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ANALYSIS OF SOLAR CHARGE CONTROLLERS

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Abstract—*The analysis of solar charge controllers is done. The characteristics of comparison of different types of controllers are determined.*

Index terms—Solar power plant; solar panels; charge controllers; maximum power point tracker; pulse width modulation charge; charge efficiency; charge controllers comparison.

I. INTRODUCTION

As we know, the overall efficiency of the solar power plant depends on following parts: efficiency of solar cells, efficiency of inverter and, as most flexible, efficiency of energy controller.

Energy controller is a main component of solar power plant and maybe the best part of the system which efficiency could be increased after some analysis and hardware improvements.

II. TYPES OF CHARGE CONTROLLERS

Charge controllers could be divided into two main groups by charging principle:

Pulse width modulation (*PWM)* controller – basically, this type of controllers is using primitive switch schematic to connect solar cells array to the battery, as result, voltage of the array output will be decreased to voltage of the batteries (acceptance level). When controller on bulk stage, current that comes from panels are slightly bigger then delivered current to batteries.

Maximum power point tracker (MPPT) controller – most intelligent controller, it begins to adjust its input voltage to follow the maximum power from solar cells an after it, by using different algorithms to find optimal conditions to charge, converts generated power into energy that required by both battery requirements to be charged and consumers (or load).

At Figure 1 we could see main difference on charging circles for this two types of charge controllers. Those tests were performed by [1] and as result we could see that total charge transferred to battery was higher in case of MPPT controller on lower harvested power from panels array.

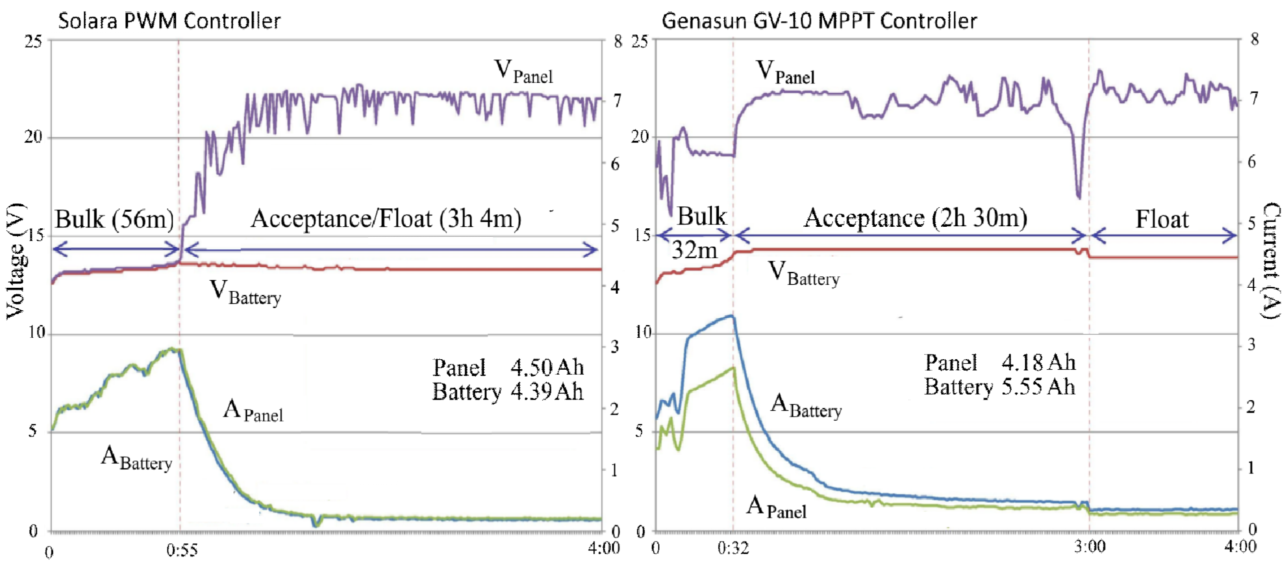

Fig. 1. Comparison of PWM (left) and MPPT (right) controllers

III. MODEL OF SOLAR CELL

To simulate solar cells array, have to provide equivalent circuit of a solar cell, where I_{PV} and V_{PV} are the current and voltage of cell and I_{ph} is the cell generated photocurrent, R_J is the nonlinear resistance of *p-n* junction, R_{sh} is the intrinsic shunt and R_s are series resistances of solar cell (Fig. 2).

Because R_{sh} is large value when R_s is small one, these values could be removed for simplification of the model:

$$I_{PV} = n_p I_{ph} - n_p I_{rs}\left(\exp\left(\frac{q}{kTA}\frac{V_{PV}}{n_s}\right) - 1\right),$$

where n_s is the number of cells connected in serial order and n_p are the number of cells connected in parallel order; q is the electron charge; k is the Boltzmann's constant; A is the *p-n* junction factor constant;   is the cell temperature; I_{rs} is the reverse saturation current of the cell.

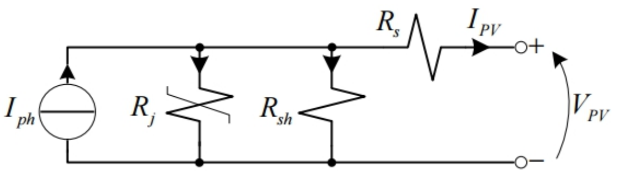

Fig. 2. Power loss between power output of MPPT and PWM controller

IV. Maximum Power Point on C-V and P-V Curves of Solar Panels

To describe this dependencies, we could use basic characteristics of solar panels that could be shown on Fig. 3. This plot represents two basic curves: current-voltage and power-voltage curves, this all curves are all drawn agains voltage axis.

P-V curve represents power obtained from the solar cells, and equals zero when it in short circuited state or when there are no current from the panels (open circuit), these points are I_{sc} and V_{oc} on the plot. Also, this power curve has a visually maximum point. And maximum power point (P_m) on C-V curve could be reached by following criteria:

$$R_m = I_m V_m,$$

where I_m and V_m could be found on the plot on projection of maximum point of P-V curve to C-V curve.

As result, if charge controller needs to get maximum output power of solar panels, it should be able to find and choose optimal point on C-V curve which will be Maximum Power Point (MPP), and this type of controller could be nameв as MPP tracker or MPPT. This is a main difference to PWM type charge controller, where it's voltage input decreased and equals to the voltage of the battery and in result we have less efficient power harvesting or power loss that demonstrated on Fig. 4.

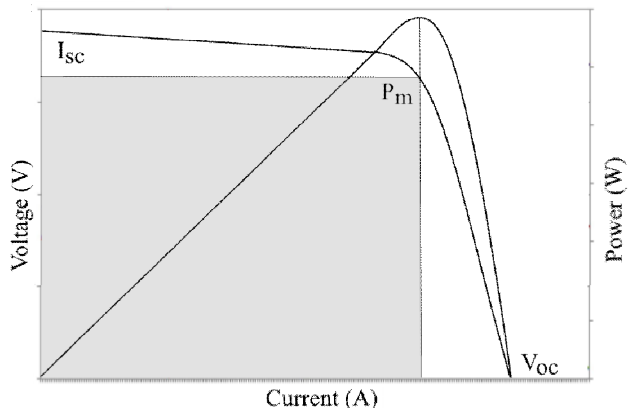

Fig. 3. Finding maximum power point via C-V and P-V curves

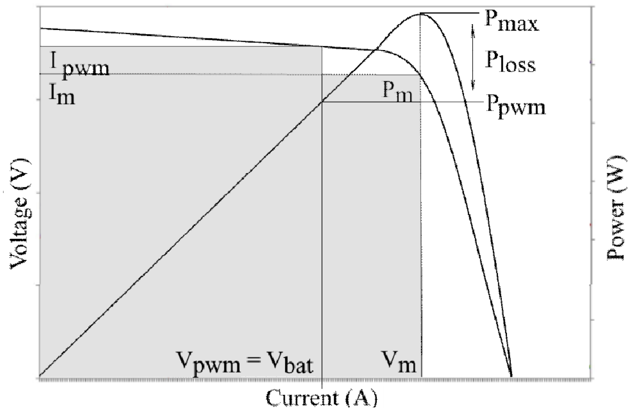

Fig. 4. Power loss between power output of MPPT and PWM controller

V. Comparison of Solar Charge Controllers

When selecting charge controller for solar power plant we must take in control many aspects which could help us to decide which solution on each case would be the best to suit its goal.

Lets look into some aspects of solar power plants and build results as Table I for it for each type of controllers [2].

TABLE I

DEPENDENCY OF THE REFLECTANCE OF SUNLIGHT AT DIFFERENT ANGLES OF INCIDENCE (GLASS) AND DIRECT POWER LOST

	PWM controller	**MPPT controller**
1	**2**	**3**
Array Voltage	Solar panels array and battery voltage must be equal	Solar panels array voltage could be higher than battery voltage

1	2	3
Battery Voltage	Best performance could be achieved on ideal temperature (near 25 C) and when battery is almost full.	Battery could be boosted on cold temperatures and on low capacity.
System Size	Best suited for smaller systems where benefits from MPPT controller are cost-ineffective.	Mostly, 200 W+ power plants are begin to take advantages from this type of charge controller
Array Sizing Method	Sizing is based on current production on fixed battery voltage	Sizing is based on power production where main characteristic is maximum charging current of MPPT controller and acceptable battery voltage

VI. CONCLUSIONS

The analysis of proposed controllers showed the advantages of MPPT controller due to the higher total charge transferred to the battery on lower harvested power from panels array.

REFERENCES

[1] Coastal Climate Control, Inc., Choosing a solar controller – MPPT vs PWM. http://www.coastal coolaids.com

[2] Solarcraft, Inc. PWM vs MPPT Solar Charge Controllers. http://www.solarcraft.net

[3] Roberto Faranda, and Sonia Leva, "Energy comparison of MPPT techniques for PV System." *WSEAS transactions on power systems*. Issue 6, vol. 3, June 2008, pp. 446–455.

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Д. П. Карабецький. Аналіз сонячних зарядних контролерів

Виконано аналіз контролерів сонячного заряду. Визначено характеристики порівняння різних типів контролерів.

Ключові слова: сонячна енергетична установка; зарядний контроллер; пошук точки масимальної потужності; ШІМ заряд; ефективна зарядка; порівняння зарядних контроллерів.

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Д. П. Карабецкий. Анализм солнечных зарядных контроллеров

Выполнен анализ контроллеров солнечного заряда. Определены характеристики сравнения различных типов контроллеров.

Ключевые слова: солнечная энергетическая установка; зарядные контроллеры; поиск точки максимальной мощности; ШИМ заряд; эффективность заряда; сравнение зарядных контроллеров.

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