Supervision System and Vibration Control of a Turbo-Compressor 100TK-51(Skikda Refinery) Using In touch-Triconex Platform

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Abstract: Industrial maintenance has become a major issue for both the sustainability of machinery and boosting the production rate and energy efficiency of industrial facilities. The present work is focused on the creation of a monitoring system for a rotating machine (100 Tk-51) in Skikda Refinery. The system offers a vibration analysis paired with a safety algorithm implemented in a higher-performance PLC (TRICONEX). The HMI (Hamman Machine Interface) is designed to employ the Intouch platform. By incorporating sophisticated vibration monitoring, the system enables early diagnosis of mechanical difficulties, directly combining maintenance activities with vibration data to avert possible breakdowns. The system's goal is to deliver a powerful tool that not only prevents accidents but also evaluates any weaknesses before any problems arise, ensuring the equipment's continuous and efficient functioning.

Keywords: Predictive maintenance, rotating machine, vibration analysis, spectrum analysis

1. INTRODUCTION

Rotating machinery is used in a variety of industries. This includes equipment such as motors, pumps, generators, compressors, turbines, and more [21]. The turbo-compressor is the heart of any unit in a petrochemical plant. Its shutdown leads to production losses and increased maintenance costs it was between 15% and 60% of the manufacturing cost of the final product [15]. Therefore, maintenance is key to ensuring safety, efficiency, and reliability [1-2], it maintain the safety instrumented systems (SIS) to identify hazardous events, processes run safely and efficiently. A SIS comprises input elements (e.g., sensors), logic solvers (e.g., programmable electronic controllers [PLCs]), and end elements (e.g., safety valves, circuit breakers, and alarms) [14].

There are three primary forms of maintenance:
Preventive Maintenance: This comprises frequent inspections and scheduled maintenance to prevent problems before they occur. This strategy minimizes the chance of occurrences by forecasting future obstacles. [6].
Corrective Maintenance: This reactive procedure takes place after a failure has happened. It comprises repairing or replacing damaged components, but may lead to unplanned interruptions and greater dangers if the failures are serious [6].
Predictive Maintenance: allows real-timemonitoring of equipment state and anticipates errors before they arise. This boosts machine availability and lowers interruptions [6] and [20]. Predictive maintenance procedures utilize vibrational analysis to tackle projected vibration concerns by utilizing electronic hardware and software for vibration monitoring [20]. discriminate between routine signals and those indicating concerns with equipment functioning [7]. Vibration monitoring programs may utilize one or more of the following methodologies Route-based: Vibration data collection sites are discovered and mapped out on a route. Technicians move from point

to point, capturing data using an accelerometer with a VAC output and portable data collection equipment [8]. Permanently placed: Accelerometers with a VAC output are permanently installed and hooked back to a data collection system [8] [9]. Process monitoring: vibration transmitters with a current output are permanently placed and hooked back to a programmable logic controller (PLC), distributed control system (DCS), or supervisory control and data acquisition (SCADA) system [8-9]. After obtaining all relevant data, the second step contains analysis. This stage entails using computer algorithms and software to identify vibration patterns and data trends, as well as comparing the obtained data to defined criteria and guidelines. Maintenance teams may use several ways to assess vibration data, including: Time domain analysis studies the raw vibration signal across a time range. Technicians may produce and examine several data points (e.g., maximum amplitude, crest factor, skewness, root mean square (RMS), etc.) directly from the time waveform. This technique is successful in recognizing transient incidents such as crashes or rapid shocks [9]. Frequency domain analysis: The Fast Fourier transform (FFT) is used to convert the time-domain data into a frequency-domain signal. This method makes it easier to detect certain frequencies that are linked to mechanical defects in the resulting frequency spectrum [9].

Envelope analysis: This approach, also known as demodulation, detects early bearing failures by extracting the high-frequency impact signals generated by damaged bearings from the overall vibration signal [9]. Modal analysis is a more sophisticated method aimed at discovering a machine's intrinsic frequencies, mode shapes, and damping properties. Analysts gain knowledge of a machine's dynamic performance and may detect probable structural faults or resonance concerns [9]. Regular maintenance of industrial equipment maintains operational reliability and safety, including components like sensors and actuators that play key roles in automation and control systems [2–5]. These systems, monitored by contemporary technologies like SCADA and controlled by MES and ERP, easily incorporate repair operations into larger operational management strategies, enhancing both equipment performance and overall production efficiency [15].

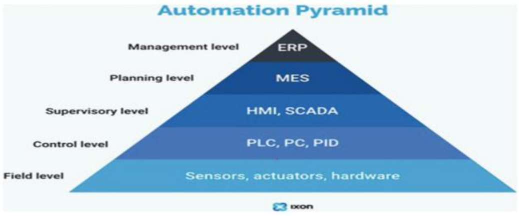

Fig *1* Automation pyramid

PLCs and SCADA-based automation spread outside the industrial sector, with PLCs being the norm for industrial process control owing to their longevity and high mean time between failures. These controllers address difficult control concerns, demanding consideration for time restrictions, safety, and dependability. PLCs are often used to control field equipment, offering integrated communication and diagnostic features. They are connected to field equipment via wired and wireless communication protocols, providing efficient and flexible automation [16] [17].

In this context, vibration analysis is experiencing significant advancements due to developments in computer science and signal processing. The purpose of such monitoring is to ensure installation safety by triggering alarms when vibration levels reach values deemed excessive for proper operation or integrity [11]. This reliable and available control system is based on programmable logic controllers such as Triconex (probability of failure on demand = 2.5 x 10^-5) for secure and high-level operation (Safety Integrity Level SIL3).

Therefore, our study aims to demonstrate the significance of implementing conditional maintenance, particularly vibration analysis

on the turbo-compressor group 100-TK-51 within the Magnaforming unit. We then plan to implement protection system blocks related to this equipment in the Triconex environment with a supervision Human-

Machine Interface (HMI) developed on the Wonderware InTouch 10.1 platform description of the system (100TK-51).

2. System Description:

The system includes a centrifugal compressor and turbine, a lubrification system, and safety and security programs implemented through Siemens PLC and the corrective Distributed Control System (DCS).

2.1. Centrifugal Compressor:

The recycled gas compressor is one of the most important pieces of equipment in the magnaforming unit; it is a two-stage centrifugal compressor driven by a high-pressure steam turbine by coupling. It consists of fixed and rotating elements that ensure gas compression from suction to discharge pressure [10] [11].

The PM gas input suction flange reaches the rotating parts and thus gets a high speed subject to centrifugal force, which allows it to pass from the low-pressure section to the high-pressure section. It is then directed by the diffuser and the rotor channel to the 2nd wheel, then the 3rd, 4th, 5th, and 6th wheels. Near which the gases leave the compressor by the EXHAUST VALU

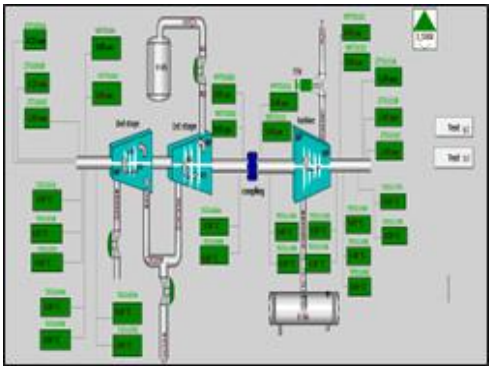

Fig 2 Turbo-Compressor constitution

2.2. The Driving Device Steam Turbine:

The TK-51 compressor is driven by a seven-stage Model 2SNV-6 steam turbine and four condensing-type intake valves. The turbine is coupled directly to the compressor and rotates at the same speed as it. It allows for the economic regulation of the flow rate of the latter by a simple variation of its rotation speed [12].

2.2.1.Security System:

The 100 TK-51 compressor is equipped with a protection system against any anomaly such as excessive vibration, low pressure, high temperature...etc., causing malfunction or technical problems.

2.2.2.Oil Lubrification:

The lube oil system supplies oil to the compressor and driver bearings, as well as the gears and couplings. Oil is drawn from the reservoir by pumps and fed under pressure through coolers and filters to the bearings, draining back to the reservoir afterwards. The reservoir is designed for fluid circulation eight to twelve times per hour and may have thermal sensors and temperature controls. The main oil pump circulates the lubricant during operation, with an auxiliary pump acting as a standby. Relief valves and check valves are used to protect the pumps. Heat from friction is transferred to coolers, either air-cooled or water-cooled. A pressure-regulating valve maintains constant oil pressure, while a pressure switch activates the auxiliary pump if pressure sensor falls too low. Filters clean the oil and are monitored by a differential pressure gauge. Orifices regulate oil flow to each bearing, and temperatures and pressures are measured at key points in the system and often recorded for monitoring [12].

2.4. Vibration Protection:

Sensors are experts in vibration sensing and can recommend suitable methods and instrumentation for rotating machinery, from small pumps to large power turbines. As a sensor designer and manufacturers, we have a thorough knowledge of the sensing technique and any limitations in terms of application [12].through the processes of reproduction, crossover, and mutation among existing organisms. These concepts in the theory of evolution have been translated into algorithms to search for solutions to problems in a more “natural” way.First, different possible solutions to a problem are created.

These solutions are then tested for their performance (i.e., how good a solution they provide). Among all possible solutions, a fraction of the good solutions is selected, and the others are eliminated (survival of the fittest). The selected solutions undergo the processes of reproduction, crossover, and mutation to create a new generation of possible solutions (which are expected to perform better than the previous generation). This process of production of a new generation and its evaluation is repeated until there is convergence within a generation [12].

These mechanical causes of vibrations include imbalances, misalignments, looseness, bent shafts, and bearing defects, among others [21]. By measuring and analyzing machine vibrations, technicians can better assess the health and performance of equipment, enabling them to pinpoint issues and implement corrective actions, so we should apply The objective of vibration analysis in petrochemical plants is to detect and monitor machinery vibrations to ensure early fault detection, optimize equipment reliability, enhance safety, minimize downtime, and comply with regulatory standards in order to detect the set of anomalies and identify their origin by vibration analysis technique. [12-13]. The vibration measurement of the global level value (NG), which is based on the detection of possible defects that disrupt the operation of the machines, Frequency analysis that allows identification and localization of the defect on the machine if it exists.

3. Emergency shutdown system

An emergency shutdown system is used in industry to promptly and automatically bring a process to a safe state in the event of an exceptional scenario or when safe operating conditions have been transgressed. Both the automatic emergency shutdown system (ESD) and the manual shutdown (MS) can use the same detector for monitoring abnormal parameters/events and perform the shutdown using the same valve [18-19]

4. Methodology:

Most of the vibrations of the machines can be mechanical, electromagnetic, hydraulic, etc.; they are transmitted to the structure through the fasteners. It is easy to understand that the best measuring points in the context of conditional maintenance on machines are bearings. Configuration of the machine to be monitored: The turbocharger unit 100-TK-51 contains four bearings (two for the compressor and two for the turbine).

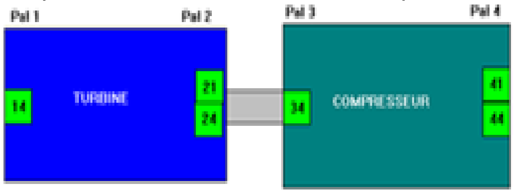

Fig. 3 Position of measuring points

The vibration amplitude is measured in two directions: radial oblique and axial which are distributed as follows:

Bearing I: the radial oblique measurement point (14)

Bearing II: the axial measurement point (21) and the radial oblique point (24).

Bearing III: the radial oblique measurement point (34)

Bearing IV: the axial measurement point (41) and the radial oblique point (44).

4.1.1.Global Vibration Level:

The evolution over time of the vibration acceleration amplitude will be represented by several curves. The presented curves show the slope of the degradation, which will allow the estimation of a failure date.

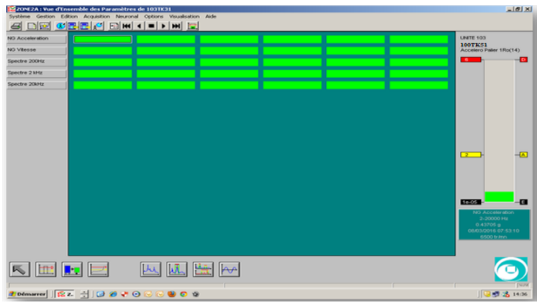

Fig.4 Overall level of good functioning

4.2. Study of vibration spectrum measurements.

In our work, we implemented an analysis method aimed at detecting and identifying anomalies while showcasing the significance of conditional maintenance through vibration analysis

4.1.2.Turbine side:

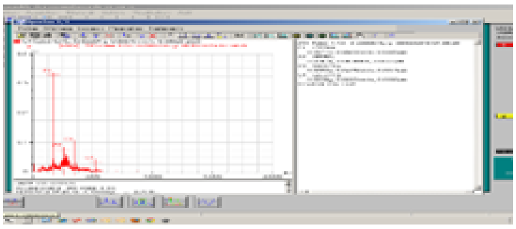

Fig.5 Bearing II: oblique radial measurement (point 14)

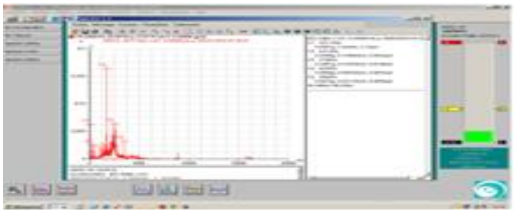

Fig.6 Bearing II: The axial measurement point (21)

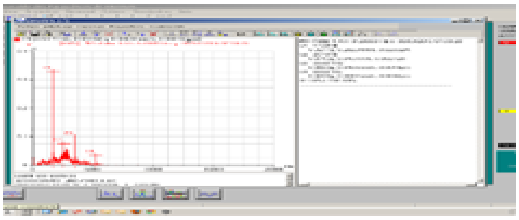

Fig.7 Bearing II: The radial oblique point (24).

4.1.3.compressor side:

Fig.8Bearing III: the radial oblique measurement point (34)

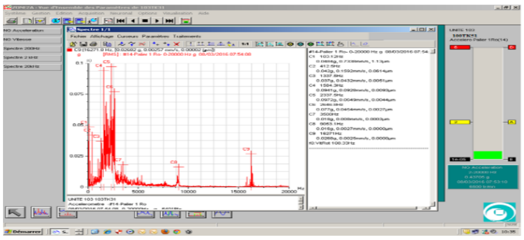

Fig.9 Bearing IV: the axial measurement point (41)

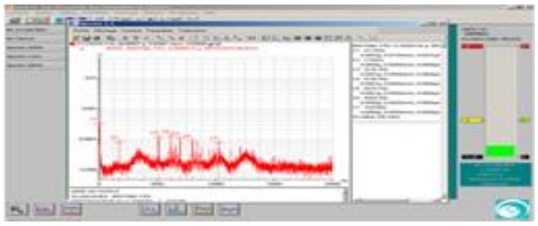

Fig.10 Bearing IV: The radial oblique point (44).

4.2. Interpretation:

Absence of Significant Peaks: Despite the presence of the C1 peak, which aligns closely with the characteristic frequency of unbalance faults, the overall vibrational values of the peaks in the spectrum are not notable. Without clear indications of peak amplitudes, it's challenging to conclusively identify any faults.

Observations on Bearing II: Examination of the spectrum during the measurement at bearing II (Roon point) reveals that the frequency peaks do not correspond to any turbine-side faults. Additionally, the similarity between the vibrational values observed here and those recorded axially on the turbine side suggests the absence of faults.

Lack of Significant Modifications: There are no significant alterations observed in comparison to previous curves. Consequently, the peaks do not suggest the presence of any faults.

5. Minimal Vibrational Values:

The vibrational values of the appearing peaks are notably low, with some amplitudes nearly approaching zero. This indicates the absence of faults on the compressor side.

In summary, the absence of significant changes in vibrational values and the similarity between turbine and compressor-side measurements suggest the absence of faults in the system.

5.1. Simulation and Result

The subject of an Emergency Shut-Down (ESD) simulation involves ensuring the

complete shutdown of the turbocharger 100-TK-51 in the event of control system disruption, anomaly detection, or other potentially hazardous process conditions. This measure is implemented to safeguard personnel, equipment, and the environment..

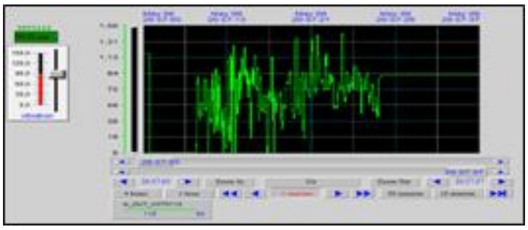

Fig.11 We conducted a simulation on the evolution of vibration values from the transmitter VXT-5112

When the safety thresholds, set at 102µm in our case, are exceeded, we observe alarms triggered on both the VXT-5112 transmitter and the interlock I-5102. This results in the compressor shutting down, and a red line appearing on the curve, indicating the presence of a defect.

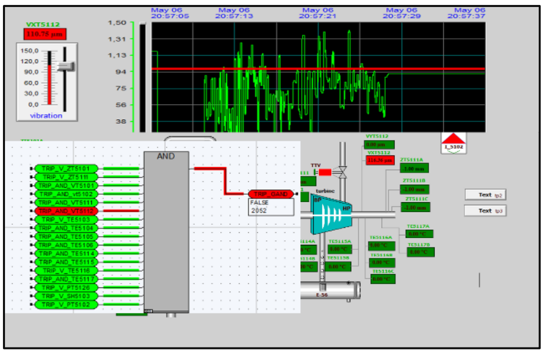

Fig.12 Alarms triggered on both the VXT-5112 transmitter and the interlock I-5102.

In this case, an HMI InTouch view of the turbo-compressor lubrication system is provided when no alarm is triggered.

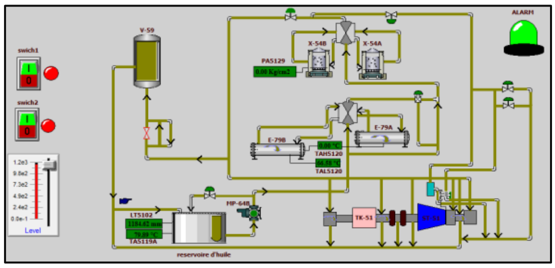

Fig.13 HMI In Touch of 100_TK_51 Lubrification System

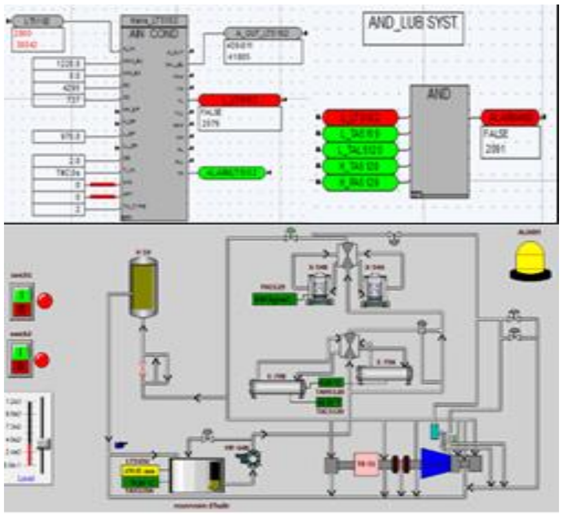

Fig .14 Simulation of the system on one alarmof the transmitters LT_5102, TA_5119, TA_5120, TAL_5120, PA_5129.

The validation of the results obtained confirms
the effectiveness of this method in safeguarding the turbocharger. Through this approach, we can significantly enhance the safety of the entire process by promptly identifying and addressing potential defects. This not only ensures the reliability of the turbocharger but also contributes to the overall operational integrity of the system.

6. Conclusion

In conclusion, our analysis highlights the pivotal role of vibration analysis in predictive maintenance methodologies, widely recognized as one of the most effective techniques for monitoring *machinery health.* The implementation of a vibration analysis program offers substantial benefits for production plants, including notable reductions in maintenance costs and enhancements in both plant reliability and safety*.*

Our study emphasizes the importance of comprehensive signal acquisition and processing in diagnosing mechanical conditions accurately, thereby improving operational efficiency and reliability. Through this approach, proactive maintenance practices are facilitated, leading to minimized downtime and optimized resource allocation. Additionally, our examination of vibration spectra provides valuable insights into the satisfactory performance of the turbocharger. However, ensuring robust safety measures remains paramount, particularly with the presence of protection systems like the TRICON system.

Our extensive analysis of the TRICON system elucidates its vital role in preserving turbo-compressor operations and ensuring process integrity. By combining vibration measurement with preventative maintenance routines, particularly via Triconex automaton programming, we develop a comprehensive approach to turbo-compressor safety and durability. Furthermore, the following validation of our multimodal approach via security function simulations, as proven by results presented using the INTOUCH interface, underlines the efficacy of proactive maintenance paired with strong safety measures.

In summary, our research highlights the crucial need for proactive maintenance, together with rigorous safety measures, to ensure the optimum performance and dependability of turbo-compressor systems. The implementation of condition monitoring and predictive maintenance not only results in significant cost savings, but it also helps to avoid financial losses. The experiment, done on a single machine with 30 days of analysed data, illustrates the possibility of maximising screw usage and reducing financial losses using rescue classification in turbo-compressors.

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