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Proposed Low Cost Passive Technique Introduced for Grid Connected Photovoltaic Systems using MPPT

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***Abstract*—The perturb and observe (P&O) algorithm is one of the most commonly utilized maximum power point tracking (MPPT) control schemes for photovoltaic (PV) generators. However, the operation of this algorithm at high perturbation frequencies, when the system response to MPPT perturbations is never allowed to settle, has not been given adequate attention in the literature. In the paper, a low cost passive technique is introduced for grid connected photovoltaic systems. The technique is based on a well known resource, already utilized and fundamental in stand-alone photovoltaic systems: the battery. In fact, a proper selected number of batteries to be put in parallel to a same number o PV sub-fields of the whole PV plant, if properly designed in their nominal voltage and in their capacity, seems able to "intrinsically" and continuously track the maximum power point of the grid connected PG, especially in case of non uniform solar irradiation (SI) conditions. In order to show the usefulness of the proposed technique, the results of a lot of measurements on a small power prototype are reported and critically analyzed**

Keywords*— MPPT, P&O, PI, PV Array, PLL, Boost Converter

I. INTRODUCTION

In 21st century, solar energy wins increasing attention due to cleaning, non-pollution and ceaseless usage etc. However, photo electricity conversion efficiency of photovoltaic cell array is not high presently; we, in order to further improve applicable efficiency of solar energy, develop the intelligent tracking strategy of the maximum power point in photovoltaic system in hope of improving and optimizing existing MPPT method, whose possibility is proved through statistical analysis. Grid-connected PV systems for electrical energy generation are, certainly, one of the most promising distributed energy resources for the future. Currently, a central aspect of PV systems is their cost, again too much high to permit their considerable diffusion. The best way to reduce costs of PV systems is, of course, the designing and the large-scale production of new materials and panels characterized by costs significantly lower than the existing ones together with an improved energy conversion efficiency. As the core component of the solar energy PV generation system of solar energy, property of photovoltaic cell is influenced by illumination intensity and temperature etc, whose volt-output characteristic shows complex nonlinearity. In order to keep maximum output power of photovoltaic cell, loading working point should be adjusted timely so as to adapt changes of output characteristic of solar energy. The existed common maximum power point tracking methods, which mainly include perturbative algorithm. In the I-V curve, there is a point which the power is maximum for a particular irradiation condition. if electrical energy storage can be, in principle, achieved by different ways (like: batteries, super capacitors, superconductors, flywheel, compressed air, ...), in the paper only the use of batteries will be explicitly taken into account.

In the following, the proposal of utilizing batteries in grid connected PV systems is presented and discussed by using different practical examples that are supported not only from the theoretical point of view but also by different experimental results that are obtained on a small-scale prototype of about 20 Wp of power, constituted by 4 photovoltaic small-panel of about 5 Wp, together with 1 NiCd rechargeable batteries, with 1.2 V of nominal voltage and 800 mAh of capacity (the prototype will be better described and fully experimented in the following). In particular, theoretical discussions and experimental tests are utilized to show that the use of batteries in grid connected PV plants can improve significantly their energy production efficiency (dramatically low in some critical unbalanced solar irradiation conditions) so representing a valid and lower cost alternative to currently utilized active MPPT apparatus.

II. PROPOSED SYSTEM DESIGN AND DESCRIPTION

For a fixed level of the solar irradiation and for a fixed temperature, the power delivered to the network by a conventional grid-connected PG, which qualitative I-V characteristic is depicted in fig.1.a), depends on the value of the network equivalent impedance as seen from the PG terminals, the behavior of the network being normally imposed to be resistive by using a power electronic PWM inverters. Unfortunately, only one working point on the I-V PG characteristic corresponds to the MPP (bold-faced circles, in fig.1.a) and it can be "caught" only carefully adjusting the value of the network equivalent resistance (i.e. by using properly designed MPPT apparatus).

Currently, for grid-connected PV systems, the most diffused MPPT techniques are in the active category. They are based on power electronic interfaces (single-stage or double-stage forced commutated PWM inverters), operated according to complex algorithms (p&o, incremental, conductance) [1-8]. Of course, active MPPTs have high performances; nevertheless, they normally require complex circuitries and are very costly. On the other hand, Fig.1 also shows that, for different solar irradiation (SI) levels, the variation of the MPP directly involves the PG current values, while the PG voltage values remain almost constant. This means that a battery, in parallel with the PG and the network as shown in Fig.1.b, if properly designed in its nominal voltage value and in its capacity, can naturally catch and maintain a PG working point very close to the MPP, for any PG solar irradiation level and for any value of the network equivalent resistance. Nevertheless, it is expected that battery used as passive MPPT has lower performances if compared with currently utilized active MPPTs. Because of this last consideration, as an alternative to the trivial idea of utilizing batteries in grid-connected PV systems in a centralized way and in the place of active MPPTs, it is proposed to use batteries in large grid connected PV plants and in a more convenient "distributed way" that can be better appreciated with the help of Fig.2. In practice, in large grid-connected PV plants, batteries can be used as passive and economical distributed MPPTs by locating them in parallel with a proper number of PV subfields, by maintaining centralized high-power electronic inverters with centralized active MPPT function. This last proposed approach can be a valid alternative to the more expensive and currently adopted PV plant electrical scheme where a number of distributed power electronic DCDC converters are normally utilized to implement an high efficiency MPPT function, together with the centralized high-power electronic inverter [5, 8].

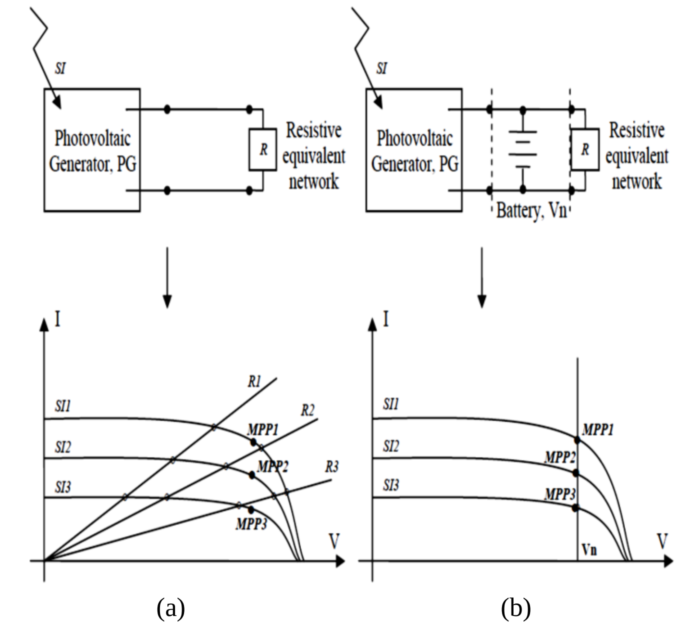

Fig.1: Working points analysis of Simplified scheme and I-V characteristics of a conventional PG grid-connected photovoltaic systems, (a) without and (b) with the use of batteries

III. SIMULATION OF THE SYSTEM

Designing of proposed system is made in SIMULINK. Here PV modules are used. For absorbing the maximum power through PV system perturbation & observe algorithm is used. IGBT based DC-DC boost converter is modeled to increase the voltage and with help of varying the duty cycles we will get exact or track maximum power point.

A. Modeling of MPPT Algorithm

Most popular PV MPPT algorithms are

- Constant Voltage
- Perturb and Observe
- incremental Conductance
- Short Circuit Current
- Open Circuit Voltage

These algorithms use the information of PV output voltage, current, or both, to perform the MPPT. PV module temperature can also be used to find the MPP of the PV system due to linear relation between the open circuit voltage value and the temperature of the PV module.

$V_{mpp(T)} = V^{STC}_{mpp} + (T - T^{STC}) \times \mu_{Vmpp}$

Here P&O algorithm has been taken into consideration for MPPT technique.

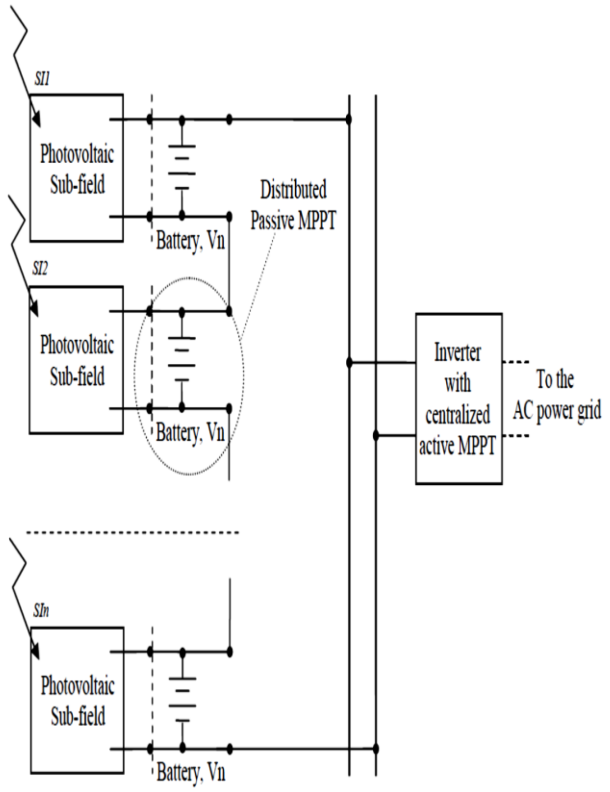

Fig.2: Grid-connected photovoltaic system with distributed use of batteries as passive MPPTs

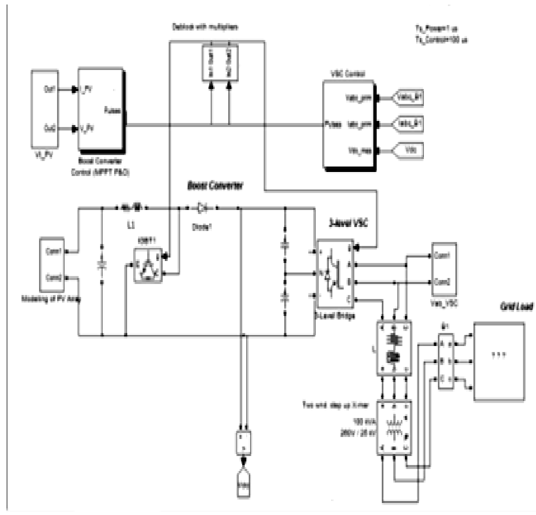

Fig.3: Circuit diagram of proposed model

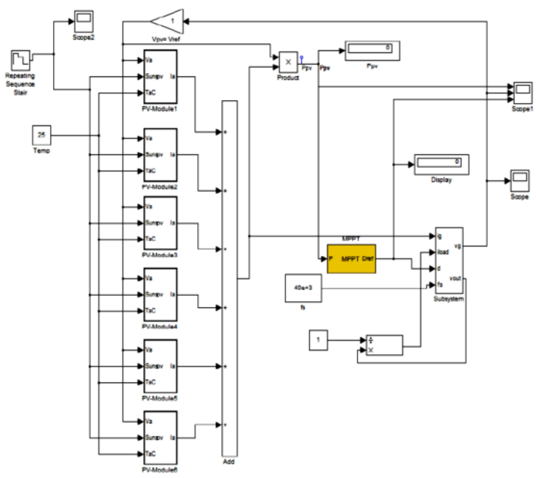

Fig.4: SIMULINK model of MPPT control system

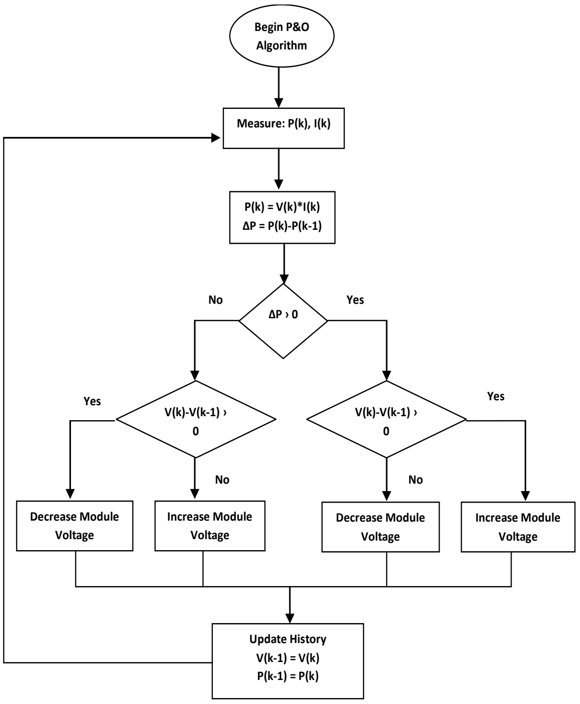

Fig.5: Flow chart of MPPT algorithm

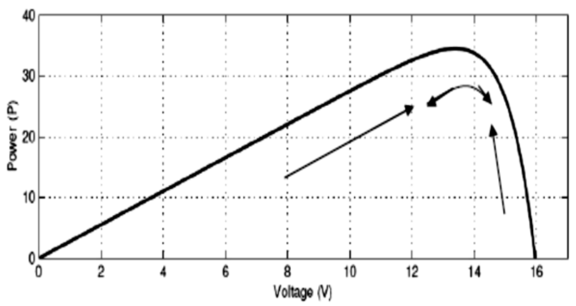

Fig.6(a): Ideal Graph Power versus Voltage for Perturb and Observe Algorithm

In P&O algorithm a slight perturbation is introduced. This perturbation causes the changes in the power of solar module. If the power increases due to the perturbation then the slope of perturbation or direction is continued as previous cycle up to peak value. After that the power at the next instant decreases and hence after that the slope of perturbation reverses. When the steady state is attained the algorithm oscillates around the peak point. Here the perturbation size is kept very small. The algorithm sets a reference voltage of the module corresponding to the peak voltage of the module and a PI controller help in moving the operating point of the module to that particular voltage level.

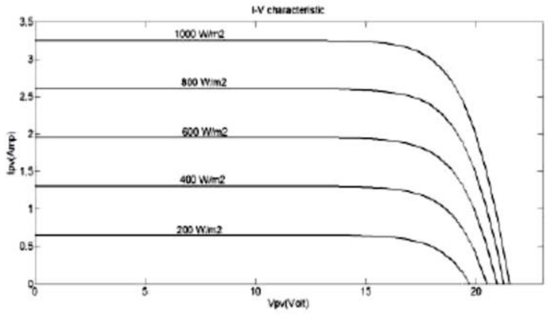

Fig.6(b): Ideal Graph for Voltage and Current for Perturb and Observe Algorithm

IV. RESULTS AND DISCUSSION

For Unbalanced solar irradiation conditions:

Table-1: Results under balanced SI of PV Panels and optimal value of the grid equivalent resistance, Ro

Generated Power [W]			
Different panel	Ratings	Without	batteries
PV 1	(SI1 = 178 W/mq)	0.60	0.58
PV 2	(SI2 = 181 W/mq)	0.63	0.61
PV 3	(SI3 = 176 W/mq)	0.62	0.61
PV 4	(SI4 = 171 W/mq)	0.61	0.59
Whole PV System		2.59	2.50

Table-2: Results under balanced SI of PV Panels and non optimal value of the grid equivalent resistance (Taking(-1/4th% of Ro)

Generated Power [W]			
Different panel	Ratings	Without	batteries
PV 1	(SI1 = 178 W/mq)	0.50	0.58
PV 2	(SI2 = 181 W/mq)	0.51	0.60
PV 3	(SI3 = 176 W/mq)	0.52	0.61
PV 4	(SI4 = 171 W/mq)	0.54	0.63
Whole PV System		2.08	2.40

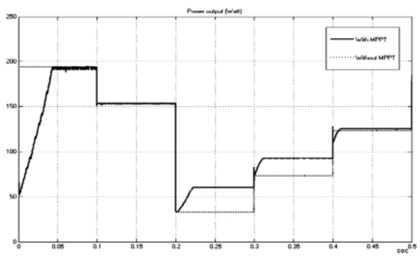

Fig.7: The result of the model with and without MPPT control

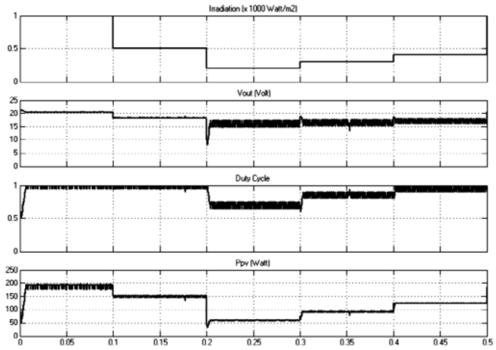

Fig.8: The result of the model with MPPT control with greater step value (step value 0.05)

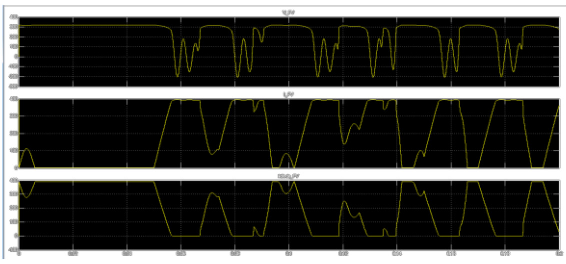

Fig.9: PV array characteristics waveforms

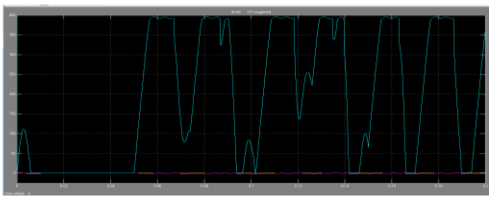

Fig.10: MPPT characteristics

V. CONCLUSION

A passive MPPT, to be utilized in large grid-connected PV plants, has been introduced and discussed. It is essentially based on the energy storage capabilities of batteries that are proposed to be put in parallel to a proper number of PV sub-fields. If well designed in their location, in their nominal voltage value and in their capacity, batteries can naturally catch the MPP of each PV sub-field, also compensating for critical unbalanced irradiation conditions. The results of proposed system showing that, in some critical irradiation conditions, batteries used in grid-connected PV plants can significantly increase the energy generation of a conventional PV plant. The proposal can be a valid and lower cost alternative to more expensive solutions based on a number of DC-DC power electronic converters to be put in parallel to each PV sub-field in order to work as distributed active MPPTs. Furthermore, the presence of an energy storage system can make more and more attractive grid-connected PV plants.

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