



Experimental Analysis Using IOT-Based Smart Power Quality Analyzer System With Remote Data Access And GSM Alerting Mechanism

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Abstract: Power Quality Analyzers (PQA) are essential for monitoring and maintaining electrical networks. These assist in identifying changes in electrical measurements due to load fluctuations and other power quality factors. Traditional monitoring systems are mostly real-time, however they do not have automated alerts which would help in fault detection and corrective actions. The system is built on top of a Raspberry Pi Pico W microcontroller to which the voltage and current sensing modules, OLED display, and communication interfaces are connected. Wi-Fi gateway is used for passing the data obtained by different sensors. The transmitted and stored Data can be processed in further with an opensource cloud platform such as ThingSpeak to help monitor different aspects like IR status, temperature etc. SIM900A GSM module is used to alert the users in real-time as soon as any abnormal power event or voltage fluctuation occurred over the system in order to ensure higher reliability of the system. This ensures timely action and aids in avoiding the destruction of electrical devices.

Experimental Results: The proposed system performance is compared with conventional measuring apparatuses like FPGA-based Power Quality Analyzers and state-of-the-art Fluke meters under different load conditions. The results collected indicate that the developed system enables correct measurements and monitoring.

The low-cost IoT design-based alternative proposed represents a simple method for managing the analysis and enhancement of power quality in home, business, and industrial electrical applications.

Keywords: Internet of Things (IoT), Raspberry Pi Pico W, Voltage and Current Sensors, GSM Alert System, Remote Data Monitoring, Cloud Platform (ThingSpeak)

I.INTRODUCTION

Running things today needs electricity, yet what matters most isn't just having it - but how steady it arrives. Devices at home or work behave differently depending on whether the supply stays smooth or wobbles without warning. What we call power quality measures if voltage holds firm, current flows evenly, and cycles per second stay predictable across wires feeding buildings everywhere.

When loads shift unexpectedly, problems often show up across real-world power networks. Faulty gear or abrupt spikes in usage tend to trigger these issues quite frequently. Voltage might dip or jump without warning because of such events. Imbalance in current flow becomes noticeable under similar conditions sometimes. Strange behaviors in electricity delivery do happen when disruptions take place. Devices connected to the grid could struggle to operate correctly during these moments. Overheated parts are common if stability keeps dropping over time. Equipment may start acting unpredictably whenever supply weakens too much. Efficiency levels drop noticeably when things run unevenly like this. Sensitive electronics face serious risks when conditions stay unstable for long.

Not long ago, checking how well electricity flows meant relying on basic tools - things like voltmeters, ammeters, or common power meters. While these devices can track voltage or current, they usually need someone watching them all the time. Without automated support, spotting issues right away turns into a challenge. Constant oversight slows things down, making real-time detection rare.

Now machines watch quietly using new tool built step by step from small parts. Built around tiny brains, they link sensors and signal boxes that talk online. Information flows without stopping, checked on its own before showing up far away.



Each piece works alone yet fits when messages move through hidden paths.

Out there, gadgets talk to each other through the web, making energy tracking smarter. Instead of staying offline, machines send electricity details straight to digital storage spaces. From those spots, numbers get organized into views people can actually understand. When something odd shows up, warnings go out - no waiting needed. Distance does not matter because checks happen far away just as well as nearby.

This report introduces a smart power quality analyzer built around Internet-connected devices. Through sensor parts, it keeps watch on key electricity levels like voltage along with current flow. Data gathered moves into a small computer brain that handles analysis before sending updates over the web. Remote access allows users to view readings from far away locations. At the device itself, numbers show up on a screen so checks can happen right there.

When anything goes wrong with power, the system sends the alert message through a built-in GSM module. Right away, people get messages about unusual voltage or current issues. Because of this setup, responses happen faster than before. Efficiency, dependability, and low cost guide how the design works across different setups. Monitoring electricity behaviour becomes simpler under real-world conditions.

1.1 Existing System

Electrical checks often rely on separate tools - things like voltage meters, current gauges, scopes, or basic power units. Though each can track key signals, most work alone, needing someone nearby to watch and record results.

Heavy-duty gear usually targets factories, costs a lot. Home users or tiny operations rarely get their hands on such tools. Besides that, old-style setups tuck data away onsite, blocking remote reach. Accessing info from afar becomes a roadblock.

What holds back current setups? They skip round-the-clock oversight. Measurements happen every now and then instead of nonstop. Sudden hiccups slip through when checks aren't constant. Problems often reveal themselves too late - after machines are already harmed.

Not built to send alerts on their own, older setups leave detection to chance. A glitch shows up, someone has to check each reading by hand. Figuring out what went wrong eats minutes, sometimes hours. With every minute passing, fixes get pushed further back.

1.2 Drawbacks:

Even so, old-school ways of checking power quality do have their place. Yet here's the catch - price tags on professional gear can be steep. Because these tools demand expert setup, getting them running isn't simple. Their expense adds up fast when you factor in labour too.

Without live online tracking, many standard setups fall short. Accessing info remotely? Often impossible with these older models. That means checking power details while away isn't really an option. Distance turns into a barrier, quietly blocking oversight.

Someone still has to watch over plenty of today's setups by hand. Equipment checks happen on site, person to machine, adding hours and work. Readings get noted the old way, step after step. Information piles up without help, slowing everything down.

Here's another catch - no built-in alerts kick in when something goes wrong. If voltage dips or current spikes happen, nobody gets a message right away. That silence means problems might sit unnoticed for longer than needed.

A lack of current capabilities means better tracking tools are necessary - ones offering constant updates, off-site control, instant alerts. What exists now falls short when real-time insight matters. Remote reach becomes possible only through smarter setups. Alerts happen without delay once systems detect change. Continuous watching improves when technology works in the background. Off-site management grows easier with updated frameworks. Instant messaging kicks in the moment conditions shift.

1.3 Proposed System:

A fresh take on power tracking begins here, swapping old methods for a smarter IoT-driven analyzer. Built with today's sensors and links, it keeps constant watch on voltage, current, and more. Real-time updates flow without pause thanks to

reliable wireless pathways. Instead of waiting, users see issues unfold as they happen across connected screens.

Voltage plus current sensors track how electricity flows through the supply. After gathering readings, they pass details along - this happens fast. Information travels toward a small brain inside the setup: not just any chip, but one built to handle tasks smoothly. That role belongs to a Raspberry Pi Pico W, sitting at the core like quiet command. It takes raw numbers, shapes them, gets ready to share what it finds.

A signal slips from the microcontroller into a wireless web, shuttling gathered details toward a cloud hub. From there, live numbers appear for anyone watching, shaped into charts that reveal how the system behaves over time.

Right where it's installed, an OLED screen shows readings up close. When something off happens, the built-in GSM part fires off alerts without delay.

A fresh approach cuts costs while staying dependable and simple to set up. Instead of old methods, it uses smart sensors tied to power systems that watch voltage and current as things happen. This setup keeps tabs on electricity behavior through connected devices, giving live updates without delays.

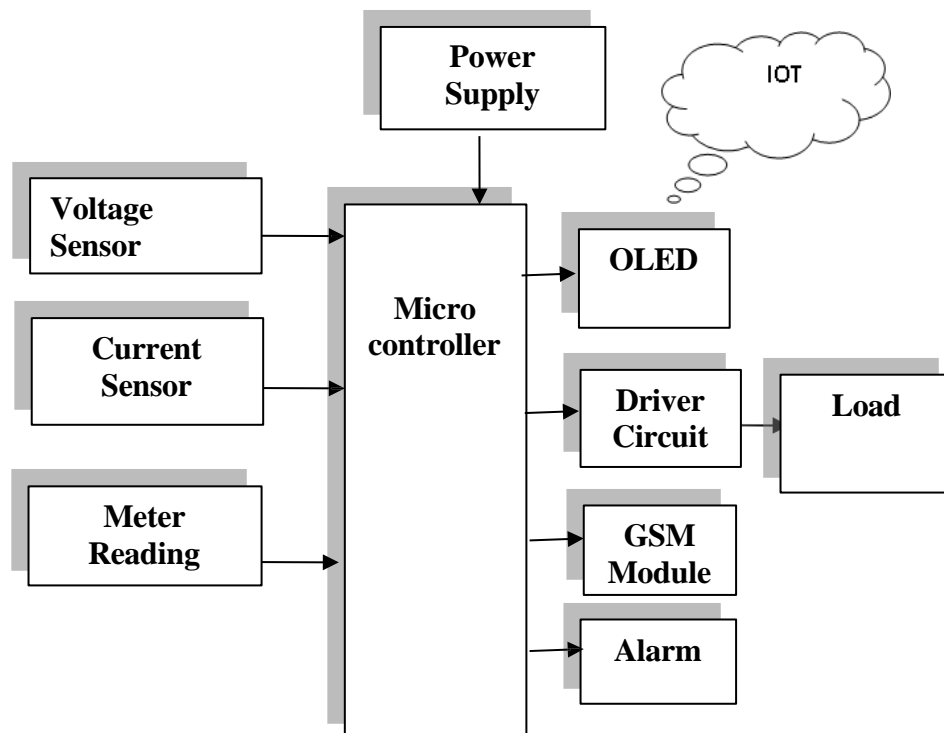
II. PROJECT DESCRIPTION

2.1 Block Diagram:

Inside the setup, every piece connects - this becomes clear right away through the drawing. Not flashy, yet it shows how things tie together across the whole arrangement.

The main blocks in this project include:

- Power supply unit
- Sensors
- Microcontroller Raspberry Pi Pico w
- Display module (OLED)
- Communication modules (IoT/GSM/Bluetooth)



Electricity enters through the power source. Next, sensing units capture voltage and current details. After collection, processing happens inside a small computer chip that organizes data flow - sending outputs toward screen output prior to transmission modules. When linked via internet-connected hardware, remote viewing becomes doable. Monitoring from distance relies on this wireless bridge staying alive.

2.3 Modules:

2.3.1 Power Supply:

Inside the machine, electrical components receive their required power thanks to the supply unit. Thanks to a consistent flow, each part operates smoothly without hiccups.

Out there where gadgets hum to life, wall sockets push out wavy AC electricity. Not what tiny brains inside devices prefer. So a quiet helper known as the power supply jumps in - reshaping that wild back-and-forth flow into something calm and straight. This evened-out stream feeds circuits just right. Microcontrollers stay cool, ticking along without a stumble.

The power supply circuit generally consists of:

- Transformer
- Rectifier
- Filter
- Voltage regulator

2.3.2 Transformer:

A transformer shifts AC voltage levels using electromagnetic effects between two wire loops around a metal frame. One loop receives alternating current, making invisible force lines spread into space. Those forces travel across to the second loop, nudging electricity inside it without physical contact. Iron holds the setup together, guiding how energy moves from one side to another. Voltage goes up or down depending on how many wraps each coil has.

Every coil's winding count shapes the voltage that comes out. Here, lowering 230V AC to 12V AC happens through a step-down setup. From there, what emerges flows into a converter, shifting it from AC to DC form. That change prepares power for the parts needing steady current.

2.3.3 Rectifier:

A rectifier is an electronic circuit used to convert alternating current (AC) into direct current (DC). It uses diodes that allow current to flow in only one direction. After the transformer steps down the voltage from 230V AC to 12V AC, the rectifier converts this AC voltage into DC voltage.

In this system, the rectifier ensures that the electronic components receive a stable DC supply required for proper operation.

There are several types of rectifiers:

- Half-wave rectifier
- Full-wave rectifier
- Bridge rectifier

2.3.4 Bridge Rectifier:

Four diodes hooked into a ring shape make up a bridge rectifier, turning AC into full-wave DC. When voltage shifts direction, different pairs take turns guiding the flow. These components move electricity along without gaps, thanks to their paired operation. No middle-connected transformer is required here. As input flips back and forth, new pathways open by themselves.

A bridge rectifier changes alternating current into direct current. Unlike half-wave models, it stays active through rising and falling phases of the signal. Since power flows regardless of direction, losses drop noticeably. With no pause between shifts in polarity, performance improves naturally. Each segment of the waveform contributes to smoothing the result.

2.3.5 Voltage Regulators:

A tremor might stay in DC power even once smoothed. Yet stability holds when guided carefully - despite rough input swings or sudden load shifts tugging from downstream.

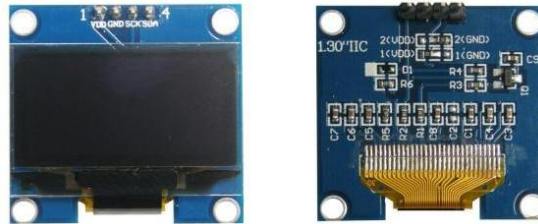
Frozen inside heaps of printed circuits, the 7805 just sits - pushing out five solid volts, never complaining. You find it everywhere, really; a quiet habit shared by builders, thinkers, anyone twisting wires after dark.

Every time energy flow changes, chips such as tiny controllers remain protected thanks to voltage regulators. They hold current stable, preventing sensitive wiring from harm caused by sharp jumps or falls in power.

2.4 Microcontroller:

2.4.1 Raspberry Pi Pico w:

The Raspberry Pi Pico W is a wireless microcontroller board designed for embedded systems and IoT applications. It is the successor of the Raspberry Pi Pico board and is built around the RP2040 microcontroller chip developed by Raspberry Pi Ltd.



2.5.2 Pin Functions Listed in Table:

Tiny wires hook the screen to the brain chip. During data transfer, each one acts differently. First this one wakes, then that one follows. Messages pass just if contacts answer in turn. Stepwise they go, never all together. Each signal hops across when its path clears. Order matters more than speed here.

Common pins include:

PIN	FUNCTION
VCC	Power Supply
GND	Ground
SDA	Data line
SCL	Clock Line

Information travels from the microcontroller to the OLED via these pins. Through narrow electrical channels, every pin delivers part of the image signal. When the chip turns on certain paths in sequence, data begins to move. It is these minute connections that allow screen changes exactly when needed. Speed makes it seem like pictures show up immediately on display.

2.6 Internet of Things:

Flying loose across the net, common things swap tiny updates without a sound. From one to another, these tools murmur their findings using digital threads.

From the chip, electrical data moves into cloud storage by way of connected gadgets. Once it arrives there, power usage can be viewed from a distance. When signals go up via web-enabled gear, someone distant sees changes in voltage.

2.6.1 Benefits of IoT

Now here's something that adds up - certain benefits do show up now and then

- Remote monitoring
- Real-time data access
- Improved system efficiency
- Automation and smart control
- Reduced manual supervision

2.7 ULN2003:

Tiny but tough, the ULN2003 lives inside countless gadgets. Though compact, it powers larger components through clusters of transistors. Because it groups switching elements, it manages high-current tasks solo - no helpers required. Imagine several relays acting in sync; that's how it reshapes feeble inputs into robust outputs. Safety improves when equipment drives lamps or motors through its circuitry. Once activated, every internal stage increases output steadily.

Little computers inside gadgets can't handle big jobs like running motors. Enter the ULN2003 - sits between the brain and the muscle. It takes the weak signal, then gives a stronger one out. Without it, strong devices wouldn't wake up. Power flows right when this piece is in place. Though small, it carries the weight of bigger tasks. Not flashy, yet always working behind scenes. Everything stays safe because the load never hits the chip. Smooth moves happen thanks to that middle step. So signals go soft to strong without breaking stride. Hidden but essential, it links two worlds quietly. Fragile circuits could break without that middle part. Because of it, low power connects well with high need.

Heavy things like motors usually take more juice than tiny computers can give. That chip pops up a lot when gadgets must talk to bigger devices. Instead of adding many pieces around, it handles the tough jobs alone. Power-hungry gear

connects through it, quietly doing its job behind the scenes.

2.8 Relay:



A relay is an electrically operated switch used to control high-power devices using a low-power signal. It works using an electromagnetic coil that opens or closes the switch contacts when current flows through it.

In this project, the relay is used as a control device to switch electrical loads when abnormal power conditions are detected. The Raspberry Pi Pico W sends control signals to the relay, allowing the system to automatically turn devices ON or OFF for protection.

2.9 Buzzer:



A buzzer is an electronic sound-producing device used to provide audible alerts. It converts electrical signals into sound vibrations, producing a beeping noise.

In this project, the buzzer is used as an alert indicator. When the system detects abnormal voltage or power conditions, the microcontroller activates the buzzer to notify the user immediately.

Alarm:

An alarm system is used to warn users when abnormal or unsafe conditions occur in a system. It helps in taking immediate corrective actions to prevent damage.

In this project, the alarm works together with the buzzer and GSM notification system. When power quality problems such as voltage fluctuations are detected, the alarm mechanism is triggered to alert the user and ensure system safety.

2.10 IR SENSOR:



A tiny beam of invisible light helps this gadget spot things nearby. It works by sending out heat signals most eyes cannot see. Some gadgets use these clues to figure how far away something sits. Heat waves bounce back, letting the tool sense presence without touch.

Facing the core, infrared detectors team up with emitters to form these tools. Built inside, one part shoots invisible light while another catches what bounces back. Together they track changes without touching anything nearby Infrared Transmitter Using Led IR receiver (photodiode or phototransistor)

A beam of invisible light passes from the emitter. If something intersects its path, the glow bounces off and travels back. That returning flicker gets caught by a sensor waiting on the other end. Instead of staying as light, it turns into a tiny electric pulse you can measure.

III. IMPLEMENTATION

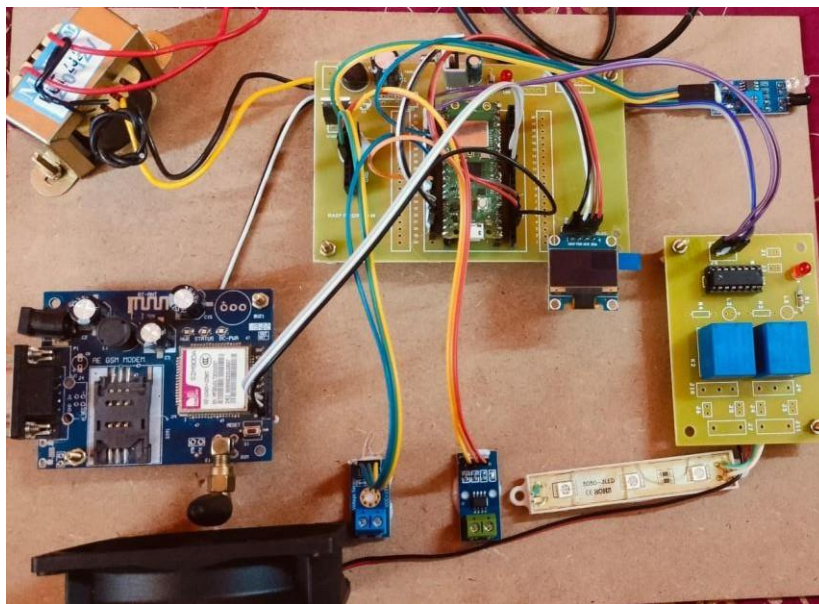
3.1 Hardware Implementation:

Few electronic pieces link together when building the setup physically. Key parts involved are these

- Raspberry Pi Pico W Microcontroller
- Voltage and current sensing modules
- OLED display module
- Relay and driver circuits
- Bluetooth and IoT communication modules
- Power supply circuit

A steady flow of controlled DC power comes from the unit that feeds the entire setup. From their positions, sensors capture electric readings while forwarding information toward the brain of the circuit. Once it gets the numbers, the small computer decides what actions happen next across linked components.

A bright screen draws out numbers like power levels and flow strength. From there, wireless parts send updates to far-off gadgets or online spots where people can check them later.



3.2 Software Implementation:

3.2.1 MicroPython with Thonny:

MicroPython is a lightweight version of the Python programming language designed to run on microcontrollers and embedded systems. It allows developers to easily control hardware components such as sensors, displays, and communication modules using simple Python commands.

Thonny is an integrated development environment (IDE) used for writing, editing, and uploading MicroPython programs to microcontroller boards. It provides a simple interface that helps in coding, debugging, running programs efficiently.

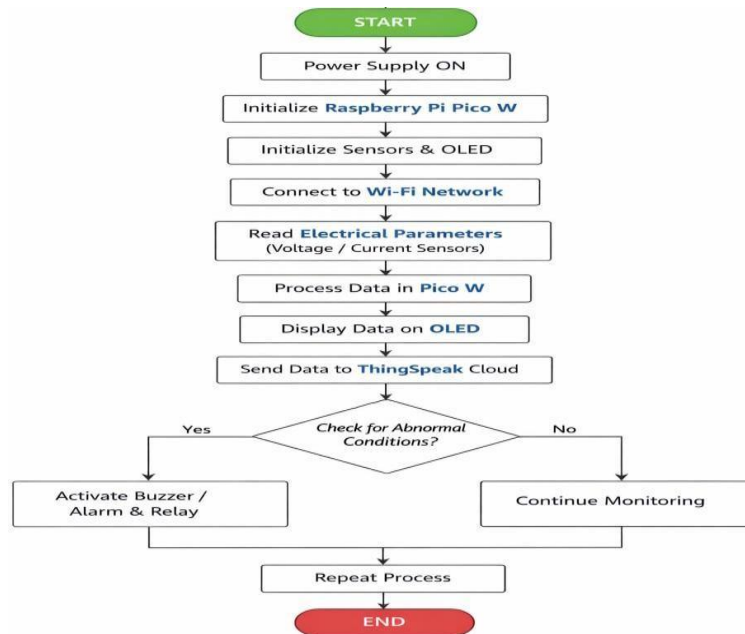
In this project, Thonny IDE is used to write and upload MicroPython code to the Raspberry Pi Pico W microcontroller. The MicroPython program reads electrical parameters from sensors, processes the data, displays the values on the OLED screen, and sends the data to the ThingSpeak cloud platform for remote monitoring.

3.3.2 ThingSpeak:

ThingSpeak is an IoT cloud platform developed by MathWorks that allows devices to collect, store, analyze, and visualize data in real time over the internet. It enables communication between hardware devices and the cloud using standard web protocols.

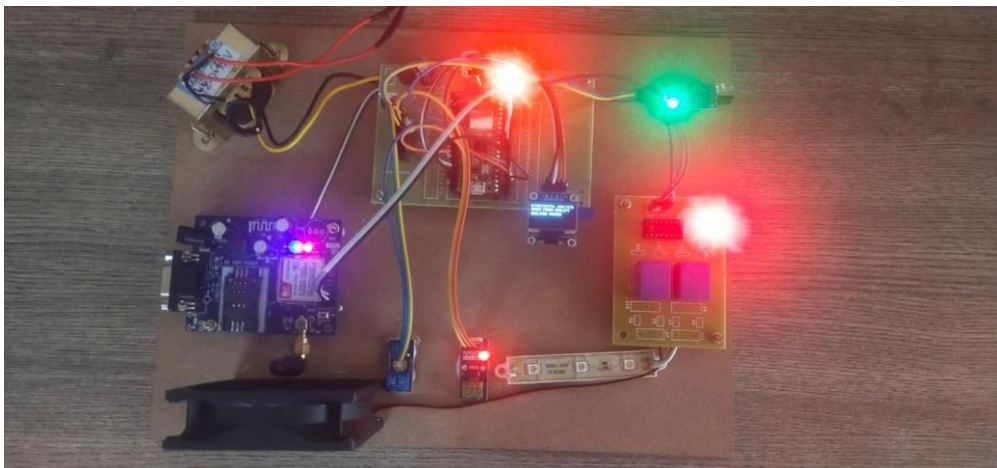
ThingSpeak provides features such as data storage, graphical visualization, and real-time monitoring of sensor data. The platform displays the collected information in the form of graphs and charts, making it easier to analyze system performance.

In this project, ThingSpeak is used to monitor power quality parameters remotely. The Raspberry Pi Pico W sends electrical data such as voltage and current through Wi-Fi to the ThingSpeak cloud. The data is then stored and displayed on the platform, allowing users to view and analyze the system data from anywhere using the internet.



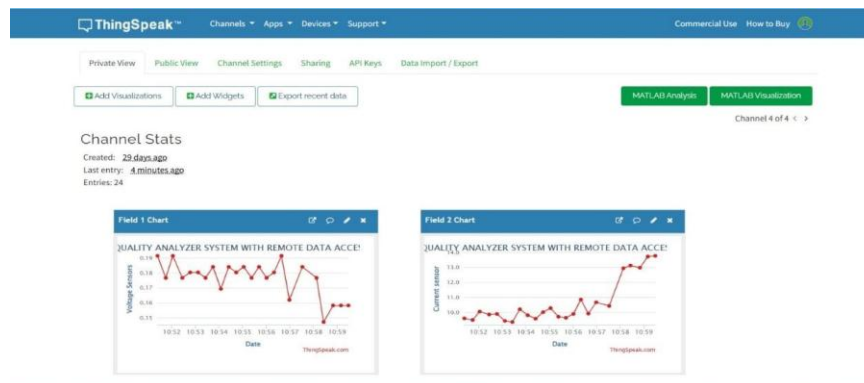
IV. SIMULATION

Simulation Results:



As per the above results we can say that the GSM will give the alert messages to the programmed mobile number and the OLED display the voltage, current, meter reading messages on its screen when the generating power crosses the predefined threshold values simultaneously based on the level of the power fluctuations the loads will be turned off one by one. The real-time monitoring will be shown in the cloud platform ThingSpeak.

The below figure shows the analysis of the current and voltage sensors.



V. CONCLUSION

The project titled IoT-Based Smart Power Quality Analyzer System successfully demonstrates the development of an intelligent monitoring system for electrical parameters.

Power readings show up fast because tiny computers talk through wireless links. Sensors feed information into a small processor that shares updates online. From far away, someone checks live electricity numbers thanks to network connections built inside. Display screens light up with details when data moves without wires.

A tiny computer called Raspberry Pi Pico W runs MicroPython, making setup easier without sacrificing power needed to collect data and send it out. Right on the device, an OLED screen shows key values at a glance instead of relying only on distant tools. Information travels wirelessly so someone far away can still keep track just as easily.

A fresh approach cuts expenses while tracking power flow instantly from anywhere. This method works at home, inside factories, or within office spaces whenever electricity behaviour needs watching. Built-in consistency keeps performance steady over time. Locations with a need to follow voltage, current, or usage trends benefit without extra complexity. Access happens online, removing the need for physical presence near equipment.

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