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Bi-directional Charger for Grid-tied Electric Vehicle with Hybrid Integration of Renewable Resources

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ABSTRACT

A hybrid renewable energy plant for Hybrid Electric Vehicle (HEV) that is based on solar and wind energy conversion systems is designed and analysed in this paper. Each separate energy conversion system is controlled either using regular PI controller or Perturb and Observe algorithm. The solar plant model is constituted by connecting photovoltaic (PV) panels serially and energy conversion is performed with maximum power point tracking (MPPT) algorithm that controls the modulator of buck converter. The MPPT algorithm utilized in the control step of converter is developed using Perturb and Observe (PO) that is extended with PI controller. The wind energy plant is designed with a permanent magnet synchronous generator (PMSG), and the AC–DC conversion stage is constituted with an uncontrolled full-bridge rectifier. All the converter outputs are connected to a busbar over interphase transformers (IPTs). The DC bus-bar voltage is supplied to a full bridge inverter to generate three-phase AC voltages at the output of inverter. The three-phase inverter is controlled with sinusoidal pulse width modulation (SPWM) scheme, which is developed with phase shifted carrier signals. A bi-directional DC-DC converter containing both buck and boost is used for charging the electric vehicle

Key words: *Perturb and observe, Photo voltaic, Sinusoidal pulse width modulation, Bidirectional DC-DC converter, 3 phase inverter, PI controller, Maximum power point tracking, Modulator of BUG converter, Boost converter*

1.INTRODUCTION

The utilization of conventional energy sources such as coal, natural gas, and crude oil causes increased generation costs in electrical energy besides their pollutant effects to environment. The renewable energy sources are paid much attention and are began intensively to be studied after the oil crisis met in 1970s [1,2]. Although the main aspects of studies performed in renewable energy are seen as cost related, efficiency and alternative source issues are also researched to improve the dissemination of renewable energy sources. On the other hand, governments define the sustainable energy management and energy 17 efficiency policies strictly, and financial regulations are performed for individuals to accelarate the renewable energy usage [1]. Although the renewable energy sources draw nonlinear characteristics when compared to nuclear and thermal energy sources, they do not have any pollution effect to environment. The most widely used renewable energy sources in electricity generation can be listed as solar, wind, hydraulic and tidal sources. Researchers separately studied these sources for a long time to increase energy alternatives and efficiency. However, it is possible to develop hybrid renewable energy conversion system owing to widely performed distributed generation studies. The hybrid system studies are assumed to contain some of the renewable energy sources together such as mentioned previously. The distributed power generation systems based on renewable energy sources such as photovoltaic (PV) cells, wind turbines, fuel cells, and micro- turbines is experiencing a rapid development to meet the energy demand all around the world [3]. Nowadays, the wind energy as a renewable energy source itself is the most widely used alternative energy source. In particular, wind energy that is commonly used in high power requirements is used either insource to weather conditions since the generated power will island mode or in grid connected mode. It is a dependent energy vary according to wind speed in island mode applications. On the other hand, the integration possibility of renewable energy sources to create a hybrid system is an excellent option for the distributed energy generation systems. Therefore, other energy sources may be added to wind energy system in order to ensure the sustainability of energy supplied to load when wind is insufficient itself. Another widely used renewable energy source besides the wind is solar energy. It is also a dependent energy source similar to wind since the generated energy is depended to several season conditions such as irradiation angle, panel temperature, and irradiation levels. Consequently, the spare energy can be stored to charge systems. The study analysed in [4] is carried out by modelling three separate solar farms that are assumed to be located in faraway places with rated power of 15 kWs. The DC–DC conversion system is based on buck converters with Perturb Observe (PO) MPPT control algorithm where the buck converter assures the stability of generated energy in each solar farm separately.

2.WIND MODELLING

A small wind system can be connected to the electric grid through your power provider or it can stand alone (off-grid). This makes small wind electric systems a good choice for rural areas that are not already connected to the electric grid. Power produced by a wind turbine is given by [1] Pm = 0.5πϱCp(λ, β)R 2 v 3 w (1) where R is the turbine radius, vw is the wind speed, ϱ is the air density, Cp is the power coefficient, λ is the tip speed ratio and β is the pitch angle. In this work β is set to zero. The tip speed ratio is given by:

λ = wrR /vw (2)

where wr is the turbine angular speed. The dynamic equation of the wind turbine is given as

dwr/ dt = 1/J [Tm − TL − Twr] (3)

where J is the system inertia, F is the viscous friction coefficient, Tm is the torque developed by the turbine, TL is the torque due to load which in this case is the generator torque. The target optimum power from a wind turbine can be written as

$$P_{max} = K_{opt} w^3_{r\_opt} \quad (4)$$

where,

$$K_{opt} = \frac{0.5\pi\rho C_{p\_max} R^5}{\lambda^3_{opt}} \quad (5)$$

$$w_{opt} = \frac{\lambda_{opt} v_w}{R} \quad (6)$$

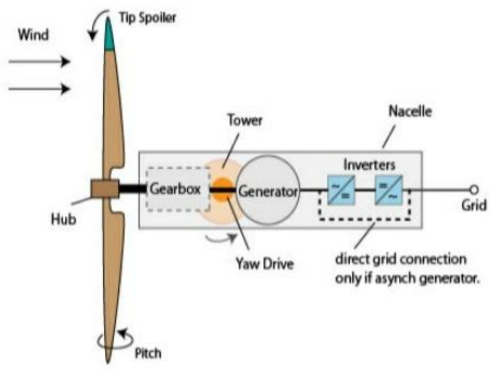


Figure 1: Wind model

The power for a certain wind speed is maximum at a certain value of rotor speed called optimum rotor speed wopt. This is the speed which corresponds to optimum tip speed ratio λopt. In order to have maximum possible power, the turbine should always operate at λopt. This is possible by controlling the rotational speed of the turbine so that it always rotates at the optimum speed of rotation.

3.SOLAR MODELLING

The characters tics of the solar panel can be better visualized using a VI graph which perfectly display es the importance of the electrical characteristic of the solar panel. However the parameter Pmax) is highly essential for calculating the overall performance of the solar panel and the solar efficiency. The solar cell generally extracts power using the sun energy to generate the current or electricity with the help of semiconductors. Solar system/ photo voltaic (PV) system commonly is a device with uses the solar light called as irradiance and converts to electricity with the help of semiconductors. While the irradiance of sun is absorbed by the semiconductor of the solar model, the electrons are generally being free and thus they generate the electricity. Photovoltaic process is commonly utilized using the panel. solar cells are mostly placed side by side and are placed on a frame or module. However, several frame also can be assembled to make an array, this also can be further scaled according to the power need of the user. Major performance of the solar cell can be stated as the relationship within the electrical parameters i.e. the current and the voltage generated for a single PV cell and is represented by I-V characteristics curve. Mainly, the irradiance i.e. the intensity of the solar radiation hits the solar cell and it controls the solar generated DC current (I) and the resulting increase in the temperature of the PV panel lowers the voltage (V). PV panels generate the direct current (DC) so can be fit to any electronic devices however the electrical appliances and industrial requirements may also need a converted to convert the DC to AC. The major importance of the IV curve of a solar panel is the characterize the performance of the solar panel over varying voltage how the solar panel reacts to its current with a constant loading condition. The resulting power curve also is most important there it has a maximum peak called as MPP. From the above figure 2 the VI curve of a solar cell can be visualized. The IV curve of a solar panel is the characterize the performance of the solar panel over varying voltage how the solar panel reacts to its current with a constant loading condition. The resulting power curve also is most important there it has a maximum peak called as MPP. ptimum speed of rotation.

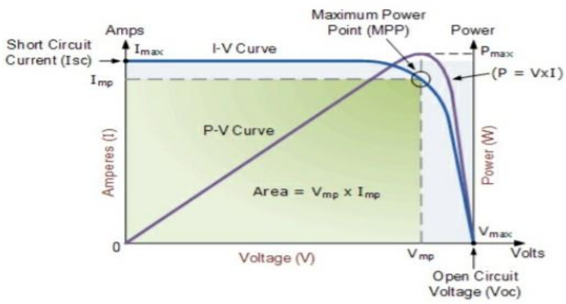


Figure 2: VI characterstics

4 MPPT

For the solar panels, the general characteristics of VI curve represent a specific region where the maximum power is observed. The resulting power operates with a specific voltage and current rating. However finding the perfect combination of the voltage and current is the basic need of an MPPT algorithm. Pertub and observe is basically a search process where the voltage is being varied and in each step the voltage changes a particular level to obtain the best power.[13][14] This can be termed as the hill climbing process as it is dependent on the gradient of the power level generally depicts like a hill.[15]. The Pertub and Observe algorithm P&O is the mostly used MPPT approach for its simplification.[13] P&O method can only reach the global optimum if a proper strategy is being adopted [16][17]

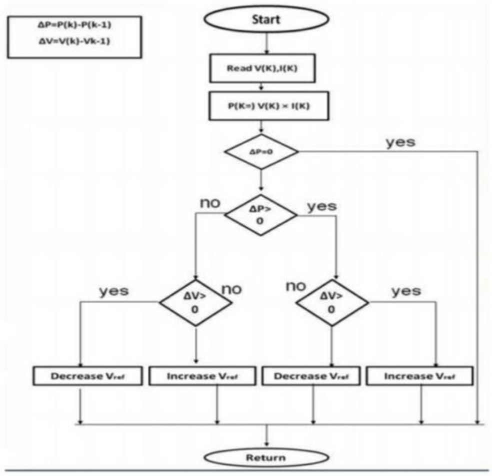


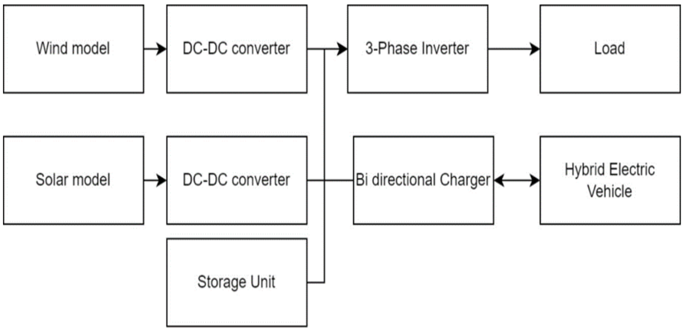
Figure 3: Pertub and Observe algorithm

5. Proposed Bi-directional Charger

In case of electronic vehicles, due to the variable configurations, the model results in different operating voltage and current. While, according to the load requirement the voltage and the current needs a limitation or control. The proper control of these electrical properties a DC-DC converter needs to implement. Such a converter converts one voltage level to another with promising to achieve the power level constant. How ever this is an ideal case, but in practical there are losses of each DC-DC converter which are comprising of conduction and switching losses. A brief description of the converter is discussed further.

6. Simulation Results

The proposed hybrid model integrating renewable resources with bi-directional charger for hybrid electric vehicles are presented in the Figure 5. Simulation and Results



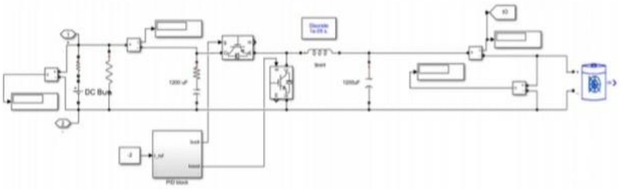


Figure 4: Proposed bidirectional charger

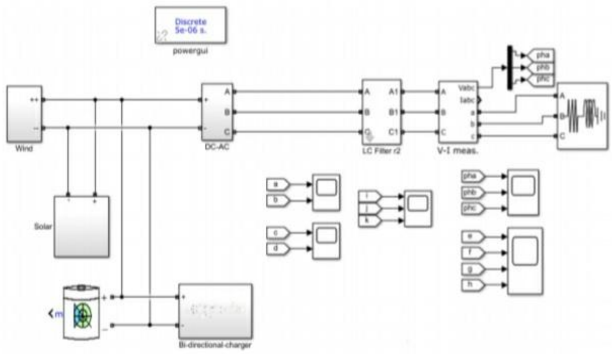


Figure 5: Proposed model

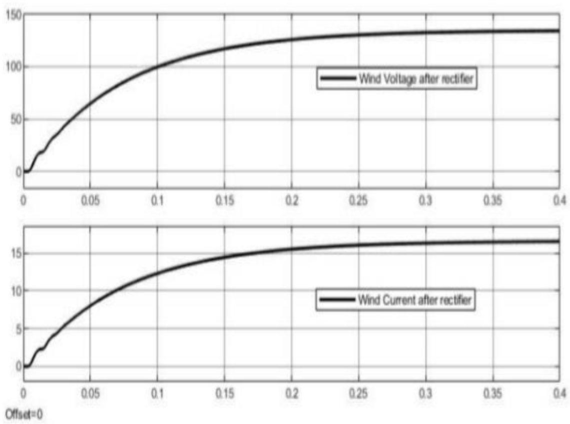


Figure 6: Wind model simulation results after rectifier

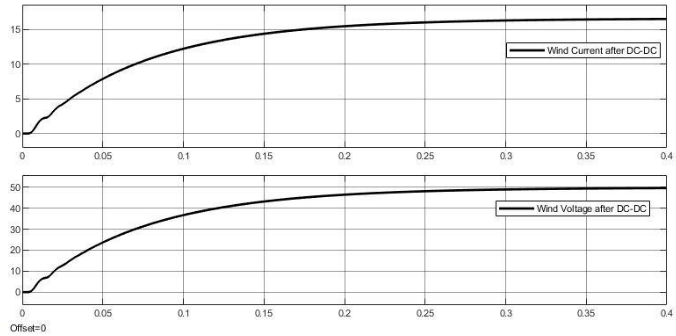


Figure 7: Wind model simulation results after DC-DC

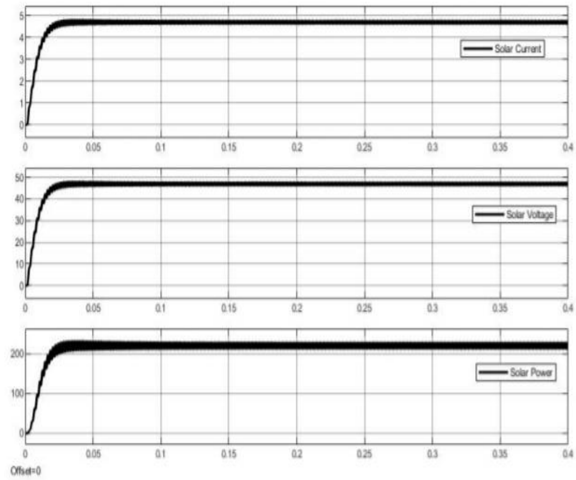


Figure 8: Solar model simulation results after DC-DC

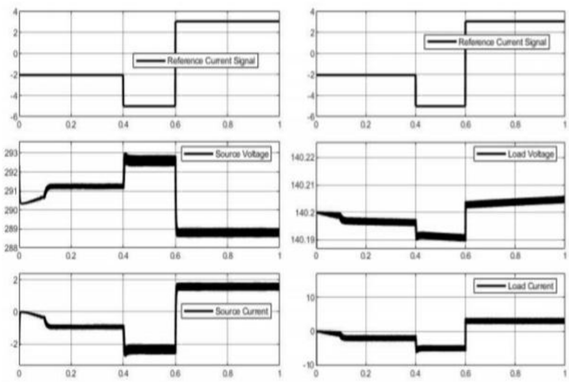


Figure 9: Bi-directional DC-DC Converter Simulation Results

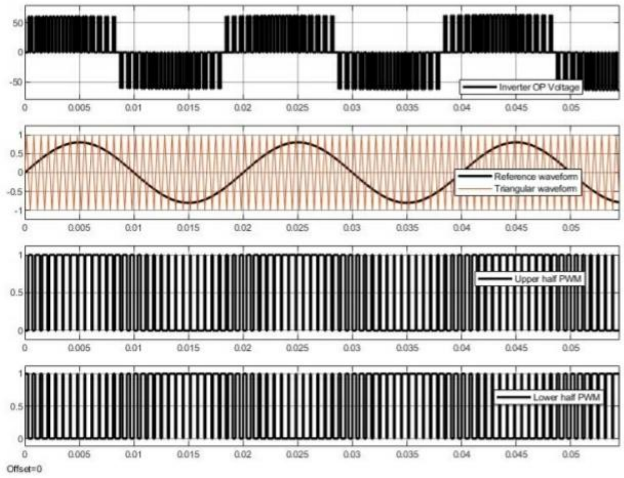


Figure 10: Inverter Simulation Results

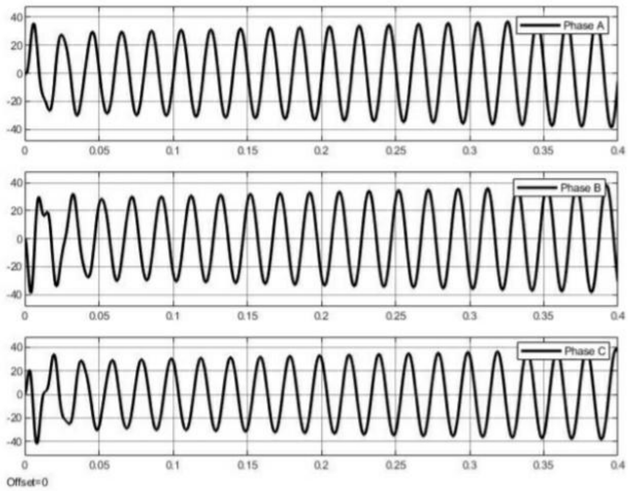


Figure 11: Inverter Output Simulation Results

7. Conclusion

The study proposed in this paper introduces a hybrid renewable energy conversion system for charging HEV in detail. The solar and wind energy sources, as being the most widely used renewable energy sources, are modelled separately and collected together to build a distributed generation system in the graphically presented Simulink model. The DC converters are designed to ensure to generate stable output values according to various conditions owing to PI and MPPT control algorithms developed for each other. The DC busbar connection prevents the intersection of separate power levels to each other and enables the energy conversion system to perform in a stable way. Bi-directional DC-DC converter shows promising results for HEV applications. The results of ongoing experimental studies also prove the efficiency of proposed system in real time.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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