Simulation of IoT based solar powered automated fish feeding system

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Abstract: To minimize manual labor in aquaculture, this paper proposed an IoT-based solar-powered automated fish feeding system. Fish feeders will be readily managed from mobile phones utilizing the mobile app and the dashboard with only a click at a time and from anywhere. To create such a prototype, hardware components required are solar panels, solar charge controller, Arduino microprocessor along with DC gear motor and ESP32+SIM800L as GPS and GSM module. MATLAB Simulink software is used to analyze the system outcome. The DC power generation unit in Simulink monitored the data of DC voltage, current, power, etc. The prototype can operate remotely based on instruction given by user through a cell phone application. As Bangladesh is a subtropical region, the temperature hike in summer as per simulation did not affect the battery's voltage output or operation as the voltage fluctuation of the battery's input from the solar panel ranged between 12.3V to 11.3V based on an outside temperature of 18-degree Celsius to 40 degree Celsius. An auger used ensured controlled food dispersion over regulated time intervals.

Keywords: charging module, DC gear motor, ESP32+SIM800L, fish feeding, IoT, MATLAB simulink, solar energy

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1 Introduction

The fish farming sector has become popular as a profession over time. It is attracting bountiful individuals, both domestically and internationally. Fresh-water fish breeding is widespread nowadays, both for commercial purposes and as a hobby in people's homes. However, there are certain issues with caring for fish and one of the major challenges is the management of feeding. Leaving extra food in the tank is an unhealthy practice for the fish owners when they become unavailable for a long time, because it may cause overfeeding or even death of the fish. Also, release of proteins and nitrites from extra foods break down in the water reduces oxygen level in the water thereby becomes a threat to the life of fish. Every day, fish owner needs to maintain the feeding schedule which makes it difficult for the owner to be away from home. To overcome this limitation owner must hire people to monitor feeding in his absence and hence maintenance cost increases. Hence an automated

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device that can provide proper timely feeding at a predetermined time is highly in need. Incorporation of advanced technologies such as an automated fish feeder can mitigate the problem and may make aqua cultural practice less laborious to the farmer. Many fisheries globally use automated fish feeders which results in significant savings in manufacturing costs.

An automated fish feeder is an electro-mechanical device that administrates appropriate measure of nourishment to the fish at a time interim according to the feeding schedule planned by the farmer. Abinaya et al. (2019) refers such devices as an arrangement of equipment implemented with programming and networks that enables farmers to exchange, measure, and break down data to facilitate various operations. Several studies have been carried out with experimental outcome in past couple of years where a significant progress has been observed in automated fish feeder development. Wei et al. (2017) proposed automatic fish feeder machines focused on design and construction which addressed features such as quantity of the food, ability to dispense food, distance of the food dispense, food blockage in the distributor, size, material, temperature, and water resistance of the feeder system. Osueke et al. (2018) proposed an automated fish feeder model where a 12 V DC motor rotates a 4 pitched screwed auger which broadcasts a particular quantity of fish food to minimize food wastage. Later modern systems incorporated temperature sensor (Uddin et al., 2016), pH sensor (Balaji et al., 2020), turbidity sensor (Ratnasari et al., 2021) and water level controller robot (Muhammad and Dermawan, 2022) to monitor the quality and height of the water as fishes are sensitive to such factors. A smart solar powered fish feeder has been proposed by Shahiran and Salimin (2021) feeding is controlled by the owner away from home through the Blync application.

This system controls the quantity of food dispersion by a servo motor, but the feeding mechanism was not clearly demonstrated. To maintain precise quantity of the food dispersion different types of feeding mechanisms have been demonstrated in research such as through diagonal impeller instrumented with DC motor (El Shal et al., 2021), using both belt and screw type conveyor (Ani et al., 2015) instrumented with 40 W and 90 W AC gear motors and feed plate instrumented with bi-directional motor (Ogunlela and Adebayo, 2016) to control food discharging operation. An efficient dispersion mechanism can ensure perfectly controlled feeding by reducing overfeed and hence ensure healthy growth of fish. Thus, this research aims to design and develop an IoT based solar powered fish feeder that is capable to monitor feeding automatically. Moreover, it has a directional feeder mechanism which will help to maintain correct quantity of the food for dispersion. It has a reliable delivery system utilizing an auger to move feed from the hopper to the impeller which blows it into the water. The auger is very precise and consistent and does not damage the fish feed like other feeder systems. The DC gear motor spins and creates a superior food distribution even better than the systems with diagonal impeller.

2 Materials and methods

To analyze the performance of solar panel, during the month of March 2021 experiments were done in Hatirjheel area which is in Dhaka City, Bangladesh with the GPS coordinates of 23°45' 37.188" N and 90°25' 27.768" E. In Dhaka hot season starts from March with an average daily high temperature above 32℃ has been surveyed by Weather Spark (2022). So, the experiment was done during March to obtain the optimal outcome from the solar system. In Figure 1, system operation is described. Solar panel will initially create electrical energy and the DC current will be energizing the 12 V battery cell through a step-down.

Then the 12 V battery will turn on motor circuit to initiate feeding operation for a certain time based on a signal send from the GSM module by the user. When GSM signal is received by the microprocessor which then regulates current flow to control motor speed.

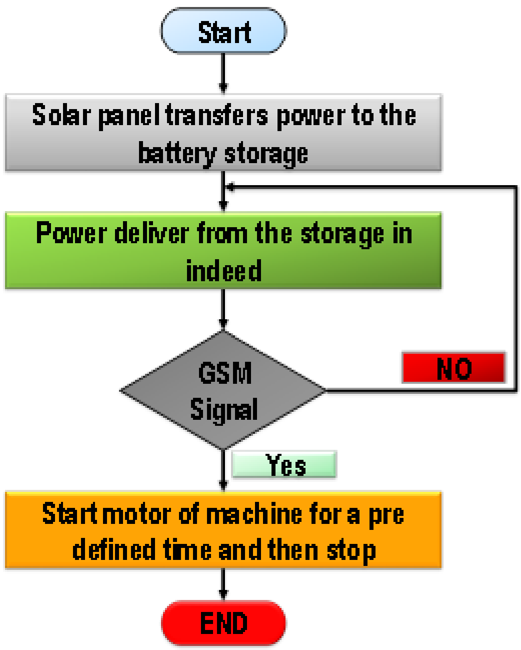


Figure 1 Flowchart of the fish feeding operation

2.1 Circuit design

This system is made up of three primary parts: solar cells, Arduino control, and GSM transmission and receiving. So, start with a PV solar panel with consistent irradiation and temperature. Then a battery was connected to the solar panels. The voltage divider rule is one of the simplest and most important in electrical circuits as shown in Figure 2. Generally, these dividers are used to lower or establish a reference voltage. Therefore, the battery's 12-volt input voltage remains constant. Voltage fluctuations won't harm the components. The manual switching button was attached to illustrate that the system could be handled manually and that the motor would start and stop after a certain period with the supplied voltage of 12 V. A microcontroller was used to give the system some additional features such as Bernoulli binary generator. To simplify the circuit operation, it is categorized into three subsystems. This design's transmitter subsystem uses Gaussian minimum shift keying (GMSK). It's a high-bit-rate modulation approach. GMSK employs consistent envelope modulation (CEM) to keep signal amplitude consistent when transmitting. Then the channel subsystem uses additive white Gaussian noise (AWGN).

According to voltage divider rule:

$$V_{out} = \frac{R_2}{R_1+R_2} \times V_{in} \quad (1)$$

$$R_2 = \frac{V_{out} \times (R_1+R_2)}{V_{in}} \quad (2)$$

Here both V_{in} and V_{out} are voltages measured in volts. V_{in} is the solar panel generated voltage and V_{out} is the parallel voltage across battery. R_1 and R_2 are the resistors measured in kilo ohms.

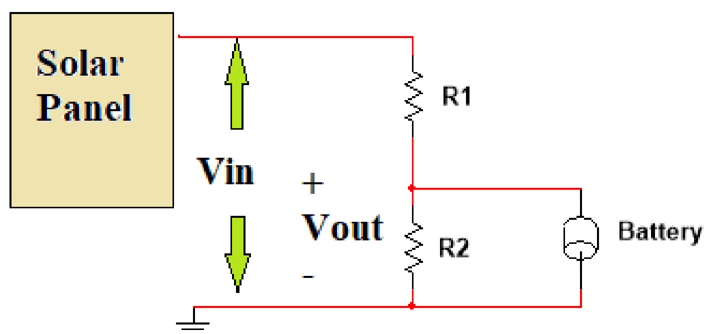


Figure 2 Voltage divider rule diagram

2.2 Simulation

There are three main components in the design of this system: solar cells, Arduino control and GSM Transmission and reception. It is therefore necessary to start with a PV solar panel that has a constant irradiance and temperature. Thereafter, a battery was attached to the solar panel outputs. When it comes to electronic circuits, the voltage divider rule is one of the simplest and most significant ones. However, in general, these dividers are utilized as a signal attenuation at low frequencies or to reduce or establish a reference voltage. As a result, the battery's input voltage, which is 12 volts, will remain constant. So, the components won't be damaged by voltage fluctuations.

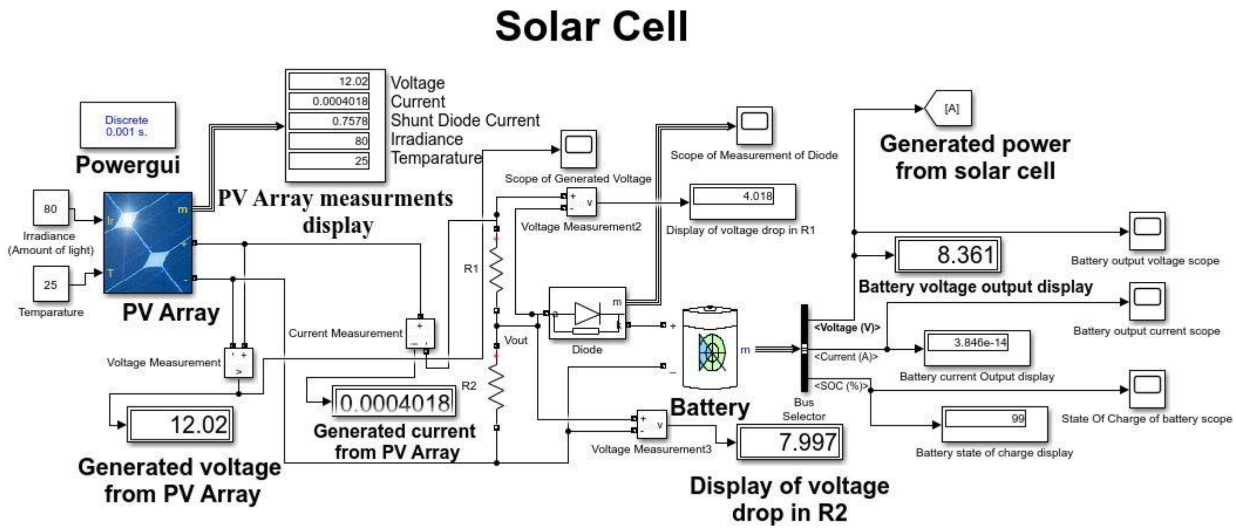


Figure 3 Generation of power

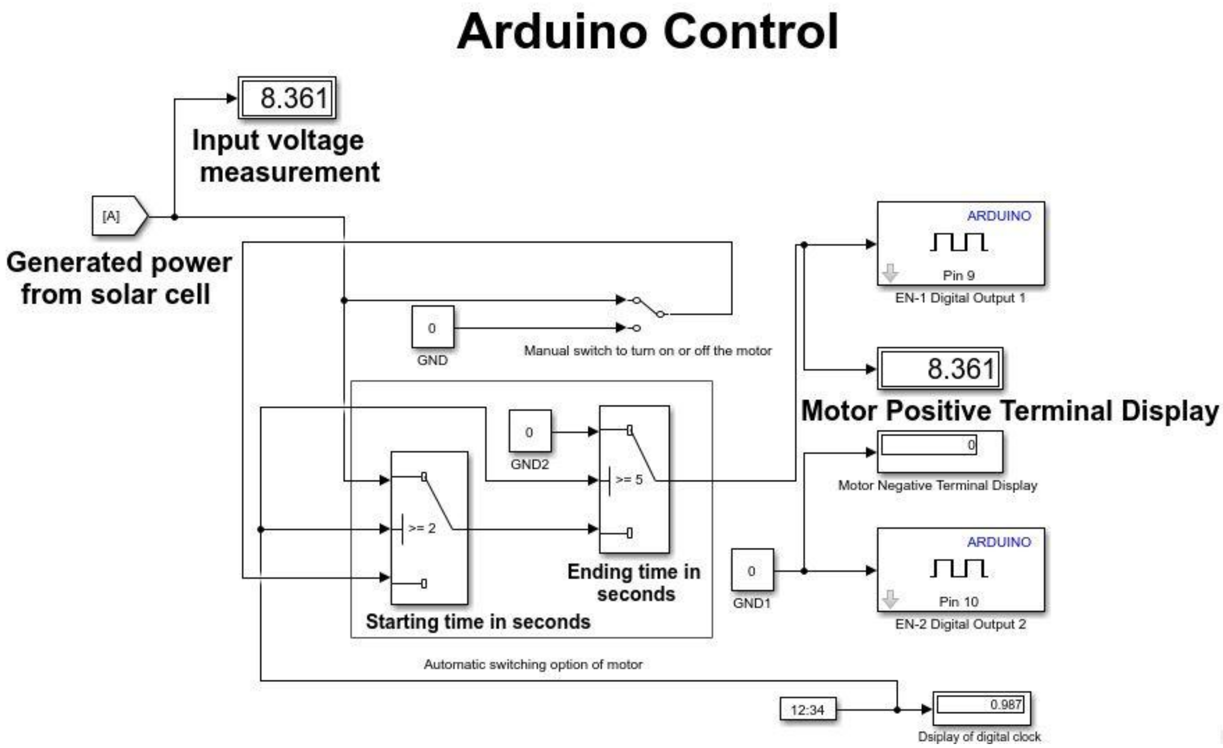


Figure 4 Arduino simulation using the power

Figure 3 shows the power producing unit. Here, a PV array is used which will convert light energy to electrical energy. The irradiance is set to 80 $^{Wb}/_{m^2}$. The PV array's generated performance parameters were recorded. In order to ensure that the battery receives consistent voltage, the voltage-divider rule is applied. This will aid the battery's ability to fend off harm. The voltage from the battery's output was then saved in a GOTO block.

The manual switching button was connected to indicate that the system could be operated manually as shown in Figure 4. The simulation shows that after a given amount of time the motor would begin to run and automatically shut off based the allotted time. The FORM block has been used to deliver the solar panel's produced electricity in this section.

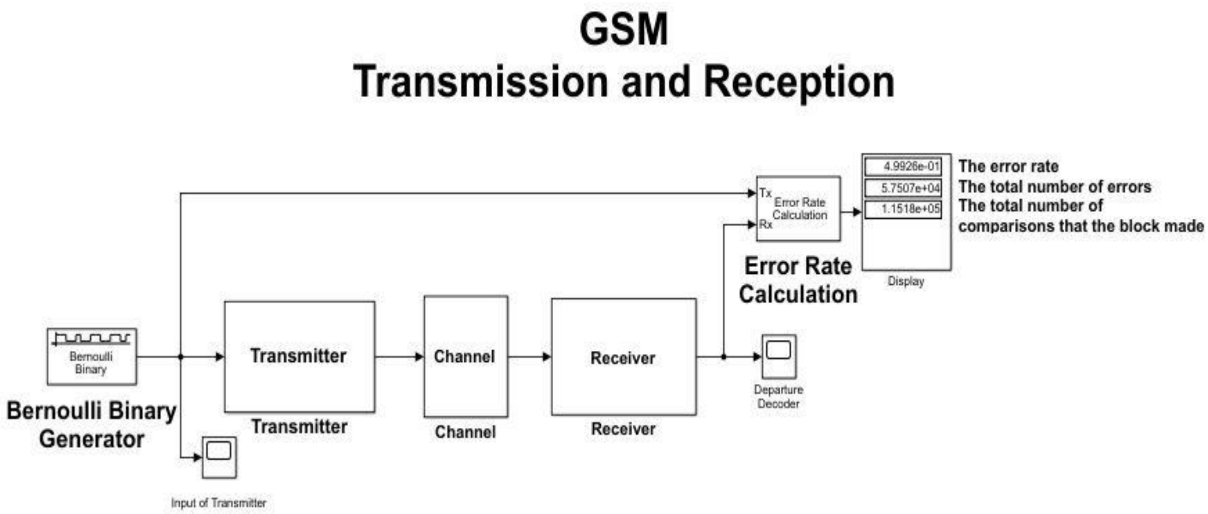
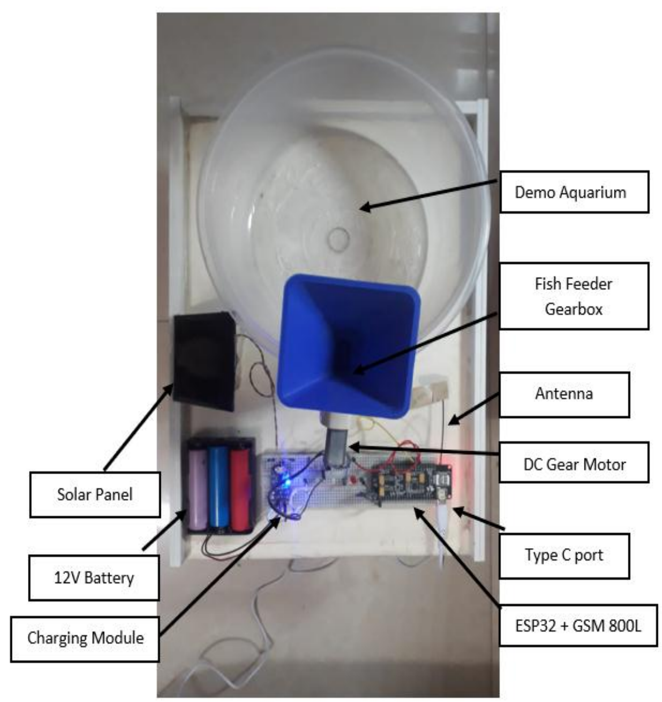


Figure 5 Simulation block of GSM transmission and reception

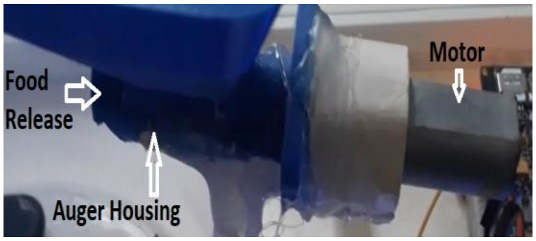
Figure 5 demonstrates how the GSM module works in this section. A Bernoulli binary generator is used to create the input for this simulation. To give the circuit a more immediate appearance, it was divided into three subsystems. GMSK has been employed in the transmitter subsystem of this design. It's a high-bit-rate modulation technique for modulating a high-rate transmission. Because it uses CEM, GMSK maintains a constant signal amplitude when transmitting. Then, in the channel subsystem, AWGN is utilized. AWGN is the primary noise model used in information theory because it closely replicates the effects of many random processes that occur naturally in the world. Finally, in the receiver, GMSK is employed and the output is found to be identical to the input.

2.3 Hardware implementation

To observe the performance of the proposed system, a prototype hardware design has been developed which is shown in Figure 6. ESP32+800L has been chosen as a microcontroller in this project. Mainly T-Call is a newly released ESP32 development board from TTGO that includes a SIM800L GSM/GPRS module (Figure 9). The new board unites the ESP32 Wi-Fi and Bluetooth WiSoC with the SIMCom SIM800L GPRS module, as well as a USB-C connector for power and programming, as opposed to the more usual micro-USB port for this sort of equipment. The board has all of the required functionality for controlling the controller and may be linked to a computer through USB to send code to the controller using the IDE (Integrated development environment) software, which was specifically designed for programming Arduino. Although IDE is compatible with Windows, Macintosh, and Linux, it is suggested that Windows is used.



(a) Components



(b) Feeder dispenser

(c) food dispersion through the food releasing hole

Figure 6 Prototype design of the proposed fish feeding system

The charging module (Figure 7) is responsible for extracting energy from the solar panel and storing it in a battery. Essentially, the module is responsible for monitoring the battery voltage that is consumed by the circuit (load). The TP4056 chip is a lithium-charge battery to protect the cell from being loaded for a single cell battery. It has two status results that indicate loading and loading. A diode is used to protect the solar panel. The power from the battery is transferred to the DC gear motor (Figure 8), which then starts the rotation of the gear platter for the purpose of tossing food. With the help of the Blynk software, an application for controlling the machine was developed. Figure 6a is the arial view of the implemented hardware of the project, Figure 6b shows the housing of the feeder dispenser and Figure 6c shows food dispersion through the food releasing hole. Practically the performance of the system was very close to the simulations performed, and the system worked without any trouble.

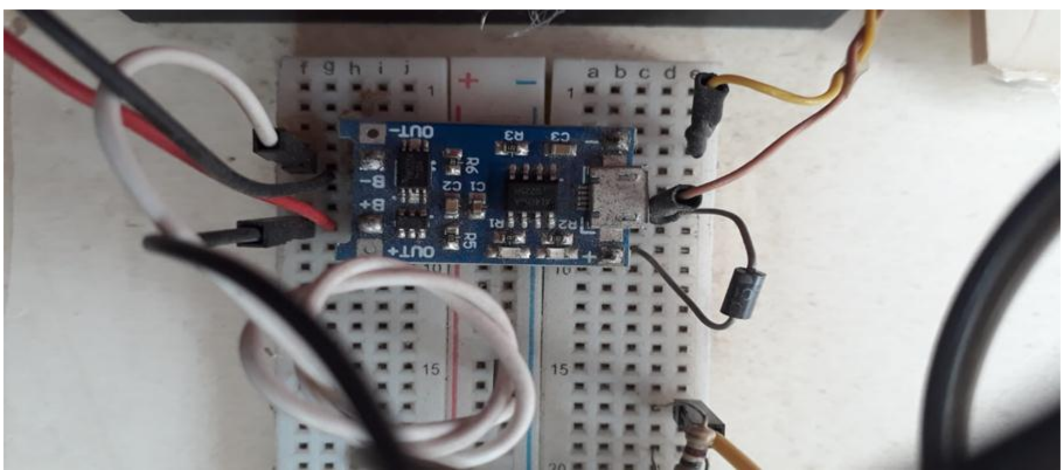
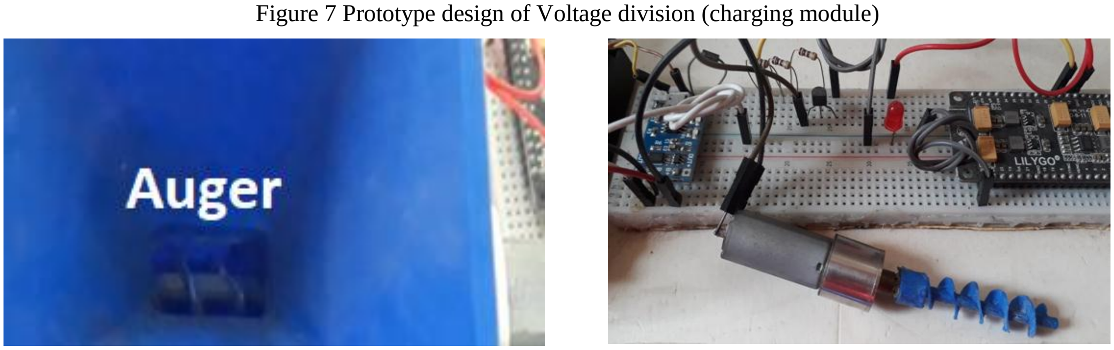


Figure 7 Prototype design of Voltage division (charging module)



(a) Placement of auger (b) motor connected to auger

Figure 8 Prototype design of motor circuit

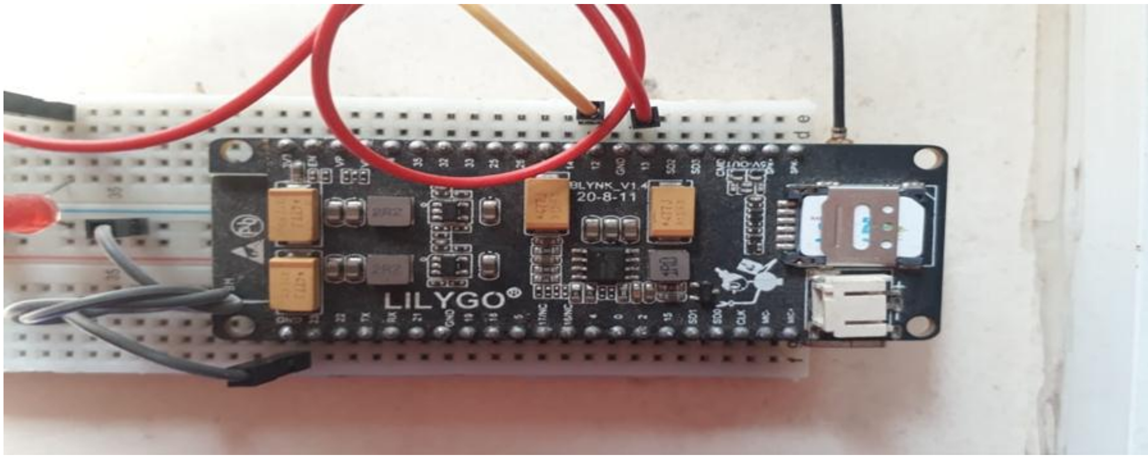


Figure 9 Prototype design of GSM module circuit

2.4 IoT in operation

Blynk software was used to operate the system remotely. It can be used to control the motor and the led. Two switches for motor and led are used which is shown in Figure 10. The system works spontaneously when the motor on switch is pressed, as the motor works by throwing fish feed. The motor will turn off when the OFF tab is pressed. The operation of LED is likewise.

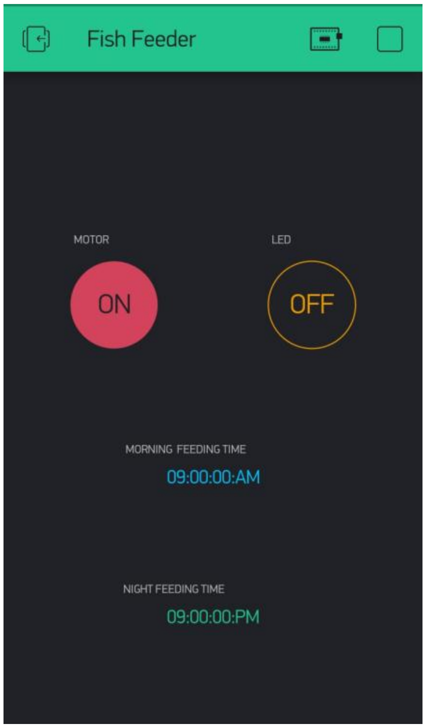


Figure 10 Control by Android Phone (Blynk Software)

Figure 11 shows the timer circuit for the prototype. For example, morning time, evening time etc. using this feature, the feeder will start and stop automatically according to the user's need.

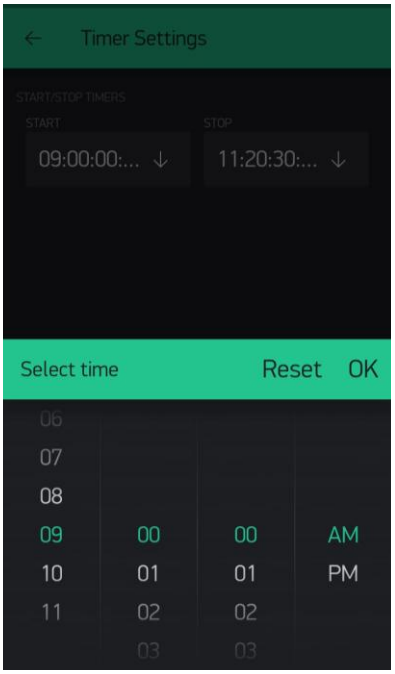


Figure 11 Set time in the mobile app

3 Results and discussion

In this instance, a solar-powered, Internet-of-Things-enabled automated fish feeding system was built. This section will describe the end output of this project in action. Numerous models, materials, techniques, and circuit designs have been fully discussed in previous subpoints. This research-based study's results are given in two sections. The MATLAB version successfully demonstrated the project's operation. All data and results were examined collectively. The critical design assessment was shown and applied in the hardware phase of this project after a considerable disagreement.

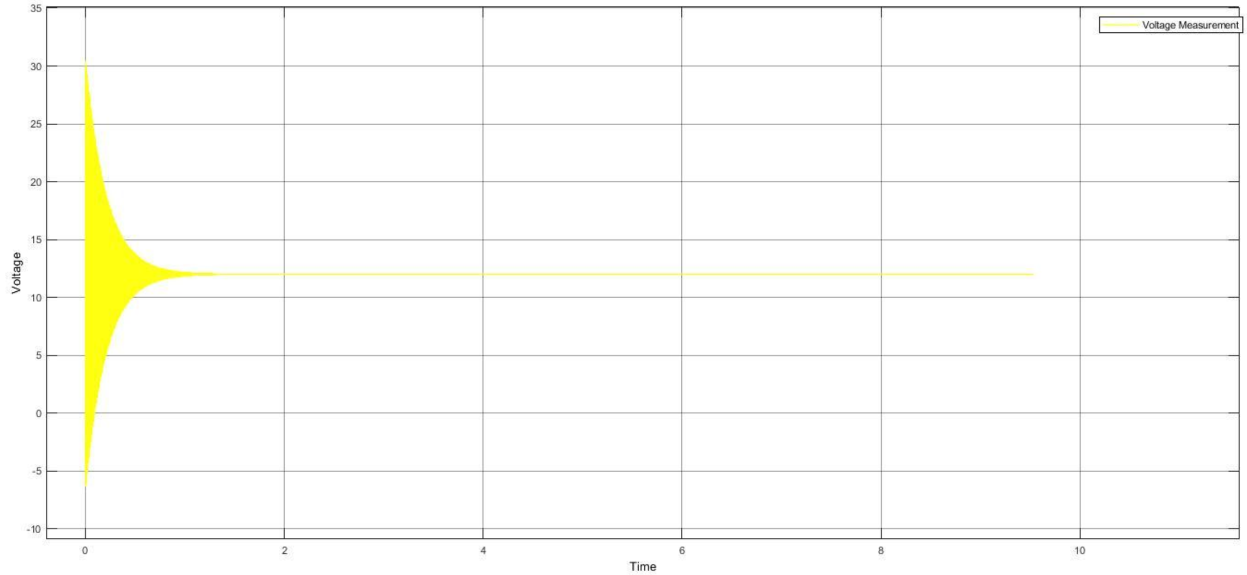


Figure 12 Generated voltage from solar

The curve for produced voltage from the solar panel is displayed in Figure 12. The solar panel receives two inputs in the circuit. Irradiance and temperature are two examples. The highest peaks in Bangladesh are generally 42 ℃/43 ℃, 40 ℃ in Dhaka and the central area, and 37 ℃/38 ℃ in the south (Mohapatra et al., 2009). Considering all the facts, the temperature range is set at (18 - 40) degrees Celsius. In addition, the irradiance was kept constant at 80 $W/_{m^2}$. As a result, the produced voltage from the solar panel is 12 V.

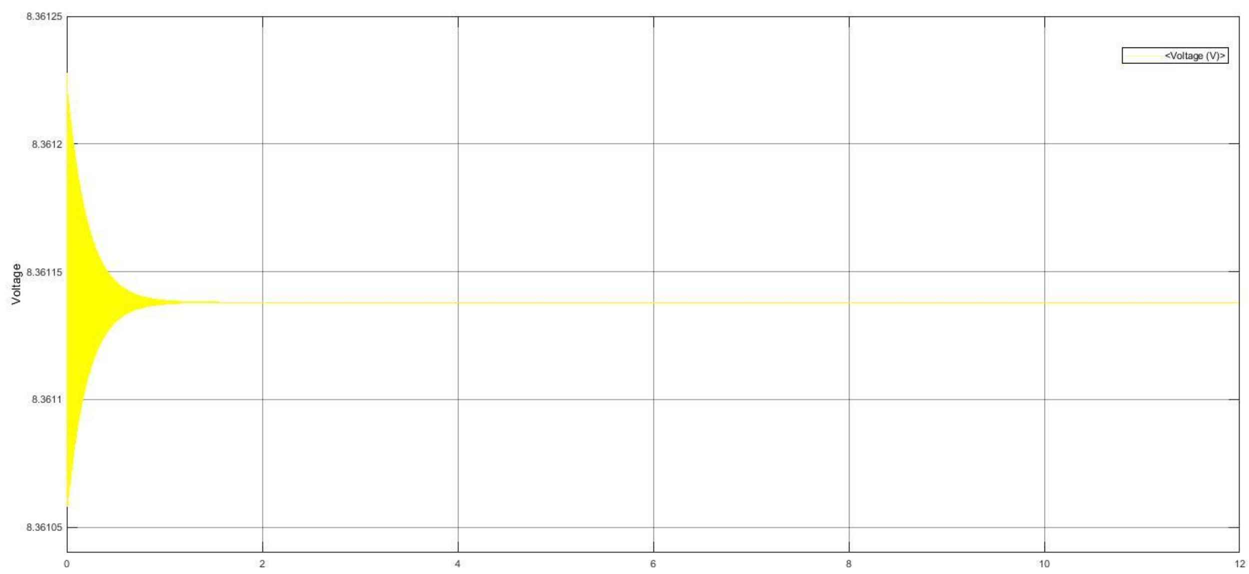


Figure 13 Battery output voltage

Using the voltage divider rule in the generated voltage from the solar panel to guarantee that the battery can find the same voltage consistently throughout the day, storing the voltage in the battery, and adding a diode to assure the PV panel's safety. The voltage is applied to the load through switches and the Arduino. As a result, the voltage divider rule is used to maintain a consistent voltage for the battery so that it does not become damaged. The graph in Figure 13 depicts the output voltage of the battery, 8.361V, which is directly linked to the load.

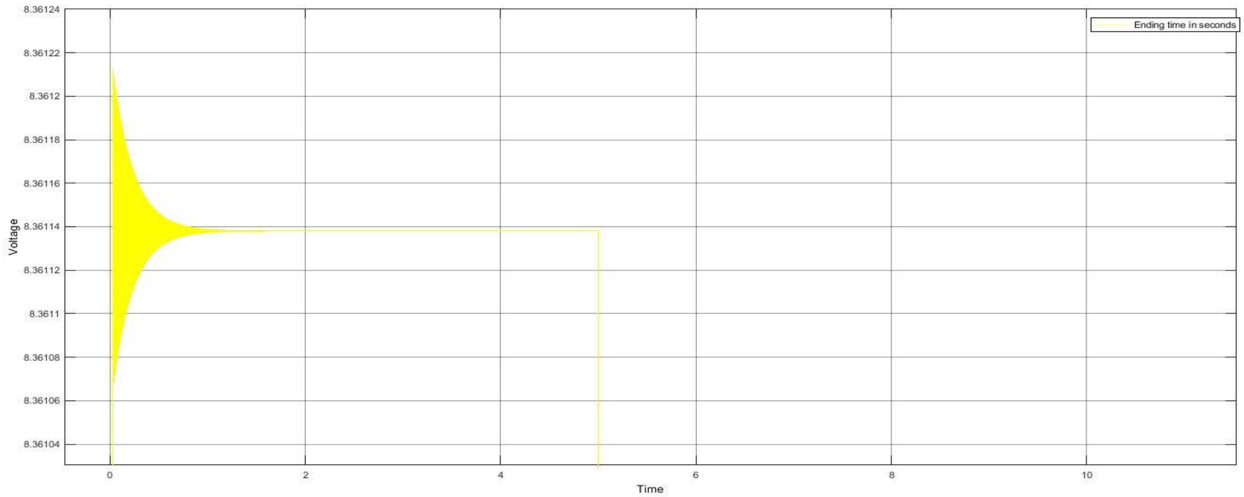


Figure 14 Voltage utilized to turn on the machine

Table 1 The numerical data recorded to charge the battery

Temperature (℃)	Shunt Diode Current (A)	Input Voltage (Battery) (V)	Output Current (Solar Panel) (A)	Output Voltage (Battery) (V)
18	0.751	12.33	0.0004125	8.361
20.2	0.7531	12.23	0.0004091	8.361
22.4	0.7553	12.13	0.0004058	8.361
24.6	0.7574	12.03	0.0004025	8.361
26.8	0.7596	11.93	0.0003991	8.361
29	0.7617	11.83	0.0003958	8.361
31.2	0.7639	11.73	0.0003924	8.361
33.4	0.766	11.63	0.0003891	8.361
35.6	0.7682	11.53	0.0003857	8.361
37.8	0.7703	11.43	0.0003824	8.361
40	0.7724	11.33	0.0003790	8.361
18	0.751	12.33	0.0004125	8.361
20.2	0.7531	12.23	0.0004091	8.361
22.4	0.7553	12.13	0.0004058	8.361
24.6	0.7574	12.03	0.0004025	8.361
26.8	0.7596	11.93	0.0003991	8.361
29	0.7617	11.83	0.0003958	8.361

A voltage versus time graph is shown in Figure 14. The curve in the graph above depicts the voltage at which the machine switches on. The necessary voltage is 8.361V.

Bangladesh's climate is subtropical in the north and tropical in the south, with a pleasant warm and sunny winter from November to February, a brief hot spring from March to May, and a long rainy season from June to October due to the summer monsoon. In February, the temperature continues to rise, and by March, it is extremely warm. Spring, from March to May, is truly the warmest season: average maximum temperatures surpass 35 ℃ in April but remain below 32 ℃/33 ℃ along the coast, with May being the hottest month due to the sea's thermal inertia. Here all the data are taken from MATLAB Simulink design as shown in Table 1.

To analyze the temperature distribution, ten data sets with temperatures ranging from 18 degrees Celsius to 40 degrees Celsius were selected for investigation. Several abnormalities were discovered over the course of the data gathering procedure. Figure 15 shows a graph of temperature in relation to shunt diode current, and it clearly shows that the shunt diode current grows proportionally to the increase in temperature in the circuit. During the winter months, when the temperature is 18 degrees Celsius, the shunt diode current is somewhat higher than 0.75 Amperes. At 40 degrees Celsius, the shunt diode current was almost as high as 0.75 amps, which was almost as high as the maximum current.

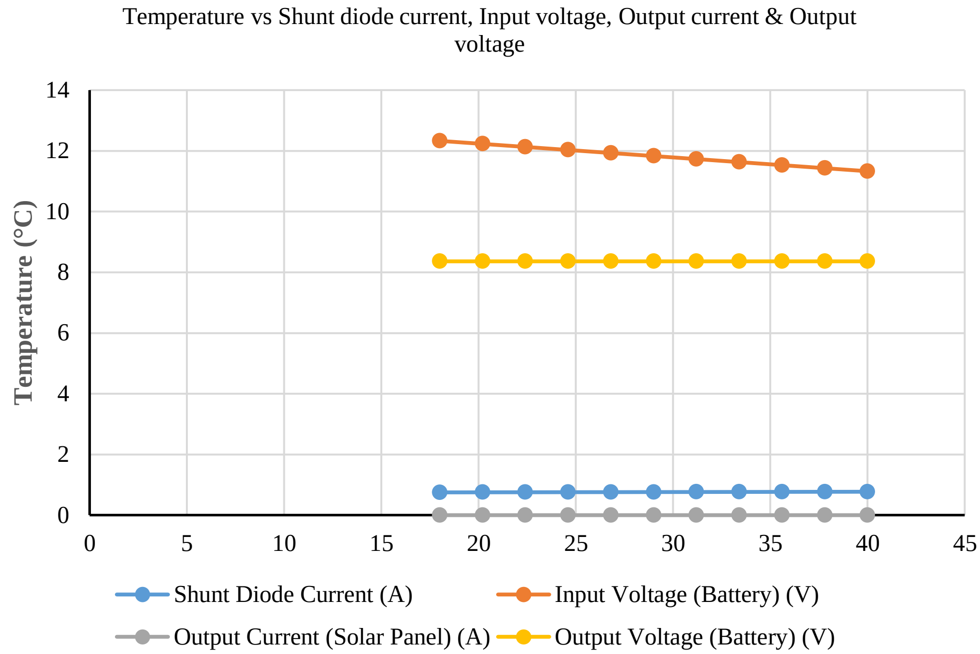


Figure 15: Temperature vs Shunt diode current, input voltage, output current and output voltage graph

As a result, the value of the shunt diode current increases in direct proportion to the increase in temperature of the circuit. Consequently, we can see that the shunt diode current reaches its maximum value when the temperature is 40 degrees Celsius. It can also be seen in the graph in Figure 15 illustrating the relationship between temperature and input voltage (Battery) that the input voltage (Battery) lowers as the temperature rises. When the temperature hits 18 degrees Celsius, the voltage reaches its greatest point, which is nearly 12.3 V, and then steadily falls as the temperature increases. At 40 degrees Celsius, the voltage drops to roughly 11.3 volts, which is the lowest it can be. Then the graph of temperature vs output current (from a solar panel), which exhibits the same characteristics as the graphs of temperature and input voltage is shown above (Battery). Because the output current of a solar panel decreases as the temperature of the environment increases. At the end of the day, the graph of Temperature against output Voltage (Battery) shows that the output voltage remains constant regardless of the temperature.

4 Conclusion

A smarter fish feeding system including some new features has been proposed in this paper. To find the results, the data were collected from the system simulation model; the solar panel used provided an output of 8 V which charged a similar capacity battery via a solar charge controller. The operation of the system was persistent even when the atmospheric temperature fluctuated between 18° to 40° Celsius as shown in simulation data. This technology will make aquaculture more efficient by reducing both labor and feeding cost. Owner can monitor feeding cycles when they are unavailable at home due to the IoT facility. The proposed model can be commercialized after enlarging it so that it can be fitted adjacent to ponds and hence maintenance cost can be reduced. More experiments need to be done for the performance evaluation of the proposed model. However, the model has scopes for further improvement, such as incorporation of wastewater measurement system that allows water to be changed automatically. A blower system can be incorporated to project the food at an angle of 45° to cover the maximum distance. An oscillating gear system can be incorporated to throw the food in different direction. More sensors can be incorporated to monitor factors responsible to vary the food demand.

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