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Modernizing Synchronous Motor Excitation Systems in Refinery Operations: Enhancing Reliability, Safety, and Control

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ABSTRACT: This article presents a case study on the upgrade of an excitation control system for a HV synchronous motor driving a Compressor unit in a refinery. The transition from an aging analog Automatic Voltage Regulator (AVR) to a fully digital, redundant excitation system has delivered substantial improvements in reliability, operational safety, fault diagnostics, and control flexibility. Key enhancements include real-time monitoring, programmable protective features, and multiple control modes, which collectively reduce downtime, optimize motor performance, and facilitate predictive maintenance. The findings underscore the critical role of excitation system modernization in process-critical equipment, offering a scalable framework for industrial facilities aiming to achieve operational excellence, energy efficiency, and long-term equipment reliability.

I. INTRODUCTION

Synchronous motors play a pivotal role in refinery operations, particularly in high-load, process-critical applications such as Make-Up Compressors. The performance, protection, and longevity of these motors are heavily influenced by the quality of their excitation systems. At the studied facility, the legacy analog AVR technology exhibited several limitations in redundancy, fault detection, and control flexibility, which posed operational risks and increased maintenance challenges.

This paper presents the technical rationale, implementation strategy, and operational outcomes associated with replacing the outdated AVR system with a modern, digitally integrated excitation control system. The study demonstrates how modernization enhances motor reliability, safety, and operational efficiency while enabling advanced diagnostics and predictive maintenance. By adopting a fully digital and redundant excitation platform, the refinery not only addresses the limitations of legacy systems but also establishes a scalable model for upgrading other process-critical rotating equipment. These insights provide a roadmap for industrial facilities seeking to improve process continuity, optimize energy use, and extend equipment lifespan through strategic modernization of excitation systems.

II. LIMITATIONS OF THE EXISTING EXCITATION SYSTEM

The existing AVR system, while functional, lacks modern diagnostic and protective capabilities essential for efficient, safe and reliable motor operation. Key shortcomings include:

- **Lack of Redundancy:** The absence of a backup AVR controller introduces a single point of failure, increasing the risk of unplanned equipment shutdowns.
- **Manual Setpoint Adjustments:** Control through potentiometers and rheostats limits precision and makes remote or automated adjustments impossible.
- **Obsolete Fault Detection:** The installed Basler EDM 200 diode failure detector is outdated and no longer supported, creating challenges for component replacement and accurate fault diagnosis.
- **Limited Alarm and Monitoring Capabilities:** The existing system provides minimal indication of system health or fault conditions, leaving operators without real-time visibility into excitation parameters.
- **Difficulty in Fault Finding and Maintenance:** Due to the analog nature of the existing AVR and the lack of integrated diagnostics, identifying the root cause of faults is time-consuming and labor-intensive. Maintenance often relies on manual inspection and trial-and-error methods, leading to increased downtime and resource utilization.



These limitations not only pose operational risks but also make maintenance and troubleshooting increasingly challenging.

III. OVERVIEW OF THE NEW EXCITATION SYSTEM

The new excitation system is designed around modern AVR controllers that offer full digital control, redundancy, and enhanced diagnostics. The following table summarizes the key enhancements achieved through the upgrade:

Function	Existing AVR	New AVR
Redundancy	No redundancy	Fully redundant Nidec D700 controllers (see Figure 1)
Power Supplies	Excitation transformer / 120V AC	Redundant 24V DC control supplies (see Figure 3)
Setpoint Control	Potentiometer / rheostat	Digital setpoints via HMI or 4–20 mA signal
Control Modes	Auto (regulator), Manual (rheostat)	Independent Auto, Manual, and Power Factor (PF) control for each AVR
Rotor Earth Fault	Remote detectors, not universally installed	New EM-type shaft-mounted detectors installed on all units
Diode Failure	Obsolete Basler EDM 200	Integrated diode failure detection with programmable settings
Stall/Locked Rotor	Not included	Stall detection with automatic circuit breaker trip
Synchronizing	Based on field current timing	Reactive power-based synchronization logic
Indication	Minimal or no alarms	Full alarm/trip display on HMI; panel meters for PF, field current & voltage

IV. TECHNICAL AND OPERATIONAL BENEFITS

The upgraded excitation system provides multiple advantages:

- **Enhanced Reliability:** Redundant controllers and power supplies ensure continuous operation with minimal single points of failure.
- **Improved Safety:** Real-time monitoring, stall detection, diode failure analysis, and protective features prevent damage to critical motor components.
- **Advanced Diagnostics:** The HMI interface and BNC test panel (see Figure 2) allow detailed fault indication and non-intrusive measurements, reducing response time for maintenance teams.
- **Control Flexibility:** Multiple control modes enable fine-tuned motor behavior under varying process loads and optimized power factor management at the grid connection or motor terminals.
- **Modern Compliance:** The system adheres to industrial standards and provides a scalable platform for integration into plant-wide automation systems.



(Figure 1 - Nidec D700 Excitation Controller)



(Figure 2 - BNC Test Panel)



(Figure 3 - Dual Power Supplies)



(Figure 4 - Complete Excitation Panel)

V. CONCLUSION

The modernization of the excitation system for the compressor motor represents a significant step toward improving the performance, reliability, and safety of critical refinery assets. Replacing the legacy analog AVR with a fully digital, redundant Nidec D700-based system has eliminated single points of failure and introduced advanced diagnostics, fault tolerance, and improved operational control. Features such as real-time monitoring, programmable protection, and flexible control modes now ensure optimized motor performance under varying load conditions while minimizing downtime.

Beyond operational benefits, this study highlights the strategic importance of digital excitation systems in process-critical environments. The integration of HMI interfaces, advanced sensors, and EM-type rotor earth fault detectors has enabled predictive maintenance, faster fault diagnosis, and precise control of excitation parameters. These capabilities



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directly contribute to enhanced plant safety, energy efficiency, and long-term equipment reliability, aligning with modern industrial and regulatory standards.

This implementation provides a scalable framework for upgrading legacy excitation systems across similar industrial applications. Refineries and process plants operating large synchronous motors in compressors, pumps, or other essential drives can adopt this approach to improve process continuity and integrate seamlessly with plant-wide automation systems. Moreover, the digital platform paves the way for future advancements such as AI-assisted predictive control and grid-responsive operation—positioning modern excitation systems as a foundation for operational excellence and resilient industrial infrastructure.

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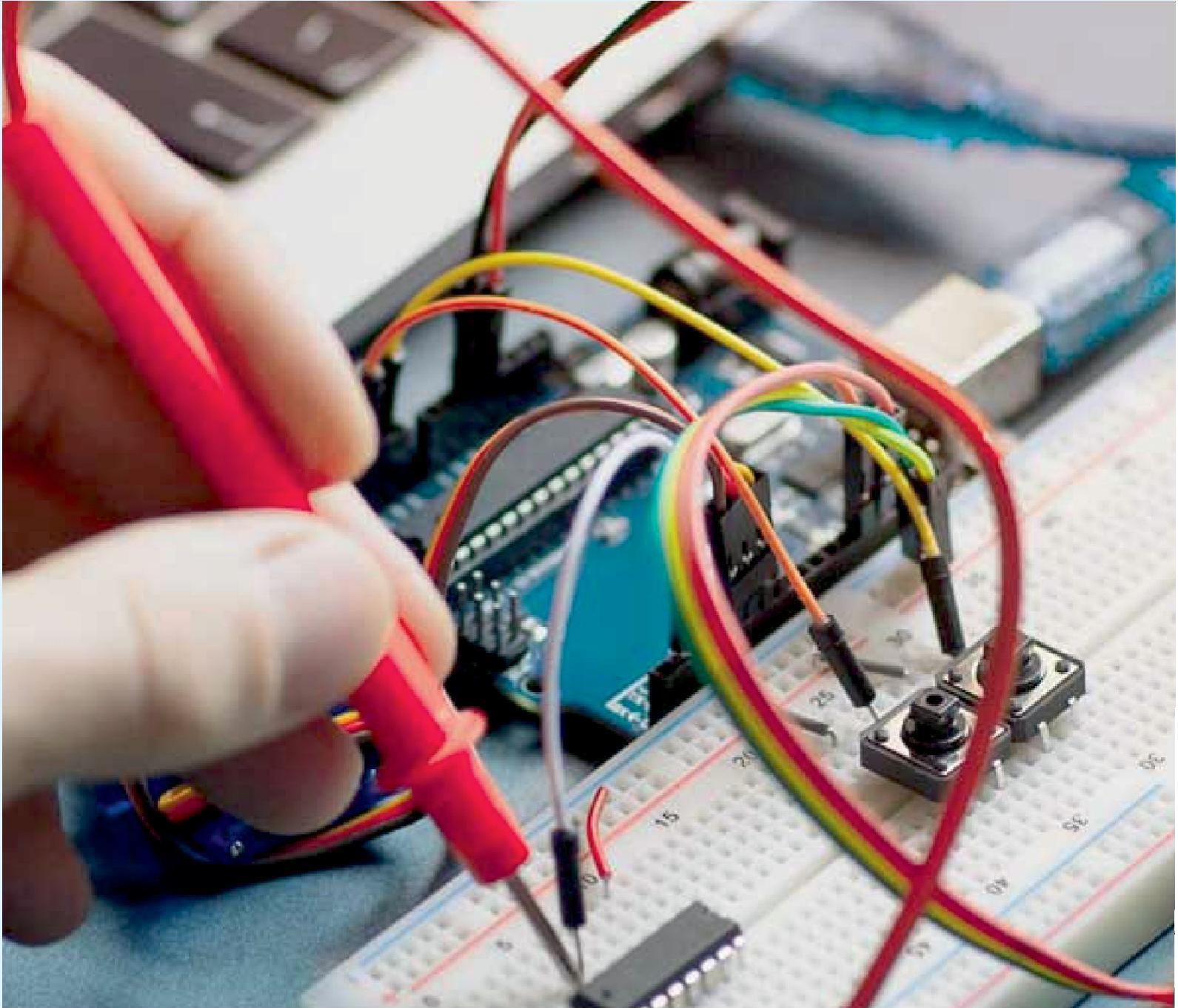
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BIOGRAPHY



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