Application of MPPT controller for hybrid alternative electrical power grid independent source

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Abstract – **In this paper one example of the field proven application of the MPPT (maximum power point tracking) controller for hybrid photovoltaic solar and wind generated alternative electrical power is presented. This power source is located in uninhabited hard to reach mountain region and completely independent from electrical power grid or any other source of energy. Successful uninterrupted operation in harsh environment including winter period of year completely approved chosen approach.**

Keywords – **Maximum power point tracking (MPPT) controller, alternative electrical power sources, photovoltaic (PV) panel, wind generator**

I. INTRODUCTION

Alternative sources of electrical energy that use renewable energy (for example: Sun energy, wind energy, sea wave and tide energy) become very significant in recent years. Besides ecological aspects, economic aspects including investment and maintenance costs are motivating factor of rising influence in process of decision making concerning choice of acceptable and cost effective energy sources of future.

As an illustration, in Germany that is one of the most developed countries of the World, constant growth of installed power of PV sources of electrical energy of more than 20% year on year is registered, reaching by the end of 2009. more than 8,5 GW of total installed power [1]. Also building and exploitation of other renewable sources of electrical energy – e.g. wind generators concentrated in so called wind farms or in single stand alone installation is in great expansion nowadays.

One of the most interesting alternative sources of electrical energy is conversion of Sun energy in photovoltaic semiconductor cells in electrical energy.

Due to properties of PV semiconductor material electrical power generated by PV semiconductor array decreases with growth of temperature (presented at Fig 1.). At the other side, electrical power generated by PV panels-arrays increases by increase of insolation of Sun (presented at Fig 2).

So in regions with continental climate hybrid configuration consisting of: PV arrays and wind generator as mutually independent and complemented by nature of generating of electrical power sources regarding day/night and seasons of the year conditions is natural choice. These alternative energy sources configurations as necessary parts have accumulators of electrical energy and controller [2].

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II MAXIMUM POWER TRACKING (MPPT) CONTROLLER FOR PV ARRAYS

Especially in situations when alternative electrical energy sources are not connected to power grid, i.e. when electrical power supply relies exclusively on local alternative energy source it is of the highest importance to use as much energy from available source of energy as possible. So obtaining maximum coeficient of energy utility is highly appreciated, as well as reliability in operation.

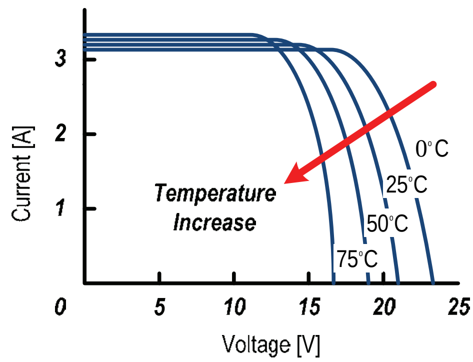

Fig 1. Dependence of PV array voltage (power) on temperature

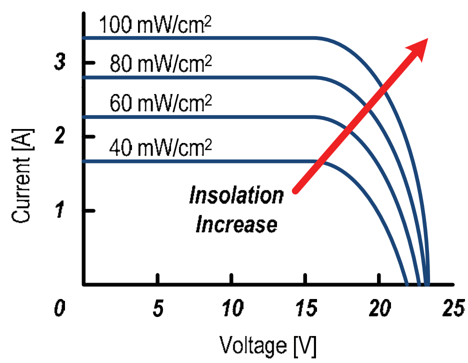

Fig 2. Dependence of PV array voltage (power) on Sun ray intensity per square meter (insolation)

Concerning obtaining as much electrical energy as possible from PV panel array two aspects are of greatest influence:

1) mechanical i.e. position of PV array upper surface to Sun rays direction – optimal position to receive maximum Sun energy is surface perpendicular to Sun light ray and

2) electrical – optimization of coefficient of utilization – conversion of PV array electrical energy to electrical energy given to electrical load (equipment and batteries)

There are two kinds of tracking concerning PV array panels [3]:

1) Panel position mechanical tracking of Sun position – panels are on mount that tracks Sun position across the sky for maximum sunlight energy reception. Increase of obtained electrical energy by this tracking is 15% in winter and up to 35% in summer (at Northern hemisphere of Earth) according to [4]. One should bear in mind that application of mechanical tracking system pose difficulties in maintenance due to existence of electromotor drive and periodic gears lubrication, icing and similar preventive maintenance actions.

2) Maximum power point tracker (MPPT) effects are just the opposite: 20 to 45% power gain in winter (i.e. in the most critical part of year when PV supply is concerned) and 10-15% in summer. This is pure electronic way of tracking and has nothing to do with moving panels. The electronic MPPT controller measure voltage output of the PV panel and voltage of the battery to find out what is the best (i.e. highest) power PV panel can take out to charge the battery. The MPPT controller takes this voltage from PV panel array and converts it to the voltage that gives maximum current in actual situation to charge the battery. According to results presented in literature, configurations with MPPT controllers have 92 - 97% efficiency in the energy conversion while classical approach can give as much as 35% worse efficiency. Actual gain vary significantly all the time depending on the changing weather conditions at the particular location (e.g. Sun light insolation, actual shadowing of PV panel by clouds, rain, fog, leafs, dust, snow etc), ambient temperature and battery state.

As the MPPT controller actually is DC/DC converter that poses optimum load to PV panel and thus makes the PV panel operate at its peak power delivery regime it is basic difference from classic controller solution that takes PV voltage value directly as battery charging voltage.

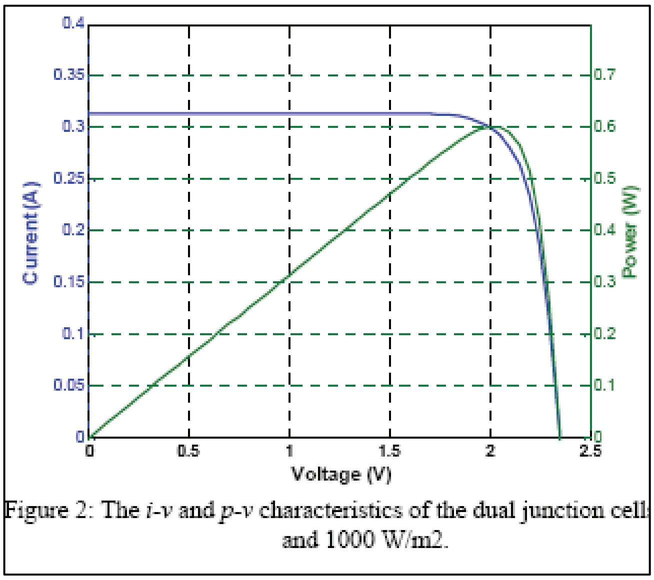

Figure 3. Curent-voltage and power-voltage dependence of the typical semiconductor junction (PV cell) – 1000 W/m2 insolation atambient temperature 20degree ^{0}C

Since the ambient working conditions are continually changing (amount and distribution of radiant sunlight, temperature of the panel first of all) MPPT must constantly adapt its state to obtain maximum energy to battery (consumer) from PV panel. Working point is in the vicinity of zero slope point of p-v curve of PV cell (PV cell is basic element of every PV array that is formed by connecting PV cells serial and parallel configurations according to request and needs of end users). One can easily see so called “knee point” at the p-v curve characterizing PV cell at Figure 3. (i.e. actual maximum power of PV panel point). At that point from mathematical point of view is zero slope of characteristic, so MPPT controller in varying environmental conditions (i.e. varying working point) tends to be as close as possible to that point to obtain as much as possible power from PV source of energy to deliver to battery and load.

III Description of the Chosen Alternative Source MPPT Configuration

Due to the very hard access to the location and severe meteorological conditions at the location, the redundant configuration of the power supply system for the communication node is chosen. It consists of three completely independent electrical power generators: two PV solar systems with identical characteristics and one independent wind generator based electrical energy generating system. Block diagram of applied hybrid alternative energy supply with MPPT controllers for PV electrical energy power sources is presented at Figure 4.

The total requested autonomy (in the worst case) is 10 days: without any Sun energy available and without any wind stronger than 3m/s available. Complete detailed analysis and estimation based on calculations is presented in [4].

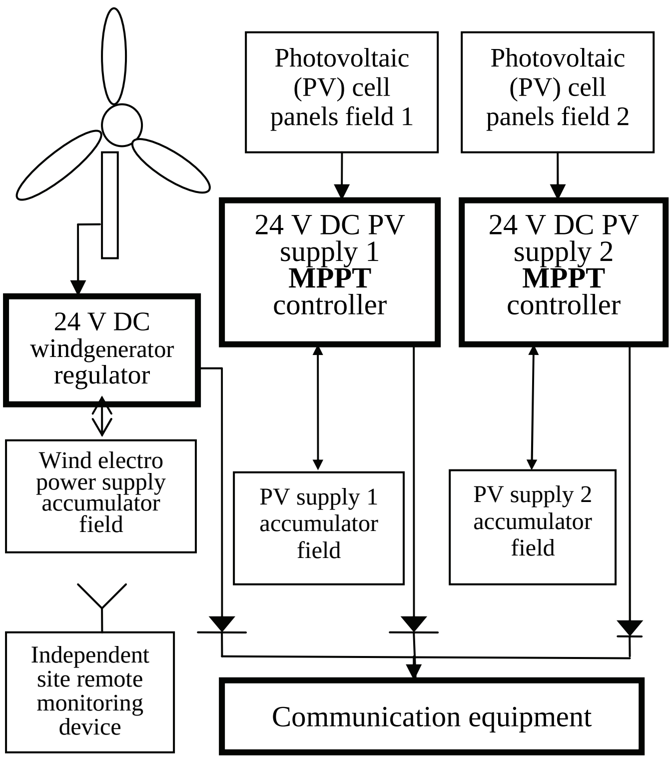

Fig. 4 Block diagram of applied hybrid alternative energy supply with MPPT controllers for PV electrical energy power sources

Due to MPPT controller application availability and autonomy of realized PV electrical power is significantly improved. At the same time MPPT application allowed use of PV panels with smaller dimensions at the field, thus enabling lighter supporting mechanical construction and easier transportation to site.

Reference [5] shows that a single PV solar system fulfills the daily request for electrical power supply, so part of the system based on the wind generator is added in purpose to upgrade the reliability of the electrical power generation 365 days a year. The accumulators are chosen to provide a 10 day total autonomy of the requested power supply for the communication node. The described hybrid alternative power system is for a microwave digital radio relay active repeater station power supply and have to secure uninterrupted functioning 24h/day all over the year in very heavy conditions that are at high mountain hard to access locations. Complete finished repeater station at work with alternative power source is presented at Figure 5. Two PV panel arrays are at the top of cabinet, facing South, and with panel angle to horizon equal to Latitude+22.5^0 (optimal position for the worst position of the site to Sun rays).

Fig 5 Photo of the realized alternative hybrid energy supply for TELEKOM Serbia microwave communication node at hard to reach Orlovac mountain location in south east part of Serbia (1670m Above Sea Level)

Wind generator is placed at the top of the tower to gain as much energy as possible from the local winds. Cabinet contains MPPT controllers, wind generator controller, wiring, fuses, batteries and independent wireless site remote monitoring device (for acquisition of all relevant data).

IV Results Obtained in the Field

The solution with MPPT controllers applied gives exelent results in the field exploitation in extremely harsh mountain environment [2],[4],[5]. Request of the maintenance free power grid independent electrical power source is fully satisfied. By continual monitoring of all vital parameters of digital radio relay node including complete parameters of power supply system – two independent PV supply systems and wind generator system as well, logging all monitored data and periodically in regular intervals sending data packets by independent wireless communication channel to remote monitoring center, not a single one situation of miss functioning or lack of energy for communication node is observed. All the time all the requested parameters of presented alternative power source were deep in the optimal region.

Results obtained during almost one year of exploitation without any problem in the field continually supplying uninterrupted electrical energy for communication node located in the extremely hard to reach mountain region at height more than 1600 m above sea level highly approve applied approach.

V Conclusion

The hybrid alternative electropower generator system based on PV panel electrical energy source and wind generator is build as uninterrupted electrical energy supply of 15 W DC power for communication node situated in very harsh and hard to reach mountain ambient.

For the PV based part of described electrical power generating system maximum power point tracking (MPPT) controller is applied, resulting in field proven high quality utilization of electrical energy obtained from PV array. Almost optimal utilization of PV array generated electrical energy due to MPPT controller usage enabled reliable and stable electrical power supply for communication equipment in all working conditions, including toughest.

Acknwledgement

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