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DC-DC Converters Using Resistive Control in Photovoltaic Applications

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Abstract:
Phototovoltaic (PV) systems must be able to maintain stable operation near the maximum power point (MPP) regardless of environmental conditions. Voltage-offset resistive control (VRC) exhibits inherently low sensitivity to irradiance changes and supports effective inner-loop control to maintain MPP operation. Small- and large-signal analysis show that VRC employed with a boost converter is stable for PV applications. VRC is tested on an experimental setup using a digital controller, PV boost converter, and dc-link load. Irradiance and control parameter step responses are observed through simulated and experimental results. VRC exhibits stable and fast transient response. Traditional and VRC maximum power point tracking (MPPT) methods that utilize sample-and-hold operation are compared through simulation. The fractional open-circuit voltage VRC and MPP-current-based VRC methods are identified as effective, simple control solutions for PV systems that seek to maintain high efficiency under irradiance transients.

Index Terms:- Phototovoltaic (PV) systems, maximum power point (MPP), Voltage-offset resistive control (VRC)

I. INTRODUCTION

Photovoltaic (PV) energy has increased interest in electrical power applications. It is crucial to operate the PV energy conversion systems near the maximum power point to increase the efficiency of the PV system. However, the nonlinear nature of PV system is apparent from Fig. 1, i.e. the current and power of the PV array depends on the array terminal operating voltage. In addition, the maximum power operating point varies with insolation level and temperature. Therefore, the tracking control of the maximum power point is a complicated problem. To overcome these problems, many tracking control Strategies have been proposed such as perturb and observe, incremental conductance, parasitic capacitance, constant voltage, neural network and PID logic controller (FLC). These strategies have some disadvantages such as high cost, difficulty, complexity and instability.

The general requirements for maximum power point tracking (MPPT) are simplicity and low cost, quick tracking under changing conditions, and small output power fluctuation. A more efficient method to solve this problem becomes crucially important. Hence, this paper proposes a method to track maximum power point using adaptive PID logic controller (AFLC). FLC is appropriate for non-linear control. In addition, FLC does not use complex mathematic. Behaviors of FLC depend on shape of membership functions and rule base. There is no formal method to determine accurately the parameters of the controller. However, choosing PID parameters to yield optimum operating point and a good control system depends on the experience of designer. FLC with fixed parameters are inadequate in application where the operating conditions change in a wide range and the available expert knowledge is not reliable. AFLC can solve this problem because it can re-adjust the PID parameters to obtain optimum performance.

There have been renewed interests in solar micro grids in recent years, and thus, led to further studies in maximum power point tracking (MPPT). MPPT in solar photovoltaic (PV) micro grid systems is normally achieved either by the perturb and observe method or by the incremental conductance method (ICM). In the ICM approach, the output resistance of the PV panel is equal to the load resistance as expected from the celebrated maximum power transfer theorem; this may be shown by linearizing the I–V output characteristic of a PV panel about the operating point. Thus, the equivalent resistance r at the maximum power point.

Where RLR is the regulated resistance in order to achieve MPPT, VP and IP are the PV voltage and current at the MPP. The actual load resistance is matched to r by a buck converter through the control of the duty cycle D.

Where D is the duty cycle of the buck converter and RL represents the micro grid load connected to the PV panel. The main equations are summarized in Appendix A. Consider two levels of illumination intensity at points_1 and _2, the current at the MPP decreases going from point_1 to point_2 that changes the value of the PV resistance at the MPP. In order to achieve MPPT, the regulated resistance RLR should be adjusted by changing the duty cycle D. The buck converter should work in the continuous current mode (CCM) in order to satisfy. In discontinuous conduction mode (DCM), this relationship is not valid and the stable operation of the converter is more complex. In continuous conduction, for a load power change, the duty cycle changes temporarily during a transient, but it reverts to Vout /Vin in the steady state. On the other hand, in discontinuous conduction, the power is a function of the dead time, and therefore, a different control strategy is required that involves dual-control moving from CCM to DCM and vice versa. This is particularly true for partially shaded conditions, where local peaks (for the shaded regions) in the P–V characteristics exist alongside the global peak, the maintenance of continuous conduction in these areas for low light levels ensures that the MPPT controller can maintain a stable response.

The PV voltage is relatively constant over the full range of solar intensity (VP = 41.6 V in the example to follow), thus the minimum inductance is a function of duty cycle D and the output current of the PV panel IP or a function of duty cycle D and the inductor current IO that feeds the microgrid under a constant switching frequency (fs = 20 kHz).

Evidently, the minimum inductance to achieve CCM falls off as the solar intensity increases. Conversely, the higher value of inductance required at light loads may be achieved without increasing the volume of the inductor.

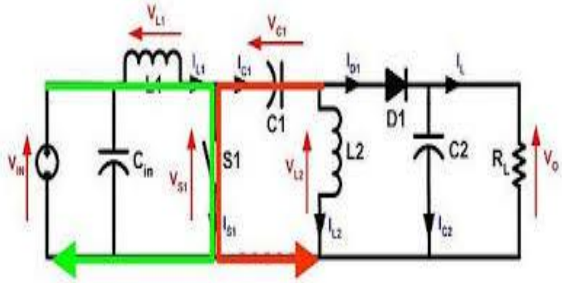

Figure1: Maximum power transfer in a PV micro grid.

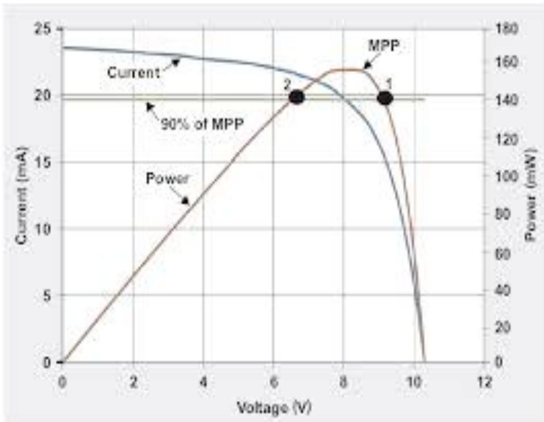

Figure 2: MPPT based on impedance matching.

The role of the variable inductor in the stable operation of the buck converter is explained by reference to Figure. Continuous conduction can only be achieved with inductance values above the dashed line in Fig 2 (the shaded area is off limits). The lower limit of load current (corresponding to low solar insolation) is given by IO 1 as long as the inductance is greater than L1. Evidently, at higher currents (and higher insolation levels), say IO 2, a smaller inductor L2 would suffice, with the added advantage of a reduced volume occupied by the inductor. Conversely, setting the inductance at L2 would limit the lower load range to values of current (and solar insolation) greater than IO 2. The variable inductor with the L–i characteristic shown in Fig. has the advantages of increasing the load range. The increased inductance at low insolation levels maintains continuous conduction, and this, in turn, means that the control strategy of the MPPT controller extends to lower power levels; this facilitates the extension of the MPPT algorithm to partial shading.

The voltage across an inductor is related to its flux linkage, and this, in turn, is related to the current, the dependence of the inductance on its current must be taken into account.

II. TYPES OF THE DC TO DC CONVERTERS

There are three basic types of dc-dc converter circuits, termed as buck, boost and buck-boost. In all of these circuits, a power device is used as a switch. This device earlier used was a thyristor, which is turned on by a pulse fed at its gate. In all these circuits, the thyristor is connected in series with load to a dc supply, or a positive (forward) voltage is applied between anode and cathode terminals. The thyristor turns off, when the current decreases below the holding current, or a reverse (negative) voltage is applied between anode and cathode terminals. So, a thyristor is to be force-commutated, for which additional circuit is to be used, where another thyristor is often used.

Later, GTO's came into the market, which can also be turned off by a negative current fed at its gate, unlike thyristors, requiring proper control circuit. The turn-on and turn-off times of GTOs are lower than those of thyristors. So, the frequency used in GTO-based choppers can be increased, thus reducing the size of filters. Earlier, dc-dc converters were called 'choppers', where thyristors or GTOs are used. It may be noted here that buck converter (dc-dc) is called as 'step-down chopper', whereas boost converter (dc-dc) is a 'step-up chopper'. In the case of chopper, no buck-boost type was used.

With the advent of bipolar junction transistor (BJT), which is termed as self-commutated device, it is used as a switch, instead of thyristor, in dc-dc converters. This device (NPN transistor) is switched on by a positive current through the base and emitter, and then switched off by withdrawing the above signal. The collector is connected to a positive voltage. Now-a-days, MOSFETs are used as a switching device in low voltage and high current applications. It may be noted that, as the turn-on and turn-off time of MOSFETs are lower as compared to other switching devices, the frequency used for the dc-dc converters using it (MOSFET) is high, thus, reducing the size of filters as stated earlier. These converters are now being used for applications, one of the most important being Switched Mode Power Supply (SMPS). Similarly, when application requires high voltage, Insulated Gate Bi-polar Transistors (IGBT) are preferred over BJTs, as the turn-on and turn-off times of IGBTs are lower than those of power transistors (BJT), thus the frequency can be increased in the converters using them. So, mostly self-commutated devices of transistor family as described are being increasingly used in dc-dc converters.

a) BUCK CONVERTER

A buck converter is a step-down DC to DC converter. Its design is similar to the step-up boost converter, and like the boost converter it is a switched-mode power supply that uses two switches (a transistor and a diode), an inductor and a capacitor.

The simplest way to reduce the voltage of a DC supply is to use a linear regulator (such as a 7805), but linear regulators waste energy as they operate by bleeding off excess power as heat. Buck converters, on the other hand, can be remarkably efficient (95% or higher for integrated circuits), making them useful for tasks such as converting the 12–24 V typical battery voltage in a laptop down to the few volts needed by the processor.

Theory of operation

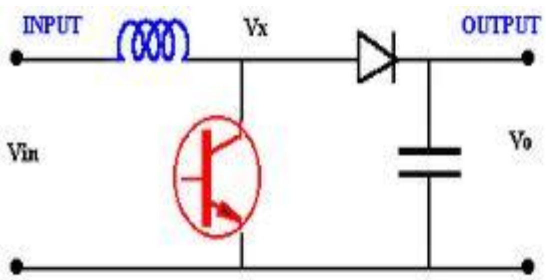

Figure 3: Buck converter circuit diagram.

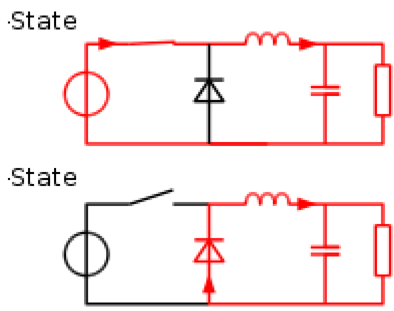

Figure 4: The two circuit configurations of a buck converter: On-state, when the switch is closed, and Off-state, when the switch is open.

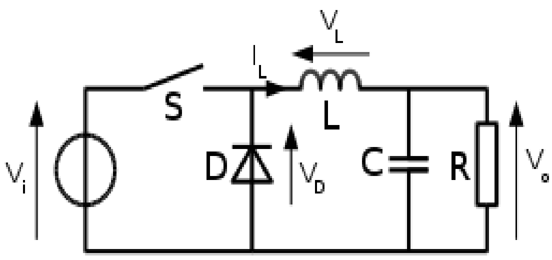

Figure 5: Naming conventions of the components, voltages and current of the buck converter.

b) BOOST CONVERTER

A boost converter (step-up converter) is a power converter with an output DC voltage greater than its input DC voltage. It is a class of switching-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.

III. PROBLEMS IN EXISITING SYSTEM

The minimum inductance in a buck converter in CCM is minimum. The output current I_O is the average current in the inductor of the buck converter. The minimum inductance may be restated it is clear that we have a relationship between the frequency, duty cycle and the incident photon based current Ip. Hence the output is of course tracked for the maximum power. But the thing is that, the values of the controller is not optimized, hence the tracking ability comes down is our claim. Also the efficiency of the system is also less because of the fixed values set in PID controllers.

IV. PROPOSED SYSTEM

In our proposed model MPPT tracking operation is done with a variable inductor current, which is optimized by selection of choosing that the average current through the load is always maintained better even when the amount of solar power illuminated comes down. And to make the tracking process is faster. Our over all aim is to maintain the inductor current and hence the load current better so that, we meet the power requirements at the load side. Usually the inductor current having more average value will give better output power. By optimizing the control parameters we try to maintain the inductor and load current to the better average value. The proposed system is designed using PID controller. The parameters of PID controller are better optimized using PID based decisions. PID being the best decision making algorithm will make the control parameters optimum, to meet the constraint of more average load current.

Solar cell is basically a p-n junction fabricated in a thin wafer or layer of semiconductor. The electromagnetic radiation of solar energy can be directly converted to electricity through photovoltaic effect. Being exposed to the sunlight, photons with energy greater than the band-gap energy of the semiconductor are absorbed and create some electron-hole pairs proportional to the incident irradiation. Under the influence of the internal electric fields of the p-n junction, these carriers are swept apart and create a photocurrent which is directly proportional to solar insolation PV system naturally exhibits a nonlinear I characteristics which vary with the radiant intensity and cell temperature. Figure 6 shows the equivalent circuit models of cell.

Since a typical PV cell produces less than 2W at 0.5V approximately, the cells must be connected in series configuration on a module to produce enough high power. A PV array is a group of several PV modules which are electrically connected in series and parallel circuits to generate the required current and voltage.

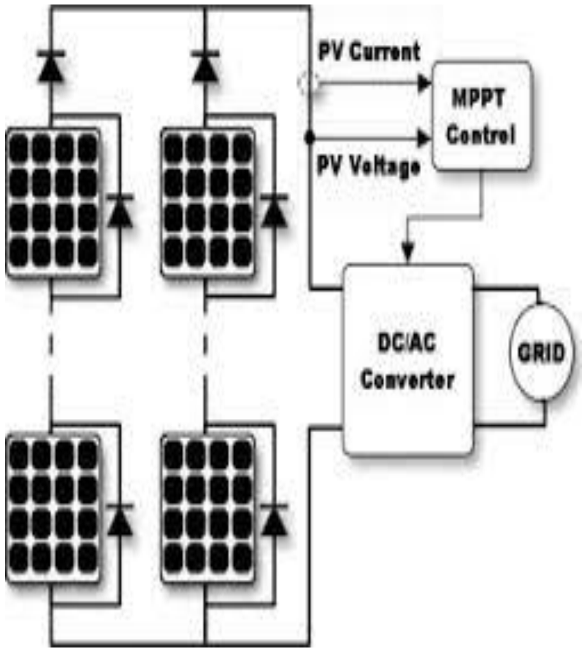

Figure 6: operation diagram

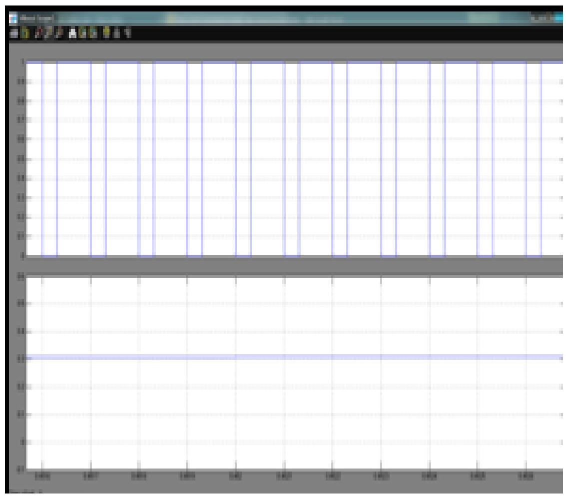

Figure 7: solar panel

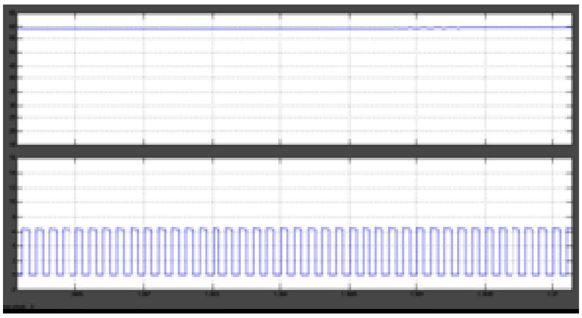

Figure 8: MPPT controller

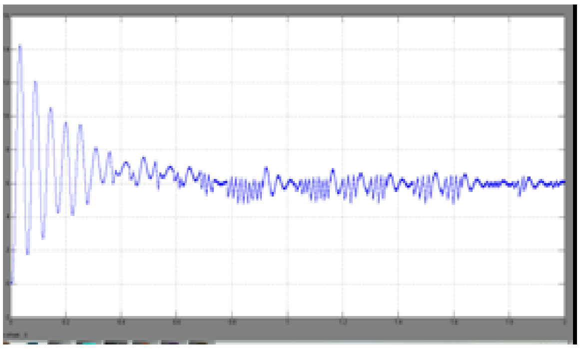

Figure 9: resultant output

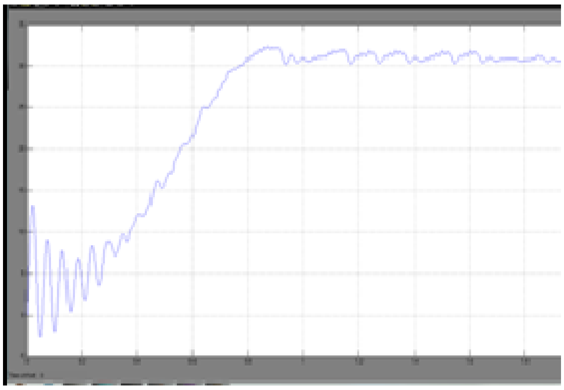

Figure 10: output waveform

V. CONCLUSION

This paper presents a new topology of an resistive based controller for solar micro grid applications that incorporates a variable inductance. Advancements in PV technology are increasingly important as clean energy sources become more prominent. The main challenges to wider PV system adoption are high cost, low efficiency, and grid stability concerns. Effective PV control reacts quickly to irradiance changes and isolates the grid from transient effects. VRC is a simple control scheme that is easily employed with dc-dc converters in PV systems.

For the boost converter, one potential VRC equation showed small- and large-signal stability. This VRC equation is stable for any Req value on the simple boost, but is limited for negative Req values with the addition of an input capacitor. Stable operation for a specific Req range is achieved by choosing capacitor and inductor values to meet stability criteria. A boost converter employing VRC is examined through simulation and experiment. The experimental controller requires voltage correction for Vos to compensate for power stage nonidealities. Both simulation and experiment show stable operation for a suitable range of VRC parameters. Step responses for irradiance, Req, and Vos demonstrate fast response times with very little power lost during the transition. This simple VRC implementation is promising as a fastreacting, stable inner-loop control scheme.

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