Centralized Medical Gas Monitoring Solution For Medical Piping Gases In The Hospitals

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***Abstract*—Medical gases are very important for any "medical center / ICU centers / Hospitals" which affect directly the patient life. The basic idea of this paper is to design a complete system to monitor the medical gases in the hospital, displaying the output pressures on a desktop computer or any smart phone using the internet at any place away from the medical gas stations of the hospital. Our proposed system implements a smart controller and digital sensors to continuously display the state of the system with messages sent to the operator, in order to avoid any human errors, which could occur at any instant of time during system operation. Our system have been succeeded to monitor up to five hospital`s Medical stations at the same time Collecting real-time readings are securely uploaded to the cloud and are accessible from any device (laptop/tablet/mobile) with Internet access.**

Keywords—Master Alarm, Medical piping system, Medical Gases, Master Alarm , Control system, Particle – electron Board & Photon electron Board.

1. INTRODUCTION

We called our system MGOC "Medical Gas Operation Center" which capitalizes on the IoT (Internet of Things) and Cloud computing to provide a centralized gas monitoring dashboard. Our system is used mainly to monitor the different medical gases which are defined as one of the most important requirements for patient in anesthesia, therapy or diagnosis. Medical gases are used as drugs [1], and affect the human health; so they are regulated by the Federal Food, Drug, and Cosmetic Act (FDA) [2] [3]. Other regulatory bodies as the Department of Transportation (DOT) and national organizations [e.g., the Compressed Gas Association (CGA) and the National Fire Protection Association (NFPA)] set the regulations and standards for compressed gases [4]. Medical gases are considered prescription drugs where by their usage they become unsafe without a specialist. Regulations regarding the purity of these substances are established by the United States Pharmacopeia/National Formulary (USP/NF) [2] [3].

The main components of medical gas systems in any healthcare building are typically shown in Fig.1:

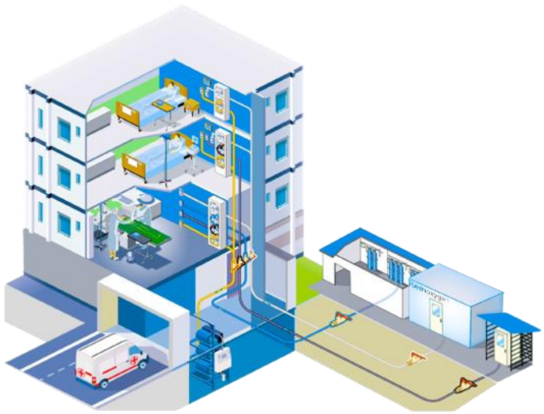

Fig.1 – Main hospital with Medical Gas Construction

1) Main station and controllers.
2) Pipelines.
3) Valve box / Zone area alarm.
4) Medical Gas Outlets.
5) Bead Head Unit (BHU).
6) O_2 / Suction Flow meters.
7) Medical Gas Master Alarm.

Functions of medical gases:

Medical gases are used in hospitals for many purposes. They should particularly supply the following [3] [5]:

1) **Oxygen:**
It is used to provide supplemental oxygen to the respiratory system and in dentistry. For a detailed description of the architecture of the oxygen station the user is referred to [4], [5].

2) **Nitrous oxide:**
It is used as an anesthetic agent in surgery and in cryosurgery (the use of extreme cold to destroy tissue) [3]. Its station has the same oxygen station configuration.

3) **Nitrogen:**
It is used to provide pneumatic pressure in medical equipment.

4) **Carbon dioxide:**
It is used to inflate areas of the body for "keyhole" surgery (small incisions made to accommodate surgical instruments) [5].

5) **Medical air:**
It is used to administer breathing treatments and as a mixing component for other respiratory gases. It provides the necessary supply of AIR (5 bar /8 bar) [6-9].

6) **Helium:**
It is used in breathing mixtures for patients with impaired lung functions and is also very important for surgical equipment, as it considered a perfect supply gas [10].

Since medical gases are the most frequently administered drugs in the United States, the FDA is attempting to organize both consumer and industry awareness about this specialized category of regulated products [4] [6].

Previous Work on similar systems:

1. Most of the designers have designed a similar device by simply using analog gauges, buzzers and LEDs, besides old technology of pressure sensors [6] as shown in Fig.2 [5] [7].

Fig.2 – Basic Medical Gas Alarm

2. Previous devices were difficult to be interfaced with computers so as to perform full monitoring without human intervention [6], as in case of any emergency the operator had to move the valves, boxes, and the central stations to shut off the valves in the section with the problem or leakage.
3. Existing solutions were limited by location and could not work, even if one or more locations got shut down [7] [8].
   Our proposed system is intended to address these weaknesses in a workable way that is not limited by location and that could work in the event that one or more locations became off.

Research Motivation:
Ordinary Master Alarm Devices have not yet been fully satisfying customers, and they were neither fully monitoring the medical piping system. So it was our main aim to design and implement a system which could be fully automated and monitoring the medical gases from anywhere using the Internet-of-Things (IoT). All these features and more have initiated this research.

2. Material & Methods

2.a.Hardware material:
The hardware material for our prototype consists of the following elements:

1) Switching Mode Power supply for the DC voltage needs, as shown in Fig.3.
2) Oxygen cylinder with double stage regulator, as shown in Figure (4a).
3) Digital pressure sensors, as shown in Figure (4b).
4) Particle – electron Board.
5) Medical piping (plastic high pressure piping).
6) Fast connectors for medical piping.
7) Manual pressurized valve.
8) Pressurized Gauge meters.
9) Main system chassis.
10) Wiring and connectors for the PCB`s as shown in Fig.5.

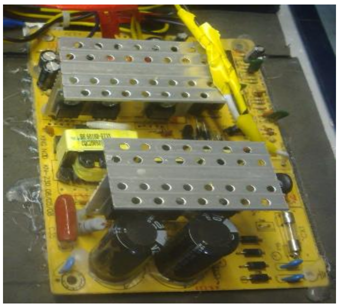

Fig.3– switching Mode Power supply

Fig.4 –a) BD digital pressure sensor; b) Oxygen Cylinder Tank with double stage regulator

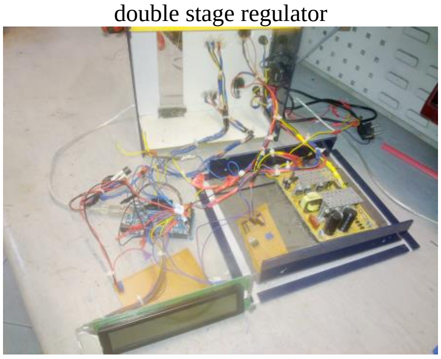

Fig.5 – Main Device cables, connectors with the PCB

2.b.Software material:
Our software consists of the following elements:

1) C++ program development tool.
2) Interface software between the computer & Particle-electron board.
3) Programming computer with WIFI compatibility.
4) Software simulators for testing the program code before uploading it on our microprocessor and using the laptop for the displaying until finalizing the program code.

2.c.System Description:

I.System modules:

Fig.6 shows the three main modules of the system.

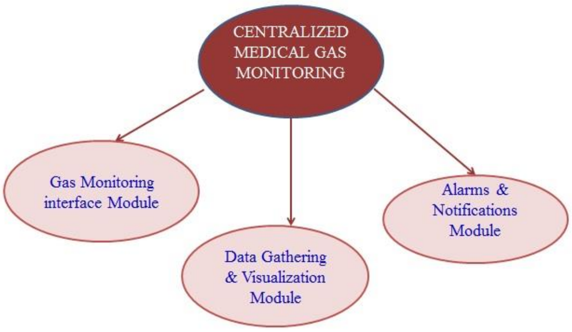

Fig.6 - Main Modules of the device

1. Gas Monitoring Interface:
   This is also known as the Medical Gas Operation Center (MGOC) and is an integration box to be installed in each site. It is linked to the gas pressure sensors and is equipped with a proprietary integrated circuit powered by a secure GSM connection, thus allowing it to work from the site's Internet connection availability. The Integration box requires nothing more than a normal power outlet and data lines from the sensors [11] [12].

2. Data Gathering and Visualization:
   Our system is intended to collect real-time readings, which are securely uploaded to the cloud and are accessible from any device (laptop/tablet/mobile). The Internet access Data readings can be downloaded as an excel file for offline analysis. Several secure dashboards can be created catering to different viewing requirements. Of course, an access policy defines what each of the users can view [14].

3. Alarms & Notifications:
   The Collecting data is analyzed in real-time using our monitoring algorithms to spot any system irregularities and provide feedback through text SMS and E-mail, which are based on pre-defined conditions with details about the alarm. The monitoring system is cloud-based with multiple redundancies making it more resilient than any self-hosted solution, because site uplinks are monitored by the system to avoid any unexpected blackouts, and an alarm notification is sent if any of the monitored sensors goes offline. Also Alarms can be disabled for downtime, or scheduled to work only during a certain time of the day [6] [9].

II. Main Features of the system:

Fig.7 shows the main Features of the system.

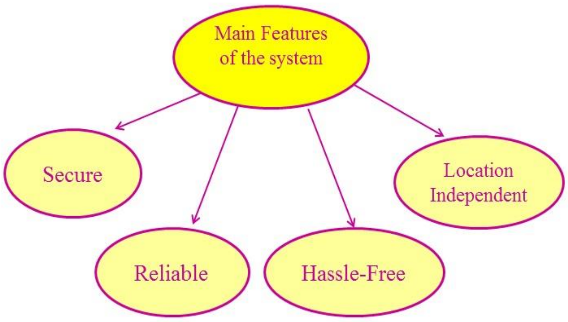

Fig.7 – Main Features of the Device

The sensors readings of the medical gas system are uploaded directly to the cloud, Alarms are triggered from the cloud, and triggering rules can be managed conveniently from a central location. The system is secure, as the data is encrypted prior to any uploading, and user authorization can be limited to a certain dashboard. Location independent, as the data is uploaded to the cloud, sites can be monitored and configured from a central or any peripheral location. The system is reliable, since it uses standard GSM to upload the data, and so it is not impacted by the site's Internet interruptions. Hassle-free, unlike all self-hosted solutions our MGOC is a managed service that requires NO administration, with most of the work being done in the cloud [10].

3. Results

The basic achievements of our system:

We used a basic switched mode power supply for all our voltage needs as shown in Fig.3. The system also implements a digital pressure sensor type (BD sensors) as shown in Figure (4a) for the prototype and for the experimental setup, in which the response time of our digital pressure sensor ≤ 3 msec and high accuracy, whereby the error does not exceed ± 0.5%. Finally, the system is also provided with a normal Oxygen Tank Cylinder as shown in figure (4b) for the pressurized gas source with a double stage regulator. First, we had to perform a test for our complete system outside the hospital to produce the pressure chart and determine reliability of the reading under all operating conditions. That's why we had to build up a small chassis for our experimental system as shown in Fig.8 [12] [13].

Fig.8 – (Front & Back) Experimental system Chassis with the O_2 cylinder for the Testing

In order to test the Gas Interface Module we used a WIFI connected microcontroller Board called "Photon" as shown in Fig.9 to reveal its response. Then we gathered the data of one pressurized sensor through our experimentally built chassis shown in Fig.8, which provided us with the necessary data for determining the pressure characteristics of the sensor as shown in Table (1). These figures were directly used for analysis by means of our program. The analysis results were then uploaded to the cloud, our major storage repository [13].

Fig.9 – Wi-Fi connected micro controller called “Photon Particle board”

Table (1) – Output data of our digital sensor with supply voltage (+12 V & Gnd = 0V)

No	Pressure bar	measured	Actual voltage	Deviation
1.	0	610	0.501	0.009304836
2.	1	945	0.77	0.008275525
3.	1.5	1239	1.014	0.015294577
4.	2	1475	1.202	0.013064973
5.	2.5	1723	1.405	0.016162677
6.	3	1951	1.591	0.018381534
7.	3.5	2191	1.789	0.022927699
8.	4	2441	1.991	0.023413288
9.	4.5	2667	2.174	0.02424426
10.	5	2,948	2.404	0.027742062
11.	5.5	3161	2.579	0.031051783
12.	6	3,390.00	2.765	0.032464582

Collecting real-time readings are securely uploaded to the cloud and are accessible from any device (laptop/tablet/mobile) with Internet access in a way to allow reviewing all of these data through the interfaced computer by the dashboard shown in Figures (10) & (11). The user can even change the dashboard's appearance according to different viewing requirements and needs. The data can be also downloaded to an excel file for offline data analysis [10] [11].

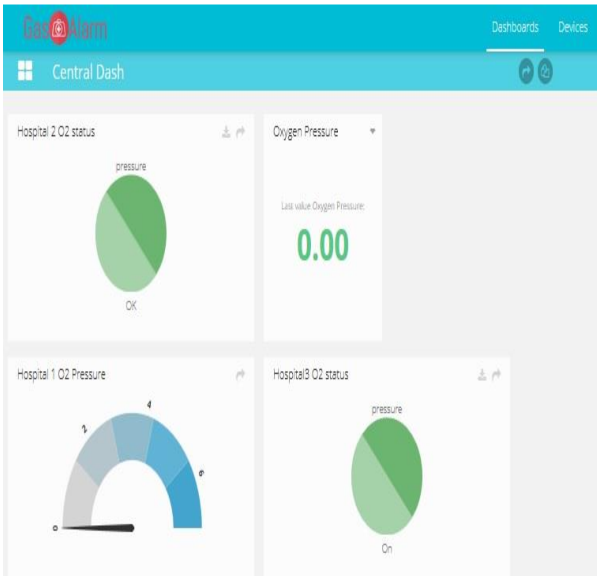

Fig.10 - Dashboard for real time data reading

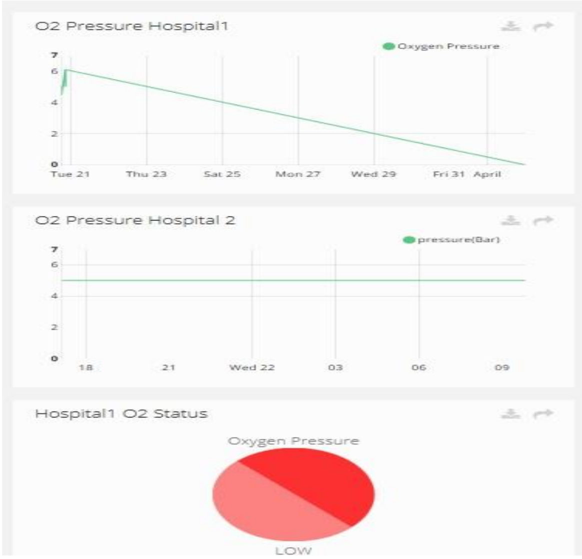

Fig.11 - Dashboard for real time data reading with curves

After collecting the necessary data from our experimental system in form of WIFI data gathering, we moved forward to install our system in a real hospital (Kobry El Koba Army Complex Hospital) in Cairo, EGYPT using a cellular connected micro controller which is called “Electron Particle Board” as shown in Figure (12) using the same dashboard. Our experimental procedure was to connect two hospitals with all its sensors (6 sensors at the same time) to a central monitoring computer in the Engineering Headquarter. This was accomplished through our system by connecting the “Monitor Gas Interface Module” with these sensors and supplying it with a small DC power converter as shown in Fig.13 for the hospital medical Gas stations and Fig.14 for our complete cellular system before connecting it in the hospital.

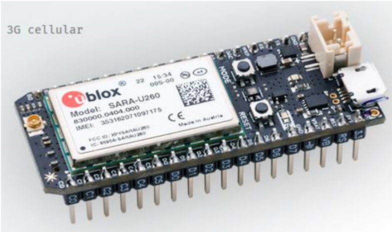

Fig.12 – 3G Cellular connected micro controller called “Electron Particle board”

Figure.13 – Hospital O_2 Stations & sensors

Fig.14 – Proposed system before connecting it in the Hospital

4. Conclusions

Our intended system proved successful at performing its main function, which is monitoring the complete gas installation in any health care building [14] without the frustration and inconvenience of connecting many wires and connectors for each sensor. It also featured a fast response time in case of a pressure fault problem. The result was to have an amazing system without any human errors; also the Research and Development (R&D) of the gas monitoring system gives the opportunity to any developing team to build a complete control system, as well as to try to reach a high level of technology at the international market scale [15].

5. Future Work

In the near future we seek to produce more systems (at the mass production scale) to link more sites and hospitals together. In the same time we plan to gather all these data into one centralized place, such as the Minister of Health in EGYPT), in order to decrease all the human errors and to increase the safety levels in the healthcare buildings.
Research may also continue to develop more efficient and intelligent systems that will be able to take actions and make decisions according to prescribed scenarios [15].

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