Improvement of Hospital Airborne Infectious Isolation Rooms using IoT technology

L.A. Roy, F.K Tekweme
Department of Mechanical Engineering
University of Johannesburg
Johannesburg, South Africa
lanceroy@aiengineers.co.za, ftekweme@uj.ac.za

Abstract

IoT technology can be used to improve the overall management of hospital infrastructure. This paper presents a case study whereby IoT technology is used to monitor and manage a cluster of AIIRs (Airborne Infectious Isolation Rooms) in a live environment. The remote management of alarms and room functionality reduces the unnecessary exposure of healthcare workers and provides an improved response time compared to a human resource. The results of real-time live testing during the COVID-19 Pandemic are discussed in this paper. We were able to reduce the exposure of human resources during the pandemic by providing remote monitoring and control of healthcare infrastructure.

Keywords
SCADA, IoT, AIIRs, Covid 19. Remote management

1. Introduction

The COVID-19 pandemic brought with it a host of challenges and obstacles. The increased burden on the health care system meant that innovative methods of dealing with these challenges and managing the human resource component which was adversely diminished by the high incidence of infection amongst health care works. Management of health infrastructure is a pivotal factor in maintaining a high uptime of hospitals and health infrastructure. Supervisory control and data acquisition systems and IoT technology is a technology platform that has been used to manage health infrastructure and improve the performance of health care systems.

2. Methods

A monitoring and control system was set up using a combined network of smart devices, PLCs, and a central server. Information from this network was processed via a local server to manage isolation rooms and other infrastructures such as medical gases and electrical reticulation back up from generators and uninterrupted electrical supplies. The following infrastructure for 12 isolation wards was connected via the network to manage pressure differentials, equipment failure temperatures, and humidity. Figure 1 illustrates some of the parameters measures across the 12 rooms.

Figure 1: AIIR dashboard of Isolation Room Status

Figure 2 is a schematic outlining the general layout of the system to allow for remote monitoring and management of electrical reticulation, HVAC system, medical gas, central sterilization, autoclaves, and theatre plant equipment.

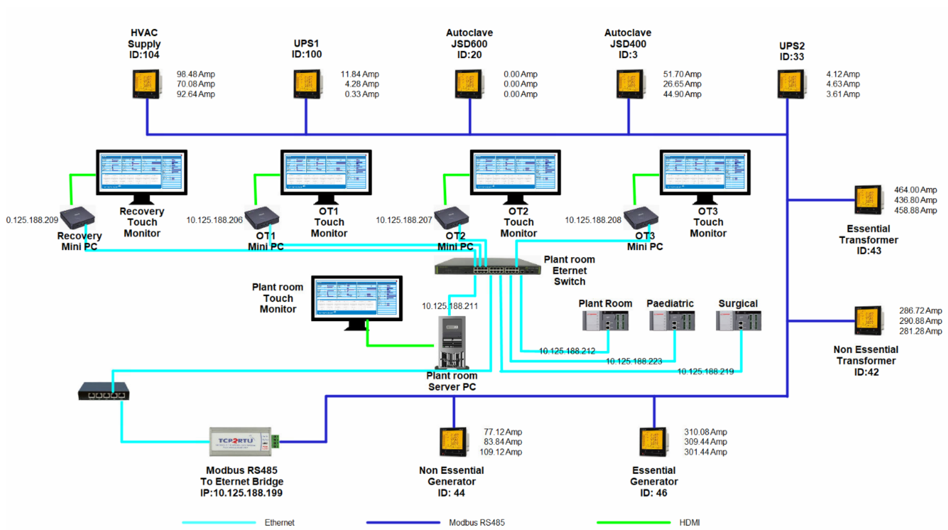

Figure 2. Network layout of power monitoring, programmable logic controllers, IoT control panels

Information from SCADA, PLCs, smart devices and IoT were converged over a network to allow for real-time monitoring and management of healthcare infrastructure. Power meters were used to manage electrical information. This system was set up to monitor critical plant and equipment and hence reduce the requirement for a human resource to enter an infectious area for reading data or to check on the status of equipment or change over setting on the machine. We considered the basic senses of human resources and attempted to mimic these on the system we set up. Sensory input that would normally be used by a human resource when diagnosing the status of hospital infrastructure:

- To mimic sight, we used input from IP cameras with PTZ axis of rotation
- To mimic the human hearing sensory input, we used input from sound meters
- To mimic tactile input, we used input from pressure, temperature, and humidity meters
- To mimic the motor input or mechanical input from a human resource actuator with various degrees of motion is used.

- Raspberry Pi boards are in some instances used to manage local alarms.

The remote monitoring and control system could record and control over 6 months during this time theatre breakdowns, end-user complaints, equipment failure, and end-user complain were recorded and documented. This data was then compared to existing data pre system installation. Comments were also gathered from end-users and maintenance personal.

Control Logic:

The main controller received input from the theatre control panel situated in each of the theatres and linked in a network to recovery, the central plant room, and the server. Information was also relayed to a remote diagnostics and maintenance program for processing and provided feedback to maintenance teams. The central controller received input from field sensors and provided feedback to actuators and dampers. In some instances, raspberry pi modules were used to manage local alarms and display reports

3. Results and Findings

- There was an overall decline in the number of breakdowns post-installation of an automated monitoring system.
- The data used for predictive maintenance and system optimization particularly on the HVAC and medical gas system was more reliable than with a human resource. The sampling time, accuracy, and consistency of data were more precise.
- The was a definite reduction in the wastage of stock from cold storage failures.
- The response time alarms were improved.
- The overall energy consumption of the plant was improved when compared watts per square meter against the same system pre-installation this can be seen by comparing figure 3, preinstallation power curve to figure 4 post installation power curve

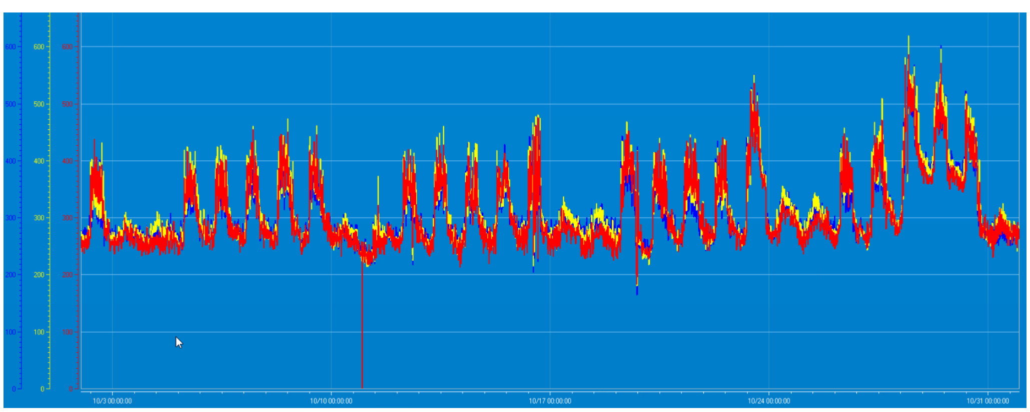

Figure 3. Snapshot of the transformer loading pre Installation averaging 380 Amps

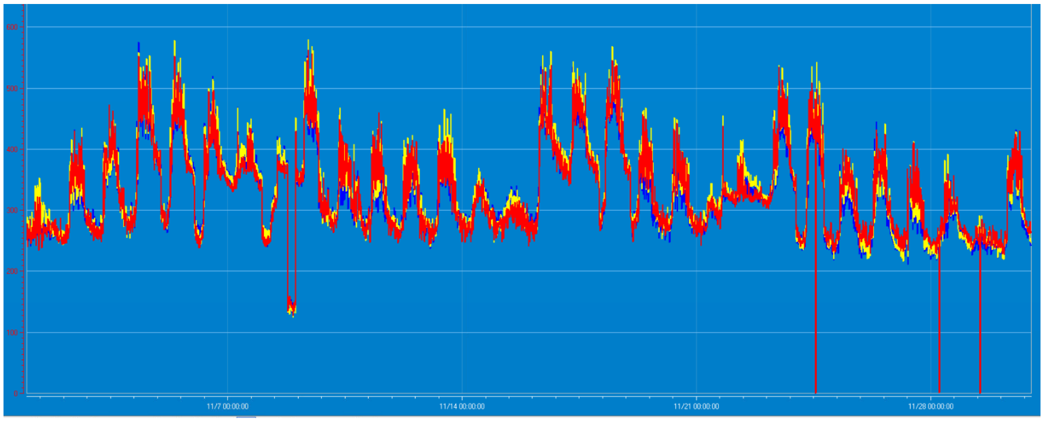

Figure 4. Snapshot of the transformer post Installation

Another significant result was the decrease in the failure of compressors and refrigeration plants leading to an improved cold chain. Maintaining the cold chain by reducing the system failures in refrigeration led to a reduction in wastage of stock both in the food and beverage department but also in the pharmaceutical arena.

4. Conclusion

This study showed that a SCADA system and IoT can be used to improve the performance of hospital infrastructure. A cluster of AIIRs was used as a case study and we were able to reduce the exposure of a human resource to an infectious environment by substituting the human sensor and tactile sensors with an automated system for remote plant diagnosis. The change over of a room from Positive to negative pressure could also be done remotely which then frees up resources of having to use a human resource.

The study also provided valuable information and data which was used to fine-tune the plant and improve overall performance and energy consumption. We were able to compare electrical data gathered from various power meters and power analyzers. Data from this study was also used to better understand the realistic uninterrupted power requirements and draw a comparison against the calculated data.

We were also able to use Raspberry pi technology to substitute otherwise expensive controllers and provide a cost-effective solution to local alarms and noncritical control. The PLC was also able to assist in the management of a backup system for fan failure and door control in the Clustered Isolation rooms. This backup system provided an n+1 design solution that further protected health care workers and visitors in the event of fan failure in the airborne infectious isolation rooms.

5. References

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6. Biography

Lance Roy is the managing member and technical director of AI Engineers, a technology consulting company in Durban, South Africa servicing the health care sector. He is a master's student at the University of Johannesburg completing his research in Hospital HVAC and Control Systems. Lance serves on the National team of the South African Federation of Hospital Engineers. Lance has spent the last decade responsible for the design, fabrication and project management of Health Care Infrastructure in ICUs, Theatres, and the Commercial sector. Responsible for control systems, HVAC and Gas.

Francis Tekweme currently works at the Department of Mechanical and Industrial Engineering Technology, University of Johannesburg. Francis does research in Mechanical Engineering. His current research interest is on the modelling, simulation and input shaped control of planar two- link flexible manipulator.