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REAL-TIME MONITORING OF MACHINE HEALTH IN MANUFACTURING INDUSTRY - AN INDUSTRIAL IOT APPLICATION

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Abstract: This proposal advocates for the integration of Industrial Internet of Things (IoT) technologies in the industry to enhance production efficiency and sustainability. Leveraging smart monitoring through IoT-based equipment, the initiative focuses on optimizing energy usage, detecting early machine failures, and ensuring precise temperature control. Implementation involves energy meters for daily voltage regulation, thermal sensors for cost-effective failure detection, and temperature sensors for climate control. By reducing downtime, operational costs are minimized, environmental impact is lowered, and pharmaceutical production becomes more sustainable and economically viable. This innovative approach aligns with the industry's high demand, promoting enhanced product quality, safety, and overall efficiency.

In simpler terms, our strategy utilizes smart monitoring to keep machines running smoothly, save costs, and maintain pharmaceutical production quality and safety

Index Terms – Predictive Maintenance, Early detection, Reduce Downtime, Energy Optimization

I. INTRODUCTION

The Industrial Internet of Things (IIoT) is a specialized subset of the broader Internet of Things (IoT) concept, tailored for industrial applications and processes. In IIoT, various devices, sensors, machines, and systems in industrial settings are connected to a network, enabling them to collect, exchange, and analyze data. IIoT often involves the use of smart sensors, enable predictive maintenance, and enhance overall operational performance in industries such as manufacturing, energy, healthcare, and transportation. The goal is to create more intelligent, interconnected, and data-driven industrial ecosystems. Energy consumption is often managed without real-time data, leading to inefficiencies and higher operational costs. In IoT Smart energy meters provide real-time data on voltage regulation, enabling pharmaceutical companies to optimize energy usage, reduce costs, and enhance sustainability.

Reliance on periodic manual inspections may result in delayed identification of machine failures, impacting production and product quality. In IIoT Thermal sensors enable cost- effective, continuous monitoring, allowing for early detection of machine failures. This proactive approach ensures uninterrupted production and maintains product quality and safety standards. Temperature control may be manual or rely on basic systems, posing challenges in maintaining precise climate conditions. In IIoT Integration of temperature sensors facilitates precise climate control, ensuring pharmaceutical product integrity, safety, and efficacy. This contributes to adherence to quality standards and regulatory requirements. Limited real-time monitoring may result in variations in product quality and safety. In IIoT Continuous monitoring ensures consistent product quality, meeting regulatory standards and customer expectations, thereby enhancing overall quality assurance.

The pharmaceutical industry faces challenges in production efficiency, sustainability, and cost-effectiveness. This deficiency results in increased downtime, higher operational costs, and environmental impact, worsened machine failures and inadequate temperature control. Our proposal advocates for integrating Industrial IoT technologies to address these issues. By implementing smart monitoring, energy optimization, and early failure detection, our solution aims to minimize downtime, reduce operational costs, and enhance sustainability. The absence of this integrated approach hampers the industry's efficiency, damaging the product quality, safety, and overall operational effectiveness.

II. LITERATURE SURVEY

Pharmaceutical continuous manufacturing, recognized as an emerging technology, aligns with Quality-by-Design (QbD) principles and the shift toward Quality-by-Control (QbC) for smart manufacturing [1]. Soft sensors play a crucial role in maintaining product quality and minimizing deviations. Model predictive control (MPC) emerges as a promising automation strategy, offering real-time monitoring and control capabilities. MPC contrasts with traditional control methods like proportional integral derivative (PID) controllers, showing potential for enhanced process control and quality assurance. Industrial applications of MPC in pharmaceutical continuous manufacturing encompass various operations, from tablet press control to full direct compaction lines, making it a cornerstone of Industry 4.0 advancements.

The Internet of Things (IoT) is pivotal in transitioning traditional factories to smart factories within Industry 4.0 [2]. By linking devices, sensors, and software, IoT optimizes production processes, facilitates predictive maintenance to prevent failures and extend equipment life, monitors energy usage for efficiency, enhances workplace safety, and improves supply chain management. Challenges include cybersecurity, infrastructure requirements, workforce skills, and data management complexities. Despite challenges, implementing IoT in smart factories offers substantial benefits like increased productivity, reduced downtime, and improved quality control, driving the digital transformation of manufacturing.

The smart factory, a key concept in Industry 4.0, is a fully connected manufacturing system that operates autonomously using data for tasks [3]. A literature review categorized research into eight perspectives: Decision making, cyber-physical systems, data handling, IT infrastructure, digital transformation, human-machine interaction, IoT, and cloud manufacturing. This categorization led to the smart factory research model, guiding future research. The methodology included systematic literature review steps: Scope definition, topic conceptualization, literature search, analysis, synthesis, and future research questions. The analysis used qualitative content analysis and coding techniques to structure findings.

Industry 4.0 is revolutionizing pharmaceutical manufacturing by integrating technologies like the internet of things (IoT), artificial intelligence (AI), robotics, and process automation [4]. This transformation involves digitizing the pharmaceutical value chain with embedded cybersecurity, utilizing AI for tasks like predictive maintenance and quality control, employing collaborative robots for various operations, implementing augmented reality for enhanced experiences, and creating digital twins for performance optimization. These advancements enable real-time data integration, proactive decision-making, and improved process control, leading to higher efficiency and product quality in pharmaceutical manufacturing.

The rapid growth of IoT technologies and their potential in various sectors like industry, smart cities, agriculture, waste management, and healthcare. It highlights the benefits of IoT in improving efficiency, monitoring systems, and enhancing quality of life [5]. However, it also raises concerns about resource utilization, environmental impact, and cybersecurity challenges. The article emphasizes the need for sustainable development and careful consideration of IoT's long-term effects. Opportunities exist for IoT to address pressing challenges in urbanization, food production, waste reduction, and healthcare, but careful planning and research are essential to maximize its benefits while mitigating risks.

The integration of automated predictive maintenance and intelligent sensors in modern smart factories, particularly focusing on their role in production robotization is reviewed in [6]. It emphasizes the need for efficient analysis of the vast data generated by intelligent sensors to support decision-making in complex systems. Using burst analysis, systematic review methodology, and keyword co-occurrence analysis, the study highlights the increasing importance of predictive maintenance in the context of Industry 4.0. The paper proposes the concept of Smart and Intelligent Predictive Maintenance (SIPM) based on its findings. Overall, it provides a comprehensive overview of current trends and challenges in using intelligent sensors for predictive maintenance in smart factory environments.

The challenges and steps involved in implementing smart factories, focusing on leveraging digitalization in manufacturing through a structured approach are discussed in [7]. It highlights the importance of addressing challenges related to people, processes, and technologies in transitioning to smart factories. The study draws from in-depth analyses of five factories in leading automotive manufacturers to identify key challenges and proposes a preliminary maturity model for smart factory implementation. This model revolves around cultivating digital skills, introducing agile processes, and deploying modular technologies to achieve connected and flexible manufacturing systems that can adapt to new demands efficiently.

The necessity and challenges of transitioning to smart factories in the context of Industry 4.0, emphasizing the integration of physical and cyber technologies is presented in [8]. It proposes a hierarchical architecture for smart factories and analyzes key technologies in the physical resource, network, and data application layers, focusing on Internet of Things (IoT), big data, and cloud computing. A case study on a candy packing line verifies the effectiveness of smart factory technologies, showing improved equipment efficiency. The paper aims to address technical issues and provide solutions for implementing smart factories, highlighting the importance of real-time data acquisition, high-speed communication, flexible network protocols, and data analysis for decision-making.

Industry 4.0's impact on the pharmaceutical sector, focusing on Ireland's perspective. It assesses the sector's readiness for 4.0 adoption, revealing that only 42% of respondents were familiar with 4.0 concepts, with higher awareness among senior and technical staff is explored in [9]. The article highlights challenges in integrating 4.0 into organizational culture. It also references other studies on 4.0 adoption in manufacturing, healthcare convergence with IT, and the potential of technologies like augmented reality in pharmaceuticals. The research methodology involved a survey with structured and Likert scale questions, aiming to provide valuable insights into 4.0 adoption readiness in the pharmaceutical industry.

The proposed ISFAMS is an IoT-based Smart Factory for Additive Manufacturing System, integrating IoT, cloud computing, and automation [10]. It enables real-time monitoring, optimal decision-making, and flexibility in production. The system utilizes Industrial Controllers, wireless sensor networks, and cloud computing for data acquisition, storage, and visualization. Automated machines handle processes like additive manufacturing, material handling, inspection, and packaging. This digitization enhances process visibility, control, and efficiency. The system addresses challenges such as lack of timely information, product flow tracking, and customization demands, offering a comprehensive solution for smart manufacturing in various industries.

III. EXPERIMENTAL SETUP

We categorize the enhancements into three crucial aspects:

- Energy optimization
- Proactive machinery health monitoring
- Precise temperature control

We divide the project into 4 units:

1. Integration Unit

An integration unit plays a important role in connecting various devices, systems, and platforms together, here we are using the Arduino as platform to connect all sensors.

- **Vibration sensor:** These are the core of the system as the Vibration sensors detect subtle changes in machine operation that can indicate impending problems by the different vibration speed in the machine. Connected to analog pin of Arduino board.
- **Temperature Sensor**: This sensor monitors the temperature of the machine. Where it protects from overheating issues . Connected to digital pin of Arduino board.
- **Voltage Sensor:** This tracks the energy consumption of the machine and monitors the day-to-day voltage consumption and upgradation of this helps to energy consumption. Connected to Analog pin of Arduino board.
- **Sensor Data Collection**: Vibration, temperature, and voltage sensors monitor continuously. All these three components are integrated onto the Arduino board which further transfer the data into cloud for storage.

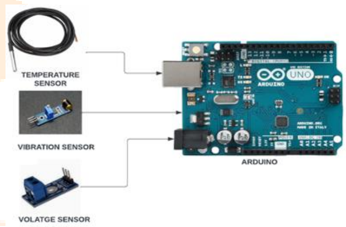


Fig 1: Integration unit

2. Display Unit

A display unit serves as an interface between the IoT system and its users. Its primary function is to present relevant information generated by IoT devices or systems in a human-readable format.
The display unit is connected to Arduino Via I2C bus to reducing connectivity to only 4 pins out of the 16 pins.

- **Arduino Processing**: The Arduino board collects and processes the raw sensor data. That are collected during the monitoring of the pharmaceutical manufacturing equipment.
- **Local Display**: The LCD screen may display real-time data or basic alerts, where the ongoing voltage(vol), temperature(T) and vibration(v) of machine is displayed and graph is displayed in cloud.

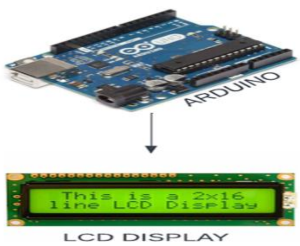


Fig 2: Display unit

3. Cloud Unit

The cloud unit serves as a central hub for managing, processing and analysing data collected from IoT devices and sensors.

- **Data Transmission**: The system transmits processed data to the cloud platform using either GSM (cellular network) or Wi-Fi, depending on connectivity.
- **WIFI Receiver**: This indicates the system can also connect to a local Wi-Fi network, allowing broader data transmission and perhaps remote access.
- **Cloud Storage**: Cloud storage involves storing data in remote servers accessed via the internet. It's commonly used in projects for data backup and collaboration.
- The data collected is being stored in cloud for backup as well monitoring the machine health in longer run.

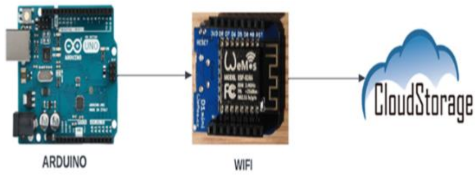


Fig 3: Cloud unit

4. Alert Unit

An alert unit serves the critical function of notifying stakeholders about specific events or conditions detected by IoT devices or sensors. Its primary role is to promptly alert users or automated systems about situations that require attention or action.

- **Alerts**: If the system detects anomalies, it sends alerts via SMS.
- **GSM**: This module enables the system to communicate with the outside world. It can send SMS alerts if problems are detected, or transmit data to the cloud. This is a crucial point where if the real time values are higher than the threshold value they send alerts to user’s device. This helps to know the problem before the machine failure.
- In this setup, Arduino continuously collects real-time data. If any of the collected values exceed predefined threshold values, an alert message is promptly transmitted via GSM to the user's device. Simultaneously, the real time values are also displayed on the LCD screen for immediate local visualization.

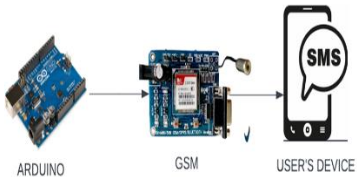


Fig 4: Alert unit

Overview of the Model

- **VIBRATION SENSOR**: These are the core of the system. They are likely attached to critical parts of the pharmaceutical manufacturing machinery. Vibration sensors detect subtle changes in machine operation that can indicate impending problems by variation in vibration of machine.
- **VOLATGE SENSORS**: This tracks the energy consumption of the machine. The power usage might be correlated with machine health issues with continuous observation.
- **TEMPERATURE SENSOR**: This sensor monitors the temperature of the machine or its components, as excessive heat can indicate problems.
- **LCD DISPLAY**: This provides a simple, on-site readout of the machine's health status.It might display real-time vibration data or alert messages.

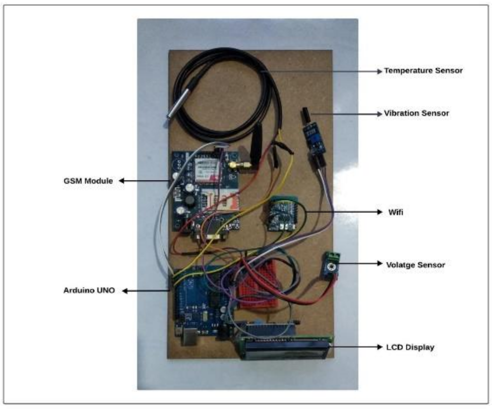


Fig 5: Experimental Setup

- **WIFI RECEIVER**: This indicates the system can also connect to a local Wi-Finetwork, allowing broader data transmission and perhaps remote access.
- **ARDUINO UNO**: This microcontroller board serves as the brain of the localsystem. It collects and processes data from the vibration sensors.
- **GSM**: This module enables the system to communicate with the outside world. It can send SMS alerts if problems are detected, or transmit data to the cloud.

IV. RESULT

The LCD screen on the system provides continuous updates on the current temperature, vibration, and voltage levels of the machine by collecting real-time data from the respective sensors. These values are then compared to predefined threshold values. If any of these values exceed their respective thresholds, the GSM module initiates an alert message to be sent to the designated mobile device.

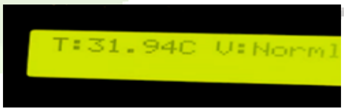
Threshold values are:

Temperature Sensor: T <= 40 ℃

Vibration Sensor: V >= 852 < 1000 = Normal, V>=600<=851=Risky, V >=0<600=Faulty

Voltage Sensor: vol <5 = Normal, vol >5 = Risky

The LCD screen serves as a real-time dashboard, showcasing vital machine metrics including temperature, vibration, and voltage. Data is gathered in real-time through Arduino sensors and seamlessly transmitted to the cloud via WIFI connectivity. Where temperature, vibration and voltage values are stored in Thingspeak cloud storage.

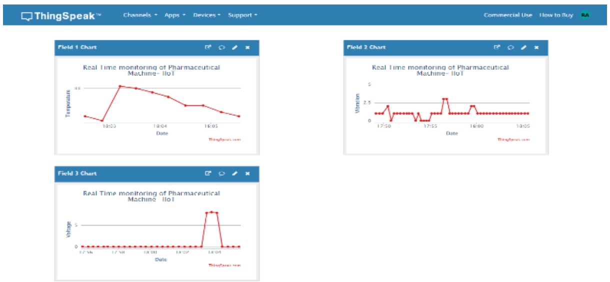


If the machine's temperature reads within the acceptable range (T ⩽ 40 ℃), voltage remains stable (V ⩽ 5), and vibration falls within the expected parameters (currently reading "Normal" within the range of 852 to 1000), the IoT system concludes that the machine's operation is normal. As a result, it refrains from triggering any alert messages to the user. This ensures that only when deviations from these parameters occur, indicating potential issues or anomalies, the system will initiate alert notifications to prompt further investigation or intervention.

Upon reaching the cloud, the data undergoes evaluation against predefined threshold values. If the temperature reads within the acceptable range (T: <=40°C) the temperature parameter work only with two ranges normal and more than 40°C. the voltage remains stable (V: <= 5) until it greater than 5V, and vibration falls within the expected parameters (currently reading "Risky" within the range of 600 to 851), the system deems the machine's operation as Risky and send alerts message as “Machine in risk attend soon” .

In this the faulty criteria where the temperature read as 40°C it exceeds the threshold value and the alert message will be sent as "Temperature is high attend soon ", the voltage reads as 5V which is above the threshold value it is caused due to over consumption of energy requires a service or checking .Whereas the vibration falls within the expected parameters (currently reading "Faulty" within the range of 0 to 600), the system deems the machine's operation as Faulty and send alerts message as "Machine is faulty attend soon".

Things speak cloud storage



Things speak is a platform acts as storage unit which stores upto 1000 raw values that is been collected by sensors process it and displays it in the form of graph.

V. CONCLUSION

Reducing downtime in the pharmaceutical industry is like ensuring operational efficiency, maintaining product quality, and meeting regulatory standards. The applications and strategies discussed earlier, such as predictive maintenance, real-time monitoring, and quality by design, play crucial roles in achieving this goal. Efforts to reduce downtime not only contribute to cost savings but also support the industry's commitment to delivering high-quality, safe, and compliant pharmaceutical products. The integration of IoT, and advanced maintenance strategies allows for a proactive and predictive maintenance approach, addressing potential issues before they lead to disruptions.

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