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Flooding Prevention in High Voltage Substations Using IoT Based System

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Abstract

Every substation in a power grid system has its own sewerages to convey the storm water or rainwater into the environment. However, when the pumping station does not work on time, the water level may significantly rise causing the flooding of the electrical equipment and consequently its damage. Therefore, keeping track of the water level inside the sewerage system and controlling the pump on time can prevent unexpected errors in the power grids. This paper proposes an Internet of Things (IoT) based water level monitoring and controlling system to solve the issue. This research model is applied at 220 kV Tra Noc substation, in Vietnam to prevent flooding in the rainy season on during the high tide days. The proposed system is a low-cost in design and easy to maintenance. The system operates reliably and efficiently, serving as a basic solution for flooding prevention to substations experiencing similar flooding.

Keywords: Water level, pump station, smartphone, alert

1. Introduction

The high voltage substation plays an important role in transmission and distribution the power in the power system. There are a lot of technologies applied in one substation to support the operator every day. Especially, in the trend of applying significantly technology into the operation, decreasing the human resources in the substation, it is necessary to have many systems working properly, including pumping station to get rid of flooding conditions.

However, technology now is still ineffective, too manual, and depends on the attention of human resources. Correspondingly, there are still many instructions for opening and closing the pumping station in the high voltage substation which are done manually by the operator or the gate guard. This is not efficient and the flooding condition sometimes happens due to the equipment or humans.

To overcome this situation, some researches were conducted including using the sensor together with the short message media but not efficiently. In [1], a smart IoT flood monitoring system helps to monitor what is happening and predicts if there is any upcoming flood at the web server. Next, a web server is used as an interface to control and monitor the water levels in real-time also mentioned in [2]. Then, IoT is used to do monitoring activity that people are not able to do it in 24 hours and inform to the user in real time [3]. In addition, the researchers proposed an IoT- based water monitoring system that measures the water level in real-time in [4]. A water level sensor is used to detect the desired parameter. If the water level reaches the parameter, the signal will be sent to social network in real-time to give a warning message. This prevented from overflowing a reservoir due to lacking information of the flood gate control system supporting the flood gate supervisor.

To evaluate the system, in [5], the researchers used the Availability (AV) to measure the availability of the IoT system. In [6], the Global IoT/IoE device forecasts and IoT applications and RF enabling technologies have been illustrated correnspondingly.

Moreover, automatic water level control system has been studied in [7, 8] to measure water level. The system can be directly supervised by the public because it was designed in real-time based on the Internet of things (IoT) with a web interface.

Based on the related conditions, automatic control and monitoring system the pumping station in the substation is a proper solution. It is expected that this work can prevent the flooding condition in the substation in the rainy season and during high tide days.

2. Literature

2.1. Current Template

The 220 kV Tra Noc substation is about 17.219 square meters, located next to the national highway N0.91 and nearby the Hau River. During the operating process, the buildings around and the highway in front of the substation were upgraded, which made the elevation of the switch yard lower than that of the road. Therefore, in the rainy season, the rain water flows from the road into the substation. If the pumping station does not work properly, this may cause flooding in the switchyard.

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There are many marshaling kiosk used for connecting and controlling the electrical equipment in a substation, as shown in Fig. 1. If the water level is high, these marshaling kiosks may not work properly. As a result, the electrical equipment cannot be controlled accurately. This influences on the reliability of power transmission and distribution.

Fig. 1. The marshaling kiosk of a substation

Fig. 2. The situation of a substation when flooding

Additionally, because of locating near the big river, Hau river, this substation also faces a high water level during the high tide days. Specially, when there is heavy rain together with high tide days, the capability of flooding happening inside the substation is very high.

Fig. 2 shows the situation of the substation after facing heavy rain together with the high tide in the big river. It caused flooding over the switchyard and affected the operation of this substation.

2.2. Internet of Things (IoT)/ Internet of Everything (IoE)

The Internet of Things (IoT) and its adoptions have continued to evolve at a very fast pace, with Gartner forecasting that endpoint devices would be growing by 31% to reach 32 Billion units in the year 2020. In addition, IoT is going to have a major impact on our life. It will make our world a better place to live in, improve our health and improve business and daily operational efficiencies.

The fundamental of this growth is the connectivity behind all these devices, which need to be properly tested to ensure robust connectivity in their intended operating environments. The global IoT/IoE device forecasts are illustrated in Fig. 3 [6].

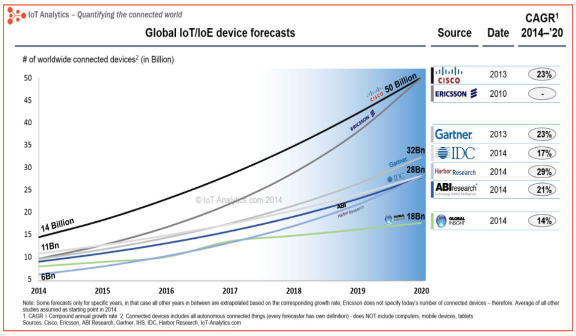

Fig. 3. Global Iot/IoE device forecasts

Many wireless standards and technologies have emerged to support a wide variety of IoT applications. These range from connecting simple wearable devices to a cell phone via Bluetooth, to mission-critical services that require constant, reliable, and secure connections.

Wearable and smart home applications centered around the smartphone often use Bluetooth, ZigBee, and Z-Wave, which offer a robust and low-power mesh network. Meanwhile, Low-Power Wide Area Networks (LPWAN) are growing to support a greater number of connected devices over longer distances with very low power consumption. LPWAN technologies, such as LoRa, NB-IoT, or CAT-M1 are ideal for smart city or industrial IoT applications whereby a large number of devices or sensors in a wide area can be connected cost-effectively.

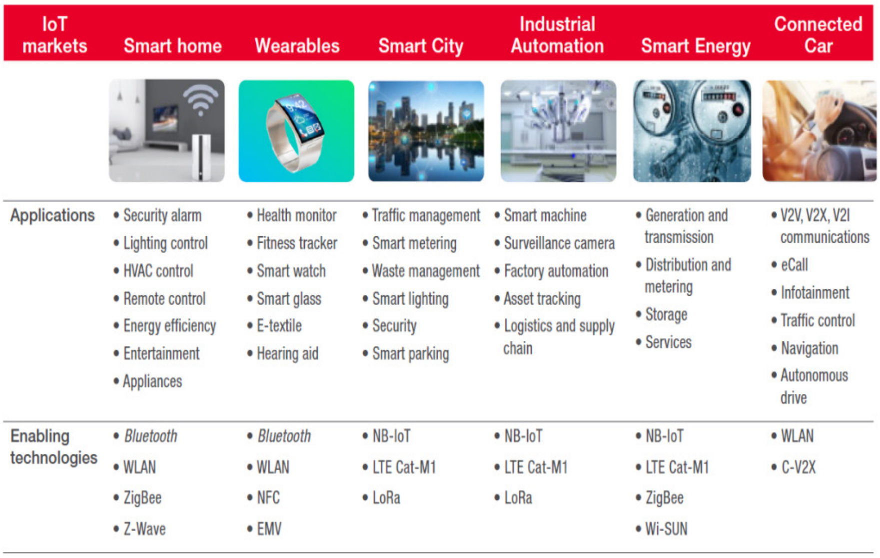

Fig. 4. IoT applications and RF enabling technologies

There are various IoT applications and Radio Frequency (RF) Enabling Technologies including smart home, wearable, smart city, smart energy, as well as Bluetooth, ZigBee, LoRa, and so on, shown in Fig. 4 [6].

3. The Goal of the System

The objective of the system is to monitor the water level in the switch yard of the substation and to control on/off the manholes of the sewerage as well as to start the pumping station conveying the water to the outside environment. The system also sends an alert to the manager of the substation via Short Message Service (SMS) to announce all the actions that it already triggered. This prevents from being flooding the substation.

In the rainy season or during the high tide days, if the water inside the substation does not punctually flow to the sewer system, flooding may happen in the switchyard of 220 kV substation.

4. Specifications of the System

4.1. System Architecture

The system uses a microcontroller Arduino Uno R3, combined with a Power Management Unit (PMU), input signals, module Sim800A displaying led and push buttons, a power supply, and a smartphone.

As shown in Fig. 5, the microcontroller Arduino Uno R3 is connected to the power circuit, which is used to operate the pumps. The input signals consist of the floating water level, manhole cover situation, and local/remote switching. Next, a module Sim800A, which can connect to a smartphone, is used to send a command to a microcontroller or vice-versa. A power supply is used to offer electric power to both the microcontroller and module Sim800A. Furthermore, the display LED and push button components are used to illustrate the operating status of the system as shown in Fig. 6.

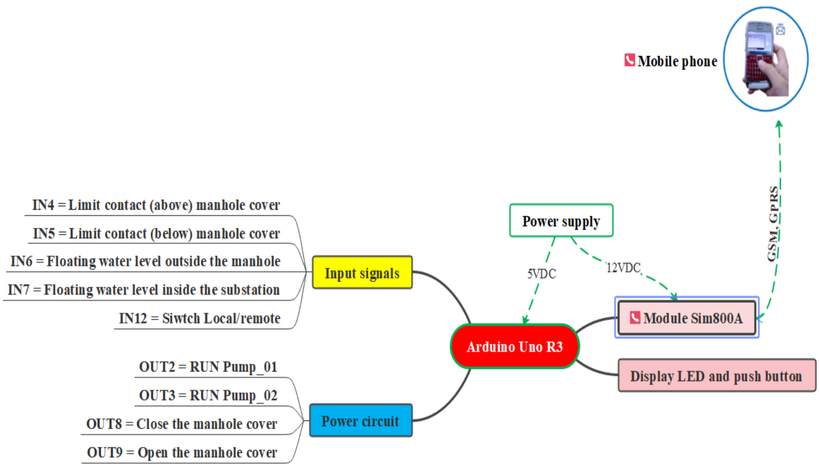

Fig. 5. The diagram of the system

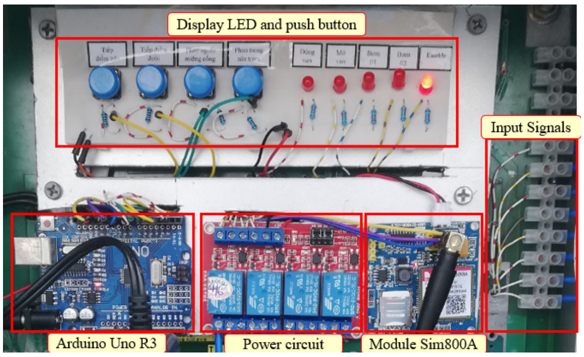

Fig. 6. The circuit design of the system

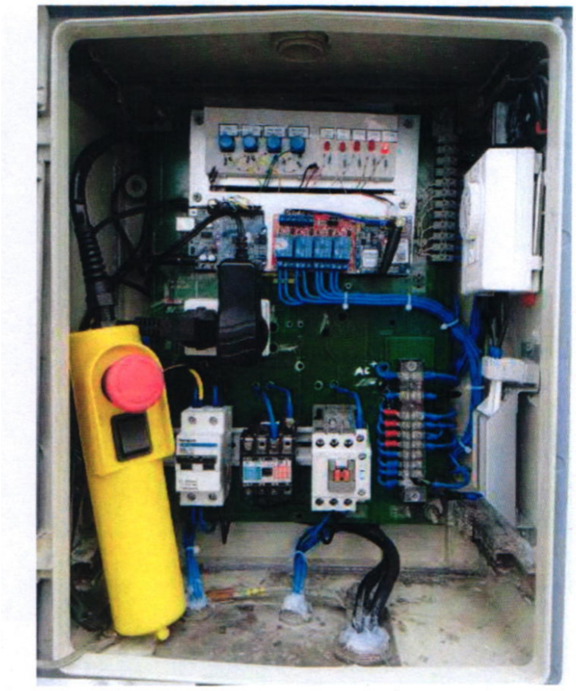

Fig. 7. The control cabinet of the system

Fig. 7 shows the control cabinet of the system. This cabinet is located near the manhole to control the drain valve.

4.2. Operating Status of the System

In Fig. 5, the Arduino Uno R3 is the central control block of the system. Arduino is a platform where all hardware devices are ready-made and standardized, users only need to choose whatever they need, assemble and program it properly. The chosen line of Arduino circuits used for programming is commonly used on the market. The Arduino Uno R3 board is programmed by using the Arduino IDE software, which is attached to the program code appendix.

This block collects digital input signals and signals from module Sim800A, then controls manhole cover opening/closing and ON/OFF pumps based on pre-programmed conditions to output.

The second important component in this system is module Sim800A. This module is a small Global System for Mobile communications (GSM) module, which can be integrated into various IoT projects. The module Sim800A can do almost everything that a normal mobile phone can do, including SMS text messages, make or receive phone calls, connect to the Internet via General Packet Radio Service (GPRS), Transmission Control Protocol/ Internet Protocol (TCP/IP). On top of that, the Sim800A module supports quad-band GSM/GPRS networks, which means that it works in different types of networks in different countries around the world.

Selecting the Sim800A module with a phone Subscriber Identity Module (SIM) card to transmit information over electromagnetic waves is the right choice for this system design.

The input signals (INT4, INT5, INT6, INT7) are located at the sewerage and the water level floats are all digital signals (5VDC impact level). Therefore, they are not dangerous to people when an electrical leakage occurs.

The manhole and the pump are programed to open/ close and/or start/stop via the detail logic values as in Table 1.

Table 1. The logic values of the input/output of the central control system.

IN12	IN4	IN5	IN6	IN7	OUT8	OUT9	OUT2	OUT3
1		1	1	0	1			
1		1	1	1	1			
1	0		0	0		1		
1	0		0	1		1		
1		1	1	1			1	1

The definition of IN/OUT is as follows.

IN12: Assign the control level; 1 is for local and 0 is for remote.

IN4: the switch behind the manhole.

IN5: the switch below the manhole.

IN6: sensor of the water level outside the manhole.

IN7: sensor of the water level in the switchyard.

OUT2: start/stop the pump N0.1.

OUT3: start/stop the pump N0.2.

OUT8: close the manhole.

OUT9: open the manhole.

Fig. 8 illustrates the installation of the sensor inside the sewerage system.

Fig. 8. Sensor installation inside the sewerage system.

In addition, display LED and push button part are used to display the operating status of the INT/OUT inputs, and the lights indicate the operating status of the system. In addition, the buttons corresponding to the state of the input signals are used to help the programmer or the simulator manager to test the working situations of the circuit.

The system uses Adapter type 12VDC - 2A to directly supply power to the Sim800A Module and Arduino Uno R3 board. The input 12VDC source will convert to 5VDC directly on the Arduino Uno R3 board to provide a stable 5VDC power supply for the Atmega 328 central processor chip.

The final component in the system is the mobile phone. This manager's smartphone will communicate with the Arduino Uno R3 board through the Sim800A Module by text message. By realizing the smartphone message, the administrator can authorize the system to work with the syntax as follows.

When the mode is in “Local” mode, it allows the system to automatically work and report actions taken to the phone. If the “Local” mode light on the circuit board is on, then the system is ready to work. Otherwise, the system is not allowed to automatically work in the “Remote” mode.

5. Operation

To prevent water from rising flood, the connection cabinets outside the power yard and the electrical cabinet in the operating room has to be in good status. The goal of our study is to apply IoT technology to construct a monitoring and controlling system that automatically detects, processes, and alerts the operator via smart phone when flooding occurs due to high tide or/and heavy rain.

Fig. 9 shows the installation of the drain valve in the sewerage system.

Fig. 9. The drain valve inside the substation

As can be seen from Fig. 10, when the system monitors and detects high tide or/and heavy rain, flooding the station yard, the system can automatically control the opening and closing of the drain valve and running the electric pump. Then, the system alerts by an SMS to the mobile phone of the manager.

Fig. 10 shows the pump which is used for the system.

Fig. 10. The pump station of the system

The manager has the right to decentralize the work for the system through her or his phone messages. When the system receives the “Local” messages, the system is allowed to automatically work and report the actions taken to the manager. On the contrary, when it receives the “Remote” message, the system is not allowed to automatically work. At this time, the manhole cover and the pump are controlled by the manager remotely via the phone messages.

Fig. 11 illustrates the total connection of the system. Specifically, a smartphone is used to control the drain valve or the pumps.

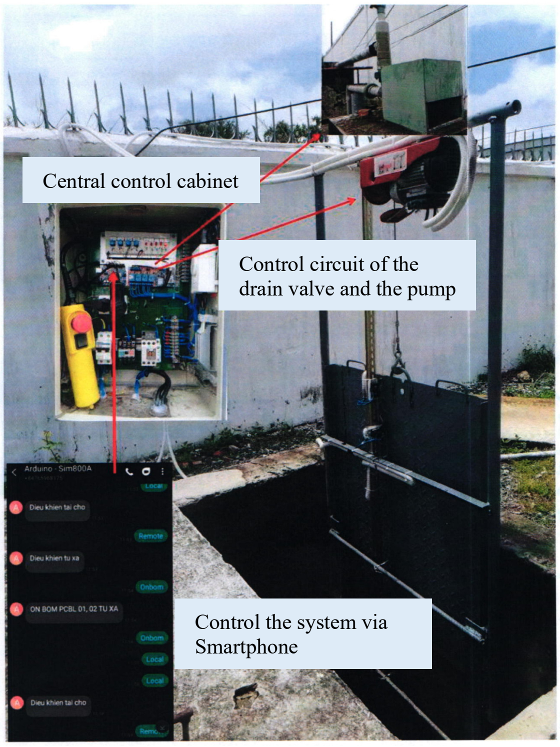

Fig. 11. Total connection of the system

5.1. System Coverage, Data Rate, Network Topology

5.1.1. The system using Wi-Fi Network

The system coverage using Wi-Fi is less than 200 m. Next, the maximum data rate is 6933 Mbps for 2.4 GHz. In addition, the network topology is a star network. Furthermore, the number of support devices is 2007 devices. The Wi-Fi network provides a high data rate but consumes high power in a short range.

5.1.2. The system using Cellular Network

The system coverage using cellular network is at most 35 km for Global System for Mobile communication (GSM) and at most 200 km for High Speed Packet Access (HSPA). Next, the maximum data rate ranges within 35-170 kbps for General Packet Radio Services (GPRS) and 3-10 Mbps for Long-Term Evolution (LTE). Furthermore, the frequency bands include 900 MHz, 1,800MHz, 1,900 MHz, and 2,100 MHz. The network topology is a star network.

5.2. Security Issue

The manager of the substation communicates with the microcontroller Arduino Uno R3 via Sim800A Module with short messages. Only he or she has the right to authorize the system to work with the appropriate command on his or her smartphone. The smartphone recognizes him or her via his or her face and password before allowing sending a command to the proposed system.

6. System Evaluation

The system has been applied successfully in 220 kV Tra Noc substation. This substation is located in the Mekong Delta and near a big river, but its basement is lower than the outside environment due to long being constructed. Flooding is usually happened in the rainy season or onhigh tide days.

The quality and reliability of the proposed system are measured under the following metrics.

Availability AV: A metric based on the uptime ratio of the service during a specified time interval is used to measure the availability of this IoT system [5] and is expressed as

$$AV = \frac{t_{up}}{t}, \tag{1}$$

where t_{up} is the time that the service is available, t is the time interval that the availability is measured. The metric measurement of the proposed system is 1, representing a 100% availability of the service.

Flaws over Time FVT: A ratio between the number of critical flaws found in the system and the period after system deployment is used to measure the system reliability [5] and is expressed as

$$FVT = \frac{n_{failure}}{n_{total}}, \tag{2}$$

where $n_{failure}$ is the total number of failure operations and n_{total} is the total number of operations toccurred in a time interval. After observation, the value of *FVT* of the proposed system is 0, indicating that there are no flaws observed in the system during the measured time.

When applying this system, the operators do not need to supervise strictly the water level in the switchyard to shut down the power to prevent power outage. The system operates properly and reliably both in rainy days and high tide days. The manager can control the operation of the sewerage system via smartphone. Furthermore, the cost is reasonable when comparing to the price of stop transmitting the power in a high voltage substation.

7. Budget Plan

Table 2 shows the budget including the following components.

Table 2. Budget plan for system designing

Components	Quantities	Cost (*USD*)
Arduino Uno R3	1 board	15
Module Sim800A	1 board	16
Power circuits (4 channels relay module)	1 board	10
Display LED and push button	1 board	5
Adaptor 12VDC-2A	1	10
Pump 1.5HP-220VAC	2	300
Electric winch kit	2	120
Sensor	4	40
Contactor 3P-20A	3	60
Cable 2.5mm2	500 m	200
Total		776

In Table 2, the microcontroller consists of Arduino Uno R3 and the module SIM800A connected to the user. Next, the power circuits consisting of four channels relay module is used to control the manhole of the sewerage and start/stop the pumping station. In addition, the input signals consist of sensors, which send the status of the water level inside the manholes to the microcontroller. The electric pump and the winch kit are used to cover the sewerage system to prevent the water from flowing back to the switchyard on high tide days. Besides, other components including the contactor, adaptor, and cable are listed in designing.

Since the module SIM800A uses Wi-Fi/cellular network to connect to the user, the cost of Wi-Fi access points or cellular network should be integrated into the total budget. Moreover, Wi-Fi or cellular is used for connecting the system to the user. Therefore, the area applied to this project should have one of this form of connection. The cost of using them should also be added as well.

Besides, the cost of testing and sparing for the system, which is approximately 200 USD, should be also integrated into the total budget. As a result, the total cost of the proposed system is around 1,000 USD.

8. Discussion

The system is very useful for monitoring the water level in the sewerage for preventing from flooding out the switch yard of the substations. An alert when an emergency happens is sent to the manager to avoid unexpected results.

However, in case of heavily raining, when the pumping station cannot work effectively, the switch yard is full of water. At that time, the system should send an alarm signal to the operating room so that the operators can shut down electrical equipment promptly. This will help to prevent power outages for the wide area of the town.

Moreover, a control center of the operating company should supervise the water level inside some substations having similar locations, surrounding environment like this substation in order to switch on or off power properly.

9. Conclusion

In general, the system is very useful for the operators when supervising the water level in both the outside environment and inside the substations. Controlling the water level punctually results in operating the high-voltage substation safely and continuously. This leads to ensure the safety of goods and people with regard to the electrical risk but also the resilience of electrical structures after the water has withdrawn.

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