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RESEARCH ARTICLE

FUZZY LOGIC CONTROLLED BASED RECONFIGURABLE SOLAR CONVERTER WITH GRID CONNECTED SYSTEM

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ABSTRACT

This paper introduces a new converter called Fuzzy logic controlled based Reconfigurable solar converter for Photovoltaic battery application. The main concept of the new converter is to use a single-stage three-phase. This converter solution is appealing for PV-battery application, because it minimizes the number of conversion stages, thereby improving efficiency and reducing cost, weight, and volume

INTRODUCTION

Solar photovoltaic (PV) electricity generation is not available and sometimes less available depending on the time of the day and the weather conditions. Solar PV electricity output is also highly sensitive to shading. When even a small portion of a cell, module, or array is shaded, while the remainder is in sunlight, the output falls dramatically. Therefore, solar PV electricity output significantly varies. From an energy source standpoint, a stable energy source and an energy source that can be dispatched at the request are desired. As a result, energy storage such as batteries and fuel cells for solar PV systems has drawn significant attention and the demand of energy storage for solar PV systems has been dramatically increased, since, with energy storage, a solar PV system becomes a stable energy source and it can be dispatched at the request, which results in improving the performance and the value of solar PV systems [1]–[3].

There are different options for integrating energy storage into a utility-scale solar PV system. Specifically, energy storage can be integrated into the either ac or dc side of the solar PV power conversion systems which may consist of multiple conversion stages [4]–[13]. Every integration solution has its advantages and disadvantages. Different integration solutions can be compared with regard to the number of power stages, efficiency, storage system flexibility, control complexity, etc.

This paper introduces a novel Fuzzy logic controlled based reconfigurable solar converter with grid connected (RSC). The basic concept of the RSC is to use a single power conversion system to perform different operation modes such as PV to grid (dc to ac), PV to battery (dc to dc), Section III introduces the proposed RSC circuit, different modes of operation, and system benefits.

System Structure

A PV system consists of a solar array which is a group of series-/parallel-connected modules, where the basic building block within the module is a solar cell. Commercially, the solar cell rated power varies between 1 and 2 W depending on the solar cell material and the surface area; therefore, to design a solar module, the solar cell's power is measured, and then, the modules are connected in series based on the desired output. Fig. 1 shows a PV system.

Generally, the electrical characteristics of the PV system are represented by power versus voltage (current/duty cycle) and by current versus voltage. The characteristic curves of the solar cell are nonlinear because of operational physical phenomena. By using the equivalent circuit of the solar cell shown in Fig. 2, the mathematical model of the generated current in a PV system is represented by Where Vpv and Ipv represent the PV array output voltage and current, respectively. Rs and Rsh are the solar cell series and shunt resistances, respectively. q is the

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electron charge (1.6 × 10−19 C), Iph is the light generated current, Io is the reverse saturation current, A is a dimensionless junction material factor, k is Boltzmann's constant (1.38 × 10−23 J/K), T is the temperature (in kelvins), and np and ns are the numbers of cells connected in parallel and series, respectively.

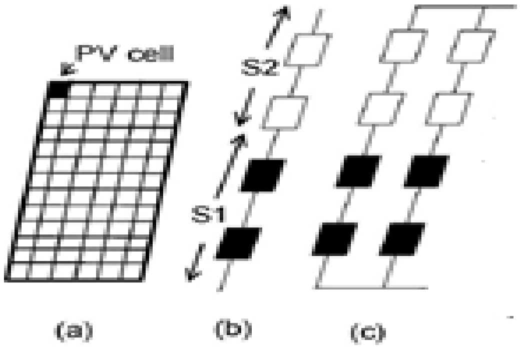


Figure 1 PV array terminologies. (a) PV module. (b) Series-assembly with two series-connected subassemblies S1 and S2. (c) Group

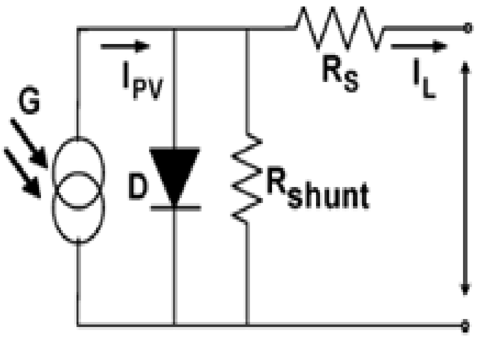
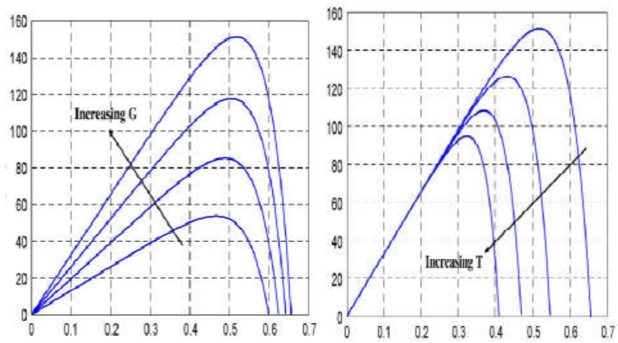


Figure 2 Equivalent circuit of a PV cell



(a) (b)

Figure 3 Influences of (a) temperature (*T*) and (b) solar radiation (*G*) on the *P–D* characteristics

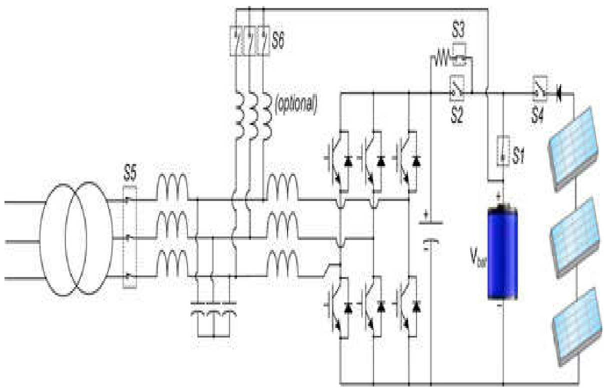


Figure 4 Schematic of the proposed RSC circuit

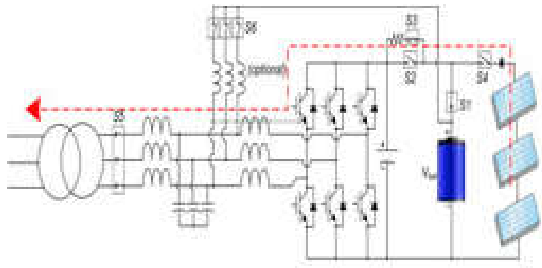


Figure 5 Mode 1—PV to grid.

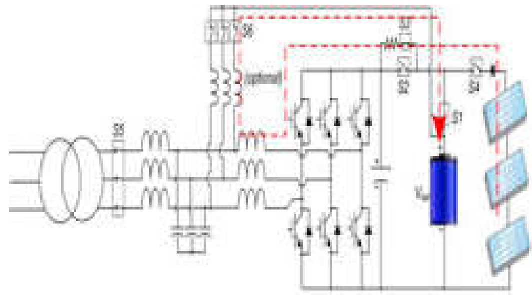


Figure 6 Mode 2—PV to battery

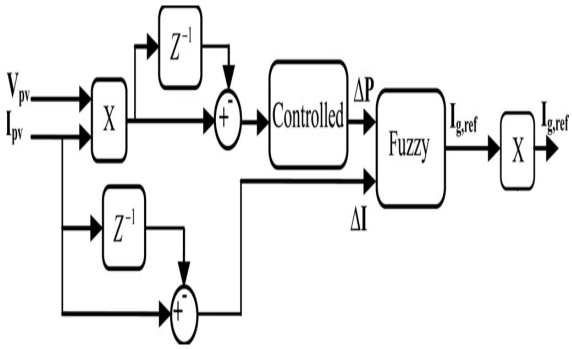


Figure 7 Block diagram of the FLC-based MPPT

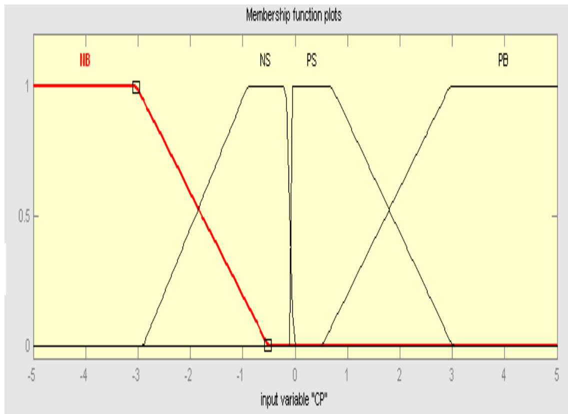


Figure 8 Membership function: Input ΔP

$$I_{PV} = N_p - I_0\left[e^{\frac{q(V_{pv}+R_S I_{pv})}{AkTn_S}} - 1\right] - \frac{(V_{pv}+R_S I_{pv})}{n_S R_{sh}} \quad (1)$$

The characteristic curves of the PV array system depend on the radiation and temperature of the PV system. For a given system, during normal conditions where the radiation is equally distributed among the PV modules, the power–duty cycle (P–D) characteristics under varying weather conditions are shown in Fig. 3.

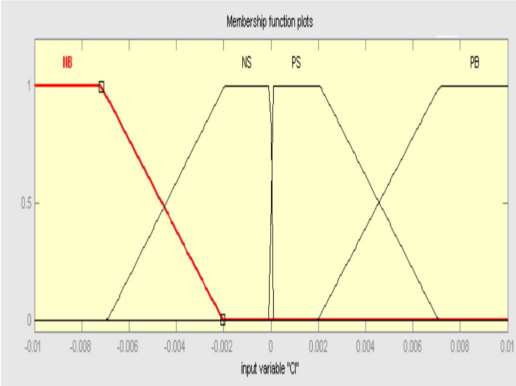


Figure 9 Membership function: Input ΔI

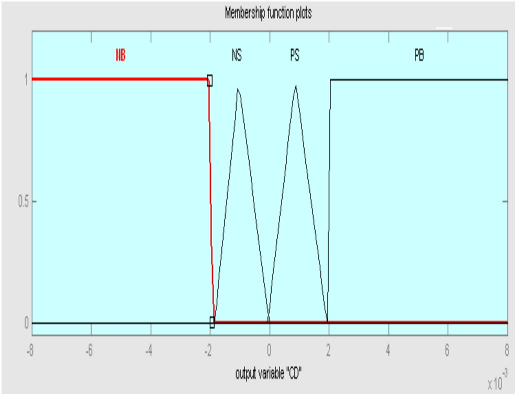


Figure 10 Membership function: Output ΔD

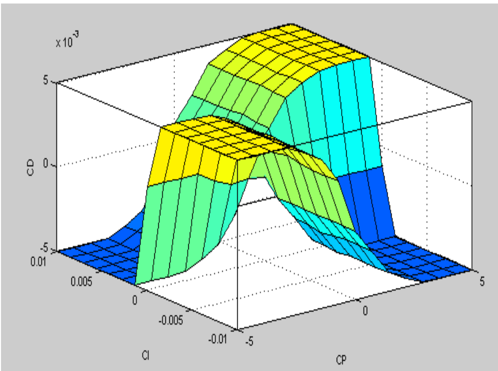


Figure 11 Surface view of the FLC

Reconfigurable Solar Converter

The schematic of the proposed RSC is presented in Fig. 2. The RSC has some modifications to the conventional three-phase PV inverter system. These modifications allow the RSC to include the charging function in the conventional three phase PV inverter system. Assuming that the conventional utility-scale PV inverter system consists of a three-phase voltage Source converter and its associated components, the RSC requires additional cables and mechanical switches, as shown in Fig. 2. Optional inductors are included if the ac filter inductance is not enough for the charging purpose

Introduction

The possible operation modes for the RSC are presented in Fig. 3. In Mode 1, the PV is directly connected to the grid through a dc/ac operation of the converter with possibility of maximum power point tracking (MPPT) control and the *S*1 and *S*6 switches remain open In Mode 2, the battery is charged with the PV panels through the dc/dc operation of the converter by closing the *S*6 switch and opening the *S*5 switch. In this mode, the MPPT function is performed; therefore, maximum power is generated from PV

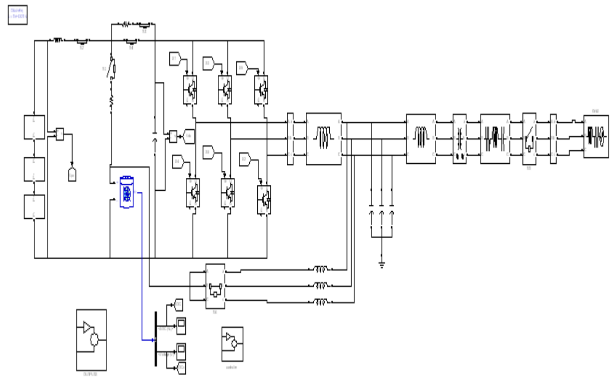


Figure12 Simulation circuit for DC-DC operation

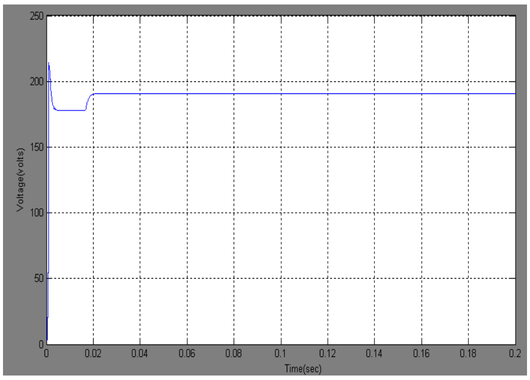


Figure 13 Output Voltage of the DC-DC Conversion

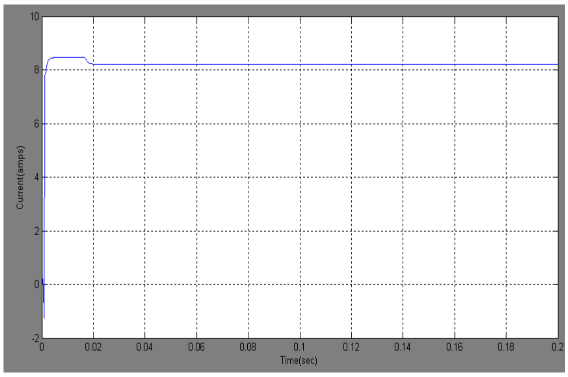


Figure 14 Output Current of the DC-DC Conversion

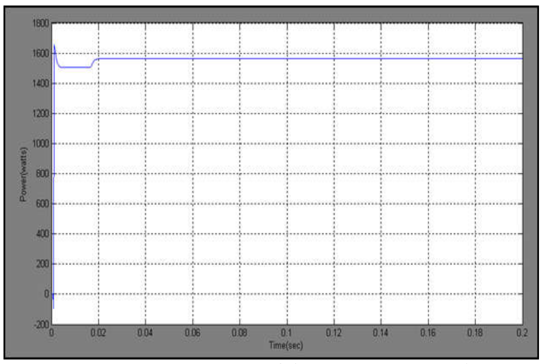


Figure 15 Output Power of the DC-DC Conversion

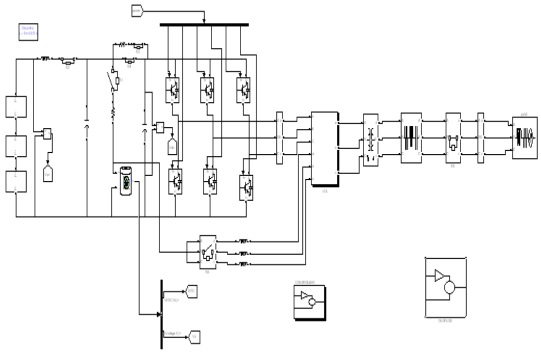


Figure 16 Simulation circuit for DC-AC operation

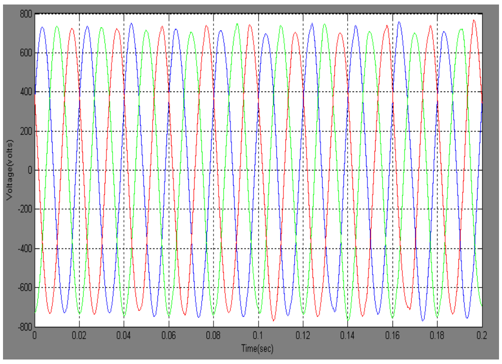


Figure 17 Output Voltage of the DC-AC Conversion

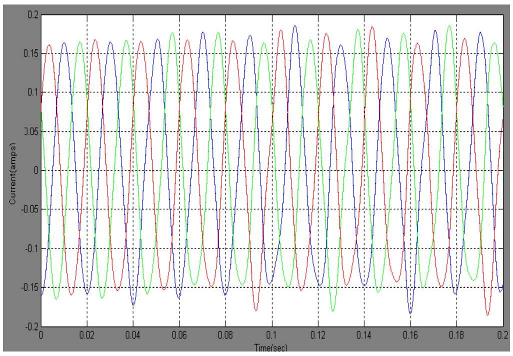


Figure 18 Output Current of the DC-AC Conversion

Proposed System Control Technique

To design a grid-connected PV system using a Reconfigurable solar converter the relationship between the PV output voltage and the grid voltage is derived as follows.

$$V_{PV}\, I_{PV} = Ig\ peak\ Vg\ peak\ \cos\theta \text{-------------} \quad (2)$$

Where θ is the phase angle, Vpv and Ipv are the PV output voltage and current, respectively, while Vg,peak and Ig,peak are the grid peak voltage and current, respectively. To operate the PV at the MPP, MPPT is used to identify the optimum grid current peak value. Any conventional MPPT technique can be used. However, to prevent significant losses in power, the tracking technique should be fast enough to handle any variation in load or weather conditions. Therefore, a fuzzy logic controller (FLC) is used to quickly locate the MPP. The inputs of the FLC are

$$\Delta P = P(k) - P(k-1) \text{----------} \quad (3)$$

$$\Delta I_{PV} = I_{PV(K)} - I_{PV(K-1)} \text{-----------------} \quad (4)$$

And the output equation is

$$\Delta I_{g\,ref} = I_{g.ref(k)} - I_{g.ref(k-1)} \text{-------------} \quad (5)$$

Where ΔP and ΔIPV are the PV array output power and current change, ΔIg, ref is the grid current amplitude change reference, Ig, ref is the grid current reference, and *k* is the sample instant. The variable inputs and output are divided into four fuzzy subsets: PB (Positive Big), PS (Positive Small), NB (Negative Big), and NS (Negative Small). Therefore, the fuzzy algorithm requires 16 fuzzy control rules; these rules are based on the regulation of the hill climbing algorithm, where the fuzzy rules are shown in Table II. To operate the fuzzy combination, Mamdani's method with Max–Min is used. From the behavior of the controller inputs and output, the shapes and fuzzy subset partitions of the membership function in both the inputs and output are shown in Fig. 8.Acenter of area algorithm (COA) is used in the defuzzification stage to convert the fuzzy subset duty cycle changes into real numbers

$$\Delta I_{g\,ref} = \frac{\sum_{i}^{n} \mu(I_{g,ref,i})\, I_{g,ref,i}}{\sum_{i}^{n} \mu(I_{g,ref,i})} \text{------------} \quad (6)$$

Where ΔIg, ref is the fuzzy controller output and Ig,ref ,i is the center of max–min composition at the output membership function

Table 1 FUZZY LOGIC RULES

	NB	**NS**	**PS**	**PB**
NB	PB	PB	NB	NB
NS	PS	PS	NS	NS
PS	NS	NS	PS	PS
PB	NB	NB	PB	PB

SIMULATION RESULTS

DC-DC Operation

The dc/dc operation of the RSC is also utilized for delivering the maximum power from the PV to the battery. The RSC in dc/dc operation is a boost converter that controls the current flowing into the battery the figure 11 shows the simulation model in the DC-DC conversion mode. In this proposed circuit using PV cell, batteries. In this DC- DC conversion mode by opening the S5 switch there is no power flow through the grid. By opening the S5 switch DC-DC converter operation is done. The inductance will store some energy this total inductance energy will add to the boost converter .In this mode of operation its converts Variable DC from PV cells to fixed DC in order to connect PV cells with the batteries In this paper, Li-ion battery has been selected for the PV-battery systems. Li-ion batteries require a constant current, constant voltage type of charging algorithm. In other words, a Li-ion battery should be charged at a set current level until it reaches its final voltage. At the final voltage, the charging process should switch over to the constant voltage mode, and provide the current necessary to hold the battery at this final voltage.

DC-AC Conversion

The dc/ac operation of the RSC is utilized for delivering power from PV to grid The RSC performs the MPPT algorithm to deliver maximum power from the PV to the grid. Like the conventional PV inverter control, the RSC control is implemented in the synchronous reference frame. The synchronous reference frame proportional-integral current control is employed. In a reference frame rotating synchronously with the fundamental excitation, the fundamental excitation signals are transformed into dc signals. As a result, the current regulator forming the innermost loop of the control system is able to regulate ac current sover a wide frequency range with high bandwidth and zero steady-state error. For the pulse width modulation (PWM) scheme, the conventional space vector PWM scheme is utilized.

CONCLUSION

This paper introduced a new converter called RSC for PV-battery application, particularly utility-scale PV-battery application. The basic concept of the RSC is to use a single power conversion system to perform different operation modes such as PV to grid (dc to ac), PV to battery (dc to dc). The proposed solution requires minimal complexity and modifications to the conventional three-phase solar PV converters for PV-battery systems. Therefore, the solution is very attractive for PV-battery application, because it minimizes the number of conversion stages, thereby improving efficiency and reducing cost, weight, and volume.

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