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A Review on Multiport DC-DC Converter for Different Renewable Energy Sources

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Abstract – *This paper focuses a review on multiport dc–dc converter for concurrent power management of several renewable energy sources which can be of similar types. The introduced dc–dc converter uses only one controllable switch in each port to which a source is connected. It has simple configuration and minimum number of power switches. The introduced converter is applied for simultaneous maximum power point tracking (MPPT) control of a wind/solar hybrid generation system consisting of one Wind Turbine Generator (WTG) and two different Photovoltaic (PV) panels.*

Keywords—Multiport Converter, Photo-Voltaic (PV), Maximum Power Point Tracking (MPPT), Wind Turbine Generator (WTG), Solar Energy, Wind Energy.

Introduction

Nowadays, there is a growing interest in generating electricity from distributed renewable energy sources. In numerous applications, it is required to connect multiple renewable energy sources of different types to a power grid or load. The multiport DC-DC converter has been proposed to efficient power management and grid integration for the multiple origins and development in a new era in a demand quality power in remote communities[8][9]. The isolated dc–dc converter has multiple input ports for connecting different sources, such as photovoltaic (PV) panels, wind turbine generators (WTGs), fuel cells, etc., The multiport dc–dc converter not only regulates the low-level dc voltages of the sources to a constant high level required by the inverter but also provides other important control functions, such as maximum power point tracking (MPPT).

The review on multiport dc–dc converter for simultaneous power management of multiple renewable energy sources uses only one power electronic switch in each input port connected to a source. The introduced converter does not use any controllable switch on the secondary side of the transformer [2]-[4]. The proposed converter has the least number of switches and thereby a lower cost. The newly introduced converter is applied for power management of a wind/solar hybrid generation systems, which consists of a WTG and two varied PV panels. The power generation from solar and wind energy are designed using perturbation and observation (P&O) MPPT algorithm, in which the WTG and PV panels can be controlled at the same time and extract the maximum power. The Figure 1 shows the block diagram of the introduced multiport DC-DC converter. It consists of PV Panels, Wind turbine generator, Boost converter, MPPT controller, High frequency transformer and an inverter.

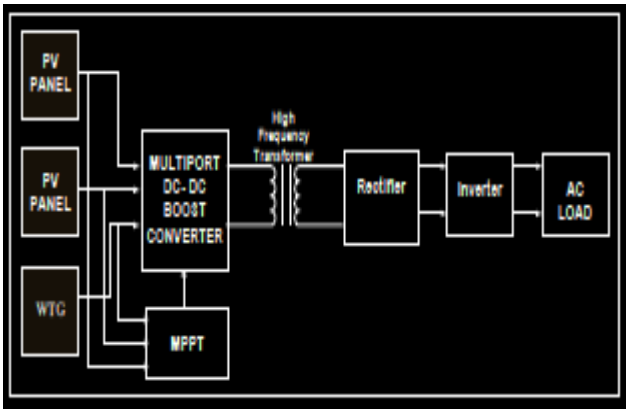

Figure-1: Block Diagram Multiport DC-DC Converter.

2. Photovoltaic system

A Photovoltaic (PV) system directly converts solar energy into electrical energy. The basic device of a PV system is the PV cell. Cells may be grouped to form arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors or connect to a grid by using proper energy conversion devices. This

photovoltaic system consists of main parts such as PV module, charger, battery, inverter and load.

A photovoltaic cell or photoelectric cell is a semiconductor device that converts light to electrical energy by photovoltaic effect. If the energy of photon of light is greater than the band gap then the electron is emitted and the flow of electrons creates current. However a photovoltaic cell is different from a photodiode. In a photodiode light falls on n channel of the semiconductor junction and gets converted into current or voltage signal but a photovoltaic cell is always forward biased.

2.1 PV Module

Usually a number of PV modules are arranged in series and parallel to meet the energy requirements. PV modules of different sizes are commercially available (generally sized from 60W to 170W). For example, a typical small scale desalination plant requires a few thousand watts of power.

2.1.1PV Modeling

PV array consists of several photovoltaic cells in series and parallel connections. Series connections are responsible for increasing the voltage of the module whereas the parallel connection is responsible for increasing the current in the array. Typically a solar cell can be modelled by a current source and an inverted diode connected in parallel to it. It has its own series and parallel resistance. Series resistance is due to hindrance in the path of flow of electrons from n to p junction and parallel resistance is due to the leakage current.

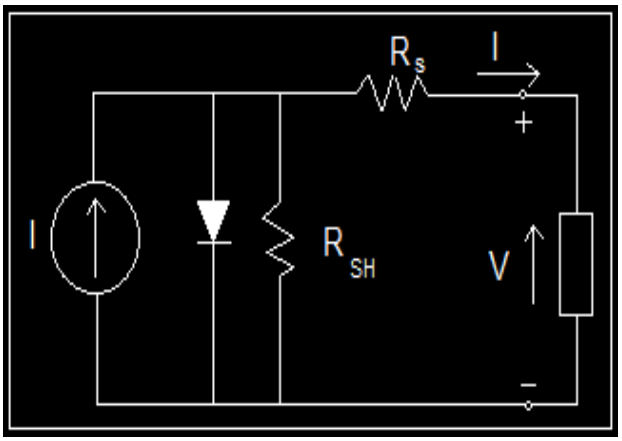

Figure- 2: Single Diode Model of a PV Cell.

In this model we consider a current source (I) along with a diode and series resistance (Rs). The shunt resistance (RSH) in parallel is very high, has a negligible effect and can be neglected.

The output current from the photovoltaic array

$$I = I_{SC} - I_d \qquad (1)$$

$$I_d = I_0\left(e^{\frac{qV_d}{KT}} - 1\right) \qquad (2)$$

where I_0 is the reverse saturation current of the diode, q is the electron charge, V_d is the voltage across the diode, k is Boltzmann constant (1.38 * 10-19 J/K) and T is the junction temperature in Kelvin (K)

From equation 1 and equation2

$$I = I_{SC} - I_0\left(e^{\frac{qV_d}{KT}} - 1\right) \qquad (3)$$

Using suitable approximations,

$$I = I_{SC} - I_0\left(e^{\frac{q(V+IR_S)}{nKT}} - 1\right) \qquad (4)$$

Where, I is the photovoltaic cell current, V is the PV cell voltage, T is the temperature (in Kelvin) and n is the diode ideality factor.

3. Boost Converter

As stated in the introduction, the maximum power point tracking is basically a load matching problem. In order to change the input resistance of the panel to match the load resistance (by varying the duty cycle), a DC to DC converter is required.

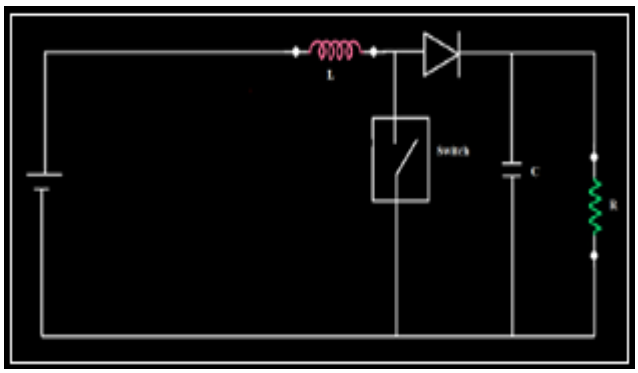

Figure- 3: Circuit Diagram of Boost Converter.

It has been studied that the efficiency of the DC to DC converter is maximum for a buck converter, then for a

buck-boost converter and minimum for a boost converter but as we intend to use our system either for tying to a grid or for a water pumping system which requires 230 V at the output end, so we use a boost converter.

4. Maximum Power Point Tracking

A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Maximum power point tracking technique is used to improve the efficiency of the solar panel. According to Maximum Power Transfer theorem, the power output of a circuit is maximum when the Thevenin impedance of the circuit (source impedance) matches with the load impedance. Hence our problem of tracking the maximum power point reduces to an impedance matching problem.

In the source side we are using a boost convertor connected to a solar panel in order to enhance the output voltage so that it can be used for different applications like motor load. By changing the duty cycle of the boost converter appropriately we can match the source impedance with that of the load impedance.

4.1. Different MPPT Techniques

There are different techniques used to track the maximum power point. Few of the most popular techniques are:

4.1.1 Perturb and Observe (hill climbing method)

4.1.2 Incremental Conductance method

4.1.3 Fractional short circuit current

4.1.4 Fractional open circuit voltage

4.1.5 Neural networks

4.1.6 Fuzzy logic

4.1.1 Peturb & Observe

Perturb & Observe (P&O) is the simplest method. In this we use only one sensor, that is the voltage sensor, to sense the PV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm. However the method does not take account of the rapid change of irradiation level (due to which MPPT changes) and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPP. To avoid this problem we can use incremental conductance method.

5. Need For Renewable Energy

Renewable energy is the energy which comes from natural resources such as sunlight, wind, rain, tides and geothermal heat. These resources are renewable and can be naturally replenished. Therefore, for all practical purposes, these resources can be considered to be inexhaustible, unlike dwindling conventional fossil fuels. The global energy crunch has provided a renewed impetus to the growth and development of Clean and Renewable Energy sources. Clean Development Mechanisms (CDMs) are being adopted by organizations all across the globe. Apart from the rapidly decreasing reserves of fossil fuels in the world, another major factor working against fossil fuels is the pollution associated with their combustion. Contrastingly, renewable energy sources are known to be much cleaner and produce energy without the harmful effects of pollution unlike their conventional counterparts.

6. Sources Of Renewable Energy

There are lots of different sources of renewable energy; here wind power and solar power are discussed below

6.1 Wind Power

Wind turbines can be used to harness the energy available in airflows. Current day turbines range from around 600 kW to 5 MW of rated power. Since the power output is a function of the cube of the wind speed, it increases rapidly with an increase in available wind velocity. Recent advancements have led to aerofoil wind turbines, which are more efficient due to a better aerodynamic structure

6.2 Solar Power

The tapping of solar energy owes its origins to the British astronomer John Herschel who famously used a solar thermal collector box to cook food during an expedition to Africa. Solar energy can be utilized in two major ways. Firstly, the captured heat can be used as solar thermal energy, with applications in space heating. Another alternative is the conversion of incident solar radiation to electrical energy, which is the most usable form of energy. This can be achieved with the help of solar photovoltaic cells or with concentrating solar power plants.

7. Conclusion

According to previous approaches multiport dc–dc converter that uses the minimum number of switches has been introduced for simultaneous power management of multiple renewable energy sources. The experimental outcomes have been provided to show the effectiveness of the proposed converter. The advantage of the introduced multiport dc–dc converter is its simple topology while having the capability of MPPT control for different renewable energy sources simultaneously. Moreover, the introduced converter can be easily applied for power management of other types of renewable energy sources. In future the hybrid energy system can be further altered to some other renewable sources like PV-Fuel cell Hybrid Energy System to meet large load depending on various applications.

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