

Design and Implementation of IoT Cloud Moveable SCADA Supported by GSM for Industrial Applications

Mahmoud Shaker Nasr

Department of electrical engineering, University of Babylon

mahmoud111957@yahoo.com

Ali Najim Abdullah

Department of electrical engineering, University of Babylon

alinajim2015@yahoo.com

Abstract:

The world at the beginning of a new era of innovation and development with the rise of the industrial Internet or Internet of Things, IoT. It takes the space through the convergence of the global industrial system with the power of advanced computing, analytics, and low cost sensor devices and innovation of communication allowed by the Internet.

One of the most important developments is IoT SCADA systems, which are considered as infrastructure of society because of their potential enormous in several industrial applications.

This paper presents the design of a new generation of SCADA, named moveable SCADA, based on IoT cloud, and supported by GSM for more flexibility and reliability. The system is applied to industrial application that consists of three-control processes which are temperature, liquid level and motor processes. The three control processes data acquisition and controllers are implemented using embedded microcontroller system while a gateway is used to transfer the data proceed in field supervisor at first as well as main supervisor and monitoring engineer through IoT cloud. The system supported by GSM unit to support the system in case of internet failure. Also a camera is added to the system in order to monitor any location, any location (determined by any of the authorities) in the field where the camera is mounted. The proposed SCADA is implemented practically and tested for many cases; the presented obtained results demonstrate that the system operation is very fair and meet the required targets.

Keywords: movable SCADA, Cloud, GSM, IoT Industrial Control System, communication protocols.

الخلاصة :

العالم على أعتاب حقبة جديدة من الابتكار والتطوير مع ظهور الإنترنت الصناعية او انترنت الاشياء (IoT). وهذا التطور يحدث من خلال التقارب بين النظام الصناعي العالمي وقوة الحاسبات المتقدمة التي تمتاز بسرعة العمل ، إضافة الى ان عملية استشعار المتغيرات الفيزيائية باتت بكلفة منخفضة ومستويات جديدة من الاتصالات الذي يسمح به الإنترنت. واحدة من أهم هذه التطورات اسكادا انترنت الأشياء (IoT SCADA) والتي تعتبر البنية التحتية للمجتمع لما لها من إمكانات هائلة في العديد من التطبيقات الصناعية. يهدف هذا البحث الى تصميم جيل جديد من الاسكادا والذي يكون متنقل ومستند على سحابة انترنت الأشياء (Cloud IoT) وكذلك مدعوم بواسطة شبكة الهاتف المحمول (GSM) لكي يدعم عمل المنظومة في حال انقطاع خدمة الانترنت وبالتالي يعطي مرونة ووثقيه أكثر.

تم تصميم وتنفيذ هذا النظام للتطبيقات الصناعية حيث تم اختيار ثلاث وحدات تحكم وهي السيطرة والقياس لحرارة فرن والسيطرة والقياس لمستوى السوائل في الخزان والأخيرة هو السيطرة على سرعة محرك كهربائي. تم تنفيذ كل عملية باستخدام المتحكم الدقيق نوع (اردينو) ومستشعراتها ومشغلاتها. تتصل الوحدات الثلاثة مع الراوتر لتبادل بيانات العمليات مع المشرف الميداني في البداية وكذلك مع المشرف الرئيسي ومهندسي المتابعة عبر سحابة انترنت الأشياء. تم دعم النظام بوحدة شبكة الهاتف المحمول وتطبيق اندرويد المبني لأشراف والمتابعة باستخدام الهاتف المحمول. كما تم إضافة كاميرا للنظام من أجل مراقبة أي مكان في الميدان أينما يتم تركيب الكاميرا.

تم تنفيذ نظام سكاذا (SCADA) المقترح عمليا واختباره للعديد من الحالات؛ وبينت النتائج التي حصلنا عليها والتي تم عرضها في هذا البحث، إن عمل النظام متميز جدا ويلبي الأهداف المنشودة.

كلمات مفتاحية: الاسكادا المتنقلة، السحابة، نظام الاتصالات (GSM)، انترنت الاشياء لأنظمة التحكم الصناعية، بروتوكولات الاتصالات.

1. Introduction:

The Internet of Things (IoT) is the network of physical devices, factories, homes, cars, buildings and other items equipped with electronics, software, sensors, and network connectivity that allows these devices to gather and transfer data (Dieter and Mark, 2011). The IoT permits devices to be sensed and controlled remotely through standing network infrastructure, making opportunities for more immediate integration between the computer-based systems and the physical world, and leading to more efficiency, accuracy and economic interest (Tiia, 2015). When IoT is increased with sensors and actuators, the technology becomes an instance of the more common category of cyber-physical systems, which also includes technologies like smart SCADA (Supervisory Control And Data Acquisition), smart grids, smart buildings, smart cities and intelligent transportation. Each thing has its embedded computing system that is uniquely identifiable and able to integrate within the standing Internet infrastructure.(Abinath and Sudhakar,2015)

According to experts, IoT will contain almost 50 billion things by 2020 (Nithya *et.al.*, 2016). IoT based on cloud computing technology to link the devices and equipment through internet. Cloud computing is a type of Internet-based computing which allows shared data and processing to computers and other electronic devices on request (Wona, 2015). This structure can employ to build a new generation of the SCADA system because all modern industries based on automation technology systems (SCADA) (Rafael, 2014; Mini *et.al.*, 2015).

Now a day, the communication is greatly developed in several fields such GSM and internet communications. Therefore, the employing of these systems contributes to build a new generation of SCADA system such as IoT SCADA system which is easily interact with fields, more effective, intelligent and flexible. IoT SCADA connects the field devices, processes, machines and any industrial equipment of the real world with the virtual world, providing a huge network of connecting objects based on IoT cloud.

Therefore, enabling anytime, anyplace (mobility) connectivity to monitor and control these things (Robert and Jacob, 2013; Frank, 2015).

2. Proposed system design.

The goal of the presented system is to build a modern generation of SCADA system, which is movable in controlling and monitoring by the main supervisor, flexible, intelligent, efficient, and capable of monitor and control the several industrial processes. Additionally, the control processes are executed using the internet sharing with cloud monitoring and chatting as well as supported by GSM network. Figure (1) shows the proposed overall system block diagram.

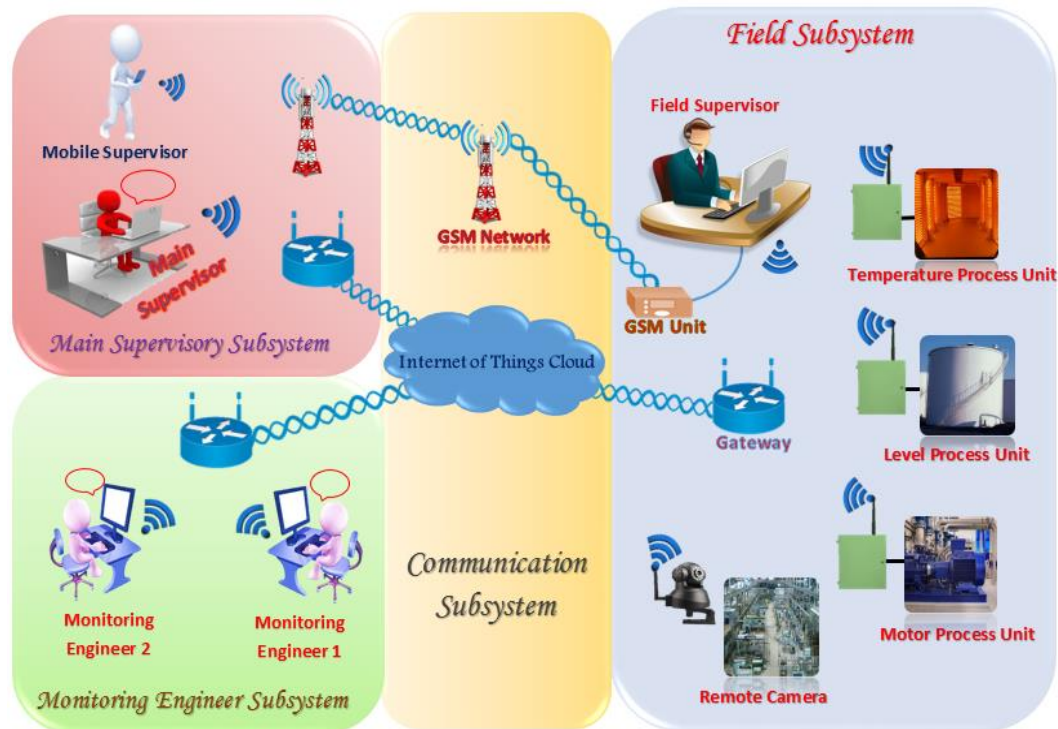


Figure (1) overall system block diagram.

The system mainly divided into four subsystems; namely field subsystem, main supervisory subsystem, communication subsystem, and monitoring engineers' subsystem. The details of these are presented in the following.

Before starting with the system's details let us define the following persons and the tasks of each of them:

- Main supervisor: is the main person how controls all the operation of SCADA system anywhere remotely. He can give the authority of control of the system to the field supervisor.
- Mobile supervisor: is the person how controls all the operation of SCADA system anywhere remotely using the mobile smart phone.
- Field supervisor: is the person inside the field (the factory). He can control and monitor all the system operation when the main supervisor gives him the authority.
- Monitoring engineers: they are a number of expert engineers. They can only monitor the system's operation and make a chat to give an opinion on the work of the system. Here only two persons are considered

2.1. Field subsystem:

Field subsystem contains oven, liquid level, and motor processes or units with their sensors, actuators and controllers, monitoring camera with its control, gateway for creating local network in a remote field, field supervisor with GUI and control and GSM unit.

2.1.1. Temperature control process

It consists of a controller and an electrical oven whose temperature to be controlled according to the set point temperature; the set point is determined by the main supervisor

or field supervisor. The controller is located near the process itself. The controller tasks are to execute the control program and then send the control signals to the oven actuator in order to oblige the oven temperature to follow the set point temperature, in addition the controller communicates with the field gateway wirelessly to transfer the data with the field gateway. Figure (2) shows the practical design. The controller components are: Arduino at Mega 2560 (microcontroller for control algorithm implementation), Yun shield (its object to communicate with gateway for data transferring), temperature sensor LM35 (for actual temperature measurement), and actuator (to connect and disconnect the heater to the AC supply according to control signal generated by the control algorithm). All the components operation and control algorithm are programmed using Arduino.cc software.



Figure (2) Temperature control process.

2.1.2. Level control process

Liquid level process consists of two tanks: lower tank and upper tank. The lower tank is considered as storing place of the liquid to avoid the problem of availability of main liquid supply. The upper tank represents the main tank and the main goal of this process is to maintain the level of this tank at a certain level determined by the main or field supervisor.

It is important to note that in case of no liquid in lower tank, the system stops completely and gives a warning alarm. The controller mission is to execute the control algorithm and sends the adequate signals to the actuator; in addition the controller goal is to transfer data between the process and the field gateway. Figure (3) shows the practical design of the level control process.

The water level control process components are: Arduino at Mega 2560 (microcontroller for control algorithm implementation), Yun shield (its object to communicate with gateway for data transferring), ultrasonic level sensor HC-SR04 (for actual level measurement), and actuator (is a relay to mandate the pump operation according to control signal generated by the control algorithm). All the components operation and control algorithm are programmed using Arduino.cc software.

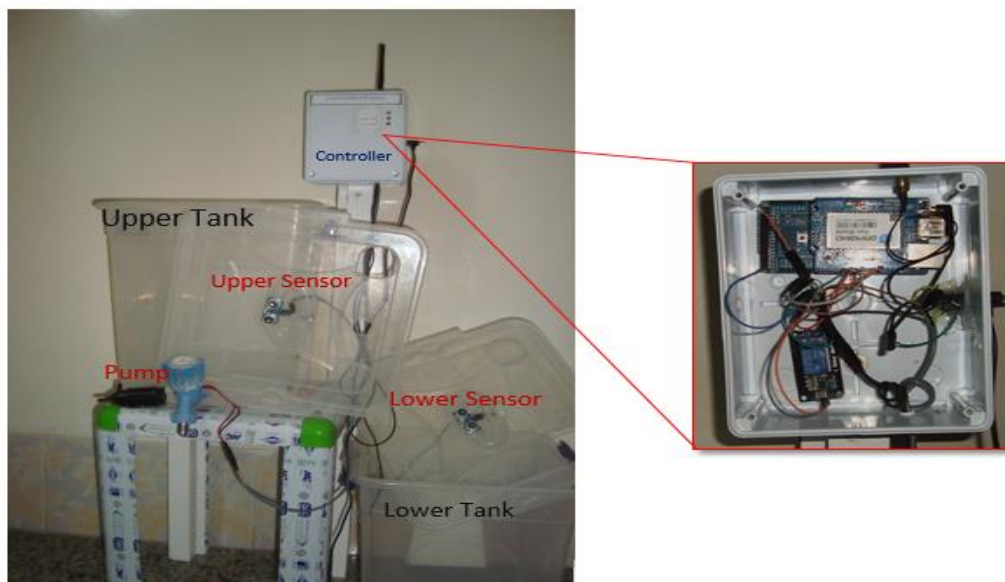


Figure (3) the practical design of level control process.

2.1.3. Motor control process

The motor control process is a system that controls the speed of a DC motor according to the required set point speed in forward or backward direction, which is determined by the main or field supervisor. The controller of this process contains the algorithm of motor speed control that generates the required signals to the actuator to oblige the motor speed to follow the set point speed with satisfied stability.

As in the previous systems, the controller also provides the data transmission between the system and the field gateway. Figure (3) the practical design of motor control process. The controller components are: Arduino at Mega 2560 (microcontroller for control algorithm implementation), Yun shield (its object to communicate with gateway for data transferring), optical digital speed sensor F1280 (for actual motor speed measurement), and driver circuit controlled by pulse width modulation technique generated by the microcontroller according to control algorithm requirements. All the components operation and control algorithm are programmed using Arduino.cc software.

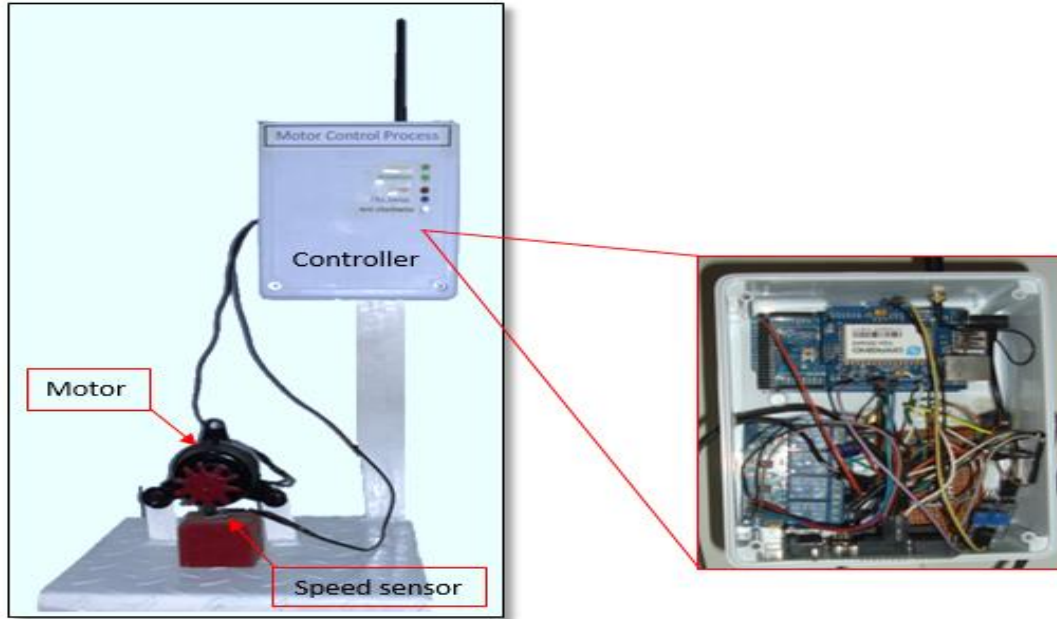


Figure (4) the practical design of motor control process.

2.1.4. Security camera:

Main objective of the development of this camera (or more than one camera) is to monitor some of the important potentialities. The place setting with this camera is determined by the main supervisor for the purpose of surveillance.

IP camera automatically connected to the gateway and the information exchange wirelessly. The live broadcasting from the camera in a remote location is getting through IP. It contains electric motor which makes it rotate in vertical and horizontal motion, which makes the rotation to a specific area, is possible. Figure (4) shows the security IP camera.



Figure (5) IP camera used in the system.

2.1.5. Field Gateway:

Field gateway (router) provides the wirelessly connection between field supervisors and field processes as well as provide field data transfer with IoT cloud in order to satisfy the connection with main supervisor and monitoring engineers. It securely communicates with the field equipment through creating Wireless Local Area Network (WLAN) and at the same time provides the Internet through a global network WAN. In this system, TL-WR940N router is used as shown in figure (5).



Figure (6) the router.

2.1.6. GSM unit:

GSM is a connection media between remote field process and mobile supervisor. Therefore, the supervisor can monitor and control through GSM SMS. This operation is done using GSM modem, which connects to field supervisor by serial communication. The components of GSM unit are ARDUINO GSM Shield CE 0700 and Arduino at Mega 2560 as shown in figure (6). The unit components are programmed using Arduino.cc software.

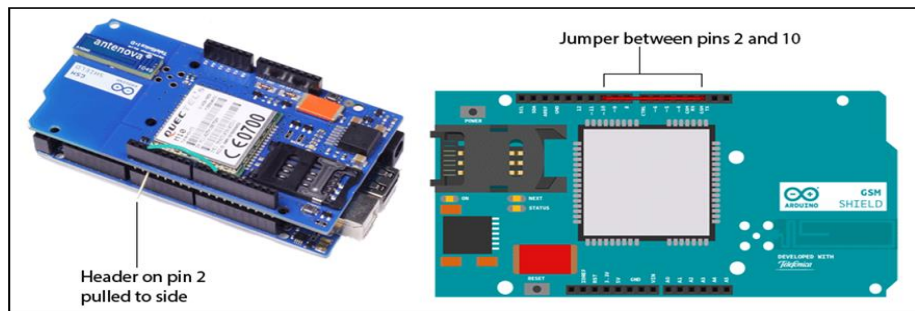


Figure (7) GSM unit.

2.1.7. Field supervisor:

Field supervisor plays a prominent role in the performance of this system. It is considered as the heart of the system because it has all necessary programs for the system operation. It has the following functions:

- Monitoring and control (field supervisory).
- Set up the connection to field processes (gateway).
- Preparing the connection with IoT cloud.
- Preparing the connection to the GSM subsystem.

The field supervisor GUI is designed and programmed by Visual Studio 2013, which provide the ideal environment for the design of such programs. It contains interactive interface, which gives a detailed and identical picture of the reality of devices in the remote field. Figure (8) shows the GUI of field supervisor.

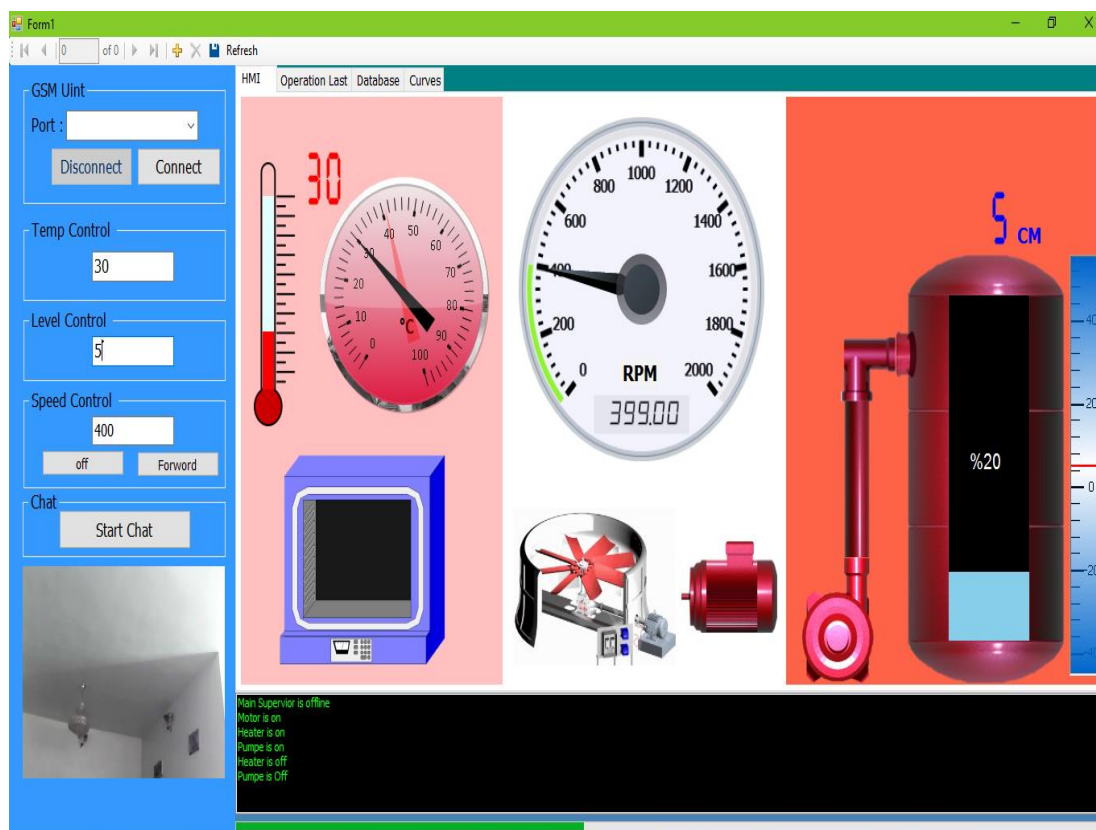


Figure (8) field supervisor GUI.

2.2. Communication subsystem:

The object of this subsystem is to provide the communication of all subsystems for data transferring. It contains the IoT cloud and GSM network.

2.2.1. IoT cloud:

In this system, the sharing information on the internet is done through the cloud hosting, which allows flowing the data in bidirectional. Cloud hosting provides store files and sites to be hosted on unlimited number of machines, which work as one system. The cloud is programmed by Visual Studio and hosted on a virtual server that provided by a Gear hosting. Figure (9) shows the detail frame of IoT cloud where the data transferring is displayed.

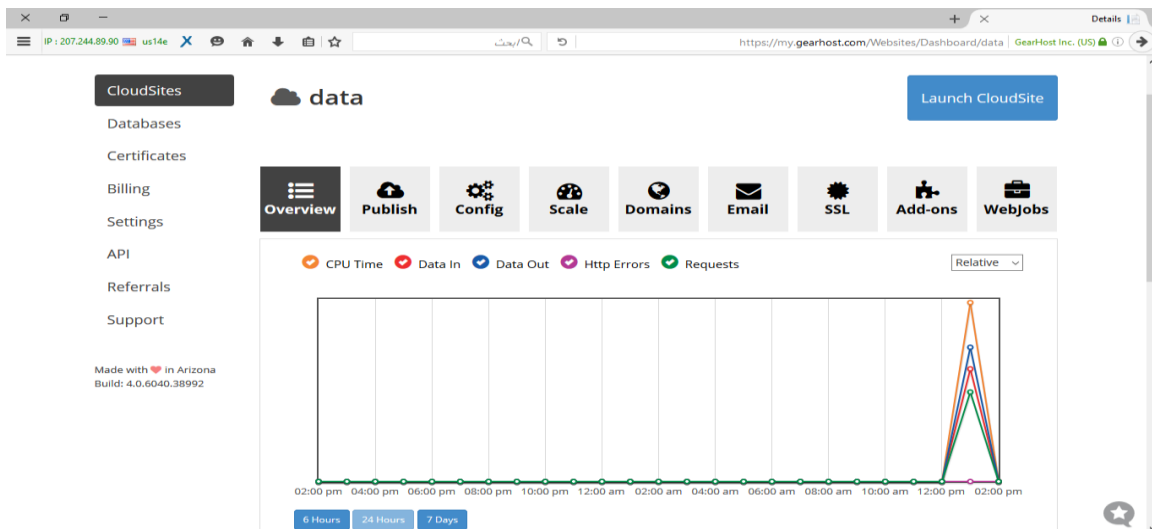


Figure (9) IoT cloud.

2.2.2. GSM network:

The GSM system works as an emergency system when the internet network fails in connection for any reason. The GSM network is used to communicate mobile supervisor with Field processes for monitoring and control the processes parameters.

2.3. Monitoring engineer subsystem:

Monitoring engineer subsystem consists more than one expert engineer (only two are considered in presented system). They are connected to internet through the router. Each engineer station contains specific GUI with specific user name and password for login to the system. Through sharing data on the cloud, monitoring engineers can just monitor the field process and broadcasting from field camera. On other hand, they can give notes by chatting with field supervisor, main supervisor and other monitor engineers. Figure (10) shows monitoring engineer GUI.



Figure (10) monitoring engineer GUI.

2.4. Main Supervisory subsystem: contains two supervisors that are main supervisor and mobile supervisor.

2.4.1. Main supervisor:

Main supervisor can monitor the operation of the field processes with all details. In addition, it can take control from field supervisor and at the same time, it controls the field processes. As well as it sends set points to field processes and monitor the changes in the field processes through sharing information on the IoT cloud. He has a specific user name and password for login to the system. Figure (11) shows main supervisor GUI.

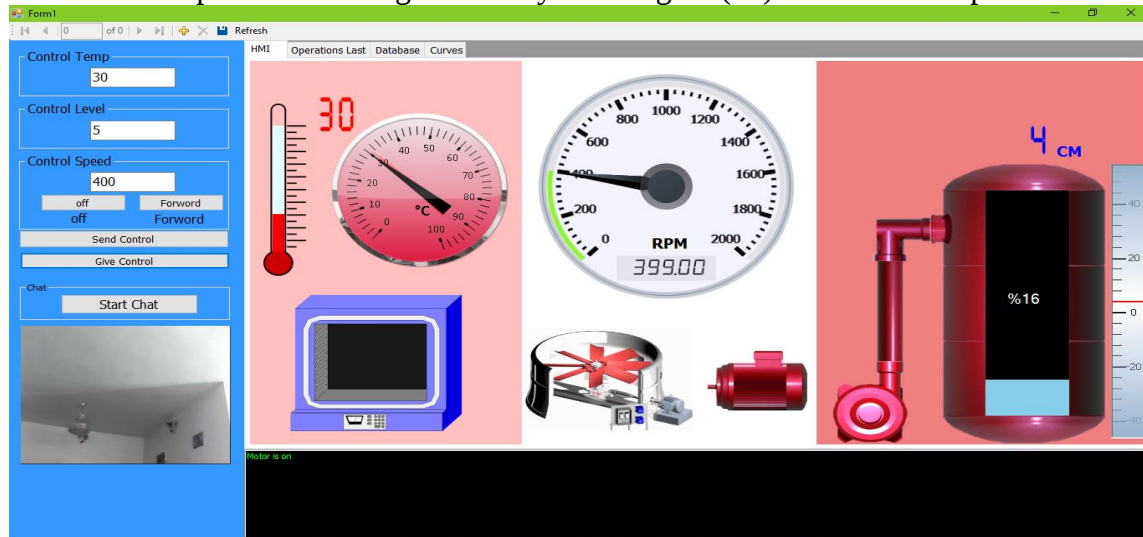


Figure (11) main supervisor GUI.

2.4.2. Mobile supervisor:

Mobile supervisor is an android application and installed on the phone as shown in figure (12). It can connect with the field devices through GSM network. It provides remote monitor and control by SMS from mobile phone to the field processes in case of losing the internet connection so the supervisor can perform the system functions normally.

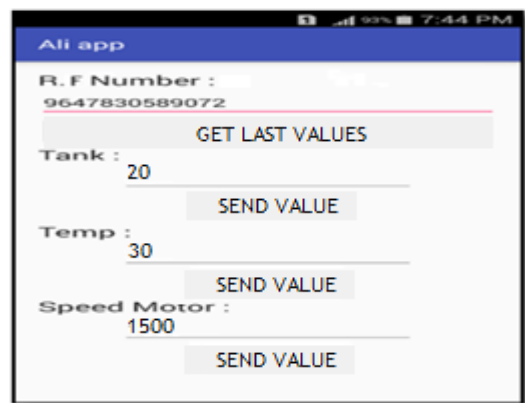


Figure (12) mobile supervisor application.

3. System Operation

The system consists of three process units, the process control and data transfer are processed with the same manner. So in order to clarify the operation steps, let us select the temperature process unit. The following steps give on excellent idea of how the system operates:

- Once the main supervisor or field supervisor (depending on which has the authority) sends the value of temperature setting (the reference temperature).
- The controller in the field receives the setting value wirelessly and start the operation of control algorithm in order to the actual temperature follows the new setting point.
- The output signal generated from microcontroller controls the actuator of the oven heater.
- The controller sends the actual temperature to the gateway and then to the field supervisor as well as to the main supervisor and monitoring engineer each 2 seconds.
- All data is displayed numerically and graphically to all persons at the same time (their GUI screen).
- If the internet failed in connection, mobile supervisor can send the setting point temperature and monitor the actual temperature through using the GSM network.
- As mention later that monitoring engineers are just monitor the operation of system and can express the opinion to the main supervisor and the field supervisor through IoT cloud.
- If the internet and GSM services are failed, all field process units operate according to last setting point received.
- The same control and data transfer are proceed for the other two process units (liquid level unit and motor control unit).

4. System Feature:

The prototype system has the following features:

- Real time monitoring and control processes.
- Data of processes can be monitored at anytime and anywhere because of using the internet for sharing data around the world.
- Multilevel Authentication to login to the system that means the main supervisor and monitoring engineers each one has his specific passwords.
- If there is no Internet connection, the system operates normally according to the last setting points.
- In case of no internet availability, the system supported by GSM service for remote monitoring and control.
- Wireless camera for living broadcast from the location to all shared persons.
- There are a number of monitoring engineers can monitor and chat with main supervisor or field supervisor from anywhere based on cloud sharing.

5. Results

As mentioned above, that the presented system is a prototype and designed to control many industrial processes. The following results are presented according to real cases.

5.1. Monitoring and control by field supervisor

As the field supervisor GUI is run, all field information appears and field supervisor can monitor and control the parameter of field process as shown in figure (12).

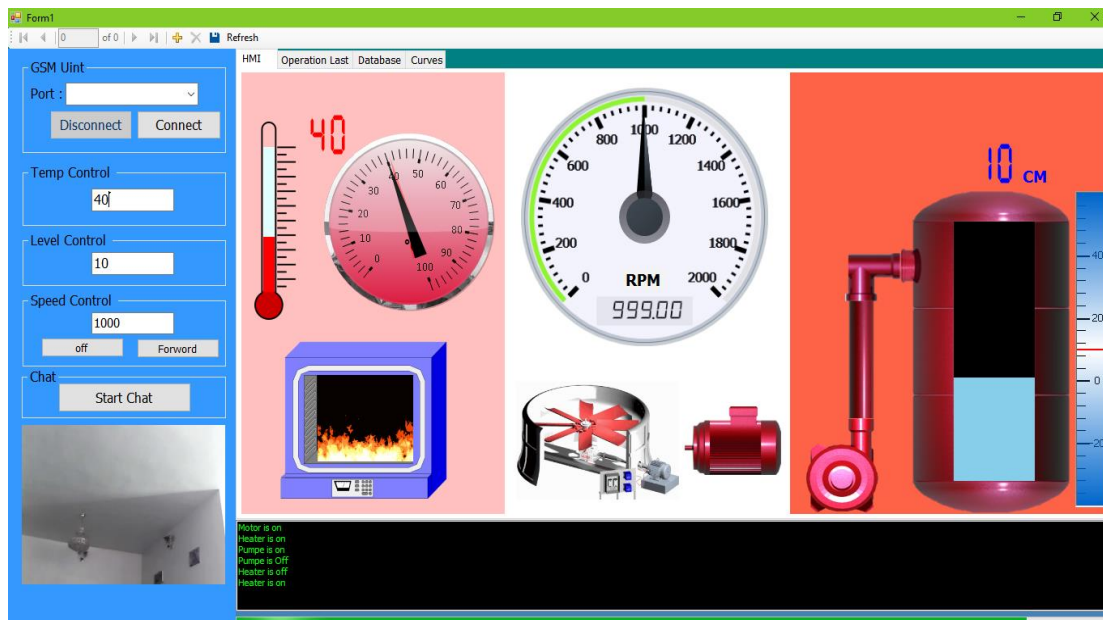
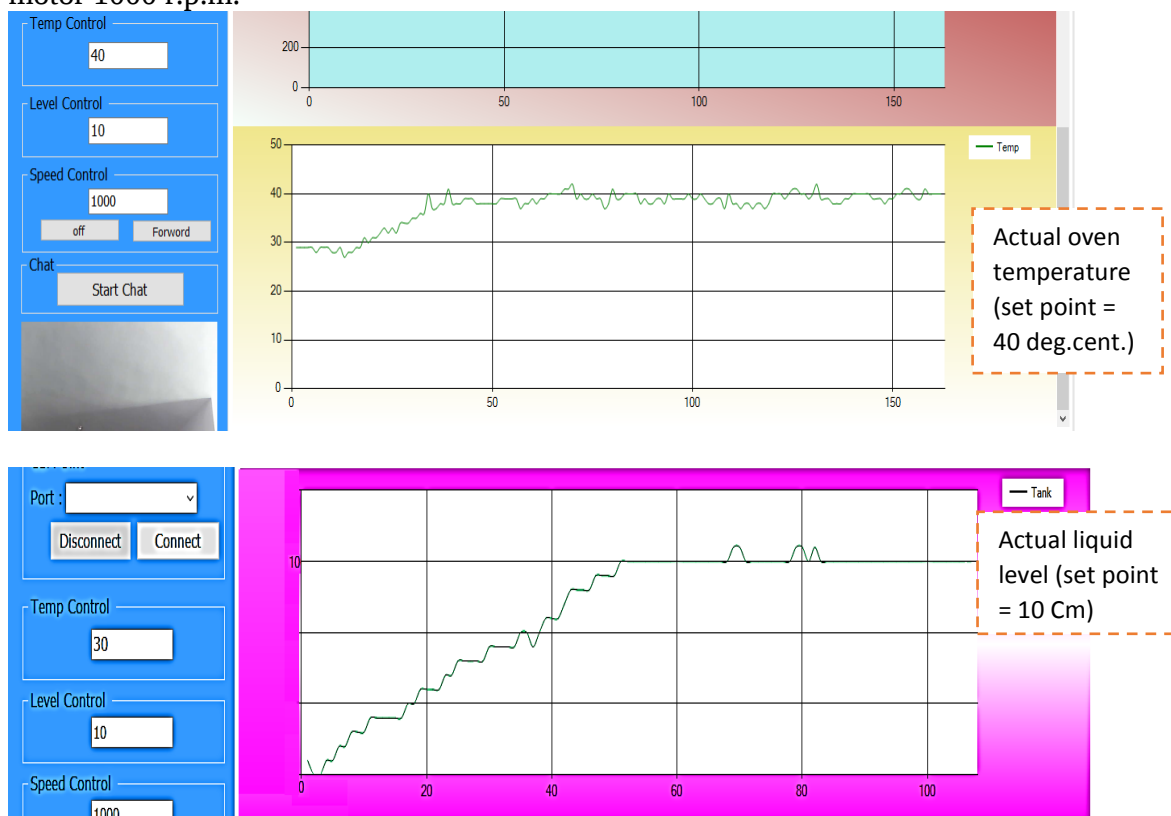


Figure (12) field supervisor GUI.

The process controller always tries to set the actual measurement equal to set point value which is determined by field supervisor or main supervisor. Figure (13) shows the curves panel of field supervisor GUI which illustrate the processes data in charts for the cases where the set points are: for temperature is 40°C, for liquid level 10 cm, and for motor 1000 r.p.m.



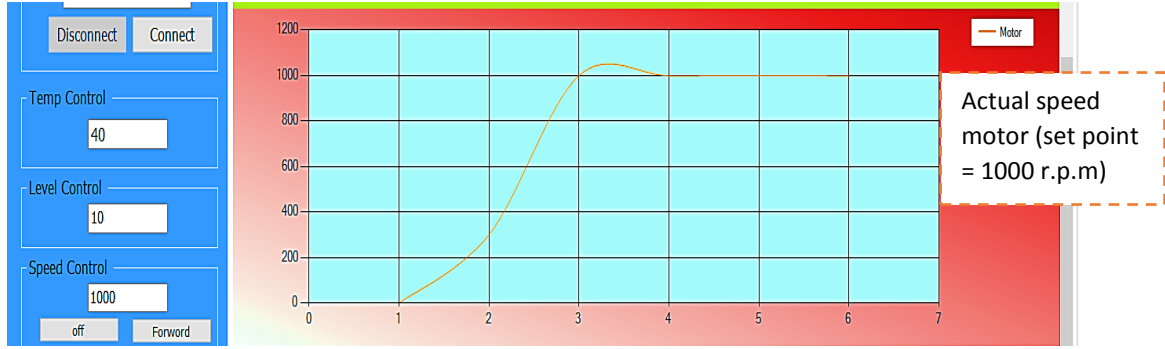


Figure (13) Results obtained in the field supervisor GUI.

5.2. Monitoring and control by main supervisor

After main supervisor enters its specific user name and password, main supervisor GUI gets all information field from IoT cloud as shown in figure (14). The main supervisor can display any data as a chart like in figure (13)/

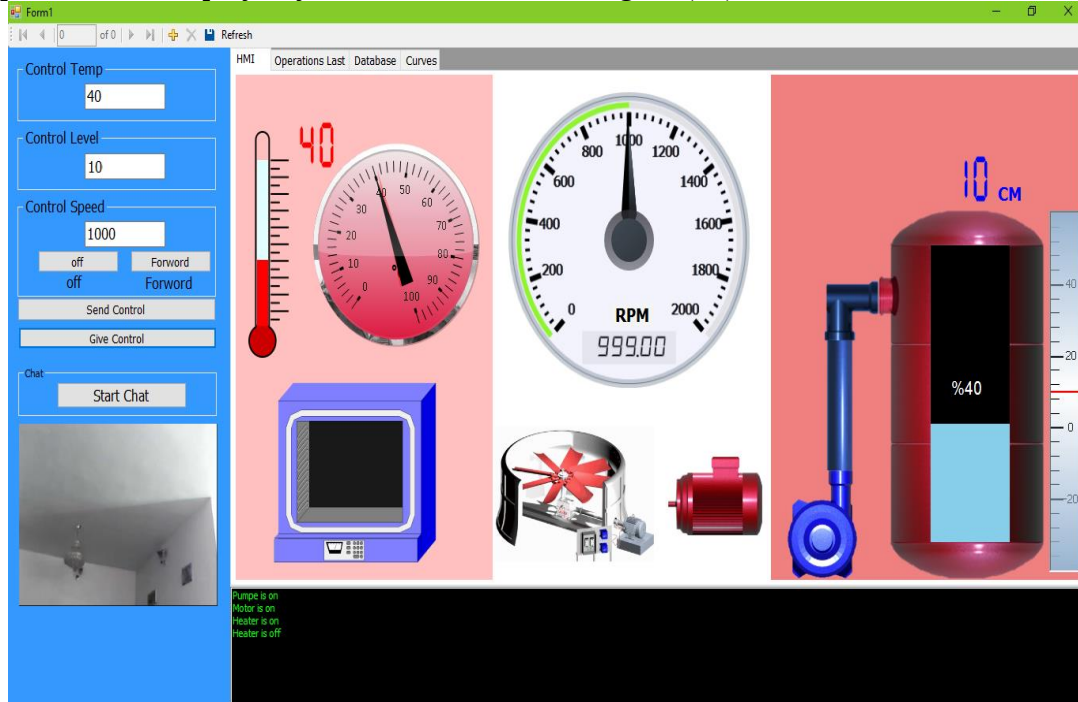


Figure (14) main supervisor GUI.

5.3. Results for monitoring engineer:

Monitoring engineer can acquit the field devices through getting information from IoT cloud as shown in figure (15).

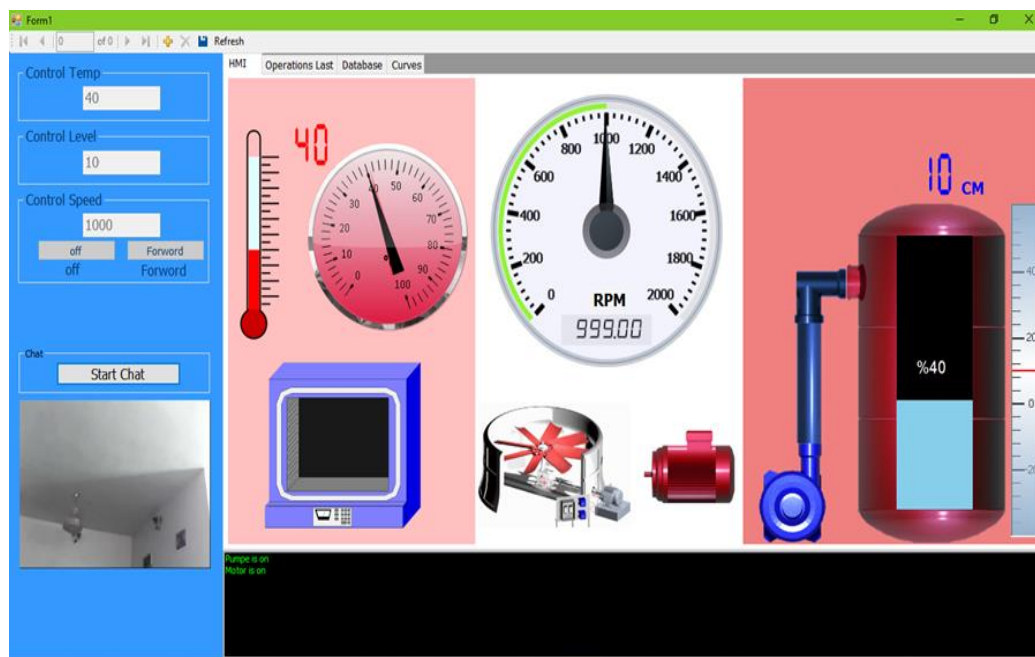


Figure (15) Monitoring engineer GUI.

5.4. Chatting through IoT cloud

Main supervisor, field supervisor and monitoring engineer can converse among themselves by using chat menu as shown in figure (16) that connects to IoT cloud.

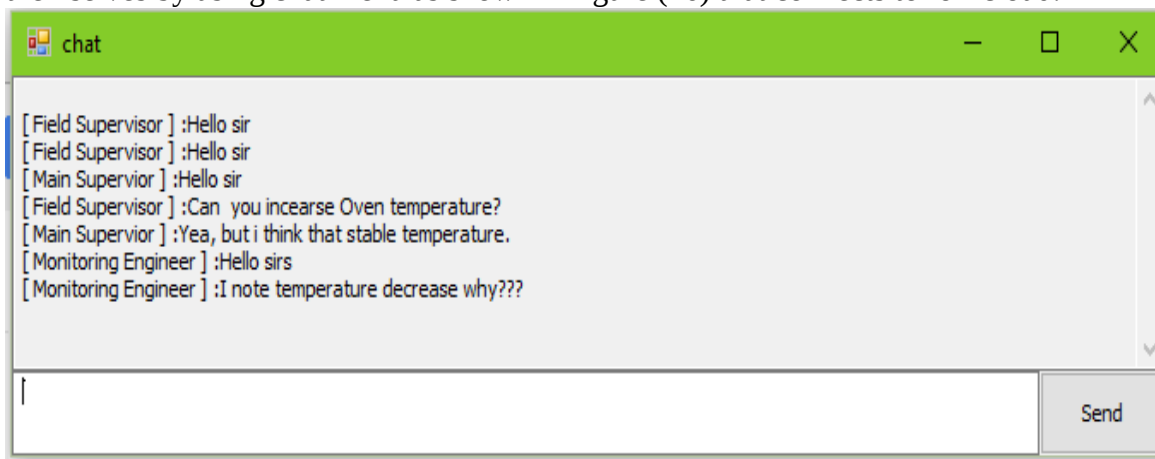


Figure (16) Chat panel.

5.5. Monitoring and control by mobile supervisor:

Mobile supervisor can control the parameters of field processes through sending SMS to the field GSM units, as well as field GSM unit can send processes information to mobile supervisor for monitoring. Figure (17) shows monitoring and control by mobile supervisor.

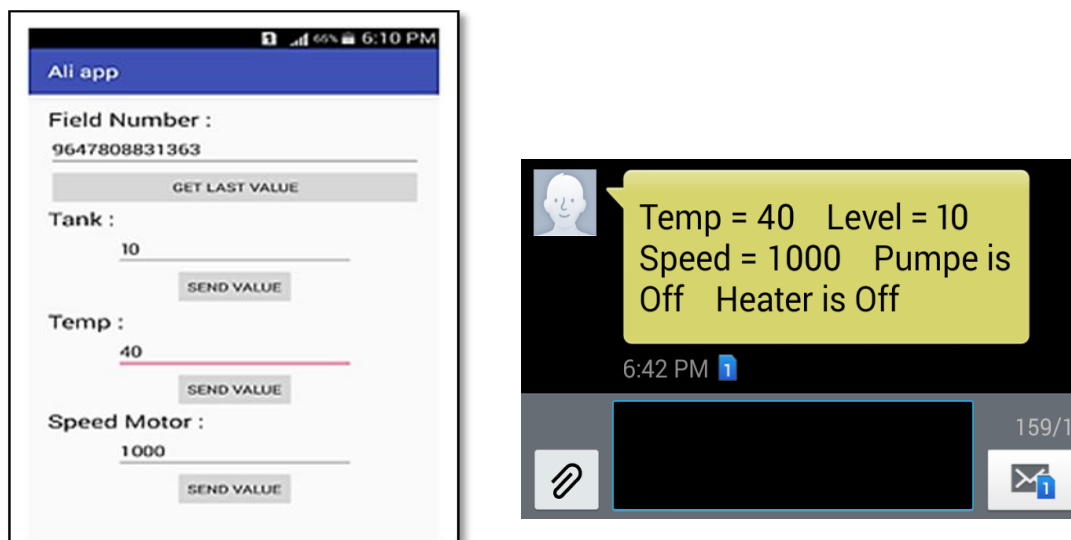


Figure (17) Results obtained in mobile supervisor.

6. Discussion

From the obtained results, the following points can be depicted:

- Reliable communication link between field processes and field gateway make HMI of field supervisor synchronized with field processes; which give instantaneous information for monitoring processes as well as the instantaneous applying control of field process, therefore the system has a high accuracy.
- High secure local area network in the field since WAP-PSK security technique is used.
- The performance of system depends on the connection speed of internet; the system has efficient performance with the high speeds connection, although the system provides a good performance with low speed connection.
- According to obtained results, the actual values follow the set point values with stability; which demonstrates the efficiency of control algorithms.

7. Conclusions

The proposed system based on IoT technology as a new technique, which has effective role in industrials future. Field process is connected to the internet for data transfer and executes the control algorithm of the processes at the same time. The system has the capability of developing with the necessities according to specialists requirements. The real time monitoring data is a good feature to take the decision as soon as possible by the supervisor. The system is supported by GSM subsystem which makes it more flexible and reliable.

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