Construction of Battery Charge Control for Photovoltaic Systems

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Abstract

This article describes a battery charging method for a solar tracker-based PV system and its application. A solar tracking system has been created as a novel PV gadget with an intelligent controller to enhance system performance. PV with a solar tracker may improve its performance by up to 40% compared to a traditional system. The solar tracker used in this study features an active tracking mode with two axes. A smart battery charging system has been developed and provided to store the electricity generated by the PV system in order to maintain optimal PV performance.

Keywords: Battery Charge, Control, Photovoltaic Systems.

1. Introduction

Photovoltaic (PV) conversion is the word used to describe the conversion of solar energy into electrical energy. When you look at a single PV cell, it is made up of P-N junction cells, which are semiconductor devices that absorb photons from the sun and emit electrons. Because a single PV cell has a maximum output voltage of 1.5 V, a large number of such PV cells must be linked in series or parallel in order to meet the specified load requirement. Power conditioning stages are required in order to convert the available solar energy into a form that can be used by the load. Depending on the load, these power conditioning stages may be either DC-DC converters or DC-AC converters. The tracking of solar panels' maximum output power is a difficult operation due to the unpredictable nature of solar energy availability, partially shaded conditions, load variations, and power converter loss. In order to harvest the maximum amount of power from a PV panel while also increasing the conversion efficiency, MPPT algorithms are required.

The basics of battery technology and charge management methods frequently utilised in stand-alone photovoltaic (PV) systems are presented in this paper. This study is based on information from a variety of sources, including PV system design guides, research papers, and component manufacturer data.

The design and construction, electrochemistry, and operational performance characteristics of the most popular kinds of flooded lead-acid, valve controlled lead-acid, and nickel-cadmium cells used in PV systems are all described in detail. Different battery technologies are compared, and design concerns for battery subsystems, auxiliary systems, maintenance, and safety are addressed.

The requirements for battery charge management in stand-alone PV systems are discussed, as well as information on several switching designs, algorithms, and operating characteristics. Different kinds of battery charge controllers have daily operating profiles provided, giving an in-depth look at how these controllers manage and restrict battery overcharge in PV systems.

Most significantly, concerns for correctly choosing batteries and matching the features of the charge controller are given. To assist system designers, specific suggestions on voltage regulation set points for various charge management algorithms and battery types are given.

Charge controllers manage the current from the PV array in stand-alone photovoltaic (PV) systems to prevent the battery from getting overcharged. Furthermore, most controllers adjust the current to the load, preventing severe discharges of the battery. In a stand-alone PV system, the charge controller serves as the energy management, ensuring that the battery is cycled in a way that does not compromise its ability to provide its rated capacity throughout its anticipated lifespan.

Most controllers will allow all of the current output from the PV array to flow to the battery at first, then taper or interrupt the current as the charging progresses, depending on the battery's capacity to take charge. Furthermore, some controllers may purposefully overcharge the battery at regular intervals, mixing the electrolyte and ensuring that all of the cells inside the battery are “equalised” at full charge. Although the controller is one of the least expensive components in a standalone PV system, it has a significant impact on the system's long-term dependability and maintenance costs. The importance of selecting the appropriate controller for a given system and application, as well as properly configuring it, cannot be overstated. These Recommended Practices are designed to offer the most up-to-date information on how to select, setup, and maintain controllers in stand-alone PV systems to PV system users, operators, and integrators.

It also has parts that are useful for charge controller makers. It should be emphasized that these Recommended Practices only relate to lead-acid battery controllers and should not be utilised with nickel-cadmium or other battery technologies. Because lead-acid batteries are used in the overwhelming majority of PV systems, this is not a significant limitation. This paper begins with a basic overview of charge controller terminology and configurations, then moves on to controller selection and set point determination, and ultimately offers procurement, installation, and maintenance best practices.

2. Literature review

Currently, the absorption of renewable energy sources into the power production system has a major impact on the overall efficiency of the power generation system. Solar energy is the most efficient and cost-effective of the renewable energy sources accessible in nature since it is readily available everywhere, is environmentally friendly, and is completely free (no fuel cost). A significant role in the generation of power is played by renewable energy sources. According to Zhou et al., photovoltaic (PV) power generation is receiving more attention as a major alternative fuel source for the future because of its flexible pattern, lack of fuel expense, and environmentally friendly character (2010).

Aside from these advantages, there are several drawbacks to using solar energy for energy production. As a result, as noted by Salameh et al. (1999) and Bader et al. (2002), the output power of a PV panel varies with variations in temperature, insolation, and shading impact, among other factors (2013). Only when the greatest amount of electricity is taken from the PV panel does the conversion efficiency of the PV generation system reach its maximum. According to Villalva et al., the maximum power can only be obtained at a certain operational point known as the Maximum Power Point (MPP) (2009). It is necessary to integrate an MPPT controller in a PV generating system in order to operate the PV panel at its maximum power point (MPP).

A large number of MPPT algorithms have been published in the literature. The Perturbation and Observation (P AND O) approach described by Santos et al. (2006) is a straightforward MPPT algorithm that tracks the maximum power point (MPP) utilizing PV panel current and voltage. Although it is simple to develop and minimal in cost, this algorithm, as noted by Al-Atrash et al., has a tendency to bounce around its operating point when subjected to partial shade (2005).

In order to overcome the constraints of the P AND O algorithm, the Incremental Conductance (INC) approach, developed by Fangrui et al. (2008), has been widely employed in a variety of scientific publications. Comparing conductance and incremental conductance allows us to track the MPP over time. As noted by Azadeh Safari and Saad Mekhilef, this method has constraints such as difficult computing under partial conditions and fast changing insolation, and it takes more time to approach MPP under rapidly changing weather conditions, among other things (2011).

Sun energy, according to the writers Lakshmi Prabha and Thangapandian (2013), is obtained from solar radiations that are renewed on a continuous basis. For extremely efficient solar energy systems, it is recommended that a suitable DC-DC converter be used.

To validate the effectiveness of the suggested converter described in Luo-Wei Zhou and Bin-Xin Zhu's paper, the experimental findings from 300 W, 30-400 V laboratory prototypes are shown (2014).

In order to test the theoretical analysis, a 500W prototype has been created, and the experimental findings have indicated that the suggested converter is a good option for the half-bridge based PV inverter systems for power conversion applications, as discussed by Yi Zhao and Xin Xiang (2014).

In the presence of rapidly changing temperature and insolation, standard algorithms such as P AND O and INC have imprecise performance. While under non-shaded conditions, both algorithms are capable of deducing the global maxima from the local maxima. According to Hohm et al. (2003; Agarwal and Patel (2008); and Moacyr Aureliano Gomes de Brito et al. (2009), under shaded conditions, these algorithms are incapable of tracking the global maxima and are instead trapped in a local maxima, resulting in low power obtained from PV panels and low conversion efficiency (2013). As described by Esram and Chapman, theS algorithms are only effective under uniform irradiation conditions in which the PV curve has a unique MPP. Under these conditions, theS techniques are ineffective (2007).

3. Batteries in PV Systems

The electrical energy generated by the PV array in stand-alone solar systems is not always utilised when it is produced. Electrical storage batteries are frequently utilised in PV systems since energy consumption does not always match with energy output. In a PV system, the main purposes of a storage battery are to:

1. Energy Storage Capacity and Autonomy: to store electrical energy generated by the PV array and provide it to electrical loads as required or on demand.

2. Voltage and Current Stabilization: suppressing or "smoothing out" transients that may occur in PV systems to provide electricity to electrical loads at stable voltages and currents.

3. Surge Currents: to provide electrical loads or appliances with surge or high peak operational currents.

3.1 Battery Design and Construction

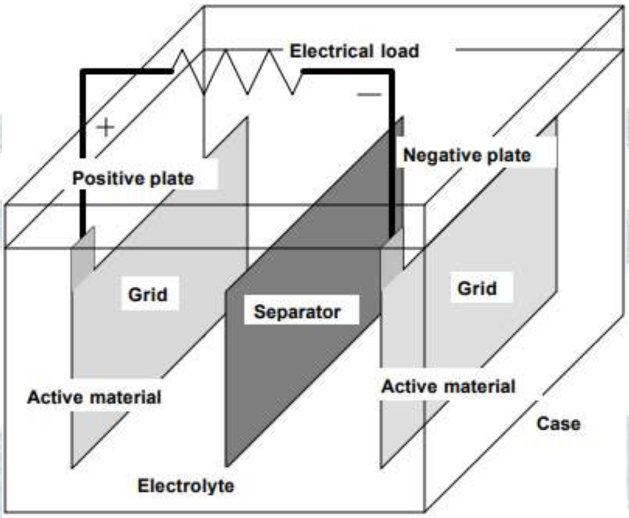
The production of batteries is a labor-intensive, heavy-industry process that involves the use of hazardous and poisonous chemicals. Batteries are usually mass-produced, with multiple sequential and parallel processes merging to create a full battery unit. Before batteries are delivered to wholesalers and customers, they are put through initial charge and discharge cycles.

Although each manufacturer's battery design differs, there are certain similar characteristics that can be stated for almost all batteries. The following are some of the most essential components of a battery's construction.

Cell: A battery's fundamental electrochemical unit is the cell, which is made up of a collection of positive and negative plates separated by separators, submerged in an electrolyte solution, and contained in a casing. Each cell in a normal lead-acid battery has a nominal voltage of approximately 2.1 volts, thus a nominal 12 volt battery contains 6 series cells. A simple lead-acid battery cell is shown in Figure 1.

Active Material: The raw composition elements that make up the positive and negative plates, as well as the reactants in the electrochemical cell, are the active materials in a battery. The capacity of a battery is related to the quantity of active material in the battery. Lead dioxide (Pb02) in the positive plates and metallic sponge lead (Pb) in the negative plates are the active components in lead-acid batteries, which react with a sulfuric acid (H2SO4) solution during battery operation.

Figure 1: Battery cell composition



Electrolyte: The electrolyte is a conducting liquid that enables current to pass between plates in a battery through ionic transfer, or the transfer of electrons. The electrolyte of a lead-acid battery is a diluted sulfuric acid solution, which may be liquid (flooded), gelled, or absorbed in glass mats. The electrolyte in flooded nickel-cadmium cells is an alkaline solution of potassium hydroxide and water. Periodic water additions are needed in most flooded battery types to replace the electrolyte lost due to gassing. It is critical to use distilled or de-mineralized water when adding water to batteries, since even the contaminants in ordinary tap water may poison the battery and cause it to die prematurely.

Grid: The grid of a lead-acid battery is usually a lead alloy structure that supports and conducts electricity while also supporting the active material on the battery plate. Antimony and calcium are common alloying materials used to reinforce lead grids, and they have distinct impacts on battery performance like as cycle performance and gassing. Some grids are produced by flattening a thin lead alloy sheet into a flat plate web, while others are constructed of long lead spines with the active material plated around them to form tubes, or tubular plates.

Plate: A plate, also known as an electrode, is a fundamental battery component that consists of a grid and active material. Each battery cell has a number of positive and negative plates, which are usually linked in parallel at the top of the plates by a bus bar or inter-cell connection. A pasted plate is made by coating a grid with a combination of lead oxide, sulfuric acid, fibres, and water. The thickness of a battery's grid and plate has an impact on its deep cycle performance. Many thin plates are utilised per cell in automobile starting or SLI batteries. This results in a large surface area for high current delivery, but little thickness and mechanical resilience for deep and extended discharges. Deep cycling applications, such as forklifts, golf carts, and other electric vehicles, need thick plates. The thick plates allow for long-term deep discharges while retaining excellent active material adhesion to the grid, resulting in extended life.

Separator: A separator in a battery is a porous, insulating divider between the positive and negative plates that prevents the plates from coming into electrical contact and short-circuiting while also allowing electrolyte and ions to flow between them. Microporous rubber, plastic, or glass-wool mats are used as separators. The separators may be shaped like an envelope, enclosing the entire plate and preventing shed materials from causing short circuits at the plate's bottom.

Element: A stack of positive and negative plate groups and separators assembled together with plate straps interconnecting the positive and negative plates are defined as an element.

Terminal Posts: The exterior positive and negative electrical connections to a battery are known as terminal posts. At the terminal posts of a PV system, a battery is linked to electrical loads. The posts in a lead-acid battery are usually made of lead or a lead alloy, but they may also be made of stainless steel or copper-plated steel for better corrosion resistance. Battery terminals, especially flooded types, may need to be cleaned on a regular basis. It's also a good idea to secure the clamps or connections to the battery terminals every now and again, since they may loosen with time.

Cell Vents: Gases are produced within a battery during charging that can be vented to the atmosphere. In flooded designs, the loss of electrolyte through gas escape from the cell vents it a normal occurrence, and requires the periodic addition of water to maintain proper electrolyte levels. The vents in sealed or valve-regulated batteries are designed with a pressure relief mechanism, which keeps them closed under normal conditions but opens them when the battery pressures rise above normal, which is often the result of overcharging or high temperature operation. A cell vent can be found in each cell of a complete battery unit.

Flame arrestor vent caps are a regular component of larger, industrial battery systems, and they are also available separately. The venting is accomplished through the use of a charcoal filter, which is intended to confine a cell explosion to a single cell, hence reducing the likelihood of a catastrophic explosion of the entire battery bank.

The case of a battery, which is often constructed of hard rubber or plastic, houses the plates, separators, and electrolyte contained within it. However, with the exception of inter-cell connectors that connect the plate assembly from one cell to the next, terminal posts, and vents or caps that allow gassing products to escape and allow for the injection of water if necessary, the case is normally completely covered. Clear battery cases or containers make it simple to check on the electrolyte levels and the condition of the battery plate inside. Plastic battery covers are frequently supported by an exterior metal or rigid plastic housing when the batteries are particularly large or tall.

Types of Batteries and Their Classifications

There are many different types and classes of batteries available today, each with its own set of design and performance characteristics that are tailored to certain uses. Each battery type or design has its own unique set of advantages and disadvantages. Lead-acid batteries are the most commonly used in photovoltaic systems due to their widespread availability in a variety of sizes, low cost, and well-understood performance characteristics. Nickel-cadmium cells are employed in a few essential, low-temperature applications, but their high starting cost prevents them from being used in the majority of photovoltaic systems. In the PV industry, there is no such thing as a "perfect battery," and it is the responsibility of the PV system designer to choose which battery type would work best for each application.

Primary and secondary batteries are the two principal forms of electrical storage batteries that can be found in most applications.

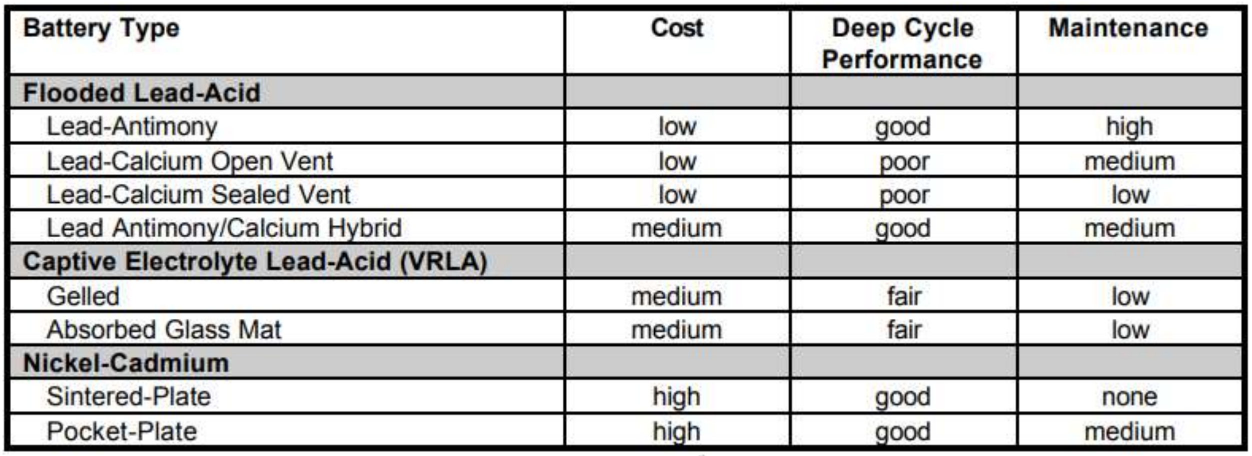
Batteries that are used as a starting point

Primary batteries are capable of storing and delivering electrical energy, but they are not capable of being recharged. These are the primary batteries that are typically found in consumer electronic gadgets, such as carbon-zinc and lithium batteries. In PV systems, primary batteries are not used because they are not capable of being recharged.

Secondary Batteries are batteries that are used after the primary batteries have been exhausted.

It is possible to recharge a secondary battery by running current through it in the opposite direction of the discharge current. A secondary battery can store and transmit electrical energy, and it can also be recharged. Secondary batteries are the type of lead-acid batteries most commonly found in autos and photovoltaic systems. Table 1 covers the most popular secondary battery types, as well as their properties that are important to PV system designers when designing PV systems. Following that, we'll go through each battery type in further depth.

Table 1 shows the different types of secondary batteries and their features



Battery Type	Cost	Deep Cycle Performance	Maintenance
Flooded Lead-Acid			
Lead-Antimony	low	good	high
Lead-Calcium Open Vent	low	poor	medium
Lead-Calcium Sealed Vent	low	poor	low
Lead Antimony/Calcium Hybrid	medium	good	medium
Captive Electrolyte Lead-Acid (VRLA)			
Gelled	medium	fair	low
Absorbed Glass Mat	medium	fair	low
Nickel-Cadmium			
Sintered-Plate	high	good	none
Pocket-Plate	high	good	medium

Charge Controller Selection

Charge controllers and system controls in photovoltaic systems must be chosen and sized with a number of parameters in mind depending on the complexity of the system and the number of control options it will require. Many other activities, including low voltage load disconnect, load regulation and management, control of backup energy sources, energy diversion to auxiliary loads, and system monitoring can be performed in addition to the core battery overcharging prevention function. An application designer must determine which alternatives are required to meet the requirements of a particular application. The following are some of the most important factors to consider while selecting charge controllers for photovoltaic systems.

- Voltage of the system; PV array and load currents;

- The kind and size of the battery; the algorithm and switching element design; the regulation and load disconnect set points; and other factors.

System indications, alarms, and meters; overcurrent, disconnect, and surge protection; mechanical design and packaging; environmental operating conditions; mechanical design and packaging

- Prices, warranties, and availability are all important considerations.

Controllers are available in various sizes.

It is recommended that charge controllers be sized in accordance with the expected voltages and currents generated by the PV system during operation. The controller must not only be capable of handling typical or rated voltages and currents, but it must also be large enough to accommodate expected peak or surge situations from the PV array or from any electrical loads that may be attached to the system. If the controller is to function properly, it must be appropriately scaled for the application for which it is intended. If a controller that is inadequate for the application is utilized and fails during operation, the costs of service and replacement will be higher than the expenses of purchasing a controller that was initially enlarged.

A PV module or array should, in most cases, provide no more current than its nominal maximum power current at 1000 W/m2 irradiance and 25 °C module temperature, according to conventional wisdom. Although it is feasible for sunshine levels on the array to be "improved" up to 1.4 times higher than the nominal 1000 W/m2 figure used to grade PV module performance, this is not guaranteed. As a result, if reflection circumstances exist, the peak array current could be 1.4 times more than the nominal peak rated value. This is why charge controllers should have peak array current ratings that are approximately 140 percent of the nominal peak maximum power current ratings of the modules or array, whichever is greater in this case.

It is necessary to multiply the peak rated current from an array by this "enhancement" safety factor in order to establish the size of the controller. It is calculated by multiplying the number of modules or strings running in parallel by the current of each module or string. The short-circuit current (Isc) is typically used instead of the maximum power current (MP) in order to be conservative (Imp). As a result, shunt type controllers that run the array under short-circuit current situations are protected in an appropriate manner.

Conclusion

The purpose of this project is to design and build a solar charge controller that is primarily comprised of discrete components. For a battery with a capacity of 200Ah, the charge controller adjusts its output voltage in steps of 12V. Current booster, battery level indicator, battery charge controller, and power supply unit are included in the design's four stages, which are divided into four parts. The planned system is extremely useful, durable, and cost-effective, and it can be built entirely from locally found and reasonably priced components.

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