Study on Control Strategies of Cascaded Solar Module System

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Abstract: **Solar photovoltaic (PV) systems have mainly been used in the past decade. Inverter-powered photovoltaic grid topologies are prominently used to meet electricity demand and to integrate renewable forms of energy into power grids. Coping with the growing demand for electricity is currently a major challenge. This article presents the basic architecture of a photovoltaic system and the characteristic performance curve of the photovoltaic generator. The description of DC voltage regulation in this paper.**

Keywords: **DC, PV, MPPT, AC.**

I. Introduction

The global demand for energy is increasing due to increasing technological development, living standards and the world population. Furthermore, producing energy from clean, efficient and environmentally friendly sources has become one of the biggest challenges for engineers and scientists due to limited fossil fuel reserves and greenhouse gas emissions. Renewable energies are expected to have great potential as an alternative energy source without reducing energy supply or greenhouse gas emissions [1–2].

Another challenge in designing a voltage-based MPPT is choosing the time between two consecutive samples of the PV array voltage, called the sampling period. If the sampling period is too long, as in the case of [3], there is a significant loss of performance. This is because the PV module output voltage follows the reference unchanged during a sampling period. As soon as an MPP is followed and there is a step in the irradiation between two successive scans, the new MPP is only calculated with the next mains voltage scan.

As a result, the procedure initially receives an incorrect MPP instead of the current one [4]. The new MPP is only reached after the next grid voltage scan. This problem is more pronounced when the exposure changes rapidly. Also, if a sample and hold amplifier such as in this document is used and the sample period is too long, the hold capacitor will decrease.

This causes a change in Vref during the sampling period and thus the PV set point deviates from the MPP. To solve this problem, the extended wait time S&H [5, 6] is used. With this arrangement, an extended wait time is achieved by stacking two S&H circuits in a chain. Using this method reduces the problem of PV duty point deviating from the MPP, but this arrangement increases the number of components and the cost of the system.

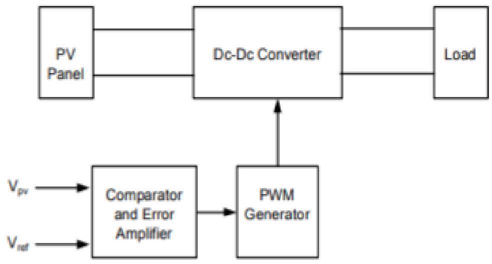

Fig. 1 Block diagram of the voltage based MPPT

Solar photovoltaic systems are available in many different configurations depending on their relationship to inverter systems, external grids, battery banks or other electrical loads. [Seven]
The purpose of the MPPT system is to sample the power of the photovoltaic cells and apply the right resistance (load) in order to obtain maximum performance in certain environmental conditions. [8] MPPT devices are typically integrated into a power converter system that provides voltage or current conversion, filtering and control to drive various loads, including power grids, batteries or motors.

a. Solar inverters convert direct current to alternating current and can contain MPPT: these inverters measure the output power (I-V curve) of the solar panels and apply the right resistance (load) to obtain maximum power.
b. Power at MPP (Pmpp) is the product of MPP voltage (Vmpp) and MPP current (Impp).

A. Implementation

When a load is connected on to the solar array, the panel's operating point is never at peak performance. The impedance seen by the panel comes from the working point of the solar array. Then, by varying the impedance seen from the plate, the working point are often shifted towards the height point. Since the panels are DC devices, it's necessary to use DC-DC converters to convert the impedance of 1 circuit (source) to the opposite circuit (load). Changing the duty cycle of the DC-DC converter causes a change in impedance as seen from the instrument panel. At a particular impedance (or duty cycle), the operating point is at the height power transfer point. The I-V curve of the panel can vary greatly counting on atmospheric conditions like radiation and temperature. Therefore, it's impossible to regulate the duty cycle under such changing operating conditions.

MPPT implementations use algorithms that always sample panel voltages and currents, then adjust duty cycle as required. Microcontrollers are wont to implement algorithms. Modern implementations often use larger computers for load analysis and forecasting. The utilization of recent and efficient photovoltaic solar cells (PVSCs) has proven to be a revolutionary alternative to energy saving, renewable energy and demand management. Due to their high initial cost, PVSCs weren't yet a beautiful alternative for energy consumption, as they will draw cheaper electricity from the general public grid. However, they need been widely used for air con in remote areas, water pumping, and isolated or remote areas where electricity isn't available or is extremely expensive to move. Although PVSC prices have dropped significantly in recent years due to new developments in film technology and manufacturing processes [9]. The utilization of solar power with photovoltaic modules has its problems deriving from the change within the insulation conditions. These changes in insulation conditions have a robust influence on the efficiency and power of the PV modules. Extensive research was conducted to enhance the efficiency of the photovoltaic system. Various methods are proposed to trace the utmost point of a photovoltaic module to unravel the efficiency problem and products are developed that use these methods and are now commercially available to consumers [10-11].

A maximum point tracker is employed to get the utmost power of the solar PV module and convert it to load. A non-isolated DC-DC converter (Step Up / Step Down) converts the utmost power into load. A DC-DC converter acts as an interface between the load and therefore the module. By varying the duty cycle, the impedance of the load because it appears from the source is modified and mapped to the height point with the source to convert the utmost power [11-12]

Therefore, maximum point detection methods are required to stay the PV generator running on its MPP. Many MPPT methods are suggested within the literature; Examples are P&O (Perturb and Observe) methods, IC (Incremental Conductance) methods and constant voltage methods. DC converters are going to be included within the implementation study. [13] [14]

Some results like current, voltage and output power for every different combination are discussed. MPPT technology is implemented using the MATLAB SIMULINK tool, taking under consideration the variant of the mixture of circuits.

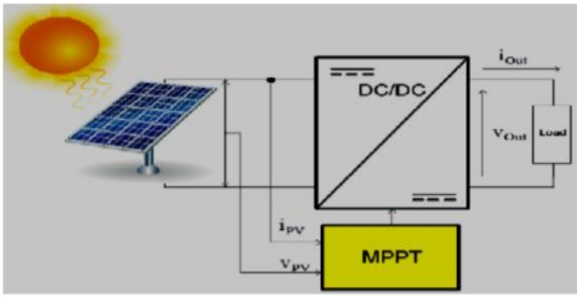

Fig. 2 PV module and dc/ dc converter with MPPT

Table 1: Comparisons of Different MPPT Techniques

MPPT Techniques	PV Array Dependency	Sensors	Tracking Accuracy	Energy Tracking Factor	Applications
VMPPT	YES	V	Low	Low	OFF_GRID
CMPPT	YES	I	Low	Low	OFF_GRID
Look up table	YES	V,I	Low	Low	OFF_GRID
P&O	NO	V,I	Medium	Good	BOTH
INC	NO	V,I	High	Good	BOTH
3 point MPPT	NO	V,I	High		BOTH
Temperature	YES	V,temp	High	Low	OFF_GRID
Intelligent control based					
ANN	NO	V,I	Very High	Good	GRID
FLC	NO	V,I	Very High	Very good	BOTH
Load parameters based	NO	V,I	High	Low	OFF_GRID
RCC	NO	V,I	High	Very good	GRID

II. LITERATURE REVIEW

Zainuri et. al [2] In this study, an adaptive MPPT (Maximum Power Point Tracking) algorithm for photovoltaic (PV) is presented. P&O is known and widely used as a very simple MPPT algorithm. Fuzzy logic is also easy to develop and provides a quick response. The proposed techniques combine both advantages. Conventional P&O control algorithms have also been developed for evaluation and benchmarking. All algorithms were simulated in Matlab / Simulink with PV modules of 330 WHT-U Sun Power (SPR-305) modules, which are connected to a PV Boost DC / DC converter. This system is followed by a DC inverter and the output is connected to the grid. Performance evaluation includes overshoot, timing, vibration and stability, as described in this study.

J.H.R. Enslin at el [3] this paper offers a Maximum point Tracker (MPPT) for a photovoltaic panel, which must be integrated into the panel during production. The MPPT is inexpensive, efficient, and has few components that serve to extend the MPPT's mean solar time between Failures. MPPT uses a cheap microcontroller to perform all its functions.

R. Faranda et al [4] this text presents a comparative study of ten widely used MPPT algorithms; their performance is evaluated from an energy point of view using the Simulink® simulation tool, taking under consideration the various variations of radiation. Numerous maximum point tracking techniques for photovoltaic systems are developed to maximize the energy produced and lots of of them are well established within the literature. These techniques differ in many aspects such as: simplicity, convergence speed, digital or analog implementation, required sensors, cost, range and other aspects.

M. Bodur at el [5] this document describes the planning of a voltage-based maximum point (MPPT) tracker for photovoltaic (PV) applications. Among the varied MPPT methods, the voltage-based method is taken into account the only and cheapest. The most disadvantage of this method is that the PV generator is disconnected from the load to detect its circuit voltage, which inevitably results in a loss of power. Another disadvantage of a rapid change in irradiation is that if the time between two successive sampling times, called the sampling time, is just too long, a clear loss occurs. This text provides an MPPT circuit where the PV generator voltage sampling interval and sampling period are shortened. The sample and hold circuit has also been simplified. The proposed circuit doesn't use a microcontroller or digital signal processor and is therefore suitable for low cost and low power consumption applications.

III. Proposed Methodology

Modeling of various parts of the system has been discussed further. The modeled PV system with MPPT technique for its optimum operation,

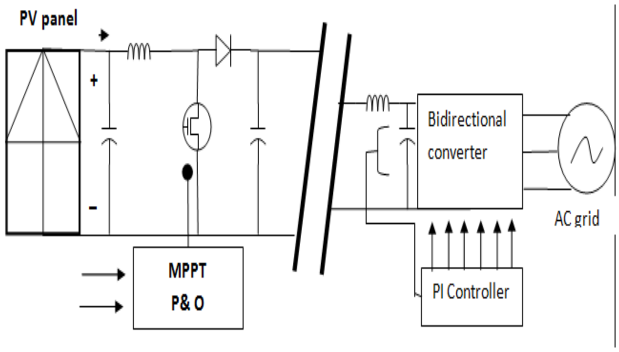

Fig. 3: Basic architecture of a PV system

How solar power works

- The sun shines on the solar panels generating DC electricity
- The DC electricity is fed into a solar inverter that converts it to 240V 50Hz AC electricity.
- The 240V AC electricity is used to power appliances in your home.
- Surplus electricity is fed back into the main grid.

Whenever the sun shines (and even on a cloudy day), the solar cells generate electricity. The grid-connected inverter converts the direct current generated by the solar panels into 240V alternating current, which can then be used by the property/household.

If a grid connection system produces more electricity than it consumes, the surplus is fed into the grid. Some utility companies measure how much electricity your system feeds into the grid and credit the bill.

If the solar cells do not produce electricity at night, for example, the electricity will be supplied from the grid as usual. The energy merchant calculates the normal tariff for electricity consumption.

A. PV Module Modelling

PV cells have single operating point where the values of the current (I) and voltage (V) of the cell result in a maximum power output. These values correspond to a particular resistance, which is equal to V/I. A simple equivalent circuit of PV cell is shown in Fig. 6.

The MPPT algorithm has been employed in order to obtain the operation of solar module at maximum power continuously.

A cell series resistance (Rs) is connected in series with parallel combination of cell photocurrent (I_{ph}

),exponential diode (D), and shunt resistance (R_{sh}) , I pv and Vpv are the cells current and voltage respectively. It can be expressed as

$$I_{pv} = I_{ph} - I_s\left(e^{q(V_{pv}+I_{pv}*R_s)/nKT} - 1\right) - (V_{pv} + I_{pv} * R_s)/R_{sh}$$

Where:

I_{ph} - Solar-induced current

I_S - Diode saturation current

q - Electron charge (1.6e^{-19}C)

K - Boltzmann constant (1.38e^{-23}J/K)

n - Ideality factor (1~2)

T - Temperature ^{0}K

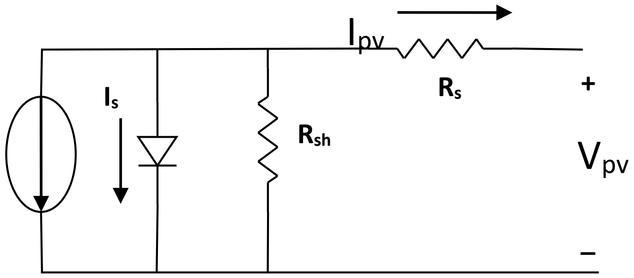

Fig. 4: Equivalent circuit of solar pv cell

The solar induced current of the solar PV cell depends on the solar irradiation level and the working temperature can be expressed as:

$$I_{ph} = I_{sc} - k_i(T_c - T_r) * \frac{I_r}{1000}$$

Where:

I_{SC} Short-circuit current of cell at STC

K_i Cell short-circuit current /temperature coefficient (A/K)

I_r Irradiance in w/m

T_C ,T_r Cell working and reference temperature at STC

A PV cell has an exponential relationship between current and voltage and the maximum power point (MPP) occur at the knee of the curve as shown in the Fig 5.

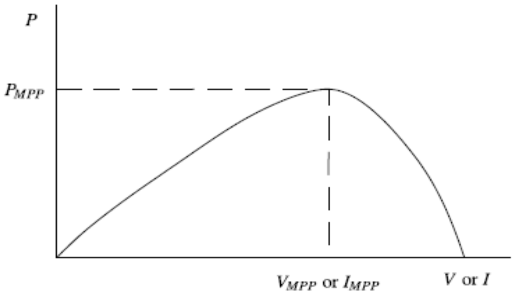

Fig. 5: Characteristic PV array power curve

The MPPT algorithm will track the maximum power to supply the DCMGs system. The assumptions for model derivation are that the ideal current source can be presented as the PVs behavior. In addition, all power converters are operated under the continuous conduction mode (CCM) and the harmonics are also ignored.

B. Dc voltage control

The continuous part of the PV system is presented in Fig.6. The first DC/DC converter is a boost chopper circuit controlled by an MPPT algorithm for rise the low PV power to an optimal level under different weather conditions. [10] The second DC / DC converter is a boost that increases the input voltage to the voltage level required by the VSI and operates with a fixed duty cycle. [1]

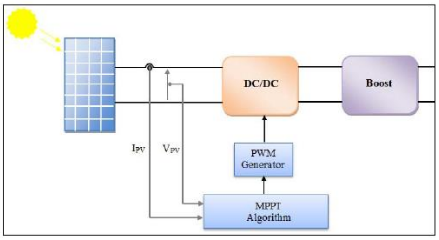

Fig. 6. DC Voltage Control

IV. CONCLUSION

The main drawback of the photovoltaic system is the relatively higher cost required to generate electricity compared to traditional power generation systems or even compared to other renewable sources such as wind power. An MPPT is an electronic DC / DC converter that optimizes the combination between solar panels (photovoltaic system) to maximize energy efficiency. Various MPPT techniques have been analyzed in publications to improve the performance of solar modules. However, the slight change in MPPT technique can lead to further improvement of the output waveform with reduced distortion levels. MPPT technology must also be based on the variation of temperature and radiation. The structure of the multistage cascade converter can be attractive for high performance solar photovoltaic (PV) systems due to its modularity, scalability and distributed MPPT (Maximum Power Point Tracking).

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