Asian Journal of Science and Applied Technology
ISSN: 2249-0698 (P) Vol.3 No.1, 2014, pp.32-35

DOI: https://doi.org/10.51983/ajsat-2014.3.1.783

Operation of PV Cells with Two-String Maximum Power Point Trackers Using DC Distribution

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(Received on 20 March 2014 and accepted on 15 May 2014)

Abstract - **This paper presents operational control of two maximum power point trackers(MPPTs) for two-string photovoltaic (PV) panels in dc distribution systems. Two PV strings and two MPPTs are implemented in this system. The proposed MPPT topology consists of buck and boost converters to deal with wide output voltage range of PV panels. The current balancing of two MPPT modules in parallel is achieved. In this paper, the system configuration and the operational principle of the proposed MPPT are first introduced. Flowcharts of the online PV-string configuration check and current balancing are explained. Current balancing in MPPT modules is done to provide thermal protection and to increase the reliability and life time of components present in the modules The validity of configuration check and current balancing is verified by the experimental results. Maximum power tracking performance and power conversion efficiency are obtained.**

Keywords: **Maximum power point tracker (MPPT), PV panel, Current balancing.**

I. Introduction

Photovoltaic electrical systems are those which convert the energy of photons directly into electrical energy. The output power of such a system is highly sensitive to the environmental parameters like-isolation and temperature. Hence, the maximum power that can be extracted from a panel also changes with change in these parameters. In order to ensure maximum extraction of power from a PV panel under varying environmental conditions load should be changed in accordance with changing environmental parameters, so that the operating point or quiescent point always lies at the maximum power point. Since, practically it is not possible to change the load time to time; there must be some interfacing circuit in between the PV panel and the load which can change the load with change in environmental parameters depending upon some control variables. As the output of PV panel is of DC in nature, generally switched mode power converters (DC to DC converters) are used as the interfacing circuit.

The operating point is changed by varying the duty-cycle of these power converters . There are so many techniques in literature according to which the duty-cycle of these converters can be changed to track the maximum power point. In this paper, variable-step perturb and observe algorithm has been used for this purpose. Variable step-size of perturbation ensures time efficient tracking and at the same time gives better stability in output power at maximum power point. In order to determine smooth and quick variation in step-size, fuzzy logic control has been used in this paper.

II. System Summary

A. *System Configuration*

The circuit topology consists of two power switches, two power diodes, and one inductor. If the PV panel voltage is higher than the output voltage, the converter will be operated in buck mode. On the other hand, it will be operated in boost mode. The MPPT module is controlled by the microcontroller TMS320LF2406 manufactured by Texas Instruments Inc. The PV voltage *V*PV, output voltage V_o , and inductor current i_{LM} are sensed by the feedback circuit to determine the operational modes and the duty ratio of the power switches.

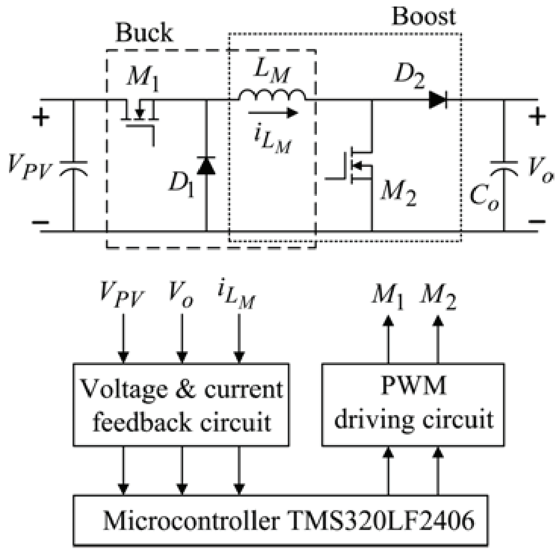

Fig. 1 Circuit configuration of the proposed MPPT module

B. Construction Details

A maximum power point tracker (MPPT) is used for extracting the maximum power from the solar pv module and transferring that power to the load.Power output of a Solar PV module changes with change in direction of sun, changes in solar isolation level and with varying temperature. PV (power vs. voltage) curve of the module there is a single maxima of power. That is there exist a peak power corresponding to a particular voltage and current. We know that the efficiency of the solar PV module is low about 13%. Since the module efficiency is low it is desirable to operate the module at the peak power point so that the maximum power can be delivered to the load under varying temperature and isolation conditions.

Hence maximization of power improves the utilization of the solar PV module. A DC-DC converter (step up/step down) serves the purpose of transferring maximum power from the solar PV module to the load. A DC/DC converter acts as an interface between the load and the module . By changing the duty cycle the load impedance as seen by the source is varied and matched at the point of the peak power with the source so as to transfer the maximum power. Maximum power point tracking is an essential issue in solar energy sources because the installation cost of PV panels is high and the conversion efficiency from solar power to electrical power is low.

The convergence speed of fuzzy logic and neural network schemes is fast. If the PV panels are connected in series to gain higher output voltage than the dc-bus voltage, the buck converter is used. On the contrary, the boost converter is employed in low PV output voltage situations. However, both buck and boost converters are not suitable for dealing with high voltage variation in the PV output end. Consequently, a buck–boost combination converter is used in this paper to solve problems of high voltage variation.

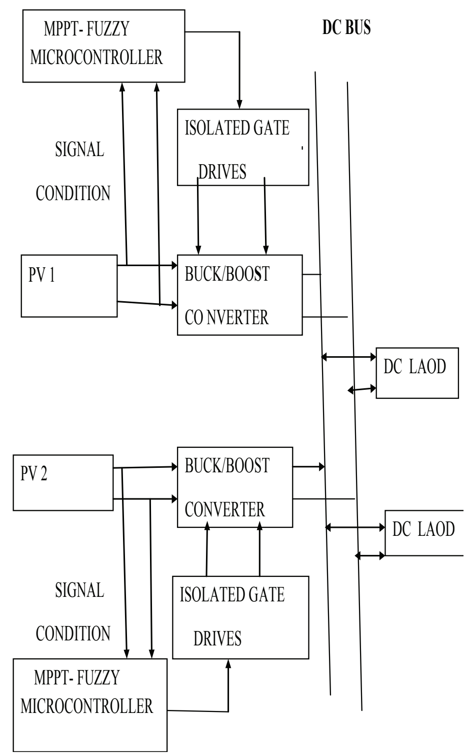

Fig. 2 overall block diagram

C. Photovoltaic Cell

A photovoltaic cell or photoelectric cell is a semiconductor device that converts light to electrical energy by photovoltaic effect. If the energy of photon of light is greater than the band gap then the electron is emitted and the flow of electrons creates current.

D. Maximum Power Point Tracking

This paper develops the maximum power point trackers (MPPTs) for two-string photovoltaic (PV) panels in a conventional 5-kW dc distribution system to obtain high utilization rate of the solar power. Maximum power point tracking is an essential issue in solar energy sources because the installation cost of PV panels is high and the conversion efficiency from solar power to electrical power is low. The conventional converter topologies of MPPTs can be classified into buck type, boost type , and buck–boost type.

If the PV panels are connected in series to gain higher output voltage than the dc-bus voltage, the buck converter is used. On the contrary, the boost converter is employed in low PV output voltage situations. However, both buck and boost converters are not suitable for dealing with high voltage variation in the PV output end. Consequently, a buck–boost combination converter is used in this paper to solve problems of high voltage variation.

PV panels are generally connected in series or in parallel to form PV arrays so that the power level can be increased. The conventional converter topologies of MPPTs can be classified into buck type, boost type, and buck–boost type. If the PV panels are connected in series to gain higher output voltage than the dc-bus voltage, the buck converter is used.

The developed two MPPTs are implemented in a 5-kW dc distribution system as shown in Fig. 2. This dc distribution system is connected to ac grid through a 5-kW bidirectional inverter. For wide application, the two-string MPPTs are proposed to satisfy different power requirements. Each MPPT has 2.5-kW rating and can be operated independently or in parallel. When theMPPT supplies power to dc appliances, such aswater heaters of which power is less than 2.5 kW, it will be operated under standalone. Moreover, it can also supply to a 5-kW home system with parallel configuration. Besides, the peak efficiency of a device is generally at the half-load condition. A single-string MPPT will have lower efficiency under the 5 kW (higher load) or 200 W (lower load) conditions. The two-string MPPTs can improve the efficiency under light or heavy load conditions.

The operational principles of the MPPTs will be introduced. Both buck and boost operational modes can be achieved by the proposed topology.

E. Buck-Boost Converter

A buck boost converter provides an output voltage which may be less than or greater than the input voltage, the output voltage polarity is opposite to the input voltage. The circuit can be divided into two modes. During mode 1, switch is turned on and the diode is reversed biased. The input current flows through the inductor and switch. During mode 2, the switch is turned off, the energy stored in the inductor would be transferred to the load.

F. DC Distribution

DC distribution systems have been used in isolated power systems such as aircraft, spacecraft, and ship, which are not connected to the ac utility grid. The trend of employing renewable energy sources is drawing more and more attention in recent years for reducing fossil fuel exhaustion and carbon emission. In the utilization of solar power and fuel cell generations for residential buildings, dc distribution systems provide higher conversion efficiency than traditional ac distribution systems because most of the energy storage units and home appliances are also dc types. For a typical dc distribution system the power conversion losses can be reduced by adopting the dc bus to minimize the power conversion stages. Therefore, this paper develops the maximum power point trackers (MPPTs) for two-string photovoltaic (PV).

III. Experimental Results

The two-string MPPTs are developed according to the specifications and the solar module used in the experiments is APOS Series AP-200, of which the maximum power is 200 W, the open-circuit voltage is 33.62 V, and the tolerated conversion efficiency is 80%. An MPPT string is connected by 13–16 pieces modules for the rated power 2.5 kW. Hence, the upper boundary of input voltage is set to 550 V in this paper. In addition, the 5-kW dc distribution system will be started up by a built-in flyback power supply. The minimum start-up voltage is 100 V. To verify the proposed control schemes and the MPPT performance, two-string MPPTs with 2.5-kW power rating per set are developed.

IV. Conclusion

The two-string MPPTs in dc distribution system are developed. This circuit topology is suitable for wide input voltage applications.

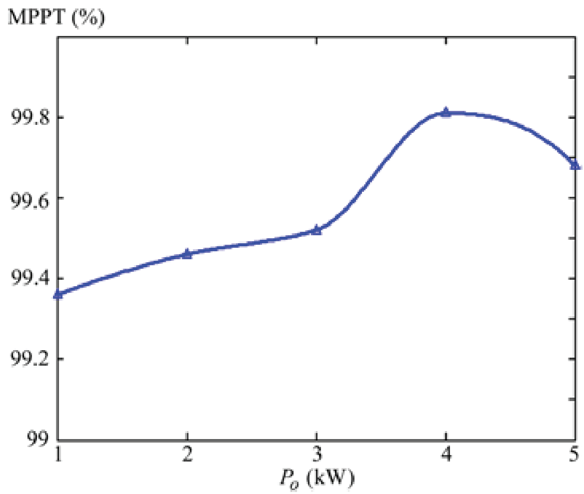

Fig.3 Maximum power tracking accuracies of the MPPT in the buck mode at different output power

The mode transition is smoothly achieved by the employed strategy. To ensure the correct operations of two MPPTs, the proposed online PV-string configuration check verifies the connecting configuration. The online plugged and unplugged are successfully obtained in both standalone and parallel modes. Experimental results also identify the current balancing and the shadow effect of the MPPTs. Maximum power tracking accuracy is higher than 99.3% and power conversion efficiency is higher than 93.8%.

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