CARLO GAVAZZI
Automation Components

White paper

NRG Digital solid state relays

Alleviating data challenges in Industrial Automation

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How intelligent IIoT field devices such as the NRG solid state relays can ease the implementation of IIoT systems in industrial machinery.

ABSTRACT

Following the trend of Industry 4.0, automation in different manufacturing processes has triggered the implementation of Industrial IoT (IIoT) systems and the use of data-driven predictive modelling to improve the availability of production systems. The implementation of such advanced technologies brings about a number of challenges. This paper introduces the various challenges related to the data collection, transmission and transformation and how the introduction of intelligent IIoT devices such as the NRG digital solid state relays by Carlo Gavazzi can alleviate such issues.

INTRODUCTION

The world of industrial automation is at the outset of a new trend of automation in data exchange. Also coined as 'Digital Transformation', 'Industrial IoT' and 'Smart Factories'; Industry 4.0 encompasses the ability for production facilities to exchange information autonomously. The automatic exchange and analysis of data offers unlimited opportunities for manufacturers to improve their operations, create new value and tackle timely issues.

Manufacturers may utilise machine learning algorithms to predict equipment failures and improve productivity. Resources can be utilised more efficiently by monitoring machines remotely. This information can be shared outside the production walls to improve the coordination of supply-chain activities and to design a digital twin for better analysis of machine efficiency and the impact of changes. In recent years, several automation-assisting companies changed their strategies to focus more on aiding production facilities implementing IIoT solutions in their plants. In a case study presented by one such company [1]; the implementation of an IIoT solution at a production facility resulted in machine downtime reduction by 5% each year over a 3 year period. Therefore, an aggregated 15% decrease in downtime.
As this was aptly analogised by this company, 'this means that on a production floor of 60 machines, it is like waving a magic wand and finding another 10!'

The objective of predictive maintenance is to determine the correctness of the operating states of physical assets and manufacturing processes. Normally, the propensity of machine fault detection lies in the hands of skilled engineers who through experience can perform appropriate actions to prevent an outage situation of the production system. However, as the structure and behaviour of production systems are getting more and more complex, the volume of machine data is outgrowing the clipboards and Excel sheets. Therefore, the possibility that engineers fail to respond to a machine fault timely and accurately has increased significantly.

Figure 1 Large volumes of data are too complex for manual analysis

For this reason, manufacturing companies are searching for solutions through which they can manage this big data efficiently and perform prognostic tasks intelligently.

However, deploying such advanced technologies brings about other challenges. The usual main issues in discussion are the definition of complex predictive models and data security. In this paper, we discuss other underlining challenges during the process of data collection, transmission and transformation when implementing an IIoT system.

DATA COLLECTION

Better decision making begins with acquiring data. When embarking on an IIoT project, the first question that crops up is – What data should be collected? There is no definitive answer to this question, but a good starting point is to capture as many process variables, states, and faults as possible.

A general rule for better predictive modelling implies that the diversity of the collected data increases the accuracy of the actual models. The manufacturer needs to keep a history of raw data from a variety of IoT devices. To collect enough data for big data analysis and to obtain a detailed representation of a specific process through the machine learning model, data needs to be transmitted at very fast sampling rates.

Figure 2 Data acquisition from industrial devices

The three main data generators in the automation industry are sensors, actuators, and PLCs.

Sensors – the sensor is the device which changes physical condition or action in a signal. The signal is sent to the PLC for further action. Sensors generate huge amount of data in manufacturing. The data from sensors is valuable for analysis and data-driven modelling. The implementation of a wide variety of sensors is a costly and challenging process due to the extensive wiring and the number of input cards required to process the data in the PLC.

Actuators – an actuator receives a signal from the PLC and converts it into a physical action. Actuators can offer a vast amount of valuable data for predictive modelling. The challenge is finding actuators which can extract such information.

PLCs – The PLC is the main controller in the machine which processes the inputted sensor data and controls the actuators. PLC is a programmable unit where the automation algorithm is stored and takes a decision based on the inputs from the sensors. PLCs generate valuable information regarding the control algorithm parameters which are essential for machine modelling.

DATA TRANSMISSION

Communication is the backbone of all IIoT applications. Data generated by sensors and devices should be transferred to storage and analytics systems to help visualise and optimise the plant's information.
One of the biggest challenges in IIoT is interoperability whereby a myriad of communication interfaces needs to be supported within the same environment.

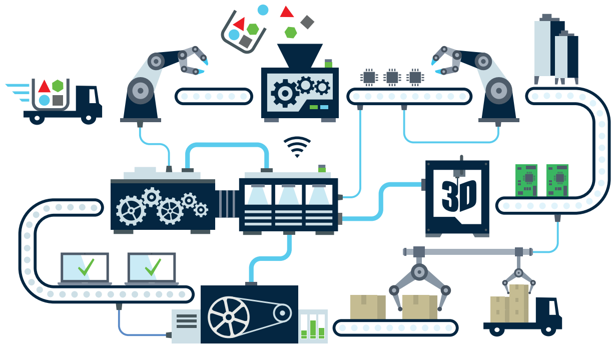

Figure 3 Interoperability in industrial automation

Suitable networking solutions are crucial for proper data collection and analysis. The immense amount of data generated has brought about new requirements on industrial data transmission [2] including:

Real-time – slow data transmission rates may affect the timely response to issues and therefore low latency data transmission is required

Data distribution – different data needs to be transmitted to different sources

Quality of service – the transmission mechanism needs to be able to provide different priorities to different applications, users, or data flows to guarantee a certain level of performance

Field level protocols have evolved to meet the requirements imposed by industrial automation. Historically, industrial communications have been developed based on serial interfaces many of which are still found in legacy systems today including Modbus RTU, CAN BUS and PROFIBUS.

To meet the new demands imposed by large volumes of data and fast communication speeds, factories are now relying on industrial ethernet protocols for field level data transfer. Ethernet based protocols offer significant other advantages over fieldbus communication including:

- **Scalability** – through flexible network topologies with a variable number of nodes
- **Maximised engineering efficiency** – through low system integration costs
- **Minimised commissioning time** – through easy device configuration from the system

There are a number of industrial ethernet protocols on the market which poses interoperability issues between different IoT devices. Could we converge to one general protocol in the future? This is highly unlikely given that different protocols tackle different use cases. For example, while the Modbus protocol is light in bandwidth and overhead consumption since it uses generic read/write functionality, EtherNet/IP is a heavier protocol incorporating much more functionality.

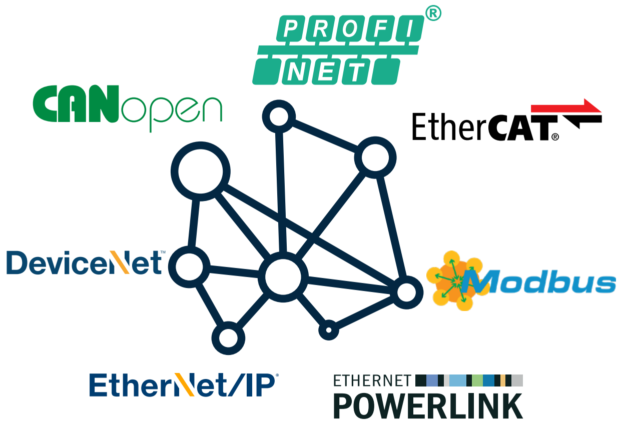

Figure 4 IIoT devices available in different ethernet protocols

According to an HMS study, the 4 protocols occupying the largest market shares in industrial automation are PROFINET®, EtherNet/IP™, EtherCAT® and Modbus TCP [3]; all offering data transfer speeds up to 100 mpbs.

PROFINET®

PROFINET® is an open, manufacturer independent protocol which is widely supported by major industrial equipment manufacturers including Siemens. The standard is maintained and supported by PI. PROFINET® uses different communication channels to exchange data with PLCs.
The standard TCP/IP channel is used for parameterization, configuration and acyclic read/write operations. The real time channel is used for standard cyclic data transfer and alarms. PROFINET® offers fast troubleshooting capabilities via an extensive diagnostic system.

EtherNet/IP™

EtherNet/IP™ is an industrial Ethernet protocol originally developed by Rockwell. It is an application-layer protocol on top of TCP/IP. EtherNet/IP™ uses standard Ethernet physical, data link, network and transport layers, while using Common Industrial Protocol (CIP) over TCP/IP. EtherNet/IP™ establishes communication from one application node to another through CIP connections over a TCP connection, and multiple CIP connections can be established over one TCP connection. EtherNet/IP™ can have an unlimited number of nodes therefore different end points in a production floor can be connected in one network.

EtherCAT®

The EtherCAT® protocol was initially developed by Beckhoff, and the standard has now been handed off to the EtherCAT® Technology Group (ETG). EtherCAT® is a very flexible Ethernet network that utilises what is known as "processing on the fly." EtherCAT® messages are passed to the next node in the ring before being processed by that node, providing the network with very fast speeds.
Real-time results have shown that EtherCAT® delivers the most deterministic response of any industrial real-time Ethernet system available.

Modbus TCP

Modbus TCP is a variant of the Modbus family of vendor-neutral communication protocols whereby, the Modbus message is transmitted between compatible devices using Ethernet and TCP/IP. Modbus TCP gives an open, accessible network for exchange of process data. It is simple to implement for any device that supports TCP/IP sockets. Modbus TCP has become popular due to its openness, simplicity, low-cost development and the minimum hardware required to support it. Since Modbus TCP does not require any certification, interoperability issues may arise in application.

At the Edge level which refers to the periphery between the physical world (devices) and the cloud lie the IoT gateways. IoT devices use a variety of the aforementioned communication protocols depending on the device, purpose and environment. An IoT gateway enables connection and communication between these devices and the higher-level system (cloud infrastructure).

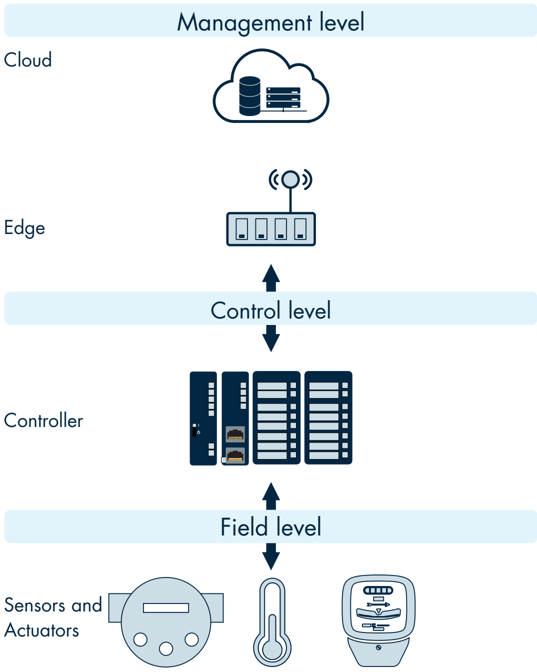

Figure 5 IIoT backbone

If a plant has hundreds of IoT devices, it is not efficient for all of them to communicate with the same resource at one time. IoT gateways can collect, process and store data in a distributed manner reducing latency and conserving network resource such as bandwidth and power usage. They can also perform advanced functions including filtering, data manipulation and data processing in what is known as edge computing. Thus, decreasing transmission, process and storage requirements.

DATA TRANSFORMATION

Stored data is not of any use to a manufacturing plant unless that data is mined to be used for increased plant efficiency and/or predictive maintenance. The manufacturing industry is a massive producer of data. Most companies are awash in an ocean of messy data that grows bigger by the second. Most collected data is unstructured and has to be mapped, cleaned and integrated before it can be utilised in predictive analysis and modelling. Data cleaning is a process to identify incomplete or inaccurate data, and then to modify or delete such data for improving data quality. Data quality determines information quality, which will eventually affect the decision- making process. Therefore, it is critical to develop efficient big data cleansing approaches to improve data quality for making accurate and effective decisions.

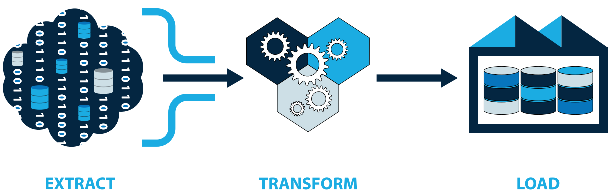

Figure 6 Data needs to be mined to be used in data driven modelling

Mapping and cleaning data has become such a big task that it leaves precious little time for analysis. In real time applications, time consumed in data integration may result in real time issues not being tackled in a timely manner.

Typically, in a manufacturing plant, data are aggregated from disparate sources at different time points using different technologies. This creates issues of heterogeneity whereby, the definition of these data varies between different sensors and domains, thus managing different types of data becomes a challenge [4] [5].
Such data management challenges include:

Data indexing – Indexing refers to the labelling of data to map it to the right process for data management and quick data retrieval when necessary and to ensure that real-time decision making corresponds to the right process.

Data integration – Multiple sensors may define similar data points in different ways. Heterogeneous data needs to be mapped to bridge the differences between two sources such that when data is acquired from a source, it is accurate and usable. Multiple sources also utilise multiple formats and languages to represent data. The mapping process becomes increasingly challenging with the immense volume of data required in IIoT.

Spatio-temporal dependency – Every data acquisition device is placed at a specific geographic location and every piece of data has a time stamp. Such dependencies need to be identified such that spatio-temporal correlation between various process variables can be analysed for better predictive data modelling.

Noise reduction – The data obtained from industrial environment is often erroneous and noisy mainly due to the interference during the process of data collection or the breakdown of sensors. Noise needs to be filtered out to ensure correct data analysis.

Once data is integrated, data scientists can provide predictive models for improved machine performance and reduction in downtime. These models can be used as a digital twin to anticipate the impact of changes on the plant floor and to predict machine component failures thereby reducing the machine downtime.

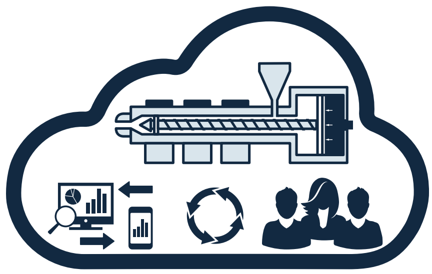

Figure 7 Utilising data for predictive modelling and designing the digital twin for performance analysis

PREDICTIVE MODELLING AND IIOT SYSTEMS IN AUTOMATED HEATING PROCESSES

In some industrial automation applications such as plastic processing, packaging machinery, semiconductor manufacturing, glass tempering and drying process; a critical part of the machine is the automated heating process. Such manufacturing plants may run 24 hours for 365 days of the year. When the equipment breaks down, the resulting downtime leads to decreased production, a waste of raw materials and compromised end-product quality.

Historically, such industries have been monitoring the heating process using current transformers (CTs) which typically indicate a fault in the heating process if current is not detected in the system. Despite aiding the troubleshooting process, using CTs is a reactive form of maintenance which still implies heavy costly downtimes. In the last years, machine manufacturers have been looking at ways to incorporate predictive modelling and IoT systems in their machinery to offer added value to their customers through data-driven decision making.

Using a data-driven approach, predictive maintenance solutions rely on machine learning algorithms to recognize complex patterns in various parameters from a wide number of diverse sensors and evaluate equipment's current condition based on these patterns. This is much more robust than just comparing static values with reference numbers. The statistical models can reliably schedule equipment services in routine maintenance plans.

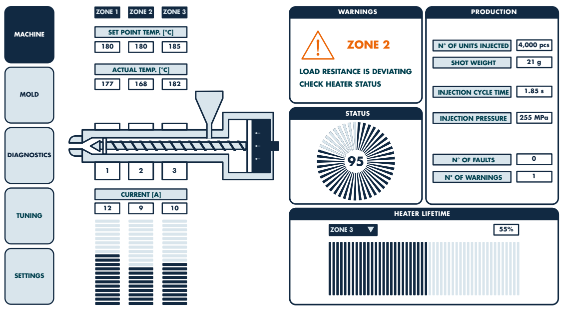

Figure 8 Visualisation of various machine parameters

To implement such solutions, IoT devices which could provide the necessary process variables at the fast rates required for data-driven modelling are required.

Implementing a variety of sensors to monitor various process variables is a costly approach considering valuable panel space, wiring time, as well as the data manipulation processes of different data formats. Finding a common communication protocol between all the different sensors is also challenging. Thus, manufacturers also have to deal with interoperability issues.

A central part of the heating process are the solid state relays which are traditionally used to actuate the heaters to control the heating process. Various solid state relays have been released which incorporate a level of sensing on top of actuating by including diagnostic features such as detection of mains loss and load loss.

What if on top of switching, a solid state relay is able to detect system parameters related to the heating process and communicate to higher level machine management?

The answer to that question is the NRG system of digital solid state relays by Carlo Gavazzi.

THE NRG SYSTEM OF SOLID STATE RELAYS DESIGNED FOR THE DIGITAL ERA

Carlo Gavazzi introduced the NRG as the solid state relay solution ready for the digital transformation currently taking place in the automation industry. The NRG is a system of IoT devices incorporating sensing and monitoring functionality of multiple parameters and fault identification on top of the switching capabilities.

The NRG also includes a communication interface which can be used for both data transfer and controlling the outputs of each solid state relay.

Initially released in a Modbus RTU interface, it is now available in the two largest communication protocols currently used in industrial automation: PROFINET® and EtherNet/IP™,with EtherCAT® and Modbus TCP following suit.

Figure 9 The NRG system including the NRG controller and the NRG solid state relays

The NRG is a bus chain of solid state relays including the:

NRG controller – which is the communication interface to the higher level controller

NRG solid state relays – which control the loads, provide data and identify faults. Up to 32 NRG solid state relays can be connected with 1 NRG controller

NRG internal bus cables – to daisy chain the solid state relays on the bus chain

Multiple bus chains can be configured in any topology for a scalable solution. Each solid state relay on the NRG bus chain is able to provide various parameters including current, voltage, frequency, power, energy and running hours. The process parameters are all available cyclically via the communication protocol, therefore data can be collected at fast rates up to 125 Hz.

The NRG inherently includes also vast diagnostic information which lends itself well to all types of maintenance plans; reactive, preventive, and predictive. For more information on the NRG diagnostic information and its application refer to the 'NRG Digital Solid State Relays' white paper available on www.gavazziautomation.com.

As a field level sensor & actuator, each NRG solid state relay collects process parameters from the heating process and communicates the information to the higher level controller (PLC). Actuating signals are passed to each solid state relay via the same communication platform. The PLC is then used to propel the data in the higher levels of the communication backbone in the machine for data to be utilised for modelling and analysis.

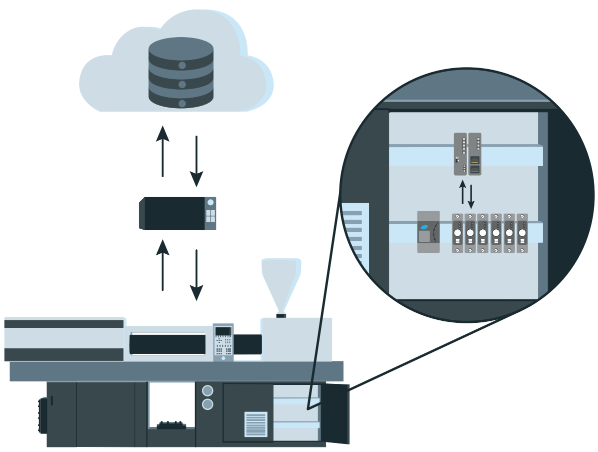

Figure 10 Integrating the NRG system in an industrial machine

5 WAYS THE NRG TACKLES DATA CHALLENGES IN INDUSTRIAL AUTOMATION

Designed specifically to be used in IIoT systems, the NRG alleviates some of the challenges related to the implementation of an IIoT system in a machine:

- With an all-in-one solution incorporating both sensing and actuating functionality in the same device, the NRG aids real time process intervention due to the easier data indexing between the sensing data and the actuator.

- With various heating process variables available from one device; data heterogeneity is minimised and complex spatio-temporal dependencies between parameters can be analysed with minimal computation expense in data integration.

- Available in a number of ethernet protocols, the NRG can be integrated seamlessly in any IIoT system without causing interoperability issues. The version with Modbus RTU, can be used to upgrade legacy systems with an added level of monitoring functionality.

- With process variables available at a fast rate cyclically, historical data regarding the heating process can be collected quicker for better predictive modelling.

- With all the functionality, both sensing and actuating, available via the communication interface; each NRG solid state relay can be accessed remotely for faster response times and better use of resources.

CONCLUSIONS

Experience has always shown that the benefits and opportunities of technological progress have always outweighed the drawbacks.

The expertise required in data analytics coupled with the challenges required to implement an IoT system have caused some trepidation in the industry, but most companies have already taken the leap forward.

Efficient machine processes, better testing and training programs through the digital twin and easier machine management through remote access is the vision of the near future.

With the introduction of intelligent IoT devices such as the NRG, the possibility of this vision has become more attainable.

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