Algorithm Based hybrid battery charge controller

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Abstract: *Maximum power point tracking manipulates the load or output voltage of an photovoltaic array in order to maintain operation at or near the maximum power point under changing temperature and irradiance conditions and to charge the battery. It is very important to improve the efficiency of charger. Charge controllers are usually installed in Solar Systems to protect batteries (from over charging and discharging) and to implement proper buck and boost charging techniques. Some MPPT controllers have also been developed to incorporate multiple charging sources (e.g. Main-Grid or PV panels). However, these controllers lack proper charging techniques to ensure efficient use of multiple charging sources. Also due to improper charging algorithm there might be unnecessary or insufficient charging of batteries. This paper presents a design of peak usage time and prediction algorithm based battery charging technique which enables intelligent battery charging decision which improve the battery life and efficiency of battery. Specifically, the system will use Mains charging only when Solar charging is insufficient. Also, the system will decide when to preserve battery and use Mains as direct drive loads. These decisions are made to utilize more solar energy and less Mains electricity while maintaining high reliability and improve efficiency. The decisions will be based upon battery's state which is calculated using various data such as peak usage time, solar voltage, solar current, load's power demand, batteries' specification etc. the system designed with this technique has better performance over other solar charge controllers.*

Keywords: *Solar System, PV panel, Peak usage time, prediction-based, hybrid charge controller,MPPT,PUT*

I. Introduction

Over the past few years solar systems are gaining popularity and it is one time investment. A solar system (SS) has an inverter, panels, batteries and charge controller. Conventional electronic charge controllers for SS are generally installed to protect batteries, from overcharging /over dis charging and to implement proper charging based on peak usage time techniques. Some solar charge controllers have also been developed to incorporate multiple charging sources (e.g. Main Grid or PV panels) to charge batteries according to the availability of the sources. Though many implementation and ideas are being developed, there is still lack of appropriate algorithm for proper utilization of solar charging sources. Majority of the charging techniques developed till now basically deals with maximizing power utilization of a single source. However these techniques do not enable automatic charging decisions to ensure efficient use of solar or mains charge sources. For instance, these controllers do not decide when it is appropriate to charge battery using Mains (Main-Grid) in addition to Solar with peak usage time and battery state. Due to lack of protection and decision, batteries in such places are either overcharge or less charged. For example, if the batteries are charged by Photo voltaic panels alone, it may not be sufficient during rainy days. This will create problem in continuous power supply. If the batteries are also charged by main line without any intelligent decision, then they may be unnecessarily charged battery. This will simply affect the battery life. This paper proposes a peak usage time and prediction - based algorithm which enables intelligent battery charging decisions based upon calculated battery's state and mains availability. The calculation is based upon several data such as solar voltage, solar energy availability, time schedule, battery specification, and load power demand and panel specification. Specifically, the system checks if solar charging alone is sufficient to charge battery to adequate level which will ensure reliability for certain time. If solar not sufficient, the controller employs Mains (if available) to charge the battery, thereby increasing the rate of charge. The system also makes other intelligent decisions according to climate condition for preserving battery, i.e. disconnecting or connecting battery as direct source to loads and connecting Mains as direct drive load. All these intelligent decisions are performed in order to maintain high efficiency while utilizing more solar energy and less Mains electricity.

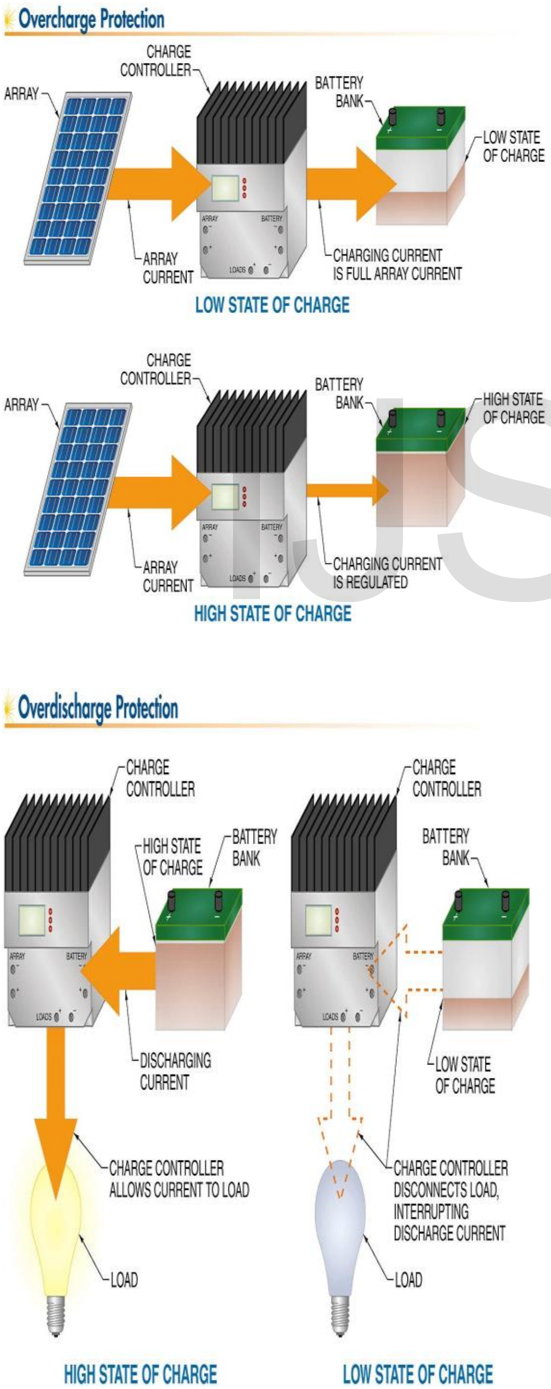


Fig.1 Over charge and over discharge protection

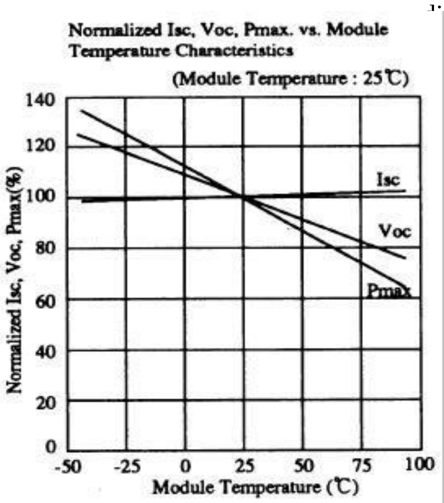
II. Maximum Power Point Tracking (MPPT)

Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of. MPPT is not a mechanical tracking system that "physically moves" the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Additional power harvested from the modules is then made available as increased battery charge current. MPPT can be used in conjunction with a mechanical tracking system, but the two systems are completely different.

To understand how MPPT works, let's first consider the operation of a conventional (non- MPPT) charge controller. When a conventional controller is charging a discharged battery, it simply connects the modules directly to the battery.

This forces the modules to operate at battery voltage, typically not the ideal operating voltage at which the modules are able to produce their maximum available power. The PV Module Power/Voltage/Current graph shows the traditional Current/Voltage curve for a typical 75W module at standard test conditions of 25°C cell temperature and 1000W/m^2 of installation. This graph also shows PV module power delivered with respect to module voltage. For the example shown, the conventional controller simply connects the module to the battery and therefore forces the module to operate at 12V. By forcing the 75W module to operate at 12V the conventional controller artificially limits power production to 53W.

Rather than simply connecting the module to the battery, the patented MPPT system in a Solar Boost™ charge controller calculates the voltage at which the module is able to produce maximum power. In this example the maximum power voltage of the module (VMP) is 17V. The MPPT system then operates the modules at 17V to extract the full 75W, regardless of present battery voltage. A high efficiency DC-to-DC power converter converts the 17V module voltage at the controller input to battery voltage at the output. If the whole system wiring and all was 100% efficient, battery charge current in this example would be VMODULE ÷ VBATTERY x IMODULE, or 17V÷12V x 4.45A = 6.30A. A charge current increase of 1.85A or 42% would be achieved by harvesting module power that would have been left behind by a conventional controller and turning it into useable charge current. But, nothing is 100% efficient and actual charge current increase will be somewhat lower as some power is lost in wiring, fuses, circuit breakers, and in the Solar Boost charge controller.

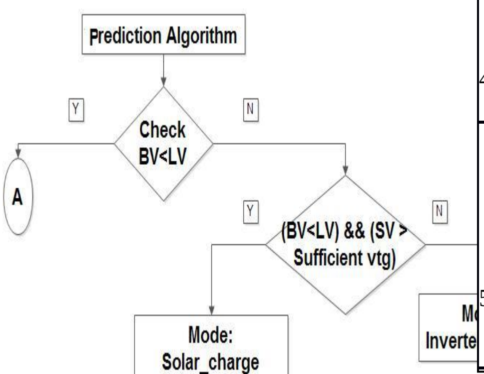


Actual charge current increase varies with operating conditions. As shown above, the greater the difference between PV module maximum power voltage VMP and battery voltage, the greater the charge current increase will be. Cooler PV module cell temperatures tend to produce higher VMP and therefore greater charge current increase. This is because VMP and available power increase as module cell temperature decreases as shown in the PV Module Temperature Performance graph. Modules with a 25°C VMP rating higher than 17V will also tend to produce more charge current increase because the difference between actual VMP and battery voltage will be greater. A highly discharged battery will also increase charge current since battery voltage is lower, and output to the battery during MPPT could be thought of as being “constant power”.

What most people see in cool comfortable temperatures with typical battery conditions is a charge current increase of between 10 – 25%. Cooler temperatures and highly discharged batteries can produce increases in excess of 30%. Customers in cold climates have reported charge current increases in excess of 40%. What this means is that current increase tends to be greatest when it is needed most; in cooler conditions when days are short, sun is low on the horizon, and batteries may be more highly scharged. In conditions where extra power is ot available (highly charged battery and hot PV odules) a Solar Boost charge controller will erform as a conventional PWM type controller.

I. Algorithm Description

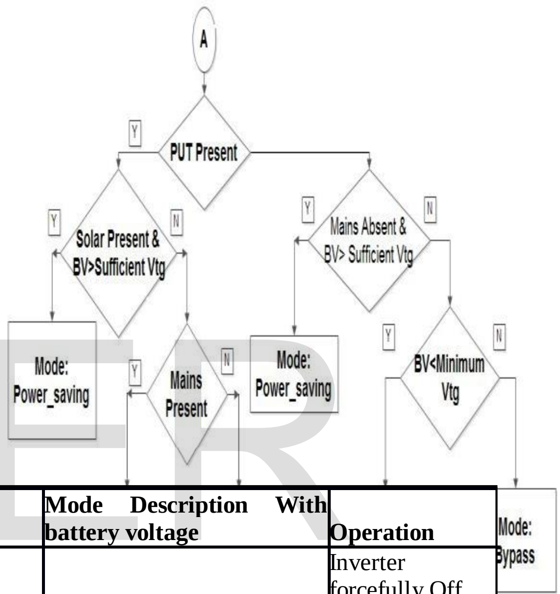
Flowchart of the prediction-based battery arging technique is shown in Fig. 4. In system e prediction algorithm is programmed and loaded a processing unit such as microcontroller which en controls the charge controller. As shown in the gure, the controller first requires various data such as solar energy availability time schedule, peak usage time, solar voltage and current, battery specification etc. It then calculates battery state using these data. The future time for the calculation can have different values it will changes according to time (e.g. 12 - 24 hours). There will be three Battery Conditions (BC) i.e. Excess, Sufficient and low. Determination of BC is further discussed in section 2.2. According to BC, the master controller performs various battery charging operations. For this operation created algorithm in that different mode use. Depending on mode and peak usage time battery charging operation will take place. In all three cases, battery charging will take place via solar as well as Mains. Switching action controlled by controller. If battery condition is critical and solar is not available then charging takes place via mains. Additionally, in the technique, battery's charging limits are also considered and are kept as protective overriding functions. For example, if battery is fully charge, charging via Mains and Solar is stopped completely irrespective to battery conditions. Since the commonly used set points for these overriding functions are also important for determination of BC, Modes are briefly discussed in the following section.Fig.4 shows the flow chart of our system mechanism. In that depending on battery voltage action will takes place. Peak usage time is the time in which battery usage is more. In prediction algorithm, First check battery voltage if battery voltage is less than low voltage (low voltage mode). And solar voltage is above the sufficient level then it will charge the battery from solar voltage otherwise charging will takes place via AC mains. Another condition is depending on peak usage time (PUT) mechanism. If PUT is present, battery voltage is greater than sufficient voltage then our system will work in Power saving mode else it will again check mains present or not. If mains is present then it will working in Bypass mode else it will working in Override mode. If PUT is absent, mains is absent and battery voltage is greater than sufficient voltage then system will working in power saving mode else battery voltage checking takes place depending on that mode switching will takes place. In mode switching, driving circuitry is present it will take care of our system. If solar voltage not sufficient then appropriate switching will takes place and situation will handled by controller.



BV: Battery Voltage

LV: Low Voltage

SV: Solar Voltage



Sl.No.	MODE	Mode Description With battery voltage	Operation
1	SunTap /Power_saving	Battery level is greater than 12.5 and solar present and PUT ON	Inverter forcefully Off, Load drive through Battery and Solar charging
2	Bypass	Battery level is less than 12.5 and greater than 10.5 and mains on, battery will charge through inverter	Inverter Forcefully Off, Load drive through mains ,solar charging
3	Inverter Charge	Battery level is less than 10.5 ,and solar absent ,	Inverter On, drive load from mains, charge battery by inverter
4	Inverter solar charge	Battery level is less than 10.5 ,and solar is present	Inverter Off, drive load by mains ,charge battery by solar
5	Override mode	Battery level is less than 10.5 ,and solar is Absent	Inverter Off, drive load by mains ,charge battery by Mains

Fig. 4: Flowchart of prediction based algorithm

System operation in 5 Modes

Table 1: Modes of System operation

IV. Implementation On Hardware

In this section hardware designs for implementation of the prediction based algorithm are briefly discussed. Design is considered to show how the technique can be implemented in simple way. Fig.5. Show the block diagram of system. In this system sensing circuit, switching circuit, microcontroller section play important role. The mode switching is based on solar voltage and battery. Sensing circuit sense battery as well as solar voltage and provide this data to controller. Controller will calculate the information with predefined data and save all this information with time into EEPROM for future use. Predefined data such as battery Ah capacity, peak usage time, grid voltage and frequency. With the help of this calculation controller send signal to switching circuit. LCD and LED are used for the indication purpose. Buzzer will indicate the critical situation. The RTC provides a time reference to an application running on the device. The current date and time is tracked in a set of counter registers that update once per second. The time can be represented in 12-hour or 24-hour mode. The RTC can interrupt the CPU every time the calendar and time Registers are updated. This will interface our project with the help of I2C bus. EEPROM stands for **E**lectrically **E**rasable **P**rogrammable **R**ead-**O**nly Memory and is a type of non-volatile memory. This is used in our project to store the configuration and also project status for every 60minute The GSM module is used to transfer status of controller and stored data in it to the user. Thus, user can control the charge controller from very long distances. It is used for run time testing purpose also. LDR is used here to sense light intensity and thermistor is used to measure temperature of the solar panel. These parameters are used to produce necessary PWM and thus obtain MPPT for charge controller with the help of ARM processor..

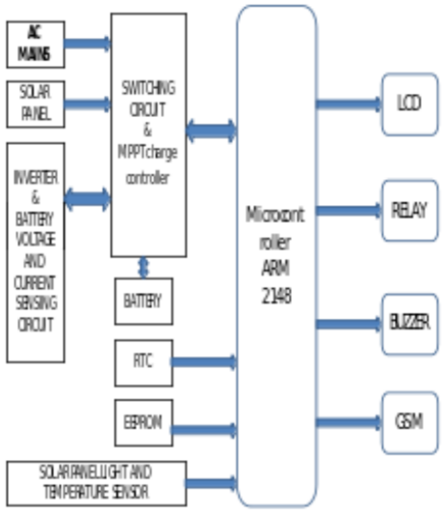


Fig.5. Block diagram of prediction based algorithm

We are dealing with AC so hardware design is very important. One of the biggest challenges in this system is sensing of battery voltage, light intensity and temperature and depending on that calculates the efficiency. For battery sensing separate circuit is designed. Because battery voltage is variable, it will suddenly change its state at the time of connecting load and disconnecting load so we have to take care at the time of battery sensing circuit implementation. This voltage measurement data is useful at the time of battery calculation. Main part of system is switching circuit. The total operation of system is depends on this circuit. IGBTs are used for switching purpose in inverter and controllers and to improve efficiency. SPDT relay are used in switching circuit .Main use of relay is to switch the system mode according to battery voltage. System needed 5V so regulated power supply is design. And for AC indication separate buzzer driver circuit is used. Opto-isolator's driver circuits are used for protection of controller because we are dealing with mains. In this we are using LED driving circuit and switching circuit. LED driving circuit used to indicate the mode of the system and mains availability.

V. Results And Discussions

In order to test Prediction Based System (PBS), i.e. the system designed with the proposed technique, it was programmed in C programming language and simulated in Proteus. Prediction based and peak usage time mechanism is used in this system along with MPPT. It focuses on how to control and manage the solar power. Read input voltage and this data are displayed on LCD. Depending on it switching of relay take place.

VI. Choosing the correct number of battery

Most batterie's AH capacity is stated for the 20-hour rate of discharge. This means that a battery has a 100 A.H. capacity if it is discharged over 20 hours, or at about 5 Amps-per-hour (100 A.H. / 20 hours = 5 Amps DC). However, this same battery would last only one hour if the discharge rate was 50 Amps-per-hour (50 Amps DC x 1 hour = 50 A.H.) because of the high rate of discharge. The more deeply the battery is discharged on each cycle, the shorter the battery life will remain. Therefore, using more batteries than the minimum will result in longer life for the battery bank. Keep in mind that batteries lose capacity as the ambient temperature lowers.

Table 2 Battery capacity and discharge time

Battery Capacity(A.H)	Hours of Discharge
100	20
90	10
87	8
83	6
80	5
70	3
60	2
50	1

VII. Conclusion

This paper included several modifications from the relative works mentioned in the references. Some important modifications are upgrading the system by including the ARM processor, GSM module and use of MPPT charge controller along with a peak usage time and prediction based algorithm for battery charging in solar home systems. The algorithm enables smart battery charging decisions based on MPPT and calculated prediction of battery future state to utilize solar energy, improve battery life and less Mains electricity while maintain high reliability. The main improvement in the system will be done in the calculation efficiency of charging and discharging of batteries. The algorithm is flexible in this respect as such changes can be easily adjusted in technique. Some theories, which give simple empirical relationship between capacity of battery and discharge rate, can be more accurate in this regard. Also, store all relevant data (such as charge/discharge rates, solar availability, load requirement, peak usage time etc.) of one day and utilizing the data for the next day while making calculations in controller. Since the data of days will change according to the climate.. But we can change setting according to our use. But most of the time data store in sequence will have similar pattern, repetition of the above process could yield more effective result. However, more time and research are required to verify that the new techniques and algorithm will be more effective for our system. By the use of GSM user can easily monitor and control the system from remote place also.

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