Journal of Discrete Mathematical Sciences & Cryptography
ISSN 0972-0529 (Print), ISSN 2169-0065 (Online)
Vol. 26 (2023), No. 3, pp. 851–860
DOI : 10.47974/JDMSC-1764

An IoT-based integrated health monitoring of bulk milk cooler

P. Ajitha *
School of Computing
Sathyabama Institute of Science and Technology
Chennai
India

Arun Mozhi Selvi Sundarapandi †
Department of Computer Science and Engineering
Holycross Engineering College
Thoothukudi
Tamil Nadu
India

M. Soniya §
Department of Information Technology
Vel Tech Multi Tech Dr. Rangarajan Dr. Sakunthala Engineering College
Chennai
India

T. Tamilvizhi ‡
Department of Computer Science and Engineering
Panimalar Engineering College
Chennai
India

Abstract

Bulk Milk Cooler (BMC) Health Monitoring at the milk collection centre assists the reception of the quality of milk at the dairy plant level, which improves the quality of milk received by the dairy plants and reduces the rejection or wastage of milk when it arrives

* *E-mail:* `ajithaponnupillai@gmail.com (Corresponding Author)`
† *E-mail:* `drarunmozhiselvi@gmail.com`
§ *E-mail:* `soniya@veltechmultitech.org`
‡ *E-mail:* `tamilvizhi.phd.it@gmail.com`

at the dairy plant. The BMC health monitoring includes the pH of the milk storage tank, digital temperature sensor which is free from frequent external calibration, and accuracy does't with lengthy cables, agitator rpm monitoring which is used to access the health of the agitator in BMC. Similarly, the health of the compressor which maintains 4 degrees C is also accessed. Based on cloud server/webpage-based analytics software as well as mobile phone-based software for live health monitoring, the agents/dairy plant supervisor can take a quick decision to recover the health of BMC, by mobilizing the manpower/service engineer, so that the quality of milk can be maintained at the collection/storage centre level.

Subject Classification: *68M25, 68P27, 68M11.*

Keywords: *Bulk milk coolers, Health monitoring, Internet of Things (IoT) and Sensors.*

1. Introduction

The amount of milk produced worldwide is rising daily. Monitoring of the cold chain management is necessary. During these phases of milk collection, cooling, and transportation, the milk quality must be watched for changes in its biochemical and microbiological composition. The original quality of raw milk is always a determining factor in the completed product's quality and shelf life. As a result, it is essential to gather high-quality milk, which should also be free of hazardous bacterial contamination, adulteration, and continuous chilling or maintain its chilling temperature during transportation. Therefore, there is a push for the organized dairy industry to improve the gathering and processing of high-quality milk for a product with appeal to the global market. Milk distributing agency like Amul, Nestle, Nadhini, Arokiya, Aavin agencies are in need of a health monitoring system which is IoT based. A rough estimation of the industrial need for monitoring the BMC is about 10,000 units for the above listed agencies. There is a great need envisaged towards milk monitoring device.IOT based solution provides the capability of health monitoring of BMC located at remote villages by empowering with remote control and monitoring capabilities of BMC deployments on a web as well as mobile platform.

2. Existing Work

According to Kumar et al. [1], bulk milk coolers are used to cool milk once it has reached the harvest temperature of 35°C in order to prevent bacterial growth and preserve the quality of the milk. Milk cooling has a poor coefficient of performance (COP) of about 3.0 and consumes a lot of energy. Due to growing energy prices, heat recovery from bulk milk coolers was examined as a conservation strategy to lower water heating costs in the dairy industry. Condenser heat loss to the atmosphere is recovered to boost the plant's energy efficiency [2]. Waste heat is utilized to heat the water that is used to clean the milk processing machinery, saving the thermal or electrical energy that would have been required to heat the water separately. Using a shell and coil heat exchanger, the condensation process' waste heat is recovered. The refrigerant's superheat and latent heat are what make up the heat rejected during the condensation process. In this work, an attempt was made to recover all superheat and a portion of the latent heat, which is a current research issue. The findings show that 35% of the latent heat is recovered together with the entire superheat. The heat recovery rate is calculated for various mass flow rates. Water and tubes carrying refrigerant are both flowing on the shell side. This study determines the heat exchanger's efficiency and presents the findings [3]. The system's COP has increased from 3 to 4.8 as a result of significant improvements. An instant milk cooling system was created by John Upton and colleagues for a variable flow milking machine that was designed, created, and tested in a number of configurations. The gadget demonstrated its capability of instantly freezing a dynamic milk flow under a variety of operational situations [4].

3. Proposed Work

Proposed IOT (Internet of Things) based solution provides the capability of health monitoring of BMCS located at remote villages by empowering remote control and monitoring capabilities of BMC deployments on a web as well as mobile platform. Our system not only tracks the quantity of milk, but also measures the quality of the milk in terms of pH and acidity, as well as the health condition of other accessories, electrical power supply to the BMC, hence it is a true BMC health monitoring system. The proposed solution expands the possibility of the live health monitoring of your BMC and takes a quick proactive and preventive decision to safe guard the quality of milk by real-time monitoring of key performance indicators of BMC [5]. Proposed IOT (Internet of Things) based solution provides the capability of health monitoring of BMCS located at remote villages by empowering remote control and monitoring capabilities of BMC deployments on a web as well as mobile platform. The proposed solution expands the possibility of the live health monitoring of your BMC and takes a quick proactive and preventive decision to safe guard the quality of milk by real-time

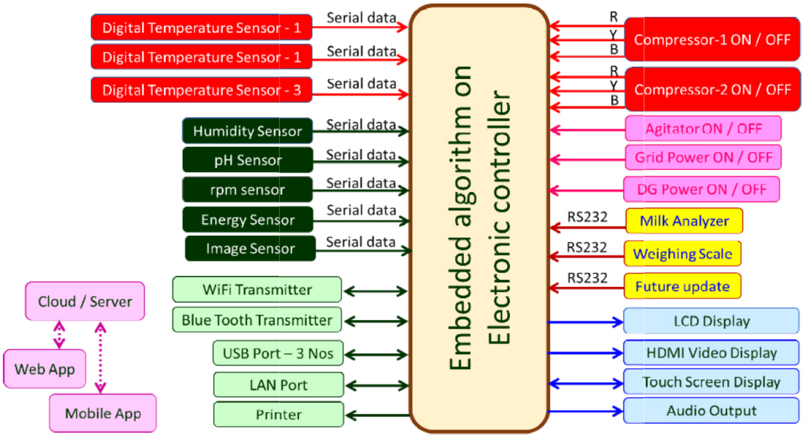

Figure 1

Architecture Diagram of BMC

monitoring of key performance indicators of BMC. Our system can do the pH measurement (acidity of Milk), rpm of agitator, status of individual phases of compressors, and temperature profile of the BMC which makes the total system as an actual health monitoring system. Acidity is directly linked to lactose to lactic acid conversion and bacterial colony growth in the Bulk Milk storage systems, as well as the quality of milk, hence our hardware & software is not only doing automated data monitoring, but also performing the health monitoring of BMC. Based on this data, the milk can be rejected or accepted at the collection centre level itself [6]. Time taken for chilling of milk is an indirect measure of the health of the storage tank insulation / compressor efficiency.

Our design is able to diagnosis not only the running status of the agitator but also the speed (rpm) of the agitator, which is the indication for the health of the agitator system [the electrically powered motor is rotating or not, whether the shaft linkage is broken or problem in the coil of the electrical motor [7,8]. Figure 1 represents the architecture of the BMC with various sensors connected to analysis the quality of milk in BMC.

3.1 *Sensors in BMC:*

Quality of the Milk is determined by using various sensors. Figure 2 shows the the various sensors with their usage in the BMC. Temperature of Milk & CIP Line are measured using the Digital Temperature Sensor with Resolution as ±0.5 °C and Temperature Range ranges from -55°C to +125°C. [Fahrenheit equivalent is -67°F to +257°F].

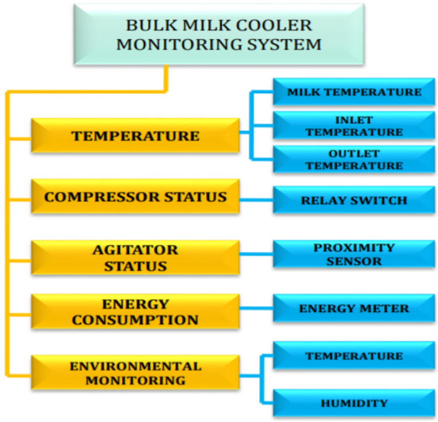

Figure 2

Sensors in BMC

Volume of Milk is measured by Ultrasonic based non-contact technology with resolution: ± 3 mm [optional: ± 1 mm] which tracks changes in case of adulteration and spillage / leakage of milk. Agitator Status and RPM are measured by means of Proximity Sensor which measures the rpm of agitator's shaft. Additional sensor to monitor the electrical ON/OFF status of agitator which is used e to diagnose health of the agitator system [the electrically powered motor is rotating or not, whether the shaft linkage is broken or problem in the coil of the electrical motor. Compressor ON/OFF Status Monitors the ON/OFF Status of individual phases of compressor. Based on live energy consumption & ON/OFF Status of individual phases of the compressor, health of the compressor can be predicted. Based on the individual phase sensor with the raw power of compressor, the health of raw power to the compressor can be assessed through pH measurement. pH measurement acidity is linked to lactose to lactic acid conversion and bacterial colony growth in the Bulk Milk storage system, as well as the quality of milk, hence our hardware for pH measurement & software is not only doing automated data monitoring, but also performing the health monitoring of BMC. Additional sensor for surrounding environmental temperature and humidity conditions, helps to access the environmental conditions where Bulk Milk Storage Tank is kept. Figure 3 shows the logical view of location of sensors in the BMC. This Model gives an idea of where the sensors are located in BMC.

Figure 3

Block Representation of BMC

BMC Health Monitoring System consists of following seamlessly integrated components to provide complete functionality:

3.2 *BMC Intelligent Monitoring Panel and IOT Gateway*

This is the heart of the system and provides KPI monitoring for BMC equipment. It consist of sensors to measure the temperature of the Bulk Milk Cooler as well as the CIP Line to the BMC. It also measures the surrounding temperature and surrounding humidity where the system is housed. The volume of milk stored in the Bulk Milk Cooler is measured based on the height of the milk level in the Bulk Milk storage tank. We use ultrasonic technology for measuring the height of the milk level. This unit also has in-built GPRS/4G modem for online transmission of data to the cloud servers. It also has RS232 and Wifi for further integration with existing equipment's. The unit is a microprocessor-based system with an embedded applications and a 7″ touch screen for ease of use and graphical display of information. The BMC Intelligent Monitoring Algorithm by using Deep Belief Network as follows.

Step 1: First, the visible unit, the parameters of the BMC, are assigned as training.

Step 2: Upgrade the visible unit and hidden unit by Back Propagation

$$\delta Wi, = <vi\ hj>data - <vi\ hj>reconstruction$$

Step 3: Streams line the visible and hidden units by repeating step 2.

Step 4: The next phase is fine-tune phase.

Step 5: The classifier is trained as 3 quality of milk as 3 class labels based on the purity of the milk.

Step 6: Using Back Propagation approach, the quality of the milk are categorized as any one of the 3 classes.

3.3 BMC Utilities Monitoring Panel

This monitoring panel is for monitoring of high-voltage equipment such as agitator, agitator status (ON/OFF), individual phase of the compressor status (ON/OFF), energy consumption etc.

3.4 *BMC Monitoring Cloud Portal*

This is web-based BMC monitoring software for centralized monitoring of BMC operations and KPIs. It is responsible for capturing data from all BMC IOT Panels at the field and provides the feature of over-the air update of the application programs on IOT panels. Our software will provide an exhaustive set of MIS reports and graphical dashboards for quick analysis of BMC operations. It also provides SMS as well as app-based alter & messaging system to highlight critical events. The portal can be accessed to mobile phone also and will allow route officers to have monitoring of BMC on the go.

3.5 *BMC Mobile App for Agents*

This is an easy-to-use multilingual application for agents with anytime-anywhere access to BMS status and provide alerts in case of a situation requiring urgent action from agents. Key Advantages of this work on BMC In order to detect variations in cases of adulteration and milk spills, the BMC tracks the amount of milk that is being stored there. b) Tracking of Milk Storage temperature to prevent curdling, souring, and spoiling of milk while preserving. c) Performance report of the compressor used for chilling the bulk milk storage tank. d) Logistical Planning / optimization of Milk Tanker Trips: Based on the volume of milk present in the BMC, the logistical plan can be made or optimized for collection through the tanker lorry. e) pH and acidity play a vital role to decide whether the milk is to be taken to the tanker or not. f) Occasionally, the collection centre representative or skilled individual needed to start the diesel generator may not be on hand when the raw power fails for a variety of reasons. In order for the agent to make prompt alternative arrangements and prevent the deterioration of large amounts of milk in the bulk milk refrigerator, this system automatically sends SMS alerts to the agent. g) Sometimes, the collection centre agent may not fill with sufficient fuel diesel for the dieselgenerator used for BMC, since the DG power line ON/OFF status is also monitored, it indirectly forces the agent to keep sufficient fuel (diesel) in the DG set. h) Continuous temperature monitoring ON/OFF status monitoring of agitator & compressor forces, the milk collection centre agent – not to switch off the compressor or agitator power to save their electricity bill. i) Based on the electrical power ON/OFF status of the agitator and the rotation per minute of the agitator, our analytical algorithm in the software can alert that there is a problem in the agitator. j) Based on the electrical power consumption incremental and electrical power ON/OFF status of individual phases of electrical compressor, our analytical software can alert there is a possible problem in the electrical compressor used for cooling the BMC. It helps to take a quick decision to recover the health of BMC by mobilizing a manpower / service engineers for the servicing of the compressor, so that the quality of milk can be maintained at the collection/storage center level.

4. Experimental Results

The system goes into testing mode once the design portion has been completed. The entire process of product development and upkeep includes testing. Error detection is the main goal of testing. It serves as a

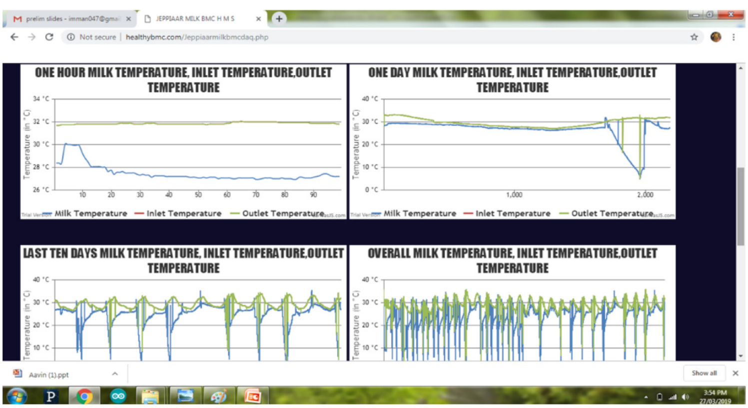

Figure 4

Graph representing various data

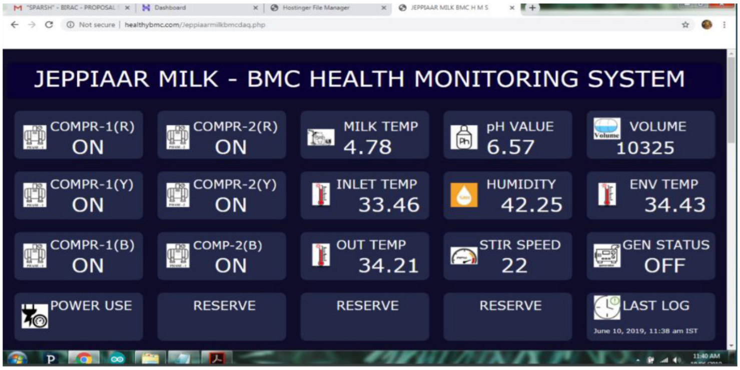

Figure 5

Dashboard representing various data

means of ensuring quality. The purpose of the testing step is to confirm that the specification has been correctly completed, taken into account in the design, and to guarantee the accuracy of the design itself. Figure 4 shows the data representation for ten days like milk temperature, inlet and outlet temperature, etc. The Figure 5 shows the dashboard representation of BMC Monitoring System, which represents the values got from various sensors used in the system. The status of which compressor is in On mode, the temperature of milk, the pH value of the milk, the volume of the milk, the environmental temperature, humidity, the inlet and outlet temperature, the stir speed and the status of the generator has been displayed.

The values are monitored and stored in Cloud Environment. From the Cloud the values are retrieved and performance analysis has been performed and represented in the visual representation in the mobile app and website.

5. Conclusion

Designed a monitoring system for bulk milk cooler (BMC) located at remote locations (Environment Temperature, Energy, Compressor On / Off Protocol, Humidity, Milk temperature, Volume of milk, Agitator speed, Inlet and outlet temperature, Generator Status and Cleaning in place (CIP) process). Here remote control capabilities of BMC deployments on a web as well as mobile platform an indigenously developed software program "www.healthybmc.com" has been developed for data acquisition and data analytics. This system procures quality and safe milk and to deliver at the processing site.

References

[1] Kumar, Sushant, and Saurabh Mukherjee, Hardware Devices Integration with IoT, *Wireless Communication Security,* 143 (2023).

[2] K.S. Riya, R. Surendran, C.A.T. Romero, M.S. Sendil, Encryption with User Authentication Model for Internet of Medical Things Environment, *Intelligent Automation and Soft Computing,* 35(1), pp. 507–520 (2023).

[3] Mohammed, Bzhar Ghafour, and Dler Salih Hasan. Smart Healthcare Monitoring System Using IoT, *Ijim*, 17.01 (2023).

[4] A. Sivasangari, P. Ajitha, and K. Indira, Air Pollution Monitoring and Prediction using Multi View Hybrid Model, *International Journal of Innovative Technology and Exploring Engineering*, 8. 6S4 (2019).

[5] T Tamilvizhi, R Surendran, R.M Bommi, Radio Frequency Identification (RFID) based ubiquitous health care data handling, *IOP Conference Series: Materials Science and Engineering*, 994 (1), 012021 (2020).

[6] Gupta, et al. Security Paradigm for Remote Health Monitoring Edge Devices in Internet of Things, *Journal of King Saud University-Computer and Information Sciences* (2023).

[7] N. Semwal, M. Mukherjee, C. Raj & W. Arif An IoT based smart e-health care system, *Journal of Information and Optimization Sciences*, 40:8, 1787-1800 (2019).

[8] L. J. B. Andrews, L. Raja, A study on m-health inline with the sensors applying for a real time environment. *Journal of Statistics and Management Systems*, 20 (2017).