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Prototype Design of Coal Feeder Pulverizer Motor Speed Control System at Paiton Unit 3 PLTU Using Altivar ATV12H075M Inverter

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Abstract
This study presents the design and experimental evaluation of a three-phase induction motor speed control system using the Altivar ATV12H075M inverter for conveyor and coal feeder simulation applications in power generation environments. The proposed system was developed to achieve stable, efficient, and precise motor speed regulation through frequency-based control. Experimental testing was conducted by varying the inverter frequency from 10 Hz to 50 Hz in forward and reverse operating modes while measuring phase voltage, phase current, and motor rotational speed. The results demonstrate a strong and near-linear relationship between inverter frequency and motor speed, with measured speeds increasing from approximately 294–296 RPM at 10 Hz to 1497–1498 RPM at 50 Hz. The inverter maintained proportional voltage–frequency characteristics, with phase voltage rising from about 151.6 Vac to 215.6 Vac, while phase current remained within a safe range of 0.6–1.2 A. The measured motor speeds closely matched theoretical synchronous speeds with deviations below 2%, attributable to normal slip. These findings confirm that the Altivar ATV12H075M inverter provides reliable, stable, and energy-efficient speed control, making the developed system suitable as both an industrial training platform and a scalable reference model for conveyor and coal feeder applications in power generation systems.

Keywords: Induction Motor Speed Control; Variable Frequency Drive (VFD); Coal Feeder Pulverizer; Altivar ATV12; Coal-Fired Power Plant

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1. Introduction

Stable and efficient combustion is a critical requirement in coal-fired power plants (CFPPs), where precise fuel supply regulation directly affects thermal efficiency and power output [1]-[4]. The coal feeder–pulverizer system plays a vital role by controlling the mass flow of pulverized coal delivered to the boiler [5]-[9]. Inaccurate motor speed control in this system may lead to combustion instability, reduced efficiency, excessive energy consumption, and unplanned unit shutdowns [10]-[12]. Conventional manual control methods are insufficient to respond dynamically to load variations and operational disturbances, highlighting the need for an automated and reliable control strategy [13]-[15].

Variable frequency drive (VFD) technology has emerged as an effective solution for precise speed regulation of induction motors in industrial applications [16]-[18]. The Schneider Electric Altivar ATV12H075M inverter enables real-time adjustment of motor speed through frequency and voltage control, offering features such as soft starting, overload protection, and energy-efficient operation [19]-[20]. Its application in coal feeder–pulverizer systems can significantly enhance operational stability, reduce mechanical wear, and improve overall system reliability [21]-[22].

Despite the critical importance of coal pulverizer systems, understanding and optimizing their control mechanisms remain challenging due to system complexity and operational risks [23]. Therefore, accurate modeling and simulation-based training modules are required to replicate industrial conditions safely and effectively [24]. A PLC- and HMI-based control system for three-phase induction motors provides a practical and interactive platform to analyze system behavior, optimize control strategies, and improve operator competency [25].

This study aims to design and develop an automated speed control system for a three-phase induction motor driving a coal pulverizer, utilizing a PLC, HMI, and the Altivar ATV12H075M inverter [26]. The proposed system is expected to enhance operational stability, improve energy efficiency, and minimize operational disturbances, thereby contributing to more reliable and sustainable CFPP operation.

2. Methods

This research adopts an experimental and developmental approach aimed at designing, implementing, and evaluating a three-phase induction motor speed control trainer using a Variable Frequency Drive (VFD) for coal feeder–pulverizer simulation in a coal-fired power plant environment.

2.1 Research Design and Workflow

The research procedure was conducted sequentially as follows:

- **Literature Review**

A comprehensive review of relevant textbooks, standards, and peer-reviewed journals was conducted to establish the theoretical foundation of induction motor control, inverter-based speed regulation, and coal feeder–pulverizer systems. This stage defined the research scope, control strategy, and system specifications.

- **System Design and Methodology Development**
  Based on the literature study, the overall system architecture was defined, including electrical configuration, control logic, protection scheme, and operational scenarios. The methodology was structured to ensure alignment between research objectives, experimental procedures, and data analysis.
- **Trainer Development**
  The trainer was designed and assembled to simulate an industrial coal feeder drive system. This stage included mechanical layout design, electrical wiring, integration of control and protection components, and verification of installation compliance with industrial safety standards.
- **System Testing and Experimentation**
  The assembled trainer underwent systematic testing to evaluate functional performance, safety, and operational stability under various speed settings.
- **Data Analysis and Evaluation**
  Experimental data were analyzed to assess system performance, stability, and control effectiveness, followed by interpretation and discussion of results.
- **Conclusion and Recommendations**
  The final stage summarized research findings and proposed recommendations for further system development and industrial implementation.

2.2 Research Location and Schedule

- Research Location:
  PT Paiton Operation & Maintenance Indonesia (PT POMI) Unit 3, East Java, Indonesia.
- Research Period:
  June 2025, adjusted to equipment availability and operational permits.

2.3 System Testing and Data Analysis

System testing and data analysis were performed after the trainer assembly was completed to evaluate the functionality, performance, safety, and usability of the proposed inverter-based induction motor speed control system.

Testing procedures were conducted as follows:

- **Functional testing**, to verify the correct operation of all components, including switches, relays, protection devices, and the Altivar ATV12H075M inverter, both individually and as an integrated system.
- **Performance testing**, to assess motor speed control by varying the inverter output frequency from 10 Hz to 50 Hz under no-load conditions. Measurements of motor rotational speed, line voltage, and current consumption were recorded for both forward and reverse operating modes.
- **Usability testing**, involving users to operate the trainer based on predefined scenarios in order to evaluate ease of operation, clarity of control functions, and practicality as a learning and simulation tool.

The collected experimental data were then analyzed to determine system performance characteristics. The analysis focused on the relationship between inverter frequency and motor speed, voltage balance across phases, and current efficiency during operation. Motor response during acceleration, deceleration, and steady-state conditions was evaluated to assess control stability and responsiveness. The results of this analysis were used to determine the effectiveness of the proposed system and its suitability as an industrial control simulation platform for coal feeder–pulverizer applications.

2.4 Trainer Design, Control Configuration, and Evaluation

The trainer was designed to represent an industrial three-phase induction motor drive system commonly used in coal feeder–pulverizer applications. The design process began with defining user requirements and technical specifications to ensure that the trainer functions as an effective learning and simulation tool for industrial motor control systems.

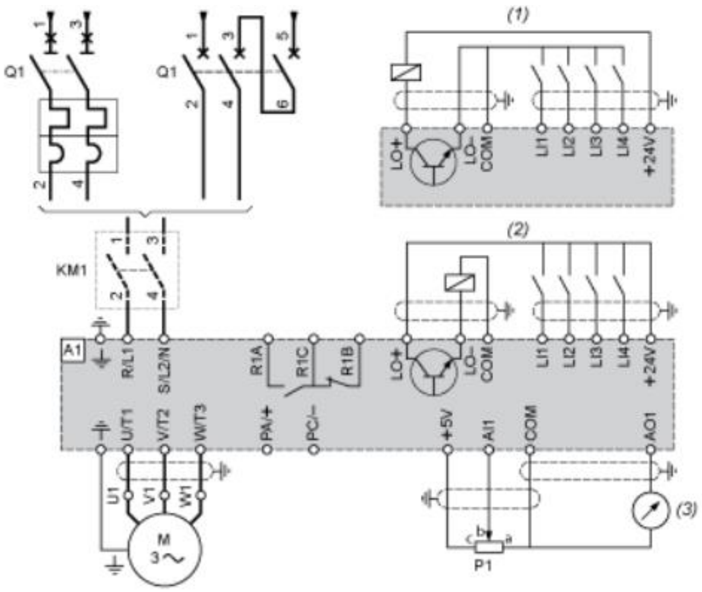

Figure 1. Wiring diagram of the Altivar ATV12H075M Inverter-Based Three-Phase Induction Motor Speed Control System.

The overall control architecture is based on a Variable Frequency Drive (VFD) using the Schneider Electric Altivar ATV12H075M inverter, which enables precise and flexible speed regulation of the induction motor through frequency variation. The inverter is integrated with protection and control components, including Miniature Circuit Breakers (MCB), contactors, thermal overload relays, and auxiliary relays, to ensure safe and reliable operation.

To accommodate industrial operational requirements, the trainer was equipped with a forward–reverse motor control mechanism. This configuration allows the motor to rotate in both directions while maintaining operational safety. The forward–reverse operation is implemented using dual contactors and an electrical interlocking system to prevent simultaneous activation, thereby avoiding short circuits and mechanical damage. Additional protection is provided by MCBs and thermal overload relays to safeguard the system against overcurrent and fault conditions.

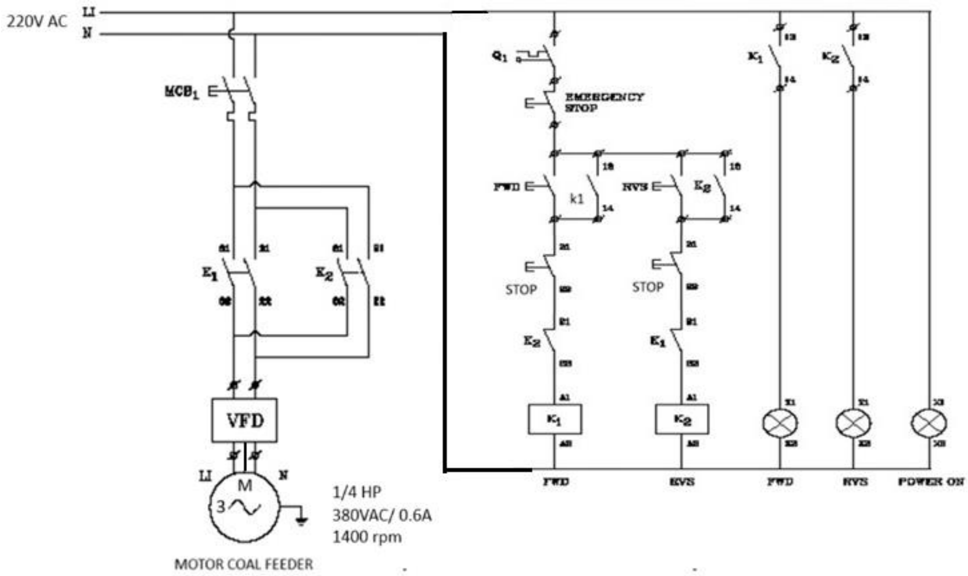

Figure 2. Three-Phase Induction Motor Wiring for Forward–Reverse Operation Using the Altivar ATV12H075M Inverter.

The control configuration was evaluated through systematic testing to assess operational reliability, safety, and performance stability. Observations focused on motor response to frequency changes, stability during steady-state operation, and system behavior during direction switching. Voltage balance across phases, current consumption, and control responsiveness were also analyzed to verify the effectiveness of the implemented design. The evaluation results confirm that the developed trainer accurately represents an industrial motor control system and is suitable for educational purposes, industrial control simulation, and as a foundational prototype for small-scale automation applications in the power generation sector.

The main design and control characteristics of the trainer include:

- Inverter-based speed control using the Schneider Electric Altivar ATV12H075M, enabling smooth and continuous adjustment of motor speed.
- Forward and reverse motor operation implemented through contactors and auxiliary relays, equipped with an electrical interlocking system to prevent simultaneous bidirectional activation.
- Protection mechanisms incorporating Miniature Circuit Breakers (MCB) and thermal overload relays to safeguard the motor and control system from short circuits and overcurrent conditions.
- Manual parameter configuration and speed adjustment through the inverter interface to simulate real industrial operation scenarios.

The control configuration was evaluated through systematic experimentation to ensure operational reliability and safety. Motor response to changes in frequency, stability during steady-state operation, and system behavior during direction switching were observed and documented. The effectiveness of the control system was further assessed by analyzing voltage balance, current efficiency, and overall system responsiveness under varying operational conditions.

Based on the evaluation results, the trainer demonstrated reliable performance and accurate representation of an industrial motor control system. The combined design and evaluation confirm that the proposed trainer is suitable for use as an educational platform, industrial control simulation tool, and a foundational prototype for small-scale automation systems in power generation applications.

3.Results and Discussion

3.1 Initial Testing, Protection System Design, and Mechanical–Electrical Integration

Initial testing was conducted prior to full system operation to ensure correct installation, wiring integrity, and proper system response. The Miniature Circuit Breaker (MCB) was activated to supply power to the system, followed by inverter startup and response verification. Motor speed was tested by gradually increasing and decreasing the inverter frequency while observing motor response time, vibration, current behavior, and inverter fault indications.

As shown in **Figure 3**, during forward operation the inverter display indicated a frequency of 30 Hz, corresponding to clockwise motor rotation. In contrast, **Figure 4** illustrates reverse operation, where the inverter display showed –21 Hz, indicating counterclockwise rotation at 21 Hz.

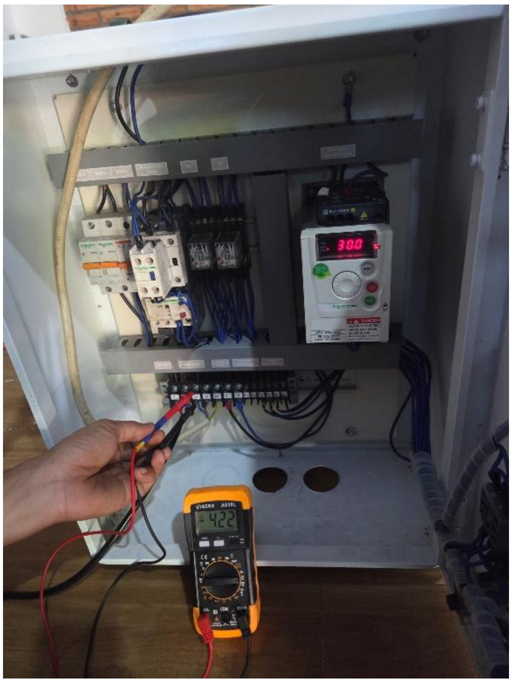

Figure 3. Initial Testing of Forward Rotation Configuration

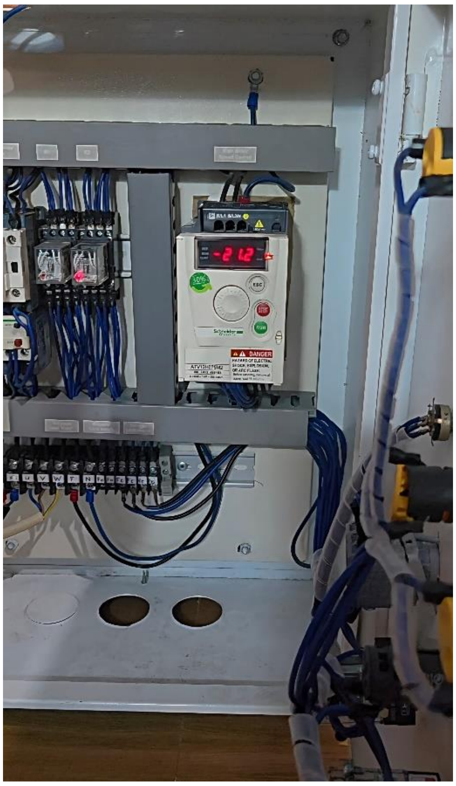

Figure 4. Initial Testing of Reverse Rotation Configuration

To ensure operational safety, a protection system was designed and implemented using both internal and external protective devices. The Altivar ATV12H075M inverter provided basic protections such as overcurrent, overvoltage, undervoltage, overtemperature, and internal short-circuit protection. Additional external protections included:

- **MCB**, for input-side overcurrent and short-circuit protection (220 V AC, type C, 2–4 A);

- **Magnetic contactors**, functioning as electrically controlled switches with current ratings exceeding motor nominal current;
- **Thermal overload relay**, set according to motor nominal current (0.6 A) with a trip setting of approximately 115% in compliance with IEC standards;
- **EMI/input filter (optional)**, to reduce harmonic disturbances to the power supply.

Mechanical construction focused on the fabrication of a conveyor frame to support the motor-driven system. The frame was designed using steel angle bars (40×40 mm or 50×50 mm, 3 mm thickness) with overall dimensions of approximately 200 cm × 50 cm × 150 cm. The fabrication process included material preparation, cutting, welding, structural alignment, surface finishing, and anti-corrosion painting. Structural inspections were conducted to ensure alignment, rigidity, and mechanical stability prior to component installation.

Following frame completion, a three-phase induction motor was installed as the primary drive unit. The motor was mounted on an adjustable base to allow belt tension regulation. Pulleys were mounted on both the motor shaft and conveyor roller shaft, aligned precisely to prevent belt misalignment and slippage. Belt tension was adjusted manually, and all fasteners were securely tightened to minimize vibration during operation.

Electrical installation was performed after mechanical assembly was completed. Power and control wiring connected the motor to the control panel, which housed the MCB, contactors, thermal overload relay, terminal blocks, and the Altivar ATV12H075M inverter. The motor was connected to the inverter output terminals (U–V–W), while control wiring supported push buttons and directional control. All wiring followed industrial standards, including grounding and cable labeling. Continuity and phase checks were performed using a multimeter prior to dry-run testing.

Finally, conveyor accessories such as belt supports and idler rollers were installed to enhance operational stability and reduce friction. All mechanical connections were rechecked to ensure safety, ease of maintenance, and readiness for operational testing. With these stages completed, the conveyor-based motor control system was fully assembled and prepared for controlled experimental operation.

3.2 Experimental Results and Discussion

Forward Operation Experimental Results

The developed control system was experimentally evaluated to assess the performance of the Altivar ATV12H075M inverter in regulating the speed of a three-phase induction motor used as a conveyor drive. The testing procedure involved activating the main circuit breaker, ensuring the inverter operated in standby mode without fault indication, selecting the motor rotation direction (forward), and varying the output frequency from 10 Hz to 50 Hz. Electrical parameters, including phase voltage and phase current, as well as motor rotational speed, were measured at each operating point.

Table 1. Experimental Results of Forward Operation

Frequency (Hz)	Phase Voltage (V_{ac})			Phase Current (Amp)			Measured Speed	Theoretical Speed (RPM)
	R	S	T	R	S	T		
10	151.6	151.6	151.6	1.2	1	1.3	296	300
20	152.7	152.7	152.7	0.7	0.6	0.7	591.2	600
30	164.4	164.4	164.3	0.7	0.7	0.7	878.6	900
40	165.2	165.1	162.2	0.7	0.7	0.7	1189.8	1200
50	215.6	215.7	215.7	0.7	0.6	0.6	1498.3	1500

The experimental results demonstrate a strong linear relationship between inverter output frequency and motor rotational speed, which is consistent with the theoretical characteristics of three-phase induction motors under variable frequency drive (VFD) control. As the frequency increased from 10 Hz to 50 Hz, the measured motor speed rose proportionally from 296 RPM to 1498.3 RPM, closely matching the calculated synchronous speed values. Minor discrepancies between measured and theoretical speeds are attributed to motor slip, which is an inherent characteristic of induction motors.

Furthermore, the phase voltages remained relatively balanced across all operating conditions, indicating stable inverter performance and proper wiring configuration. The phase currents were observed to remain within a safe operating range (0.6–0.7 A) at medium to high frequencies, reflecting efficient power utilization and the absence of abnormal loading conditions. At lower frequencies, a higher current was recorded, which is commonly associated with starting torque requirements.

Overall, the results confirm that the proposed inverter-based control system provides reliable, efficient, and stable speed regulation for conveyor applications. The close agreement between experimental and theoretical results highlights the suitability of the Altivar ATV12H075M inverter for small-scale industrial automation and training systems, as well as its potential implementation in conveyor-driven processes within power generation and material handling industries.

Reverse Operation Experimental Results

To evaluate the performance of the control system under reverse rotation, additional experiments were conducted by reversing the motor rotation through the inverter control configuration. The testing procedure and measurement instruments were kept identical to the forward operation test to ensure data consistency. The inverter output frequency was varied from 10 Hz to 50 Hz, while phase voltage, phase current, and motor rotational speed were recorded.

Table 2. Experimental Results of Reverse Operation

Frequency (Hz)	Phase Voltage (V_{ac})			Phase Current (Amp)			Measured Speed (RPM)	Theoretical (RPM)
	R	S	T	R	S	T		
10	151.6	151.6	151.6	1	1.02	0.39	294	300
20	152.7	152.7	152.7	0.9	0.9	0.8	589.2	600
30	164.4	164.4	164.3	0.8	0.7	0.7	875.6	900
40	165.2	165.1	162.2	0.7	0.7	0.7	1186.8	1200
50	215.6	215.7	215.7	0.7	0.7	0.6	1497.3	1500

The experimental results presented in Table 2 indicate that the inverter-based control system maintains stable and predictable motor behavior during reverse operation. Similar to forward rotation, a linear relationship between inverter output frequency and motor speed is observed. As the frequency increased from 10 Hz to 50 Hz, the measured motor speed increased proportionally from 294 RPM to 1497.3 RPM, closely approximating the theoretical synchronous speed.

The phase voltages remained well balanced across all test conditions, demonstrating that the inverter operates symmetrically in both rotation directions. Phase current values were slightly higher at low frequencies, particularly at 10 Hz, which is attributed to higher torque demand during startup and reverse acceleration. However, at medium and high frequencies, the phase currents stabilized within a safe operating range of 0.6–0.7 A, indicating efficient power utilization and the absence of abnormal electrical stress.

The small discrepancies between measured and theoretical speeds are primarily caused by motor slip, which is an inherent characteristic of induction motors and occurs similarly in both forward and reverse directions. Overall, the reverse operation test confirms that the proposed control system using the Altivar ATV12H075M inverter provides reliable bidirectional speed control, making it suitable for conveyor applications requiring flexible direction control in industrial automation and training environments.

4. Conclusion

This study successfully designed and experimentally validated a three-phase induction motor speed control system using the Altivar ATV12H075M inverter for conveyor and coal feeder simulation applications. Experimental results show that increasing the inverter frequency from 10 Hz to 50 Hz increased the measured motor speed from approximately 294–296 RPM to 1497–1498 RPM in both forward and reverse modes, demonstrating a strong and near-linear frequency–speed relationship. The phase voltage increased proportionally from about 151.6 Vac to 215.6 Vac, confirming consistent V/f control implementation, while the phase current remained within a safe operating range of 0.6–1.2 A without indications of overload. The measured motor speeds closely matched the theoretical synchronous speeds, with deviations generally below 2% due to normal induction motor slip. Similar performance characteristics were observed in both operating directions, indicating that direction reversal did not significantly affect voltage stability, current balance, or speed accuracy. Overall, the results confirm that the Altivar ATV12H075M inverter provides efficient, stable, and precise speed control, making the developed system suitable as an industrial training platform and a scalable reference for conveyor and coal feeder applications in power generation systems.

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