IoT-Based Monitoring and Management Power Sub-Station of the University of Mosul

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Abstract: Managing power plants usually involves monitoring many data and parameters that occur within minutes, hours, or days. Nowadays, a mount of digital data can be exchanged, analyzed and easily accessed through modern technology called the Internet of Things (IoT). In this paper, an IoT (using Wi-Fi development kit called Photon) is used to remote control and monitor the performance of the University of Mosul power plant. This includes monitoring the Power Factor, supplied voltage and total load current of each sub-station within the university area. The system also applies a safety feature to completely close the power plant in the event of a serious condition such as a fire. ThingSpeak is used in this paper as an IoT analytics platform service which lets the programmers collect, visualize and analyze incoming data streams to the cloud. The collected data is sent to the ThingSpeak by the Photon devices, create instant visualization of live data related to the monitored station, and send the required alerts. The engineers responsible for the station can monitor the progress of the work of the station through any connected device - a computer or a smartphone - from anywhere in the world and even reprogram the system during operation, if necessary.

Keywords: IoT, Energy Monitoring, Photon, ThingSpeak.

1. Introduction
Internet of Things is a modern typical path in IT arena, it is a revolution in transducing the data from things-to-things, human-to-human and human-to-things. It was created in the year 1998 and the Internet of Things term was first emanated by Kevin Ashton in 1999[1]. Smart devices can be transferred, connect information and make orders instead of people. Connectivity for anything is a new technology that can communicate anytime, anything and anywhere.

Internet of Things architecture comprises of three layers as shown in Figure 1.1: perception or sensing, application and network. The application layer utilizes in intelligent computing technologies (e.g., cloud computing, data mining) to extract useful information from a
huge amount of processing data and provide linking between IoT and users[2, 3]. The network or sometimes called the transport layer deals with network operations, whereas the sensing layer is in charge for assembling the information[4].

IoT platforms use different methods and technologies to communicate (each one it has specific characteristics), depending on application requirements. Examples of these technologies it includes Wi-Fi, Bluetooth, ZigBee and cellular technology such as LTE-4G and 5G networks[5, 6].

Many articles discuss the role of the Internet of Things in improving and controlling energy efficiency in buildings. The Internet of Things is also used in environmental monitoring, health care systems, and efficient energy management in transport, as well as in drone applications[8, 9].

In the field of monitoring and controlling of power systems, for example, the authors in[10], built an "Automatic Power Factor Correction Unit (APFC)”, for a purpose monitor the system's power consumption and automatic power factor improvement using Arduino microcontroller[11], design a smart energy monitoring system based on an IoT device "Photon microcontroller" and sensors. The system is used to sense or measure voltage and current levels in a house and integrated of web interfaces that are can keep analytical and graphical reports of daily power consumption.

The main idea of the current paper is to design and build a system for monitoring and management power distribution substation of University of Mosul with automatic power factor correction technique and fire detecting/alariming unit. The system based on IoT using Photon device to send the measured data via the internet to ThingSpeak cloud to store, visualize and
analyze this data information. The most important design features are build a cheap energy monitoring system with power factor correction unit, real-time measure data visualization and system protection from fire or any other fault.

1.1 UNIVERSITY OF MOSUL POWER LINE SYSTEM

University of Mosul is the bigger government organization located in Mosul city, Nineveh-Iraq. The university supplied by 3 feeders each 11KVA as shown in Figure 1.2. There are 21 distributed sub-stations diffused in the university region arranged in 3 ring connection diffused in the university area. University of Mosul has 23 colleges, 6 consultant bureaus, 6 centers, hospital and clinic, 6 museums, a number of administrative and technical units and directorates[12].

The maximum load of the organization is 12.5 Mega Ampere. Its power grid could be considered an old grid and it has many problems like cannot detect any faults or fire if it occurs. For example, when the supplied power is off, a call and manual notification will be received at peak demand and immediate high voltage (causing some hardware sensitive components to be damaged). Therefore this paper aims to develop this old grid to a smart grid to solve these problems. Which includes a variety of operating and safety procedures, including sensors and smart devices. This will help in improve electronic energy, better controlling the distribution of electricity, and efficiently handling problems. And finally, this will contribute to maintaining the durability of different devices and equipment.
Figure 1.2 Map of the University of Mosul power plant

2. **System Design**

2.1 **System Architecture**

The implemented system of controlling, monitoring and automatic power factor correction of the system constructed of eight modules. Figure 2.1 shows the electrical wiring diagram and connected devices for obtaining the primary data for the system.
Figure 2.1 system block diagram

It consists of the microcontroller (Particle Photon), three current transformers (CT) for measuring current values, voltage sensor for measuring voltage value, relay model to connect three capacitor banks for power factor correction, 3-phase digital circuit breaker, smoke sensor and fire alarm. The circuit breaker is used to connect/disconnect the loads to the 3-phase power line under the control of the microcontroller system. The voltage sensor and the capacitor banks are attached in parallel with the main supply, where the CT is connected in series with an operated load. The smoke sensor is located inside the station for sensing fire if detected.

A Prototype design has been implemented in the laboratory to emulate controlling and monitoring power distribution substation remotely by using Particle Photon IoT device. Correcting the power factor has many benefits including reducing the system lost energy, improved load-carrying capabilities, improved voltages, increasing stability and efficiency of the system and much more. This correction is done by activating a capacitors banks which connected to Photon through solid-state relays for compensating the power factor value near unity. After these internal calculations the Photon sent the data to ThingSpeak cloud via Wi-Fi technology which is located in the device. ThingSpeak collects, plots graphs and saves these live data. The following subsections are brief description of the main system components.

2.1.1 Particle Photon

It is undeniable that Particle Photon is one of the most suitable choices for developing IoT equipment. It contains all the required functions, such as Wi-Fi which is considered as encrypted communication. The photon mobile applications are all open-source, making it easy to recreate designs or applications without any restrictions. Photon also uses C/C++ programming language, which is exactly the same as Arduino. Also particle mix of ARM Cortex M3
microcontroller with a Broadcom Wi-Fi chip in a tiny sized module. These advantages make it very useful when comparing with other development kits.

Figure 2.2 shows a pin diagram for the Photon. It has 18 general purpose input output (GPIO) pins, these pins used to connect Particle Photon with other general purpose devices by programming it according to the required function. Voltage, current and smoke sensors collect the actual data and sent it to the photon through the GPIO pins.

Particle using the same style of coding as the Arduino platform, Particle IDE is the official software used for programming the Particle boards. It uses the C++ programming language for programming where Arduino IDE is based on the C programming language. For more information see photon’s functional description[13].

![Particle Photon (IoT Wi-Fi Board)](image)

The Photon is programmed to perform the power calculation for obtaining the present data of 3-phase voltage, 3-phase load current, power factor, applied power and appearance power values. After these calculations, the Photon makes a suitable correction for the power factor.

2.1.2 Voltage Sensor ZMPT101B

ZMPT101B is a perfect voltage transform used to measure the AC voltage. It has very high accuracy, good regularity for voltage and power measurement up to 250V AC, very easy to use and it is designed with a multi-turn trim potentiometer used for providing desired ADC output[15].
2.1.3 Current Sensor SCT-013-030

The SCT-013-030 is a sensor of non-invasive current transformer, which used for measuring the intensity of a current that crosses through the conductor. It is a kind of "transformer device" that is used to measure alternating current in its secondary winding which depends on the current measured in its primary winding. SCT-013-030 CT measures a maximum flowed current of 30A and the CT's secondary output a maximum voltage of 1 volt[16, 17].

2.1.4 Six channel Relay driver HL-56S V1.0

A relay is defined as an electric switch; used to control high voltage electrical circuits by means of a low-power signal (3.3 volts in our design). HL-56S V1.0 is a six-channel relay driver. Its interface can be controlled directly by the microcontroller. This module is isolated from the high voltage side for safety requirement and also prevent ground loop when interface to microcontroller[18].

2.2 System operation

The system software is implemented as shown in flowchart in Figure 2.3. The Photon is the center of the design. Initially, the Photon tries to establish an internet connection. If the connection is established the Photon reads the value of the smoke sensor and checking fire is detected. If it is sensed that there is a fire, the station will be extinguished immediately, and the fire alarm will be activated. If there is no sensitivity to the presence of the fire, it will proceed to collect station data.
Figure 2.3 System flowchart

It imports the values of voltage sensors and CTs. The Photon then does the calculation of both phase shift and magnitudes for the voltage value of the main supply and current load value by using a special library called EMONlib uploaded in the Photon. Based on these values, EMONlib uses power basic formulas for calculating appearance power, active power and the power factor of load. Based on measured power factor value, a selection of capacitor bank is specified and it is switch in or out by relay module. Finally, the measured data is uploaded to the ThingSpeak cloud via the Wi-Fi network device of the Photon.

2.2.1 ThingSpeak

ThingSpeak is an open-source Internet of Things (IoT) application and Application Programming Interface (API) to store the sensors data of different IoT applications and display the collected data graphically using HTTP over the Internet. It was originally launched in 2010 as a service to support IoT applications. ThingSpeak helps build different applications like sensor logging as well as location tracking logging and create a social network of things with status updates[19].

As shown in Figure 2.4, with the aid of internet connection which considered act as a data packet carrier, ‘things’ are connected to the ThingSpeak cloud to analyze, store, retrieve and observe the collected data from the sensors. The Photon device in our project act as a smart connected device shown in the figure.
Figure 2.4 ThingSpeak cloud interface[20]

In the ThingSpeak webpage, as shown in Figure 2.5, a channel has been created and generated channel ID and API keys automatically for establishing the connection between the Photon and ThingSpeak cloud. Each channel allows to store a maximum of 8 fields of data that need to measure and visualized. ThingSpeak also can create a public channel to analyze and visualize data through public. The received data to ThingSpeak platform can be processed and visualized its information by MATLAB software as well as respond the data via tweets or another type of alerts[19].

Figure 2.5 ThingSpeak website

3. Results

A prototype design was created in the laboratory for power station emulation and implementation of the flowchart steps shown in Figure 2.3. The results are shown below graphically, the channel fields are created by ThingSpeak platform for monitoring our design measurements of power factor, voltage and 3 phase current load. All the results also saved as Microsoft Excel format.
Figure 3.1 shows the curve of field1 in ThingSpeak channel for power factor measurements with and without power factor correction unit, where the measurements are changed when the capacitor banks are inactivated near 5:45, the value of power factor decreased from 0.93 to 0.74.

![Figure 3.1 Power Factor measures](image)

Figure 3.2 shows the measure values of the supply voltage for the implemented circuit. The curve indicates different values between 222 and 224 volts recorded in 40 minutes. We notice a change in the voltage readings with a change in the load balance, as well as due to the instability of the source voltage.

![Figure 3.2 voltage measures](image)
Figures 3.3, 3.4 and 3.5 show the measure values of the load current of 3-phase of the implemented design. Note that the values of current differ every time, and this difference occurs due to the amount of load related to each phase.

4. **Conclusion**

Based on the IoT, a prototype design was implemented in the laboratory for University of Mosul power distribution substation to monitor supplying voltage, load current and power factor measures. And to design an automatic power factor correction technique as well as fire detection and alarm unit. The system uses a Wi-Fi (Photon) development kit to upload measured data to the ThingSpeak cloud to process and display instant measurements. Thus, the station performance can be monitored and the best decision made depending on the station performance, in the event of a fire or any emergency. Also, the system implements automatic power factor correction which can be used to increases efficiency and the capability of the power system.
References:

[1] R. Porkodi and V. Bhuvaneswari, "The internet of things (IOT) applications and communication enabling technology standards: An overview," in *2014 International conference on intelligent computing applications*, 2014: IEEE, pp. 324-329.

[2] S. Madakam, V. Lake, V. Lake, and V. Lake, "Internet of Things (IoT): A literature review," *Journal of Computer and Communications*, vol. 3, no. 05, p. 164, 2015.

[3] A. Tewari and B. Gupta, "Security, privacy and trust of different layers in Internet-of-Things (IoTs) framework," *Future generation computer systems*, vol. 108, pp. 909-920, 2020.

[4] S. Cirani et al., "A scalable and self-configuring architecture for service discovery in the internet of things," *IEEE Internet of Things Journal*, vol. 1, no. 5, pp. 508-521, 2014.

[5] N. Hossein Motlagh, M. Mohammadrezaei, J. Hunt, and B. Zakeri, "Internet of Things (IoT) and the energy sector," *Energies*, vol. 13, no. 2, p. 494, 2020.

[6] Y. Yang, X. Luo, X. Chu, and M.-T. Zhou, "IoT Technologies and Applications," in *Fog-Enabled Intelligent IoT Systems*; Springer, 2020, pp. 1-37.

[7] A. C. Net burner. "Architectures in the IoT Civilization." [https://www.netburner.com/learn/architectural-frameworks-in-the-iot-civilization/](https://www.netburner.com/learn/architectural-frameworks-in-the-iot-civilization/).

[8] T. K. Hui, R. S. Sherratt, and D. D. Sánchez, "Major requirements for building Smart Homes in Smart Cities based on Internet of Things technologies," *Future Generation Computer Systems*, vol. 76, pp. 358-369, 2017.

[9] N. H. Motlagh, M. Bagaa, and T. Taleb, "Energy and delay aware task assignment mechanism for UAV-based IoT platform," *IEEE Internet of Things Journal*, vol. 6, no. 4, pp. 6523-6536, 2019.

[10] Y. Kabir, Y. M. Mohsin, and M. M. Khan, "Automated power factor correction and energy monitoring system," in *2017 Second International Conference on Electrical, Computer and Communication Technologies (ICECCT)*, 2017: IEEE, pp. 1-5.

[11] J. Gaurav, I. Pooja, C. Y. Devi, and C. Prashanth, "Real Time Web Enabled Smart Energy Monitoring System Using Low Cost IoT Devices," in *International Conference on Remote Engineering and Virtual Instrumentation*, 2019: Springer, pp. 330-342.

[12] University of Mosul. "University of Mosul in Figures." [http://uomosul.edu.iq/pages/en/home_page/42663](http://uomosul.edu.iq/pages/en/home_page/42663).

[13] Particle Docs. "Photon Functional description." [https://docs.particle.io/datasheets/wi-fi/photon-datasheet/](https://docs.particle.io/datasheets/wi-fi/photon-datasheet/).

[14] MARCOS PLACONA. "Getting started with the Particle Photon – IoT." [https://www.twilio.com/blog/2015/10/getting-started-with-the-particle-photon-iot-for-under-20.html](https://www.twilio.com/blog/2015/10/getting-started-with-the-particle-photon-iot-for-under-20.html).

[15] S. Ginting, J. W. Simatupang, I. Bukhori, and E. R. Kaburuan, "Monitoring of Electrical Output Power-Based Internet of Things for Micro-Hydro Power Plant," in *2018 International Conference on Orange Technologies (ICOT)*, 2018: IEEE, pp. 1-7.

[16] A. H. Shajahan and A. Anand, "Data acquisition and control using Arduino-Android platform: Smart plug," in *2013 International Conference on Energy Efficient Technologies for Sustainability*, 2013: IEEE, pp. 241-244.

[17] A. H. Bagdadee, M. Z. Hoque, and L. Zhang, "IoT Based Wireless Sensor Network for Power Quality Control in Smart Grid," *Procedia Computer Science*, vol. 167, pp. 1148-1160, 2020.

[18] LYCHEE LIMITED. "6 Channel DC 5V Relay Module." [https://www.amazon.com/Lysignal-Channel-Expansion-Optocoupler-Insulation/dp/B073HZ7Y49](https://www.amazon.com/Lysignal-Channel-Expansion-Optocoupler-Insulation/dp/B073HZ7Y49).

[19] S. Pasha, "ThingSpeak based sensing and monitoring system for IoT with Matlab Analysis," *International Journal of New Technology and Research*, vol. 2, no. 6, 2016.

[20] ThingSpeak. "ThingSpeak for IoT." [https://thingspeak.com/pages/commercial_learn_more](https://thingspeak.com/pages/commercial_learn_more).