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Maximum Power Point Tracking to Assist Optimum Power Production in Photovoltaic Systems Using Reinforced Learning

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Abstract
Owing to the rapid development in materials and technology, Photo Voltaic systems dominate the renewable electrical power generation sector. The sustainability and quality depend on the optimum harvest of renewable energy. Significant improvement in harvest of solar energy is being reported through researches carried out worldwide by adopting to maximum power point tracking assisted techniques (MPPT). This paper presents a novel maximum power point tracking assisted technique based on reinforced learning. Reinforced learning learns from its environmental variables and attempts to produced desired output. Proven to be a much more reliable and efficient machine learning training technique, reinforced learning is adopted to suggest and implement required input to the system based on MPPT. This paper introduces a new method for maximizing the output power of a PV system while associated to a DC/DC SEPIC converter under variable load conditions.
Keywords: Reinforcement learning, MPPT, SEPIC converter, Photovoltaic (PV).

Introduction

It is now well learnt that quality and self-sustainable electrical power production is the order of the day. From research works, it is learnt that Photo Voltaic systems are widely used and relied upon for electrical power production due to the enormous availability and numerous advantaged associated with it. Traditionally fossil fuel-based power generation has dominated the sector for many decades from now. The carbon footprint of these power generation systems is of greater concern for the sustainable environment policies. The intense research in finding and developing alternate to fossil fuel based electric power generation is continuing and will do so until a optimum alternate is obtained. Judicious availability of solar energy around the world, lower carbon foot print and environmental sustainability presented by solar power generation methods have started to prove their viability. Solar energy harvest through Photovoltaic systems (PV) are promoted worldwide because of the ease of operation and aforesaid advantages of renewable energy sources. The economic aspect and rugged technology used in PV systems are proving to be the back bone of such technology. Sunlight is turned into electric power which can be readily utilized, saved in battery or synchronized immediately to the grids aided by Power electronic systems. The scarcity in availability of photovoltaic silicon substance has driven the project cost of solar power generation stations. Moreover, the power transmission process is relatively complex in PV systems. The estimated 1.8^{1011} MW of solar radiation energy made available on earth's surface by sun, has the potential to feed all electrical needs of this world, if harvested effectively and efficiently. The complexity of material properties of PV arrays and cost of control systems required for proper functionality of the generation system. The lower reliability and complexity of power electronic and control systems pose further more challenges. The introduction of algorithms in machine learning and sub electronic systems that are in development today aid in the development of a viable and novel process system for PV based power generation systems. MPPT method in conjunction with reinforced learning algorithms have been adopted and tested for the design of a PV system that has low Voltage generation.

The notable downside of a PV system, is its nonlinearity in performance. This leads to implementation of multiple MPPT approaches to derive full power from the PV module. The MPPT algorithms have been designed and developed for a specific PV system. The adaptive approach included in this paper, completely adjusts the step size of DC link voltage boost in conjunction with the gap in power

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between two disturbances. The ratio of the step-size and power differential are to be calculated specifically for the system model to obtain the optimum performances. The RL based adoption of duty ratio by adjusting the input amplitude, proves to be much more effective and simpler. The impedance match between the PV system and to its load is monitored and controlled by a regulator and maximum power generation is achieved.

Reinforcement learning (RL) is commonly used to address control issues since it is able to perform model-free management since it is possible to learn by communicating with the process without previous experience of the system model. The rapid industrialization has led to increased carbon foot print and electrical foot print of industries. Harvesting solar energy is challenging compared to the benefits offered. Ability to store electrical energy empowers industries to utilize it without any boundary to time and location. This paper aims at providing a novel solution to generate electrical energy from PV panels using cascaded multilevel inverter (CMLI) technique. CMLI with reduced switch implementation reduces the requirement of voltage gain and harmonics.

CASCADED MULTILEVEL INVERTER

The lower levels of Voltage and current produced by photovoltaic cells need to be conditioned in accordance with utilization. This paper proposes Li-ion battery charging using PV output. Hence standard voltage and current output in the range of 10-24 Volts and 0.5 to 1 Ampere current output of PV cells are required to be enhanced to few hundred Volts to 1 to 10 Amperes current rating. The method proposed in this paper as detailed in Fig.1, is highly efficient in converting photovoltaic DC to fixed DC or AC, implementing switched inductor quasi-impedance source inverter (SL-QZSI) cascaded multilevel inverter. SL-QZSI has been chosen to improve the power generation from PV. A nine-level cascaded multilevel inverter is proposed for controlling the voltage and current output without need of filters.

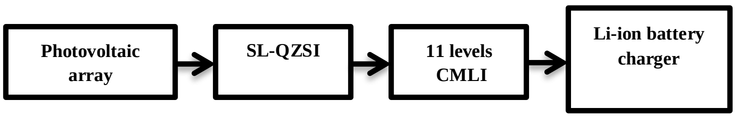

Figure 1. Proposed SL-QZSI based CMLI

The SL-QZSI topology proposed, suffices the requirement of extracting optimum possible power with greater efficiency using the incremental conductance algorithm.

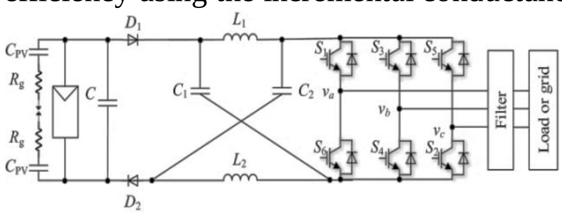

Figure 2. Circuit diagram for SL-QZSI

The above schem of SL-QZSI varies from classical QZSI circuits in the ways of passive elements count and sizewise. The Inductors L_1, L_2 , capacitors C_1, C_2 and diodes D1, D2 are switched ON and OFF in sequences to achieve harmonic free output. The shoot through and non-shoot through states are listed below is followed for the smooth operation of proposed SL-QZSI. At shoot through state, two switches are ON in same leg of the circuit for short time duration. Simultaneously the diode remains in OFF state and are remain in ON state thereon. L_1 and L_2 are connected in parallel with C_1 and C_2 circuit, which provides a low resitance path for discharge in this mode and inductors store energy during this mode. Following equations express the relationship between inductor voltage, capacitor voltage and input voltage of proposed SL-QZSI configuration.

$V_{L2} = V_{in} + V_{C1}$
$V_{L1} = V_{in} + V_{C2}$

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In the non- shoot through mode, the relationship between input voltage, capacitor voltage and inductor voltage are given by,

$V_{in} = V_{DC} - V_{C1} + VL_1$

$V_{L2} = -V_{C2}$

$V_{L1} = V_{L2} = -\frac{1}{2} V_{C1}$

$V_{DC} = V_{in} + V_{C1} + V_{C2}$

In addition to this, H-bridge rectification is utilized to achieve harmonic filtering and to reduce voltage balancing problem.

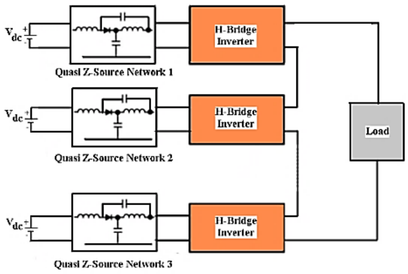

Figure 3: Proposed H-bridge configuration for SL-QZSI.

The cascaded H-bridge configuration is designed to decrement voltage gain requirement for individual module and harmonic level that is induced between levels of cascading. This single-stage voltage and power amplification reduces stress on the passive components of the circuit. The boosting factors are brought into effect using load transformer and front-end boost converter. The module number requirement is proposed to be optimized with the requirement of output voltage and inverter efficiency, because of the fact the ZSI is immune to the shoot-through faults.

Proposed system

In the proposed PV system, low Voltage generated from the PV array is enhanced to ready to use D.C grid power by using CML power electronic converters. The solar system energy is absorbed by PV array and 12V DC is generated, which is fed to the SEPIC to improve DC link voltage. The proposed system is shown in Fig. 1. The DC link enhances the output Voltage to the required levels. To control the proposed SEPIC converter, the RL based MPPT technique is utilized and the duty ratio of the power switch is controlled. The DC link voltage is regulated using power SEPIC converter with the help of RL based MPPT technique. The D.C link connects the PV grid that is generation power to the D.C load. The A.C electrical loads can be connected using multiple phase inverter that converts D.C to A.C power and the grid is linked with it. In the DC bus bar voltage, more than one category of either DC or AC systems can be added and connected to DC loads and AC loads.

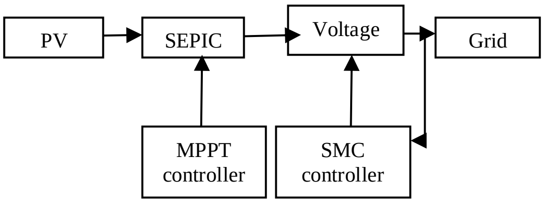

Fig. 4. Proposed System

For the maximum and optimal use of the available resources, several factor influencing the efficiency of the PV energy so that tracking system must be analysed in detail. This research explores the

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monitoring of the sun's location and the position of the solar panel at full power. In operating the photovoltaic source, the MPPT is a vital job, provided that, under climate change scenarios, the importance of the load resistance is variable in the most of the implementations. Furthermore, the electric current is not static but dynamic in very many systems. RL algorithms aspire to understand the conduct of a process or regulation that optimizes the effectiveness of the system by communicating with its environment. These algorithms are programmed to learn the transitional capacity of the environment and prepare the optimum policy or learn the ideal policy directly from its behaviour (returns). Model learning demands detailed data and a lot of experimentation in actual systems that are not always feasible. A strategy can be much more effective and easier to understand while still working efficiently online. The PV Based MPPT challenge is a definitive problem since with any mixture of states in the same system the PV transformations seem to be the same. In general, the difficulty is approximately linear and under the same operating environment the same power is generated.

The PV array is generating low voltage DC supply for the SEPIC fed grid system using sliding mode controller (SMC). The resistors are connected both in series leg and shunt leg with diode along with current source. Fig.5 illustrates the SEPIC mode of control.

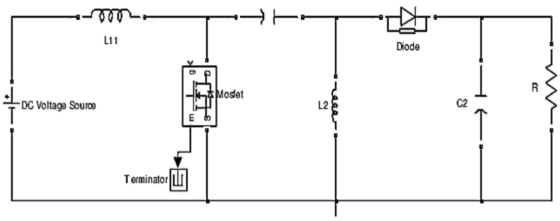

Fig. 5. SEPIC Model circuit for a PV cell

Simulations and Results

The total system as illustrated in Fig.4 was constructed as a Simulink model with PV array, SEPIC converter, MLI, MPPT controller, SMC controller and Reinforced learning algorithm. The PV array system generates a constant 12 Volt electrical power at .1 Amperes. The SEPIC converter acts as DC-DC link and enhances the 12 V to 400 V. Further conditioning is provided through RL control systems. The SMC controller and MPPT controllers aid the optimum harvest of energy at source. The performances of PV array system, MPPT system and SEPIC system are studied and recorded. The Fig. 5 to 9 demonstrates the efficiency of the operations. The proposed system with DC-DC SEPIC converter is used to extract the primary energy source from the PV arrays. The inverter is implemented with SMC controller to achieve the system stability through control of Voltage and Current.

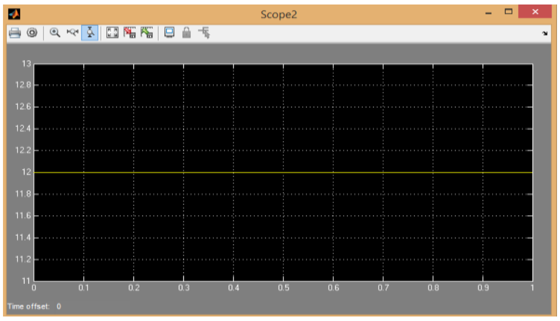

Fig. 7. PV system output Voltage

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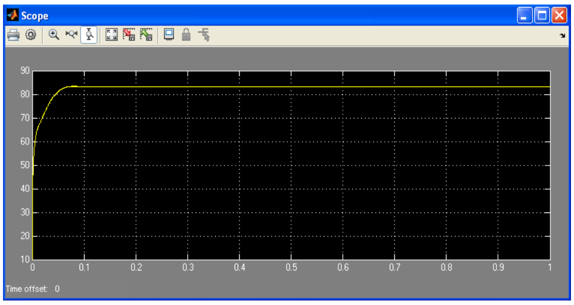

Fig. 8. DC link Voltage of SEPIC converter

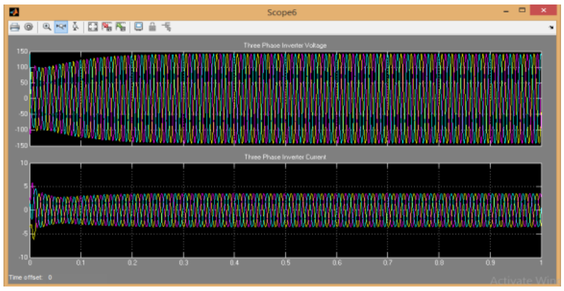

Fig. 9. Grid Voltage after implementation of Reinforced learning MPPT

Conclusion

The SEPIC converter which is controlled by the reinforcement learning based MPPT system and the power from the PV system has provided desired output grid Voltage in simulations. The proposed MPPT- RL - SMC control is found to be superior in control of inverter operation through the provision of switching signals. The SEPIC converter with control of MPPT is noted to be increasing the DC bus Voltage. The proposed multi controller with Machine learning algorithms were simulated using Simulating and MATLAB model blocks.

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