Contributions to the development of acid battery charging regulator from photovoltaic panels with MPPT function

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***Abstract* — This charge controller can be used with all different types of photovoltaic panels and batteries. Its control unit generates variable 0-100% duty cycle, resulting in efficient battery charging. To optimize the energy losses at the connection between photovoltaic panel and battery, this type of controller contains a MPPT algorithm, implemented with the help of a microprocessor.**

I. INTRODUCTION

Charge regulator (Fig.1) is used in photovoltaic systems, coordinating the functions of photovoltaic panels, batteries and consumers. The controller contains several protective functions, so that the entire system to operate efficiently and safely.

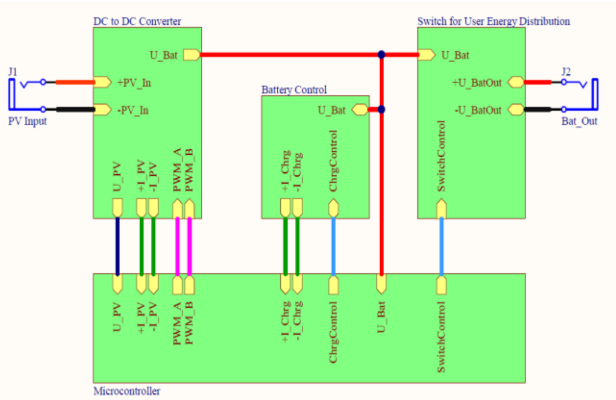

Figure 1 Schema of device.

The device consists of:

- Microcontroller
- DC to DC converter
- Battery Charger
- User control

Control module based on microcontroller ATtiny44V keeps control on the photovoltaic array voltage and accumulator. In case the battery is discharged below the minimum allowable limit, the microcontroller disconnects the load to prevent over discharge and enter Charge algorithm [5]. If the battery charge current is zero or small, Maximum Power Point Tracking of solar battery array is activated.

II. WHAT DOES MPPT MEAN?

MPPT (Maximum Power Point Tracking) represents the maximum power curve of the voltage - current. With charging algorithm, the controller takes the most energy available from solar panels and transmits it to the battery with minimum losses.

To charge a battery as a photovoltaic panel it is necessary to provide higher voltage than the battery. If the voltage (V_{mp}) photovoltaic panel is under the battery, the charging current is zero. Therefore the measured voltage (VMP) to photovoltaic panels terminals of 12V, is generally, 17V measured at 25 ° C. The reason is that on a very warm day the voltage can drop to 15V, and can go up to 18V on very cold days.

When the voltage from solar panels is less than the battery voltage, it means that the battery charge does not occur. MPPT controller makes an analysis of the PV panel output voltage and compares it with battery voltage.
Following this analysis, the controller decides the optimal power load of photovoltaic panels with DC-DC converter for charging the battery.

The MPPT algorithm, built in the microprocessor controller, calculates and adjusts continuously the optimal voltage that can be charged with maximum current battery charged by photovoltaic panel, battery charging current that is essential. Most modern MPPT controllers have a conversion efficiency close to 92-97%. With this device, a typical increase between 20% and 45% of the amount of energy transferred during the winter and between 10% - 15% in summer can be obtained. Energy gain depends on the weather, temperature, solar radiation changes, battery charge status, differences in manufacturing of photovoltaic panels, and other factors.

MPPT controllers operate most efficiently in the following situations:

In winter and / or on cloudy, foggy days , when extra energy is needed.
In cold weather: solar panels work better at low temperatures, but without the MPPT algorithm the electrical power generated additionally is lost. Low temperatures are found in winter when the number of sunny hours is low and all the energy is needed to recharge the batteries.

III. MPP TRACKING ALGORITHM

In literature, there are many MPPT algorithms including the most used P&O (perturb and observe algorithm

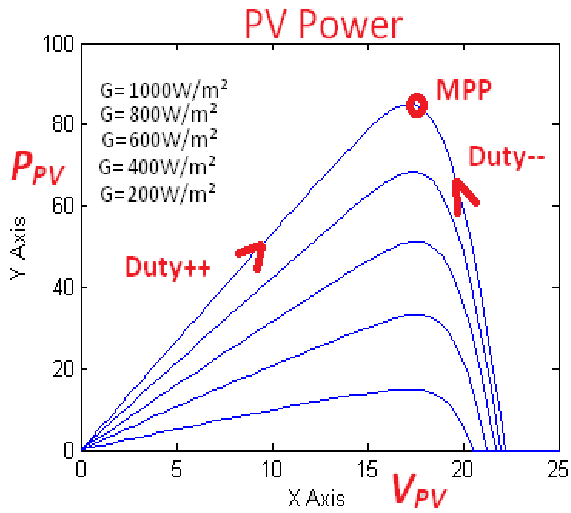

Figure 2 Power versus-voltage curve of a PV generator

Due to its simplicity, P&O algorithm is the most popular. The principle of this controller is to provoke perturbation by acting (decrease or increase) on the PWM duty cycle command and observe the output PV power reaction. Fig.2

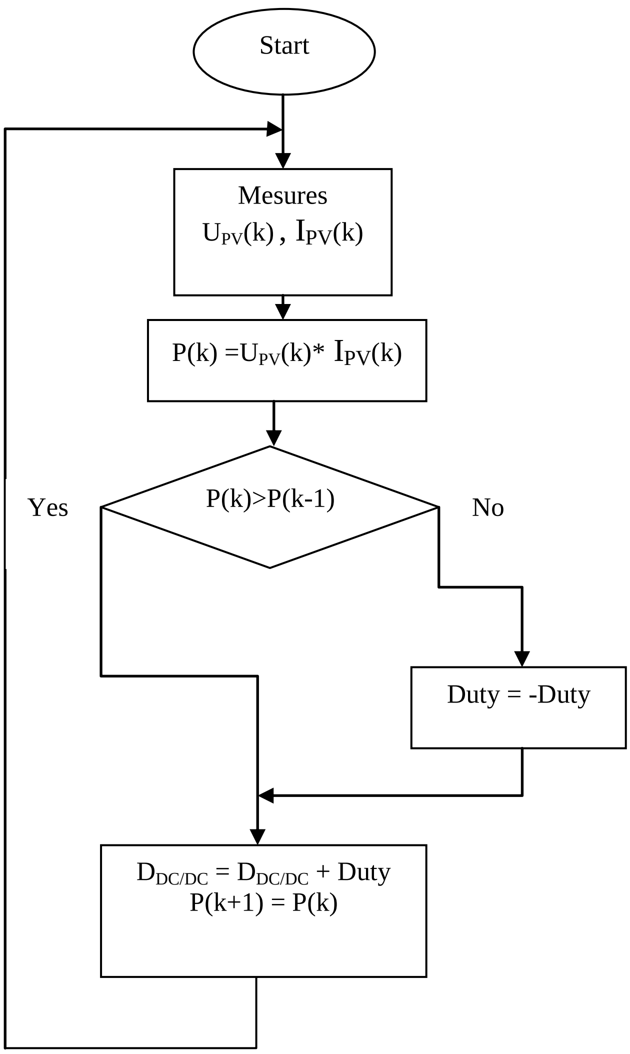

Figure 9. P&O Algorithm structure

IV. DC/DC CONVERTER

Due to temperature and solar irradiation variations, the PV module generated power feeding the load is going through a regulated converter to hold its maximum. Hence, the efficiency of the photovoltaic system is performed. In this section the design the used boost converter is detailed in Fig. 3.

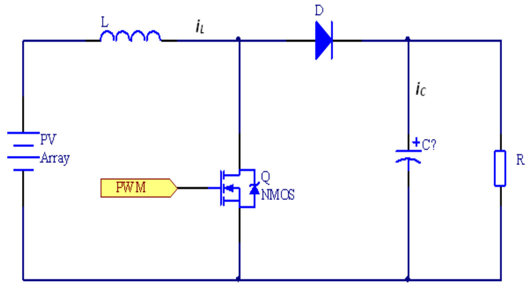

Figure 3 Circuit diagram of proposed Boost converter

The output voltage is always larger than the input voltage. Even if the transistor is not switched on and off the output capacitor charges via the diode until Vout = Vin. When the transistor is switched the output voltage will increase to higher levels than the input voltage.

A distinction is drawn between discontinuous and continuous mode depending on whether the inductor current IL reduces to zero during the off-time or not. With the help of Faraday's Law the continuous mode and steady state conditions can be established.

$$\Delta I_L = \left(\frac{1}{L}\right) V_{in} \cdot t_1 = \left(\frac{1}{L}\right) \left(\lbrack (V \rbrack_{out} - V_{in} \right) (T - t_1)$$

$$V_{out} = V_{in} \cdot \frac{T}{T - t_1}$$

The ratio between on-time and the period t1/T is Duty Cycle.

For continuous mode the output voltage is dependent on the duty cycle and the input voltage, it is independent of the load

V. BATTERY CHARGE

When lead-acid batteries are charged from a variable source, such as PV panels, three charging stages are normally provided by the charge controller:

- Bulk Charge – Current is sent to the batteries of the maximum safe rate they will accept until their voltage rises to about 80 to 90% of their fully charged value. The bulk charging voltage is typically about 14.8V but may be as high as 15.5V for a 12V system, this may vary so that the maximum possible current in maintained. Gel batteries often have lower recommended voltages in the region of 13.8 to 14.1V.
- Absorption Charge – The voltage remains constant, typically about 14.2V for a 12V system (depending on temperature) and the current tapers off as the battery reaches 100% charge.

- Trickle or Float Charge – For a 12V battery bank a voltage of about of about 12.8 to 13.2V is maintained across the batteries to keep them in good condition. Some charge controllers have pulse width modulation (PWM) which can be used to provide the last bit of charge and maintain a trickle charge. Rather than letting the current taper off a larger current is pulsed into the battery, the length of the pulses reduces as less charge is required.

A key rule is that the cell gassing voltage should not be exceeded except during the finishing step of charge. The gassing voltage is the voltage at which the predominant reaction consuming charge current is electrolysis of water in the electrolyte with evolution of oxygen at the positive plates and hydrogen at the negative plates.

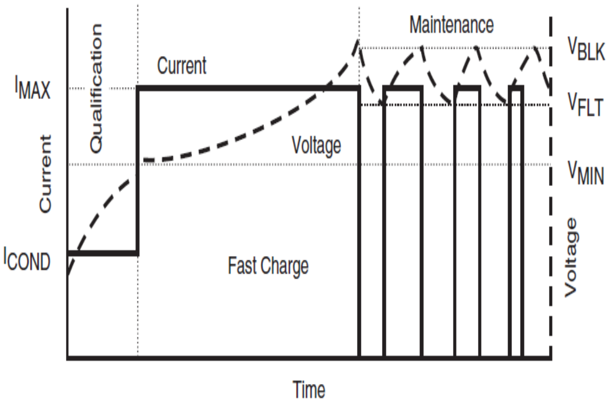

Figure 4 PbSO4 battery-charging profile

Gassing voltage decreases with increasing electrolyte temperature. See Table 1 In PV systems the electrolyte temperature is usually close to (neglecting thermal time lags) room temperature due to relatively low charge and discharge rates represented by many days of autonomy.

Table 1 Temperature Compensated Charge Voltage

AMBIENT TEMPERATURE	**CHARGE VOLTAGE PER CELL**
-20°C	2.970V
-10°C	2.650V
0°C	2.540V
+10°C	2.470V
+20°C	2.415V
+25°C	2.390V
+30°C	2.365V
+40°C	2.330V
+50°C	2.300V

VI. Battery Life

In a small autonomous power system (i.e. one without a mains grid connection) the batteries will be continually charged and discharged. The life span of a deep-cycle battery is normally quoted in the number of cycles that it can be expected to perform, a cycle being a discharge followed by recharging. Deep cycle batteries should not be discharged by more than 60% of their capacity and the less one regularly discharges a battery the longer it will last. A battery in daily use and discharged by no more than 40% of its capacity should last for more than 3000 cycles and may not need replacing for up to 12 years. A battery that is frequently heavily discharged may last no longer than 2 years.

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