Solar Powered Water Pumping System Automation and Control Using a Microcontroller for Aquaculture

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Abstract — **This work represents an automated solar-powered water pumping system for a fish farm located off-grid in a rural area of Pakistan. The ultrasonic water level sensor is used with the microcontroller Arduino UNO to automate the pumping system. The water level sensor is connected to the microcontroller based on the sensor programming and sensor data extraction from the water ponds of the fish farm. The microcontroller controls the water pump automatically to switch ON/OFF. This solution is very cost-effective for local farmers, and no human is needed on the site to monitor and operate the water pumping system for the fish farm. The designed system can reduce labor costs and effectively provide fish farms a smooth automated water pumping system.**

Keywords — **Automation and Control, Microcontroller, Renewable energy, Water level sensor, Water pumping system.**

I. Introduction and Literature Review

Over the last few decades, efforts have been made to reduce fish harvesting from the ocean to maintain the ecosystem of the marine environment [1]. As a result, aquaculture is growing fast, particularly in developing countries in the Asia-Pacific region [2]. 18 million population dependent on aquaculture in the Asia Pacific region according to the (FAQ) Food and Agriculture Organization of the United Nations [3], and 90% are categorized as small-scale fish farming. Rural populations are mostly connected to the fish farm industry, and numbers are increasing in this business that can meet the world food security and sustainable source of income [4], and 65% of the population of Pakistan lives in rural areas.

Fisheries production businesses on the shore are dependent on the water daily to meet their production targets. 5000m³ per capita recorded in 1950s studies and 1000m³ per capita found in recent studies that Pakistan is going downward to water shortage problems [5], and by 2025, expecting a shortfall of 150.8 million acre-feet [6]. Due to short waterfalls, tube wells, water pumping systems, artificial lakes, and other measures are taken to meet the water supply in demand. The fast decline in natural water supplies in rivers and dams and electric power generation also declined to 5000MV and power shortages increased from time to time [7]. So, Rural areas remain in high load shedding, some areas do not have access to power transmission lines, and the local farmers consume fossil fuels for cultivating the crops. But,

Pakistan also has few fossil fuels reserves and 346,400 barrels of daily imports to complete their consumption [8]. According to the radiation and clearance index data, their location of Pakistan has great potential for renewable in Pakistan, around 167.7 GW. In renewable energies, Pakistan has the potential for photovoltaics of around 100,000 MW, and the average solar insolation for the country is about 5.5 kWh/m²/day [9].

The above studies and facts encourage implementing solar water pumping systems for off-grid aquaculture, a totally independent renewable energy-based system against fossil fuel consumption in Pakistan. The Primary aspect of this work is making the local fish farms self-sufficient and creating a sustainable power system for their business and families. On the other hand, Pakistan has excellent potential for Solar energy-based systems that can help reduction of consuming fossil fuels and start being dependent on renewable energy. This initiative can help the world with a carbon emission control policy.

In the [10] study, the EPS32 microcontroller was used for water pumping automation for an irrigation system—the programmable sensors were used to detect temperature, humidity, and soil moisture levels. The microcontroller sends results to the web server so the user can operate the irrigation system far from the field by a simple ON/OFF [10]. The water management system is designed for the home to reduce water consumption that can reduce global water crises. PIC1650 microcontroller used in this system, made by General Instrument's Microelectronics Division. Water level sensor used in the water storage tank. The water pump automatically turns on when the tank water level is low and then turns off when the water tank is full [11]. GSM module and a PIC16F877A microcontroller are used to automate the water pump for irrigation purposes. The system operates through the mobile phone to start or stop the water pump. The water level is also monitored through the mobile phone. This project optimized the power and saved 22% of the water wastage [12]. ATMEGA 3 GSM microcontroller is the heart of this system and is used to automate farmers' 3-phase water pump control. Automation of the water pump monitored the electricity supply, water flow rate, and water level in the reservoir and took care of short circuit conditions related to the irrigation pump [13]. Automation of the water pumping station of Kurutie community using a programmable logic controller (PLC). The system consists of two parts one is hardware, and the second is software. The hardware unit used a Mitsubishi Fxis-20mi-001 switch mode power supply, micrologic 1000 PLC, six OMRON MYAN-1 relays, 10 pilot lights, and a float level sensor. The software codes were written in ladder logic using RsLogix1500 and RsLinx driver for communication [14]. An automation system for fishpond water circulation designed using

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Arduino UNO. The system consisted of a pH sensor, water level sensor, and water pump. Using this system, farmers can monitor the water pH level and water level in the pond. The system is useful for water circulation in the pond [15].

A low-cost automated water pumping system using a microcontroller for the fish farm is proposed here. Present work provides a system design of an automatic and controlled Solar powered water pumping system for a fish farm in developing countries. Low-cost, modern, straightforward microcontroller Arduino Uno R3 and ultrasonic water level sensor are used, which is affordable for farmers in developing countries. The proposed system can improve conventional fish farming to modern fish farming with current technologies and features.

II. SITE SELECTION AND SOLAR PV SIZING

The Fish farm needs mainly enough water resources for operations throughout the year and an uninterrupted Power system for smooth running. The present section represents the site selection for an off-grid fish farm and is based on the site resources design and implementation of the renewable Solar PV power system for the fish farm.

A. Site Selection

An off-grid located proposed site is chosen for a fish farm for Solar PV system design and implementation. The site is "Saif Khosa Fish Farm" near the bank of river Indus, Wasti Mahermani, Kot Haibat, District Dera Ghazi Khan, Punjab, Pakistan. Location coordinates are 30° 6' 40.88753" E, 70° 38' 56.34821"N [16]. The Fish farm area is approximately 7.35 acres.

The Saif Khosa Fish Farm can be seen in figure 1. Five ponds can be seen, and the black circle indicates the water pump location. Location surrounded with agriculture lands. The fish farm wasted water can be used for these agriculture lands.

Fig. 1. Location of Fish Farm from Google maps [21].

B. Data Collection from the Site

The extracted through the National Renewable Energy Laboratory (NERL) on the selected site in Fig. 2. Solar radiation and the clearness index data can see in Fig. 3 for Dera Ghazi Khan, Pakistan. Data shows that the location is suitable for Off-grid Solar powered systems and has enough Solar resources throughout the year. The system can run smoothly off-grid fish farm operations.

The weather temperature dataset of the selected site was retrieved through NASA. Based on the dataset observation, the total solar power production on the selected site can be estimated. NASA provides the prediction of the Worldwide energy resources through the database. The temperature of each month observed in figure 3 for Dera Ghazi Khan, Pakistan

C. Chosen HOMERPRO for Sizing and Optimization

HOMER Pro software is used for designing and optimizing an off-grid Solar PV system for a Fish farm. HOMER Pro widely uses software in the renewable field for designing and optimization purposes and based on a bunch of features of renewable tools consisting of NASA database for solar radiation and temperature, worldwide location selection, renewable components library with ratings, brands, that can provide to the user complete flexibility in design and optimization. Homer is stands for Hybrid Optimization of Multiple Energy Resources and developed under the National Renewable Energy Laboratory (NREL) in USA.
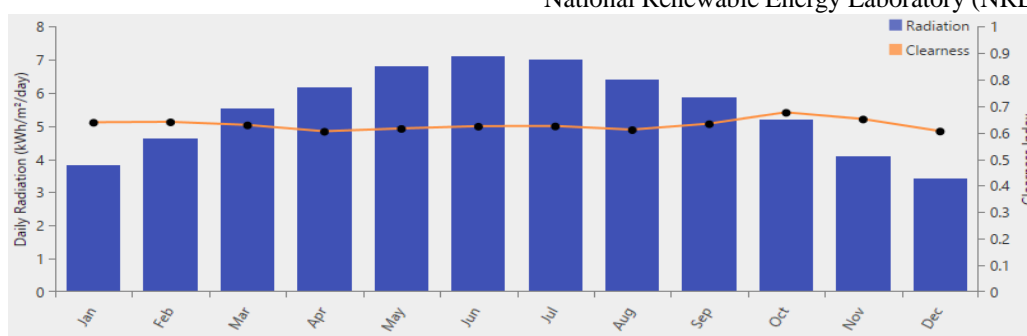

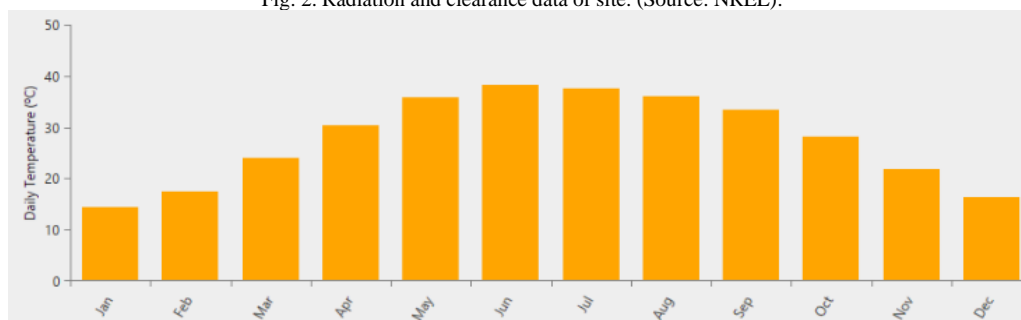Fig. 2. Radiation and clearance data of site. (Source: NREL).

Fig. 3. Site each month data (Source: NASA POWER).

D. Calculation of Water Pump Load

In Table I described the data collected from the proposed fish farm site. Proposed Fish farm consisting of five water ponds. Each water pond depth, area and water volume are different according to the fish farm operation throughout the year. According to the above-required water volume, 230 m³/hour water flow is suitable for the fish farm. Based on the selected flow rate, 156 hours are required to fill the water into the ponds as needed.

TABLE I: FISH FARM WATER PONDS DATA

Ponds	Surface area (m²)	Average water depth (m)	Water volume (m³)
1	10052.84	1.5	15079.26
2	6045.34	1.5	9068.02
3	2841.63	1.5	4262.44
4	5366.36	1.2	6439.63
5	1003.84	1	1003.84

Water level = 15 ft= 4.57 m

Dynamic head = 25 ft= 7.62 m

Pipe diameter= 6 inch

Water flow requirement = 230 m³/h

The WILO tool used for accurate motor/pump size [17]. The online software calculated the 10 Hp motor size based on input data. The motor data shown in Fig. 4 and pump model is Atmos GIGA-B 150/180-7, 5/4 Single-Stage centrifugal pump.

Motor data
Motor efficiency class: IE3
Mains connection: 3~400V/50 Hz
Voltage tolerance: +-10 %
Rated power: 7,5 kW
Rated speed: 1450 1/min
Rated current: 14,9 A
Power factor: 0,81
Motor efficiency: 87,4 %
Motor efficiency: 89,3 %
Motor efficiency: 89,8 %
Insulation class: F
Protection class: IP55
Motor protection: PTC integrated

Fig. 4. Motor Specifications [17].
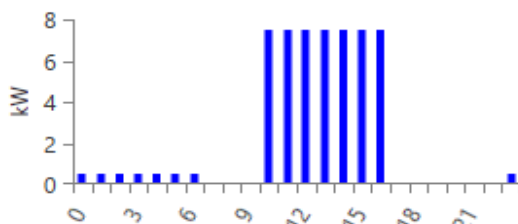
E. Load Profile

Fig. 5. Day and night load calculation.

Hence, HOMER Pro calculated the load of the duration day and night based on selected maximum load in the yearly profile according to the input loads in Tables I. Fig. 5 describes the working cycle of the system in 24 hours. Blue

lines indicated the peak load in the daytime when the water pump was used to refill the fish farm's ponds.

F. Design and Optimized System

In resulting, HOMER Pro software designed the comprehensive system for an aquaculture farm. Fig. 6 is the proposed design of the required system and the ratings of the necessary components. Following components model selected using the library of the HOMER Pro software and resulted autonomous off-grid solar powered system designed.
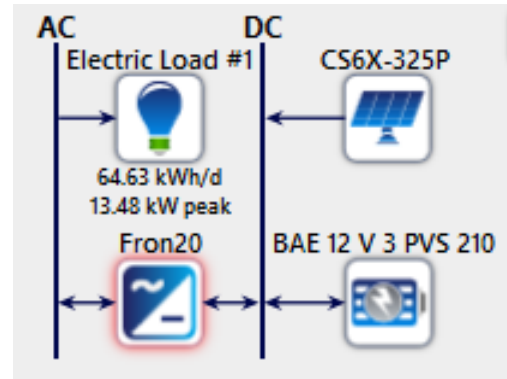

Fig. 6. Proposed System for Fish farm.

Fig. 6 is proposed system by the HOMER Pro. 64.63 kWh/d load resulted for the fish farm on the average day, and the maximum load under the observation noted 13.48 kW. 77 Solar PV panels of 325V proposed under the using model of Canadian solar max power CS6X-325P [18], 210 bise of 60 batteries proposed using the model of BAE secura solar 12V 3 PVS 210 [19] and selected the model of 20kW Fronius Synmo 20.0-3-M is enough to fulfill the 100% renewable based solar-powered PV system for the fish farm [20].

HOMER Pro simulated designed and optimized system and Fig. 7 displays the 24 hours working of Solar PV system for the fish farm. Can be seen that fish farm required operational load accommodating smoothly through proposed system. Orange line representing the Solar PV production during the daytime and observed Solar PV power production remain high in daytime when sun light on its peak. Blue line representing the fish farm operating load in 24 hours and production is higher in compare of production. Lastly Green line representing the battery usage of the fish farm for 24 hours. When green lines going down to the 0 values in above graph that show fish farm system using the storage power from the batteries. And when green turned up to 0 value means batteries turned on charging mode. Fig. 7 shows the batteries only accommodating the power to the fish farm during sunset and sun rise when sun light remains low.

III. SITE SURVEY FOR DATA COLLECTION

On 4th February 2022, we conducted a Fish farm site survey with local aquafarmer and gathered all information from the fish farm.

Fig. 8 is taken from the fish farm while refilling the water after the yearly cleaning of the pond. Solar PV panels can be seen in the picture.
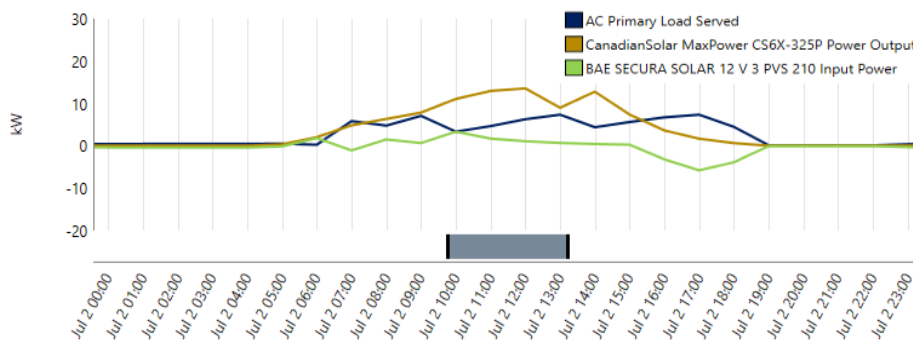
Fig. 7. Simulation result of designed system.

Fig. 8. Fish Farm Pond refilling after cleaning.

The water pumping system can be seen in Fig. 9. The pumping system consisted of conventional, and the pump was operated by 100% Solar PV panels. System operation was totally manual and run by the operator. There was no water level measurement system, and the pump was operated through an ON/OFF switch. Fish farm owner hired a man for monitoring and operating the pumping system that comes under the direct cost of fish farming, increasing the labor cost and reducing the annual profit.

Fig. 9. The water pumping system of the fish farm.

Fig. 10. Nursery Ponds and Aeration Blower in operation at the site.

Nursey ponds can be seen in Fig. 10. The Aeration blower was in the process which is used to maintain oxygen levels in the ponds.

IV. PROPOSED AUTOMATION AND CONTROL SYSTEM

Based on the fish farm survey and collected information, there was no automated water pumping control system. Here, we proposed an automation and control system for turning fish farms into modern fish farms, low cost, and featured with current technologies. For design and simulation purposes, we are using TinkerCad Software. This software is used for 3D modeling and circuits design and simulation. TinkerCad also generates code for programming Arduino microcontroller.

A. Arduino Uno R3

Arduino UNO is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins, six analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, ICSP header, and a reset button. Simply can connect to the computer through a USB cable. This microcontroller is readily available at a low cost [21].
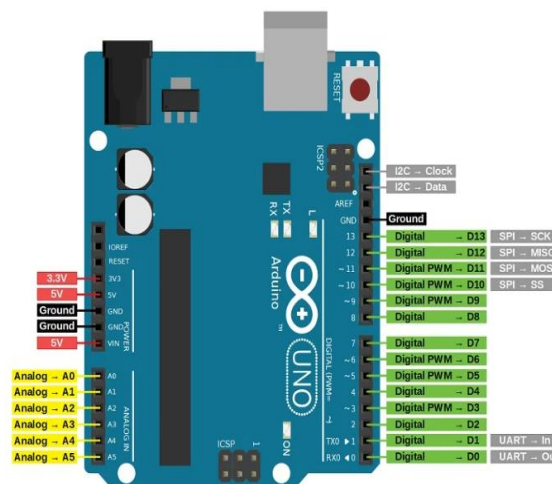

Fig. 11. Pin Configurations of Arduino Micro Controller [22].

B. Ultrasonic Sensor

Ultrasonic water level sensor PING is also low cost and easily available in the market. Approximately range is 1inch to 10 feet and dimensions are 0.81×1.8×0.6 in operating temperature range +32 to +158 F (0+70 ºC) [22].

Fig. 12. Ultrasonic Sensor.

C. Motor

Motor is used from the library of the TinkerCad and the part of this system. Motor converts electrical energy to the mechanical energy. In the system, Motor attachment to the system demonstrates the water pump run by electric motor.

D. Relay

Relay is a switch that open and close the circuits electromechanically or electronically. Relays control one electrical circuits by opening and closing another circuit. In this system, Relays attached to the motor in series connection using TinkerCad.

E. LCD Screen

The liquid Crystal Display (LCD) 8-bit used from the TinkerCad Library allows display of the system. LCD accept the serial input from the computer and upload the sketch to the Arduino and characters displays on the Screen.
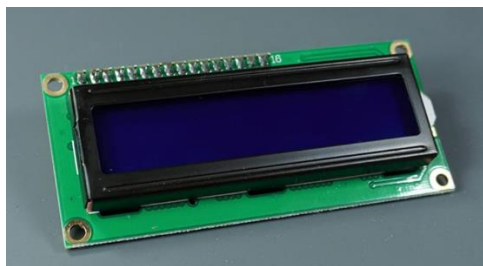

Fig. 13. LCD Screen.

F. Used Components

Name	Quantity	Component
R5	1	220 Ω Resistor
U7	1	Arduino Uno R3
U8	1	LCD 16 x 2
PING1	1	Ultrasonic Distance Sensor
T1	1	NPN Transistor (BJT)
R6	1	1 kΩ Resistor
M1	1	DC Motor
S4	1	Slideswitch
K1	1	Relay SPDT

Fig. 14. System components list.

G. Flow Chart of the System

The Solar PV panels Produce 64.63 kWh/d, and a 20 kW inverter converts this variable direct current (DC) output into alternating current (AC). This AC power is used to power the water pump. The water pump used to lift water from the groundwater, and water goes to the fish farm ponds. The microcontroller is used to control the water pumping system. The ultrasonic water level sensor is programmed with the microcontroller and based on water level information, and the microcontroller turns ON/OFF the water pumping system. The system algorithm shown in Fig. 15.
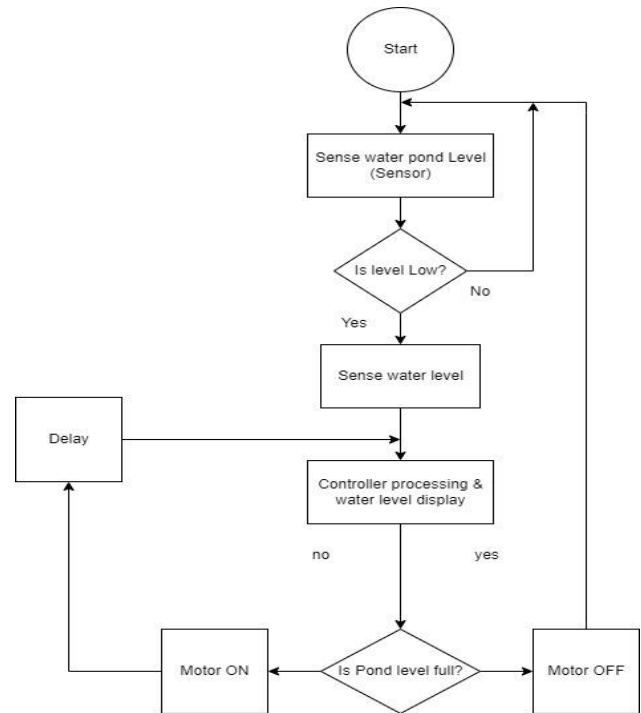

Fig. 15. Flow Chart of the System.

H. System Design and Simulated

During simulation in TinkerCAD designed system captured in the Fig. 16 and can observed system is running smoothly when the pond water capacity noted on 37% and water pump simultaneously started automatically turned ON for refilling the pond. The Proposed Control system is based on the Arduino UNO R3 microcontroller device. Fig. 15 shows all system components of the system. Design components are a motor, relay, Display screen, Arduino UNO, and water sensor. Usually, the water level required in the ponds is between 1-2 meters. There is an ON/OFF sliding switch in the center of the board. When the switch turns on System start working instantly. The water level sensor gives the information to the microcontroller and based on this information microcontroller turns the ON/OFF motor, and the system works smoothly.
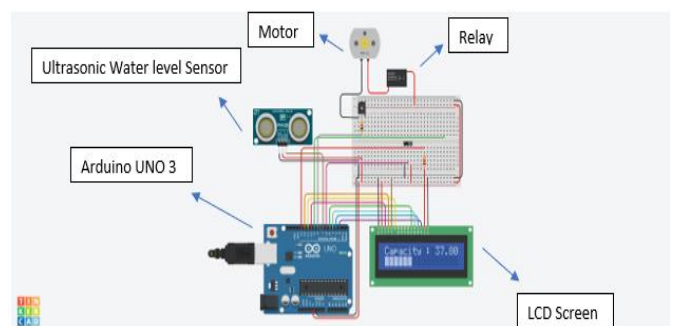

Fig. 16. System design and simulation in TinkerCAD.

Table II explains the system working-water level required in the pond maximum 1.5 m. Using Tinkercad software water pumping automation and control system is designed, and the ultrasonic sensor is programmed at a 1.5 m water level maintained in the pond. ThinkerCAD simulation shows that the microcontroller turns ON the water pump when the water level remains below 1.5 m and starts filling the water

pond. Three observations were noticed in the simulation results first, when the pond level is empty, and second when the water level is below 1.5 m. In both conditions, the water pumping system turned ON. The third condition observed when water remained at 1.5 m only this condition water pumping system turned OFF automatically.

TABLE II: OBSERVATION TABLE

Sr.No	Observation	Motor Status	Pond Level
1	Motor Switch	ON	Empty
2	Filling the Ponds	ON	1 m
3	After reaching the level Motor Switch	OFF	1.5 m

A Diagram of the circuit can be seen in Fig. 17. Diagram shows all component ports and can easily understand the connections between each component. Green lines indicating the connections and components are indicated with red color. The diagram is auto-generated by the TinkerCad after simulation results.
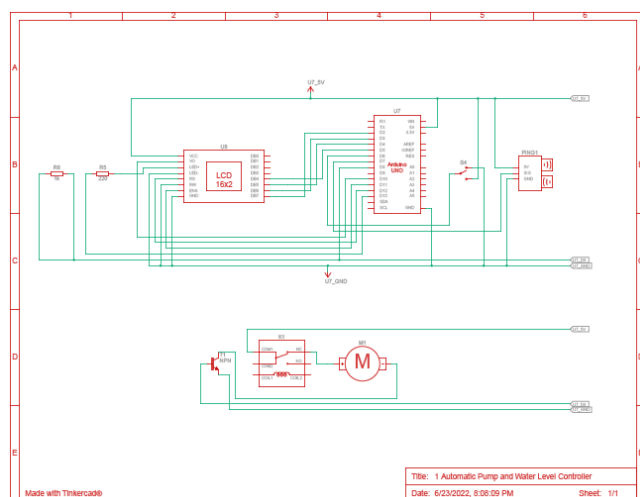

Fig. 17. Diagram of the designed system.

V. CONCLUSION

The proposed automation and control system is beneficial for a low-cost automated solar water pumping system, a modest solution for the fish farm business in developing countries. This system can save labor costs and electricity from a manually operated water pumping system. Arduino microcontroller and sensor module are user-friendly and affordable cost. The commercial cost of the water pumping system automation is approximately 800$ USD and could be used in developing countries.

ACKNOWLEDGMENT

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