Effective power generation and utilization of solar photo voltaic system

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Abstract. Solar Energy (SE) is the primary energy source and that is freely available in all the regions in the world. The isolated and remote areas can electrify using SE and it is pollution-free for electric power generation. This paper presents the generation of electrical energy from the solar photo voltaic system (SPVS). The SPVS output can increase with the help of synchronised maximum power point solar tracking system (SMPPSTS), hence the system efficiency can be increased. The load on the system is regulated with the effective operation of controller, relays, driver circuit, and sensors.

Keywords: Battery Energy Storage System, Renewable Energy, Sensor Module and Synchronised Maximum Power Point Solar Tracking System

1. Introduction
Most of the electrical energy is generated from nonconventional energy sources such as coal, gas, oil, etc. The electrical energy per unit cost is more and such type of generating stations release high-level harmful gases such as sulphur dioxide, carbon dioxide, nitrogen oxide, and produce other wastages. It leads to the global warming and acid rains. To minimise the effects and supply the required electricity as per the increased load demand due to industrial, commercial, and residential needs, worldwide, the countries looking towards the renewable energy-based electricity generation. The renewable energy sources (wind and solar) are freely available in every country and there is a possibility to generate more electricity from the sources. In India and most of other countries, either coal or oil-based power plants are operating as base power plants. In India, coal-based power plant installed capacity is 205954.50 MW from the total installed capacity of 371976.84 MW as end of July 2020 [npp.gov.in]. Some of the power generation capacities (MW) in India shown in Table 1 respective graph is shown in the figure 1. From the table it is observed that solar power plants capacity installed in India is 35303.3 MW and at the end of this year (2020) it will be 36.6 GW.
Table 1. Power generation details in India

| Type of Source | Power Generation Capacity in MW |
|---------------|---------------------------------|
| Coal          | 205954.5                         |
| Gas           | 24991.51                         |
| Diesel        | 509.71                           |
| Nuclear       | 6780.00                          |
| Hydro         | 45699.22                         |
| Wind          | 37940.95                         |
| Solar         | 35303.3                          |

Figure 1. Graphical representation of Power Generation from various types of generation stations in India.

To increase the solar photo voltaic panel (SPVP) performance efficiency and to scale down the operation and maintenance cost, many industries and educational institutions do research. In the solar photo voltaic system (SVPS), the power electronics device plays a vital role to improve the reliability and efficiency. They are DC-DC boost converters and DC-AC inverters. The DC-DC boost converter simplifies the implementation of maximum power point tracking [1]-[2]. A solar panel energy conversion system designed using inciter, Arduino Uno, linear actuator and motor control unit for the effective electrical power [3]-[4]. The maximum power extract from the SPVP array using DC-DC converter and dynamic maximum power point tracking was obtained by DC-AC inverter [5]-[6]. For the rural area electrification, solar energy is one of the alternative energy sources. By implementing the solar tracking system and interconnecting the standalone PV systems, the size of the PV systems can be reduced, the reliability of power supply can be increased [7]. The solar panel efficiency increased by solar tracking system with the help of LDRs [8]-[22]. In this system, load regulation was not implemented.

In the above systems, it can be observed that the load connection and isolation as per the availability of energy were not present. In this paper a simple and reliable system is proposed to improve the SPVS efficiency and reliable operation of the system. A prototype system is developed.
with the help of controller (ESP32), sensor module witching arrangement and maximum power tracking system. The available power will be measured by voltage and current sensors and as per the priority, the loads are connected to the SPVS.

2. System description

Simplified schematic diagram of the proposed system is shown in figure 2 with the synchronised maximum power point solar tracking system (SMPPSTS), controller (ESP32), and sensor module. In this system, solar photo voltaic system (SPVS) converts the solar energy to electrical energy. The average efficiency of the SPVP varied from 2% to 24.1% based on the type and construction. In this system, the overall efficiency is increased by implementing the SMPPSTS. The SMPPSTS operation is depending on the effective operation of photo sensors, controller, driver circuit, and two servo motors. The photo sensor (Light Dependent Resistor (LDR)) identifies the direction of sun light and it sends the signal to the controller. The driver circuit interface with the controller and based on the controller commands through the driver circuit, DC servo motors which are coupled with the solar panels can rotate the solar panel. In this manner, the solar panel can produce more electrical power. In the proposed system, four numbers of LDRs are used to identify the direction of solar radiation (sun light rays) and the same send to the controller. The servomotors, which are fixed with the solar panel, are used to rotate the panel in dual axis based on the controller action through the driver circuit. The driver circuit is used to control the speed of the motors. As compared with the fixed panel system, the SMPPSTS efficiency is more.

![Schematic diagram of proposed solar photo voltaic system.](image)

The solar panel delivers DC output. The output connected to battery energy storage system (BESS). The DC loads and controller connected to the battery through the DC-DC voltage regulators. The DC supply is given to inverter (DC-AC converter) to produce AC output voltage. However, the outputs of the inverter voltage and current have higher order harmonics because of switching. They can be minimised by LC filter. The regulated AC supply is given to the AC loads through the relay circuit.

In any electrical system, load demand is variable and solar power generation is not constant due to the weather effect. At a particular instant, if the load demand is less than the generating power, the
power is stored in BESS. In another instance, the generated power is less than the load demand, the BESS also deliver the power to the load to meet the load demand. In another case, the sum of generating power and BESS power is less than the load demand, the relays are used to connect the suitable loads to the system. If any open circuit and short-circuit faults will be occurred in the system, they can be sensed by the sensor module and the same data given to the controller. Based on the controller commands, the fault section is isolated from the system with the help of relay circuit.

3. Implementation

The electrical energy which is produced in the SPVS is measured by sensor module. Based on available electrical energy, suitable loads are connected to the SPVS. The sequence of implementation of connection of loads to the SPVS is flow chart is shown in the figure 3. If the instantaneous generating power is high, it is supplied to DC loads through battery and AC loads through the inverter, LC filter, and switching system. The power is low, the sensor modules measure the storage energy in the battery. If the combination of storage energy and solar energy is very low because of weather and other effects, all the loads are disconnected from the system. In case the measured power is medium, initially emergency loads (In the implementation DC loads are considered as emergency loads) connected to the system. Another condition is that the available power is more than the AC loads (Lamps) and DC loads connected to SPVS.

![Flow chart of sequence of load regulation on SPVS.](image-url)
4. Results and conclusions

Figure 4. Single AC load is connected to SPVS.

Figure 5. All AC loads are connected to SPVS.
In the proto-type system testing, LED light and buzzer are considered as DC loads as well as emergency loads. In SVPS, available power is sufficient to operate only DC Loads, the controller allows connecting the DC loads. In case of available power is just greater than the medium energy, only the suitable AC load(s) is / are connected to the SVPS. In figure 4, it can be observed that only a single load(bulb) is connected to the system based on available energy, i.e., total energy available in the battery and instantaneous power produced in the solar panel. In figure 5, it can also be observed that all the DC and AC loads are connected to the system.

In the solar photo voltaic system (SPVS) output power can be increased by implementing the synchronised maximum power point solar tracking system (SMPPSTS). It can be achieved by effective arrangement of photo sensors. Based on the photo sensors inputs, the controller can control the position of SPVS through the driver circuit. The available power in SPVS (storage power in the BESS and generating power) can sensed by the sensor module. The suitable loads (DC loads and AC loads) can be connected either manually or automatically through the switching module to SPVS. The SPVS efficiency is more and generating electrical power can effectively supplied to the loads. Further this work is extended to online monitoring of the system using Internet of Things (IoT).

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