

**APPLICATION OF INFORMATION TECHNOLOGIES IN ELECTRIC DRIVE CONTROL SYSTEMS OF INDUSTRIAL CONVEYORS**

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The article considers the application of modern information technologies in automated electric drive control systems for industrial conveyor lines. The object of study is the waste transportation line of a woodworking shop, which includes belt conveyors, a scraper conveyor, a reversible belt conveyor, and a disk chipper. The technological process requires coordinated operation of multiple electric drives, which determines the necessity of implementing an efficient automated control system.

The main drive element is the Siemens Micromaster 440 frequency converter, which provides smooth speed control of an asynchronous motor, reduces starting currents, and ensures protection against overload conditions. The selection of the frequency converter is substantiated based on the analysis of nominal and starting parameters of the drive. The application of the PROFIBUS-DP industrial network for data exchange between the Siemens S7-314C-2DP programmable logic controller and multiple frequency converters is justified. The structure of cyclic data exchange based on the PROFIDrive PPO3 profile is described, ensuring minimal communication delay and efficient control signal transmission.

The architecture of the human-machine interface (HMI), developed using the SIMATIC OP 170B operator panel and WinCC Flexible software, is presented. The HMI provides real-time monitoring of process parameters, visualization of system states, and implementation of manual and automatic control modes. The functional control scheme of the electric drive system, including current and speed feedback loops, is analyzed. This structure ensures stable dynamic performance, accurate speed regulation, and effective limitation of starting currents.

Computer simulation of transient processes was carried out using a mathematical model of the «frequency converter - asynchronous motor» system. The simulation results demonstrate high dynamic performance of the system, including a short acceleration time, low overshoot, and stable steady-state operation. A comparative analysis of power consumption at different operating modes confirms the energy efficiency of frequency control, showing a significant reduction in power consumption when operating at reduced frequencies.

The obtained results confirm the effectiveness of integrating modern information technologies, industrial communication networks, and intelligent control systems in automated multi-motor conveyor lines. The proposed solutions improve the reliability, flexibility, and energy efficiency of the technological process and can be recommended for implementation in woodworking, agro-industrial, and other industries with similar transport systems.

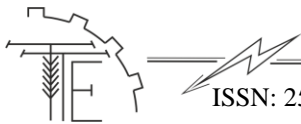
Keywords: frequency converter, conveyor, electric drive, PROFIBUS, PLC, HMI, automated control system, information technologies.

Eq. 2. Fig. 12. Table. 3. Ref. 17.

1. Problem formulation

Modern industrial enterprises increasingly require the implementation of automated transport systems capable of ensuring stable operation, high productivity, and improved energy efficiency. Conveyor lines are





widely used in woodworking, agro-industrial, mining, and manufacturing industries due to their ability to provide continuous transportation of bulk and piece materials within technological processes. However, traditional electric drive control methods based on direct motor starting do not provide sufficient flexibility, smooth speed regulation, or effective adaptation to variable operating conditions.

The rapid development of modern information technologies and industrial communication networks creates new opportunities for improving the performance and reliability of conveyor electric drive systems. The application of programmable logic controllers, frequency converters, industrial PROFIBUS communication networks, and human-machine interfaces enables the implementation of intelligent automated control systems with real-time monitoring, diagnostics, and coordinated multi-motor operation.

At the same time, industrial conveyor systems are often subjected to significant dynamic loads, high starting currents, and increased energy consumption, which negatively affect the reliability, durability, and operational efficiency of electrical equipment. Therefore, the development and implementation of modern automated electric drive control systems based on advanced information technologies is an important scientific and practical task aimed at improving energy efficiency, operational reliability, and the level of process automation in industrial enterprises.

2. Analysis of recent research and publications

Conveyor transport is one of the most advanced types of internal cargo handling, providing high productivity under significant material flows. In modern production, conveyors are an integral part of the technological process, regulating the production rate, ensuring its rhythm, and contributing to increased labor productivity [1-4].

Of particular importance is the comprehensive mechanization and automation of conveyor lines in woodworking, metallurgical, and agro-industrial sectors, where the technological process requires continuous and coordinated operation of several drives. Traditional control schemes with contactor starting do not provide the required level of flexibility and energy efficiency [5-8].

An analysis of scientific publications [1, 3, 6, 9] indicates the widespread use of frequency-controlled electric drives based on frequency converters (FC) such as Siemens Micromaster in conveyor transport systems. Such solutions allow smooth speed control of asynchronous motors (AM), reduction of starting currents, and implementation of protective functions. Works [2, 10-12] consider the use of industrial PROFIBUS-DP networks for organizing data exchange between programmable logic controllers (PLC) and actuating devices.

The development of human-machine interfaces (HMI) for automated electric drive control systems is addressed in works [13-16], which explore the capabilities of WinCC Flexible software and SIMATIC OP operator panels. However, a comprehensive analysis of the integration of frequency converters, PLCs, and HMI interfaces into a unified automated control system for a conveyor line remains a relevant task.

3. The purpose of the article

The aim of this work is to analyze the application of modern information technologies in automated control systems of electric drives for industrial conveyors, using the example of a wood chip transportation line in a woodworking shop, as well as to develop and substantiate the structure of a control system based on Siemens Micromaster 440 frequency converters, Siemens S7-314C-2DP PLC, and the SIMATIC OP 170B operator panel.

4. Results and discussion

The object of the study is the waste unloading line of a woodworking shop (Figure 1). The technological process is carried out as follows: coarse wood waste from processing is fed into the wood raw material storage hopper (1), then to conveyor (2), which delivers it to the disc chipper (3). From the chipper, the wood chips are transferred to the scraper conveyor (4), and the standard-compliant chips are then directed through a chute to the reversible belt conveyor (5), which distributes the material between two bins (6) - for meeting the needs of the boiler house and for pellet production.

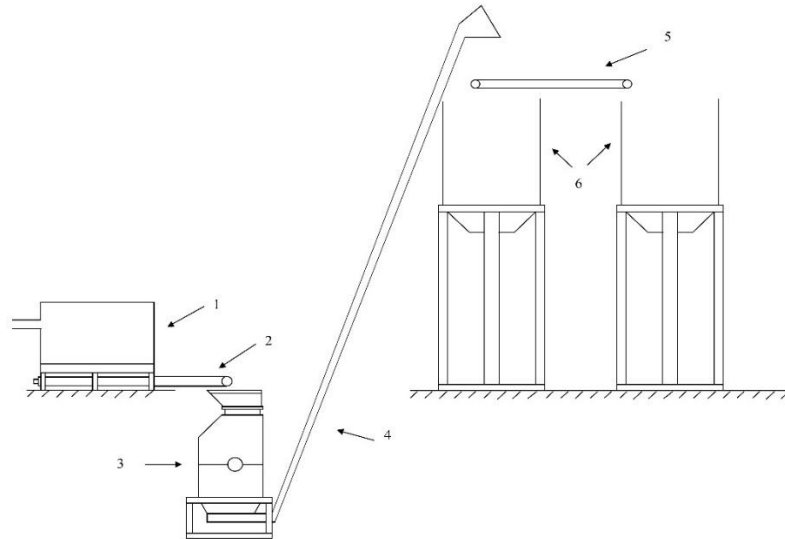


Fig. 1. Technological diagram of the wood chip transportation line:

1 – wood raw material storage hopper, 2 – feeding conveyor, 3 – disc chipper, 4 – scraper conveyor, 5 – reversible belt conveyor, 6 – storage bins (for the boiler house and for pellet production)

The main type of drive for all conveyors is an electric drive with an asynchronous motor. Conveyor transport has significant advantages over traditional methods of cargo handling: maintenance personnel are engaged only in servicing the equipment rather than directly participating in the transportation process; only electrical energy is consumed, whereas wheeled transport uses significantly more expensive organic fuel [1].

To control the electric drives of the conveyor line, a Siemens Micromaster 440 frequency converter was selected. The choice was made based on the calculation of the motor’s power consumption in the nominal operating mode and the starting power. The power consumption, taking into account the input current distortion coefficient of the converter ($k = 0.95$), is:

$$P_{drv.cons} = \frac{k \cdot P_{drv.nom}}{\eta_{drv.nom}} = \frac{0.95 \cdot 2.2}{0.81} \approx 2.6 \text{ kW} \quad (1)$$

Verification under the overload condition during startup $\lambda_{FC} = 1.7$:

$$P_{FC} \geq \frac{P_{drv.start}}{\lambda_{FC}} = \frac{4.3}{1.7} \approx 2.5 \text{ kW} \quad (2)$$

Based on the obtained conditions, a Siemens Micromaster 440 6SE6440-2AB23-0CA1 frequency converter with a rated power of 3 kW was selected. The technical specifications of the converter are presented in Table 1.

Table 1.

Technical specifications of the Siemens Micromaster 440 frequency converter

Parameter	Value
Type of frequency converter	Siemens Micromaster 440 6SE6440-2AB23-0CA1
Rated power P_{FC} , kW	3
Calculated input current $I_{FC.start}$, A	20
Calculated output current I_{FC} , A	24
Rated power factor $\cos \varphi$	0.95
Rated efficiency $\eta_{drv.nom}$ % , %	97
Supply voltage, V	3 AC 200-240 \pm 10%
Supply frequency, Hz	47-63
Overload capacity λ_{FC}	1.7

The Micromaster 440 frequency converter can be used both as a standalone device and integrated into automated systems with data exchange via the PROFIBUS network. Connection to the PROFIBUS network is carried out using a special communication module (Figure 2).



Fig. 2. External view of the Siemens Micromaster 440 frequency converter and PROFIBUS communication module:
1 – control unit connector, 2 – PROFIBUS address switches, 3 – communication module status LEDs, 4 – communication module interface, 5 – external 24 V power supply connector, 6 – service switches, 7 – MICROMASTER4 status LEDs

The PROFIBUS communication module supports data transmission rates from 9.6 kb to 12 Mb. The address of the frequency converter in the PROFIBUS network can be set either hardware-wise using DIP switches or software-wise via parameter P0918 of the frequency converter. The hardware-set address has priority. Communication diagnostics are performed using status LED indicators on the PROFIBUS module [12].

To control the electric drives of the scraper conveyor, a functional diagram of the automated electric drive system (AEDS) was developed, as shown in Figure 3. The diagram includes a speed control loop (Speed Controller) and a current control loop (Current Controller) with a PWM comparator (PWM Compare Ref).

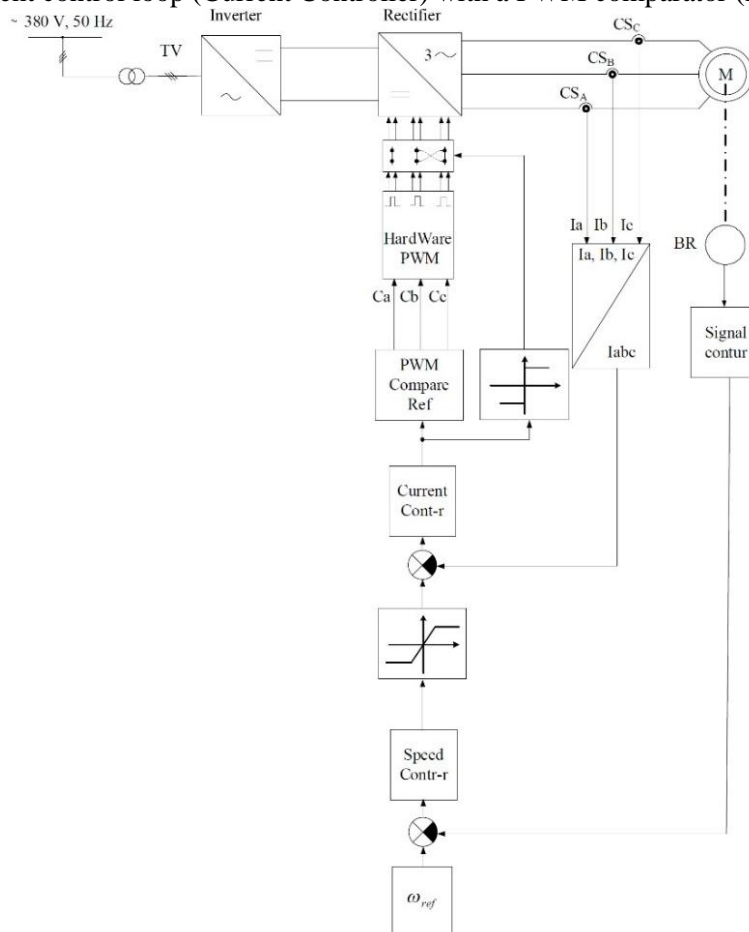
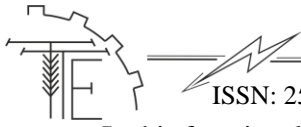


Fig. 3. Functional diagram of the conveyor electric drive with current and speed feedback control loops



In this functional diagram, two feedback control loops are implemented: current and speed. The outer loop regulates the motor speed by generating a reference for the inner current loop. The inner current loop ensures the required torque and protects the motor from overload. The PWM signal from the comparator is fed to the inverter of the frequency converter, which supplies the asynchronous motor M through a three-phase 380 V/50 Hz network [13].

To implement an automated control system for a multi-motor conveyor line, the industrial PROFIBUS-DP network is used. In this architecture, the PLC acts as the master device, while the frequency converters act as slave devices. Data exchange is carried out cyclically in accordance with the PROFIDrive profile.

The structure of working data in cyclic exchange is divided into two areas: the parameter area (PKW) for reading and writing converter parameters, and the process data area (PZD), which contains control words, setpoints, and actual values. Process data are processed by the drive with the highest priority. According to version 2.0 of the PROFIDrive profile, five PPO types are defined (Table 2). MICROMASTER 4 supports only PPO1 and PPO3.

Table 2.

Types of process data parameter structures (PPO) according to the PROFIDrive profile

PPO Type	Description	MICROMASTER 4 Support
PPO1	Parameter area + 2 PZD words	Yes
PPO2	Parameter area + 6 PZD words	No
PPO3	Without PKW + 2 PZD words	Yes
PPO4	Without PKW + 6 PZD words	No
PPO5	Parameter area + 10 PZD words	No

For data exchange between the PLC and frequency converters in this system, the PPO3 structure is used - without the parameter area (PKW), with two process data words (PZD). This ensures a minimal communication cycle time and a sufficient amount of data for transmitting the control word and frequency setpoint from the PLC to the frequency converter, as well as receiving the status word and actual frequency in the reverse direction [12].

PKW				PZD									
PKE	IND	PWE		PZD1 STW1 ZSW1	PZD2 HSW HIW	PZD3	PZD4	PZD5	PZD6	PZD7	PZD8	PZD9	PZD10
1. word	2. word	3. word	4. word	1. word	2. word	3. word	4. word	5. word	6. word	7. word	8. word	9. word	10. word
PPO1													
PPO2													
PPO3													
PPO4													
PPO5													

Fig. 4. Structure of the PROFIBUS network for data exchange between the S7-314C-2DP PLC and Micromaster 440 frequency converters:

PKW – assigned parameter value, PZD – process data, PKE – parameter assignment, IND – index, PWE – parameter value, STW – control word 1, ZSW – status word 1, HSW – main setpoint, HIW – main actual value

To implement the automated control system of the conveyor line, a Siemens S7-300 series programmable logic controller, specifically the S7-314C-2DP model (Figure 5), was selected. The choice is обусловлений by its functional capabilities, which fully meet the task requirements: the presence of a PROFIBUS-DP interface for connecting frequency converters and an MPI interface for communication with the operator panel and a computer [11-13].



Fig. 5. External view of the Siemens S7-314C-2DP PLC

The main technical characteristics of the selected controller are presented in Table 3. The controller is characterized by high performance, the presence of built-in counters and analog outputs, which allows flexible implementation of automatic control algorithms without the use of additional modules.

Table 3.

Main technical characteristics of the SIMATIC S7-314C-2DP PLC

Characteristic	Value
Rated supply voltage	24 V
Input voltage (lower limit)	20.4 V
Input voltage (upper limit)	28.8 V
Starting current	11 A
Rated current	150 mA
Power consumption	14 W
Built-in memory	96 KB
Number of S7 counters	511
Number of digital outputs	16
Number of analog outputs	2
Number of counters	4
Pulse output switching frequency	2.5 kHz
Short-circuit protection at the output	electronic

For programming and configuration of the S7-314C-2DP controller, the TIA Portal software package is used, providing a convenient environment for software development and network configuration. In the TIA Portal environment, the PROFIBUS-DP network was configured with the connection of four Micromaster 440 frequency converters as slave devices (Figure 6).

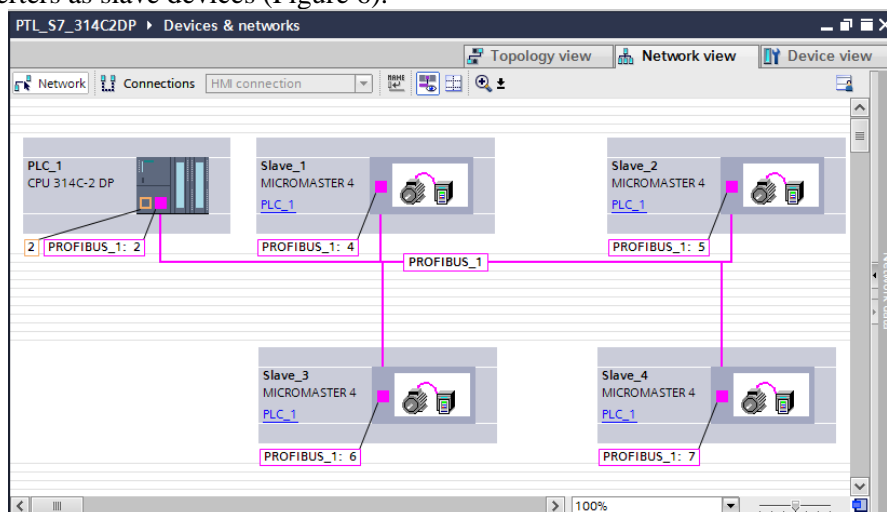


Fig. 6. PROFIBUS network configuration in the TIA Portal environment with four Micromaster 440 frequency converters connected

The PLC software structure includes the main program in the organizational block OB1, a control subroutine for each frequency converter (FB1 - Steuer_PCH), an automatic control subroutine for the line (FC2 - Automatic), a global data block for communication with HMI devices (DB2 - HMI_DB), and separate data blocks for each frequency converter (DB1...DB5). For data exchange between the PLC and frequency converters, the PPO3 structure of the PROFIDrive profile is used. The global data block HMI_DB [DB2] contains status variables, speed values, and setpoints for all four frequency converters, which are available for reading and writing from the operator panel [12].

To control the conveyor line, a human-machine interface (HMI) was developed based on the Siemens SIMATIC OP 170B operator panel (Figure 7). The panel is equipped with a 5.7" STN CCFL display with a resolution of 320×240 pixels, a membrane keyboard with 35 system keys and 24 programmable keys, as well as RS 422/RS 485 interfaces for connection to MPI and PROFIBUS-DP networks [16].

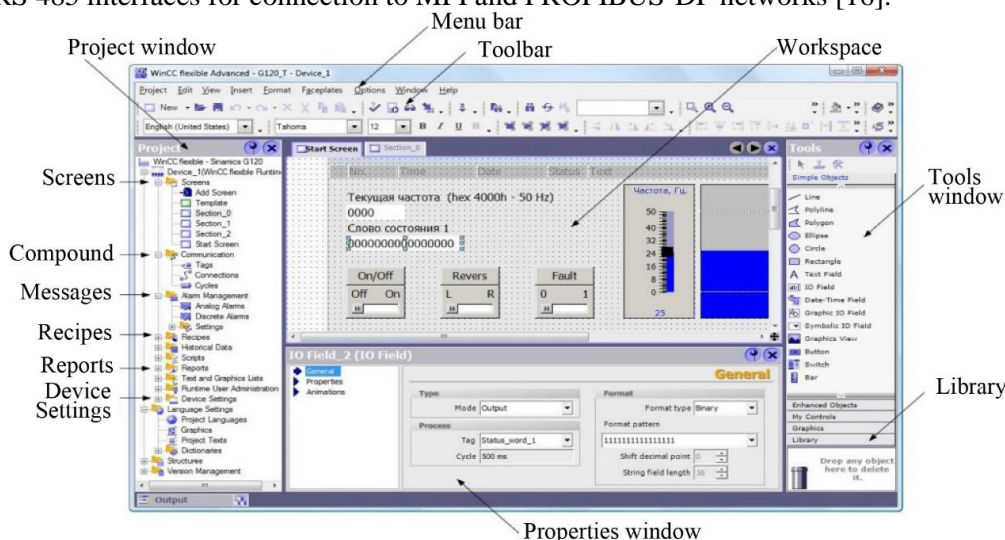


Fig. 7. External view of the Siemens SIMATIC OP 170B operator panel and the main screen of the line control system

The HMI software was developed in the WinCC Flexible environment. Data exchange between the operator panel and the PLC is carried out via the MPI network, where the panel acts as the Master and the PLC as the Slave. In the PROFIBUS network, which connects the PLC with the frequency converters, the PLC acts as the Master, while the frequency converters operate as Slave devices.

The developed HMI interface includes a main screen displaying the overall view of the waste transportation line and four separate control screens: for conveyor T1, conveyor T2, reversible conveyor T3, and the crusher. Each screen displays the current and set speed of the electric drive, the power supply status, and the presence of frequency converter faults. The interface provides functions for start (F1), stop (F3), fault reset (F5), and reverse operation (F7, only for T3).

Automatic startup of the line is performed in reverse order: first T3, then T2, followed by the crusher and T1, with time delays between starts. Emergency stop (F7 on the main screen) ensures simultaneous shutdown of all line equipment [17].

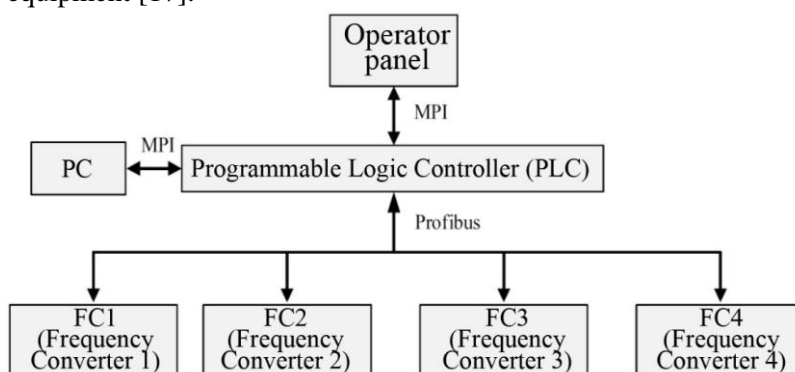
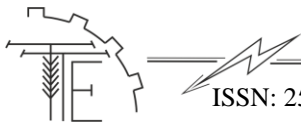


Fig. 8. Structural diagram of the network architecture of the control system (MPI and PROFIBUS)



To verify the effectiveness of the developed control system, computer simulation of transient processes of the scraper conveyor electric drive was performed, taking into account the parameters of the selected Siemens Micromaster 440 frequency converter and an asynchronous motor with a rated power of 2.2 kW. The simulation was carried out using a mathematical model of the «FC - IM» system with a two-loop control structure.

Figure 9 shows the transient characteristic of the rotor angular speed $\omega(t)$ during the startup of the electric drive. The acceleration time to the rated speed $\omega_{nom} = 149$ rad/s is approximately 2.5 s, which corresponds to the configured acceleration ramp of the frequency converter. The speed overshoot does not exceed 1.5%, indicating proper tuning of the control loop.

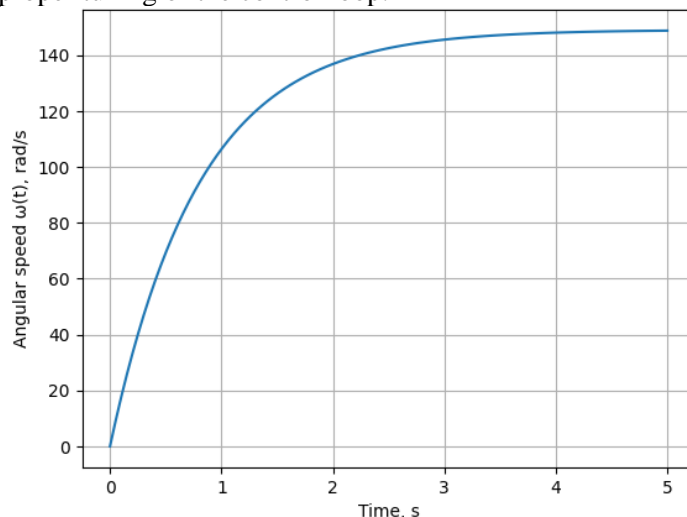


Fig. 9. Transient speed characteristic of the conveyor electric drive

Figure 10 shows the transient process of the stator current $I(t)$. At the initial stage of startup, an inrush current is observed, reaching a value of $I_{start}=11.8$ A, which is 2.3 times higher than the rated value $I_{nom}=5.2$ A. Due to the current limiting function implemented in the control loop of the Micromaster 440 frequency converter, the current decreases to the operating level already after $t=0.5$ s and stabilizes at the nominal value upon completion of acceleration.

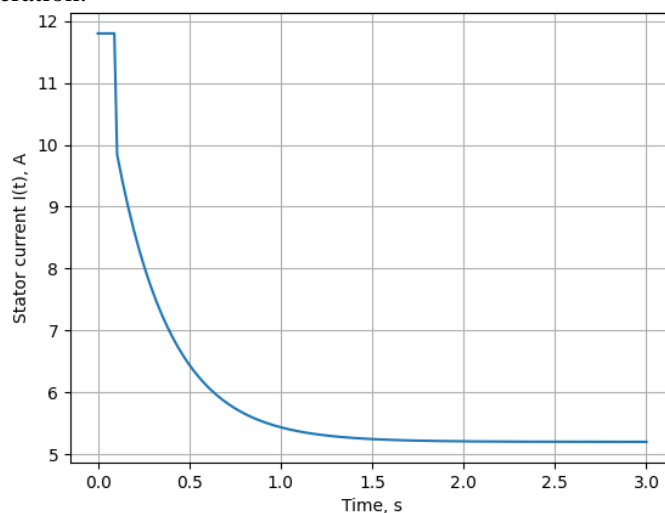


Fig. 10. Transient stator current characteristic during electric drive startup

The transient characteristic of the electromagnetic torque $M(t)$ is shown in Figure 11. During startup, the torque reaches a value of approximately 29 N·m ($2.1 \cdot M_{nom}$), which ensures reliable startup of the loaded conveyor. In steady-state operation, the electromagnetic torque stabilizes at the level of $M_{nom}=14.0$ N·m with minor fluctuations not exceeding 3%, which is acceptable for conveyor load conditions.

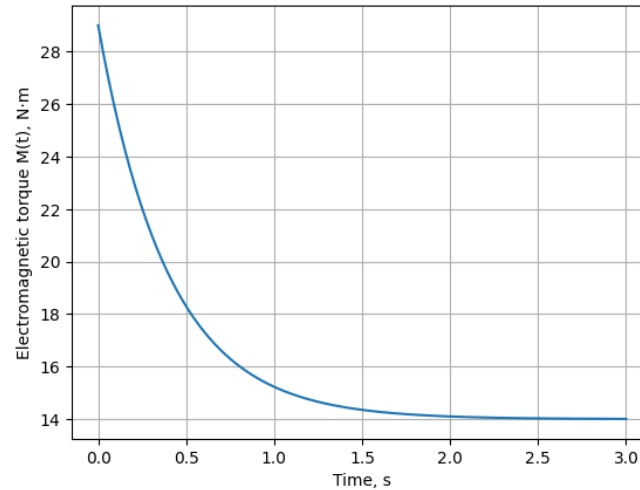


Fig. 11. Transient electromagnetic torque characteristic of the electric drive

To assess the energy efficiency of frequency control, a comparative analysis of power consumption under different operating modes of the electric drive was carried out (Figure 12). The results show that reducing the supply frequency from 50 Hz to 30 Hz makes it possible to decrease the power consumption from 2.60 kW to 0.95 kW, i.e., by 63.5%. This is achieved due to the cubic relationship between power and rotational speed for fan-type loads, which are typical for a number of conveyor mechanisms.

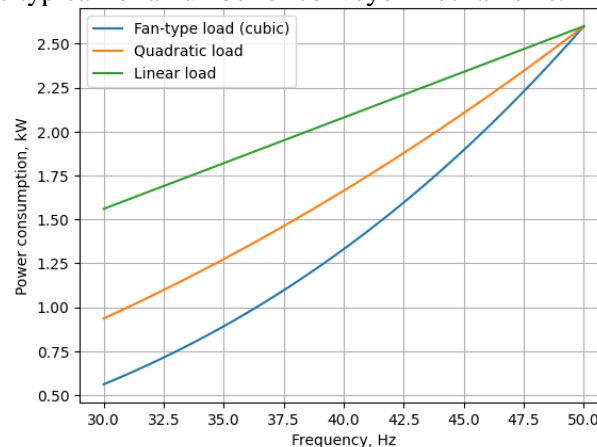


Fig. 12. Comparison of electric drive power consumption under different operating modes

The obtained simulation results confirm that the use of the Siemens Micromaster 440 frequency converter with a two-level control system (current and speed control loops) provides high-quality dynamic performance and significant energy savings compared to the direct startup of an asynchronous motor.

5. Conclusion

The conducted study confirmed the effectiveness of applying modern information technologies in automated control systems of electric drives for industrial conveyors. The developed control system for the conveyor line of a woodworking shop, based on Siemens Micromaster 440 frequency converters, Siemens S7- 314C-2DP PLC, and the SIMATIC OP 170B operator panel, ensures reliable and energy-efficient operation of the technological process.

The use of the PROFIBUS-DP industrial network with the PROFIDrive profile (PPO3 structure) made it possible to organize efficient cyclic data exchange between the PLC and four frequency converters, ensuring minimal system response time. The implemented HMI interface based on WinCC Flexible provides the operator with complete real-time information about the state of each electric drive and enables remote control in both manual and automatic modes.

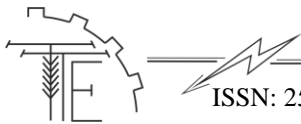
The results of computer simulation of transient processes of the electric drive confirm the high-quality dynamic characteristics of the system: the acceleration time to the rated speed $\omega_{nom}=149$ rad/s is 2.5 s, the speed overshoot does not exceed 1.5%, and the inrush current is limited to 11.8 A ($2.3 \cdot I_{nom}$). A comparative



analysis of energy consumption showed that the use of frequency control allows reducing power consumption by up to 63.5% compared to the nominal operating mode when reducing the frequency from 50 to 30 Hz. The proposed technical solutions are recommended for implementation in similar conveyor systems in agro-industrial and woodworking enterprises.

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**ЗАСТОСУВАННЯ ІНФОРМАЦІЙНИХ ТЕХНОЛОГІЙ У СИСТЕМАХ КЕРУВАННЯ
ЕЛЕКТРОПРИВОДАМИ ПРОМИСЛОВИХ КОНВЕЄРІВ**

У статті розглянуто застосування сучасних інформаційних технологій в автоматизованих системах керування електроприводами промислових конвеєрних ліній. Об'єктом дослідження є лінія транспортування відходів деревообробного цеху, яка включає стрічкові транспортери, скребковий транспортер, реверсивний стрічковий транспортер та дискову рубильну машину. Технологічний процес вимагає узгодженої роботи кількох електроприводів, що зумовлює необхідність впровадження ефективної автоматизованої системи керування.

Основним елементом приводу є перетворювач частоти Siemens Micromaster 440, який забезпечує плавне регулювання швидкості асинхронного двигуна, зменшення пускових струмів та захист від перевантажень. Вибір перетворювача частоти обґрунтовано на основі аналізу номінальних та пускових параметрів електропривода. Обґрунтовано використання промислової мережі PROFIBUS-DP для обміну даними між програмованим логічним контролером Siemens S7-314C-2DP та кількома перетворювачами частоти. Описано структуру циклічного обміну даними на основі профілю PROFIDrive (структура PPO3), що забезпечує мінімальні затримки передачі та ефективно керування.

Представлено архітектуру людино-машиного інтерфейсу (HMI), розробленого на базі панелі оператора SIMATIC OP 170B із використанням програмного забезпечення WinCC Flexible. HMI забезпечує моніторинг параметрів процесу в реальному часі, візуалізацію станів системи та реалізацію ручного й автоматичного режимів керування. Проаналізовано функціональну схему керування електроприводом із контурами зворотного зв'язку за струмом і швидкістю, що забезпечує стабільні динамічні характеристики, точне регулювання швидкості та ефективне обмеження пускових струмів.

Виконано комп'ютерне моделювання перехідних процесів на основі математичної моделі системи «перетворювач частоти - асинхронний двигун». Результати моделювання демонструють високі динамічні показники системи, зокрема малий час розгону, незначне перерегулювання та стабільну роботу в усталеному режимі. Порівняльний аналіз енергоспоживання в різних режимах підтверджує енергоефективність частотного регулювання та показує значне зниження споживаної потужності при зменшенні частоти живлення.

Отримані результати підтверджують ефективність інтеграції сучасних інформаційних технологій, промислових мереж зв'язку та інтелектуальних систем керування в автоматизовані багатодвигунні конвеєрні лінії. Запропоновані технічні рішення підвищують надійність, гнучкість та енергоефективність технологічного процесу і можуть бути рекомендовані для впровадження на підприємствах деревообробної, агропромислової та інших галузей із подібними транспортними системами.

Ключові слова: перетворювач частоти, конвеєр, електропривод, PROFIBUS, ПЛК, HMI, автоматизована система керування, інформаційні технології.

Ф. 2. Рис. 12. Табл. 3. Літ. 17.

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