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Implementation of Photovoltaic Module as an Input Source in development of Full Bridge Converter

Neha Bhagat
Phd(EE).Astt. Professor &Head (EE)
Jalandhar , Punjab, India
nehabhagat23@gmail.com

Abstract: An electrolyzer is part of a renewable energy systemand produces hydrogen from water electrolysis that is utilizedin fuel cells. A dc-to-dc converter is essential to couple the electrolyzerto the system dc bus. This paper presents development & implementation of full bridge converter in Renewable Energy System application using PV module is designed and simulation results are presented.

Keywords: DC-to-DC converters, electrolyzer, renewable energy system (RES), resonant converters.

1. INTRODUCTION

Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat. A renewable energy system (RES) transforms the energy found in sunlight, wind, falling water, waves, geothermal heat, or biomass into a useable form, such as heat or Electricity. Renewable energy storage in the form of hydrogen may overcome the inherent weakness of battery-basedenergy storage methods like physical size, inadequatelife span, and initial capital cost of the battery bank coupled with transportation, maintenance, and battery disposal issues. [1].

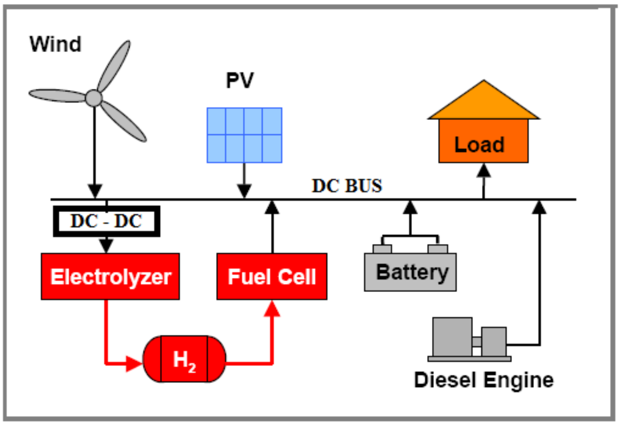

Fig 1. Block diagram of typical RES system[5]

At the times when the renewable resources exceed the load demand, hydrogen would be produced and deposited through water electrolysis. For this purpose, electrolyzer that breaks water into hydrogen and oxygen is used as an essential part of RES in Fig. 1. At the times when the load demand exceeds the renewable resource input, a fuel cell operating on the stored hydrogen would deliver the balance of power. To ensure proper flow of power between the system elements, the existing energy from different sources is coupled to a low voltage dc bus. A direct connection of dc bus to the electrolyzer is not appropriate because it lacks the ability to control the power flow between the renewable input source and the electrolyzer. Therefore, a power conditioning system, typically a dc–dc converter, is required to couple the electrolyzer to the system bus.

2. Photovoltaic (PV) System

Solar energy maintains life on the earth and it is an endless source of clean energy. Large quantity and sustainability of solar radiant energy are important causes that characterize the energy through the PV (photovoltaic) effect among the renewable energy resources. Irrespective of the intermittency of sunlight, solar energy is widely existing and completely free of cost.a photovoltaic system is one of the most able technologies because of its specifically advantages like long life, low maintenance, and environmental friendly and reliable nature. Photovoltaic (PV) generation has improved by 20% to 25% over the past two decades. The demand for PV systems is increasing worldwide. Research activities are being conducted in this track for improvement of cell efficiency, cost and reliability for improved utilization. In recent year's photovoltaic power system have drawn considerable research importance where in modeling and computer simulations are necessary to examine the system operation and integration with utility grids.

PV modules are the fundamental power transformation unit of a PV generator system. The output characteristics of PV modules areinfluenced by on the solar insolation, the cell temperature and the output voltage of the PV module. Since PV modules reveal nonlinear electrical characteristics, designing and simulation of this system need reliable PV modeling.

2.1Mathematical Model of Photovoltaic Module

A typical PV cell produces an open circuit voltage around 0.5 to 0.7 volts depending on the semiconductor and the developed technology. Therefore the cells must be coupled in series configuration to form a PV module, to rise the voltage. Further, modules are connected in series and parallel configuration to form an arrangement of desired voltage and current.

A photovoltaic module is statisticallymodelled using single diode equivalent circuit. The various factors which influence the characteristic of a cell are categorized as environmental factors like irradiance and temperature, internal factors like ideality constant, Boltzmann constant energy band- gap and

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charge of electron, electrical factors like open circuit voltage, short circuit current, series resistance, and shunt resistance.

A mathematical model of single diode PV cell is established based on current-voltage relationship of a solar cell. An ideal PV cell is represented by a current source and an anti-parallel diode connected to it. A practical PV cell is an addition of equivalent series and a shunt resistance factor to an ideal PV cell.

Fig. 3 shows the block diagram of the proposed PV module. The first block, discussed asbehavioural PV model, performs theoretical calculations built on physics of the PV cell and it yields insignificant values of voltage and current generated by the panel. The second block electrically drives to the electrical load according to the inadequate power I-V characteristics. Depending on the load value, the voltage drop over load (V_L) and the load current (I_L) are adjusted according to maximum power delivered

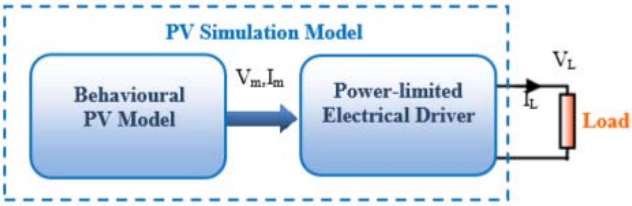

Figure 3.Block Diagram of PV Simulation Model[37]

2.2 Behavioral PV Modeling

The physics of the PV cell is very similar to that of thetraditional diode with a pnjunction. When the junction absorbs light, the energy of absorbed photons is transferred to the electron-proton arrangement of the material, producing charge carriers that are alienated at the junction. An ideal PV cell is assumed to have no series loss and no leakage to ground. On the other hand, due to its non-ideal structure in nature, there are some losses occurred in real PV cells. Therefore, these losses are assumed by using resistances in equivalent circuits. Fig. 4 shows an equivalent electrical circuit forming the composite physics of the PV cells. The developmental model of the proposed PV model is based on this equivalent electrical circuit model. Current source, I_{ph}, which is a current produced by the photons, is constant at a stable value of radiation and temperature. The shunt resistance, R_{sh}, is used to denote the shunt-leakage current, I_{sh}. The series resistance, R_s, is used to denote the voltage drop at the output. PV power conversion efficiency (PPCE) is sensitive to small changes at R_s, but the PPCE is not sensitive to changes at R_{sh}. The small escalation in $R_s$considerablyeases the output of the PV module. In the equivalent circuit, the current, I_{cell}, delivered to the external load matches the current IL and voltage over the load matches the voltage of PV cell, V_{cell}.Current and voltage of PV panel depends on load value and presents nonlinear, power limited electrical characteristics.

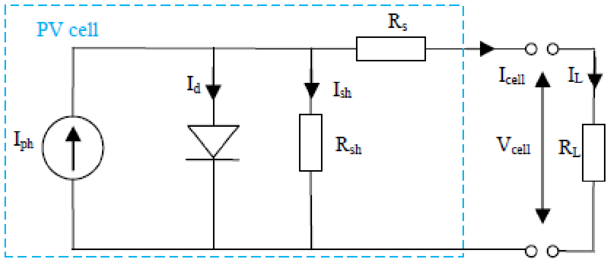

Figure 4.Equivalent Electrical circuit model of PV cells [37]

The Equation (1) defining output current of the non-ideal PV cell was derived using Kirchhoff's current law as follows:

$Icell = I\,ph - Id - I\,sh$ (1)

The overall current, which the PV cell can offer, was formulated by Equation (2), where G and Gr are active and the reference radiation, T_c andT_{cr} are module temperature and reference temperature of the component, respectively. Manufacturers usually provide electrical specifications of the PV module at standard conditions, namely solar radiation of 1000 W/m2 and cell temperature of 25°C. These values correspond to Gr and Tcr, respectively.

$I_{cell}=I_r+[\alpha(G/G_r)(T_c-T_{cr})+(G/G_r-1)I_{sc}]$ (2)

The parameter I_{sc}characterises short circuit current of the module and α is the temperature coefficient of short circuit current. The voltage of PV cell was formulated by Equation (3) and Equation (4) , where ß are temperature coefficient of open circuit voltage.

$V_{cell}=-\beta)(T_c-T_{cr})-R_s\Delta I+V_r$ (3)

$\Delta I=[\alpha(G/G_r)(T_c-T_{cr})+(G/G_r-1)I_{sc}]$ (4)

Herein, R_s is used to denote the voltage drop at the output of the PV cell. The parameters$I_r$and V_r are reference values taken from I-V curve. PV module is designed by connecting PV cell in series and parallel to each other. In this case, the output current and voltage of PV module is expressed in Equation (5) and Equation (6), respectively.

$V_m=N_{sc}V_{cell}$ (5)

$I_m=N_{pc}I_{cell}$ (6)

Herein, V_m is the output voltage, and I_m is the output current. N_{sc} and N_{pc} are expressed numbers of series and parallel connected PV cells, respectively.

The proposed PV module can be active in transient analysis of power system providedwith PV panels. It is also useful for testing MPP tracking methods.

Nowadays, solar energy integration in micro grids is becoming primary concern of power system industry. Modelling renewable energy sources for a large-scale power system integration simulation is more important today, because these simulation tools will be a part of optimal designand intelligent management process.

3. Design of Models

The design of the converters are based on the operating conditions of minimum input voltage V_{in} = 40V, Maximum output voltage V_o = 60V.

Here Renewable Energy system model using Photovoltaic module is shown in the figure 6. Simulation result obtained is also shown in Figure 7. The waveform clearly demonstrates that ZVS is obtained for the boost switchand all full-bridge switches for the complete operating range.

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A. Photovoltaic Model

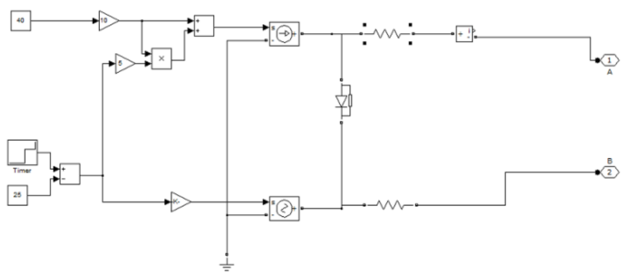

Figure 5. PV Model

B. Renewable Energy System (RES) Model using PV module

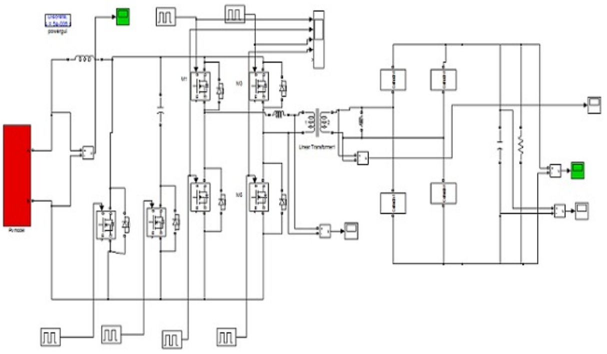

Figure6. Renewable Energy System (RES) Model using PV module

Performance of the renewable Energy sources(RES) Model using PV Module designed as shown in Figure 6.and is predicted using the analysis for the minimum input voltage $V_{in,min}$ = 40V for different load conditions with an output voltage of Vo = 60V.Design values of various passive components used in the experiment were 1) ZVT boost: boost inductor Lb = 50 μH; resonant inductor La = 300 nH; snubbercapacitor Cb = 220 nF, and 2) LCL SRC: resonant inductor Lr = 3.3 μH, resonant capacitor Cs = 1 μF, parallel inductor Lt = 12 μH, and snubber capacitors Cn 1–Cn 4 = 6.8 nF, HF transformer turns ratio = 10:6. Shows some waveforms obtained with minimum input voltage (40 V) and maximum output power (2.4 kW) at 60-V output.
Simulation Result for Renewable Energy System model using PV Module.

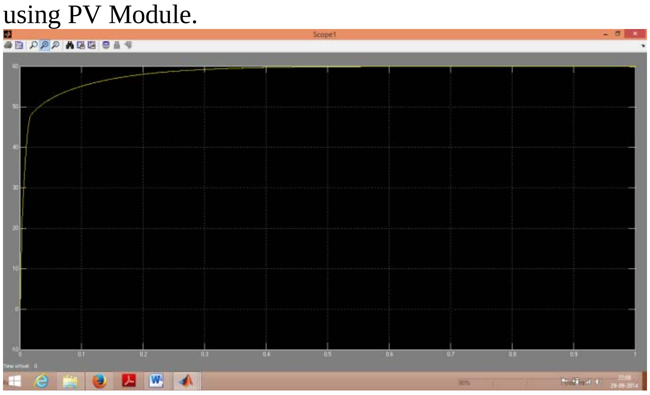

Figure 7.Result for RES model using PV Module

4. Conclusion

This paper presents Renewable Energy System model using PV module, input to the model is given by the PV module and output obtained is as shown in the simulation result shown above. Voltage obtained is approx. 60V DC. This PV model iseasy to configure for a desired PV response characteristics andit directly connects to Sim Power Systems electrical circuit for transitory response analyses. The PV module has two mainparts: A behavioral model of PV cells and a power–limitedelectrical driver forcircuit connection. The behavioral modelestimates voltage and current potential of PV panel for a givensolar radiation (G) and module temperature (Tc) conditions.
Nowadays, solar energy integration in microgrids is suitable primary concern of power system industry.Modeling renewable energy sources for a large-scale powersystem incorporation simulation is more important today,because these simulation tools will be a part of optimal designand intelligent management process.

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