A Control Scheme for Grid Integration of the Photovoltaic (PV) Generation System

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Abstract: ***This paper introduces a fuzzy logic-based controller model for the integration of the photovoltaic system into the utility grid. Recently, the photovoltaic (PV) generation is growing fast as an effective and cheap energy source. In any PV based system, the inverter is an essential part, which can regulate the current flow between the grid and DC. However, the problem of the integration of PV is that it relies on weather conditions. Therefore, there is a necessity for developing control techniques for the grid integration PV system including a method for voltage and current control that stabilizes the voltage and current at the inverter input to guarantee a continuous flow of energy among the grid and the PV system. This paper presents control and simulation for the integration of the PV system into a grid using MATLAB/Simulink. The PV integration is connected to the boost DC/DC converter and the controller system is based on the maximum power point tracking (MPPT) with a fuzzy logic based controller that helps PV to ensure the maximum power in case of fluctuation in the weather, and then integrated into the AC utility grid by DC/AC inverter. The system stability tests for different weather conditions in the PV system. This paper advocate that the proposed fuzzy logic controller gives a good performance over regular control methods.***

Keywords: PV system, Fuzzy logic controller (FLC), Boost converter DC/DC, Maximum power point tracking (MPPT)

1. Introduction

Generated the power from RES is on the increase in developing countries. They try to improve the integration of renewable energy generation into the grid by using hybrid power energy PV and wind energy, the storage is important by using the battery. There is a necessity to address the problem faced by the grid integration of hybrid energy, so a result of the intermittent nature of the use of renewable energy resources. The developed countries used to predict several techniques to predict solar radiation and wind speed on a significant period of time [1]. The world is looking for alternative energy methods from renewable energy for clean and cheap energy that will get rid of the dependence on costly oil and also gas. Generating electric power by using solar cells is an effective technique nowadays. The various local voltage control approaches utilizing PV storage systems. This design center on adding a voltage control ability to self-consumption plans by a set of voltage following battery charging, automatic reactive power equipment like PV power reducing. [2]. At this time, the researchers are interested in the generation of electric power from renewable energy and the most focused in the solar energy, Solar energy (PV) can be used today in many applications now because of where advantages such as pollution-free and can be maintained. The high cost of oil and gas has weakened the economies of several countries. Since solar PV is capable of generating large amounts of clean and chip electrical energy. It can be connected to the inverter to the electric produced from PV to be used for the purpose of conversion of DC power from PV to AC power for the purpose of feeding the electrical grid [3]. The efficiency of MPPT maximum power point tracking depends on the quality of an inverter. To increase the performance of PV panel and the inverter is not easy it mostly depends on the technology that is available, the best components it can increase the cost of installation this is a problem, the control.

It will develop the tracking of the maximum power point so it will immediately increase in PV generation of power and reduction in PV price. The control of MPPT is necessary because of the non-linear V-I characteristic in the PV array when the power generated is maximized. The MPPT relies on the irradiance conditions and the temperature of the panels. It can be both conditions change in amid the day and rely upon the period of the year [4]. They gave the Altaeros system’s dynamical paradigm after that addressed how that paradigm is utilized in the plant outline, the design of the control, which gives full self-governance, from departure, amid force generation, to self-governing landing. The provided simulation results that illustrate the behavior of the model and indicate critical ranges where Altaeros will center its endeavors advancing [5]. The control technique is to integrate the distributed generation (DG) resources to the utility grid. The designed controller can be compensated for reactive, active, and harmonic load current components while the linkage of DG links to the power grid. The performance of the control method in distributed generation enforcement is demonstrated by adding the maximum power from the distributed generation to the grid, while, the rise of the power factor of the grid also, decreased total harmonic distortion of grid current in simulation and real-time situation under relentless status and element working cases [6]. The reliability of the system when the PV plant is linked to the grid is strengthened when the power factor, the utilization of safety and grid synchronization capabilities functions are improved. Development in the efficiency of photovoltaic cells and low price make them widely accepted and concentration in the entire world and not to rely on non-renewable energy sources, the most important advantages we have electrical energy through clean renewable energy.

The power plants in recent times need to increase their energy output, need appropriate control methods to resolve the issues associated with the partial shading phenomena and different orientation of the PV modules closer to the solar [7]. The evolution of the grid-connected Large-scale power plants because of the increasing penetration of renewable energy. The control approach is able to reduce the reactive power beside it can control the power quality required by a voltage sag/swell for the stability of the grid. This approach does not require any change in the hardware when compared with the employ of existing strategy [8].

The photovoltaic (PV) systems were designed to aim until now, to get the superior power from the PV and integrated into the utility network. Therefore, the MPPT of a uniformly irradiated PV array and the main design issues is the increasing of the conversion effectiveness. However, when the PV system is linked to the grid, a great observation of the power quality, the reliability of the system and the use of security and grid synchronization functions have to be considered. Nowadays the power plants need their power generation, requiring appropriate control technologies to remedy the issues related to the PV modules toward the sun. The numerous important issues, which include the maximum dependable models, used for simulation, were covered, which are helpful in the controller design and the MPPT function, particularly in distributed applications. The grid linkage fields are studied, confirming security, integration, and synchronization [9].

Since the use of electrical energy in the world rise significantly and therefore, the need for extra power generation is necessary. Therefore, the need for more energy can be generated by RES up to any of the large load of the whole needed. The hybrid renewable energy PV power system and wind power system can perform an efficient performance in overcoming the energy consumption on this day by use of the renewable energy system integrated into the utility grid. The integration of hybrid renewable energy resources into the grid is profoundly appreciated for giving stable energy to the consumers [10].

A solar array (PV), and wind energy are a principal supply for the grid, but the use of fuel cells in some cases as a backup power source if there is no generation of electricity from hybrid sustainable energy. Hence, the use of hybrid renewable energy to supply the power it most requires power-storing devices. So the battery energy is used for storing the power and it can use anytime with three various power management strategies [11]. Although a solar PV system model a good choice, as in a critical era of low energy system performance, energy conversion good needs energy conversion performance of the system. This should differ MPP experienced by the maximum possible power transfer to the load can be changed. Although, the study in this area provides the availability of different techniques. Every one of them has its advantages and disadvantages. This status everywhere in the possible (MPPT) discovers the complexity of its time choice [12]. A Fuzzy logic controller based on hybrid renewable sources (HRS) for Grid integration is observed to be more outstanding & enough to decrease power quality problems subjected to all Non-Sinusoidal conditions [13].

The grid integrated a hybrid model, it gives wind energy and PV as a major energy and a storage system depends on the battery storage. Total power energy utilizes DC/DC converters required to integrate hybrid to the DC line [14]. The gridwork under immediate power cut or surge situation, the distributed generation DG like PV and wind systems need to remain integrated into the grid through a specific period of time. So, the DG distributed generation has to be suitable to work under abnormal cases, like current changes and reactive power, so that harm the system and critical loads [15].

The control tactics include 'continuous' and 'ON/OFF' work of the diesel generator in the wind -PV-diesel-battery hybrid systems are formed. The wind, Solar and battery cell used in a hybrid energy system study were undertaken to get better the smoothing execution of PV/wind/battery power storage hybrid energy generation [16].

The ever-growing attention to renewable energy problems and the improvement of sustainable energy sources are gaining great considerations. The wind turbine system and solar cell system, energy production methods and their maximum-power-point tracking (MPPT) technique. So, the hybrid energy systems, the wind–PV production system is proposed for enforcement to a distant, remote region [17]. The control design for grid-integrated hybrid wind energy, (PV) system and battery-based on a system. The system goals to satisfy the load required, control the current and voltage movement from various sources, integrating the current and voltage into the utility grid, and freightage the battery from the utility grid as and when demand [18].

The converter is employed to provide current and voltage from the wind, a bidirectional buck-boost converter is employed to harness current and voltage from PV for battery controller charging/discharging [19]. In [20], the system is stabilized and annexed because of turbine inertia and the simplification of high PV breakthrough into the utility grid. A Novel Structure of a hybrid energy producer depends on solar PV and wind turbine lasting magnet synchronous generator. The systems are linked with each other to the network using the assist of just a single boost converter followed via an inverter. The hybrid system wind and PV use to individually excite the DC-DC converter and the inverter for following the (MPPT) maximum power of the hybrid [21]. The future of renewable energy ought to be accurately limited if the possible classical generators are not capable of responding timely to the changes produce by intermittent renewable energy-producing [22]. The photovoltaic inverter residue inactive through the evening or in minimum solar radiation. Massive hard works by academics to beat the problems related to renewable energy as the PV system and wind system by suggesting more advanced and accurate control applications, containing a lot of hybrid energy topology simple power but are just proper for applications stand-alone [23]. PV systems including a battery show that in which both sources integrated into grid combined DC bus by different power converters, next, the grid transmission line integrated into the network by an inverter [24].

So, integration includes uncertainties in the scheme that are discussed by using the FLC design. The behaviour of hybrid energy systems based on a wind energy system, solar energy system, micro-turbine, and battery use for storage in the system is studied [25]. Next, the system control by a fuzzy logic controller is used to integrate the system into a grid for the hybrid system to reach the extra load demand from the consumers.

The use of a hybrid energy system, micro-turbine, and battery storage mix as a backup to provide the consumer's needs under all requirements [26].

In this paper, good control and simulation model of PV is given with a clear idea of the appropriate control FLC system and behavior of an actual system with change time during the day that can be utilized to investigate the performance of the PV system. The control is advanced and simulated in Matlab/Simulink program and the performance consequences depicted it's well worth.

2. Model of solar PV

The Solar PV system scheme includes the demanded quantity of PV cells, it is referred to as PV module, linked in series or in parallel to produce the wanted output The essential equation of the semiconductor theory, which arbitrary define simple equivalent circuit of the photovoltaic cell model.

$$I = I_{pv} - I_0\left[e^{qv/\alpha KT} - 1\right] \qquad (2.1)$$

The simple PV cell does not express the I–V curve of an actual PV array. Cells linked in parallel increase the current while cells linked in series produce higher output voltages. Practical arrays are formed of some linked PV cells and the detection of the property of the effect of the PV array requires the composition of combine parameters to the fundamental equation.

$$I = I_{PV} - I_0\left[exp\left(\frac{V+R_s I}{V_t\,\alpha}\right) - 1\right] - \frac{V+R_S I}{R_P} \qquad (2.2)$$

We assume I_{sc} and I_{PV} are ordinarily used in the modeling of PV devices as in practical designs the parallel resistance is high, but series resistance is low.
The diode saturation current is presented by

$$I_0 = \frac{I_{SC,n} + K_I\,\Delta_T}{exp\left(\frac{V_{OC,n} + K_V\,\Delta_T}{\alpha V_t}\right) - 1} \qquad (2.3)$$

From the equation, the model is simplified, and the model error is canceled at the neighborhood of the open-circuit points, and thus, at other points of the I–V characteristic

$$I_{PV} = \left(I_{PV,n} + K_I\,\Delta_T\right)\frac{G}{G_n} \qquad (2.4)$$

The R_S and R_P The relationship is an unknowns of (2.2) may be calculated by making $p_{max,m} = p_{max,e}$ and solving the resulting equation for R_s, as shown

$$R_P = \frac{V_{mp} + I_{mp} R_S}{\left\{V_{mp} I_{PV} - V_{mp} I_0\, exp\left[\frac{\left(V_{mp} + R_S I_{mp}\right)}{N_S\alpha}\frac{q}{KT}\right] + V_{mp} I_0 - P_{max,e}\right\}} \qquad (2.5)$$

The means of equation 2.5 that for any value of R_P there will be a value of R_S that makes the mathematical I–V characteristic passes the actual (I_{mp} , V_{mp} ,) point. The aim is to find the value of R_P and R_S the best model solution.

$$I_{PV,n} = \frac{R_P + R_S}{R_P} I_{SC,n} \qquad (2.6)$$

The initial conditions can be set as

$$R_S = 0\,, \quad R_{P,min} = \frac{V_{mp}}{I_{sc,n} - I_{mp}} - \frac{V_{oc,n} - V_{mp}}{I_{mp}} \qquad (2.7)$$

From equation (2.7), the smallest value of R_P is provided through the slope of the line portion within the MPP and the short-circuit.

3. The Control Program of the grid-Integrated PV System

The control approach of Grid-Integrated PV, MPPT theory is applied. The boost converter increases DC voltage from 273.5 V to 500V. This component utilizes an MPPT system, which automatically changes the duty cycle to produce the necessary voltage to obtain maximum power. In this paper, the FLC controller is good control, a simulation model of PV is introduced giving an obvious view of the proper control FLC, and the performance of any actual system.

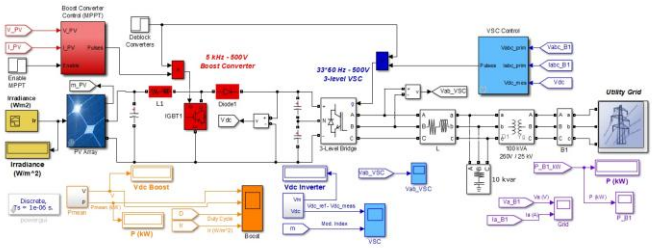

Figure 1: Grid integrated PV farm

3.1 MPPT Control algorithm

The maximum power point tracking algorithms are desired because PV arrays have a non-linear voltage-current characteristic with a single point where the power produced is maximum. This point relies on the temperature of the board and on the irradiance time. Both terms vary during the day and are also unlike relying on the time of the year. Moreover, irradiation varies fast due to varying climatic phases such as cloudy interval. It is important to follow the MPP exactly under all reasonable circumstances therefore that the supreme possible power is continuously achieved.
MPPT by incremental conductance method + Integral regulator MPP is obtained when:

$$dP\,/\,dv = 0 \text{ where } P = V * I$$
$$d(V * I)/dV = I + V * dI/dV = 0$$
$$dI/dV = -I/V$$

The FLC controller minimizes the error:

$$(dI/dV + I/V)$$

3.2 Fuzzy logic controller system (FLCS)

The Fuzzy Logic Control system, Inverter in the integration of PV into the utility grid. The effort starts to study the utilization of the fuzzy logic controller design in the renewable energy system, particularly PV, micro-grid. So, the fuzzy logic controller designs are greatly utilized in the last few years for renewable energy systems, for PV, the maximum power point tracking in solar (MPPT) of PV power systems, optimization between different criteria. The study shows that fuzzy logic controller designs give pragmatic estimates.

The FLC is added between rectifier, PV produces, also use in the boost converter. The fuzzy logic controller is utilized to control regular current and voltage Over the framework. The produce of the fuzzy logic controller is work in the system which is provided to the gate pulse of design in the hybrid renewable energy system that is applied to the boost converter.

3.3 Tables Parameters of the PV System

The selected simulation parameters of the solar equivalent circuit and MPPT are given in Table 1.

Table 1: Parameters of the PV System

Parameter	Value	Parameter	Value
No. of cell	96	R_p	999.51
V_{oc}	64	R_l	5Ω
I_{sc}	5.96	L	5 mH
V_{mp}	54.7	C3	1200MF
I_{mp}	5.58	R	0.038

4. Simulation Results

The fuzzy logic controller of the integration of the PV system into a grid will be created and examined by using MATLAB/SIMULINK utilizing a block set of the power systems. The generating energy from the PV system framework can be changed according to the various values of heavily on weather conditions in PV. The output from the inverter system DC voltage is suitable and the voltage stabilizes after short and the current is regular and suitable by using the fuzzy logic controller of integration of PV system into a grid that has been created and examined by means of MATLAB/ SIMULINK using the power systems block set.

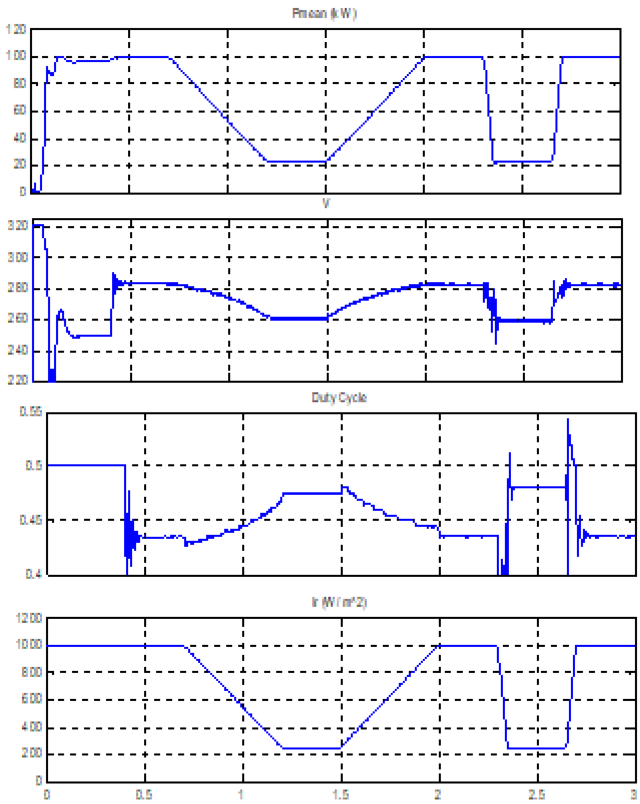

Figure 1: Response of altering irradiance corresponding MPPT algorithm output voltage, output power, and Duty cycle.

A MATLAB/SIMULINK model for the 500 KW grid integrated PV control was summarised and described in this work. This model is depending on the essential circuit of a solar PV cell considering the consequence of various parameters such as solar radiation. The PV integration is connected to the boost DC/DC converter and the controller system is based on the maximum power point tracking (MPPT) with PI controller helps PV to ensure the maximum power in case of fluctuation in the weather, and then integrated into the AC utility grid by DC/AC inverter. Through the simulation results, it presented that the system tracks maximum power when the irradiance stays constant.
The electrical circuit is discredited at 1μs sample time, whereas sample time used for the control systems is 100μs the simulation result of changing irradiance corresponding MPPT algorithm for PV Systems using a fuzzy logic controller with Boost DC/DC Converter is shown in figure 1. From this figure, it is observed that the performance of the PV grid under different irradiance variations. It can be indicated that this kind of MPPT controller follows maximum power only when irradiance remains fixed.

5. Conclusions

The paper presents a fuzzy logic-based control model for an integrated PV system and the utility grid. This a fuzzy logic-based model is based on the basic circuit of the PV system and integrated into the grid showing the effects of regulating the grid-side converter control system. The system behavior and performance of the developed system in Matlab are studied. The controller system is based on a grid-side converter control system with a fuzzy logic-based controller that ensures the power regulation in case of fluctuating weather conditions, which is then integrated into the AC utility grid by DC/AC inverter. The results are relevant and show a fair degree of accuracy.

References

[1] E. Baleke Ssekulima, M.B. Anwar, A. Al Hinai, M. Shawky, E. Moursi, Wind speed and solar irradiance forecasting techniques for enhanced renewable energy integration with the grid: a review, IET Renew. Power Gener. 10 (2016) 885–898.
[2] Von Appen, T. Stetz, M. Braun, and A. Schmiegel, Local voltage control strategies for PV storage systems in distribution grids, IEEE Trans. Smart Grid, vol. 5, no. 2, pp. 1002–1009, 2014.
[3] Yuncong Jiang; Abu Qahouq, J.A., Study and evaluation of load current based MPPT control for PV solar systems, in Energy Conversion Congress and Exposition (ECCE), 2011 IEEE , vol., no., pp.205-210, 17-22 Sept. 2011
[4] Kjaer, S.B.; Pedersen, J.K.; Blaabjerg, F., A review of single-phase grid-connected inverters for photovoltaic modules, in Industry Applications, IEEE Transactions on , vol.41, no.5, pp.1292-1306, Sept.-Oct. 2005.
[5] C. Vermillion, T. Grunnagle, R. Lim, and I. Kolmanovsky, Model-based plant design and hierarchical control of a

prototype lighter-than- air wind energy system, with experimental flight test results, IEEE Trans. Control Syst. Technol., vol. 22, no. 2, pp. 531–542, 2014.
[6] E. Pouresmaeil, C. Miguel-Espinar, M. Massot-Campos, D. Montesinos-Miracle, and O. Gomis-Bellmunt, A control technique for integration of DG units to the electrical networks, IEEE Trans. Ind. Electron., vol. 60, no. 7, pp. 2881–2893, 2013.
[7] Romero-Cadaval, E.; Spagnuolo, G.; Garcia Franquelo, L.; Ramos-Paja, C.A.; Suntio, T.; Xiao, W.M., Grid-Connected Photovoltaic Generation Plants: Components and Operation, in Industrial Electronics Magazine, IEEE , vol.7, no.3, pp.6-20, Sept. 2013.
[8] Youngsang Bae; Trung-Kien Vu; Rae-Young Kim, Implemental Control Strategy for Grid Stabilization of Grid-Connected PV System Based on German Grid Code in Symmetrical Low-to-Medium Voltage Network, in Energy Conversion, IEEE Transactions on , vol.28, no.3, pp.619- 631, Sept. 2013
[9] S. Sumathi, L. Ashok Kumar, and P. Surekha, Solar PV and Wind Energy Conversion Systems. Cham: Springer International Publishing, 2015.
[10] A. Faiz, A. Rehman, Hybrid renewable energy systems: Hybridization and advance control, 2015 Power Gener. Syst. Renew. Energy Technol. PGSRET 2015. (2015).
[11] M.G.S.; A.M. J. Lagorse, A multiagent fuzzy-logic-based energy management of hybrid systems, IEEE Trans. Ind. Appl. 45 (2009) 2123–2129.
[12] E. Dursun, O. Kilic, Comparative Evaluation of Different Power Management Strategies of a Stand-Alone PV/Wind/PEMFC Hybrid Power System, Int. J. Electr. Power Energy Syst. 34 (2012) 81–89.
[13] D. Verma, S. Nema, A.M. Shandilya, S.K. Dash, Maximum power point tracking (MPPT) techniques: Recapitulation in solar photovoltaic systems, Renew. Sustain. Energy Rev. 54 (2016) 1018–1034.
[14] R.K. Majji, J.D. Kumar, T.S. Rao, Fuzzy Based Hybrid PV-Wind Systems Using Active Power Filter For Grid-Interconnection, in: IEEE Int. Conf. Recent Trends Electron. Inf. Commun. Technol., 2016: pp. 604–608.
[15] J. Lagorse, D. Paire, A. Miraoui, A multi-agent system for energy management of distributed power sources, Renew. Eneg(2010) 174–182.
[16] [16] H.C. Chiang, T.T. Ma, Y.H. Cheng, J.M. Chang, W.N. Chang, Design and implementation of a hybrid regenerative power system combining grid–tie and uninterruptible power supply functions, IET Renew. Power Gener. 4 (2010) 85.
[17] P. García, C.A. García, L.M. Fernández, F. Llorens, F. Jurado, ANFIS-Based control of a grid-connected hybrid system integrating renewable energies, hydrogen and batteries, IEEE Trans. Ind. Informatics. 10 (2014) 1107–1117.
[18] K. Hossain, M.H. Ali, Transient stability augmentation of PV / DFIG / SG-based hybrid power system by parallel-resonance bridge fault current limiter, Electr. Power Syst. Res. 130 (2016) 89–102.
[19] K. Kusakana, Optimal scheduled power flow for distributed photovoltaic/wind/diesel generators with battery storage system, IET Renew. Power Gener. 9 (2015) 916–924.
[20] X. Li, S. Member, D. Hui, X. Lai, Battery Energy Storage Station (BESS) -Based Smoothing Control of Photovoltaic (PV) and Wind Power Generation Fluctuations, 4 (2013) 464–473.
[21] C. Liu, K.T. Chau, S. Member, An Efficient Wind – Photovoltaic Hybrid Generation System Using Doubly Excited Permanent-Magnet Brushless Machine, 57 (2010) 831–839.
[22] R.G. Wandhare, V. Agarwal, Novel Integration of a PV-Wind Energy System With Enhanced Efficiency, Ieee Trans. Power Electron. 30 (2015) 3638–3649.
[23] J.C. Smith, M.R. Milligan, E.A. DeMeo, B. Parsons, Utility wind integration and operating impact state of the art, IEEE Trans. Power Syst. 22 (2007) 900–908.
[24] R. Karki, P. Hu, R. Billinton, Reliability evaluation considering wind and hydro power coordination, IEEE Trans. Power Syst. 25 (2010) 685–693.
[25] Y.-M. Chen, C.-S. Cheng, H.-C. Wu, Grid-connected hybrid PV/wind power generation system with improved DC bus voltage regulation strategy, in: Twenty-First Annu. IEEE Appl. Power Electron. Conf. Expo. 2006. APEC'06., IEEE, 2006: p. 7–pp.
[26] F. Nejabatkhah, S. Danyali, S.H. Hosseini, M. Sabahi, S.M. Niapour, Modeling and control of a new three-input DC–DC boost converter for hybrid PV/FC/battery power system, IEEE Trans. Power Electron. 27 (2012) 2309–2324.

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