**MPPT Solar charge Controller**

This project was started by Debasish Dutta in India. I am contributing to designing a more advanced version with greater capacity and more potential applications.

When complete, this controller should be useful for off grid electricity users, control of autonomous street lights and signs, and many other applications that need medium power levels and efficient reliable operation.

**Requirements for MPPT controller Version 4.**

I suggest we need a "Version 4" or even an entirely new project, and should engage in a bit of consultation with all of the people you have received comments from, before we undertake the hardware and software design process.

Changes I see at the moment are:

1. increase panel voltage rating to allow for panels with 60 cells (ie up to 40 V, so-called "grid connect" panels);
2. higher current rating, at least 20 amps and preferably 40 amps;
3. metering current on the battery and load;
4. improve design robustness to ensure external conditions do not cause any failures;
5. design that allows multiple controllers to feed into a power distribution switchboard;
6. Optimal battery management for several different battery types, such as Lead Acid (several variants), NiFe, LiFePO;
7. Ability to control more than one load output – either to allow for greater capacity, or timing control of when the output is on or off.
8. Real time clock with date to enable time stamping of statistics and timer control of loads.
9. operational configuration capability (buttons or via WiFi?);
10. greater data collection to get illumination statistics, battery performance statistics, load statistics.
11. higher battery voltage (to 24 or 48 V) and associated higher solar panel voltages;
12. much higher panel voltage (to 150 V or so)
13. Multiple Load outputs regulated to close to 12 V
14. Panel safety and overload disconnect

In addition there are some “internal” matters that are worthy of investigation:

1. focus on maximising efficiency
2. fail-safe software or self-recovery features
3. MPPT algorithm refinements
4. will it all fit in Arduino Nano?

// we should not restrict to Arduino Nano; it may be other Arduino compatible board which suit to our requirement.

Arduino Nano, Arduino UNO and Arduino Pro Mini all uses same MCU i.e ATmega328P.But including Pro Mini in final design is better as its size is small and price is less in compare to other boards with same features.We can test it by using any board ( with ATmega328 MCU ) stated above.

// http://www.arduino.cc/en/Main/ArduinoBoardProMini

**Discussion**

1. increase panel voltage rating to allow for panels with 60 cells (ie up to 40 V, so-called "grid connect" panels)

The majority of solar panels being sold today have 60 cells and a maximum power point voltage of about 30 Volts. Being unable to use this type of panel would restrict the choice of panels for the user, and very likely increase the cost.

To enable this higher voltage we need to check the voltage ratings of all components, and make sure that the buck converter inductance, capacitors and PWM algorithm are compatible.

// 60 cells or 40V choice is more versatile than others rating solar panels

// So our choice is 60 cells

Keith: As a good example, the Trina Honey TSM-PC05A with 60 cells has a maximum open circuit voltage at STP of 38.1 Volts. Its MPP voltage at STC is 30.6 Volts. If the temperature of the panel is -10 degrees C, the OC voltage rises to 42.5 Volts (calculated value). So our components need to withstand an OC voltage of at least 85 Volts, and work efficiently with an MPP voltage of 61.2 volts or maybe a little more in case the panels are colder than STC (25 degrees C).

1. higher current rating, at least 20 amps and preferably 40 amps;

Many installations require more power than 50 Watts. A design that allows for up to 500 Watts with a 12 volt battery would be more useful to more users.

To enable higher current we need to make sure the current rating of key components are sufficient, or make a modular design that distributes the extra current across several modules. With higher power the converter efficiency will be a prime concern, in particular (but not only) because of the need to keep components within their allowed temperature ranges. Depending on the number of modules, we may run out of digital interfaces on the Arduino Nano.

// we should choose 40A for more reliable and useful applications

1. metering current on the battery and load;

Introducing current measuring on battery and load will enable the gathering of more comprehensive statistics, as well as ensure that the current ratings of these interfaces are not being exceeded, resulting in greater robustness.

Design changes include adding additional current metering modules (similar to the Solar Panels metering) and will consume an additional Arduino analogue interface for each module.

// we have to add another Current Sensor at load side

Petar: We must choose current sensor between ACS chips, TL431 or OP-AMP method. I think that TL amd OP-AMP is more safety for MCU than ACS chips. I think that all current sensors must be identical.

* ACS758 can measure up to 200A
* TL431 is precision voltage reference and we can measure the difference between setpoint voltage changed value of voltage
* OP-AMP: <http://m.eet.com/media/1122458/sense2fig1.gif> I think that the explanations of how it work is unnecessary.

Keith: to meter both battery and load we need 2 more current sensors. The existing device ACS712 should continue to be OK on the solar panel side, although the less sensitive version would be needed. However on the Battery and Load interfaces, the ACS712 is optimised for up to 30 amps, so would not quite meet the requirement for 40 Amps. We need to look at other options.

1. improve design robustness to ensure external conditions do not cause any failures;

Making the design resilient to incorrect connections (eg polarity reversal), short circuits, overloads, excessive solar panel power will make more customers happy with the equipment.

This improvement should make use of current metering on the input and output side, and possibly add a temperature measuring device for components that carry high currents (requires another Arduino analogue interface). As well as this the software will need review and change.

// Reverse Polarity to be included, I think others protections already implemented

Keith: I think we also need to add temperature sensor(s).

Petar: We can use DS18B20 which is One Wire Temperature sensor. In this way we releasing one analog input. Arduino have library for One-Wire protocol.

1. design that allows multiple controllers to feed into a power distribution switchboard;

Installations with higher power may need to be constructed using multiple sets of panels and associated controllers, feeding to a single battery and load distribution switchboard.

Typical load distribution switchboards use a common Earth bar and multiple distribution ponts for the positive side. The existing design turns off the load by interrupting the Earth side of the load circuit, which is likely to create an Earth loop and would not be effective. The positive side of the load needs to be the one that is controlled.

// Not getting // need some example

Keith: I will draw some pictures and make them available soon.

1. Optimal battery management for several different battery types, such as Lead Acid (several variants), NiFe, LiFePO;

Although lead acid batteries are commonly used in off grid power systems, several other battery chemistries are available. The economics of different chemistries results in a diversity of optimal charging regimes.

This is mainly a matter of software to implement the best charging regime for each chemistry, and requires a means of operational configuration to select the type of battery currently connected.

// It’s really an interesting idea which can make our controller more powerful and enhanced the applications area

// LiFePo4 is most emerging now a days .So we should focus more on Lead Acid and LiFePo4 first then include other chemistry

// Need help from some good coder for implementing charging algorithm

Petar: Should the user select battery type with key or controller will select it automatically? Will we add more buttons and customisable options?

1. Ability to control more than one load output – either to allow for greater capacity, or timing control of when the output is on or off.

Loads may be classified into priority classes, so that if battery energy is at risk of running out, the low priority loads could be disconnected and the battery energy in reserve kept for the high priority loads.

To implement this requires more than one controlled load output, with associated Arduino control interface and configuration software.

1. Real time clock with date to enable time stamping of statistics and timer control of loads.

A real time clock will improve usability of collected data, and provide more sophisticated control of the load or loads.

This is a software change to keep track of the time and datel; and requires operational configuration capability to set it correctly.

// by including a RTC, it helps in software for all time related calculations

// DS1307 is most popular module used for Arduino which uses I2C communication for interfacing with arduino

//Arduino can communicate more I2C module by using same pins ( only address of the module to be different )

Petar: RTC is useful.

1. operational configuration capability (buttons or via WiFi?)

Once we introduce more than one way to operate the controller, it becomes necessary for the user or installer to be able to select the appropriate configuration.

To provide operational control, we need something like 6 buttons (maybe less) and some way to receive the data in the Arduino. Alternatively, it may be possible to do this control via an Application on a mobile device via the WiFi interface.

// At the beginning stage we should implement control from a button and data logging through the WiFi Module. Later we will implement WiFi control

1. greater data collection to get illumination statistics, battery performance statistics, load statistics.

With the addition of additional current metering and possibly temperature, these will allow two sorts of things: collection of more raw data; and situation-dependent data collection (collecting data when set conditions are reached, such as battery charge or discharge levels, temperatures, power levels, etc.)

This is a software function, based on hardware added for other reasons.

1. higher battery voltage (to 24 or 48 V) and associated higher solar panel voltages

Installations that require higher power and energy commonly use multiples of 12 Volts as their battery voltage – typically 24 or 48 Volts. Being able to adapt to these higher voltages would bring this controller into a wider market for solar panel systems.

Design changes involve revision of voltage ratings of components, revision of the buck converter components, and configuration capability. Solar panel voltage needs to increase at least to cover the increase in battery voltage (eg 30 V for 24 V battery, 60 V for 48 V battery).

// Auto detect of battery voltages 12v/ 24V/ 48V

//This can be easily done by software by detecting the battery voltage. Then updates all the charging set points accordingly

Petar: For different battery voltage we should use different voltage devider for accurate measurement.

1. much higher panel voltage (to 150 V or so)

Higher power installations commonly need to separate the panels from the controller, because of space restrictions. With greater separation comes either thicker wires over a longer distance, which can be a significant cost; or running multiple panels in series to give a higher voltage but less current, saving cost for wire.

Design changes are to ensure the higher voltage is compatible with all components. Also it is necessary to have a higher focus on occupational health and safety, to minimise the chance of electrocution. This in turn may lead to additional hardware (eg metering) and software changes.

1. Multiple Load outputs regulated to close to 12 V

With the addition of capability for a higher voltage battery, the ability to operate DC loads at 12 Volts is lost. Also all chemistries require more than 12 volts during the charging stage, with the excess voltage over the nominal 12 volts varying from 1 or 2 volts to up to 6 volts. One or more regulated outputs at just over 12 volts (possibly adjustable) would enable the correct voltage to be delivered to DC appliances in an off-grid installation.

1. Panel safety and overload disconnect

In some countries, the regulatory regime requires solar panel installations to be installed with circuit breakers at least in the solar panel interface, so that a worker can disconnect the panels from Earth and eliminate dangerous voltages.

A manually switched control that isolates both positive and negative from the solar panels, and which operates automatically in case of excessive current or unbalanced current, could remove the need for a separate circuit breaker at least in some countries.

**Design approach**

It is still early days in the design and implementation strategy, but the concept I expect to start with is a modular one, where there is essentially a single buck converter design, consisting mainly of the switching elements (almost certainly MOSFETs), inductor and capacitors, with about a 10 Ampere capacity. Multiple units of these will be combined into the final product to achieve the target capacity. Efficiency is a key requirement. I am thinking of an initial design target of 96% efficiency (ie 4% losses). At 40 Amps and with a 12 Volt battery, this equates to (40\*12)\*4% = about 20 Watts. This level of heat generation should be OK without fan forced cooling, especially if we can use some metal heat sinks for key components and there is space for reasonable air flow through the enclosure.

A modular design should also make the development process a bit easier, since we can do testing on the modules without having to test the complete capacity.

**Design stages**

The first steps of the design are to look at the following:

* digital and analogue input/output requrements for the Arduino Nano
* inductor sizing, design and its impact on efficiency
* switching element (MOSFET) selection and its impact on efficiency
* operational control interface via WiFi

Once preliminary decisions are made on these, we can put together a more detailed design description, performance and efficiency modelling, and hopefully start work on example hardware and software.

Keith: I suggest that, as part of deciding on the key converter items (Inductor, MOSFETs, switching period) the following table needs to be filled in for the selected design with calculated efficiency values for each cell in the table. Notes should be added which can reference information about the main source of the losses, whether the controller is in CCM or DCM, and any other relevant information.

I think we should aim for at least 96% efficiency in every cell of the table.

It is not clear yet whether we need a modular design, or if we can do it with a single buck converter output stage.

With a single output stage at least, at light loadings the converter will be in Discontinuous Current Mode (DCM). All the analyses I have seen show a much greater efficiency in DCM with a diode for the ground path, compared to the synchronous design with a MOSFET in the ground path (Q2). The use of a diode (ie asynchronous converter) will reduce efficiency at high loads (I expect). I am interested in exploring alternatives that do not sacrifice efficiency at any load level, such as modular designs, and synchronous operation with the Ground MOSFET turned OFF when it would otherwise conduct current from the output back to ground.

Calculated Efficiency results

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Panel Voltage | | 18 | 30 | 60 | 30 | 60 | 60 |
| Battery Voltage | | 12 | 12 | 12 | 24 | 24 | 48 |
| Load current | |  |  |  |  |  |  |
| % | Amps |  |  |  |  |  |  |
| 1% | 0,4 |  |  |  |  |  |  |
| 5% | 2 |  |  |  |  |  |  |
| 10% | 4 |  |  |  |  |  |  |
| 20% | 8 |  |  |  |  |  |  |
| 50% | 20 |  |  |  |  |  |  |
| 80% | 32 |  |  |  |  |  |  |
| 100% | 40 |  |  |  |  |  |  |