AIR PRODUCTS

Driving efficiency in the cryogenic freezing industry using the industrial internet of things and industry 4.0

This paper is published to encourage the sharing and transfer of technical data.

Abstract

Food freezing and chilling is a competitive industry, to be successful, a company needs to keep operating costs down and run as efficiently as possible. However, the industry faces multiple challenges like a shortage of trained manpower and equipment reliability which impact efficiency and the bottom line. This paper discusses how the Industrial Internet of Things and Industry 4.0 can be leveraged to drive efficiency in the use of cryogenics for freezing and chilling food products.

Introduction

The Internet of Things (IoT) is a network of connected devices, sharing data with each other and the cloud. These devices are embedded with sensors and software that allow them to collect data, process it, and make decisions based on the findings. The devices –"things"—can range from household items like toasters, thermostats, and refrigerators to multi-million dollar industrial equipment. Industrial Internet of Things (IIoT) primarily uses IoT paradigms in an industrial environment to build smart factories, optimize production lines, and enable customized manufacturing, using connected machines leading to an intelligent workforce[1].

IIoT and Industry 4.0 are related concepts but cannot be used interchangeably. IIoT technology refers to sensors, communication & smart devices whereas the term Industry 4.0, or the fourth industrial revolution or simply I4.0 encompasses the entire digital change of the industry.

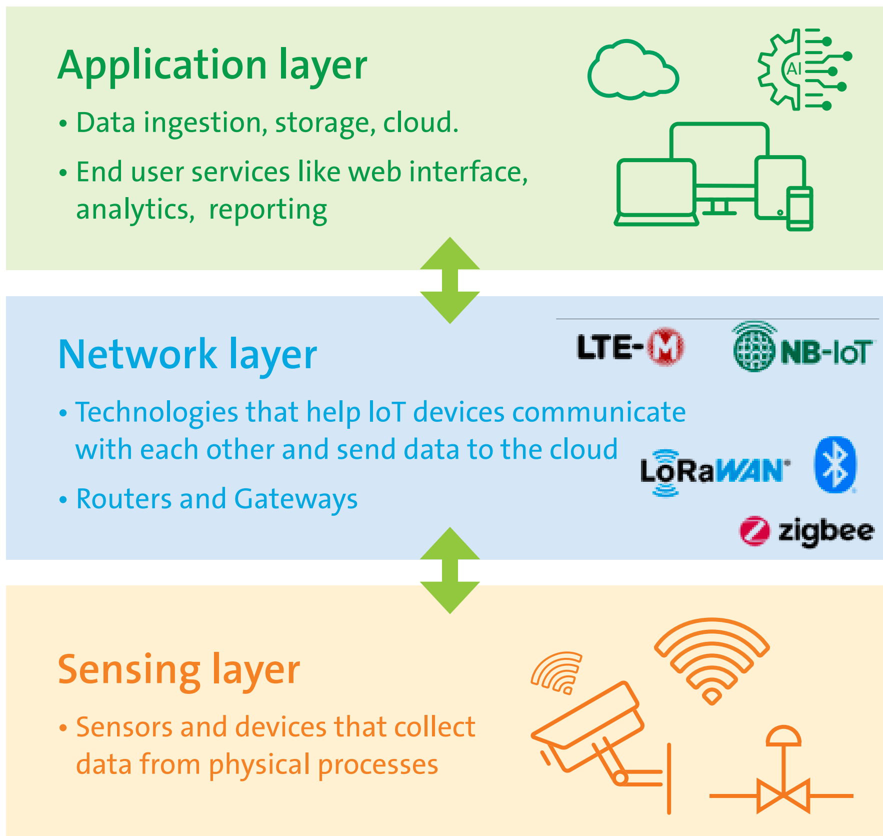
It may help to think of these concepts in a hierarchical format. The Industrial IoT is one of many emerging Industry 4.0 technologies to be adopted by manufacturers increasingly. For reference, whereas the First Industrial Revolution was dominated by basic materials like iron and steel and fuels such as coal and steam, the Fourth Industrial Revolution is driven by big data, the cloud, artificial intelligence, Industrial IoT, and several other technologies[2].

In the following sections, this paper discusses the implementation of IIoT and Industry 4.0 technologies, the challenges faced during implementation, and the applications of these technologies to improve efficiency in the cryogenic chilling and freezing industry.

Implementing IIoT solutions

The first step in implementing any IIoT application is building an IIoT framework or technology stack. Applications can be built by leveraging this framework once it has been developed. The framework must be flexible, secure, and scalable to meet the diverse technical and business requirements of different types of applications. Various IoT architectures have been proposed over the years. For example, the International Telecommunication Union proposes a 5-layer architecture that consists of sensing, accessing, networking, middleware, and application layers[3]. Jia et al.[4], Domingo[5], and Atzori et al.[6] recommend a three-layer architecture consisting of a perception layer, a network layer, and a service layer. Liu et al. [7] designed an IoT application infrastructure that contains a physical layer, transport layer, middleware layer, and applications layer. In this paper, we will discuss the widely accepted 3-layer architecture.

Three Layer IIoT Architecture



Application layer

The application layer is the final layer in the IoT architecture. This layer is responsible for ingesting, processing the incoming data, and writing it to a storage location such as a database. The application layer provides various services to the end users based on their roles such as authentication, access to collected data, analytics, reporting, alerts, device administration, and management, etc.

Network layer

The network layer or the transmission layer is the second layer in an IoT architecture, responsible for providing secure and reliable communication between the devices and the application layer (the final layer in the IoT architecture). Various wired protocols like Modbus, Profibus, PROFINET, etc., and wireless protocols like Zigbee, Bluetooth, LoRa, and Sigfox are used to communicate between devices. Connectivity to the application layer can be achieved through various cellular technologies like 4G, LTE, 5G, or the IoT-optimized LTE-M or Nb-IoT. Satellite IoT is increasingly becoming a viable option for locations where cellular networks are not available.

Sensing layer

The sensing layer, also referred to as the perception layer, is the first layer in an IoT architecture. This is where all the data originates and terminates. This layer translates the data from the physical world into a digital format using various sensors like temperature, pressure, visual & acoustic, etc. The sensors are typically connected to control boards which provide data processing, configuration, and communication capabilities. The control boards can be bought off the shelf e.g., Arduino, ESP32, Raspberry Pi or they can be custom-built to suit specific requirements. The control board connected to a sensor/actuator is referred to as an IoT node or a device. The IoT devices can communicate with each other or a central gateway to facilitate the transmission of the collected data to the network layer.

Challenges implementing IIoT solutions

Security and privacy

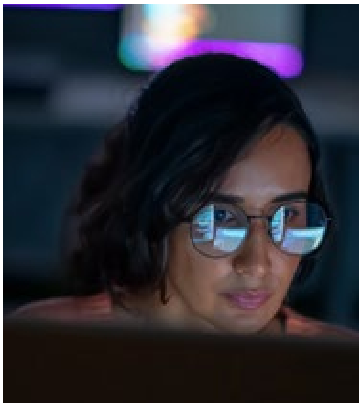
One of the biggest challenges in implementing an IIoT solution is data security and privacy. IoT systems usually store equipment/process data. Appropriate security measures must be implemented at each stage of the IoT architecture to keep this data safe and secure. The devices used to collect data at the sensing layer are typically resource-constrained, low-power devices that cannot support complex security algorithms. These devices are susceptible to physical tampering, data manipulation, and network-related attacks. The devices should be safeguarded by restricting unauthorized physical access and securing digital access to the device using good password policies. The data transmitted by the devices should be encrypted with lightweight cryptographic algorithms suited for IoT devices such as AES, DES, PRESENT, TE, etc.[8]

The transport layer or the transmission layer responsible for sending device data to the cloud is at risk from man-in-the-middle attacks (MITM), denial of service (DoS) attacks, and data stealing. It is strongly advised to use encryption techniques such as Transport Layer Security (TLS) to secure your transmission level protocol communications. Up-to-date versions of TLS with no known vulnerabilities should be used to secure communications in the transport layer.

The application layer can contain personally identifiable information (PII) along with process data. Authentication mechanisms such as Single Sign On should be used to maintain data security and privacy. Access control techniques such as Mandatory/Role-based access control etc. should be followed to ensure data security and privacy. Administrative Access rights to applications/data should be reviewed regularly. OS, anti-virus, and software patches should be regularly installed on your infrastructure.

Scalability

When implementing an IIoT solution, it is very easy to make decisions that prioritize speed of development over scalability, however, these decisions can prove costly in the long term. It is very important to design your application so that it can easily scale to meet the increasing business requirements. Features and tools should be developed to automate tasks such as new installations, device management, access control, etc.



Reliability

The reliability of an IoT system is an often overlooked topic. Users expect access to their data at all times. To ensure your system is reliable, high-availability solutions should be implemented for servers, databases, and any other infrastructure. Platform as a Service (PaaS) should be used as appropriate as these are natively highly available. All your infrastructure should be backed up regularly in multiple locations. Disaster recovery and business continuity plans should be in place.

Applications in the cryogenic chilling and freezing industry

Realtime monitoring, alerts and reporting

Almost every parameter of cryogenic equipment or process can be monitored in real-time using appropriate sensors. When these sensors are connected to an IoT platform, the parameters can be monitored remotely from anywhere in the world using a web interface or a mobile application. The web/mobile interface can be used to trend live or historical equipment data using graphs. The site management can use this information to ensure that their equipment and processes are operating efficiently. When all the equipment at a site is being monitored, bottlenecks in production can be easily identified and rectified. The tank level can also be monitored using the right sensor to ensure cryogen is always available to run your freezing equipment.

Once the data is stored in the database, a variety of alerts can be configured to monitor for parameters operating over or under the recommended limits, unauthorized/unintended changes to equipment set points, etc. Alerts can also be used to ensure the safety of equipment, for example, cryogenic equipment is prone to failure when operating continuously outside of its recommended operating temperature range, operating with a blocked exhaust, operating with blocked belts, etc.[9]. The alerts can be displayed locally and sent via email or text.

Equipment data stored in a database can be analyzed and summarized as a report. The report can contain important information related to the operation of your equipment like operating hours, setpoints, alarms generated, recipes used, whether the proper startup and shutdown process were followed, etc. Site managers can use these reports to review potential concerns and improve operating efficiency. For batch-freezing applications, with the right setup, efficiency can be reported by monitoring the quantity of the product frozen and the amount of cryogen used. Reports can also be generated for meeting regulatory requirements such as processing and storage of food at required temperatures and durations.

Predictive maintenance

Faulty or broken-down equipment can bring production to a halt. Traditionally, maintenance activities are performed at regular intervals or as and when required. Predictive maintenance takes a proactive approach and aims at fixing potential issues before they become a problem. Key parameters from critical parts can be monitored and analyzed to look for potential problems. For example, cryogenic equipment usually uses electric motors in various capacities. To decrease the number of unexpected breakdowns, multiple predictive approaches can be applied to the data collected from motors. Mechanical interpretations can be used such as Vibration Signature Analysis, Acoustical Signature Analysis, and Speed Oscillations Signature. Electrical signature analysis can be performed such as Motor Current Signature Analysis (MCSA), Expanded Park's Vector Approach (EPVA), and Instant Power Signature Analysis (IPSA)[10]. Mechanical and electrical signature analysis is not constrained to motors, it can be used to predict failure on a variety of parts such as belts, fan blades, actuators, bearings, seals, etc. Standard mathematical or machine learning models can be used to analyze data and look for anomalies that can predict a part/system failure.

Analysis of data for predictive maintenance is usually performed in the cloud since the IoT devices collecting data from equipment are usually low-powered, resource-constrained devices that cannot support complex data analysis. The results from data analysis can be displayed over a web, or mobile interface or sent back to the device for decision-making.

Using digital twin and machine learning to drive efficiency

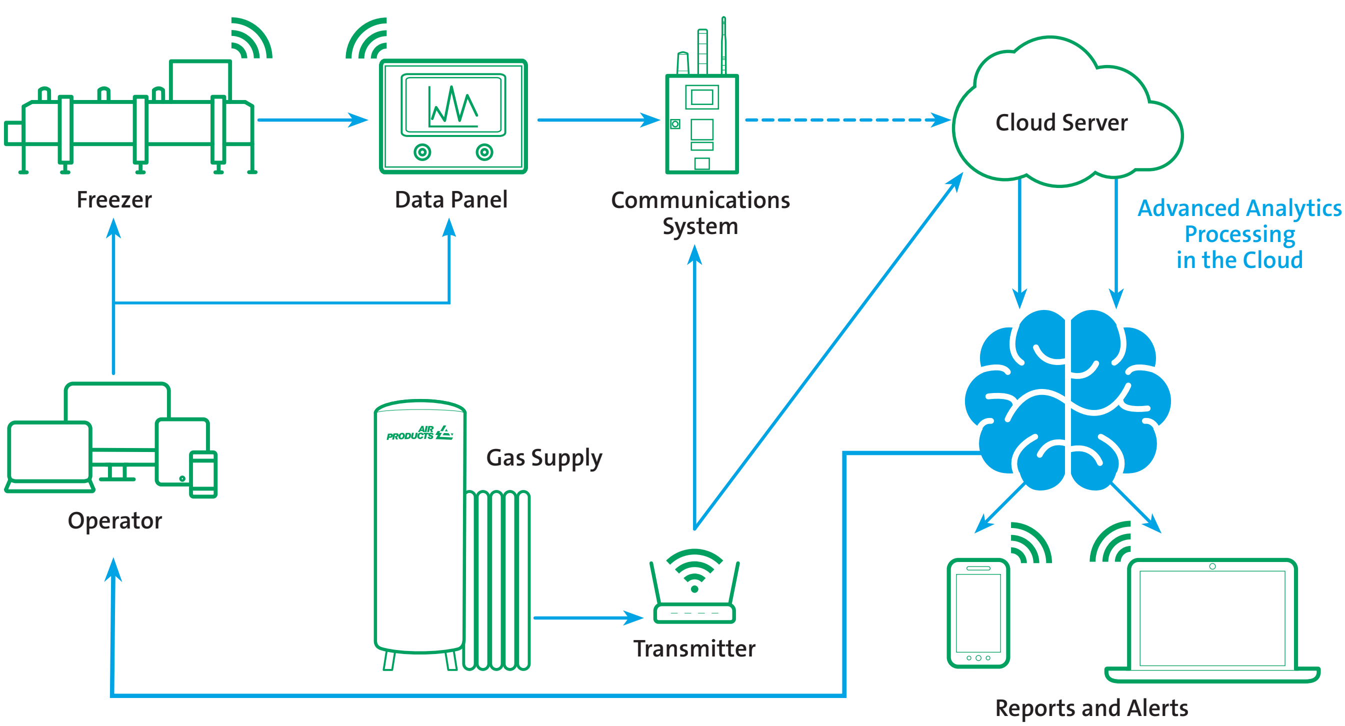
Incorporating a range of IIoT methodologies, the digital twin can be considered the pinnacle of Industry 4.0[11]. Digital Twin (DT) refers to the virtual copy or model of any physical entity or process, for example, cryogenic freezing equipment. The digital twin and the physical device or process are interconnected via the exchange of data in real time to keep the digital twin in sync with the real-world counterpart. Conceptually, a DT mimics the state of its physical twin in real time and vice versa[12]. Applications of DT in the cryogenic freezing industry include optimization, decision-making, remote access, etc. The types of digital twins that can be implemented range from the simplest (digital model) with no data exchange, to digital shadow with one-way data exchange, and a full digital twin with bi-directional data exchange[13]. A Digital Twin can display key parameters for a piece of equipment or process such as its running efficiency, and any alarms/ warnings, it can analyze the current operating conditions of cryogenic equipment and make recommendations based on best practices in real-time to ensure the equipment is running as efficiently as possible. These recommendations can be displayed over a web-based dashboard, or mobile application or the results can be sent back to the equipment to be displayed locally for operators to act on.

The large amount of data collected from the day-to-day running of equipment can be analyzed using Machine Learning (ML) models to gain insights into your cryogenic freezing process. Machine learning is a subset of artificial intelligence (AI), which uses algorithms that learn from data to make predictions[14]. By capturing production data and key process parameters for the product to be frozen, like the type of product being frozen, temperature before the product is frozen, weight, temperature after the product is frozen, etc., an ML model can make recommendations on how to solve problems like improving yield, freezing efficiency, etc. Operating conditions vary based on the cryogenic freezing application; models should be trained using appropriate datasets to ensure the model works over wide operating conditions, Self-learning models that improve and adjust over time should be used when possible.

Air Products Smart Technology

Air Products has developed its suite of propriety IIoT, and Industry 4.0 technologies collectively called Air Products Smart Technology. Almost any industrial equipment can be IoT enabled using the Air Products Smart Technology. In the cryogenic freezing industry, real-time equipment monitoring can be enabled with minimal effort using proprietary IoT devices and the data can be viewed using the apsmartview.com web interface. In addition to real-time monitoring of data, Air Products offers text and email alerts, and custom reporting to help improve production efficiency.

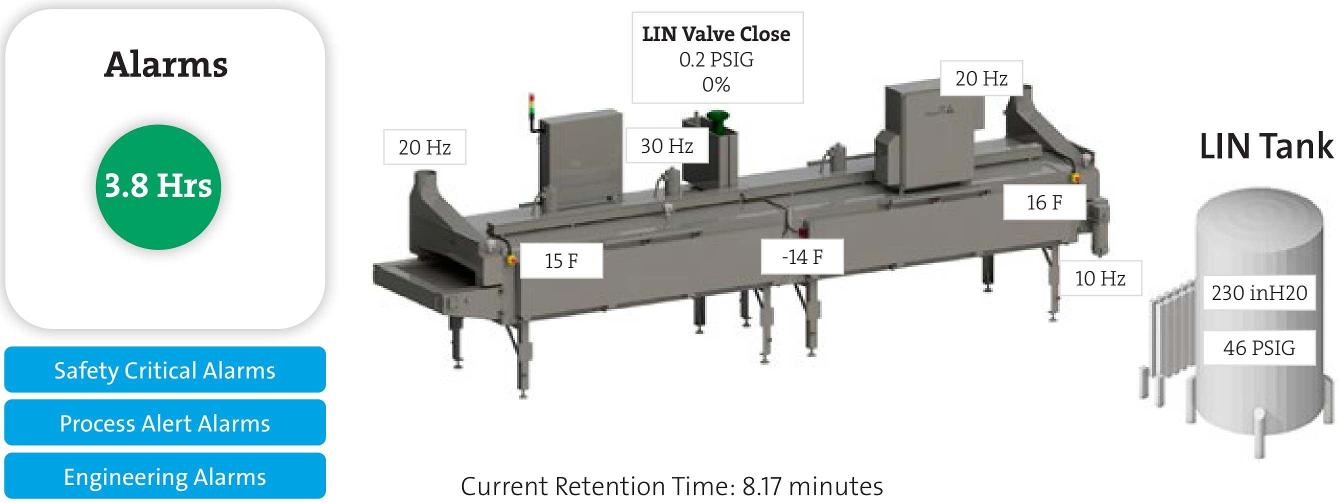
Freshline® Smart Technology Platform



Online dashboards display key equipment data, and any active warnings/alarms in an easily digestible format. The dashboards also improve the quality of technical support by helping an Air Products expert troubleshoot issues by remotely accessing current and historical equipment/process data. Using the patented Food detection camera, Air Products freezers can adjust to varying levels of belt loading by autonomously switching between appropriate operating modes and thus using every drop of cryogen effectively.

Air Products Smart Technology provides access to a live dashboard of your freezer model. Easily view your freezer's data in real-time. All data is securely stored in our cloud-based server.

Freshline® IQ Freezer – Current Mode: at Rest/Manual



Customized Smart Technology solutions also available for other freezer types (MP, IQ, IQF+), mixers, and more.

Conclusion

This paper discusses the implementation of IIoT, Industry 4.0 technologies, and the challenges associated with the implementation of these technologies. The paper then discusses the various applications and benefits of these technologies like real-time data monitoring, predictive maintenance, using ML to make recommendations on how to operate your equipment, and how these applications can be used to ensure your cryogenic equipment/processes are running as efficiently as possible to help improve operating margins.

Air Products Smart Technology offers a wide range of IIoT and Industry 4.0 solutions to help you monitor, analyze, and improve the efficiency of the cryogenic freezing process. For more information, you can visit the Freshline Smart Technology website or contact an Air Products expert using the Contact Us link.

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