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Solar Energy Harvester For Pet GPS Collar

Abstract*. The power source of wireless technology depends on the device's battery life and need to be plugged in for recharge purpose. This problem can be solved using energy harvesting system which directly converts solar energy radiated from the sun into electricity. In this project a solar energy harvesting pet collar is developed to harness solar energy and charge the installed battery. The GPS system used a minimum of 2.2V up to 3.6V input voltage. The result obtained shows that the solar panel can give enough power to power up the GPS system as that energy harvester circuit and is able to deliver output up to 4.3V in direct sunlight with an input voltage as low as 3.25V.*

Streszczenie. *Źródło zasilania technologii bezprzewodowej zależy od żywotności baterii urządzenia i musi być podłączone w celu naładowania. Problem ten można rozwiązać za pomocą systemu pozyskiwania energii, który bezpośrednio zamienia energię słoneczną wypromieniowaną ze słońca na energię elektryczną. W ramach tego projektu opracowano obrożę do zbierania energii słonecznej, która wykorzystuje energię słoneczną i ładuje zainstalowaną baterię. System GPS używał napięcia wejściowego minimum 2,2 V do 3,6 V. Uzyskany wynik pokazuje, że panel słoneczny może zapewnić wystarczającą moc do zasilania systemu GPS, jak obwód urządzenia do pozyskiwania energii i jest w stanie dostarczyć do 4,3 V w bezpośrednim świetle słonecznym przy napięciu wejściowym tak niskim, jak 3,25 V.* (***Pozyskiwaniew energii słonecznej do obroży GPS dla zwierząt***)

Keywords: Solar Energy Harvester, GPS, Pet Collar
Słowa kluczowe: energia słonewczna, GPS, obroża psa

Introduction

Today, we have restricted non-renewable power sources, for example, coal, nuclear oil, and gas, on account of the developing populace. There is alternative energy which is renewable energy. The most widely recognized sustainable power utilization for electrical energy is Solar Energy; called solar energy harvesting system, as commonly used in [1-4]. For this project, the concept of solar energy harvesting is applied to a GPS pet collar. The idea is to give an embedded GPS pet collar with the ability to generate its own power rather than only depending on the battery.

This project will focus on designing the solar energy harvester circuit and GPS that uses IoT platforms as a medium for transferring and receiving data. The embedded GPS with IoT connection platform is installed in an ordinary pet collar. Therefore, the system is controlled by a microcontroller that will execute a coding of instruction for the whole system. This project uses two mini solar panels to harvest the energy radiated from the sun into electrical energy to power up the GPS pet collar. The solar energy harvester circuit performance will be thoroughly experimented to analyze the performance and compatibility of the solar energy harvester circuit with the GPS pet collar.

Extracting electricity directly from the sun is made possible today by discovering the photoelectric mechanism and subsequent development of the solar cell. This semiconductive material converts the visible light into a direct current [5]. The small size solar panels that are connected to low-power energy harvester circuits and rechargeable batteries provide a loom to make the WSN nodes or any wireless devices completely self-powered with an infinite lifetime [6] and are widely used in nowadays devices. As shown in Figure 1, Malaysia has recorded a value of 4.96 kWh/m2 on average per day of its solar insulation has been produced [7]. The maximum value of 5.56 kWh/m2, and the minimum value of 4.21kWh/m2 daily. The monthly average of sunshine ranges from four to 8 hours, or about 2200 hours of daylight a year [8].

Solar energy harvesting using a solar panel is done through photovoltaic (PV) cells consisting of silicon which converts light energy to electrical energy by absorbing photons from the sunlight [9]. Several solar cells are made from different layers of material on each of these solar panels. An anti-reflective surface coating helps absorb as much light as possible from the cell. The lower layer between the top of a negative conductor and the bottom of a positive conductor is a sandwiched semiconductor (usually silicon). Once the photons are absorbed by the solar cell, the outer electrons of the atoms inside the semiconductor are liberated. The positive and negative conductors provide a pathway to the particles and produce an electrical current. Then this electrical current is transmitted to the solar panel through DC electrical capture cables. The energy efficiency of most of today's photovoltaic cells is only around 15 to 20 percent. Since the strength of solar radiation is poor to begin with, even moderate amounts of power require extensive and expensive assemblies of such cells [10].

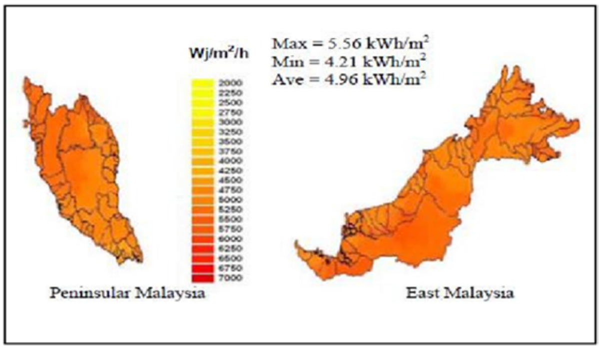

Fig.1. Annual Average Daily Solar Radiation map in Malaysia [8]

Global Positioning System (GPS) is a system that navigates around Earth and sends its location details back to the Earth. The vital part of this GPS is the satellites that navigate around the Earth. The GPS works in three segments: the space segment, control segment, and user segment [11]. Furthermore, the GPS Receivers can recognize their area when three GPS satellites locate and measure the distance to the recipient and analyze the estimations. A fourth satellite estimates the chance to the collector. The data from each of the four satellites are ordered to decide the area. The complexity of a GPS collector impacts the Reliability and Accuracy of the GPS information. Figure 2 visually shows how exactly the GPS worked.

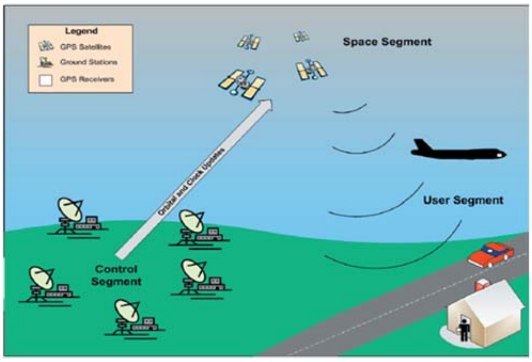

Fig. 2. GPS Segment [11].

GPS has many application for both military and minor civilian applications which is Navigation, astronomy, cartography, mapping, cellular telephony, disaster relief, radio Occultation, clock synchronization, geotagging, geofencing, fleet tracking, air tracking, mining, tours, recreation, robotics, surveying, sports, tectonics, telematics and other uses.

Results and Analysis

A. Software result

The main result desired for this project is the GPS coordinate and the battery percentage of the designed solar energy harvester for GPS pet collar devices. The serial monitor result shown in Figure 4 is the Latitude and Longitude value of the current location received from the NEO 6m-0-001 GPS module connected with the NodeMCU-ESP32 after a wi-fi connection is made between NodeMCU-ESP32 and smartphone, which had been set in the coding for the system. Figure 3 shows the Blynk application interface before and after starting and connecting the system. In Figure 3, After the system is connected, the location appeared as a pin location on a Google map. The black pin represents the GPS or the pet location and the green dot represent the smartphone's location. The percentage of the current battery life also showed on the application, together with the latitude and longitude value of the pet's current location. The location is a little bit inaccurate because of the inaccuracy of the used GPS module but still tolerable and able to track down the cat.

When comparing the received location data from the GPS module with the GPS data received from the user's mobile phone, they show slightly different results in coordinate value and the pin location on the map. The coordinate is supposed to be the same as the black pin and the green dot must overlap because when the test is conducted, the GPS module is placed right next to the user's mobile phone. As shown in figure 3, the black pin location from the GPS module is located a little bit far from the green dot from the user's mobile phone GPS location. To be accurate, the difference in distance is approximately from 5 meters to 10 meters. From the coordinate value obtained in Figure 3, the value of the latitude and longitude for the GPS module is 2.281798, 102.280388, and kept changing as the location updated. The GPS coordinate for the user's mobile phone is 2.281879, 102.280384. The error for this result is due to the GPS module error. There are a few reasons leading to this error: clock error, ephemeris error, Earth atmosphere, Multipath errors, and Satellite geometry. Those errors can affect the GPS module accuracy and lead to the difference in the coordinate location obtained from the GPS module and the user's mobile phone. However, the error can be tolerated when a field test is conducted. The location of the subject for this energy harvester pet collar which is the cat, can be found with the given coordinate location by the GPS module.

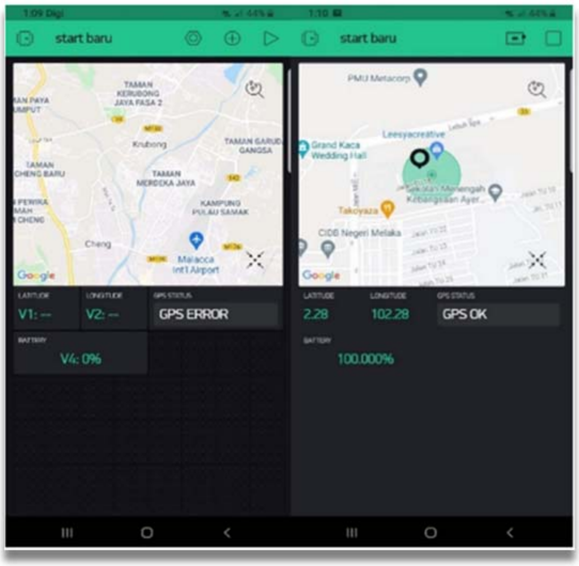

Fig. 3. Blynk interface application.

B. System performance without presence of sun (Night) experimental result

The result in Fig. 4 is obtained from a study conducted by measuring the voltage and the current consumed every one hour for 12 hours. The experiment is done for the 600mAh rechargeable 3.7V Lithium-ion battery installed in the circuit as the backup power source for the solar energy harvester GPS pet collar to prove the battery endurance and life span when used overnight without solar energy presence.

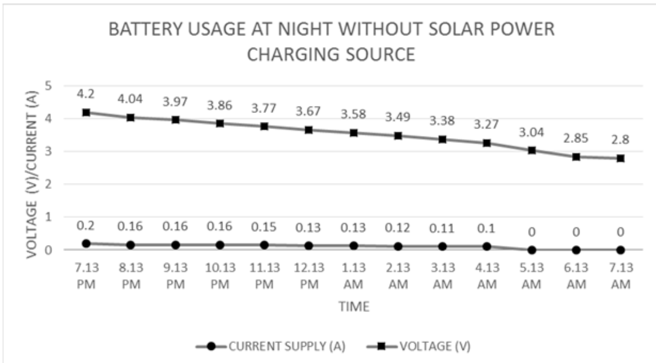

Fig. 4. Battery current supply and voltage value per hour.

As mentioned before, NodeMCU-ESP32 operating voltage is between 2.3V and 3.6V, but the recommended voltage is 3.3V. As for the operating current, the NodeMCU-ESP32 needs 0.05 A. This experiment is conducted to prove this matter. The experiment is conducted by measuring the voltage and current consumed by the NodeMCU-ESP32 using a multimeter and the result can be seen in Fig. 5.

As stated in the datasheet of NEO-6M-0-001 GPS module, the operating voltage and current are in the range of 2.7V to 3.6V and 0.45 A. An experiment is conducted by measuring the value of voltage and current consumed of the GPS module using a multimeter to prove this matter.

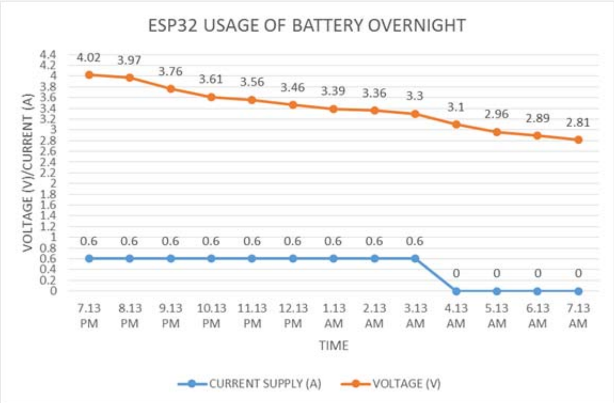

Fig. 5. Current and voltage usage value for ESP32 per hour.

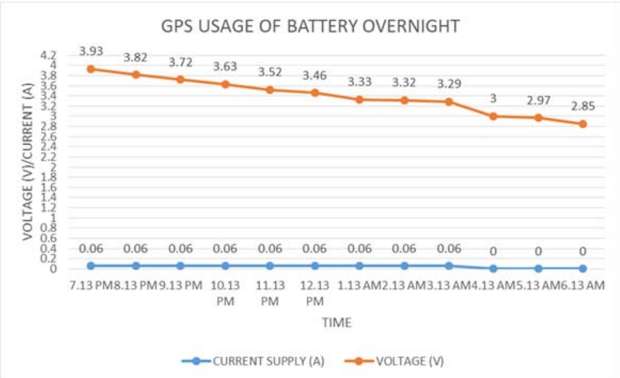

Fig. 6. Current and voltage usage value for GPS module per hour.

The result obtained from Figure 4 shows that the battery can only power up the circuit approximately about 9 hours straight from fully charging until it loses its power after 8 to 9 hours of operating. The result proves that the battery capacity plays a significant role in backup power. A longer battery lifespan is needed to supply voltage to the circuit for the larger battery capacity. When conducted with a bigger battery capacity, the outcome will be more efficient as the battery will have enough power to supply to the circuit until sunrise. Besides that, the power used by the NodeMcu-ESP32 and GPS module as shown in the Figure 5 and figure 6 also affected the outcome of Figure 4 for the battery usage and power consumed. The experimental result for both ESP32 and GPS module shows the same pattern of voltage and current consumed. The result proves that the 3.7V lithium-ion battery can give enough power for the component to operate at full potential. However, the ESP32 stop receiving Wi-Fi connection when the voltage dropped over 3.2V.

As mentioned before, the operating voltage of the ESP32 is between 2.2V and 3.6V but the connection became unstable when the ESP32 voltage dropped over 3.2V. The result proves that the voltage at the ESP32 needs to be maintained over 3.2V for the system to fully operate with high potential. For the GPS module, the minimum operating voltage is 3V. The result proves that when the voltage at the GPS module reaches below 3V, the module stops giving coordinate data for the system. This is due to the ESP32 stop operating, and the GPS module also will stop running simultaneously due to the ESP32 playing the data transfer center for the system. However, the current consumed by both ESP32 and GPS modules is at the very minimum value of 0.06 A. The result shown in Figure 4 and Figure 5 also affected the result obtained in Figure 6 as the lower the power consumed by the component of the circuit, the longer the battery lifespan.

C. System performance with presence of sun in direct and indirect condition experimental result

From the theoretical output voltage of the solar panel, the output voltage can be generated by the solar panel depending on the angle of the solar panel facing the sunlight. To investigate this matter, a study is done by measuring the output voltage value produced by the solar panel while exposing it to direct sunlight without any resistance, as shown in Figure 7.

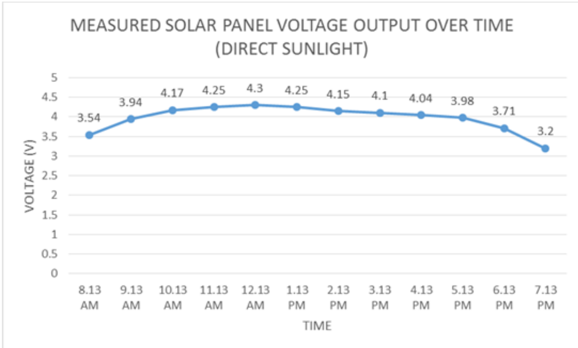

Fig. 7. Measured solar panel voltage output (direct sunlight).

As stated before, the output voltage generated by the solar panel depends on the environment around the solar panel that will change the angle of the sunlight towards the solar panel or the environment that can prevent the sunray from emitting directly to the solar panel. However, the sun is 90 degrees toward the Earth. To investigate this matter, a study is held by measuring the voltage output generated by the solar panel while placed under a roof with indirect sunlight exposed to the solar panel.

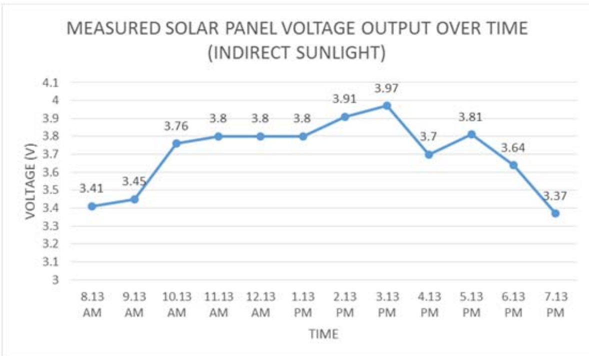

Fig. 8. Measured solar panel voltage output (indirect sunlight)

The result shown in both Figure 7 and Figure 8 shows that the output voltage generated by the solar panel differs over time. This is due to the different sun angles towards the solar panel and the environment around the solar panel that prevent the solar panel from taking direct sun rays emitted from the sun. As time flows, the sun orbits the Earth, and the sun's angle keeps changing over time. From the result in Figure 7, the peak output voltage is at 12.13 P.M, when the angle of the sun is at 90°, proving that the amount of power produced by a photovoltaic solar panel is proportional to the amount of sunlight falling on it. Because the sun's angle influences the energy of the light absorbed by the Earth, the sun's location affects how much energy a solar panel creates. Besides that, the solar panel specification used for this project also influences the output result; for example, if the higher voltage and wattage solar panels is used, the output voltage is predicted to be higher compared to this result. The result in Figure 8 shows unstable and unpredictable output voltage, but Figure 7 shows a different pattern. It is easier to be predicted. The result of the measured voltage output generated by the solar panel with different situations simulating the cat movement showed positive results. The component used in this project consumed very minimum power and the power produced by the solar panel is high and enough to power up the circuit and charge the backup battery at the same time. Therefore, this project can achieve 100% performance in the daytime. This study is conducted in a straight daytime without interference from the cloudy sky or bad weather.

Rate of charge and discharge of the battery

The lithium-ion battery depends on the voltage rather than current, and recommended voltage to charge a 3.7V rechargeable lithium-ion battery is 4.2V. To prove the statement, predict and assume the percentage of the battery corresponding to the battery's voltage, a study and observation is conducted by measuring the battery's voltage over time with output from the solar panel as shown in the previous Figure 7 considering direct sunlight all day.

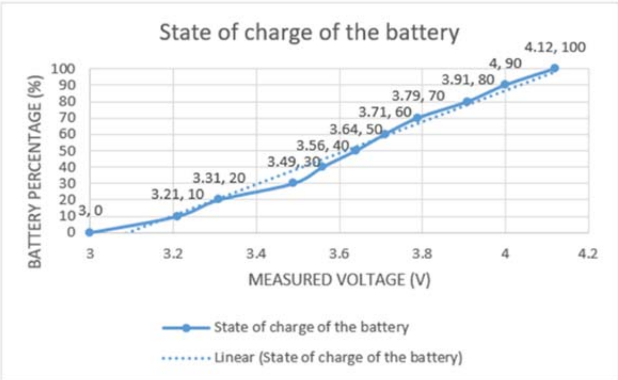

Fig. 9. State of charge of the battery

The battery capacity is 600mAh and has around 6 to 7 hours of lifespan in continuous usage by the GPS circuit. To observe the battery's discharge rate, a study is conducted by measuring the battery's voltage over time while in use by the GPS circuit. This study then presented a state of discharge graph in Figure 10 showing measured voltage in volt for the x-axis and the assumed battery percentage for the y-axis. The result indicates that the graph decreases linearly as the battery keeps consuming power to the circuit over time before reaching 0% at 3.08V when the battery is in an open circuit condition. This measured data is consistent with the expected result for the battery lifespan considering the battery capacity and is used to compare the state of charge graph in Figure 9.

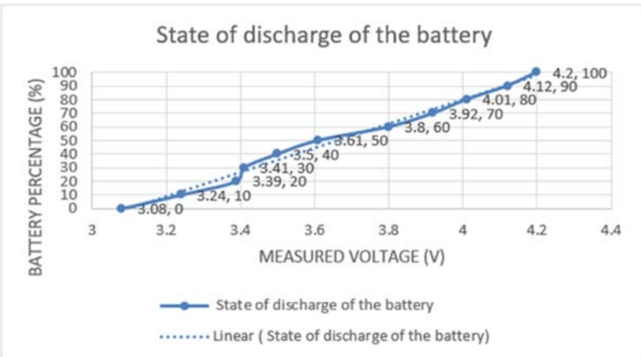

Fig. 10. State of discharge of the battery

When compared, the state of charge and discharge had the same pattern of linearity consistent with the theoretical graph of charge and discharge of the 3.7V lithium-ion battery. The difference is the time taken for the battery to fully charge to 100% with a voltage of 4.12V, which took about 11 to 12 hours charging period, while the discharge time only took about 6 to 7 hours to reach 0% at 3.08V for the measured value of battery voltage. The charging time depends on the type of solar panel used to charge the battery and the sun position towards the solar panel process, considering good sunny weather without any resistance from the cloudy sky and bad weather. For the discharge graph in Figure 10, the study is conducted when there was no sunlight for the charging process and the only process occurring is discharge. The result shows the constant level of assumed battery percentage respected to the measured value of the battery's voltage. The battery used is a low cost, and the minimum size battery is perfect for installing the pet collar. The component used had minimum power to contribute to a longer battery lifespan than expected. From the graph observation, the calculation of the assumed battery percentage concerning voltage output can be made and executed in the system's coding. Therefore, this project can achieve 100% battery performance with controlled charging and discharge time.

Project full prototype result

From Figure 11 the collar design choice is considered in the solar panel installation to the pet collar. The solar panel is placed on the upper side of the collar to receive as much solar energy as possible from the sun with perfect angle.

Fig. 11. Project final complete prototype.

Fig. 12. Cat wearing the pet collar.

The space to install the solar panel is perfectly fitted with the collar and makes the cat comfortable with the solar panel, as shown in Figure 12. The container containing the circuit also perfectly fits with the collar, and the size of the container plays an essential role as it is kept at the minimum extent possible not to bother or annoy the cat. After that, the first field test is held with tracking the cat's whereabouts using the GPS application within the BLYNK software in the smartphone.

Conclusion

The solar energy harvested from the sun for this system has zero pollution effect on the environment and can help improve our living costs today. Although there are a lot more room of improvement especially on increasing the battery capacity for longer lifetime and also using much more accurate GPS module to increase the accuracy of the object location so this solar energy harvesting pet collar to be worked perfectly without any flaw. This project also promotes the green energy usage from any renewable energy source available on this planet.

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