

Energy Efficient Pump Control with VFD and Pressure Setpoint Optimization using PLC

Mr. V. K. Jadhav, Lokhande Sae, Randive Prasad, Shinde Sujit

Department of Instrumentation and Control Engineering

Pravara Rural Engineering College, Loni, India

vilas.jadhav@pravara.in, saeelokhande.12@gmail.com

prasadrandive2005@gmail.com, sujitshinde0505@gmail.com

Abstract: Energy consumption in pumping systems is a significant concern in industrial and water distribution applications. Conventional pump control methods generally operate pumps at constant speed, which often results in unnecessary energy consumption and inefficient system performance. To address this issue, an energy-efficient pump control system using a Programmable Logic Controller (PLC) and Variable Frequency Drive (VFD) is proposed.

The proposed system controls the speed of the pump motor through a VFD based on the required pressure setpoint. A pressure sensor continuously monitors the system pressure and sends feedback to the PLC. The PLC processes this feedback signal and adjusts the pump speed through the VFD to maintain the desired pressure level. By optimizing the pressure setpoint and varying the motor speed according to demand, the system minimizes energy consumption and improves overall efficiency.

This method reduces mechanical stress on pumps, extends equipment life, and ensures stable and reliable pressure control. The integration of PLC automation with VFD technology enables real-time monitoring, better control accuracy, and improved energy management. The proposed system is suitable for applications such as water supply systems, irrigation systems, and industrial pumping processes where energy efficiency and reliable pressure control are critical.

Keywords: Energy consumption

I. INTRODUCTION

The project “Energy-Efficient Pump Control with Variable Frequency Drive (VFD) and Pressure Setpoint Optimization using PLC” is designed to enhance the operational efficiency and energy performance of industrial pumping systems through intelligent automation and control. In traditional pumping systems, motors often run at a constant bypass arrangements. This approach not only leads to significant energy wastage but also increases mechanical wear, maintenance frequency, and operational costs. To address these challenges, this project proposes an advanced PLC-VFD integrated control system that automatically regulates the pump speed in accordance with the real-time process requirements, thus ensuring optimal energy consumption and consistent pressure output. At the heart of the system lies the Programmable Logic Controller (PLC), which serves as the central processing unit responsible for monitoring, decision-making, and control operations. Pressure sensors installed in the discharge line continuously measure the actual system pressure and send analog signals to the PLC’s input module. The PLC compares this measured pressure with a predefined setpoint value, and the resulting error signal is processed through a PID (Proportional-Integral-Derivative) control algorithm or a setpoint optimization logic. The control algorithm calculates the optimal speed reference required to achieve and maintain the desired pressure efficiently. This reference signal is then transmitted to the Variable Frequency Drive (VFD), which adjusts the supply frequency and voltage to the pump motor, thereby controlling its speed. When system demand decreases, the VFD reduces the motor speed, and during high demand conditions, it increases the speed proportionally. This dynamic speed control results in significant energy savings, as the power consumed by a centrifugal pump is proportional to the cube of its speed, making even small



speed reductions yield substantial energy benefits.[1] Furthermore, the system is equipped with a Supervisory Control and Data Acquisition (SCADA) interface to provide real-time visualization and control. Through the HMI, operators can monitor key parameters such as pump speed, discharge pressure, motor current, and energy consumption. They can also modify the setpoint, select control modes (manual or automatic), and observe alarm or fault conditions. This enhances system transparency, facilitates user interaction, and simplifies maintenance operations. The PLC, known for its robustness, scalability, and communication capabilities, ensures reliable performance and easy integration with industrial communication protocols such as Modbus, Profinet, or Ethernet for remote monitoring and data logging. The primary objective of this project is to achieve energy- efficient operation of pumps by eliminating unnecessary power consumption and ensuring pressure stability through optimized control logic. Additional goals include extending the mechanical life of the pump and motor by reducing start– stop cycles, minimizing hydraulic shocks, and improving overall system reliability. 2 From an industrial perspective, the implementation of this project contributes to reduced operational costs, enhanced automation flexibility, and compliance with sustainable energy management standards.[2] This project demonstrates a comprehensive and modern approach to pump automation that aligns with the objectives of Industry 4.0 and smart manufacturing. By integrating real-time process monitoring, intelligent PLC- based control, and variable-speed drive technology, the system not only enhances energy efficiency but also ensures reliable and adaptive pressure control. It exemplifies how the combination of PLC and VFD technology can be leveraged to build sustainable, intelligent, and cost-effective solutions for water supply, HVAC, and industrial fluid handling applications. Pumping systems are among the most energy- intensive components in industrial, commercial, and municipal operations. In many facilities, pumps account for nearly 25–50% of total electrical energy consumption. Traditionally, most pump systems are operated using fixed speed motors, where the flow or pressure is regulated by mechanical throttling valves or bypass systems. Although this approach is simple, it results in significant energy waste, increased wear and tear, and reduced operational efficiency. With the growing global emphasis on energy conservation, process automation, and sustainable development, industries are shifting toward smart and energy-efficient pumping systems. The integration of Variable Frequency Drives (VFDs) with Programmable Logic Controllers (PLCs) has become a practical and cost -effective solution to achieve these objectives. A Variable Frequency Drive allows the motor speed to be varied according to real-time demand rather than running continuously at full speed.[3] The motor’s frequency and voltage of the VFD enables smooth acceleration and deceleration, precise pressure or flow control, and most importantly, substantial energy savings. The energy required by a centrifugal pump is proportional to the cube of its speed, which means that even a small reduction in speed results in a large reduction in energy consumption. In this project, the PLC is employed as the core controller to achieve closed-loop pressure control and intelligent setpoint optimization. The PLC continuously monitors the pressure signal from a transmitter installed on the discharge line. Based on the deviation between the measured and desired pressure, it computes a control output using PID (Proportional-Integral-Derivative) logic. This control output is sent as an analog signal to the VFD, which in turn regulates the motor speed to maintain the required pressure. To enhance system performance and energy efficiency, pressure setpoint optimization is implemented. The setpoint is dynamically adjusted based on real-time system load or demand patterns, ensuring that the pump always operates at the most energy-efficient point. For instance, during periods of low demand, the system automatically lowers the setpoint, thereby reducing the pump speed and saving energy without affecting service quality. The proposed system not only improves energy efficiency and operational reliability but also minimizes mechanical stress on the pump and motor. Reduced wear leads to lower maintenance requirements and longer equipment life. Moreover, features like automatic start/stop, fault detection, and data logging contribute to system safety and operational intelligence. By integrating a Variable Frequency Drive (VFD) with a Programmable Logic Controller (PLC), the system dynamically adjusts the pump’s motor speed 3 in response to real-time process conditions. The PLC, known for its reliability and flexibility, acts as the control brain that monitors pressure, flow rate, and energy parameters and sends appropriate control signals to the VFD.[4]



II. LITERATURE REVIEW

M. N. B. K. Bawa, M. M. B. Azizan and et al [1] This focuses on analyzing the performance and energy-saving benefits of using a Variable Frequency Drive (VFD) for pump speed control. The study demonstrates that by adjusting motor speed according to system demand, power consumption can be significantly reduced compared to traditional constant-speed operation. G. F. Loureiro and A. Colombo [2] It Investigates the implementation of a remote-controlled VFD system to optimize energy usage in industrial motor and pump applications. The research highlights how remote monitoring and control of VFDs enable better adjustment of motor speed based on real-time operational needs, resulting in significant reductions in power consumption and operational costs. The authors conclude that integrating remote VFD control enhances system flexibility, maintenance efficiency, and energy management, aligning with modern Industry 4.0 and IoT-based automation practices. Lu Xiu he [3] The study introduces a control strategy that divides pump operation into multiple speed sections based on system load and demand conditions. By adjusting the pump speed within these sections using a Variable Frequency Drive (VFD), the system achieves optimized energy usage, reduced power losses, and improved operational stability. The author concludes that section-based VFD control offers a practical and efficient approach to energy saving in industrial and water supply pumping applications. M. Filipe, C. L. Moreira and et al [4] It Investigates the optimal operation of variable-speed pump storage systems in electricity markets. The study focuses on how variable-speed pump turbine units can participate in frequency restoration reserve (FRR) services by dynamically adjusting their operating points to balance grid frequency and energy demand. Using optimization 7 algorithms, the authors demonstrate that variable-speed control enhances flexibility, response speed, and efficiency compared to fixed-speed systems, allowing pump storage plants to contribute effectively to grid stability and energy market profitability while maintaining high energy efficiency. S. Uddin and D. D. Suhar so [5] It Investigates and demonstrates how PLCs can be used to regulate motor speed, start/stop operations, and fault handling, while SCADA provides real-time data visualization and remote supervision. The results show that combining PLC and SCADA enhances system automation, energy efficiency, operational safety, and reliability, making it an effective solution for industrial motor and pump control applications.

III. METHODOLOGY

A. System Overview

The Energy-Efficient Pump Control System using PLC and Variable Frequency Drive (VFD) is designed to control pump operation efficiently by maintaining the required pressure while minimizing energy consumption. The system uses a pressure sensor to continuously monitor the pressure in the pipeline. The sensed pressure signal is sent to the Programmable Logic Controller (PLC) for processing.

The PLC compares the actual pressure with the predefined pressure setpoint. Based on the difference, the PLC sends control signals to the Variable Frequency Drive (VFD), which adjusts the speed of the pump motor. When the pressure demand is low, the VFD reduces the motor speed to save energy, and when demand increases, it increases the speed to maintain the required pressure.

This automated control system ensures stable pressure, reduced energy usage, improved pump life, and efficient system performance.

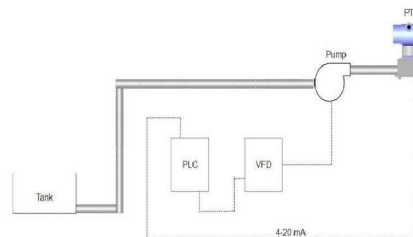


Fig. 1. Schematic representation Energy Efficient Pump Control with VFD and Pressure Setpoint Optimization using PLC



Functional Requirements

- Pressure Transmitter measures pipeline pressure and sends the signal to the PLC.
- PLC (Programmable Logic Controller) Processes pressure data and controls the pump speed based on the setpoint.
- VFD (Variable Frequency Drive) adjusts motor speed by varying frequency to maintain required pressure.
- Pump and Motor pumps the fluid through the pipeline according to the speed controlled by the VFD.
- SCADA displays system parameters.
- Power Supply provides electrical power to all system components.

IV. EXPERIMENTAL RESULTS

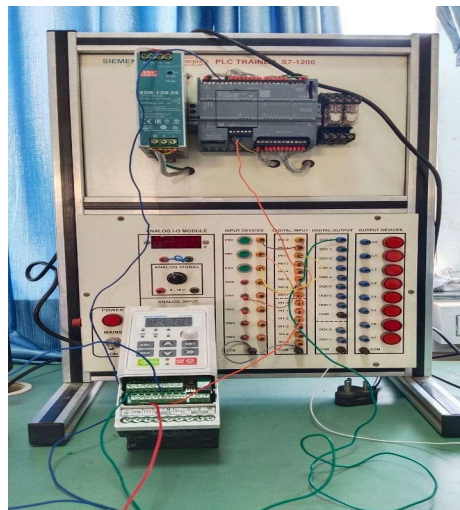


Fig. 2. Energy Efficient Pump Control with VFD and Pressure Setpoint Optimization using PLC

V. CONCLUSION

The project “Energy-Efficient Pump Control with VFD and Pressure Setpoint Optimization using PLC” concludes that integrating advanced automation with intelligent control strategies can greatly improve the efficiency and performance of pumping systems. By using the PLC to monitor real-time pressure data and control the Variable Frequency Drive (VFD), the system effectively adjusts the pump speed according to demand, reducing unnecessary energy consumption. The inclusion of a pressure transducer ensures accurate feedback, while the SCADA system provides real-time monitoring, data logging, and fault detection, making the overall system more reliable and user-friendly. This approach eliminates the energy losses commonly found in constant-speed pump operations, leading to optimized energy usage, smoother operation, and longer equipment life. Furthermore, it demonstrates how automation technologies like PLC, VFD, and SCADA can work together to create a smart, efficient, and sustainable pumping solution. Overall, the project proves that pressure-based VFD control using Siemens PLCs is a practical and effective method for achieving energy conservation and improved process control in industrial and water management application.

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