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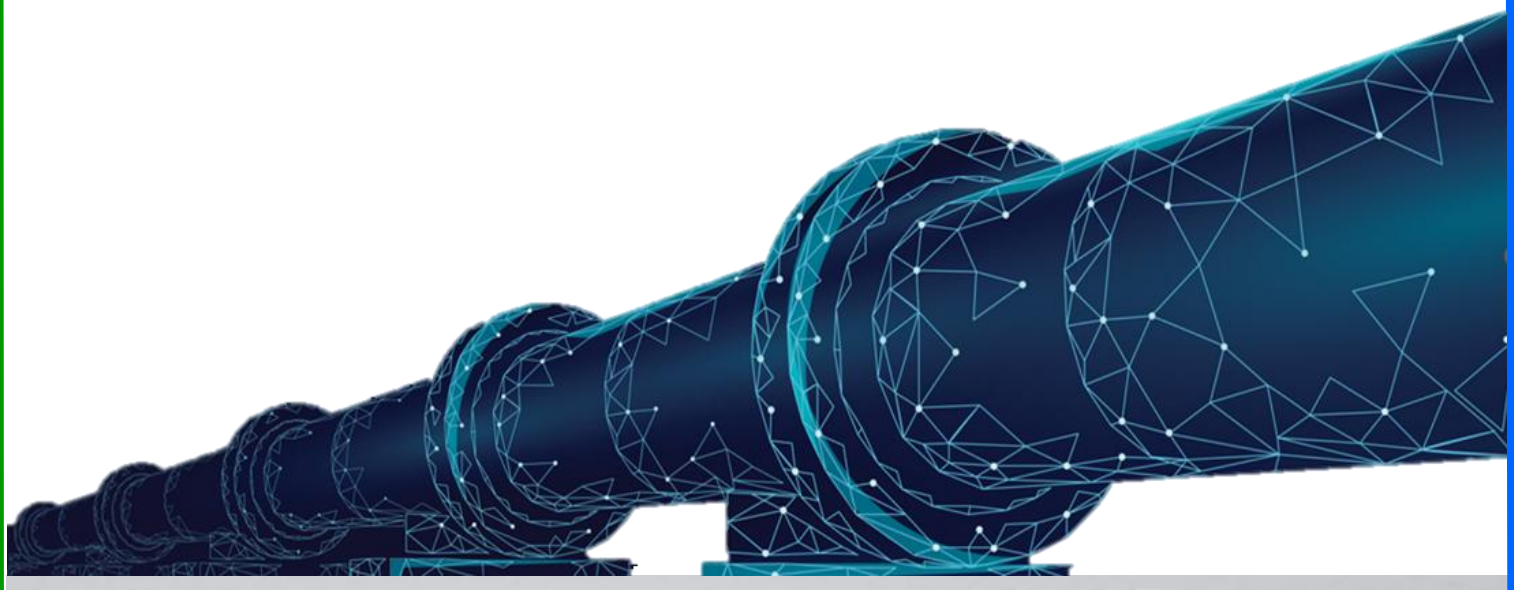
SUSTECH
INTEGRATED TECHNOLOGIES

Remote Monitoring Technology for Pipeline Cathodic Protection



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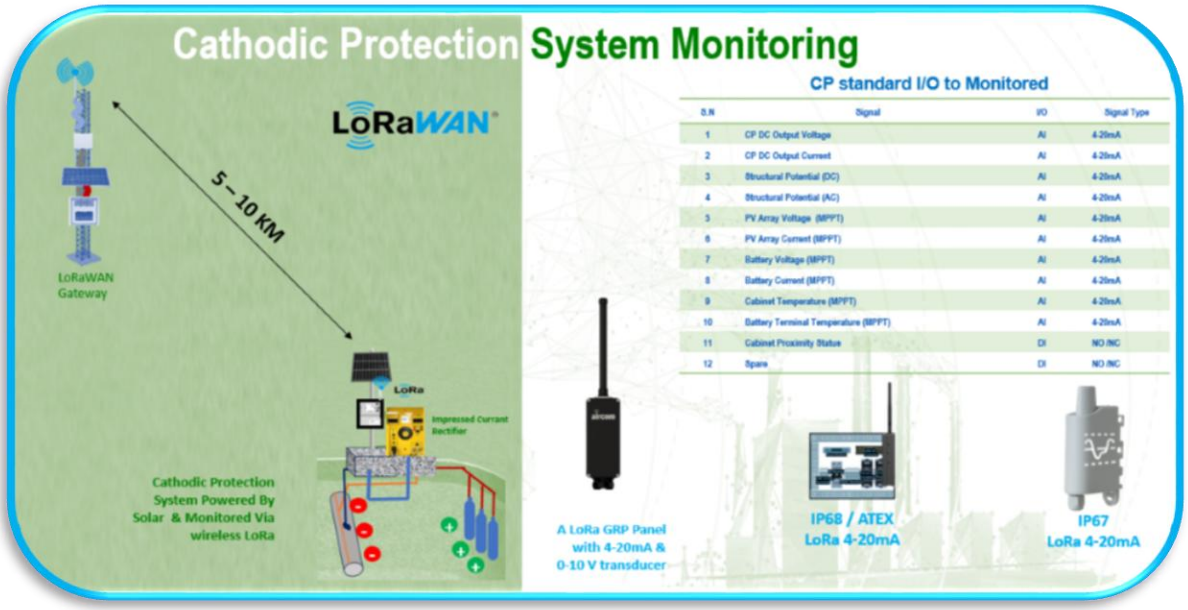


Remote monitoring of cathodic protection via LoRaWAN allows supervising systems without on-site inspection, detecting failures and optimizing the service life of metallic infrastructures.

Introduction

Ensuring the integrity of oil and gas pipelines is a significant technical challenge, particularly when these infrastructures are situated in remote, hard-to-access locations or densely populated urban environments. ADNOC's digital transformation initiatives have revolutionized pipeline monitoring, utilizing cutting-edge remote systems for impressed current cathodic protection. These advancements allow for real-time condition assessment and immediate intervention when necessary, significantly improving operational efficiency and safety.

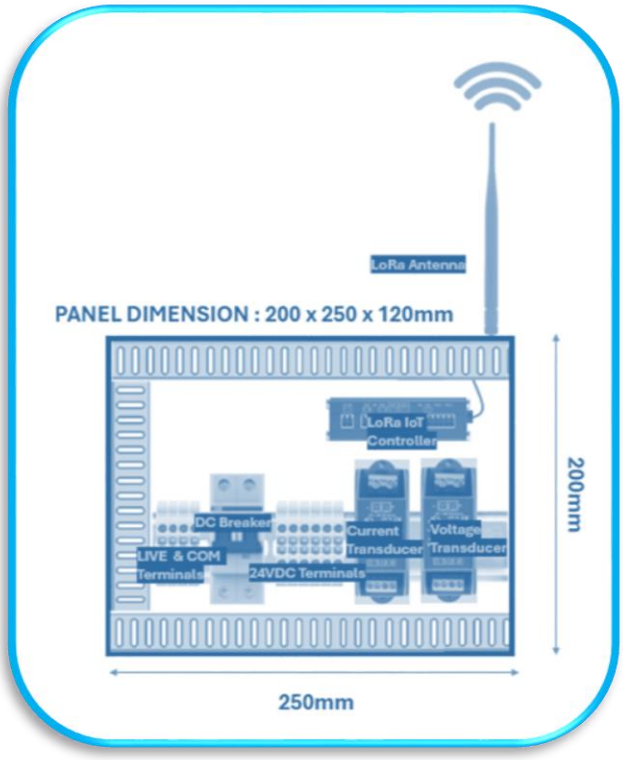
Moreover, when pipelines are exposed to stray currents, the complexity of monitoring increases. ADNOC has integrated AI-driven predictive analytics and IoT-enabled sensors into its cathodic protection systems, offering a proactive approach to pipeline integrity management. By leveraging these digital innovations, ADNOC ensures greater precision, confidence, and sustainability in pipeline operations, reinforcing its commitment to excellence in the oil and gas sector.

Remote monitoring via LoRaWAN of cathodic protection is a technique that uses sensors, software and communication systems to monitor the effectiveness of cathodic protection (CP) systems remotely, without the need for on-site inspections. This allows detecting anomalies, failures and adjusting the CP system remotely, optimizing its efficiency and prolonging the life of the protected structures with respect to a traditional Cathodic protection system.

Millions of kilometers of subway metallic pipelines, distributed throughout the world, constitute essential corridors for the transport of fluids such as oil derivatives and natural gas.

This network infrastructure is constantly exposed to corrosive threats, either from contact with the surrounding soil or from electrical interactions with nearby facilities, such as power transmission lines, power trains or cathodic protection systems of other adjacent pipelines.

SUSTECH ETO capabilities developed a complete system based on Lora Communication to meet IIoT technology for remote asset monitoring using industry-leading data collection, transmission, and analysis platforms. This results in greater operational efficiency, increased data reliability and infrastructure integrity.



Online monitoring of pipeline assets with LoRaWAN technology.

Wireless remote monitoring and control of cathodic protection systems

One of the fundamental aspects in the operation of cathodic protection (CP) systems is to ensure proper operation to guarantee protection that provides control over pipelines and reduce the incidence of corrosion. Currently, the proposed systems integrate LoRa wireless sensor network (LWSN) technology to collect potential data and perform remote data transmission.

In this system, each LWSN receives data from the environment and forwards it to LoRaWAN gateway (GW) . Then, each (GW) forwards to LoRaWAN Network server (LNS), then send the DATA to Client IIOT Platform to monitoring data, in order to obtain optimal results, less time delay and high speed to avoid corrosion.

LoRaWAN Wireless cathodic protection monitoring helps extend asset lifespan, reduce downtime, lower operational costs, and protect the environment from leaks and spills. Additionally, in many industries, collecting and reporting CP operational data is a regulatory requirement.

Although the oil and gas industry has used CP systems for decades, automating their monitoring, data collection and control through wireless devices is a relatively recent addition. Without this technology, technicians must physically travel to each rectifier and test point to verify operation and perform periodic manual measurements of the potential between the pipe and the ground.

With companies currently managing extensive pipeline networks, these inspections may only be carried out once or twice a year, leading to significant data gaps. This means that if a CP system

fails, the problem could go undetected for months, exposing the infrastructure to corrosion. In addition to the cost and time involved, these visits involve risks associated with weather, travel to remote areas, and exposure to electrical hazards. Specialized personnel must interrupt maintenance and optimization work to dedicate themselves to laborious and inefficient inspections.

the concept of LoRaWAN wireless remote monitoring of Cathodic Protection.

The operational flow can be described as follows:

1. Local transmission: Acquired data is sent from each monitoring unit (such as transmission poles) via wireless (LoRa) technologies to a LoRaWAN Gateway (GW).
2. Remote network link: From the (GW), the information is transmitted via ethernet backhaul to 5G router , depending on the location and available coverage. The image shows the connection to the LNS cloud 5G Private Network: use of existing telecommunication towers.
3. Cloud storage and processing: Data are hosted on remote servers or cloud platforms, where they are processed using analytical algorithms to identify deviations, critical conditions or risk events.
4. Field data acquisition: Sensors installed at key points of the cathodic protection system (such as test points, rectifiers or reference cells) record critical parameters such as electrical potential, current and system status.
5. Remote visualization and control: Technical personnel can access information through graphical interfaces on monitoring stations or mobile devices. This real-time visualization allows timely decisions to be made for maintenance or adjustment of the CP system.

Factors to consider when choosing a remote monitoring system for CP

Selecting an efficient remote monitoring system involves considering multiple variables. A malfunction not detected in time can seriously compromise the integrity of the network. Three factors are critical:

- Flexibility: These devices must offer hi availability connectivity options: by designing minimum 2 GW cover the LoRa end node , allowing them to operate even in areas with limited coverage; guarantee fast, secure and easy access to data; and integrate seamlessly with pre-existing systems, expanding their operational capacity.
- Maintenance: the IIOT application have algorithm and analyses of the data for Beter predictive and awareness via email.

What are the advantages of remote monitoring of cathodic protection?

The importance of remote monitoring lies in its benefits, which are discussed below:

- Real-time measurements: An advanced system allows measurements to be taken every second, all day long, 365 days a year, capturing details impossible to obtain through manual inspections.
- Accurate anomaly detection: Data analysis allows rapid identification of specific faults: from rectifier downtime to anode resistance variation or damage to unidirectional drains, speeding up corrective interventions and optimizing maintenance programs.
- Electrical interference mitigation: In areas affected by stray currents, continuous remote monitoring can capture critical conditions that might go undetected in brief inspections. Simultaneous measurement of ON potential, IR-free and alternating currents is key to assessing regulatory compliance and the effectiveness of mitigation devices.

Technological innovations in CP remote monitoring

LoRa long range technology, make it possible to visualize multiple variables, automate analysis and generate alarms. The more sophisticated the system, the higher the quality of the data obtained and the more efficient the management of the CP system, reducing on-site inspections to those strictly necessary.

Systems such as LoRa connectivity , as long range and have long life battery , allow up to 10 of continuous operation without changing the battery .

Digitization has profoundly transformed the implementation and management of CP systems. Smart sensors, SCADA systems and real-time analytics improve monitoring accuracy

SUSTECH as a LoRaWAN solution provider extensively work LoRaWAN technologies, such technology extend asset life, preserve public safety and minimize environmental impact.

Selecting and developing the write design enables constant monitoring of Oil and Gas pipelines, even beyond corrosion.

SUSTECH Solution have option to design and deliver The system can operate uplink and downlink modes, using LoRaWAN long-range communications, making it an essential tool for operators managing geographically dispersed pipeline networks.

Conclusions

Cathodic protection remains a fundamental barrier against corrosion in pipelines and buried pipelines, but its effectiveness depends directly on continuous operational control. The implementation of remote monitoring systems for cathodic protection transforms reactive maintenance into a predictive strategy, minimizing failures, optimizing resources and extending asset life.

In an era where connectivity and data are strategic, adopting advanced monitoring technologies is not an option, but a necessity. Companies that integrate intelligent solutions into their integrity programs not only comply with regulations, but also lead in efficiency, sustainability and operational reliability.