Power Conditioning Converter

System Architecture and Regulation of Power Supply

I. PWM or MPPT

Here is a quick remind of the interest of a BCR. Charge regulators are used to handle the output voltage of the PVs and then make it suitable for the battery input voltage. The absence of this electrical system could certainly generate damages to both of the battery and PV. Charge controllers prevent battery overcharging and also prevent the batteries from sending their charge back through the system to the charging source. Because it exists 2 types of charge regulator whose use depends on the type of PV's and battery, the cubesat is integrating : PWM and MPPT. The former is less sophisticated than the latter. Simple charge controllers stop charging a battery when they exceed a set high voltage level, and re-enable charging when battery voltage drops back below that level, adjusting charging rates depending on the battery's level, to allow charging closer to its maximum capacity.

PWM

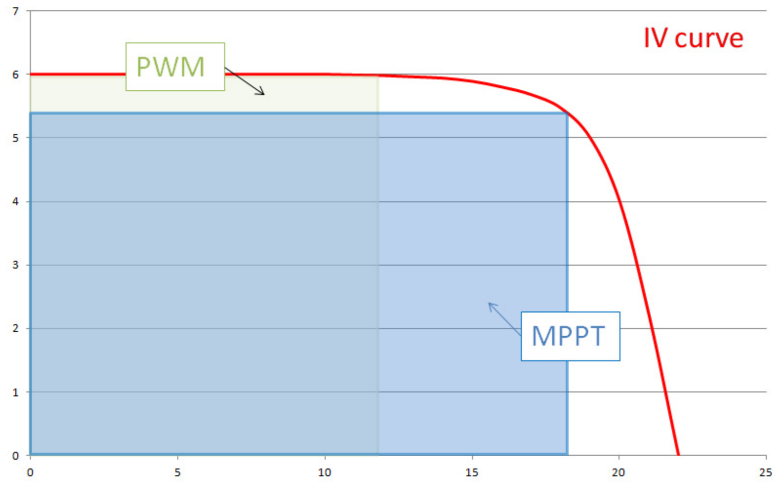
To summarize a PWM is just a simple switch that connects the solar panels and the battery. Then , this is the battery which define the module operating voltage. PWM are mostly use as a pull down. The PV's output voltage is adjusted near to that of the battery. Depending on the charging rate of the battery, PWM systems give out a more or less part of the effective available power. In average, the loss amounts to between 15 and 35 %.

MPPT

The solar panels power curve has a specific point where the tension UMPP and the current IMPP are computed to obtain the maximum power point. MPPT regulator is always precisely computing the maximum power point and convert electronically into the lowest battery tension in order to charge it with the higher current possible.

To fully exploit the potential of the MPPT controller, the array voltage should be substantially higher than that of the battery. MPPT controller is the solution of choice for higher power systems (because of the lowest overall system cost due to smaller cable cross sectional areas). The MPPT controller will also harvest substantially more power when the solar cell temperature is low (below 45°C), or very high (above 75°C), or when irradiance is very low.

Unfortunately due to the fact, that with PWM controllers the PV module is not feeding the battery from its maximum power point (MPP), the system loses a lot of energy. In the following diagram you can see, the area of the MPP in blue (Vmpp * Impp) is up to 30% larger than the PWM area (Vbatt * ~Isc) within the IV curve.



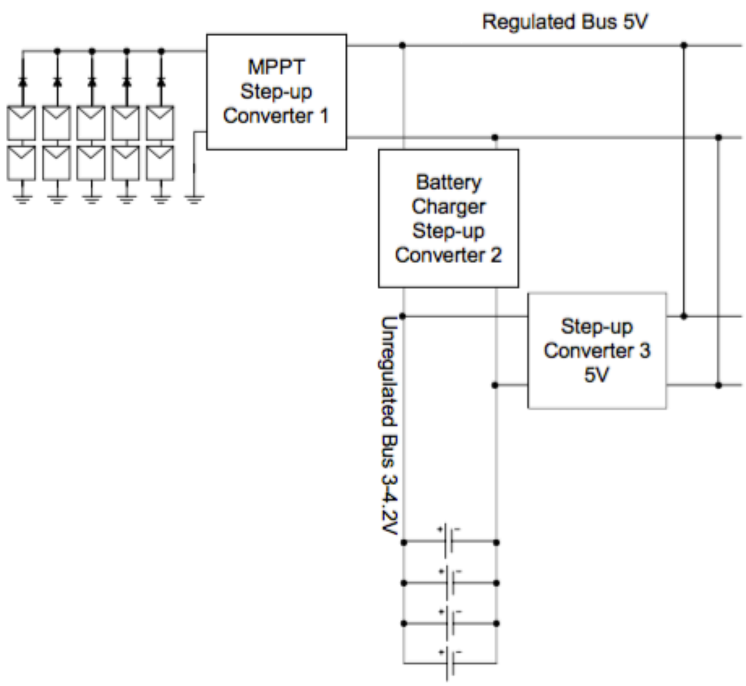
www.victronenergy.com-Matching solar panels to MPPT charge controlers

The PWM charge controller is a good low cost solution for small systems only, when solar cell temperature is moderate to high (between 45°C and 75°C).

MPPT is more sophisticated. The main advantage is that the system will harvest the maximum power from the solar array. A charge controller with MPPT capability frees the system designer from closely matching available PV voltage to battery voltage. Consequently MPPT remains the better choice.

II. The MPPT-driven regulation circuit

The University of Aalborg precised in the system analysis of a similar cubesat student project different arrangements of regulators (MPPT and charge regulators) between PV, batteries and the modules. They detailed 4 layouts of power supply demonstrating their advantages and disadvantages. It appeard that considering the ECE cubesat requirements the following structure could reasonably suit the power system :

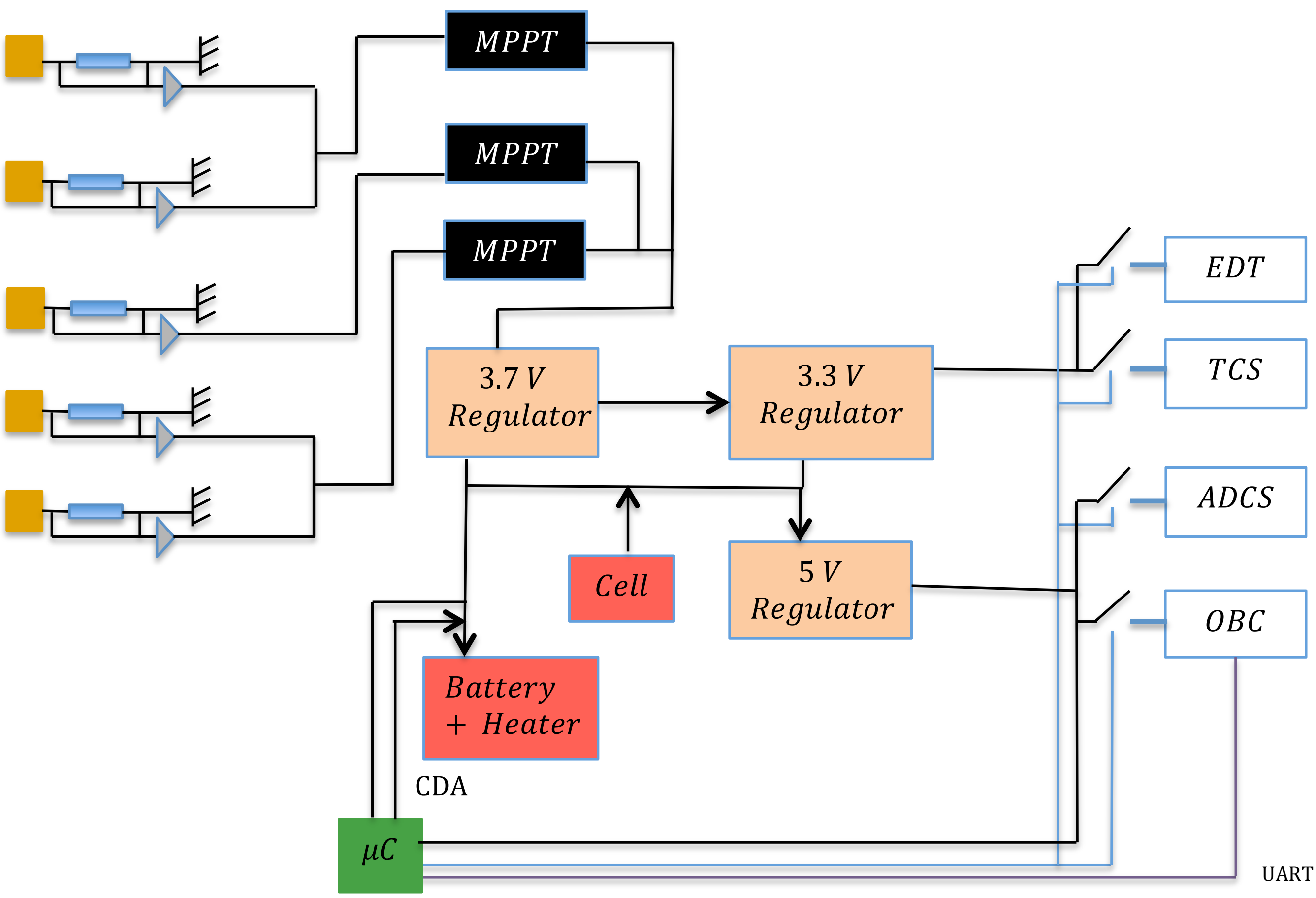


Since the cubesat modules has been sized to receive 3.3V and 5V voltages, this configuration seems well adapted as it provides a good redundancy for 5V supply. However according to the power supply study, it has been established that a 3.3V regulated bus detumbling could be used to connect ADCS and TCS, the other 5V converters will be connected to OBC and EDT. These figures are for now only indicative and will have to be changed accroding to the need of each module.

For the safety of the cubesat during the revolution around Earth all modules will be both connected directly to the solar panels (through MPPT) and the battery. As explained above, only the configuration of the MPPT allows automatically the battery to charge when the voltage drows back to a certain voltage level. Thus, the modules will receive power directly from solar panels when this situation is happening. Then the Micro Controller Unit (MCU) will adapt the modules consumption.

The MPPT will have to handle a maximum input voltage of 4V from solar panels and supply power to a 3.7 V battery. Redirecting the current to a 3.7V converter protecting the battery or the other regulators providing energy to the modules (3.3V and 5V). The modules are both connected to the panels and the battery, that is why regulators will be connected in parallel to the MPPT output and the battery. An additional cell has been integrated because of the large amount of energy needed for the *detumbling* phasis, the battery will not be enough to ensure the power supply in this time.

A schematic of the description above, develops the architecture more clearly :



Protection circuits are provided for every load. The main function is to limit the output current to a safe level and to give a flag to the MCU indicating an overcurrent. It can also be driven externally to connect or disconnect the user through the intermediary of opto coupled switches. The current is measured as housekeeping data for each user. The protection for MCU is different than that for regular users. The amount of energy used is not risky enough to use a self-protected voltage regulator with internal limiting and thermal shutdown features.

The MCU is used for gathering and computing the housekeeping data, taking decisions for connecting/disconnecting users in case of failure and communication with OBC managed by a UART bus. The battery charge level is harvested through a digital-analog converter.

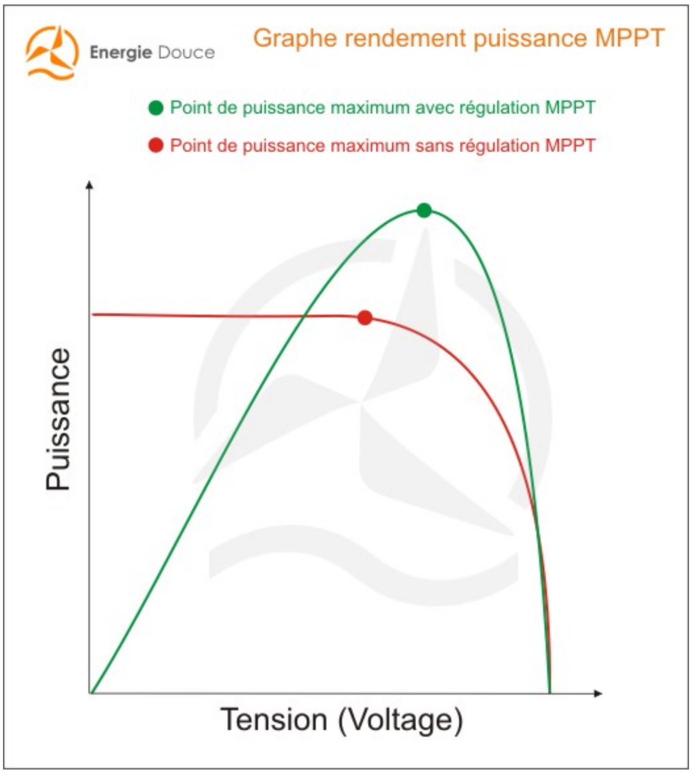
III. Type of regulators

According to the availibility on the market, the type of regulators varies as a function of the input and the output. As the battery charge regulator receives a various input from MPPT which can be superior or inferior of 3.7V, it has to work as a step up and step down regulator. For increasing the voltage to 5V the second regulator should be a step up. As the last regulator decreases the voltage to 3.3V, it should be a step down regulator.

IV. MPPT operation

The maximum power point research is all eletronically driven. The regulator is always monitoring and comparing the voltage delivered by the battery and the solar panels. These computations means finding the maximum level of power (1) the panels can deliver to the battery and (2) the battery can receive. With this maximum power, the regulator determine the most adapted voltage to have the maximum current in the battery. Generally the performance is close to 95%. 100% is never obtainable because the voltage feeding the battery should always be superior to its capacity. Furthermore, there is two main outstanding of using an MPPT.

- in very cold environment the MPPT increase in efficiency.
- The more the battery voltage level is low the more the MPPT supplies it in current.



Maximum power point using MPPT regulation (green) and without (red)

The MPPT research system is a DC to DC converter . The device convert the C current from the solar panels in AC current with high frequency and convert it again in DC current whose tension and intensity is well adapted to the battery. MPPT regulator works with very high frequency, generally in a range of 20 to 80 kHz, because they can be build of small and efficient transformer.