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Optimizing Sugar Factory Operations Using Cloud based IoT And Predictive Analytics

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Abstract
Manual checks used to monitor the sugar industry are the cause of inefficiencies and unplanned downtimes considering that the sugar industry struggles to curb these unexpected downtimes and inefficiencies of the sugar industry. The present paper suggests an IoT monitoring system based on the cloud that will fit the needs of sugar factory in terms of sugar temperature, pressure control, and equipment conditions monitoring in real-time. Through predictive maintenance concepts, the system will strive to predict possible equipment breakdowns hence minimizing both the downtime and maintenance expenses. The combination of cloud computing will provide scalability and access to data, which will enhance responsible decision-making. The method has major benefits of efficiency in operations and quality of the product when compared to the traditional practices.

Keywords: *IoT Monitoring, Predictive Maintenance, Cloud Computing, Sugar Factory Automation*

1. Introduction
Sugar business is the oldest and most important stakeholder in the agro-industrial sector particularly in those countries whose economy is based on agriculture. Nevertheless, the majority of the sugar factories are based on the manual or partially automated principles of monitoring and controlling the key processes like juice extraction, crystallization, boiler operation, machinery health status supervision [1]. Such traditional methods are time-consuming, labor-consuming and they are prone to bureaucracy and human error and un-scheduled equipment breakdown. In the Industry 4.0 age, the need to have smart and connected systems that will give real-time information to achieve more control over operations and to have a strategic advantage is growing. IoT (Internet of Things) and cloud computing represent new opportunities in the sugar industry because they allow data-driven and intelligent, as well as predictive operations. By installing sensors and actuators based on IoT in several sections of a sugar refinery facility, one can continuously observe the condition of the temperature, pressure, humidity, flow of material, vibration of the equipment, etc. [2]. The cloud tech also complements the effectiveness of IoT by offering a central place where collection and storage of information can be centralized as well as analyzed and visualized. Decisionmakers and supervisors working in the factory have the ability to use dashboards no matter where they are [3], discuss KPIs, get alerts, and react to anomalies on a real-time basis. Such a degree of digitization can significantly enhance the use of resources, decrease the operational expenses, as well as raise the quality of products. Predictive maintenance is one more important part of this system. Maintenance approaches that are conventional simply include reactive repair (after breakdown) or preventive measures that are founded on schedules that might not show the real condition of equipment [4]. Predictive maintenance involves machine learning models and sensor data to predict the possibility of equipment undergoing faults. This reduces downtimes, unnecessary servicing and lengthens the life of equipment. This study is driven by the need to eradicate the shortcomings in regard to efficiency and pattern differences in already established sugar factories. Planned and unplanned downtimes and quality problems are typically the cause of financial losses and failure in the delivery of commitment [5]. The integration of cloud-based

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system and IoT not only eliminates these issues but also promises scalability, security and extensibility to make future extensions. Further, in developing countries where most sugar facilities are managed using old machinery, the given solution can be tailored to be used in conjunction with the infrastructure that is available [6]. Such a hybrid compatibility will mean that there need be no wholesale changes in modernization but it will be cumulative. Major goals of this research are:

- In order to create a cloud-enabled IoT system to real-time monitor the operational parameters in sugar factories.
- To evaluate the collected data and help make decisions based on data to have optimum operations.
- To achieve a predictive maintenance module that reduces on the downtimes and increases the lifetime of equipment.
- To contrast the performance of the systems with formal monitoring as an effort to confirm the improvement in terms of efficiency, productivity and quality.

2. Related Work

The latest industrial development in Industrial Internet of Things (IIoT), and cloud computing has transformed the way manufacturing and processing industries conduct their operations. The sugar industry used to the manual/semi-automated mode is now turning toward these digital technologies and improving its operational visibility and reliability. Industrial applications and a number of studies have proven the benefit of IoT and cloud-based monitoring to accomplish the real-time control, data-driven decisions, and predictive maintenance [7]. In one of such studies, IoT based boiler health monitoring systems in sugar factory was examined. The other thing essential in sugar production is the use of boilers in generation of steam. Conventionally they are either maintained reactively (once failed) or in a scheduled manner without awareness of conditions. But with the help of the use of temperature, pressure and vibration sensors on the components of the boilers, real time data could be gathered and analyzed and appropriate measures could be taken in time before the catastrophic failures took place. The strategy led to significant minimization of downtimes and maintenance costs thus increasing operational efficiency. Simultaneously, big data and predictive maintenance has acquired significant traction in the use of IIoT. Predictive maintenance takes historical and real sensor data and then forecasts the possibility of future equipment problems with the help of an algorithm of machine learning. This approach makes maintenance less fixed-schedule based and more of a condition-based maintenance which will eliminate unnecessary maintenance actions and prevent sudden failures. The history of normal and abnormal behavior can be learned and used in predictive models, which raise alerts when something goes awry [8]. Consequently, service can be scheduled in advance by the organizations without a disruption of operations. Market report prediction done in 2025 is that the predictive maintenance industry will be worth USD 1.69 billion in 2030. With AI-powered cloud, big volumes of data can be processed with a real-time performance guarantee, fatefully accurate forecasts, and performance that scales appropriately. Such technologies will be of tremendous benefit in the sugar industry which depends on intricate machineries, season changes and varying demand. Additionally, there exists other studies which touch on deployment of cloud dashboards coupled with edge computing (real time analytics are executed at the closest location to the source of information, and the aggregated information is moved to the cloud to be stored long-term and analyzed strategically). Such hybrid architecture minimizes latency, provides constant monitoring despite network downtimes and makes maximum use of bandwidth. To sum up, the evolution of combining IoT with cloud computing is an unjustified trend but rather a must-have of the contemporary industrial automation. By studying these effective models, the sugar industry can also stand to benefit much by improving the quality of production, reducing its wastages as well as maximizing uptimes. The combination of such studies sets the necessary basis for the development of a full-fledged cloud-based web-based monitoring system in accordance with the requirements of Industry 4.0 [10]. The paper is based on these innovations to customize, scalable, secure and cost-

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efficient solution to the sugar manufacturing sector.

3. Proposed Approach

The recommended solution employs an expandable, modular framework through which it utilizes the capabilities of evolving the power of IoT, cloud computing, and machine learning to track, study and improve the work of sugar factories in real-time. The system is made of a distributed network of IoT sensors that are placed strategically on important factory machines and infrastructure. Such sensors are in charge of measuring important parameters of operations against temperature, pressure, humidity, rotational speeds, levels of vibrations, motor currents and other performance of components such as boilers, turbines, conveyor systems, pumps and crystallizers among others [10]. The information that is obtained by the sensors is relayed to Edge Devices at the factory. These edge units conduct real-time preprocessing of raw sensor data such as the noise, Time-Stamping, the earlier detection of anomalies to data compression. The local processing guarantees that the data transmitted to the cloud is relevant and also accurate and saves a lot of bandwidth since the relevant and accurate data is transmitted to the cloud and a good network communication occurs. The processed data are then securely sent to a Cloud-Based Platform via secure IoT connectivity through protocols such as MQTT or HTTP via TLS. The cloud system is the brain system of the system. It will do data aggregation, long-term storage, machine learning-based analytics and actionable insights. Such a layer can be constructed with the help of scalable services, such as AWS IoT Core, Microsoft Azure IoT Hub, or Google Cloud IoT [12]. Machine learning Algorithms are utilized in this layer, to establish trends in performance, anomalies, and anticipate possible failures in the machinery, prior to occurrence. As an example, when a particular pattern of learned threshold is crossed by the vibration data of a motor, then the system can indicate that as a pre-illustration of bearing failure. In the same manner, temperature peaks observed with time in a crystallization unit can be traced to inefficiencies or pending failures. The user interface is made of dashboards that show a real-time status of the monitored components, illustration of historical data, warnings of maintenance, as well as operational comparisons. Operators through any internet-connected device including a computer, tablet, or phone, could confirm machine health, download logs, set thresholds and get predictive warnings [9]. Role based control can also be supported in the dashboard, so that only concerned parties will be able to make changes or access sensitive information. It also has Reporting Module, produces operational summaries of the day/week, maintenance logs and compliance reports that can be exported in either PDF or CSV formats. This reporting assists in regulatory compliance, intra-corporate audit and long term planning. The architecture as a whole facilitates the aspect of Predictive Maintenance that allows the transition of reactive to proactive maintenance. It reduces unforeseen equipment breakages, increases factory utilization, and optimizes the utilization of the resources. Moreover, it is designed such that all of the legacy machinery may be fitted into the system through retrofitted sensor modules, which makes it retrofriendly to any old factory without having to perform a whole new reconstruction of the factory [10]. To summarize it, the suggested system establishes a well-rounded ecosystem where the raw data turns into meaningful action. An active connection between edge processing, cloud analytics, a machine learning solution, and the availability of dashboards helps factory managers to modernize their work, inventing ways to cut expenses, and improve the quality of their products [11]. The system is also scalable and can be expanded to include more processes in the future, including inventory tracking, energy tracking, or supply chain visibility among others.

4. Result Analysis

In order to analyze the efficacy of the proposed cloud based IoT monitoring system, a comparative assessment was done based on key performance indicators (KPI) that are operational downtime, maintenance costs and product quality. The comparison was made based on the measures of performance obtained when traditional monitoring was done manually and the measures when the implemented system by using IoT based method was used. These findings saw the drastic reduction of the

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unplanned downtimes dramatically improve 25 hours to 10 hours a month when the IoT system was involved. Maintenance cost was also reduced to 65 000 a rupi from 120 000 INR which means that resources were used wisely and interventions were made on time. Also, the product quality, which is rate as a scale of 10 [11], increased by an average form 6.8 to 8.9 as a result of constant check and early warning of any anomaly in the operations. Improvements are shown in the table 1 and the figure 01 below.

Table 1 Show the Exiting Approach with Some Basic Parameter

KPI	Traditional Monitoring	Cloud-Based IoT System
Downtime (hrs/month)	25.0	10.0
Maintenance Cost (INR)	120000.0	65000.0
Product Quality Score (/10)	6.8	8.9

The table 01 and graph 01 show clearly the advances provided by the cloud-based IoT monitoring system compared to the traditional methods of application. The downtime was decreased to 25h per month to 10h saving on the overall factory uptime. The maintenance cost also lowered down by a great figure by pouring 65,000 compared to 120,000, a sign of improved resource utilization. The quality of the products also increased, where the scores during the initial stage were 6.8 and 8.9 at the end of the monitoring process that uses constant observations and real-time notifications [11]. These findings prove that the system was useful in streamlining the operations and limiting the losses. The Figure 1, 2 and 3 with the name comparison of Monitoring Methods makes it easy to observe graphic optimization of the use of the cloud-based IoT monitoring system on the territory of a sugar factory as compared to traditional methods. Three major parameters (KPIs) are evaluated; downtime, maintenance costs and product quality score. The system is much faster with the use of the IoT considering the downtime is decreased per month down to 10 hours as compared to 25 hours. In the same way, the maintenance costs displayed a steep decrease of 120,000 to 65,000, which reveals an increased efficiency in the use of resources and ability to interrupt the process at the right time thanks to monitoring in real time. It is remarkable that the quality score of products has been increased by 8.9 out of 10 against 6.8, as production quality was stable, parameters of product processing were controlled better. The findings taken altogether support the benefits of automation through the use of IoT in raising productivity, lowering the costs of operation, and quality of the end-products. The bars representing IoT (orange) and the traditional (yellow) are color-coded allowing one to have a clear side-by-side comparison, which supports the proposed solution and helps to clarify the superiority of the IoT solution. All in all, the graph proves the hypothesis that digital transformation has the potential of transforming traditional manufacturing systems into the smarter and responsive systems.

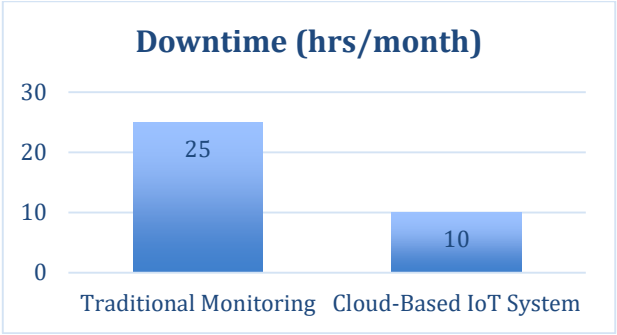

Figure 1 Show the Analysis Using Some Basic Parameter (Downtime (hrs/month))

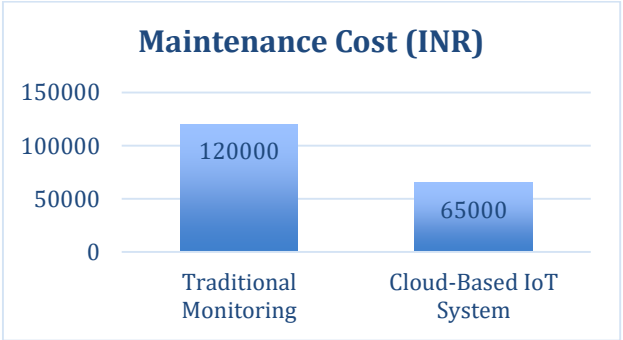

Figure 2 Show the Analysis Using Some Basic Parameter Maintenance Cost (INR)

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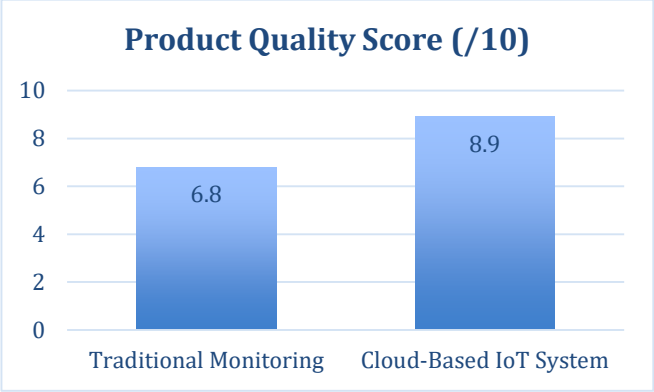

Figure 3 Show the Analysis Using Some Basic Parameter (Product Quality Score (/10))

Conclusion and Future Scope

Implementation of cloud-based IoT monitoring system within sugar factories offers a revolutionary model of industrial activities. Factories can make a lot less downtime and even improve the quality of products because of the ability to control the processes and predict when it is time to carry out maintenance. In the next development, it is necessary to introduce the opportunities of advanced analytics, AI-based decision-making, and to broaden the functionality operated by the system including supply chain management and inventory management. Blockchain integration shall likewise be tapped into to boost traceability of data.

Journal Reference Style

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