

DEVELOPMENT AND IMPLEMENTATION OF FULL BRIDGE CONVERTER WITH PHOTOVOLTAIC MODULES AS AN INPUT SOURCE

Neha Bhagat¹, Mr. Gagandeep Sharma²

¹Student M.tech (EE), ²Assistant. Professor (EE)

DAV Institute of Engg & Technology, Jalandhar, Punjab, India

ABSTRACT: An electrolyzer is part of renewable energy system and produces hydrogen from water electrolysis that is utilized in fuel cells. A dc-to-dc converter is essential to couple the electrolyzer to 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.

Index: Terms—DC-to-DC converters, electrolyzer, renewable energy system (RES), resonant converters.

I. 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-based energy storage methods like physical size, inadequate life span, and initial capital cost of the battery bank coupled with transportation, maintenance, and battery disposal issues. [1].

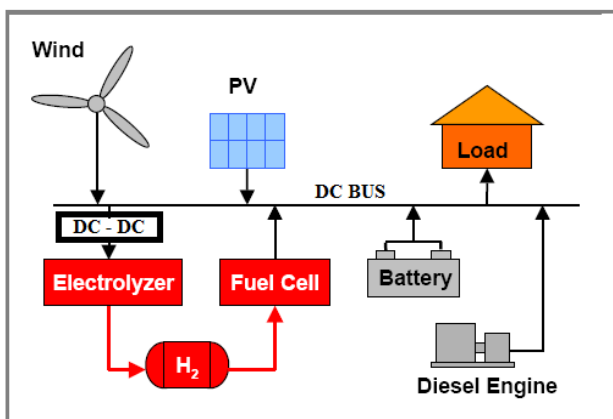


Fig 1. Block diagram of typical RES system [5]

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.

II. 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 are influenced 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.

A. Mathematical 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 statistically modelled 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 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 as behavioural 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 (VL) and the load current (IL) are adjusted according to maximum power delivered

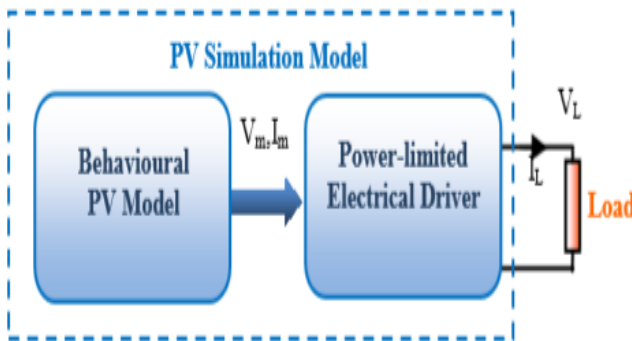


Figure 3. Block Diagram of PV Simulation Model [37]

B. Behavioral PV Modeling

The physics of the PV cell is very similar to that of the traditional diode with an injunction. 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 considerably eases the output of the PV module. In the equivalent circuit, the current, I_{cell} , delivered to the external load matches the current I_L 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.

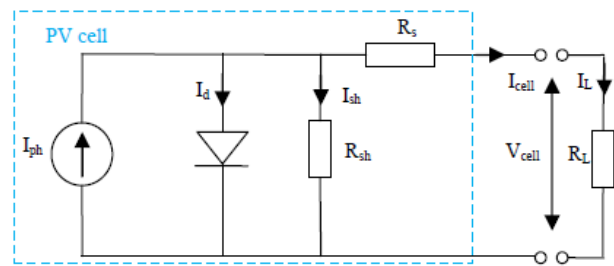


Figure 4. Equivalent Electrical circuit model of PV cells [37]

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

$$I_{cell} = I_{ph} - I_d - I_{sh} \quad (1)$$
 The overall current, which the PV cell can offer, was formulated by Equation (2), where G and G_r are active and the reference radiation, T_c and T_{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/m^2 and cell temperature of 25°C . These values correspond to G_r and T_{cr} , respectively.

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

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 β are temperature coefficient of open circuit voltage.

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

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

Herein, R_s is used to denote the voltage drop at the output of the PV cell. The parameters I_{rand} 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.

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

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

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 provided with 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. Modeling 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 design and intelligent management process.

III. DESIGN OF MODELS

The design of the converters are based on the operating conditions of minimum input voltage $V_{in} = 40\text{V}$, Maximum output voltage $V_o = 60\text{V}$. 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 switch and all full-bridge switches for the complete operating range.

A. Photovoltaic Model

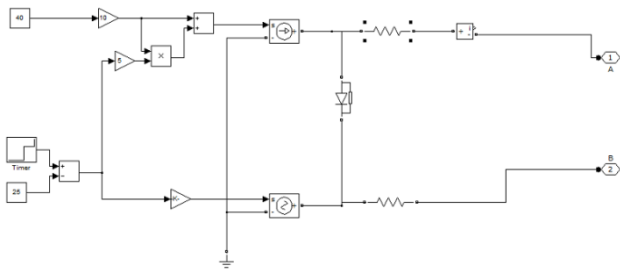


Figure 5. PV Model

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

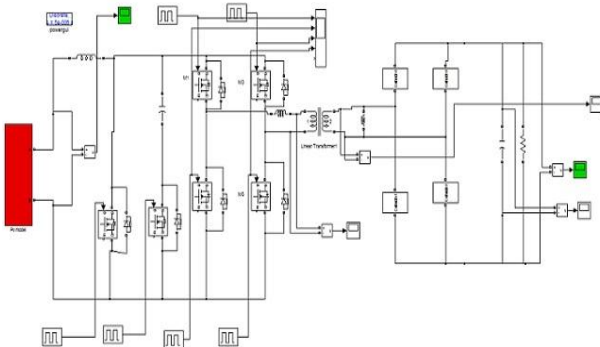


Figure 6. Renewable Energy System (RES) Model using PV module

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 $V_o = 60V$.Design values of various passive components used in the experiment were 1) ZVT boost: boost inductor $L_b = 50 \mu H$; resonant inductor $L_a = 300 nH$; snubber capacitor $C_b = 220 nF$, and 2) LCL SRC: resonant inductor $L_r = 3.3 \mu H$, resonant capacitor $C_s = 1 \mu F$, parallel inductor $L_t = 12 \mu H$, and snubber capacitors $C_n 1-C_n 4 = 6.8 nF$, 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.

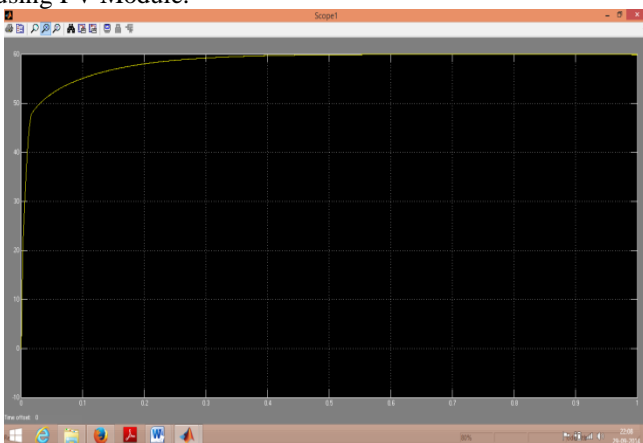


Figure 7.Result for RES model using PV Module

IV. 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 is easy to configure for a desired PV response characteristics and it directly connects to SimPower Systems electrical circuit for transitory response analyses. The PV module has two main parts: A behavioral model of PV cells and a power-limited electrical driver for circuit connection. The behavioral model estimates voltage and current potential of PV panel for a given solar radiation (G) and module temperature (T_c) conditions. Nowadays, solar energy integration in micro grids is suitable primary concern of power system industry. Modeling renewable energy sources for a large-scale power system incorporation simulation is more important today, because these simulation tools will be a part of optimal design and intelligent management process.

REFERENCES

- [1] Deepak S. Gautam, Ashoka K. S. Bhat, "A Comparison of Soft-Switched DC-to-DC Converters for Electrolyzer Application", Proceedings of International the IEEE on power Electronics, vol. 28, no. 1, pp: 54-63 ,January 2013
- [2] MilanaTrifkovic, Mehdi Sheikhzadeh, KhaledNigim and ProdromosDaoutidis, "Modeling and Control of a Renewable Hybrid Energy System With Hydrogen Storage", Proceedings of Intemational the IEEE on control systems technology, vol. 22, no. 1,pp: 169-179 January 2014
- [3] Riccardo Pittini, Zhe Zhang, Michael A.E. Andersen, "Isolated Full Bridge Boost DC-DC Converter Designed for Bidirectional Operation of Fuel Cells/Electrolyzer Cells in Grid-Tie Applications: Technical university of Denmark , Department of Electrical Engineering
- [4] D. Iannuzzi, and M. Pagano, "Efficiency of Hydrogen based Storage Systems for Stand-Alone PV applications: Numerical and Experimental results", University of Naples, Proceedings of the IEEE © 2009,pp: 555-561
- [5] P. Chandrasekhar and S. Rama Reddy "Performance of Soft-Switched DC-DC Resonant converter for Electrolyzer" , Proceedings of the IEEE International © 2011, pp: 95-100
- [6] Francisco da Costa Lopes and Edson H. Watanabe "experimental and theoretical development of a pemelectrolyzer model applied to energy storage systems", Proceedings of the IEEE International © 2009.,pp: 775-782
- [7] KodjoAgbossouMamadou L. Doumbia and AdilAnouar, "Optimal hydrogen production in stand – alone renewable energy system", Proceedings of IEEE © 2005, pp:2932-2936, Canada
- [8] KodjoAgbossou, SousoKélouwaniAdilAnouar, and MohanlalKolhe, "Energy management of hydrogen – based stand- alone renewable energy system by

- using boost & buck converters”, Proceedings of IEEE © 2004 , pp: 2786-2793, Canada
- [9] Ali Elrayyah, Ali Safayet, YilmazSozer and Malik Elbuluk , “Efficient harmonic and phase estimator for single-phase grid connected renewable energy systems”, Proceedings of IEEE transactions on industry applications, vol. 50, no. 1, January/February 2014 pp: 620-630
- [10] Juan M. Galvez, Martin Ordonez, “Swinging Bus Operation of Inverters for Fuel Cell Applications with Small DC-Link Capacitance”, Proceedings of IEEE transactions on Power Electronics, 2013
- [11] Bor-Ren Lin, Shih-Kai Chung “Analysis and implementation of a new zero-voltage switching DC converter with less active switches”, Proceedings of the IET Power Electron, © 2014, Vol. 7, Iss. 1, pp: 85-95.
- [12] Rui Yang, HongFa Ding, Yun Xu, Lei Yao, and YingMeng Xiang, “An Analytical Steady-State Model of LLC typeSeries-Parallel Resonant Converter With Capacitive Output Filter”, Proceedings of IEEE transactions on Power Electronics, vol. 29, no 1, pp: 328-338, Jan 2014
- [13] FarhadPothukattil, Tiju Baby and Prabakaran M , “Isolated dual input dc-dc converter with ZVS for hybrid energy system applications”, Proceedings of International Conference on Advances in Energy Conversion Technologies (ICAECT), pp: 237-240, 2014
- [14] Luca Corradini, Daniel Seltzer, Douglas Bloomquist, Regan Zane, DraganMaksimović and Boris Jacobson “Zero voltage switching technique for bidirectional DC/Dc converters”, Proceedings of IEEE transactions on power electronics, vol. 29, no. 4, April 2014, pp: 1585-1594.
- [15] Hector Sarnago, Oscar Lucia, Arturo Mediano and Jose M. Burdio, “Direct AC-AC Resonant Boost Converter for Efficient Domestic Induction Heating Applications,” Proceedings of IEEE transactions on power electronics, vol. 29, no. 3, March 2014, pp: 1128-1139
- [16] Xiaodong Li, “A LLC-Type Dual-Bridge Resonant Converter, Analysis, Design, Simulation, and Experimental Results,” Proceedings of IEEE transactions on power electronics, vol. 29, no. 8, August 2014, pp: 4313-4321
- [17] Xiaohu Liu, Hui Li, and Zhan Wang, “A Fuel Cell Power Conditioning System With Low-Frequency Ripple-Free Input Current Using a Control-Oriented Power Pulsation Decoupling Strategy,” Proceedings of IEEE transactions on Power Electronics, vol. 29, no. 1, January 2014, pp: 159-169
- [18] Minsoo Jang and Vassilios G. Agelidis, “A Boost-Inverter Based Battery-Supported Fuel-Cell Sourced Three-Phase Stand-Alone Power Supply,” Proceedings of IEEE transactions on Power Electronics, Feb 2012
- [19] Shu-Kong Ki and Dylan Dah-Chuan Lu, “A High Step-Down Transformer less Single-Stage Single Switch AC/DC Converter,” Proceedings of IEEE transactions on Power Electronics, Vol.28, No.1, Jan 2013, pp:36-44
- [20] Sayed Ali Khajehoddin, MasoudKarimi-Ghartemani, AlirezaBakhshai and Praveen Jain, “A Power Control Method With Simple Structure and Fast Dynamic Response for Single-Phase Grid-Connected DG Systems” Proceedings of IEEE transactions on Power Electronics, Vol.28, No.1, Jan 2013, pp:221-233
- [21] R.Samuel Rajesh Babu and Joseph Henry, “A Comparative Analysis of DC-DC Converters for Renewable Energy System” Proceedings of the international Multi conference of Engineers & Computer Scientists IMECS March 2012, Vol II
- [22] Deepak S. Gautam, and Ashoka K.S. Bhat, “A Two-Stage Soft-Switched Converter for Electrolyser Application,” Fifteenth National Power Systems Conference (NPSC), IIT Bombay, December 2008, pp: 524-529
- [23] Samuel Rajesh Babu R and Henry Joseph, “Embedded controlled ZVS DC-DC converter for Electrolyzer application,” International Journal on Intelligent Electronic Systems, Vol. 5, No.1, January 2011, pp:6-10
- [24] Deepak Kumar Nayak and S.Rama Reddy, “Simulation of Soft Switched PWM ZVS Full Bridge Converter,” International Journal of Computer and Electrical Engineering, Vol. 2, No. 3, June, 2010, pp:595-601
- [25] J. A. Sabate and F. C. Lee, “Off-line application of the fixed-frequency clamped-mode series resonant converter,” IEEE Trans. Power Electron., vol. 1, no. 1, pp. 39-47, Jan. 1991.
- [26] A. K. S. Bhat and F. Luo, “A new gating scheme controlled soft-switching DC-to-DC bridge converter,” in Proc. IEEE Power Electron. Drive Syst. Conf. Rec., 2003, pp. 8-15.
- [27] S. V. Dhople, A. Davoudi, A. D. Dominguez-Garcia, and P. L. Chapman, “A unified approach to reliability assessment of multiphase DC-DC converters in photovoltaic energy conversion systems,” IEEE Trans. Power Electron., vol. 27, no. 2, pp. 739-751, Feb. 2013.
- [28] W. Chen, X. Ruan, and R. Zhang, “A novel zero-voltage-switching PWM full bridge converter,” IEEE Trans. Power Electron., vol. 23, no. 2, pp. 793-801, Mar. 2008.
- [29] Andrijanovits A, Vinnikov D, Roasto I, Blinov A, “Three-level half bridge ZVS DC/DC converter for electrolyzer integration with renewable energy systems”, in Environment and Electrical Engineering (EEEIC), 10th International Conference , 8-11 May, 2011.
- [30] A. Kirubakaran “Renewable and sustainable energy reviews 13”, 2009, pp:2430-2440
- [31] E. Santi, D. Franzoni, A. Monti, D. Patterson, F.

Ponci and N. Barry, "A Fuel Cell Based Domestic Uninterruptible Power Supply" IEEE Transactions on Power Electronics, Volume: 11 Issue: 5 , Sept. 1996, pp: 731 -742.

[32] <http://en.wikipedia.org>

[33] D. Kanimozhi, Prof K. Balakrishnan, "A Comparative Study on Various Dc-Dc Converters Configurations for Industrial Drives" International Journal for Research and Development in Engineering (IJRDE), Methods Enriching Power and Energy Development (MEPED) 2014, pp: 040-046

[34] Savitha P B, Shashikala M S, Puttabuddhi K L, "Modelling of 250wp Photovoltaic module and its performance analysis using MATLAB /SIMULINK" Proceedings of IRF International Conference, Bangalore 23rd March-2014, pp:34-40

[35] Praveen bansal, "Matlab /Simulink Based-analysis of Photovoltaic Array Fed Multilevel Boost Converter" Innovative Systems Design and Engineering. Vol.4, No.7, 2013 - National Conference on Emerging Trends in Electrical, Instrumentation & Communication Engineering, pp 20-27

[36] Cemal Keles, B. Baykant Alagoz, Murat Akcin, Asim Kaygusuz, Abdulkerim Karabiber "A Photovoltaic System Model For Matlab/Simulink Simulations" Inonu University Malatya, Turkey