Design of Multi-input Converter for a Hybrid PV/Wind power Generation System and I-PVSC for Battery Charging and MATLAB Software

Deeksha K S1, Dr.N.Amuthan2
1PG Scholar: Electrical and Electronics Engineering, AMC Engineering College, Bengaluru, India
2Professor & Head, Department of EEE, AMC Engineering College, Bengaluru, India

Abstract— This paper presents a multi-input converter (MIC) for hybrid PV/wind power charger system which can simplify the power system, and also I-PVSC is used for charging of battery. reduce the cost, deliver continuous power, and overcome high-voltage-transfer-ratio problems is proposed. In this paper, the operational principle of the proposed S-MIC is explained, the small-signal ac model is derived, and the controller design is developed. Simulation work will be carried out using MATLAB/Simulink software and the results will be verified with our required outcomes.

Keywords— Renewable systems, PV panel, wind turbine, Maximum Power Point Tracking (MPPT)

I. INTRODUCTION

The MIC has several advantages such as providing simple circuit topology, centralized control, and low-manufacturing cost and size. However, it also contains multiple interacting variables. Therefore, in order to increase the dynamic response and stability of the MIC, the small-signal analysis of the MIC is necessary. Moreover, due to the cross-coupling nature of the MIC, the controller design is not as straightforward as the controller design in a single-input single-output system. The control loop needs to be decoupled in order to separately design the closed loop controllers. Many literatures have been found focusing on the modeling and control of a MIC. For example, a two-loop control strategy for a buck-type PVSC SEPIC prime converter has been proposed in [19], with the small-signal ac model developed for dc battery sources and a dc load.

The N-MIC has no isolated transformer within the converter, while each energy source of the I-MIC is electrically isolated to the load. For the S-MIC, only some of the energy sources are isolated to the load. For the hybrid PV/wind power charger system application, since the output voltage of the battery and PV module are usually quite low and the rectified output voltage of the small-scale wind turbine might be much higher, the N-MIC might encounters some implementation difficulties due to the high voltage transfer-ratio. Therefore, in this paper an S-MIC consists of a forward-type isolated PVSC (I-PVSC) and a buck–boost prime converter is proposed for the hybrid PV/wind power charger system to realize the maximum power point tracking (MPPT) function for each PV/wind source.

Generally, various sources can be connected in parallel at the load through an intermediate power converter to draw the maximum power and to increase the power reliability. However, in order to increase the flexibility of power expansion and the utilization of the power converter, different types of multi-input dc–dc converters (MICs) have been proposed [3]–[5]. The MIC can deliver power from different energy sources to the load simultaneously or individually. A systematic approach to develop the circuit topologies of the MIC had been proposed [6]. In [8], the concept to pulsating source cell (PSC), including pulsating voltage source cell (PVSC) and pulsating current source cell (PCSC), was first proposed and rules of connecting them with other dc–dc converters were established. To synthesize the MIC with isolation property, the isolated PSC (I-PSC) needs to be generated in advance. The developed I-PSCs in this paper and the previously proposed PSCs in [8] and [9] can be integrated with either isolated or nonisolated converters to
synthesize different types of MICs. Eventually, the synthesized MIC can be further divided into three categories: Nonisolated MIC (N-MIC), I-MIC, and semiisolated MIC (SMIC), which will form the whole MIC family.

II. DIFFERENT PC’s

A commonly used real transformer circuit model is shown in Fig.1(a), which consists of an ideal transformer and other parasitic components, such as the winding resistance Rk1 and Rk2, the leakage inductance Lk1 and Lk2, the magnetizing inductance Lm, and the magnetizing resistance Rm. However, except for the Lm, the Rk1, Rk2, Lk1, Lk2, and the Rm do not involve in the operation principle of the isolated dc–dc converter. They only affect the efficiency of the transformer. Consequently, the simplified transformer circuit model used in this paper only consists of an ideal transformer and a magnetizing inductor as shown in Fig. 1(b). Furthermore, the Lm will not affect the operation principle of the half-bridge, full-bridge, and push–pull dc–dc converter, and it can be further neglected. Besides the transformer circuit mode, different types of rectifier circuit topologies can be used at the secondary side of the transformer to provide the desired dc output. The full-bridge rectifier needs four diodes but each diode has lower voltage stress. Besides, the realization of the transformer is easy, and there is no secondary winging imbalance problem. Therefore, the full-bridge-type rectifier is selected in this paper, although the central-tapped type one can achieve the same function. In the following, different types of I-PVSCs and I-PCSCs will be developed based on the above mentioned basic isolated PWM converter with a simplified transformer circuit model and full-bridge-type secondary rectifier.

Fig. 1. Transformer equivalent circuit models. (a) Real transformer. (b) Simplified transformer

A. Flyback:

The circuit topology of a flyback converter is shown in Fig. 3(a) with the input portion (IP) and output portion (OP) marked. Since the flyback converter uses the magnetizing inductor of the transformer as the energy storage component, a high-frequency pulsating current will flow out these condo winding of transformer. Eventually, the flyback-type I-PCSC can be defined and showed in Fig. 3(b).

Fig. 2. Flyback converter and its developed I-PCSC. (a) Flyback converter. (b) Flyback-type I-PCSC.
B. Full-Bridge:

Full-bridge converters are also found to have both the voltage fed type and the current-fed type. The operation principle of the full-bridge converter is similar to the one of the push–pull converter except that four switches are needed and only one primary winding of the transformer is required. By following the development methodology of the push–pull type I-PVSC or I-PCSC, the full-bridge type I-PVSC or I-PCSC are illustrated in Fig. 3(a) and (b), respectively.

![Fig. 3.Different full-bridge-type I-PSCs. (a) Full-bridge-type I-PVSC. (b) Full-bridge-type I-PCSC.](image)

III. SOLAR PHOTO VOLTAIC SYSTEM

The PV array must operate electrically at a certain voltage which corresponds to the maximum power point under the given operating conditions, i.e. temperature and irradiance. To do this, a maximum power point tracking (MPPT) technique should be applied. Various MPPT techniques like look-up table methods, perturbation and observation (P & O) methods and computational methods have been proposed in the literature. The perturbation and observation (P&O) method has been used in this work. In incremental conductance method the maximum power points are tracked by comparing the incremental and instantaneous conductance values of the PV array. If the array is operating at voltage $V$ and current $I$, the operation point toward the maximum power point by periodically increasing or decreasing the array voltage, is often used in many PV systems. The advantage of this method is that it works well when the irradiation does not vary quickly with time, however, the P&O method fails to quickly track the maximum power points.

The physical of PV cell is very similar to that of the classical diode with a p-n junction formed by semiconductor material. When the junction absorbs light, the energy of absorbed photon is transferred to the electron-proton system of the material, creating charge carriers that are separated at the junction. The electrical characteristics of the PV module are generally represented by the current vs. voltage (I-V) and the Power vs. Voltage (P-V) curves. The charge carriers in the junction region create a potential gradient, get accelerated under the electric field, and circulate as current through an external circuit. The solar cell is the basic building of the PV power system it produces about 1 W of power. To obtain high power, numerous such cell are connected in series and parallel circuits on a panel (module). The solar array or panel is a group of a several modules electrically connected in series-parallel combination to generate the required current and voltage.

IV. WIND ENERGY CONVERSION SYSTEM

The maximum power for different wind speeds is generated at a different rotor speeds. Therefore, the turbine speed should be controlled to follow the ideal TSR, with an optimal operating point which is different for every wind speed. This is achieved by incorporating a speed control in the system design to run the rotor at high speed in high wind and at low speed in low wind.

Power from the wind turbine, real and reactive power, is basically controlled by the wind-side converter and stalled by the wind blade. Below rated wind speeds, the real power from the wind generator is regulated to capture the maximum wind energy from varying wind speed. Reactive power generation is maintained at zero to minimize the thermal rating of the generator and the converter. Above rated wind speeds the maximum power control is overridden by stall regulation for constant power. In this study, the wind blade is assumed to be ideally stall regulated at rated power so that rotor speed can keep constant at rated speed under high wind speeds.
V. FUTURE HYBRID ENERGY SYSTEM

The configuration of household hybrid wind and PV system is shown in Figure 5. This configuration is fit for stand-alone hybrid power system used in remote area. Wind and solar energy are converted into electricity and then sent to loads or stored in battery bank. The topology of hybrid energy system consisting of variable speed WT coupled to a permanent magnet generator (PMG) and PV array. The two energy sources are connected in parallel to a common dc bus line through their individual dc-dc converters. The load may be dc connected to the dc bus line or may include a PWM voltage source inverter to convert the dc power into ac at 50 or 60 Hz. Each source has its individual control. The output of the hybrid generating system goes to the dc bus line to feed the isolating dc load or to the inverter, which converts the dc into ac. A battery charger is used to keep the battery fully charged at a constant dc bus line voltage. When the output of the system is not available, the battery powers the dc load or discharged to the inverter to power ac loads, through a discharge diode. A battery discharge diode is to prevent the battery from being charged when the charger is opened after a full charge. As depicted in the system to a fixed dc bus line voltage and the output dc voltage from each source is controlled independently for both generation systems to get maximum power point tracking. The schematic diagram of the proposed S-MIC for hybrid PV/Wind battery charger. The input voltage sources Vpv and Vwind are the output terminal soft he PV panel and the rectified output voltage of a wind turbine driven permanent magnet synchronous generator(PMSG). By controlling the switches S1 and S2, both sources can achieve their maximum power with appropriate MPPT algorithm individually or simultaneously.

**Fig.4. The schematic diagram of the S-MIC for hybrid PV/Wind battery charger**

**Fig.5. Control block diagram of the proposed S-MIC.**
According to the status of the power switches, there are four different operation modes which can be explained as follows.

Mode I (S1: ON, S2: ON): where both S1 and S2 are turned ON, and D2–D4 are turned OFF with reverse-biased voltages. In this operation mode, the input sources Vwind and Vpv are connected in series to charge the energy storage component inductor L1.

Mode II (S1: ON, S2: OFF): where the power switch S1 is turned ON and S2 is turned OFF. The diode D2 and D3 are reverse biased and can be treated as an open circuit. On the other hand, power switch S2 for the input source Vpv is turned OFF, and the power diode D4 will provide a bypass path for inductor current iL1. In this mode, the input source Vwind will charge the energy storage component inductor L1, as well as provide the electric energy for the battery.

Mode III (S1: OFF, S2: ON): The power switch S1 is turned OFF, and S2 is turned ON. Also, the power diode D1 and D4 are reverse biased as open circuits, while D2 and D3 are forward biased as short circuits. In this operation mode, the transformer will be reset. The input source VPV will charge the energy storage component inductor L1.

Mode IV (S1: OFF, S2: OFF): The both S1 and S2 are turned OFF. Power diodes D2 and D4 will provide the current path for the inductor current. In this mode, the input sources Vwind and Vpv are disconnected from the proposed double-input converter, and the transformer will be reset. The electric energy stored in L1 will be released into the load.

VI. SIMULATION PART

Simulation of the hybrid wind and PV system is shown in Figure 6 which was done in MATLAB/SIMULINK environment. In Hybrid Wind-PV System, PV system acts as a main source. In Wind Energy conversion system, wind speed is varied continuously. PV and Wind systems are connected in parallel and the across this parallel combination, more than 33 V battery is connected which is in charging mode. If voltage across this parallel combination is less than 33 V, battery is in discharging mode. If battery is only present in the circuit, percentage semi-oxide concentration linearly decreases and battery voltage rapidly decreases.

![Fig:6. Simulation of the hybrid wind and PV system](image-url)
The main blocks in the above Simulink diagram are Wind turbine block, Squirrel cage Induction Generator block, PV model block, MPPT block, DC/DC converter block, Battery model and discrete PWM generator block. The Wind turbine with optimum power control and pitch angle control act as prime mover for induction generator. The external inputs to the turbine are wind speed and rotor speed. Optimum power is obtained from the Power-Speed characteristics and it depends upon the speed of the turbine. Rotor side converter is controlled by vector control and its main objectives are active and reactive power flow control and maximum power point tracking. The grid side converter (Front End converter) main objective is to regulate the DC link capacitor voltage and this converter controls the power flow between the DC bus and the AC side.

Fig: 7. Wind current

Fig: 8. PV current
Fig. 9. State of Charge Battery

Fig. 10. Output Voltage.
VII. MODIFIED I-PVSC

Fig. 11. Schematic of modified I-PVSC

Fig. 12. Output voltage and state of charging battery.
VIII. CONCLUSION

A simple and cost effective maximum power point tracking technique is proposed for the photovoltaic and wind turbine without measuring the environmental conditions. This is based on controlling the photovoltaic terminal voltage or current according to the open circuit voltage or short circuit current and the control relationship between the turbine speed and the dc-link voltage is obtained using simple calculations. A complete description of the hybrid system has been presented along with its detailed simulation results which ascertain its feasibility. The power fluctuation of the hybrid system is less dependent on the environmental conditions as compared to the power generated of individual PV and WG systems. This power fluctuation has been suppressed using a battery in this project and it will be the subject of future work.

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