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Research Article

Design of Peak Usage Time and Prediction Algorithm Based Battery Charging Technique

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Abstract

Solar resource is freely available so government is trying to implement the use of Solar panels as an energy source in rural and sub urban areas for lighting the street lights, but the battery used to store the power gets affected due to overcharging & discharging. Charge controllers are usually installed in Solar Home Systems to protect batteries (from over charging and discharging) and to implement proper buck and boost charging techniques (e.g. Maximum Power Point Tracking etc.).Some MPPT controllers have also been developed to incorporate multiple charging sources (e.g. Main-Grid or PV panels) (W.Xiao,N.Ozog et al , 2007;Zheng, L. Wang et al, 2011). 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 decisions (E. Koutroulis, K. Kalaitzakis et al, 2001*) and 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. It will calculate efficiency of system with the help of solar voltage and current. This paper also presents hardware designs to implement algorithm.*

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

1. 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 (K. Balasubramanian *et al* , 2008) .Conventional electronic charge controllers for SS are generally installed to protect batteries, from overcharging/ less 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 (Samantha J. Gunter *et al*, 2013). 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

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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.

2. Description of system

The prediction-based battery charging technique is shown in Fig. 2. In system the prediction algorithm is programmed and loaded to a processing unit such as microcontroller which then controls the charge controller (Mateo Sanguino *et al*, 2013). As shown in the figure, 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. Fig 3 shows the mode of our system. Mode is depending on solar and battery voltage.

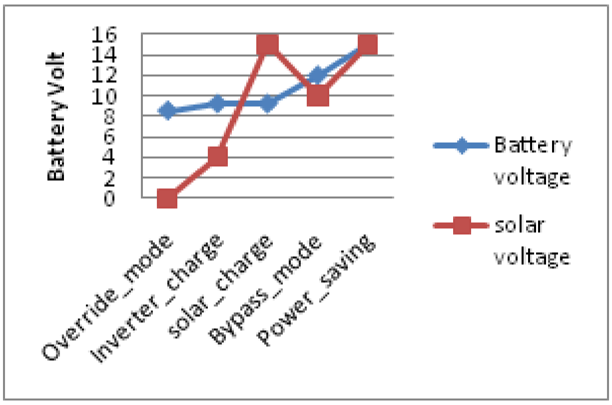

Fig. 1: Graph of prediction based algorithm

In this section designs for implementation block diagram 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 (Mateo Sanguino *et al*, 2013). 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. 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.

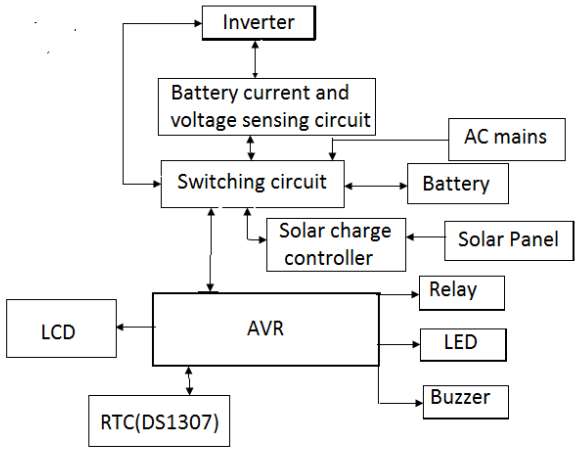

Fig.2 Block diagram of prediction based algorithm

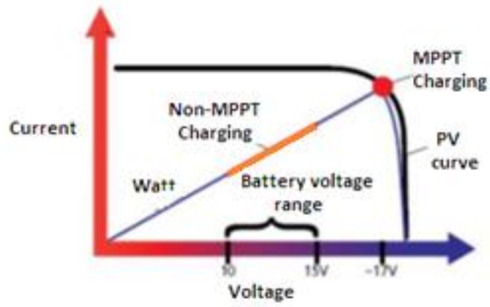

Fig 3 I-V characteristics of MPPT charge controller system

I-V characteristics of MPPT charge controller system is in Fig 3. The applications of space programs, significant solar radiation power is filtered and blocked by the atmosphere and cloud before it is received at the earth surface, which dramatically affects the available insulation for photovoltaic generators. The operation of MPPT is to adjust photovoltaic interfaces so that the operating characteristics of the load and the photovoltaic array match at the maximum power point (MPP) considering some criteria like cell temperature, shadowing etc. Here Photovoltaic voltage is a preferable control variable in case of MPPT since current is heavily dependent of weather conditions. The study (E. Koutroulis *et al*, 2001) shows that the photovoltaic current value at MPP is close to 86% of the short-circuit current. Because the photovoltaic current dramatically varies with insulation, the transient response of MPPT can occasionally cause the photovoltaic current to reach its saturation point, which is the short-circuit current. This should be prevented because its nonlinearity causes a sudden voltage drop and results in power losses. However, for the regulation of PV voltage, the voltage saturations can easily be avoided because a controller knows the operating range is bounded about 70%–82% of the open circuit voltage (E. Koutroulis *et al* 2001; W.Xiao; N.Ozog *et al*, 2007). Furthermore, a good-quality measurement of voltage signal is cheaper and easier than that of current measurement. Here, MPPT is utilized to ensure maximum gain when battery voltage is low. During the lower voltage period, this MPPT charge controller provides the extra power to recharge the battery.

In normal operating environment, it forces to operate at battery voltage and not Vmp, modules maximum power. Here, operating voltage always maintains at 11.5-14.5 V showed in I-V characteristics of Fig.2 that can be slightly varied system to system. Fig.2 also clarifies the advantages of MPPT charging over non-MPPT charging.

We are dealing with Ac so hardware design is very important. One of the biggest challenges in this system is sensing of battery voltage 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. And for current measurement differential ADC used which inbuilt in AVR. This voltage and current measurement data is useful at the time of battery calculation. In this MOSFET and BJT are used for switching purpose. 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.

3. Usage Time Mechanism

Battery usage is depending on peak hour in which battery usage is more. To find out peak usage time is depend on rural and sub urban area. Fig.3. Shows the time on X-axis and usage in % on Y-axis. Depending on this information we will implement the prediction based mechanism. Graph showing the battery usage with respect to time. Morning time and evening time battery usage is more. In this time our algorithm will check the battery condition, solar availability and mains availability depending on situation it will take perfect decision. If PUT is absent then our system will take decision as per situation. Due to this mechanism efficiency, performance, battery life will increase and maintenance reduces because it will working in proper way and proper algorithm.

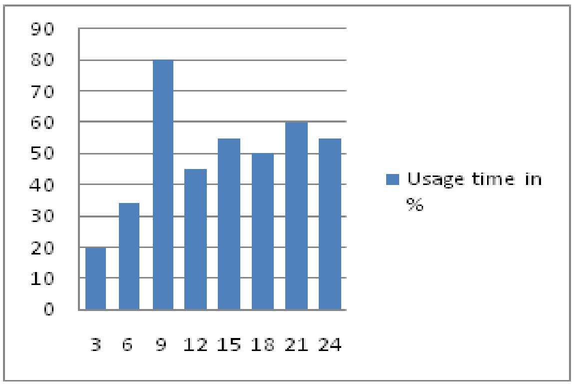

Fig. 3 Graph battery usage with time

4. Set Points limit for algorithm

The actions perform on battery according to Battery Condition; some overriding operations and method are also implemented for protection of battery. These protective operations have higher preference and are activated according to various levels of battery known as set points. Depending on set point operation performs on battery (Samuele Grillo *et al*, 2012).

For this operation two limits is present i.e. upper and lower limit .upper limit is set point is the maximum voltage above which a battery is charged. Similarly, lower limit is the minimum voltage up to which the battery is discharge. These two set points are used as charging and discharging. Above lower limit system will work properly. Upper limit and lower limit are the voltage levels at which charging and discharging can start respectively. These two set points are implemented to prevent fast charging and discharging fluctuation in battery.

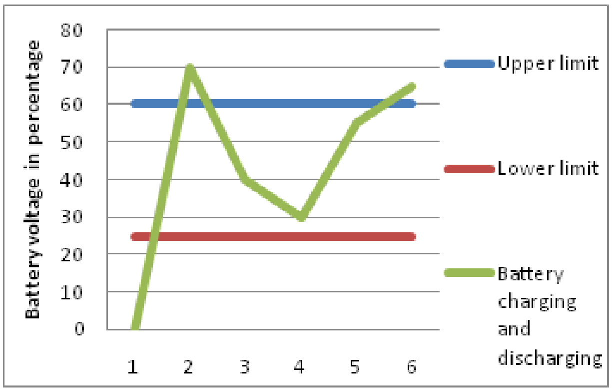

Fig. 4 Hysteresis limit set point

5. Important Features

This complete system includes the feature of easy installation, maintenance free use, no requirement of fuel or lubricant, stainless steel hardware, built-in over-load, over charge, low voltage protection, temperature compensated charging and low battery disconnect facility. Moreover, it ensures maximum continuous power at full load and simultaneously pollution free and noiseless maintenance. Furthermore it has the ability to charge the battery in low voltage so it will get sufficient backup in case of power failure.

Conclusions

This paper has presented a peak usage time and prediction based algorithm for battery charging in solar home systems. The algorithm enables smart battery charging decisions based on 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 algorithmic flexible in this respect as such changes can be easily adjustedin 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.

As of now, the designed algorithm has shown that it has superior performance and less maintenance over conventional charge controllers. The hardware designs for the algorithm can be simple as shown in section IV. The designed technique is flexible, reliable, effective and easy to implement.

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