APPROACHES TO MONITORING OIL AND GAS PIPELINES

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Abstract: *Effective monitoring of oil and gas pipelines is critical to the safety of both the energy infrastructure and the surrounding environment, making it an integral part of any nation's energy system. Protecting the energy system and the environment requires thorough monitoring of oil and gas pipelines, recognizing their indispensable role in a country's overall energy infrastructure. Adequate monitoring of oil and gas pipelines is essential as they are woven into the energy system of any nation and play a critical role in preserving the environment through which they pass. There are different approaches for monitoring oil and gas pipelines, the main objective of which is to have their conditions in real-time, especially in cases where they are exposed to various natural events, such as seismic effects, movements of tectonic blocks, karsts, landslides, frost and other natural phenomena, which often lead to the accidental destruction of oil and gas pipelines. This paper provides an analysis of the various approaches used to monitor major oil and gas pipelines.*

Key words: reactive and proactive monitoring, SCADA, oil and gas pipelines

1. INTRODUCTION

To better understand the importance of oil and gas pipelines to human civilization, it is best to look at all the wars of the last 120 years that have been fought over the resources transported by these pipelines (Meierding, 2020). The struggle for resources such as oil and gas has its own direct and indirect effects, which can be seen in the analysis of the most recent conflict in Europe (European Parliament, 2023). In addition to the economic, social and political aspects of this pipeline, it should also be considered from a technical point of view.

The history of oil and gas pipelines can be traced back to the mid-19th century when the first gas pipeline was built in the United States of America (USA). The first pipeline was used to transport natural gas from a well in Fredonia, New York to a nearby production facility. However, it was not until the early 20th century that oil and gas pipelines began to be used on a larger scale to transport crude oil and natural gas. The first major oil pipeline in the United States was built in 1917. This oil pipeline, which was over 200 km long, was built by the Texas Company (Texaco). Many more were built after this, and by the 1920s pipelines had become a common method of transporting oil and gas across the U.S. In the years that followed, pipelines became longer and more complex, and their construction and operation had to be constantly monitored. The first transcontinental pipeline was built in the 1950s, and by the 1960s pipelines were being used to transport oil and gas across international borders. Today, oil and gas pipelines are a critical component of the global energy infrastructure, with millions of kilometers of pipelines transporting oil and gas around the world. The transport of crude oil, natural gas and other petroleum products is an essential part of the supply chain for the entire energy infrastructure, not only of individual countries but of the entire world (Smirnov, 2023, Tusiani 2005, Andrews 2014).

In many cases, oil and gas pipelines are part of a complex technical system. There are generally two main approaches to monitoring technical systems: reactive monitoring and proactive monitoring. These two main approaches can also be applied to the monitoring of oil and gas pipelines. In addition, oil and gas pipelines can be viewed as a complex network of sensors and communications. Reactive monitoring in a technical system usually means the detection of problems or failures and the reaction to them after they have already occurred. This approach is typically based on using a variety of sensors, alarms and feedback mechanisms to detect any deviation from the normal operating conditions. This means, when a problem is detected, alerts or notifications are triggered to prompt immediate action for diagnosis and resolution. In other words, reactive monitoring aims to minimize downtime and mitigate the impact of failures by responding quickly to problems as they occur (Dilman, 2002). Proactive monitoring focuses on the detection and resolution of potential problems in a technical system before they result in failure or downtime. This approach involves the continuous monitoring of system performance and the analysis of data trends in order to identify patterns or indicators of impending problems. Proactive monitoring allows preventive action to be taken to minimize the likelihood of system failure or disruption by identifying early warning signs (Koliousis, 2007).

In most cases, various SCADA (Supervisory Control and Data Acquisition) platforms are used to monitor, control and collect data on the condition of oil and gas pipelines. Most of today's SCADA systems allow you to use both main approaches to monitoring oil and gas pipelines (Bailey 2003, Yadav, 2021).

2. DATA ACQUISITION

Both approaches to monitoring oil and gas pipelines are based on data acquisition. The main source of data is sensors installed to measure/detect the conditions (like pressure, temperature, and flow) of pipelines, but also data can be collected from other elements in pipelines, such as networks, pumps, transfer terminals, ... (Prodanovic, 2021, Sarang, 2023, https://janaf.hr/). The choice of sensors depends on the specific requirements of the pipelines and the type of data that is needed for monitoring, control and maintenance purposes. In addition to these conditions, other data related to the production of elements in pipelines are also very important, especially in the approach of proactive monitoring (Klasnja 2019, Stankovski, 2020, Stevanov, 2022). Some of the most common sensors in use for monitoring oil and gas pipelines are:

- pressure sensors,
- flow meters,
- temperature sensors,
- level sensors,
- positions sensors
- ultrasonic sensors
- optical sensors,
- corrosion sensors,
- vibration sensors,
- voltage sensors,
- current sensors,
- location sensors.

Communication between sensors and the monitoring system for oil and gas pipelines is crucial/critical for reliable and efficient data transfer between these entities. Of course, the type of communication technology used will depend on the type of sensors, distance, communication channels, monitoring system, etc. Typically, the monitoring systems for oil and gas pipelines use wired and wireless sensor communications for data transfer.

Wired communication involves the physical connection of sensors to the monitoring system using cables. Depending on the type of sensors, distance, communication channels, security and other requirements, different protocols are used for data transfer, such as Modbus, Profibus, DNP3, Ethernet/IP, PROFINET. Usually, we can find different protocols in one monitoring system.

Wireless communication is the transfer of data between sensors and the monitoring system without the use of cables. Depending on the type of sensors, distance, security, protocols and other requirements, radio waves, GSM, WiFi, Bluetooth, satellite communication, etc. can be used for data transfer. Usually, we can find different wireless communication channels in one monitoring system.

Other aspects of data transfer are also very important, such as redundancy and data integrity. Redundant communications, redundant servers and backup databases are some techniques used to increase redundancy. To ensure quality data integrity, some secure communication protocols are used, such as encryption, which protects data from unauthorized access.

Having in mind the consequences that can have on the operation of oil and gas pipelines, it is often not possible to identify the conditions that lead to incidents without adequate data. Unfortunately, the number of incidents is high, as is the impact on the pipeline systems themselves and the environment in which they are located (Shan 2017, Dröge 2018, Lu 2023). Figure 1 shows the number of incidents per year in Europe for gas pipelines for the period 1970-2016. Besides technical conditions, the main factors that cause significant damage to pipelines are geological and hydrological natural phenomena (Lu, 2023).

These factors create loads that are short-term or transient and are difficult to predict at the design stage, requiring constant monitoring of their operation.

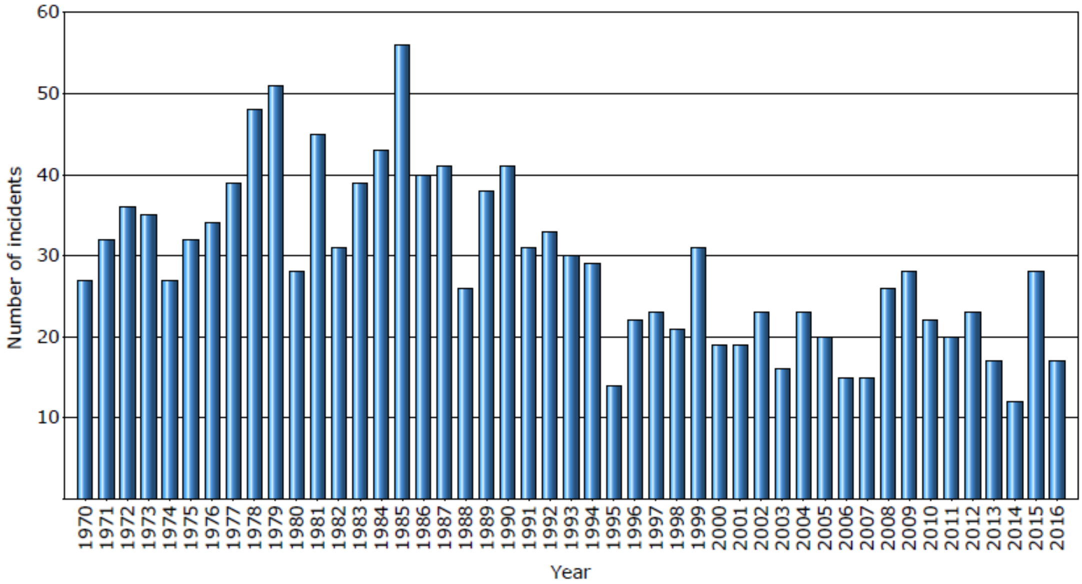

*Figure 1: Number of incidents per year (*Dröge 2018*)*

Despite the fact that there are a significant number of systems for monitoring oil and gas pipelines, research continues and in recent years one of the main focuses has been to develop/add new functionality for predicting undesirable conditions.

3. DISCUSSION

One of the main objectives of proactive monitoring is to prevent system downtime. There are several aspects of proactive monitoring that contribute to achieving the main objectives. The first is mentioned in the last section and relates to data acquisition of key conditions in oil and gas pipelines. Monitoring specific parameters or indicators that reflect conditions in pipelines can detect early signs of failures that lead to downtime. The second is preventive maintenance, which refers to maintenance activities that are scheduled based on the condition of the system and failure probabilities to reduce the likelihood of unexpected failures and downtime (Basri 2017). The third is the use of various predictive analytics techniques. These techniques use historical data and algorithms to predict future behaviours, detect anomalies and predict potential failures or performance degradation (Feblowitz 2013, Kumar 2018).
Based on research conducted in NIS (Naftna indsutrija Srbije), as well as on the basis of available literature, one of the important trends in proactive monitoring is the use of digital twins (Wanasinghe, 2020). The deployment of digital twins is still at an early stage in the monitoring of oil and gas pipelines and it needs time to understand the full potential of digital twins. The current status of research activities in the monitoring system of oil and gas pipelines in NIS shows the wide scale of opportunities in the deployment of digital twins and how their importance in proactive monitoring and predictive maintenance. The initial results are very encouraging and show that digital twins can be easily implemented in the existing SCADA system and that digital twins with historical data can reliably predict alarm situations.

4. CONCLUSIONS

Successful monitoring of oil and gas pipelines ensures energy stability and at the same time prevents damages or quickly repairs damages that can significantly impact the environment in which they are located. Proactive monitoring is an approach that enables the use of various methods of data analysis in addition to preventive and corrective maintenance so that all the benefits of predictive maintenance can be exploited.

The analysis of approaches to the implementation of oil and gas pipeline monitoring presented in this paper shows that we are entering a period in which particular attention will be paid to the collection, analysis and use of data.

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