

Design and Development of Automatic Solar Tracker System for Wireless Sensor Network Node

D. Baghyalakshmi*, Jemimah Ebenezer, R. Jehadeesan

Abstract

Energy Harvesting Technique (EHT) extracts energy from the renewable sources available in environment. Among all, the solar energy harvesting technique extracts maximum harvested power. The need for energy has grown in recent years in commercial, residential, agricultural, and industrial sectors. Non-conventional or renewable energy sources are being examined as an alternative when traditional, conventional energy sources run out. They are devoid of pollution and kind to the environment. Energy is extracted from a variety of renewable energy sources found in the environment using the Energy Harvesting Technique (EHT). In general, thermal, light, radiofrequency, and vibration are the energy sources that are available. In our work, we have designed and developed a solar-powered Wireless Sensor Network (WSN) node with smart auto power switching mechanism, which extends the node's battery life. To harvest solar power more efficiently from solar panel, a microcontroller-based single-axis Automatic Solar Tracker System (ASTS) has been designed and developed. This study briefs about the design, development and performance evaluation of the ASTS in comparison with Normal Solar Panel System (NSPS).

Keywords: Energy harvesting, solar tracker, solar charger, solar energy harvesting technique, normal solar panel system

INTRODUCTION

In recent years, the demand of energy is increasing more in industry, agriculture, commercial and residential areas. As the traditional, conventional energy sources become exhaustible, the renewable or non-conventional energy sources are considered as an alternative option [1]. They are environment friendly and pollution free. The Energy Harvesting Technique (EHT) extracts energy from various renewable sources of energy available in environment. Generally the available sources of energy are

Thermal, Light, RF and Vibration. Table 1 shows the feasible power levels that can be harvested from the energy sources mentioned. It shows that, the outdoor light energy source offers the maximum energy than the other available sources.

The solar energy is ecofriendly, cheap and available in abundant. The solar energy harvesting provides the maximum energy when compared to other energy sources [2]. A solar cell converts the illuminated light energy into electricity by using the photo voltaic effect [3]. It generates current in proportion to light incident on active area and its conversion efficiency. In addition, by using the Automatic Solar Tracker System (ASTS), surplus solar energy can be harvested by adjusting the solar panel directly facing towards the sunlight persistently.

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Table 1. Energy sources and feasible harvested power levels.

Type of energy source	Categories	Harvested power	Efficiency
Light	Indoor	100 $\mu\text{W}/\text{cm}^2$	10–24%
	Outdoor	100 mW/cm^2	
Thermal	Industrial	$\sim 1\text{--}10 \text{ mW}/\text{cm}^2$	$\sim 3\%$
	Human	60 $\mu\text{W}/\text{cm}^2$	$\sim 0.1\%$
RF	Wi-Fi	0.001 $\mu\text{W}/\text{cm}^2$	$\sim 50\%$
	GSM 900 MHz	0.1 $\mu\text{W}/\text{cm}^2$	
Vibration	Machine	$\sim 800 \mu\text{W}/\text{cm}^2$	25–50%
	Human	$\sim 4 \mu\text{W}/\text{cm}^2$	

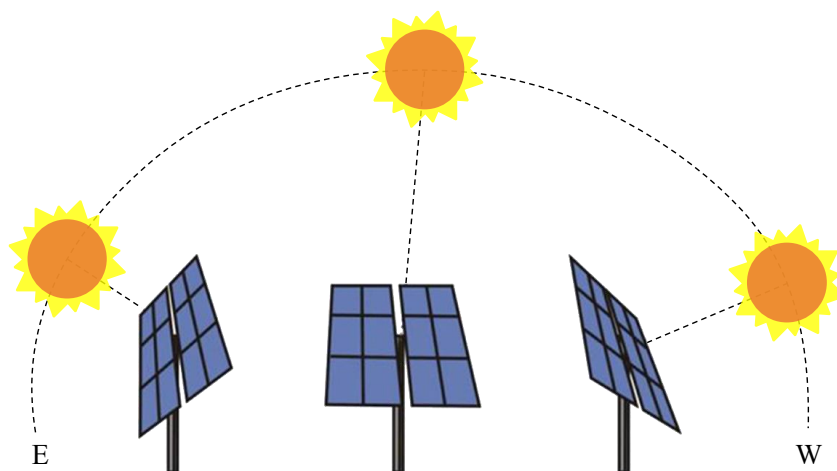
This study describes about the ASTS developed inhouse for powering WSN node. First, introduction about the ASTS is given. Then, the development and implementation of ASTS in Wireless Sensor Network (WSN) node is described; the performance testing of the ASTS is elaborated and in the end the conclusion is given.

AUTOMATIC SOLAR TRACKER SYSTEM

The quantum of solar energy harvested depends on the direct sunlight illumination on the solar panel. As the sun's position keeps varying throughout the day, the energy harvested from a solar panel fixed in a constant direction will be reduced relatively. Solar tracker is a mechanical structure that helps to change the solar panel orientation towards the sun direction. Hence the implementation of solar tracking system improves the solar energy harvesting efficiency of the solar panel. In general, two types of solar tracker methodologies exist, namely, single axis solar tracker and dual axis solar tracker [4–7]. A single axis solar tracker rotates the panel from East to West direction. Dual axis solar tracker generally rotates the panel from East to West direction and depending on yearly change in sun's position, adjusts itself in North to South direction [8, 9]. We have designed and developed a microcontroller based single axis ASTS that can be deployed outside. The developed system identifies and sets the optimum solar panel position based on the sunlight's intensity by using a servo motor controlled by a controller unit which receives the light intensity information from the light dependent sensors. The implementation of ASTS allows the solar panel to automatically shift its mounting position focusing its face towards the sun as shown in Figure 1.

DEVELOPMENT OF AUTOMATIC SOLAR TRACKER SYSTEM

Wireless Sensor Network consists of numerous sensor nodes, router nodes and Base Station (BS). The sensor nodes will be interfaced with sensors. It process and transmit the data either directly or through router node to BS located in a central location [10–14]. In general, WSN nodes are battery

**Figure 1.** Solar panel's mounting position focusing its face towards the sun.

powered. As Solar Energy Harvesting Technique (SEHT) affords more energy, it was considered as the best option for powering the WSN devices in outdoor deployments. In our work, the solar-powered WSN nodes with smart auto power switching technique have been designed and developed in-house, which makes the node to work with solar power for longer duration. This extends the battery life by avoiding the unwanted battery charging cycle. Further, the power requirement of WSN devices has been optimized by designing it with low dropout regulators, switching and charging circuits [15]. In addition, by using the ASTS, more solar energy can be harvested by adjusting the solar panel directly facing towards the sunlight persistently [16–22]. The harvested solar energy provides power to the node as well as charges the rechargeable batteries. Hence a microcontroller-based single-axis ASTS has been designed and developed. The implementation of ASTS allows the solar panel to automatically shift its orientation with respect to sunlight's intensity.

Generally in a day, the intensity of sun illumination is more in East direction during morning and it is more in West direction during evening. The Light Dependent Resistor (LDR) is used to sense the intensity of the sun light. Its resistance decreases with increase of light. To measure the intensity of sunlight throughout a whole day, a test setup with two LDRs and a solar panel fixed mechanical structure has been deployed at outdoor (Figure 2). It was ensured that there were no trees or high rise structures/buildings near the deployed area which may obstruct the direct sunlight to LDRs. LDR1 has been mounted facing East direction and LDR2 has been placed facing West direction.

The LDR1 and LDR2 values have been logged continuously. Figure 3 shows the variation of the values in LDR1 and LDR2 for a whole day. It was observed that during day time, LDR1 value is less than LDR2, during evening, LDR2 value is less than LDR1 value, and during noon, both the values are almost same.

With the measured values of LDR1 and LDR2 it was practically understood that if the solar panel is mounted in a fixed direction, the solar energy can be effectively harvested for half of the day. To utilize the solar light available for a whole day, the solar panel direction has to be changed with respect to the sun's position instantaneously. Hence, to harvest the solar energy efficiently, the solar tracking system helps to change the solar panel direction by tracking the sun's position. An ASTS has been designed and developed. For this development, two LDRs, a servo motor, a controller and two gears were used. The block diagram is shown in Figure 4.



Figure 2. Light intensity variation measurement setup.

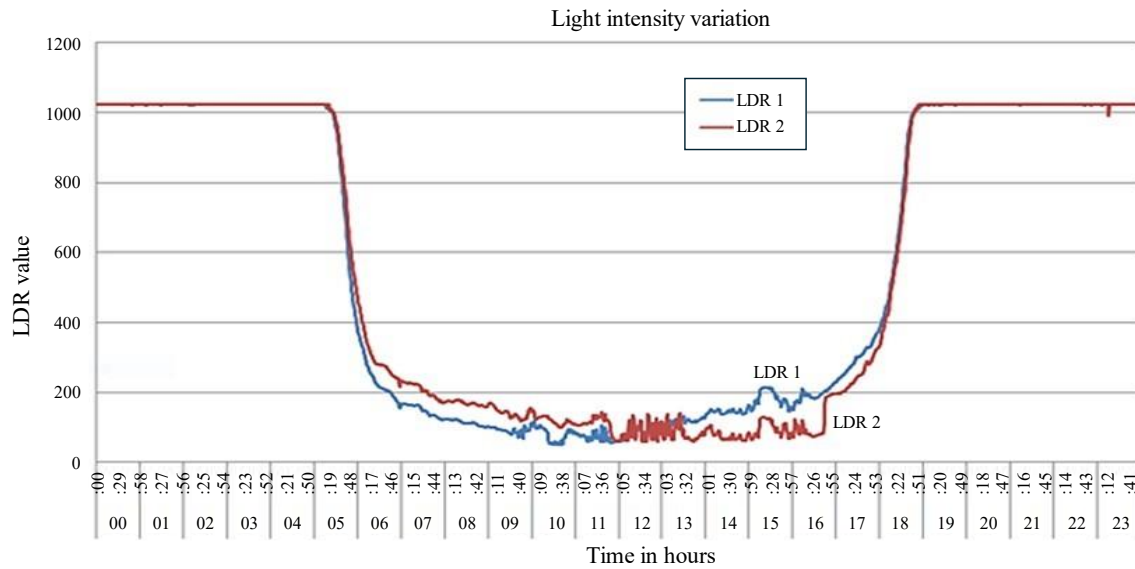


Figure 3. Light intensity variation measured by LDR1 and LDR2.

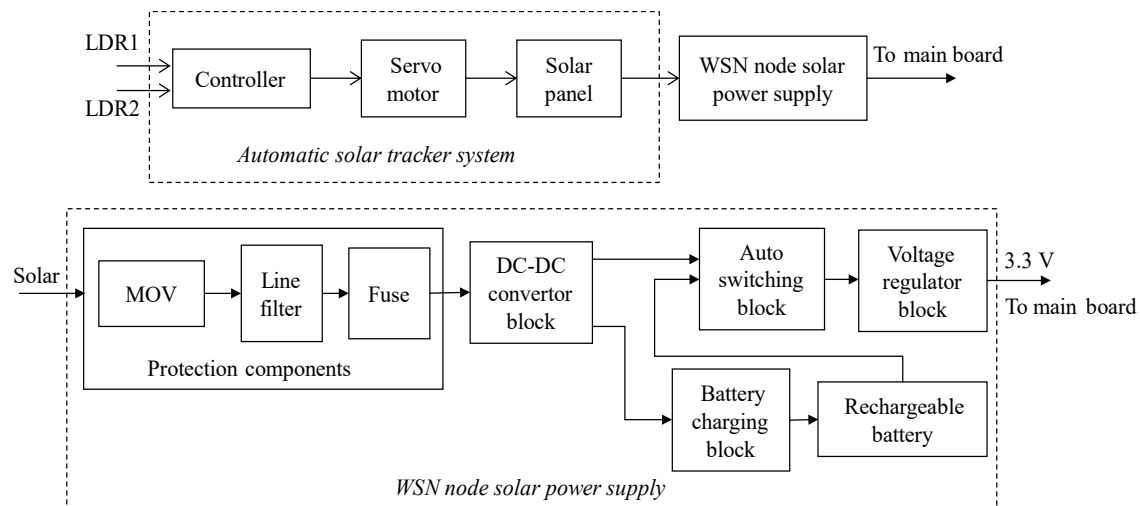


Figure 4. Block diagram of Automatic Solar Tracker System and WSN node solar power supply.

The developed ASTS is shown in Figure 5(a). LDR1 is fixed at the East side of the solar panel and the LDR2 is fixed at West side. Two gears were used, Gear_1 fixed to the axle of servo motor. The Gear_2 is fixed to the rust proof steel smooth rod. To this rod, the solar panel also is fixed. The Gear_1 interfaced with servo motor is placed exactly below the Gear_2 which is fixed to the rod. They were positioned in such a way that, the teeth of both the gears will be in touch, as shown in the Figure 5(b). Whenever one gear rotates in clockwise direction, it rotates the other one in anticlockwise direction. The 12 V solar panel changes its direction to the servo motor through its axle. Hence whenever the servo motor rotates, the solar panel also rotates. Ball Bearing Blocks were fixed at the end of rod for smooth rotation. The rotation of the panel based on the LDR value has been controlled by program.

PERFORMANCE TESTING OF THE ASTS

A test setup has been established at outdoor to analyse the power harvested by the ASTS in comparison with the NSPS setup. The single axis ASTS setup with rugged mechanical structure and NSPS setup with metal stand has been installed at outdoor. The solar panel of ASTS is placed facing East-West to track the sunlight. The solar panel of NSPS is placed in horizontal position towards East-West direction. The test setup is shown in Figure 6.

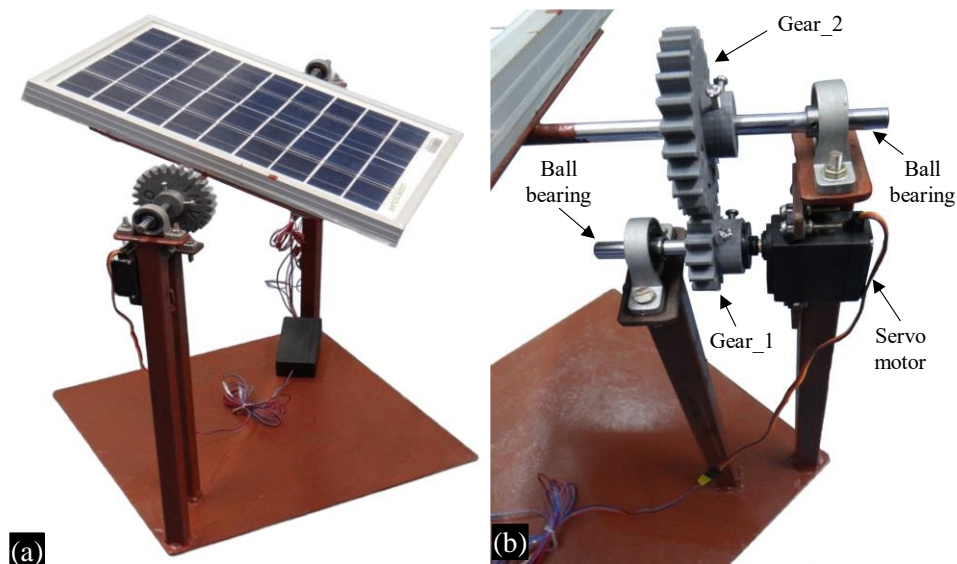


Figure 5. (a) Developed single axis ASTS, (b) Gear arrangement in ASTS.

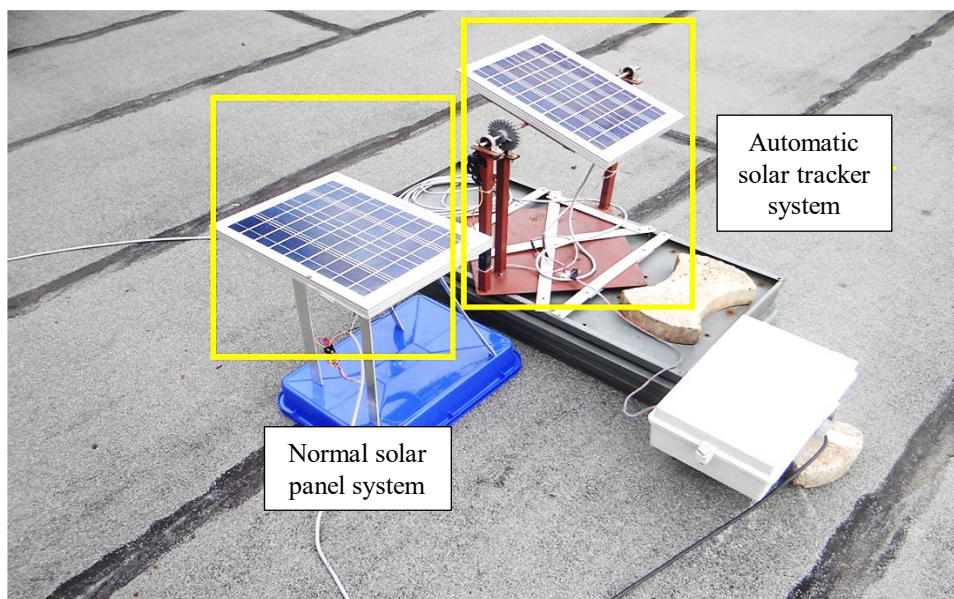


Figure 6. Outdoor test setup of ASTS and NSPS systems.

The LDR senses the intensity of the sun and its output is fed as input to the controller board. Based on the LDR output, the controller program changes the servo motor angle, which in turn aligns the solar panel either towards East direction or West direction as the day progresses.

The panel movement has been planned for five steps: 45, 60, 90, 120 and 135°. The LDR values were fed to ADC. If the value of LDR1 facing East is more than the value of LDR_2 facing West, then the panel will be rotated to face West and vice versa. Initially, the threshold value has been calculated based on the LDR resistance variation with varying light intensity.

As per the program logic, five angle steps were achieved based on the difference between the LDR1 and LDR2 value. If the LDR1 value is more than LDR2 and more than threshold_1 value, the solar panel will be moved towards West with angle 60° or if the difference is more than threshold_2 value, the solar panel will be moved towards West with angle 45°. If the LDR2 value is more than LDR1 and more than threshold_1 value, the solar panel will be moved towards East with angle 120° or if the

difference is more than threshold_2 value, the solar panel will be moved towards East with angle 135° . If the difference is less than threshold_1, the solar panel will be moved towards angle 90° and positioned in horizontal direction. With practical test, it was observed that, when the sun rises in the morning, the solar panel faces East and when sunsets in the evening, the panel faces West. During cloudy time or night, the panel will be placed in horizontal position.

With the ASTS setup and NSP setup, 3.6 V rechargeable Li-ion batteries were interfaced with charging module to get it charged by its solar panel. The charging module is featured with Maximum Power Point Tracking (MPPT). It provides the maximum charge current. It maintains the solar panel to operate at peak power point. Whenever the input voltage reduces below the set voltage, it reduces the charge current.

As shown in Figure 7, for measurement and analyses, the ASTS solar panel's voltage, current, battery voltage and the NSPS solar panel's voltage, current and battery were interfaced to different channels of data logger. The data logger was configured to log data every 1 min once. From the logged voltage and current, the power harvested by both ASTS and NSPS has been analyzed (Figure 8). It was observed that, on daily basis, the energy harvested by ASTS by tracking the sunrays is more than NSPS. Even during the cloudy day, the energy harvested by ASTS is more. The system harvested power gain was calculated by considering the ASTS and NSPS power difference with respect to NSPS. The observation is shown in Figure 9.

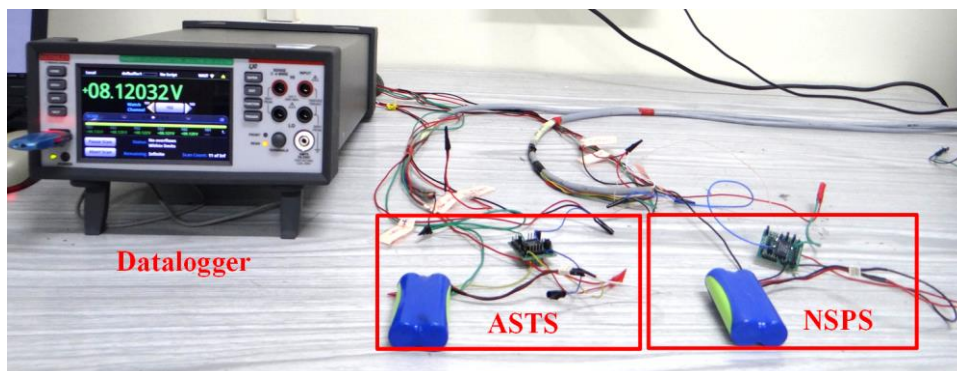


Figure 7. Datalogger test setup of ASTS and NSPS systems.

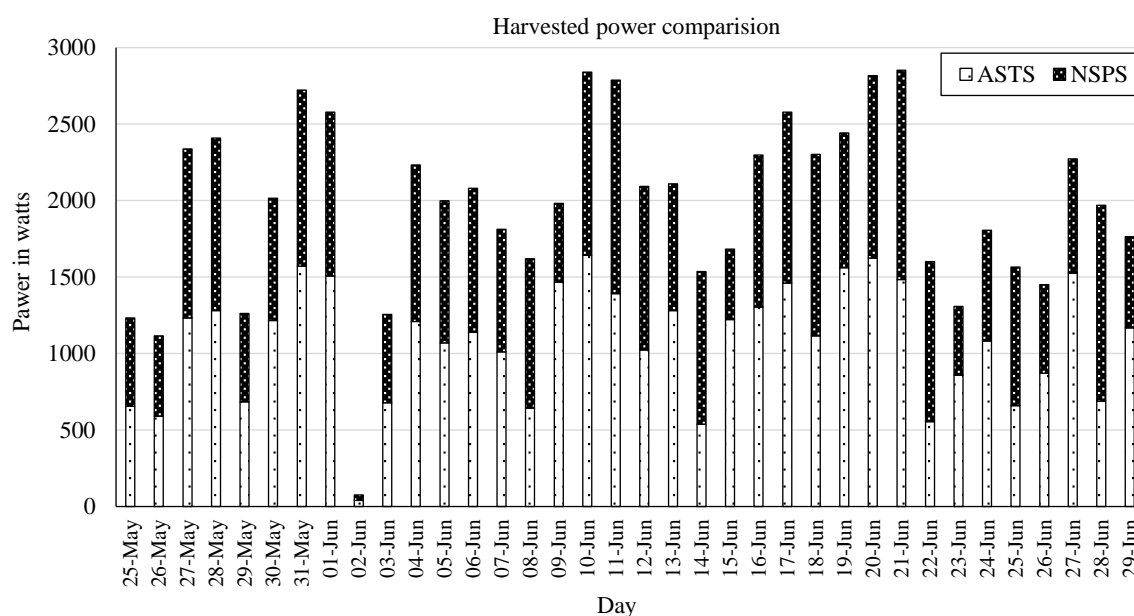


Figure 8. ASTS and NSPS systems harvested power comparison.

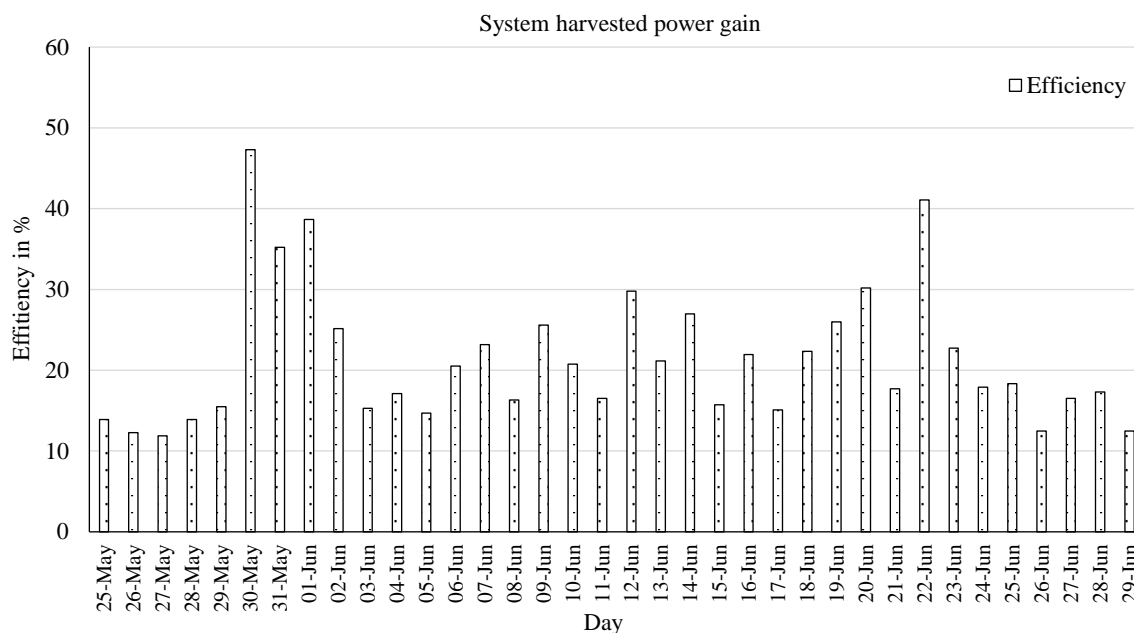


Figure 9. Systems harvested power.

It was found that on a sunny day at the maximum 48% of more power than NSPS could be harvested; and on cloudy day, 13% of more power than NSPS could be harvested by using the ASTS. Hence, as an average, 22% of more power can be harvested efficiently by tracking the sun’s position. A test WSN was established at outdoor using the solar powered WSN node along with the developed ASTS. The solar energy harvested with this setup provides power to node and also charges the battery. The node transmits the LDR1 value, LDR2 value and the solar panel current position along with timestamp to the BS placed inside WSN lab. A Wireless Network Management Station (WNMS) is used to display and log the received data in database. The performance of the deployed solar powered node was found working satisfactorily.

CONCLUSION

Solar energy harvesting provides maximum energy compared to other ambient energy sources. For outdoor WSN deployments at remote area, the solar energy harvesting will be the effective option for powering the WSN devices. The quantum of solar energy harvested will depend on the direct sunlight illumination on the solar panel. As the sun’s position keeps varying throughout the day, the energy harvested from a solar panel fixed in a constant direction will be reduced relatively. Hence to improve the solar energy harvesting, a single axis Automatic Solar Tracking System (ASTS) has been developed and tested. It was observed that ASTS tracks the solar rays more than the Normal Solar Panel System (NSPS) with solar panel in a fixed position and harvest power of about 22% higher on average.

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