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Design and Implementation of An Integrated Industrial Cloud-Based Measurement and Control System

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Pham Ngoc Minh, Thai Quang Vinh, Ngo Duy Tan

***Abstract:** In a industrial-scale production environment, many factory parameters need to be collected in real time are hard to integrate and synchronous operate. The solution is still being researched and developed by major industrial and technology companies in the world. The article aims to propose a method to integrate a system for measuring and control with cloud computing servers via the Internet to monitor and control the factory operating parameters on a cloud computing platform. Specifically, the authors will describe the mechanism of data collection from measuring devices and control via industrial communication networks, Internet and cloud computing server to ensure the system accessibility from anytime and anywhere.*

***Index Terms:** Cloud Computing, Google App Engine, Programmable Logic Controller, Supervisory Control and Data Acquisition.*

***Abbreviation:** PLC: Programmable Logic Controller, SCADA: Supervisory Control And Data Acquisition, MPI: Multi Point Interface, GAE: Google App Engine, WPN: Wireless Plant Network, WFN: Wireless Field Networks.*

I. INTRODUCTION

Today, in a modern, industrial-scale production environment, various factory parameters need to be collected in real time such as temperature, humidity, light, dust concentration, pressure or monitoring such as camera images, warnings such as fire alarms, smoke alarms and controls such as engines, pumps. The integration and uniform operation of those parameters is not easy and is still being researched and developed by major industrial and technology companies in the world.

Therefore, the purpose of the paper is to propose a method to connect data from measuring devices and control via industrial communication networks and the Internet to the cloud computing server In the network system that connects measurement and control devices to the server, SCADA monitoring and control center is installed on the cloud computing server with the aim of optimizing the use of resources and operating structures. as well as the storage, distribution and handling of operating parameters such as temperature, humidity, light, fire alarm, smoke alarm, dust concentration, measuring devices, image monitoring, and actuators such as engines, pumps etc. via wireless network, and also allows administrators and users to access data intuitively and quickly within the factory.

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II. DESIGN OF SYSTEM MODEL

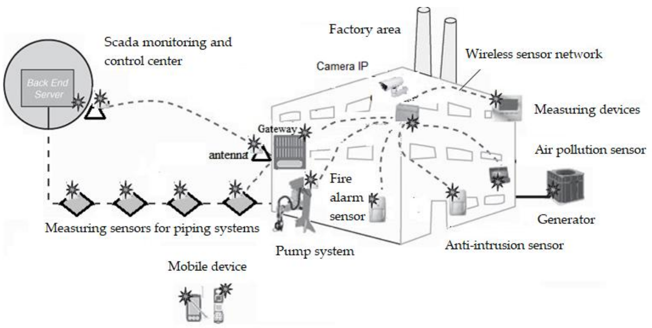

Fig. 1 Measuring and control devices system model of operating parameters in the fact [7]

When building a measurement and control system for a specific production unit, data on operating parameters such as temperature, humidity, light, dust concentration, pressure or monitoring such as camera images, warnings such as smoke alarms, smoke alarms and controlling such as motors, pumps etc. should be collected through sensors. These measurement and control parameters are intended to ensure that the production environment complies with the technical requirements, supports the supervision, operation, warning and troubleshooting quickly. These parameters will be measured and controlled via sensors, actuators, and then transmitted to the cloud computing server via an industrial communication network and the Internet.

The wireless network infrastructure for the plant includes mesh access points, a wireless intranet controller and network management software integrated with cloud computing technology. Some access points are distributed throughout the plant to create umbrella-like wireless coverage.

This architecture allows integrating transmission lines in the existing IT infrastructure of power plants, so there is no need for a wireless coating. There are:

- Wireless Plant Network - WPN, based on the IEEE 802.11 standard, uses WiFi technology to build networks for plant operation.
- Wireless Field Networks - WFN is based on a wireless sensor network standard that allows measurement data transmission and diagnosis, without the need for large investments in plant-wide infrastructure.

- In this paper, the method of connecting measurement and control devices to the cloud computing server via the Internet is built on the following main technologies:
- Wireless network such as Wifi and Zigbee;
- PLC technology integrates industrial communication network technology MPI.
- Cloud computing technology.

In particular, the data connection model between measuring, control devices and cloud computing server via the Internet is composed of:

- The sensor measures operating parameters in the factory
- PLC measuring and control devices
- Computer operating production

Cloud computing server at the center installs SCADA monitoring and control software system.

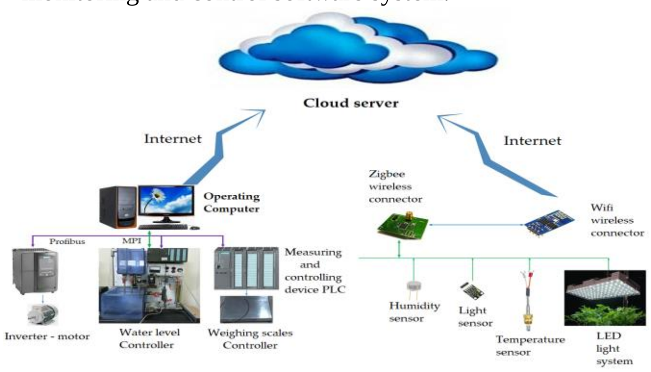

Fig. 2 Data connection model between measuring, control devices and cloud computing server via the Internet

III. DATA COMMUNICATION BETWEEN OPERATING COMPUTER AND CLOUD COMPUTING SERVER

In the world, big companies like Google, Microsoft, and Amazon are providing users with software on their servers in the "cloud" such as Gmail services, Google Docs, Office Live, etc... Within the scope of the research, we choose to use Google's cloud computing service. This is a distributed computing model with great elasticity, oriented towards economically beneficial elasticity; which contain the computing power, storage, platforms and services that are intuitive, virtualization, elasticity flexibly and will be distributed according to the needs of external customers via the Internet. In this computer model, all IT related capabilities are provided in the form of "services", allowing users to access technology services from a certain provider "in cloud "with neither having the knowledge and experience of that technology nor needing to care about the infrastructure that serves that technology.

Operating computers connected to PLC measuring and control devices have the function of collecting data from sensors, actuators, and then sending an http request (which can be a GET-formed request with measurement parameters is attached to the Http Request path, for example /? Nhietdo = "30" & doam = "70" & ...; or it can also be a POST-formed request with the measured parameters sent in the message body of HTTP Request) via the Internet to cloud computing server in order to update data to cloud.

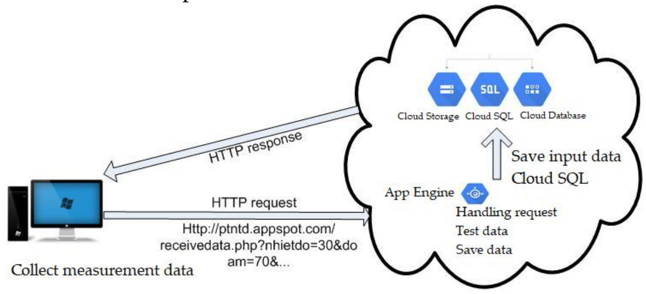

Fig. 3 Updating data to App Engine model

Google App Engine (GAE or App Engine for short) is an application development environment based on cloud computing technology. In that, Google provides a system that includes programming languages, database systems, and programming libraries. Programmers will write applications, and the application will run on Google's servers. Google App Engine is provided free for each application within a limit, there will be an extra fee that must be paid for the applications ' limit excess.

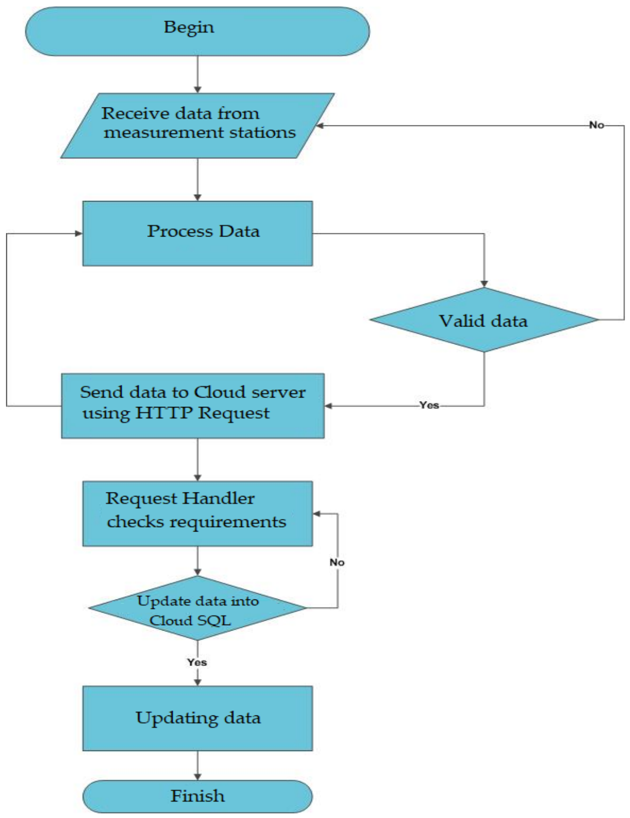

Fig. 4 Updating data to App Engine flowchart

App Engine determines that a request is sent to the application, which is created on the App Engine using the application's domain name.

When applications are created on App Engine, App Engine will give each application an identifier ID.A request is sent to the domain http://id_ung_dung.appspot.com, it will be directed to the user-created application whose ID is "*id_ung_dung*".

When App Engine receives a web request for the user-created application, it calls a script to handle the request corresponding to the URL described in the application configuration file *app.yaml*.

The cloud computing server determines which script is run to process the request by comparing the URL of the request with the URL pattern in the application's configuration file. The server will run the script corresponding to the request data and put the request data into the variable environment and data stream into the standard. The script will perform the appropriate actions with the incoming request, prepare the response data and put this data into the standard output stream. An incoming HTTP request includes HTTP headers sent by the client. For the purpose of securing some headers will be improved or modified by the intermediate proxies (delegate) before it can reach the application.

The following headers will be removed from the request:

- Accept – Encoding
- Connection
- Keep – Alive
- Proxy – Authorization
- TE
- Trailer
- Transfer Encoding.

Google Cloud SQL provides a relational database that can be used in App Engine applications. Cloud SQL is a MySQL database on Google Cloud. The script on the App Engine application will be responsible for collecting data from the HTTP requests (GET or POST), connecting to the Cloud SQL database, and then adding the collected data to Cloud SQL for demonstration serving purposes on the web.

An example of a GET request, which is sent from the monitoring and controlling software system on the server to the Cloud computing server:

http://ptntd.appspot.com/receivedata.php?nhietdo=30&doam=70&domovan=20&...

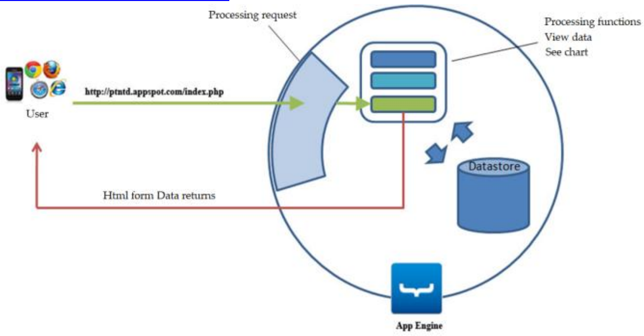

Fig. 5 Data presentation model to users

In it:

- ptntd is the ID of the application created on Google App Engine
- appspot.com is the domain name provided by Google App Engine
- Receivedata, is the script that processes the request on the Google App Engine application; it is responsible for collecting data and adding data to Cloud SQL database..

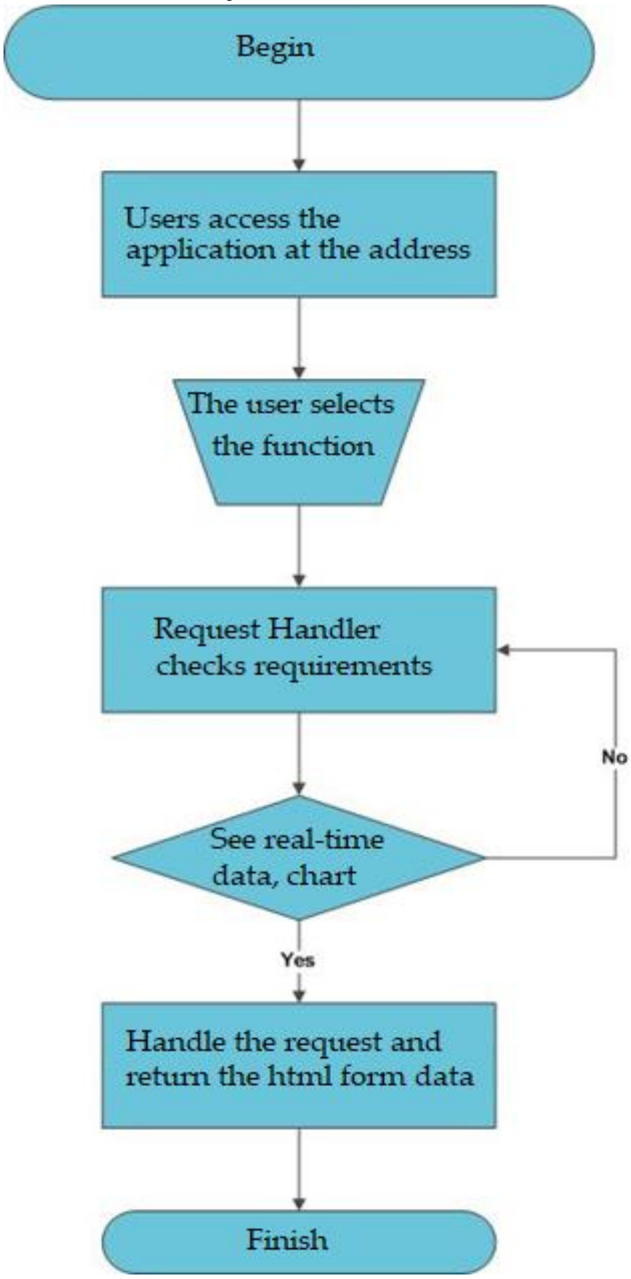

Fig. 6 Users access the application on App Engine Flowchart

IV. PROPOSED METHOD FOR MEASURING AND CONTROL DEVICE COMMUNICATION TO CLOUD SERVER VIA INTERNET

The connecting method of measuring and control equipment with cloud computing server via the Internet includes many combine steps to develop into an overall system on cloud computing platform, in which this method includes following steps:

- Step 1: Identify the measurement and control parameters including the measurement and control data needed to be stored, the frequency and type of updated signals suitable for the environment and production methods of the user unit.

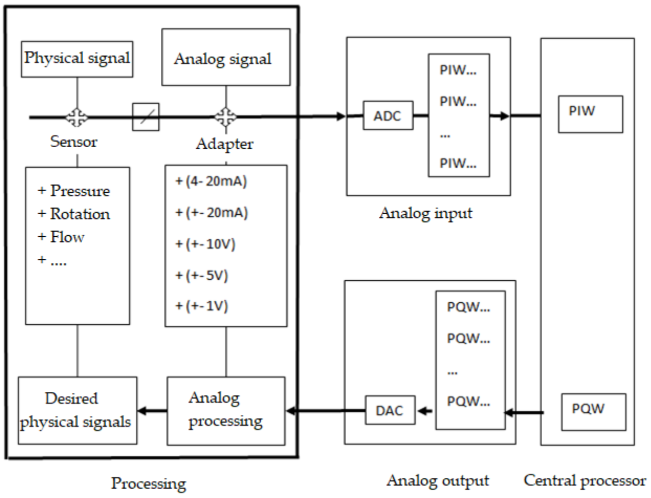

Fig. 7 Connecting measurement data from sensors, actuators to PLC

- Step 2: Connecting data from sensors and actuators to PLC control and measuring devices;
- Step 3: Connecting data from the measuring device and Programmable Logic Controller to the operating computer;
- Step 4: connecting data between operating computer and cloud computing server;.

Step 1 is done as follows:

- Selecting measurement and control parameters that includes temperature, humidity, light, water level, pressure, flow, rotation speed of engine, distance length and working range, accuracy, sensitivity for each parameter;
- Select measuring sensor that is suitable for each measurement parameter and has output signal following one or more industry standards including 0-10V, 0-5V, 0-20mA, 4-20mA, RS232 / RS485 / RS422;
- Select the device to comply with the practical technology requirements and to have control signals following one or more industry standards 0-10V, 0-5V, 0-20mA, 4-20mA, RS232 / RS485 / RS422;
- Select PLC measuring and control device with input / output port suitable for sensors and actuators;

Step 2 is done as follows:

- Measurement and control parameters from sensors and actuators are passed through a line / voltage signal converter to signal following one or more industrial standards 0-10V, 0-5V, 0-20mA, 4-20mA, RS232 / RS485 / RS422;
- PLC Measuring and control device will read / write data from sensors and actuators via analog ADC / DAC input gateway and convert into digital data in storage;

Step 3 is done as follows:

- PLC Measuring and control device transmits data to operating computer via the MPI industrial communication network (Multi Point);
- The operating computer will store data in the database, in which the database is built to continuously store data collected from sensors and actuators into the database system. The data is constantly updated periodically with high frequency (every few seconds to a few tens of seconds), so it needs a strong database management system to store and process with high speed;

Step 4 is done as follows:

- Operating computer, connected to the PLC and control device, has functions of collecting data from sensors, actuators, and then sending an http request (can be a GET formed request with the measurement parameters attached to the Http Request path) to cloud computing server to update. data on the cloud;
- The App Engine integrated on the computing cloud computing server determines that a request sent to the application, created on the App Engine, using the domain of the application; When creating an application on App Engine, App Engine will give each application an identifier ID
- When the App Engine receives a web request for the user-created application, it calls a script to process the request corresponding to the URL described in the *app.yaml* application configuration file;

The cloud computing server determines which processing script is run to process the request by comparing the request URL with the URL pattern in the application's configuration file; The server will run the script corresponding to the requested data and put the requested data into the variable environment and standard data stream. The script will perform the actions appropriate with the incoming request, prepare the response data and put this data into the standard output stream.

We tested the method of connecting measuring device with cloud computing server via the internet on WIMAX 4G platform in Buon Ma Thuot City, Dak Lak province, Vietnam to provide some environmental monitoring services for the Highlands area.

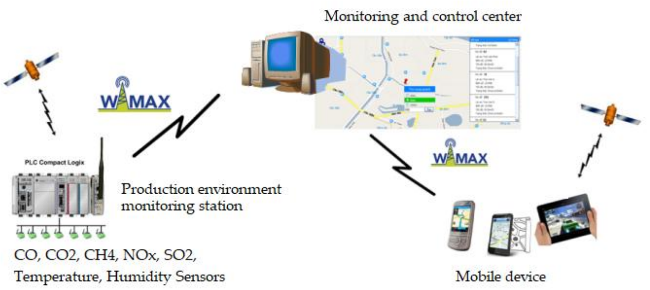

Fig. 8 Solution for transferring environmental parameters via WIMAX network [5], [6]

The system includes measuring stations to monitor production environment parameters (soil, gas, water in planting coffee, pepper, rubber, parcel of land etc. or production line parameters) built on the control monitoring, data collecting PLC technology foundation and PSoC technology for measurement sensor modules.

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The SCADA software system monitors and controls the measurement of production environment parameters and connects wirelessly to the Monitoring and Control Center via WiMAX telecommunication network.

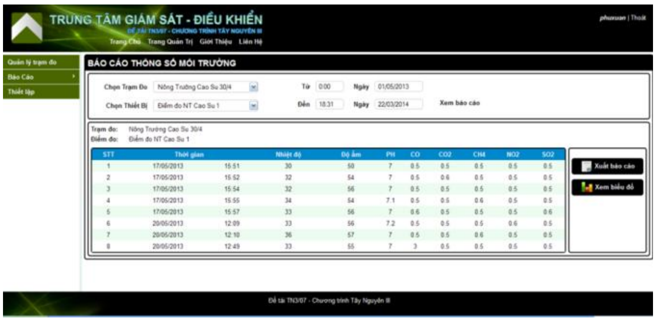

Fig. 9 Report data of environment parameters stored on the central server

In particular, the system has the function of measuring and storing parameters measurement data including CO, CO2, CH4, NOx, SO2 concentration, temperature, air humidity, soil moisture, soil pH ... etc. Service users can check data regularly and everywhere via internet-connected mobile devices

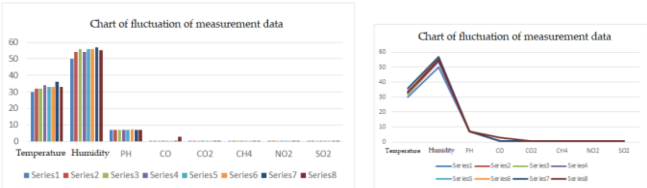

Fig. 10 Variation of environment parameters stored on the central server [5], [6]

This environmental parameter monitoring system has contributed to limiting environmental impacts, increasing land use efficiency and saving irrigation water by properly controlling the amount and timing of irrigation for some coffee, pepper growing areas of DakLak province, Vietnam.

In addition, we have applied this solution to design automation systems for production process and clean water supply of Cau Nguyet water plant - Hai Phong (Vietnam). In this project, we studied the design and application of SCADA monitoring and control system based on cloud computing technology, PC technology, Siemens PLC which integrated with the inverter, set ABB's specialized smart meter for clean water, data display devices on MIMIC console of Redlion and Schneider.

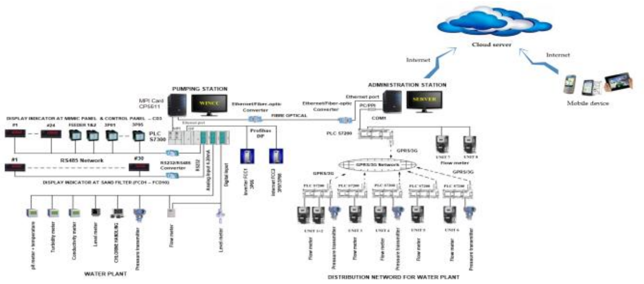

Fig. 11 SCADA system to monitor and control Cau Nguyet clean water plant

The SCADA monitoring and control system consists of pump control station integrating programmable control devices PLC and remote monitoring network for pipeline transmission at operator; they are connected to each other via fiber-optic Ethernet. In it,

- Devices for measuring water quality parameters such as pH, turbidity, conductivity and In-plant devices for measuring flow, pipeline pressure are connected to PLC S7300 of the main pump control station via 4 -20mA current signal.
- The data display device at the MIMIC console connects to the PLC S7300 of the pump control station via the RS485 communication network.
- PLC S7300 control device connected to inverter via Profibus DP network has the ability to control main pumps in the plant under pipeline pressure by PID control law.
- Remote measuring system based on the S7200 PLC monitors 03 pressure measuring devices at pipelines supplying clean water and 08 water flow measuring devices to monitor water distribution network. This system transmits data to the operator monitoring station via GPRS / 3G wireless network.
- Station computer, which is at the pump station, monitors and controls the clean water production system, connects the programmable controller PLC S7300 via MPI network.
- Server at the distributing clean water network monitoring operator connects to PLC S7200 programmable controller via PC / PPI cable.
- The server at the operator connected to the cloud server (cloud server) via the internet allows users to monitor measurement data via mobile devices such as smartphones and tablets.

Fig. 12 SCADA center for monitoring and controlling the main pump station

V. CONCLUSIONS

This paper provides a detail description for the mechanism of data collection from measuring devices and control via industrial communication networks, Internet and cloud computing server. The method shall support a way to ensure the system accessibility from anytime and anywhere. It is hoped that in the near future, useful solutions related to the method of connecting data from measuring and controlling devices via industrial communication networks and the Internet to cloud computing server will have numerous practical applications in the current thriving revolutionary era 4.0.

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