by its gain depicted as:

$$G_S = 1 - \frac{V_{PV}}{V_{DC}} \quad \text{-----}(2)$$

where, V_{PV} and I_{PV} are the PV voltage and current, respectively. G_S is the variable duty cycle and V_{DC} is the direct current link voltage. In this work, the incremental conductance (INC) algorithm is chosen owing to its effectiveness, The flowchart of the INC algorithm is shown in Fig. 2.

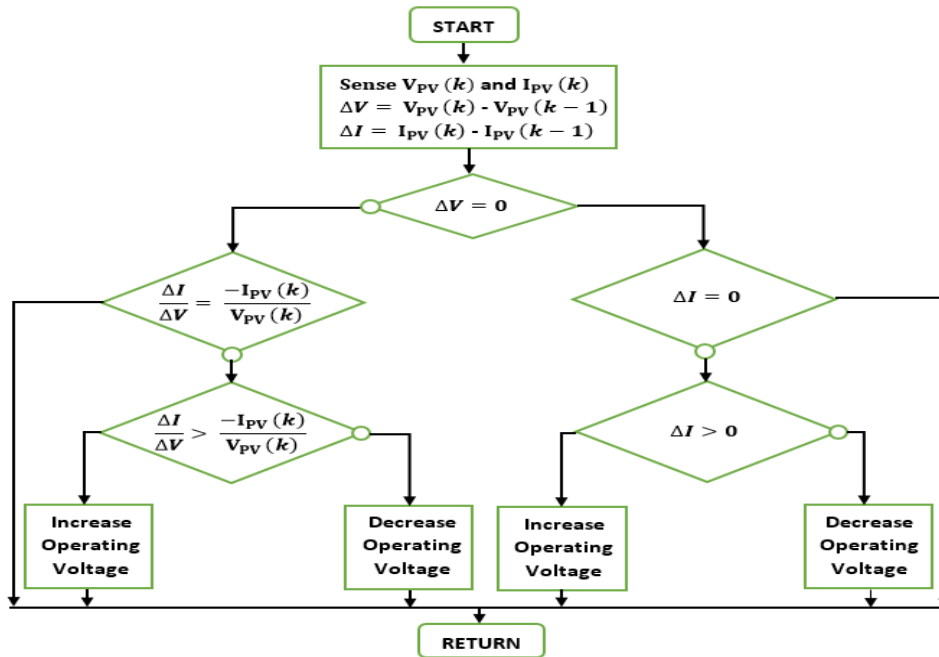


Fig. 2. Flowchart of the INC MPPT algorithm

II.2. Wind Energy Conversion System (WECS)

A WECS includes wind turbine, permanent magnet synchronous generator (PMSG), control system, a three phase diode bridge rectifier, and a single ended primary inductor converter (SEPIC) [14]. Fig. 3 illustrates the block diagram of the proposed WECS.

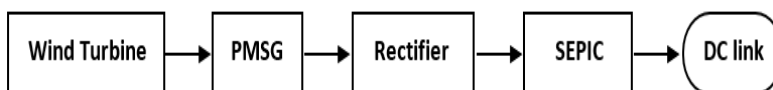


Fig. 3. Block diagram of the WECS

III. Predictive Power Management System (PPMS)

In compliance with the provided parameters as the applied demand from EVs, the stored energy in the CS and the available power from RES, the charging operations selected by CS customers have been divided into three typical rates of power i.e., small, medium, and large. Moreover, a PPMS is designed to set an efficient fore casted model to react fast when a huge power demand appears in the CS and to establish a reliable real time monitoring of data [26]-[28]. The SOC of storage buffers i.e., BSB and EV battery are also involved in the optimization approach via equations to settle the optimal power flow for a scheduled charging mode. In order

In order to get simulation results similar to the proposed goals, and in order to apply efficiently the approach, the algorithm of energy management requires call control programs i.e., MPPT for the boost converter, the voltage source converters (VSC) for the inverter and the PI constant current control for bidirectional dc/dc converter and SEPIC. The PPMS is continuously updating the calculation power demand from connected EVs so that the affectation of energy sources can be made taking into consideration some energy criteria i.e., gaining as much as possible from solar energy and wind speed in the first place, the BSB and the grid, respectively.

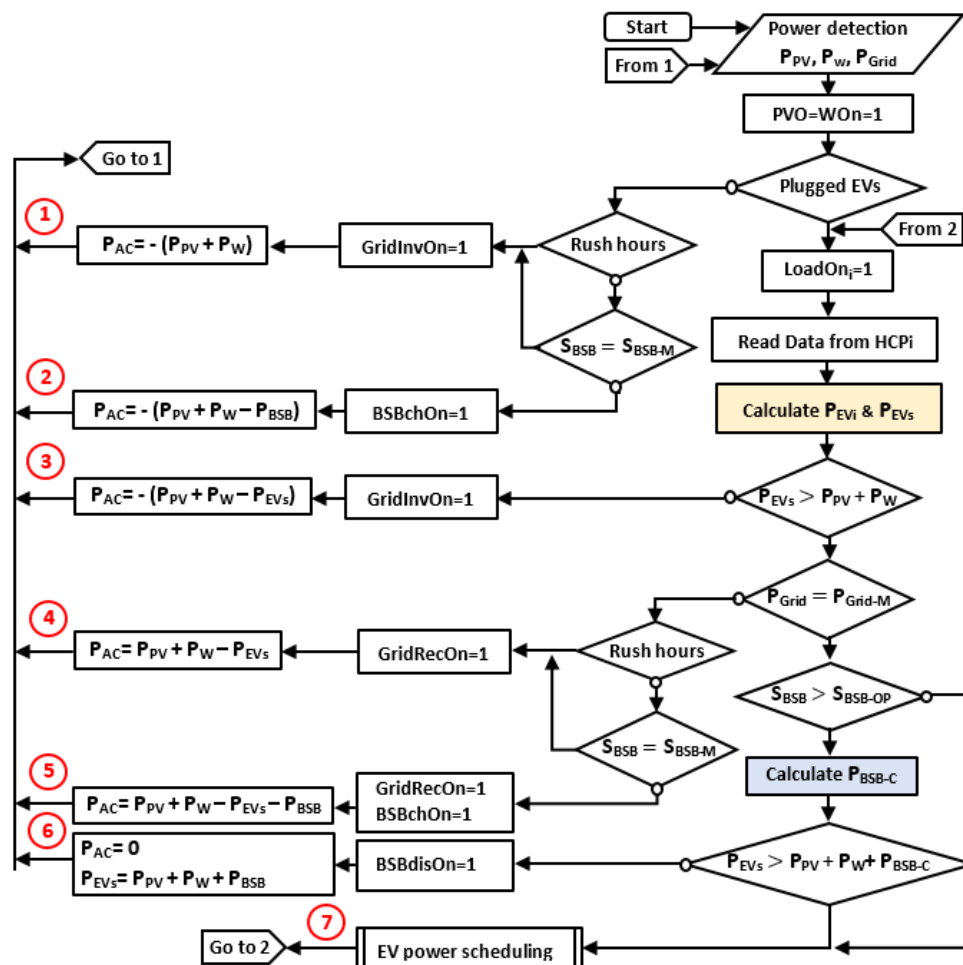
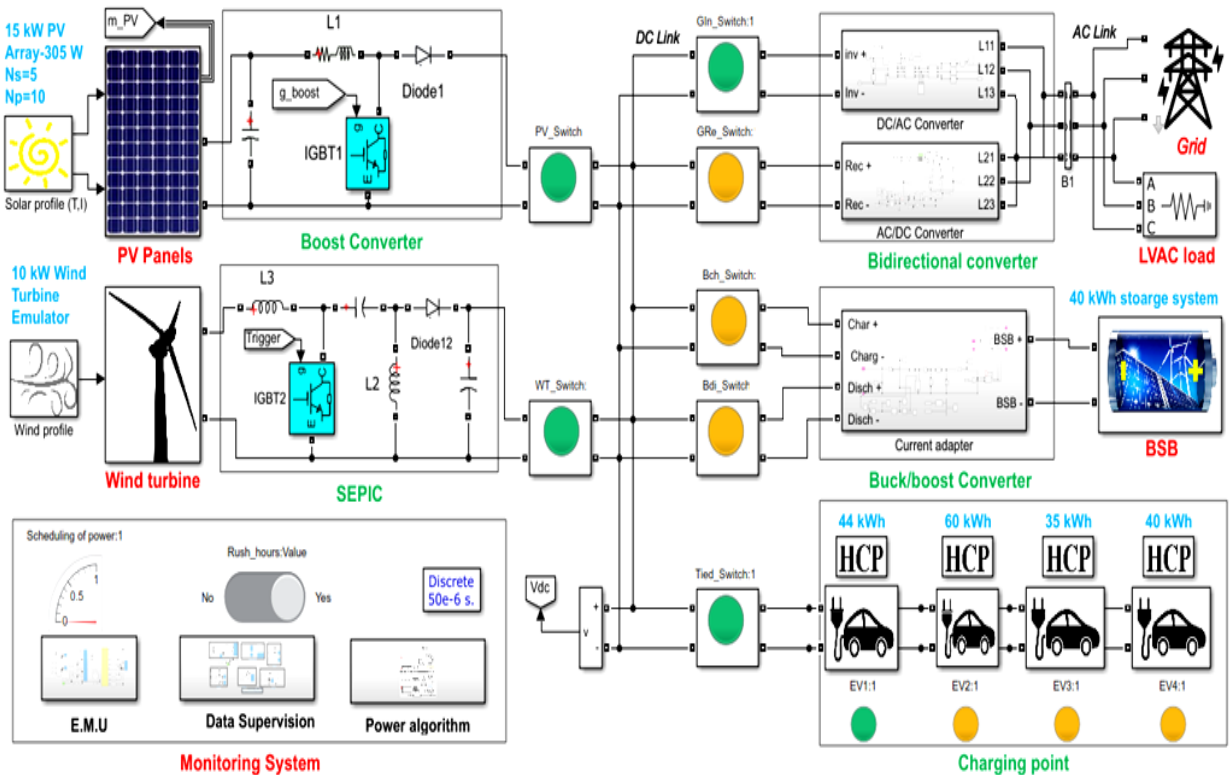


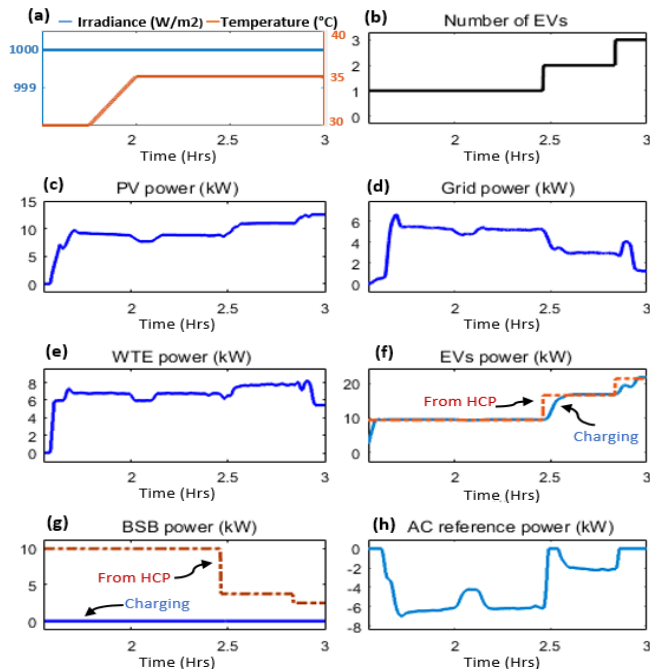
Fig. 9. Flowchart of the predictive powermanagement algorithm

V. Simulation results

In order to check the validity of the proposed topology and its algorithm, various climatic and load scenarios are carried out in Matlab/Simulink in order to test all the previous operating modes. Figs. 10 show the meteorological scenario of temperature and irradiance for PV system, the wind speed profile for WECS and also a load flow scenario of EVs. The designed diagram depicted in Fig. 11, consists of a 15kW PV system in (5×10) configuration tied to a boost converter delivered 600V, the wind turbine based WECS delivers 10kW to DC link via SEPIC. Besides, the system contains a 30kWh storage system represented the BSB of 200V/150Ah. In order to add further complexities to the control strategy, the system has been modeled to test all the scenario cases under limited power from DT. As follows from the figures shown above, the grid contributes via two modes i.e., rectification and injection.

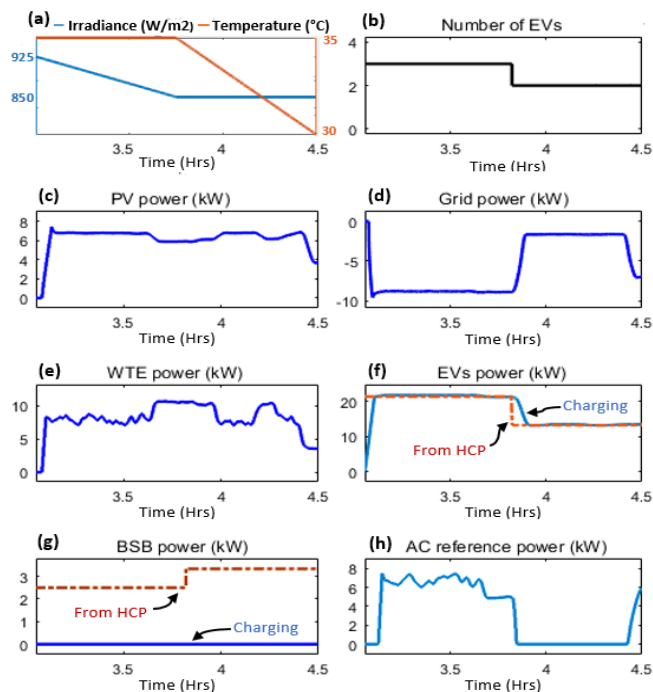


The proposed CS is developed for a study case of a small parking place equipped with four charging points; each one has provided an HCPi interface so the customer could set



Figs. 13. RGTEC simulation results for t = 1.5-3 Hrs

As it can be seen in Figs. 14, the RGTREC mode uses a different climatic scenario with a random number of EVs versus time.



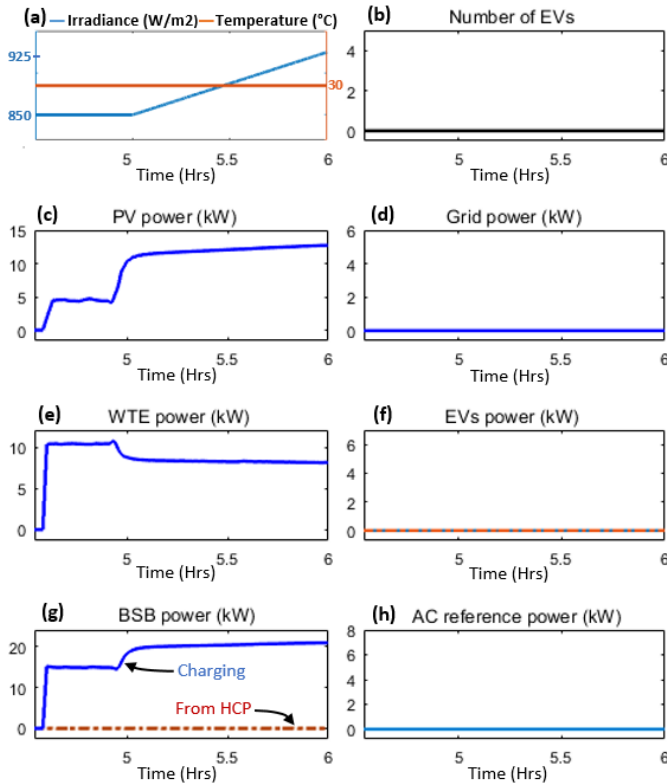
Figs. 14. RGTREC simulation results for t = 3-4.5 Hrs

The dc/ac converter will be operated as a rectifier to

fit the selected operation. At the beginning of this case, the system is responding as quickly as the PPMS could choose the optimal solution, where the RES are providing their maximum power. The negative sign of grid power in Fig. 14(d) indicates the stream direction and at what level the grid is supporting the 20kW load flow presented in Fig. 14(f). The AC power of Fig. 14(h) is referred to which operating phase has the most advantageous profit for the CS system in cases where the grid is involved in the operation.

Figs. 15 illustrate the last operating phase in this day scenario. Since there is no EV connected in the station after $t=4.5$ Hrs, the CS has an excess of energy which has only two ways to be distributed i.e., inject it into the grid during rush hours or when the BSB is fully charged, otherwise the BSB would take a high priority to be powered up from the PV/WECS. In this case, the system is running at off-peak hours and, as results, the PPMS will be operated under RTBC mode. The accompanied control activates switch. As it can be seen in Fig. 15(c) and Fig. 15(e), there is a sort of complementary between the PV array and the WECS within the adopted climatic scenario and the limited current of charging BSB. After $t=5$ Hrs, the PV power is slightly affected by the temporal variations of temperature that increases the produced rated power to 12kW at $t=6$ Hrs. Meanwhile, the PPMS is decreasing the wind power from its maximum rate, so the controller could avoid an overloading issue of the BSB. In order to keep the system stable, it is fundamental to evacuate all the produced power from the energy sources to the selected loads so that the DC link would sustain its DC link power at zero value. This work has explained in detail all the potential operating modes via charging/discharging the BSB and operate the grid under inversion/rectification modes. Thus the PPMS would achieve financial goals from less reliance on the national grid.

The proposed optimization algorithm has been validated by simulation results performed in Matlab/Simulink. However, the analysis of data is established by the HCP in order to feed the PPMS with the required load flow specification of EVs, so that it can calculate the total power demand and monitor the available energy in the CS. In terms of decreasing the charging cost from over-relying on the grid and for a smooth integration of RES, the PPMS would set the optimal charging scenario from the RES battery and grid, based on a smart scheduling of power.



Figs. 15. RTBC simulation results for $t = 4.5-6$ Hrs

VI. CONCLUSION

In this paper, a predictive model is presented in detail to forecast EVs power demand and to maintain a high level of accuracy and stability of the charging station by securing an effective real time monitoring of each part including the grid. The reliability and the flexibility of the hybrid power sources are achieved via seven operating phases by which a large scale of power for any EV charging mode is fulfilled. The findings have a number of possible limitations, namely a decreased of the available power at the charging station during night time, caused by the grid operated in peak events mode and by a limited stored energy of the BSB.

The proposed optimization algorithm has been validated by simulation results performed in Matlab/Simulink. However, the analysis of data is established by the HCP in order to feed the PPMS with the required load flow specifications

of EVs, so that it can calculate the total power demand and monitor the available energy in the CS. In terms of decreasing the charging cost from over-relying on the grid and for a smooth integration of RES, the PPMS would set the optimal charging scenario from the RES battery and grid, based on a smart scheduling of power.

Declaration of Conflicting Interests

The authors declare no potential conflicts of interest with respect to the research, authorship and publication of this article.

Funding

The author received no financial support for the research, authorship and publication of this article.

References

- [1] A. Moro and L. Lonza, Electricity carbon intensity in European Member States: Impacts on GHG emissions of electric vehicles, *Transportation Research Part D*, July 2017, pp. 1–10.
- [2] B. Dolter and N. Rivers, the cost of decarbonizing the Canadian electricity system, *Energy Policy*, vol. 113, February 2018, pp. 135-148.
- [3] A. R. Bhatti, Z. Salam, M. J. B. A. Aziz, K. P. Yee, A Comprehensive Overview of Electric Vehicle Charging using Renewable Energy, *International Journal of Power Electronics and Drive System*, vol. 7 no. 1, March 2016, pp. 114-123.
- [4] P. Grahn and L. Söder, The customer perspective of the electric vehicles role on the electricity market, 8th International Conference on the European Energy Market, May 25-27, 2011, Zagreb, Croatia.
- [5] D. T. Hoang, P. Wang, D. Niyato, and E. Hossain, Charging and Discharging of Plug-In Electric Vehicles (PEVs) in Vehicle-to-Grid (V2G) Systems: A Cyber Insurance-Based Model, *IEEE Access*, vol. 5, January 2017, pp. 732 – 754.
- [6] S. Chalise, J. Sternhagen, T. M. Hansen, R. Tonkoski, Energy management of remote microgrids considering battery lifetime, *The Electricity Journal*, vol. 29 no. 6, July 2016, pp. 1-10.
- [7] K. Engeland, M. Borga, J. Creutin, and B. François, Space-time variability of climate variables and intermittent renewable electricity production – A review, *Renew. Sustain. Energy Rev*, vol. 79, November 2017, pp. 600–617.
- [8] A. Hassoune, M. Khafallah, A. Mesbahi, and T. Bouragba, Power Management Strategies of Electric Vehicle Charging Station Based Grid Tied PV-Battery System, *International Journal of Renewable Energy Research*, vol. 8, no. 2, 2018, pp. 851-860.
- [9] S. Z. Hassan, S. Mumtaz, T. Kamal, L. Khan, A Road to Wind based PHEVs Smart Charging Station, 13th International Conference on Frontiers of Information Technology, December 14-16, 2015, Islamabad, Pakistan.
- [10] A. Luo, Q. Xu, F. Ma, and Y. Chen, Overview of power quality analysis and control technology for the smart grid, *J. Mod. Power Syst. Clean Energy*, vol. 4 no. 1, January 2016, pp. 1–9.
- [11] S. Rivera and B. Wu, Electric Vehicle Charging Station with an Energy Storage Stage for Split-DC Bus Voltage Balancing, *IEEE Trans. Power Electron.*, vol. 23 no.3, March 2017, pp. 2376-2386.
- [12] L. Pan and C. Zhang, Performance Enhancement of Battery Charger for Electric Vehicles Using Resonant Controllers, *Energy Procedia*, vol. 105, May 2017, pp 3990-3996.
- [13] A. Dandoussou, M. Kamta, L. Bitjoka, P. Wira, and A. Kuitché, Comparative study of the reliability of MPPT algorithms for the crystalline silicon photovoltaic modules in variable weather conditions, *J. Electr. Syst. Inf. Technology*, vol. 4 no. 1, May 2017, pp. 213–224.
- [14] Tazerart F, et al., Direct torque control implementation with losses minimization of induction motor for electric vehicle applications with high operating life of the battery, *International*
- [15] L. Benaouinate, M. Khafallah, A. Mesbahi, A. Martinez, Development of a useful Wind Turbine Emulator Based on

Permanent Magnet DC Motor,

- ,[16] L. Lu, Z. Xie, X. Zhang, S. Yang, and R. Cao, A dynamic wind turbine simulator of the wind turbine generator system, Intelligent Conference on Intelligent System Design and Engineering Application, pp. 967-970, 6-7 January 2012.
- [17] S. Venkatanarayanan, M. R. M. Nanthini, Design and Implementation of SEPIC and Boost Converters for Wind and Fuel cell Applications, International Journal of Innovative .