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Solar power applications and integration of lithium iron phosphate batteries in off-grid photovoltaic system

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ABSTRACT

Lithium iron phosphate battery is a type of rechargeable lithium battery that has lithium iron phosphate as the cathode material and graphitic carbon electrode with a metallic backing as the anode. It is a relatively new emerging energy storage battery that is Cobalt-free and Nickel-free. However, its integration with solar PV systems and the specific precautions for its use is not well known to most technicians and installers, especially in developing countries. In this paper, the issues on the applications and integration/compatibility of lithium iron phosphate batteries in off-grid solar photovoltaic systems are discussed. Also, the characteristics, properties, advantages, and disadvantages of the battery are presented. From the study, it is shown that if the battery operates with a charge control algorithm specially set for long charge durations, the energy storage system is an ideal choice for an off-grid photovoltaic system. This is due to their high energy density, long cycle life, relatively low cost compared to Li-ion, high safety, low toxicity, low risk of thermal runaway or combustion, low self-discharge rate, high capacity, lightweight, lower environmental impact, low maintenance, high cell voltage, fast charging, high-temperature stability, high discharge power, a good lifetime when deep cycled, etc. Additionally, the advantages have made the battery to be highly valued in energy storage, backup power, vehicle use utility-scale stationary applications, electric vehicles, commercial batteries, solar power, and other renewable energy applications, etc.

KEYWORDS

Lithium iron phosphate battery, Off-grid PV system; Device integration, Characteristics, Advantages

1. INTRODUCTION

The alarming depletions of high-grade energy, exponential increasing in the cost and green-house emissions of fossil fuels and the inherent threats to human survival accompanying its utilizations have been the impetus for the utilizations of different renewable energy options such as solar, wind, geothermal bioenergy, wave energy, hydropower, Ocean energy, tidal energy, etc. In the pool of the alternative energy sources, the vast and various applications of solar power system in providing sustainable power supply cannot be underestimated. It is virtually an inexhaustible renewable source which produces little or no greenhouse gases, notable reductions in the consumption of the finite fossil fuels, pollution levels and worrying climate changes. As good as this alternative energy source is, its applications and installations especially in the developing countries have been impeded by a number of challenges such as (i) improper selections and specifications of the required solar components, equipment and systems, (ii) lack of proper installation guidelines and the specific precautions (iii) faulty wiring, inappropriate load calculations and installations coupled with deteriorated solar-support structures, (iv) dubious practices in the procurements of solar power systems (v) installations of low quality of the solar power components such as the use of low quality inverters and batteries, faulty controllers, low quality/heat-damaged solar panels and other solar components, (vi) lack of feedback on the field performance and effective long-term maintenance system. These problems have continued to discourage the applications of solar power systems in these countries. In such installations and practices, batteries have been found to be the most expensive and dangerous components. Therefore, there is a need for providing proper information and integration/installation guidelines for their usage and applications.

Indisputably, battery is the major and most expensive device in Off-grid PV systems. In developing countries, lead acid batteries are widely used as energy storage in solar system applications. This is because of their relatively low cost, mature, reliable and well-understood technology. However, the various disadvantages of these batteries such as heavy weight, low energy density, relative slow charging, leakage of acid due to damage or spillage, noxious fumes given off during the charging process, fast aging and disposal challenge have paved ways for considerations of alternative energy storage systems such as lithium-ion batteries [1-4]. These group of batteries include lithium cobalt oxide, lithium nickel oxide, Lithium nickel cobalt aluminium oxide, Lithium nickel cobalt magnesium oxide, lithium manganese oxide, lithium nickel manganese cobalt oxide, lithium-iron-phosphate batteries. In such low energy density batteries, lithium iron phosphate battery is considered as a relatively new emerging energy storage battery that has obviated the various challenges in the lead acid batteries and other lithium-ion batteries. However, its integration/compatibility to the solar PV systems, guidelines for its proper installation and the specific precautions for its use are not well known to most technicians and installers especially in developing countries. Therefore, in this work, the issues on the applications and integration/compatibility of lithium iron phosphate battery in Off-grid solar photovoltaic (PV) systems are discussed. Also, the characteristics, properties, advantages and disadvantages of the battery are presented.

2. SOLAR PV SYSTEMS DESIGN AND INTEGRATION

In an installed solar power system, electric current flows from the solar panels through the solar charge controller and the bank battery bank, before it is finally converted into AC by an inverter. In such power set-up, the solar panels convert light from the sun to electricity through their solar cells while the solar charge controller (charge regulator or battery regulator) regulates the rate of current being delivered to the battery bank, and protect the batteries from overcharging and over-discharging. The batteries which act power backups device stored generated energy from the solar powers while the inverter converts the generated direct current (DC) from the solar panels to alternating current (AC) to power the connected AC loads to the solar PV system. In all solar systems, it is required to include AC and DC safety disconnects.

The installations of solar power system are of three types namely On-grid (grid-connected, grid-tie or grid-feed, utility-interactive, grid intertie, and grid backfeeding) PV system, Off-grid (stand-alone) PV system and Hybrid PV system. Each of these types of the solar PV system has a unique setup which has direct impact on the equipment used, costs and savings, and the ease or complexity of installation.

2.1. On-Grid Solar PV System

The On-grid solar PV system are of two types which are grid-connected system without battery and grid-connected system with battery. The grid-connected system without battery is a solar system that is connected to the utility power grid without any added battery for energy storage or to function as power backups as shown in Fig. 1. Since the electricity generated by the PV system is required to be fed into the grid, the voltage and frequency of the generated electricity by the solar PV system should be the same as that of the grid voltage and the frequency. The system makes use of solar panels, grid-tie inverter (grid-interactive or synchronous inverters) or microinverters, AC breaker and Power meter to achieve this purpose. The PV system uses a grid-tied or grid-fed inverter. The direct current electricity generated by the solar panels is sent to the inverter (which converts the direct current into alternating current electricity). The electricity generated from the power system is first used to power the home loads, while all surplus energy is sent to the grid in return for electric bill credits. Therefore, this type of solar connection helps in generating and saving money. Also, it has lower equipment and installation costs, and better efficiency rates. The absence of batteries in this system makes the system cheaper, simpler to install, less replacements of components, low maintenance requirement, comparably low cost and flexibility in design. It is ideal for residential applications and large capacity solar PV plants. One major downside about the system is that system does not provide any form of outage protection.

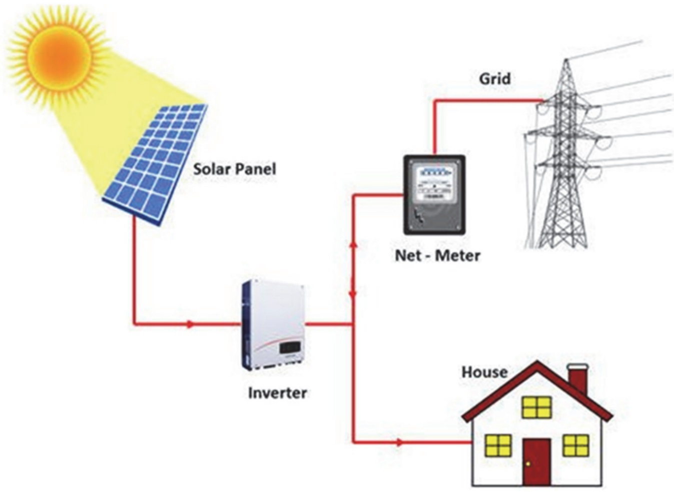

Figure 1: A grid-connected system without battery [5]

In the grid-connected system with battery is a solar system that is connected to the utility power grid and with added batteries for energy storage as backups for power outage (Fig. 4). The system provides better energy independence for residential use as it reduces reliance on grid-generated electricity and the energy retailers. It combines the best of On-grid and off-grid solar systems as it possesses the properties of off-grid solar system and grid-tied solar system but with backups batteries. The system often uses batteries as back-up energy storage system in order to maximize its efficiency and power availability. The system used battery-based grid-tie inverters (hybrid inverters) that draws electrical power to and from battery banks and also synchronize with the utility grid. The electric power generated from the system is first used to power the home loads, after the home's energy needs have been supplied, the solar power is used to charge the solar batteries as energy storage to make electricity available for use during power outage. If there is still an excess power available after the batteries are fully charged surplus energy is sent to the grid in return for electric bill credits. The use of batteries in the system makes it more complicated, expensive, and decrease overall system efficiency as compared to the grid-connected system without battery. In this power system, the power generated from the solar panels is first used to power the home's electrical loads. This type of solar PV system configuration is commonly used in telecom tower and hospitals where the running of load for 24 hours is critical.

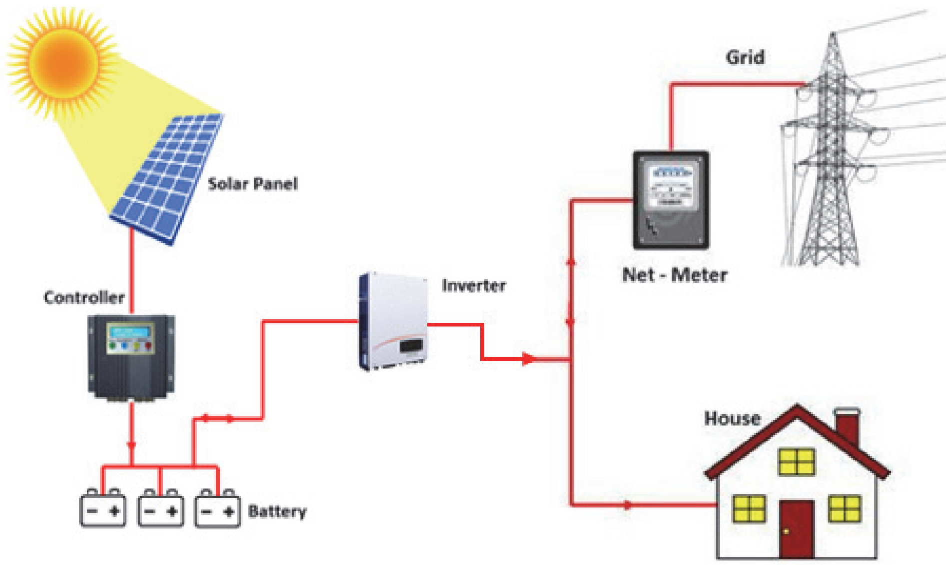

Figure 2: A grid-connected system with battery

2.2. Off-grid/Stand-alone Solar PV System

Off-grid (stand-alone) PV system as the name implies is a not grid-connected system as shown in Fig. 3. Therefore, such system needs battery storage to function. The system is an ideal and very useful for rural or remote areas that are not connected to grid system. This solar power system is highly beneficial in a place where there is no access to the utility grid and where the solar systems is found to be cheaper than extending power lines to certain remote areas. It can be seen as an energy self-sufficient system which is a form of energy security. Such a system is not affected by power failures on the utility grid. However, this system can only power the connected loads based on the amount of energy that the battery can supply. Therefore, one of the major components in off-grid system is the battery and such must be given good considerations in Off-grid (stand-alone) PV system. As pointed out previously, in all solar systems, it is required to include AC and DC safety disconnects and for off-grid solar systems, one additional DC disconnect is installed between the battery bank and the off-grid inverter. This is used to switch off the current flowing between these components for the sake of maintenance, troubleshooting and protection against electrical fires. On the considerations for its applications, the Off-grid system are suitable for small electric loads in remote areas where there is no grid supply. There are some other examples of Off-grid solar PV system such as solar water pumping systems, solar home/street lighting systems, etc.

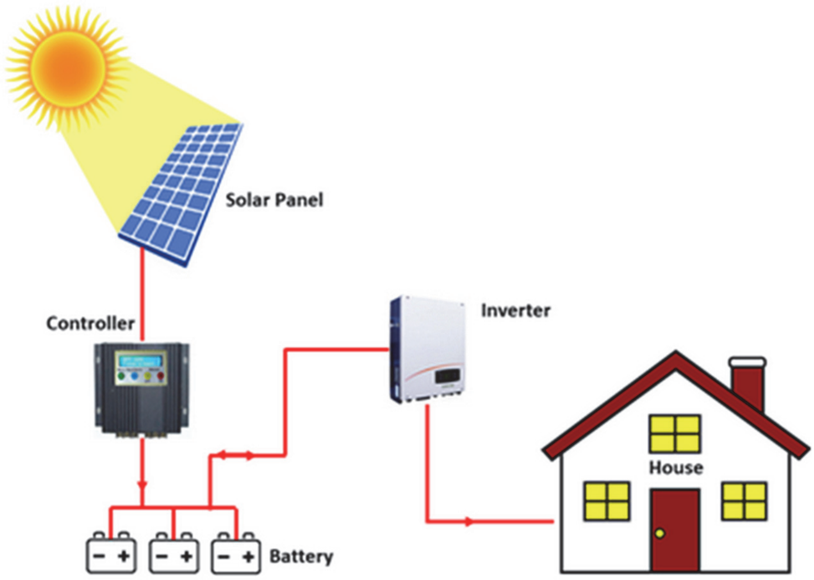

Figure 3: Off-grid/Stand-alone PV System [6]

2.3. Hybrid Solar PV System

Hybrid solar PV system combines two or multiple sources of power systems to improve the power availability and usage of power. The power generating units could be the combination of solar PV system and diesel generator as shown in Fig. [4]. Also, the system can contain more than two power generation units which might include solar PV system, diesel generator and wind turbine. Therefore, a hybrid solar PV system is a type of system configuration where two or multiple power generating units are connected in a system. Such system ensures that power is always supplied to the load whenever it is needed. Therefore, it is often used to increase the reliability of load operation. Also, the system often uses batteries as back-up energy storage system in order to maximize its efficiency.

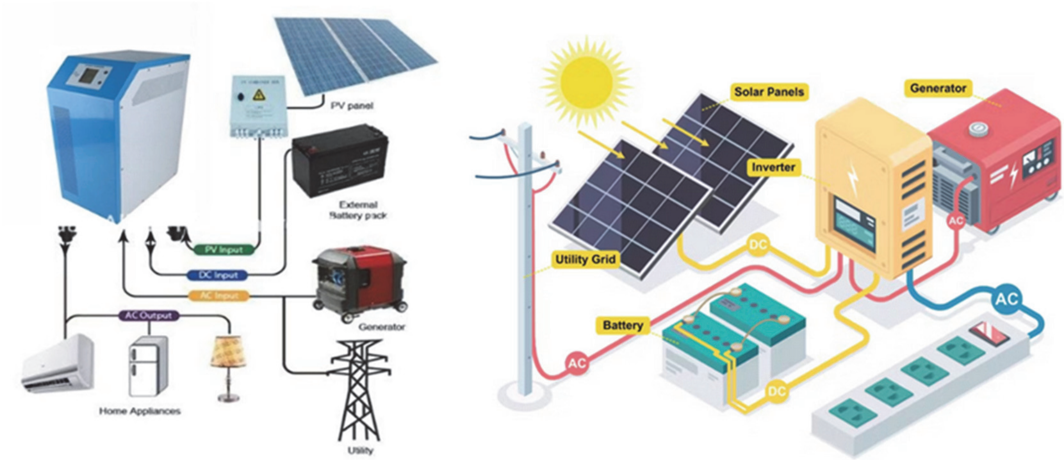

Figure 4: Hybrid Solar Power System [7, 8]

As pointed out in the previous section that battery is the major and most expensive device especially in Off-grid PV system. The next focus of the present study will be on the batteries as backups or energy storage device in the solar PV system design and integration. The subsequent section will discuss the challenges of the applications of batteries in solar PV systems, compatibility of lithium iron phosphate battery for solar PV system, the characteristics, properties, advantages and disadvantages of the batteries in the systems.

3. CHALLENGES OF VARIOUS ENERGY STORAGE SYSTEMS IN SOLAR POWER APPLICATIONS

In most developing countries, lead acid batteries are widely used for On-grid, Off-grid and hybrid solar systems for energy storage. However, these batteries come some drawbacks such as possible leakage of acid due to damage or spillage, noxious fumes given off during the charging process, low energy density, relative slow charging and their heavy weight [1]. Also, their disposal has been an environmentally challenge. Additionally, lead-acid batteries age faster when kept in a low state of charge. Moreover, such batteries are not the best choice for use in off-grid PV systems because the standalone systems largely depend on the lifecycle cost of the systems, which are majorly driven by the cost and the frequency of exchanging the batteries [1]. Consequently, there is a need for the applications of alternative energy storage systems which have long cycle life, high safety, low toxicity, low self-discharge rate, lightweight, lower environmental impact, maintenance free and a good lifetime when deep cycled. Hence, lithium-ion batteries (lithium cobalt oxide, lithium nickel oxide, Lithium nickel cobalt aluminium oxide, Lithium nickel cobalt magnesium oxide, lithium manganese oxide, lithium nickel manganese cobalt oxide, lithium-iron-phosphate, etc.) are proposed [2, 9-14]. In this group of high energy density batteries, Lithium cobalt oxide (LiCoO2) battery has been applied as energy storage system but its major drawbacks such as accelerated aging at high currents and low thermal stability when operating in temperatures between 100 and 150oC [12]. Therefore, lithium nickel oxide (LiNiO2) battery was produced by partial substitution of cobalt in lithium cobalt oxide with Nickel in order to reduce the cationic disorder in lithium cobalt oxide. However, this type of battery is thermally disturbed even more thermally unstable than lithium cobalt oxide [11]. Lithium nickel cobalt aluminium oxide (LiNixCoyAlzO2) battery is a widely applied type of lithium battery but it causes fast capacity decrease rates at elevated temperatures of operation [11]. Lithium manganese oxide (LMnO2) battery comes with change in structure during the lithium-ion extraction. Such modification has a negative impact on cycle life of the battery. Also, the magnesium in the type of battery tends to dissolve into the electrolyte when it is not cycled [14]. Good cycle stability at 50oC is achieved in Lithium nickel manganese cobalt oxide (LiNiMnCo) battery but comparatively high cost, voltage instability and the unique voltage profile, which lacks the expected flat region found in the cells of thermal, electrical and chemical stable lithium batteries such as lithium iron phosphate batteries, is one of the significant issues in the applications of the LiNiMnCo battery [2]. Hence, lithium-iron-phosphate battery is highly considered and widely applied. Lithium iron phosphate ($LiFePO_4$) battery is a more mature and stable Li-ion technologies [9] with an excellent thermal and chemical stabilities as well as a very good cycle life and power capability. It is the safest lithium battery type because it has the safest chemistry of all the lithium batteries. Considering thermal runaway risk which are common with lithium-ion batteries, $LiFePO_4$ battery is regarded as the safest lithium-ion type battery.

Comparison of various types of batteries as shown in Table 1 depicts that although $LiFePO_4$ have a higher initial investment cost, their lifecycle storage cost is lower than that of other kinds of batteries. This is because of their higher numbers of cycles, higher usable capacity and higher energy efficiency which are are highly suitable for off-grid PV systems [1].

Table 1. Comparison of batteries for stand-alone PV systems' design [15]

Battery type	Lead acid Flooded	Lead Acid AGM	Lead Acid GEL	Li-Mg/Co	$LiFePO_4$
Nominal voltage	2.12	2.12	2.12	3.7	3.3
Lifespan [cycles]	300	300	300	300	2000
Energy efficiency (%)	80	80	80	90	>90
Usable capacity [%|	70	70	70	90	>90
Self-discharge rate [% p. month]	3	3	3	1	1
Cost [US$/kWh]	0.1	0.15	0.15	0.3	0.3
Sizing rule [module]	1.2	1.2	1.2	1.1	1.1
Sizing rule [days]	3	3	3	2	2
Lifecycle storage cost [US$/kWh]	0.33	0.5	0.5	1	0.15
Environmental friendliness	Low	Low	Medium	High	High
Overall evaluation	-	0	+	+(+)	++(+)

4. LITHIUM IRON PHOSPHATE BATTERY AND ITS ADVANTAGES

Lithium iron phosphate battery as a type of deep-cycle batteries, is one of the most popular types of lithium batteries for solar various applications in the recent years due its numerous advantages.

Lithium iron phosphate batteries have the advantages of long charge durations, the battery is an ideal choice for an off-grid photovoltaic system. This is due to their high energy density, long cycle life, relatively low cost compared to Li-ion, high safety, low toxicity, low risk of thermal runaway or combustion (since it is Cobalt-free and Nickel-free), low self-discharge rate, high capacity, lightweight, lower environmental impact, maintenance free, high cell voltage, fast charging, high temperature stability, unaffected by longer durations in low states of charge, high discharge power, a good lifetime when deep cycled, etc. Lithium iron phosphate batteries have 4 to 5 times the cycle life and 8 to 10 times the discharge capacity of conventional lithium batteries. At the same weight, $LiFePO_4$ batteries are 30-50% lighter than ordinary lithium batteries. The total lifespan (cycles) is about 2000-10,000 cycles with the capacity still reaching 80%, which is 6-7 times higher compared to lead acid batteries over the entire lifetime [1]. $LiFePO_4$ are lighter, more durable and have higher discharge power than regular or traditional lithium batteries. It offers a longer lifespan than lithium-ion batteries. The long cycle life of $LiFePO_4$ has been seen as a major advantage because the battery can typically go through thousands of charge cycles (which make them to be used for a longer time before any considerations for its replacement). $LiFePO_4$ batteries also have a high energy density (which allows them to store a large amount of energy in a compact size). The battery is environmentally friendly as it does not have any hazardous or noxious substance. They are safer and more stable alternative to other lithium-ion batteries, such as lithium cobalt oxide (LiCoO2) batteries. It is less prone to thermal runaway as in the case of lithium-ion batteries. It is more portable having specific volume and weight are 65% and 1/3 of lead-acid batteries, respectively [5]. Additionally, these advantages have made the battery to be highly valued in energy storage, backup power, vehicle use utility-scale stationary applications, electric vehicles, commercial batteries, solar power applications and other renewable energy storages, etc. It is a very good solar power system option for remote areas, where safety awareness is very low.

Wang et al. [1] reported in their works that $LiFePO_4$ batteries efficiencies decrease with increasing charge and discharge currents. It was reported that the efficiencies become as high as 99% at a current density used for 100 hours charge duration as shown in Table 2.

Table 2. Efficiencies of batteries from different manufacturers at different charge durations [1]

Charge duration	Manufacturer A	Manufacturer B	Manufacturer C	Manufacturer D	Manufacturer E	Manufacturer F
2 h	92%	93%	92%	90%	87%	92%
l0 h	97%	97%	96%	96%	95%	97%
100 h	99%	99%	99%	99%	99%	99%

5. APPLICATIONS OF LITHIUM IRON PHOSPHATE BATTERY

Lithium iron phosphate ($LiFePO_4$) battery, also known as LFP battery is a type of rechargeable lithium-ion battery that has cathode made of lithium iron phosphate and graphitic carbon electrode with a metallic backing as the anode. The lithium iron phosphate at the cathode is a solid-state material that does not release oxygen when heated, thereby significantly reduces the risk of thermal runaway or combustion, making them more stable and safer to use. Studies have shown that if the battery operates with a charge control algorithm specially set for long charge durations, the battery is an ideal choice for an off-grid photovoltaic system. This is due to their high energy density, long cycle life, relatively low cost compared to Li-ion, high safety, low toxicity, low risk of thermal runaway or combustion, low self-discharge rate, high capacity, lightweight, high cell voltage, fast charging, high temperature stability, high discharge power, a good lifetime when deep cycled, etc. Additionally, these advantages have made the battery to be highly valued in energy storage, backup power, vehicle use utility-scale stationary applications, electric vehicles, commercial batteries, solar power applications and other renewable energy storages, etc. However, the $LiFePO_4$ batteries do not perform well at low temperatures, therefore, it has low efficiency at extreme temperature. It is affected by aging and transportation which can cause capacity loss. Its major drawback are deep discharge and low density which make them not to be used for small devices such as smartphones.

6. INTEGRATION AND COMPATIBILITY OF LITHIUM IRON PHOSPHATE BATTERY IN SOLAR POWER SYSTEMS

Since the battery is relatively new emerging energy storage battery as compared with lead-acid battery (which has mature/well-understood technology and knowledge about its installations and application), its proper installations and the specific precautions for its use are not known to most technicians and installers especially in developing countries. Due to the lack of knowledge about the compatibility of the energy storage system with the other power components, the installations of the LFP batteries come with several issues especially in developing countries. The common problems about the use, compatibility and installation of the LFP batteries for stand-alone and hybrid solar power system include lack of selection of the proper solar charge controller which are meant for or compatible with the lithium iron phosphate batteries, lack of parameter setting of the charging and discharging voltage and current of the charge controller for the lithium iron phosphate batteries, lack of selection of the solar Inverter that is compatible with the lithium iron phosphate batteries, lack of recommended charger for the grid-connected system was not used, lack of installation of battery management system (BMS) in the Lithium iron phosphate batteries, etc. It should be noted that lithium iron phosphate batteries are more susceptible to damage under certain conditions such as overcharging, undercharging and overheating is the above issues are not properly resolve before and during installations. Therefore, before setting up solar PV stand-alone/Offgrid or grid-connected system using lithium iron phosphate batteries, some facts about lithium iron phosphate battery that are needed to be known.

6.1. Solar Charge Controller Type for Lithium Iron Phosphate batteries

Power generated from solar panels is always at different voltage and current levels due to variable weather conditions and time of the day. Such erratic voltage and current levels cannot be used to charge the batteries or connected directedly to a load. Therefore, a charge controller (Pulse width modulation (PWM) or Maximum power point tracking (MPPT)) is installed in order to regulate the flow of charge from the solar panel to the battery and also, to regulate the flow of charge from the battery to the load connected. Therefore, in order to regulate, monitor and control the charging and discharging of the battery or battery bank, it is very important to install a solar charge controller in the solar power system. However, proper setting (such as battery type selection, battery voltage selection, charge voltage and disconnect voltage parameters setting) of the charging parameters must be done in order to ensure that all batteries are charged to their fullest potential.

The lithium-ion or lithium iron phosphate solar charge controller is a kind of charge controller specialized for charging lithium-ion or lithium iron phosphate batteries. Lithium iron phosphate ($LiFePO_4$) batteries can be charged with solar systems using charge controllers designed for lithium iron phosphate or lithium-ion batteries It should be noted that most $LiFePO_4$ batteries get easily damaged because of over-charging and over-discharging. If the batteries overcharged or discharged quickly, it can catch fire and release toxic fumes. Therefore, for charging $LiFePO_4$, a charge controller specially designed for $liFePO_4$ or lithium-ion batteries should be used as the $LiFePO_4$ battery has a specific algorithm to charge. The $LiFePO_4$ or Li-ion charge controller will help prevent over-charging and over-discharging. Also, it will be best always to use $LiFePO_4$ battery with a BMS (Batteries management system). If $LiFePO_4$ batteries is used in a solar power system, a lithium battery compatible solar charge controller is needed to prevent over-charging and over-discharging of the batteries.

Example of lithium batteries compatible solar charge controller such as Victron SmartSolar, Victron BlueSolar, Exotronic, Votronic, Western Co. WRM20, Genasun, Enerdrive, EPever TracerAN, ZHCSolar SCF60, ESmart, MC RV MPPT charge controllers, etc. These type of MPPT solar charge controllers (which uses a maximum power point tracking algorithm to harvest the most energy from the solar array) are designed specifically for charging lithium batteries/ LiFePO4 solar batteries. Also, like other dedicated two types of solar controllers for lead-acid batteries, lithium batteries solar controllers have both MPPT (Maximum Power Point Tracking) type and PWM (Power Width Modulation) type. The dedicated PWM solar charger controllers for lithium batteries are BB01 Buck Boost, HP6024, WP5048D, Lithium SL03 Series, HQST solar charge controllers, etc. In practice, MPPT charge controller is highly recommended because the PWM charge controllers usually has only 70% conversion capacity compared to an MPPT mode.

6.2. Parameter Setting of the Charge Controller

The best charger setting for a 12V LiFePO4 battery is usually around 13.8-14.4 volts with a charge current of 50-100 mA. The charge within this voltage range can effectively charge the LiFePO4 battery. Proper setting (such as battery type selection, battery voltage selection, charge voltage and disconnect voltage parameters setting) of the charging parameters must be achieved in order to ensure that all batteries are charged to their fullest potential. The battery voltage selection must be done in a way that battery voltage select on the charge controller must match the battery voltage. A 12V mode must be chosen for a 12V battery while 24V system must be selected for a 24V mode. For the charge voltage (the maximum charger output voltage that will be allowed to charge the LiFePO4 battery pack), the boost charge voltage must be set to 14.4V for a 12V LiFePO4 battery, and multiplied by two for 24V system. For the disconnect voltage (voltage at which the charge controller will disconnect power from the solar panels), overvoltage disconnect setpoint must be set to 16.0V for a 12V LiFePO4 battery, this is the same as lead acid and gel batteries.

6.3. Solar Inverter type for Lithium Iron Phosphate Batteries

Solar inverters are used to convert the DC power generated by the power panels into an AC power that can be used by the AC household appliances. It is important to select a LiFePO4 battery that is compatible with the solar inverter (or vice versa) that will be used in the solar storage system.

6.4. Application of BMS in LiFePO4 battery utilization for solar storage system

Battery Management System (BMS) is an intelligent component of a battery pack responsible for advanced monitoring and management. It is the brain behind battery and plays a critical role in its levels of safety, performance, charges rate and longevity. Lithium-ion or LiFePO4 are more susceptible to damage under certain conditions such as overcharging, undercharging and overheating. In order to harness the full potential of these batteries, it is essential to incorporate a battery management system into the design. This keeps the battery within the safety operation region in terms of voltage, current, and temperature during the charging, the discharging and in certain cases at open circuit. Through the use of cell phone, BMS can check the status of the battery in real-time. It can detect the current and voltage of the battery. In case of any abnormality, the BMS system can automatically adjust it.

6.5. Charging of Lithium Iron Phosphate batteries

Lithium-iron or Lithium iron phosphate batteries are more susceptible to damage under certain conditions such as overcharging, undercharging and overheating. It is best to use the special charger provided by the manufacturer of the batteries to charge the energy storage devices when connected to grid. Therefore, it is highly recommended that any charger that is not recommended by the manufacturer for charging the batteries should not be used.

6.6. Operating Environmental Temperature of Lithium Iron Phosphate Batteries

The operating environmental temperature of lithium iron phosphate batteries should be suitable. The charging temperature of the lithium batteries is 0oC to 45oC, and the discharging temperature of the battery is -20oC to 60oC. Therefore, the environment must be well ventilated, clean, dry and free of corrosive substances, fire and heat sources.

7. CONCLUSION

In this work, the issues on the applications and integration/compatibility of lithium iron phosphate battery for solar photovoltaic system have been presented. The characteristics, properties, advantages and disadvantages of the battery have been discussed. It is therefore concluded in this study that in the use of lithium iron phosphate battery for solar power system, especially for off-grid system,

I. there should be proper selection of solar charge controller which are meant for or compatible with the lithium iron phosphate batteries.
II. parameter setting charging and discharging voltage and current of the charge controller for the lithium iron phosphate batteries must be correctly done to the requirement standards.
III. the installation of battery management system (BMS) in the lithium iron phosphate batteries must be ascertained.
IV. there should be proper selection of the solar inverter that are compatible with the lithium iron phosphate batteries.
V. the recommended charger for the grid-connected system must be used.
VI. the environment where the batteries are installed the environment must be well ventilated, clean, dry and free of corrosive substances, fire and heat sources.

With these proper installation guidelines and specific precautions for the use of the lithium-iron phosphate batteries, it is hoped that the batteries will continue to be highly valued as energy storage devices for various energy storage technologies such as in utility-scale stationary, electric vehicles, uninterrupted power supply systems, solar power and other renewable energy applications.

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