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Journal of Electrical and Computer Engineering Innovations (JECEI)

Journal homepage: http://www.jecei.sru.ac.ir

JECEI

Research paper

GSM based Water Salinity Monitoring System for Water Gate Management in Salt Farms

M. Enriquez*, A. Abella

College of Engineering, Occidental Mindoro State College, San Jose, Occidental Mindoro, Philippines.

Article Info

Article History:
Received 12 January 2023
Reviewed 05 February 2023
Revised 28 February 2023
Accepted 01 March 2023

Keywords:
Salt
Salinity
GSM module
Arduino uno
Solar sheets
DC motor

*Corresponding Author's Email Address:
michelle_enriquez_d@dlsu.edu.ph

Abstract

Background and Objectives: Salt production is an ancient industry that still used primitive or traditional systems of evaporation. As technology continues to prosper in all aspects of life; the use of technology-based products is still a challenge in salt production. With the tedious activities and processes in salt farming; salt producers and salt farmers continue to look for alternatives to lessen the hard works. Salt farm activities initially started with the intrusion of saline water into the salt beds, but monitoring of the saline water is needed to ensure that only saline water can enter the salt farms to ensure the quantity and quality of salts.
Methods: This study aims to present a GSM-based water salinity monitoring system to lessen the frequent and manual monitoring of water salinity. The system is equipped with a solar panel, solar charger control, 12V battery, 12V relay, Arduino Uno, and GSM Module.
Results: The overall rating of 3.32 reflects that the developed system met the design functions; the materials are appropriate and the specifications meet the desired purpose; the system is efficient and consistent with its desired objectives of lessening the manual activities involved in the monitoring of water salinity. As the pH and conductivity sensors read the salinity value, it sends signals to the Arduino Uno; when the salinity level reads 34,000-35,000ppm a signal trigger the GSM Module to send a message to the gate valve. The performance efficiency of the system implied that the reaction of the Arduino Uno in triggering the GSM Module is in real-time as the salinity readings are received.
Conclusion: The real-time reaction of the Arduino Uno to send signals to the GSM Module proved the advantages of using the system and the automatic salinity readings can lessen the frequent and laborious activity in water salinity monitoring.

Introduction

Salt is a mineral that is broadly spread in almost all continents [1]. As one of the ancient industries, the primitive or traditional method is still the emanating process used by most salt farmers, but the application of technology based methodologies in the salt production is becoming popular [2]. In the Philippines, the used of ancient traditional and artisanal methods are commonly used relying greatly on solar evaporation.

The province of Occidental Mindoro, facing the abundant source of seawater contributed to 18% of the country's total salt production [3]. As the province is trying to reclaim its reputation in the salt industry, salt farmers are continuously seeking ways on increasing their harvest and ensure year-round production. The use of technology-based products in salt production has always been one of the objectives of the Tamaraw Salt Producers Cooperative and salt farmers in the province, as studies and researches applied in the salt farms are limited. An attempt to mechanize the production process has been introduced in brine management by speeding up the crystallization process; and placing the Salt washer to purify and clean salts. However, salt farmers and managers desire technologies that could lessen manual labor and shorten processes involved in salt production.

Traditional salt production starts with the intrusion of saltwater in bed farms by manually opening a gate design to control the flow of saltwater. Water entering the salt farms is dependent on the required salinity before it allows to enter the salt beds and such activity requires constant monitoring, visual testing, and on-site visit as salinity changes quickly in time and is greatly influenced by the lateral water movement [4]. Human activities relating to the monitoring of water salinity have been described as tedious, extensive field works, and require a day-round observation.

At present, there are many technologies related to water level monitoring and the use of microcontrollers and sensors has been the favorite area of research. The application of sensors ranging from simple, web-based, and complex system architecture manifested the usefulness of microprocessors and sensors in water quality monitoring and agricultural use. A simple four electrodes conductivity sensor is used for the automatic logging of soil water salinity extracted from the wetting front of the irrigation cycle [5]. The wireless sensor modules: Zigbee communication was used in monitoring the precision of the agricultural system with temperature, soil humidity, light, and pH of the soil as the input parameters [6]. While the capability of the Zigbee wireless sensor network was explored in agriculture in monitoring environmental conditions like weather, soil moisture content, soil temperature, soil fertility, weed detection, water level, monitoring growth of the crop, precision agriculture, automated irrigation facility, and storage of agricultural products [7]. Zigbee wireless electronics was also used in developing remote water salinity based using a fiber-optic U-shaped sensor to strengthen the sensitivity and increase the range [8].

The use of microcontrollers and Internet-of-things provided the easiest means of water quality monitoring and showed applicability in assessing the water salinity of water bodies. A real-time water quality monitoring system using a wireless element capable of providing a warning to farmers was developed in fish farms and improving aquaculture [9]. A WIFI-microcontroller coupled with a parallel capacitive plate was developed and tested and found to increase the coverage range of the water salinity sensor [10]. A digital salinometer was designed based on electrode sensor ATmega 328 microcontroller programmed using Arduino IDE with salinity value obtained by measuring the voltage of the difference in resistance [11]. An IoT-based real-time management system for monitoring the water in the fishponds was installed with the use of sensors and CCTV; and a food control system to manage the food intake and the water system in the pond [12]. A Modbus TCP/IP communication based on IoT integrated sensors in monitoring the water quality parameters like dissolved oxygen, pH, and water temperature [13]. Further, temperature sensors, pH, and salinity sensors were used in managing the water system of a shrimp farm using the Fuzzy logic processing method [14]. Also, a salinity detecting instrument using processor SOC MCU C8051F040 designed based on ARM7 microprocessors considered the effect of temperature on the conductivity of water was successfully installed to get the real-time data [15]. Further, an Arduino Uno chip coupled with GSM Module 6900a was developed for the monitoring of total dissolved solids as part of the water quality monitoring system [16]. Another microprocessor known as MSP432 connected to LoRA network read data such as water salinity, water level, and temperature was developed and used in the river salinity monitoring; the Raspberry Pi 3B+ was installed to allow the receiving and uploading of data to the could server connected to the Internet [17]. The capability of Arduino Uno coupled with Raspberry Pi 3B+ and LoRaWan IoT protocol was used in monitoring the water quality parameters such as temperature, pH level, turbidity, salinity, and dissolved oxygen has an automatic correction to ensure the growth of the aquatic animal. The sensors used web applications to get information and monitor the parameters acceptable for fish growth [18].

Literature shows the capability of the microcontrollers like Zigbee and IoT –based technology in providing efficient monitoring of water in the fishponds and agricultural areas. Since the study area has a weak internet connection, the use of web-based applications is not feasible; this study aims to present a sensor-based water salinity monitoring system that can automatically open the gate to allow the saline water to enter the salt farms. The combination of the GSM module and Arduino Uno were used to detect the water salinity level in the study area. GSM module and Zigbee were used in monitoring the farm environment data such as soil moisture level, water level, temperature, and humidity by providing the farmer a text message [19]. GSM module coupled with a 16F877 microcontroller was used in establishing a link with the farmer, soil, and crop conditions by automatically sending text messages to the farm owners [20]. The use of the GSM module was also applied in monitoring the water quality parameters for a prawn farm by sending text messages on the status of pH, temperature, and dissolved oxygen [21]. Further, the microprocessor called Arduino Mega 2560 was used as a command controller in monitoring the pH, water turbidity, and water temperature and sending signals to the GSM module to send text messages in assessing the quality of drinking water [22]. GSM module was also applied in monitoring the water quality parameter in India using the combined capabilities of conductivity sensors, pH sensors, and temperature sensors. The detected water quality parameters from the Arduino Uno send signals to the GSM module and send water quality status to the users [23]. Further, the ability of the Arduino Uno and sensors effectively monitored the pH, temperature, turbidity, and electrical conductivity in identifying possible water contamination and efficiently send text messages and utilized a buzzer to alert that water is not safe for drinking.

To help the salt farmers of Magsaysay, Occidental Mindoro, Philippines, lessen the burden of manual work, the researchers developed a water salinity monitoring system using the combined capability of the microprocessor and water salinity sensor. The detection of water salinity level and automatic manipulation of the gate valve is the focus of this study. The study aims to detect the amount of salt present in the seawater before it allows it to flow into the salt bed. This study aims to present a sensor-based water salinity monitoring system that can automatically open the gate and allow the saline water to enter the salt farms. The researchers tried to incorporate the use of solar panel to maximize the capability of the sun to run the system at all times as many of existing studies are electrically powered. The system relies on the use of text messaging as the medium for monitoring the salinity of the water. This makes the water salinity monitoring system novels as most of the existing monitoring system lies on the AC source and internet-based system. Specifically, the study aims to test and evaluate the system in terms of functionality, durability, and efficiency; to determine the performance efficiency rating of the developed system through salinity reading on the sensors, reaction time of the installed microcontrollers-Arduino Uno and precision of the water gate management system in salt production.

Materials and Methods

A. System Components

The design for the water salinity monitoring system is consists of a 100W solar panel acting as the power source; a solar charger controller for the monitoring of solar energy generation; a 12V battery for the storage of the energy harvested; a DC motor, relay, Arduino Uno, and the GSM Module for the automation process. Fig. 1 show the components of the GSM based water salinity monitoring for salt farm gate operations.

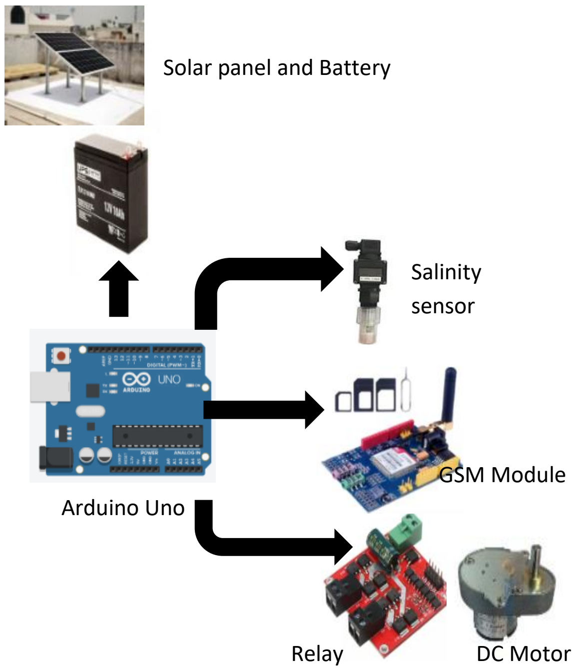

Fig. 1: Components of the GSM based water salinity monitoring system.

Solar Panel and Battery

The developed water salinity monitoring system used 100W solar panel for the energy generation and storage. Specifically, a cell-type monocrystalline solar panel with 36 cells (3 x 12) and cell efficiency of 22.0% was used in the study. The solar panel is installed facing the nearby sea water source to fully capture the solar energy. While the 12V battery was coupled with solar panel to ensure that the system will work at all times thru the energy stored in the battery.

Arduino Uno

Arduino Uno is the microcontroller used in the study and acts as the brain of the system. An ATmega328P Arduino Uno with operating voltage of 5V-20mA (per I/O pin) and 14 digital I/O pins (PWM output) was used as the command controller in the system. The board is connected to the computer where the programming is initialized and adjusted. It sends signal to the relay and GSM Module to perform the default functions.

Salinity Sensor

The salinity sensor ranging from 0 to 50,000 ppm was used in the system to measure the salt content of the sea water. The sensor was initially calibrated and design to have a response time of 90% of full-scale readings in 10 seconds. The sensor is submerged in the seawater for the automatic detection of the saline level. The salinity sensor was programmed to accept the standard salinity value of 34,000-35,000PPM to be considered as the appropriate/good level for salt ponds.

GSM Module

The GSM Module enables the devices to send messages about the default information programmed in the microcontroller. It is the component that links the mobile devices to the system. Specifically, the SIM900 and 1800MHz -dual band GSM (phase 2/2+)/GPRS (multi-slot class 10) was installed in the system. The smallest GSM module (24mm x 24mm x 3mm) was used and can control via AT commands. The module has high compatibility rating with the selected Arduino Uno and sensor used in the system. The module has the keypad and display interface that allows the salt farmers to receive and read the message even in remote areas. The applicability of the GSM module in the study area was the first factor considered in the study since the internet is not viable in the study area.

Relay and DC Motor

The relay coupled with DC Motor is used as an electrically operated switching device that controls the opening of the gate in the salt farm. A 5V reed type standard relay is design to control the load in monitoring the salinity level. While a small DC Motor (8 x 35mm) with speed ranging from 5,000 -14,000rpm and 0.36-160mNm motor torque was installed in the system. When the detected salinity value conforms to the default level, it controls the gate facing the sea water to automatically open and allow the intrusion of water.

B. Fabrication of the Prototype

After procuring all the necessary materials, all parts are connected and assembled based on the design of the prototype. The solar panel, battery and solar charger controller were initially tested to determine charging and discharging time; then the sensors, Arduino Uno, relay and DC Motor were connected and programmed based on required salinity readings; while the GSM module was last to install to ensure that all other system components connected to the module is functioning well. After the components are installed, initial testing was done to ensure the functionality and efficiency of the system. After analyzing the results of the evaluation, modification and adjustments were considered to finalize the system.

C. System Work Flow Diagram

Fig. 2 presented the system workflow diagram of the system. The operations started with the harvesting of solar energy. The 100W solar panel harvests the energy and converted it to electrical energy and is stored in the connected 12V battery. The charger controller connected to the battery ensures the power requirement of the system. Since the sensors are exposed to sea water, it was programmed to read the salinity levels every hour. It will send signals to the GSM Module and interprets the data. When the default salinity level is read by the system, it will be interpreted by the Arduino Uno and send message to the GSM Module and salt farmer. The other components will work based on the program and will send signal to the other components connected to the gate of salt farms. This enable the automatic openings of the gate and allow the saline water to enter the salt beds.

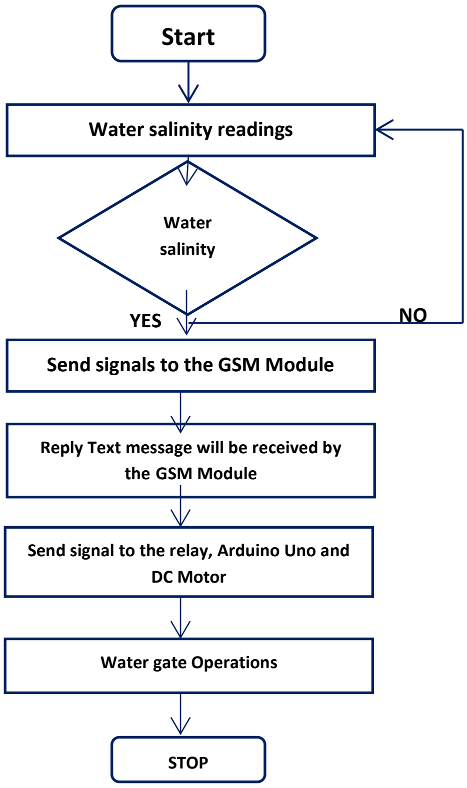

Fig. 2: System work flow diagram.

The operations of the GSM-based water salinity monitoring system in the salt farm start with the readings of the salinity level. The sensors dipped in the seawater monitors the saline level basis, when the required saline level is reached, the sensors send the readings and the data is analyzed by the Arduino Uno and GSM Module. Then, a text message is received by the mobile phone connected in the system indicating the saline level. The system provides an opportunity for the salt farmers to lessen the manual inspection of the salinity level in the gates of the salt ponds. The automatic readings of the salinity level of the sensors, Arduino Uno and GSM Module allowed the real time opening of the gates.

Results and Discussion

Product Description

The GSM-based water salinity monitoring system is designed to lessen the tedious, extensive field work and the regular sampling of saltwater. The system was configured and programmed considering the required salinity level, the volume required to fill the salt beds, and the prompt response of the module to the commands.

A 12V battery is used in the system that stored the energy harvested from the solar sheets while the DC Motor is designed to convert the direct current into mechanical energy. Attached to the battery is the microcontroller: Arduino Uno which serves as the brain that sends the command to all the components attached. The water salinity sensors are programmed to the microcontroller and read the salinity levels of the water.

The GSM Module is programmed to the microcontroller to receive, analyze, and respond to the commands. While the 12V channel relay is programmatically controlled to switch on/off the devices attached.

Fig. 3 illustrates the actual view of the GSM-based water salinity monitoring system facing the saline water source.

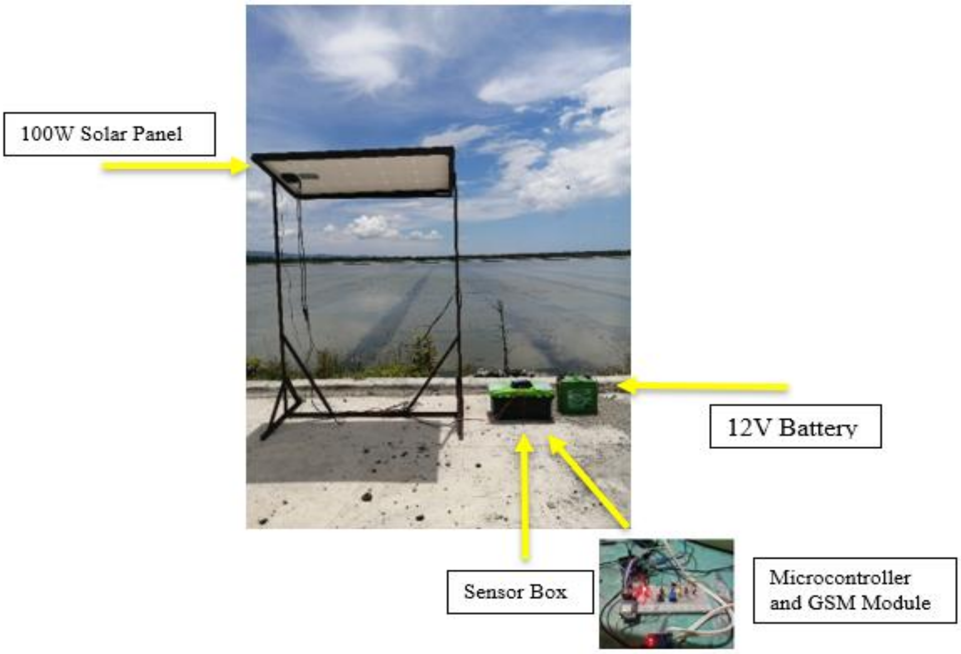

Fig. 3: Actual view of the GSM based water salinity monitoring system.

Testing Results

After the initial testing and checking of the programs, the system is installed in a salt farm in Magsaysay, Occidental Mindoro allowing the selected salt farmers to test and evaluate its efficiency. The system was energized and a demonstration of the function was conducted before the evaluation process.

The functionality of the system which refers to the usefulness and observance of the desired output obtained a mean score of 3.45 interpreted as "Very Good". This means that the system is useful and design objectives are achieved. Durability refers to the strength of the system in terms of materials and design obtained a mean score of 2.86, interpreted as "Good" reflecting that the material and design need some modification as some parts are exposed and should have a protected mechanism to ensure the longevity of the usage as recommended by the evaluators.

Lastly, the efficiency of the products in terms of conformance to the desired output and the absence of human work was rated 3.67 interpreted as "Very Good", describing that the product achieved the desired objective of lessening the manual operations as the salinity sensors read the salinity level lessening the monitoring process and the on-site observation of salt farmers.

Table 1: Grand mean score of evaluation

Content	Mean	Interpretation
1. Functionality	3.45	Very Good
2. Durability	2.86	Good
3. Efficiency	3.67	Very Good
Grand Mean	***3.32***	***Very Good***

Legend: 0.00-1.00-Poor; 1.01-2.00 Fair; 2.01-3.00-Good; 3.01-4.00 Very Good; 4.01-5.00 Excellent

The grand mean of 3.32 interpreted as "Very Good" reflects that the system met the design functions; the system design and materials are appropriate and specifications meet the desired functions though additional protective mechanism must be provided to ensure the safety of the devices and parts; the system is efficient and consistent with its desired objectives of lessening the manual activities involved in the monitoring of water salinity.

Performance Efficiency of the Product

After testing the functionality, durability, and efficiency of the developed system by the selected salt farmers, testing of the system components followed to determine the precision of salinity sensors, solar sheets, and battery. The salinity sensors were programmed to accept 34,000-35,000PPM as the standard salinity level, once the required level is obtained; it automatically sends a message to the mobile phone through the GSM module. The system was initially installed and observed from 6:00 am to 4:00 pm. Table 2 shows the observed salinity level and the response of the system.

Table 2: Salinity monitoring and reaction time in GSM module

Voltage reading	Salinity (PPM)	Time	Send message to the GSM Module	Reaction time (milliseconds)
13.4 V	32,000	6:00	No	220
13.3 V	33,000	7:00	No	215
13.0 V	33,432	8:00	No	220
13.0 V	33, 445	9:00	No	230
12.5 V	34, 995	10:00	Yes	215
12.4 V	35,112	11:00	Yes	225
12.2 V	33, 435	12:00	No	225
12.1 V	33,128	1:00	No	230
12.3 V	33,000	2:00	No	240
11.9 V	34,123	3:00	Yes	225
11.8 V	24,500	4:00	No	235

The table shows the variation of salinity with time, voltage readings, and the recorded reaction time of the GSM Module. It can be observed that voltage readings drop with time as it is being utilized by the devices attached to the water salinity monitoring system. However, charging of the battery is done every morning before the energization of the system to ensure continuous power. The table also reflected the salinity readings vary with time with maximum salinity measured during noon and decreasing when the sunsets. The salinity sensors upon reading the default salinity value send the message to the GSM module. Three (3) recorded salinity values reach 34,000-35,000ppm and triggered the Arduino Uno to send a signal to the GSM Module. However, it can also observe that below the default salinity value recorded reaction time is still present as the Arduino Uno receives the salinity readings but no message will be received by the GSM Module.

The reaction time in the Arduino Uno further implies a real-time response as indicated in milliseconds. Moreover, once the message is received in the Arduino Uno, the opening of the gates can be triggered. Results of the performance efficiency suggested that the GSM-based water salinity monitoring system can be a great help in salt production as the tedious monitoring of the salinity is lessened.

Conclusion

The developed GSM-based waster salinity monitoring system is designed to lessen the human activities entailed in ensuring the required salinity in salt farms. The materials used in the developed system suit the design purpose and achieve functionality, durability, and efficiency. The overall rating of 3.32 reflects that the system met the design functions; the design and materials are appropriate and the specifications meet the desired purpose; the system is efficient and consistent with its desired objectives of lessening the manual activities involved in the monitoring of water salinity. The performance efficiency of the system implied that the reaction of the Arduino Uno in triggering the GSM Module is in real-time as the salinity readings are received. The default salinity value of 34,000-35,000ppm triggered the Arduino Uno to send a signal to GSM Module and send a message to the gate operations. The solar panel and the battery installed in the system ensure the continuity of usage and power up the devices, circuit boards, GSM Module and Arduino Uno to operate on its design purpose. The technology developed and tested by selected salt farmers can eventually provide a system for gate operations.

Author Contributions

M. Enriquez, A. Abella designed and constructed the system components. A. Abella, tested the developed system and gather the data. M. Enriquez analyzed the data, interpreted the results and wrote the manuscript.

Acknowledgment

The authors would like to thank the Tamaraw Salt Producers Cooperative for the data provided and for allowing the conduct of testing in their salt farms; and the salty farmers who willingly joined the demonstrations and the evaluation of the system.

Conflict of Interest

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

Abbreviations

GSM	Global System for Mobile communications
IoT	Internet of Things
IDE	Spectral Angle Mapper
TCP/IP	Transmission Control Protocol/Internet Protocol
pH	Potential of Hydrogen
ppm	Parts per minute
WIFI	Wireless fidelity
CCTV	Closed-circuit television
MCU	Microcontroller
SOC	System on chip

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Biographies

Michelle D. Enriquez is presently designated as the Dean of the College of Engineering of Occidental Mindoro State College, Philippines. She is currently finishing her degree in PhD Civil Engineering at De La Salle University, Philippines. Her research interests include water resources engineering; development researches in salt processes; water quality monitoring system and policy directions for water management.

- Email: michelle_enriquez_d@dlsu.edu.ph
- ORCID: 0000-0002-1618-6335
- Web of Science Researcher ID: ABE-3230-2021.
- Scopus Author ID: NA
- Homepage: NA

Adrian Paul N. Abella is a faculty of College of engineering of occidental Mindoro State College, Philippines. He is currently pursuing his Master of Science in electronics Communication Engineering at Mapua University, Philippines. His research interest includes application and development of system using electronic and electrical devices, sensors, and microcontrollers.

- Email: adrianpaulabella@gmail.com
- ORCID: 0000-0001-9822-2143
- Web of Science Researcher ID: NA
- Scopus Author ID: NA
- Homepage: NA

How to cite this paper:
M. Enriquez, A. Abella, "GSM based water salinity monitoring system for water gate management in salt farms," J. Electr. Comput. Eng. Innovations, 11(2): 383-390, 2023.

DOI: 10.22061/jecei.2023.9564.633

URL: https://jecei.sru.ac.ir/article_1844.html