

Step-by-Step Installation of Solar Energy and Its Maintenance

Muhammad Haseeb Abid¹, Wasif Shafiq¹, Muhammad Dayem¹, Hassan Riaz Khan¹

¹ Department of Electrical Engineering, NFC Institute of Engineering and Technology, Multan, Pakistan

*Corresponding Author: Muhammad Haseeb Abid (Email Address: raohaseeb045@gmail.com)

Received: 14-11-2024 Revised: 18-04-2025 Accepted: 10-06-2025

Abstract— The study reviews how solar panels are a green energy solution and discusses the procedure for installing solar panels from beginning to end. As costs continue to increase, as environmental issues are raised and with geopolitical issues also involved, solar energy use has risen as an alternative to regular energy sources. The analysis points out that solar energy can reduce arguments over energy supplies, make people less dependent on rare fossil fuels and give zero emissions of gases that impact climate change. While installing a solar system, the solar panels, inverters, batteries and all the needed cables are talked about in detail, as are their individual uses. Also, for the most efficient use of energy, selecting devices that protect the environment and cooperate with solar systems is emphasized. This research explores how solar can help meet energy needs sustainably and without harming the environment, by closely inspecting each stage of installing a solar system.

Keywords—Solar system, battery, inverter, mounting, appliances.

I. INTRODUCTION

In this article, we will explain how to install solar panels and detail their advantages. Due to rising energy costs, foreign conflict and damage to nature, solar energy has become a more popular way to generate energy. The largest benefit of solar energy is that it doesn't add any greenhouse gas emissions to the environment. Rather than adding to global warming like fossil fuels, solar energy is a clean and green source of power. Solar panels allow us to produce energy in a way that greatly decreases our impact on the environment and helps address the problems of climate change.

Solar energy can help us use less of our standard energy sources. Alternative energy sources such as coal and oil are limited in what is available and may soon cost more. Because it is renewable, solar energy can always be accessed and does not have the same large changes. This action could reduce our energy prices and give us a reliable way to meet our needs well into the future.

In addition, solar energy contributes to less political tension than are seen with traditional forms of energy. Since many fossil fuels are found in unstable nations, this often results in disputes over power sources and disputes over energy. Switching to solar helps us tackle these challenges and achieve secure energy supplies.

Anyone with the right knowledge, training and skills can find solar design and installation fairly easy. We will now cover the components needed for solar installation and what they do. A solar panel includes other components that are needed for its proper operation. These include

- a. Solar System
- b. Solar Panels
- c. Mounting System
- d. Battery
- e. Inverter
- f. Connecting Wires
- g. Appliances

The solar system is made up of the Sun and everything that orbits around it, including satellites. However, in this paper, we will only refer to the Sun and Earth as the solar system. Solar energy is the energy that originates from the Sun, reaching us in the form of light and heat. Pakistan receives a significant amount of solar radiation due to its geographical location and climate, averaging 5 to 7 kWh of solar radiation per square meter per day. Annually, this amounts to 2190 kWh per meter square per year, which is a remarkable potential for solar power systems in Pakistan. [2]

A solid cell or photovoltaic cell is a device that converts light energy into electrical energy through the photovoltaic effect. This effect generates voltage across the P-N junction in a semiconductor through the absorption of light radiation. Devices that use this effect are called photovoltaic devices. Solar panels convert solar energy into electrical energy for the purpose of charging batteries. To effectively use solar panels, they are connected in series, known as a string, and in parallel connections, known as an array, to collect a good amount of sunlight. This collected sunlight is capable of supplying the amount of electricity needed to run an entire household.

Solar panels are rated in different watts, depending on their use. In Pakistan, people typically use 545-watt solar panels for domestic purposes, which have a 70% efficiency and can provide approximately 500 watts in one sun hour. These solar panels have dimensions of 3.25 feet by 5.5 feet. To install a 5-kilowatt solar system in a house, 10 plates of 545 watts would be required. Two types of connections are done while connecting the solar panels.

In a series connection, each plate is connected to its neighbouring plate, meaning that the positive terminal of one plate is connected to the negative terminal of the adjacent



plate. This arrangement forms a string, allowing the voltage of each panel to add up to the total number of plates. [3] However, the current remains the same as that of an individual plate. This type of configuration is used when high voltage is required in the system.

Side-by-side connections of plates link the positive terminals of each plate and the two negative terminals together. This means that the total voltage doesn't vary, but the total current has the sum of the separate plate currents. This method is important for providing high operating current.

Making these types of connections means ensuring that the solar panel's input voltage is lower than the inverter's PV voltage maximum. To make sure the voltage and current are evenly balanced, we assembled two arrays of five solar panels, joined them in parallel and attached them to the system.

A solar panel stand is made to support solar panels as shown in Fig. 1. Their structure is often aluminum which enables them to resist problems caused by the weather. Solar stands keep the panels lifted so they can be angled right for maximum benefit.



Figure 1: Mounting the solar panels.

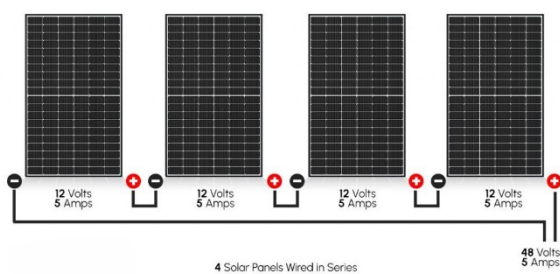


Figure 2: Solar panel wiring in series.

II. LITERATURE REVIEW

For Pakistani homes, a recommended way to angle the panels is between 20 and 30 degrees for the best solar gain. Most people use the rack mounting system as their main type of solar stand. The mounting system holds your roof down and the solar panels up with a metal frame as shown in Fig. 2. For farmers, industries, homes and businesses, rack mounting systems are often the easiest to install among the various choices.

Daylight creates power with solar panels which is then stored in batteries ready for use. The stored energy is sent to the panel to keep up the output when it doesn't produce enough power. Any solar system relies most on its batteries, but they are the easiest to damage. For this reason, the battery should have enough Ampere-hour (Ah) capacity to meet the system's power requirements which are usually greater when the skies are overcast.

There are two types of batteries: deep cycle discharge (used in photovoltaic (PV) systems) and shallow cycle discharge (used in cars). The daily discharge rate of shallow-cycle batteries should not exceed 10% to 20% of their Ah capacity. Discharging them beyond this point without recharging them may shorten their lifespan. In contrast, deep-cycle batteries can discharge between 60% and 80% of their Ah capacity.

It's important to remember that a battery with a 1-amp discharge rate will have a larger Ah capacity than one with a 4-amp discharge rate. For instance, a 100 Ah capacity battery can provide 1 amp of power for 100 hours. To generate enough electricity to power the entire residence, two 24-volt 200 Ah batteries wired in series are used in the 5KWatt system.

An inverter is a key component of a solar electric system because it transforms the direct current (DC) electricity produced by solar panels into alternating current, or AC, electricity, which may be utilized to power lights, appliances, and other electrical equipment in residences or commercial buildings. The function of an inverter in the solar power setup is broken down as follows:

DC to AC Conversion: The solar panels in your home generate direct current (DC). Most homes and the grid itself depend on alternating current (AC). An inverter is used to change the DC electricity made by solar panels into AC, so it can be used by the household appliances and sent to the electrical grid.

Voltage Regulation: They also modify the voltage so that the power generated by solar is suitable for both the grid and the devices working in your home. As a result, equipment in the electrical system continues to operate safely and no unnecessary damage happens.

Grid-tied solar panels regularly use inverters to match the electricity generated from the cells with that on the electrical grid. With this synchronization, the solar system operation is secure and it can put extra power back onto the grid.[5]

Monitoring and Control: There are many inverters today that give people access to real-time monitoring of their photovoltaic system. It means following the solar panel system's total energy output, the energy being consumed and the way the system works. Some inverters also come with online systems or apps so you can control and watch your solar system from anywhere.

Safety Measures: A range of safety features is built into inverters to protect solar power systems and avoid electrical issues. Proper operations and safety of the system can be protected with ground fault, overvoltage and overcurrent protections.

For power to pass safely between all the parts of a solar system, connecting cables are very important. Here, I explain the different kinds of wires and what role they play in a standard solar installation.

Solar Panel Wiring: To obtain suitable voltage and current, solar panels are often arranged either in series or parallel. Copper wires cover each solar panel and are often coated to make them safe against shock. Solar panel electricity is carried by the cables to be put together at the junction or combiner box.

Combiner Box Wiring: In big solar systems, combiner boxes gather each panel's wiring, then send it to the inverter. The correct electrical cords connect each solar panel string to the contacts in the combiner box. Following this, the mixtures of DC from the combiner box go to the inverter.[6]

Inverter Wiring: DC input terminals are used to link the inverter to the solar panels. Using the proper connections, wires transporting the DC current from the photovoltaic cells are linked to these terminals. The building's electrical panel receives the alternating current (AC) that the inverter has transformed from direct current (DC).

Electrical Panel Wiring: The building's electrical panel, sometimes referred to as the distribution board or breaker box, receives the AC energy generated by the inverter. Usually, insulation and electrical wires with the proper gauge are used for this. The circuit breakers or fuses in the panel, that distribute power to different circuits throughout the building, are connected to the wires.

Grid-Tied System Wiring for Grid Connections: Adding solar systems to the utility grid requires wires in grid-tied configurations. Once on the grid, the solar-powered AC electricity takes over powering the building when it is synchronized with the grid.

Grounding Wiring: The safety of a solar power system is achieved mainly through correct grounding. To prevent electric shock or fire due to any stray electricity, grounding wires are hooked into the solar panels, inverter systems and a variety of metal parts.

Your safety and the efficiency of the solar system will be best served if you adhere to both manufacturer and local electrical rules when wiring everything together. Moreover, the safety of the solar system over the long term and the reduced chance of electrical risks are both possible with the use of top-quality parts and suitable installation approaches. [7]

In a solar system installation, the kind of appliances chosen can make a big difference in how much energy is used and how efficient the system is. Before installing appliances, keep the following suggestions in your mind:

Energy Efficiency: Use equipment that uses the smallest amount of electricity. Buy only appliances that have been certified for energy efficiency by ENERGY STAR. Solar-powered appliances help you get the most out of your system and decrease your energy bill.

Grid-Tied and Off-Grid Systems: Off-grid systems differ from grid-tied systems, so your solar choices will affect the appliances you buy. Because these homes are off the grid, solar power runs them and the appliances used in such homes are usually made to be power efficient and suit off-the-grid living. You can connect regular home appliances to grid-tied panels, but it's smart to pick energy-saving ones to use less electricity.

Size of Appliances: Be certain that the appliances you intend to use are sized according to your solar energy system. To find out how much power an appliance uses, count its wattage or kilowattage and the length of time it is running. You can simplify your analysis by looking at how much your solar system and battery storage can supply shown in Fig. 3.

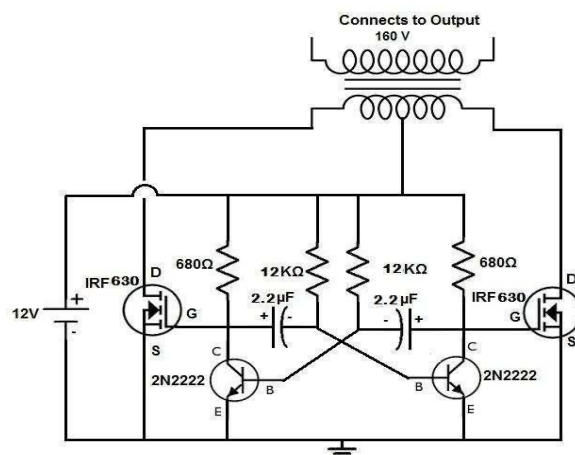


Figure 3: Schematic of appliances connection.

Load Control: One way to make better use of your solar system's power is to install and use load control methods. A lower total demand for power might be achieved by carrying out energy-intensive activities at the brightest hours or by turning on lower energy-use appliances.

Battery Compatibility (Off-Grid Systems): Choose appliances matched to your battery voltage and charger if you are not linked to the main grid. It is possible that a few pieces of equipment may work better with conventional electrical sources than they do with battery-powered solar and these can be altered or added for better operation.

Backup Power Requirements: Get appliances that work with backup power, so you can keep using them if the electricity is often not available. Even when the grid fails or sunshine is limited such systems will ensure critical services continue.

Appliances That Work with Solar Power: A limited number of appliances are specially built to be powered by solar electricity systems. Examples of solar energy devices are solar-powered lights, solar freezers and solar water heaters. Getting these tools can make your solar installation run more smoothly and help the environment. Make sure the choices in monitoring and control on your appliances match your solar panel setup. As a result, you can check your energy use, improve your efficiency and turn on or off equipment from another location to save energy.[8]

III. STEP-BY-STEP INSTALLATION OF SOLAR PANEL

There is a sequence to installing a solar system, starting with designing, planning and then mounting the panels and joining the system to your home's electrical grid. This section will walk you through the whole process:

In the planning stage, your energy needs are studied closely and solar panels are evaluated for suitable installation on your property. Remember to think about the area you have, the shade in your yard and where the roof is facing. Define the

system's size, what kind it is (options include ground-mounted and rooftop) and how it will be connected to the electric grid (off-grid or grid-tied). Get the necessary consent from utility firms, organizations for homeowners or city agencies before starting. A properly designed solar system yields more energy, complies with rules and fits what you require.

Select your solar panels by considering how efficient they are, their expected lifespan, the kind of guarantee they offer and how they look. Make sure to check how efficient the units are, what the manufacturer is known for and if the solar panels are monocrystalline or polycrystalline. Work out the number of panels needed to accomplish your energy goals. Talk to solar professionals or engineers to help you pick the best solar panels for yourself and your budget. Make sure the solar system you get is compatible with your chosen system mounting method and the inverter you want.

A. Inverter Installation

Depending on your panel design and energy needs, choose the right inverter type (string inverter, micro-inverter, etc.) and capacity. Place the inverter next to the electrical panel in a well-ventilated location. By utilizing DC wire and according to electrical rules and manufacturer requirements, plug the inverter into the solar panels. To transform DC power from the panels into useful alternating current power for your house or the grid, efficient inverter installation is essential.

B. Mounting The Panels

Getting the most sunlight means placing and positioning your solar panels smartly. Properly mounting the equipment will ensure your roof or ground system stays intact against weather elements. Install the solar panels so they are guided by the designer's plans for the angle and spacing. For a solar energy system to work well and last over time, panels must be installed correctly.

To make sure energy doesn't get lost and harm doesn't occur, route DC wire from the solar panel array to the inverter securely. Connect the inverter to the electrical panel by using conduit that meets the strictures of local electrical rules. Before attaching the inverter outlet to your home's electrical system, always take all the needed precautions and ground it.

C. Electrical Connections And Wiring

Solar panels should be connected to the inverter by using DC wire. In addition, attach and arrange the cables so that they do not lose energy or put you at risk. Be sure to install the conduit according to local electricity rules when you connect the inverter to the electrical panel. It is important to ensure you have grounding and have taken the right steps before you link the inverter outlet to your house's electrical system. For safe and building code-approved wiring, knowing electrical workings is often necessary.

D. Grid Connectivity

Work with your utility company to meet their rules and procedures for setting up solar energy systems on your grid. A bi-directional meter is needed to see how electricity moves from the solar panels to the grid. Team up with the utility company to get all the permission needed and make sure you adhere to interconnection requirements. Being linked to the

grid lets you earn credits from net metering, as your extra solar energy goes to the grid [9].

E. Examining And Verifying

Check and follow the rules by carefully testing your solar energy system after installation. Check each part such as panels, inverters and electrical links, to see how it works. Work with the suppliers and local authorities to check that codes, rules and connection demands are met during the inspection.

F. Maintenance And Regulation Of Solar System

For photovoltaic or PV, panels to operate reliably and efficiently over the long term, maintenance is essential. The following is a thorough overview of solar PV system maintenance procedures:

G. Frequent Cleaning

In time, the panels can become covered by dirt, bird and other waste, lowering their effectiveness as they block sunlight. Based on guaranteeing full sunlight usage, cleaning the panel regularly is necessary to keep your solar energy bottom line at its peak. Brush the panels clean by hand using a little bit of water, sparkling water and a water-based detergent solution. The number of cleanings will depend on what surrounds your panels and the weather, but experts suggest washing them several times each year. You should plan regular cleanup after there is a lot of rain or strong winds stirring up dust. Cleaning your solar PV system on a regular basis will ensure its reliable efficiency and avoid energy loss.[10]

H. Inspection Of Panels

You should inspect your solar panels from time to time to catch and fix any worries before they shorten the system's lifetime or its performance. During your check, watch for chips, cracks and any color changes that might suggest something is wrong. Look at parts of the roof that are next to large neighboring objects, plants or obstacles to see if any shade is preventing the panels from working their best. To ensure everything is secure, the frame and its mount are part of every inspection. Rapidly handling problems found is necessary to prevent added damage and keep the installation running well. Key checkups can keep your solar energy system in top shape for a long time by helping you address Issues early.

I. System Performance Monitoring

If you track your solar PV system's operation, you can follow its energy production, identify trends and notice if anything is working differently than it should. Place devices that measure energy output, monitor how available the system is and check for factors that can reduce the system's performance, for example, soiling or shading. Updates and watches performance reports day by day, to watch for any problems and learn about the health of the system. As action is needed fast in some cases, monitoring systems can also warn when they see abnormal situations. Supervising how your system functions can improve its outputs, show areas where it may struggle and ensure it keeps running efficiently for many years.

J. Testing Electrical And Inverter Components

The solar panels make DC power and the inverters and electrical equipment are needed to convert this into AC electricity for your house or the grid. Proper performance and working can only be ensured for inverters, wiring and electrical connections through routine testing. Regularly inspecting your sound system will help you spot loose parts, signs of rust and overheating. If you want your test equipment to perform well, reference both the user guidelines and industry standards when checking inverters and assemblies. Adapt the inverters when needed for maximum results and safety compliance. Testing inverters and electrical pieces often allows you to identify faults early and solve them before they become serious.[11]

K. Trimming Vegetation

Solar panels work less effectively when shade is cast on them by trees, bushes and shrubs. The plants near the solar panels should be carefully cut back on a regular schedule to avoid them blocking too much sun. Cut back branches that block the light from your solar panels in the hours when they get the most sunlight. Ensure that nothing is next to the panels so they get all the sunshine they can. If you want to get more sunlight on your solar panels, consider planting plants that won't grow tall enough to block the light. Keeping vegetation from your solar panels will allow your system to generate a regular amount of energy and ensure your initial cash outlay is well spent.

L. Professional Maintenance

Though homeowners may manage a lot of the upkeep themselves, it's important to arrange frequent checks by certified techs or experts to keep a solar PV system operating well. Because of their training and the unique equipment, they have, experts can inspect large structures clearly, detect possible problems and perform the necessary corrections or additions. Maintenance crews may check every part of the system, examine the electrical connections and test how everything is working during a visit. They are often able to provide useful advice for improving the system's performance and handling any problems. Reduce costly maintenance by having documents to keep track of all your maintenance work and following the instructions given to you by the manufacturer. If you use skilled maintenance, you can expect a lasting system, less downtime and guaranteed reliability in your solar energy system.

IV. CONCLUSION

All in all, this research paper has explained the important benefits of solar energy for people, communities and the environment, plus the installation method in easy-to-follow steps. The increase in solar energy use can be linked to worries about the environment, unrest between countries and the rising cost of standard sources.

Solar energy helps lower greenhouse gas emissions which is a major strength in fighting climate change. Solar energy does not pollute the air like fossil fuels which is why it helps prevent the negative effects of climate change.

In addition, relying on solar energy can lower our dependence on fuel supplies that might be continually limited. Because

solar systems use the sun's energy as a free resource, they provide a reliable source of power and help us avoid any problems caused by energy price changes or disagreements over resources. Each component—panels, inverters, batteries and connecting wires—has been explored for its part in turning solar energy into useful forms.

It is highly suggested to pick energy-efficient products that cooperate well with solar systems. Pick appliances that make the best use of solar energy and fit the specific conditions of your solar setup to catch every opportunity for efficiency.

Solar energy is useful because it produces environmentally friendly energy which may play a key role in solving current concerns about energy and protecting the environment. As technology matures, lawmakers show support and more people notice, solar energy's share in global energy will grow.

ACKNOWLEDGMENT

The authors extend their sincere gratitude to the Department of Electrical Engineering, NFC Institute of Engineering and Technology, for providing a supportive research environment and access to advanced computational resources, which enabled the successful execution of this study.

FUNDING STATEMENT

The author(s) received no specific funding for this study.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest to report regarding the present study.

REFERENCES

- [1] Sengupta, M., et al. (2021). Best practices handbook for the collection and use of solar resource data for solar energy applications, National Renewable Energy Lab.(NREL), Golden, CO (United States).
- [2] Sampaio, P. G. V. and M. O. A. González (2017). "Photovoltaic solar energy: Conceptual framework." *Renewable and sustainable energy reviews* 74: 590-601.
- [3] Keisang, K., et al. (2021). "Review of operation and maintenance methodologies for solar photovoltaic microgrids." *Frontiers in Energy Research* 9: 730230.
- [4] Kebede, A. A., et al. (2022). "A comprehensive review of stationary energy storage devices for large scale renewable energy sources grid integration." *Renewable and sustainable energy reviews* 159: 112213.
- [5] Kalogirou, S. A. (2023). *Solar energy engineering: processes and systems*, Elsevier.
- [6] Kabir, E., et al. (2018). "Solar energy: Potential and future prospects." *Renewable and sustainable energy reviews* 82: 894-900.
- [7] Hernández-Callejo, L., et al. (2019). "A review of photovoltaic systems: Design, operation and maintenance." *Solar Energy* 188: 426-440.
- [8] Bird, L., et al. (2016). "Wind and solar energy curtailment: A review of international experience." *Renewable and sustainable energy reviews* 65: 577-586.
- [9] Al Garni, H., et al. (2016). "A multicriteria decision making approach for evaluating renewable power generation sources in Saudi Arabia." *Sustainable energy technologies and assessments* 16: 137-150.
- [10] Abdmouleh, Z., et al. (2015). "Review of policies encouraging renewable energy integration & best practices." *Renewable and sustainable energy reviews* 45: 249-262.
- [11] Denholm, P., et al. (2015). Overgeneration from solar energy in California. a field guide to the duck chart, National Renewable Energy Lab.(NREL), Golden, CO (United States)