Comprehensive Analysis and Control of Reactive Power and Harmonic Distortions in Modern Conveyor System

Islom Togaev1, a), Akram Tovbaev1, b) and Shuhrat Abdullayev1, c)

1*Navoi State University of Mining and Technologies, Navoi, Uzbekistan*

*a) Corresponding author:* [*togayev.islom@mail.ru*](mailto:togayev.islom@mail.ru) *b)* [*tovboyev70@mail.ru*](mailto:tovboyev70@mail.ru) *c) shuxrat.shodmonovich@gmail.com*

**Abstract.** This article simulation result of the direct torque control system of the motors ensure such quality parameters as rotation speeds and torques of the motors are always stable during operation, the stator current has a sinusoidal shape. From the characteristics of the electromagnetic torque and speed of three conveyor motors, it is clear that direct torque control of the motor ensures high quality control without overshooting the speed and torque. Currently, frequency converters are widely used in the conveyor electric drive system in Vietnam in combination with reactors at the input to reduce higher harmonics of the current in the network.

**Keywords:**  Electric drive systems, conveyor motors, sinusoidal shape, electromagnetic torque characteristics, conveyor motor speed, smooth and consistent with the specified value, reduces jerks and dynamic loads

# INTRODUCTION

The two-way power transmission is a great advantage of the direct power control method of the active and reactive. It is an energy-saving solution for the system when working with frequent stops, braking processes, while eliminating the intermediate braking circuit in the design [1, 2]. The analysis of the method of the control system of the active rectifier with orientation by the voltage vector is carried out. A simulation model of the electric drive system with a frequency converter and with an active rectifier is created. The end outcome and general effectiveness of the system are thus largely dependent on the caliber of the control strategy that is used. The simplest solution is based on calculating the difference between the measured current value and the required current to ensure precise control, stable DC voltage and a reliable control system [3, 4, 5, 6]. This method deals with instantaneous variables, so the estimated values contain not only unit components, but also harmonic components. These in accurate actors can solely a dust themed ate real power without fixing the reactive power mistake. In the process of selecting the state of the voltage vector, this will lead to a change in the active and reactive power directly at the input of the rectifier. However, according to the published research, the use of the six-sector switching table has many disadvantages, so it is not considered in this thesis. In this thesis, the direct power control method of the active rectifier will only consider the use of the switching table for 12 voltage sectors.

# LITERATURE SURVEY

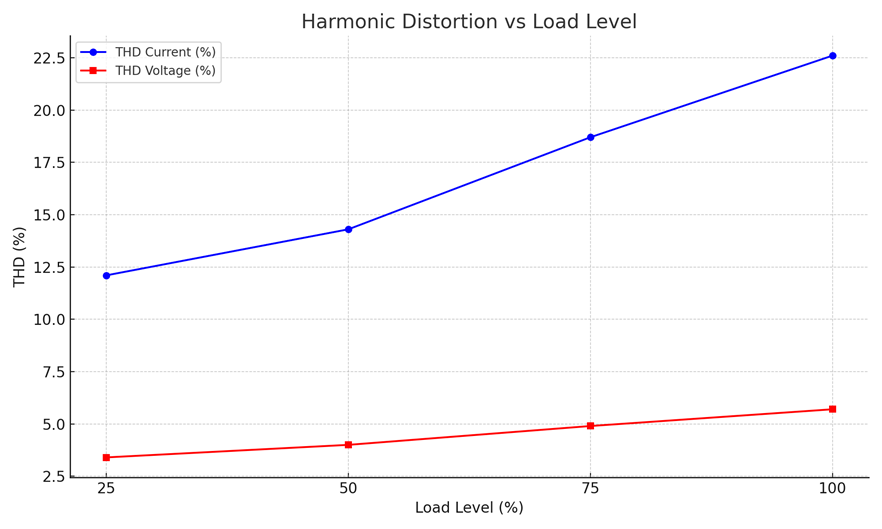
This approach illustrates that merging active and passive harmonic filtering, with real-time surveillance and simulation-based assessment, yields a robust and effective solution for maintaining power quality in conveyor systems featuring nonlinear loads. After implementing harmonic mitigation methods (passive LC filter and active power filter), the subsequent improvements were observed:

• The present THD level was lowered effectively, dropping from 22.6% to 6.3%.

• The need for reactive power diminished, descending from 16.1 voltage-amperes reactive.

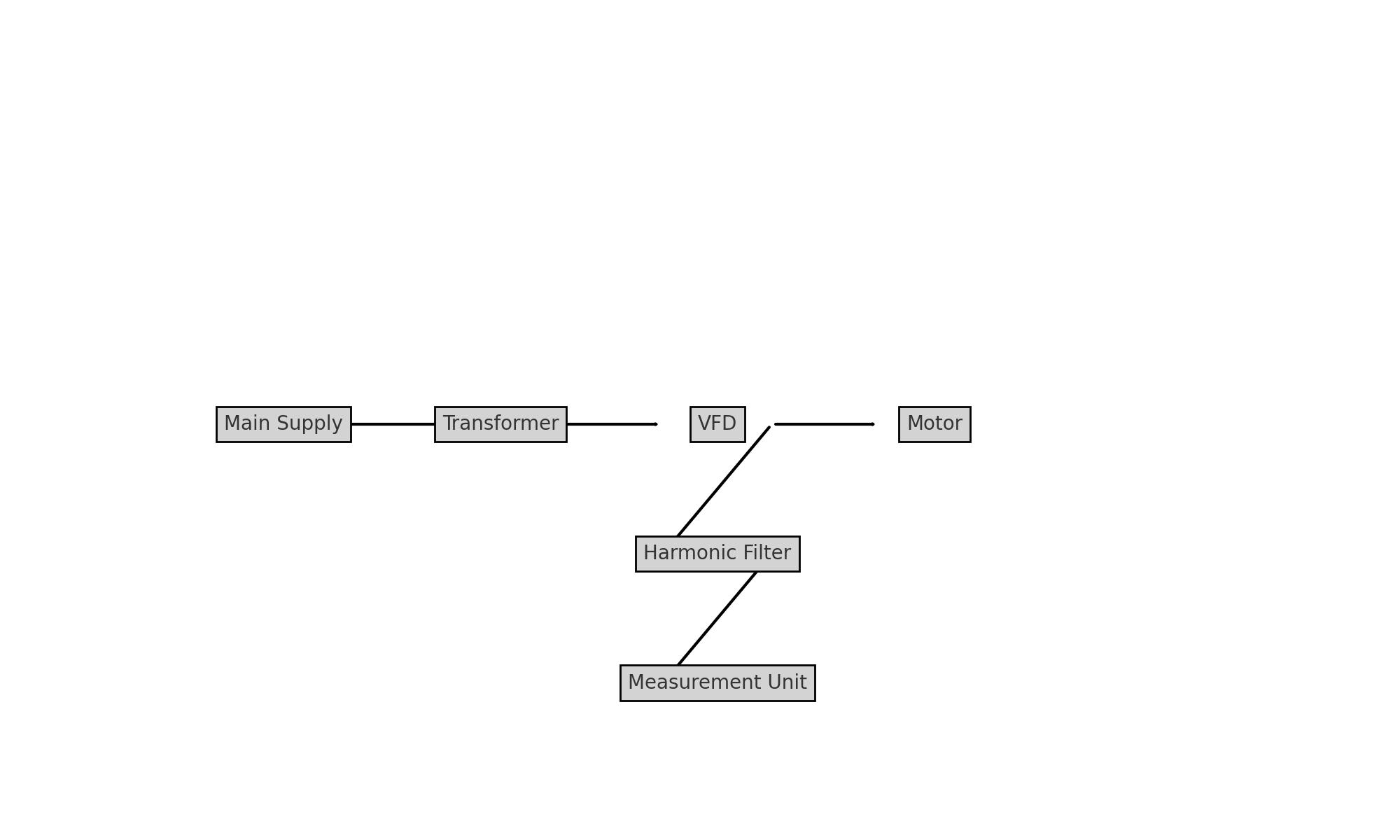
• The power factor experienced a substantial improvement, climbing from 0.72 to a value of 0.94.

Nonlinear loadings are an integral element of modern industrial power supply systems and the main source of high harmonica, leading to inconsistency of the quality level of electricity and violation of the norms of the International and national standard. This feature is also cited in almost all industries, including mining, oil and gas sectors, where regulated systems exist. High current and voltage harmonics have a number of negative consequences for elements of power supply systems, including losses in additional air and cable lines, reduction in the life of power transformers and electrical equipment, improper operation of relay protection, leading to additional vibrations in electromechanical systems. To improve the quality of electricity, a number of technical means are successfully used, including Active, Passive, hybrid filters, ant resonance dresses, as well as electronics devices for changing the configuration of power supply systems and the power part of the non-linear load. However, the theory and practice of using these tools and solutions does not fully account for the existence of resonance phenomena due to reactive power compensation capacitors and supply transformers due to the presence of nonlinear loading [7, 8]. Sample power supply systems for industrial enterprises, in particular enrichment factories, include capacitor devices connected to 6 (10) kV tires, and a variety of filter compensation devices, active filters, etc.in the non-linear loading of controlled electrical devices with a frequency of 0.4 kV direction of comprehensive distribution devices the system architecture is shown in Figure 1.



**FIGURE 1.** The relationship between harmonic content and the strength of the load

The conveyor power supply block diagram is shown in Figure 2.



**FIGURE 2.** Conveyor power supply block diagram

Table 1, presents the load and harmonic distortion levels.

**TABLE 1.** Load and Harmonic Distortion Levels

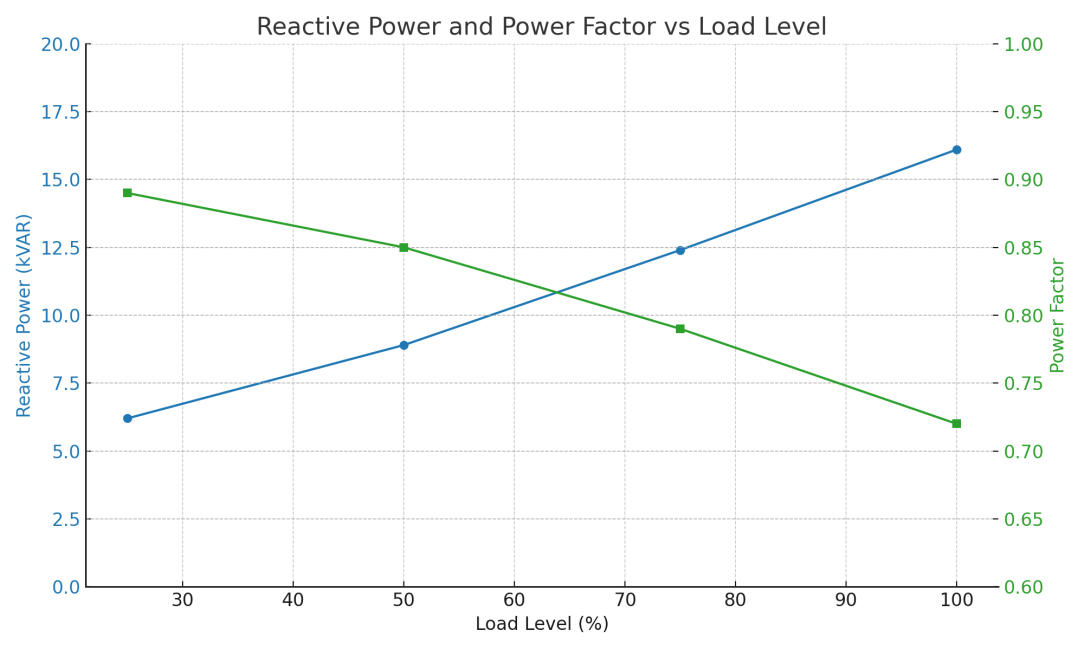
|  |  |  |  |
| --- | --- | --- | --- |
| **Load Level (%)** | **THD (Voltage) %** | **THD (Current) %** | **Power Factor** |
| 30 | 4 | 13 | 0.9 |
| 40 | 5 | 15 | 0.85 |
| 80 | 5.5 | 18 | 0.81 |
| 110 | 6 | 22 | 0.8 |

Table 2, presents load level and harmonic distortion and power factor.

**TABLE 2.** Load Level and Harmonic Distortion and Power Factor

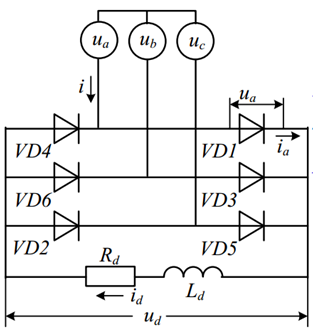
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Load (%)** | **THD Current (%)** | **THD Voltage (%)** | **Power Factor (PF)** | **Reactive Power (kVAR)** |
| 25 | 12.1 | 3.4 | 0.89 | 6.2 |
| 50 | 14.3 | 4.0 | 0.85 | 8.9 |
| 75 | 18.7 | 4.9 | 0.79 | 12.4 |
| 100 | 22.6 | 5.7 | 0.72 | 16.1 |

The reactive power and power factor compared to load level is shown in Figure 3.



**FIGURE 3.** Reactive Power and Power Factor Compared to Load level

The regulations put the responsibility on electricity users to actively take part in preserving the quality of electricity. This involves not only the utilization of appropriate equipment, but also guaranteeing its correct upkeep and operation to prevent a detrimental effect on the performance and effectiveness of the power system overall. An electrical complex is an electromagnetic environment in which electrical devices that generate, transmit and consume electricity operate and interact. The set of characteristics of the electromagnetic environment, systems, affecting the normal operation of electrical equipment and the level of electromagnetic noise, is characterized by the quality of electricity in the power supply. For example, such values can be a network organization that is obliged to deliver high-quality electricity to the distribution tires of the consumer and to the consumer himself, he undertakes not to worsen the quality of the power supply of electrical equipment on the side of the network company's power grid. One of the main parameters that determine the quality of electricity is the sinusoidal non-sinusoidal nature of the voltage form caused by the flow of the harmonic components of current and voltage in the distribution network [9, 10]. A simulation of a multi-motor electric drive system with an active rectifier and a vector control algorithm has been performed. The simulation results are analyzed and the electromagnetic compatibility of conveyor electric drive systems using active rectifiers and electric drive systems with diode rectifiers, such as multiples rectifiers with active filters and reactors installed at the rectifier inlet is compared. The three-phase bridge scheme of the corrector is shown in Figure 4.



**FIGURE 4.** Three-phase Bridge Scheme of The Corrector

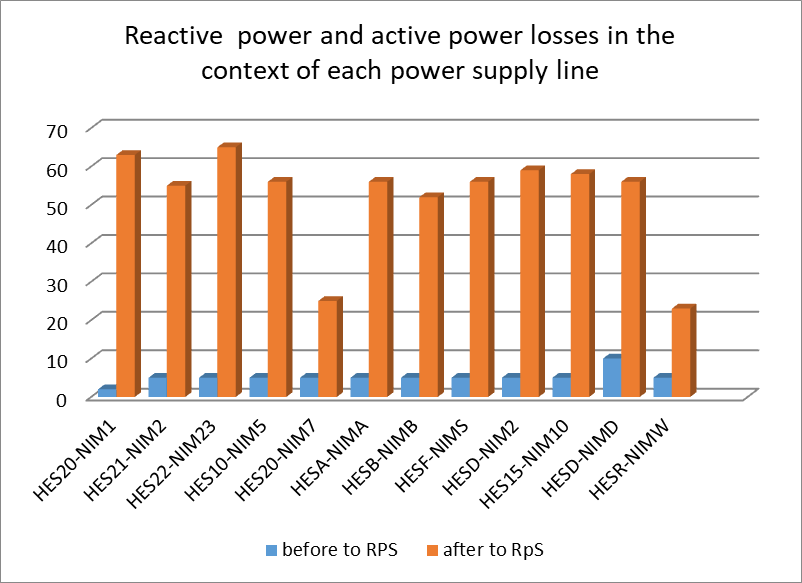
The non-linear load of industrial power supply systems are consumers based on Valve straighteners. Such consumers include, for example, Frequency-Controlled drives, which include frequency shifters that allow electricity consumption to be reduced by 10-25% in power supply systems. At the same time, the widespread use of Frequency-Controlled guidance systems of technological equipment has a significant impact on the deterioration of the quality indicators of electricity [11, 12].

Non-Sinusoidal voltage reduces the efficiency of electrical equipment and reduces its service life. The main factors of the negative impact of high harmonics on the performance of elements of industrial power supply systems are as follows:

* Additional losses of active at in power transformers, electric machines and distribution distribution networks.
* Can cause resonant contact rust between the induction of the system and the capacitance of the capacitor battery at high harmonic frequencies.
* Resonance modes significantly increase the values of high current and voltage harmonics, which can lead to a reduction in the service life of the equipment, a violation of technological processes as a result of the accident state of the equipment.
* The complexity of performing reactive power compensation using capacitor devices.
* False (in error) operation of electrical network automation and microprocessor relay protection and automation devices.

**RESULTS AND DISCUSSIONS**

Basic techniques and solutions were analyzed to compensate for the high harmonics of current and voltage, schematic solutions for rational construction of a distribution network with nonlinear loading were studied, capacitor devices, passive, active and hybrid filter counter-resonant dresses were used in the chain of compensatory devices. The classification of filter compensation devices was considered as follows, analyzing their structure, control methods and methods of connecting to a compensated network. The main methods for managing active filter compensatory devices were considered, with Park-Clark's phase changes, incorporating Acai’s instantaneous power theory, showing their characteristics, advantages and disadvantages. Recommendations were made to use various methods and means of improving the quality of electricity in industrial power supply systems based on the power value of the non-linear load on the power of the transformer in the power supply system. Advances in power electronics have led to the installation of many new non-linear power loads, such as power converters, arc furnaces and motor drive systems, which in turn change the existing infrastructure and inject new types of harmonics. This study analyzes a static Kramer drive system for its harmonic behavior. The system is broken down component by-component and analyzed. The analysis includes classical harmonics of integer multiple of the fundamental frequency as well as sub-harmonics and inter harmonics. This paper shows that there are significant harmonic issues in a static Kramer drive that are likely to be present in similar drive systems. Due to the unknown frequencies at which inter harmonics and sub-harmonics arise it is difficult to estimate the magnitude and phase of these harmonics. It is proposed that state estimation techniques such as digital filtering coupled with windowing techniques can be used to properly pinpoint the frequency components, magnitudes and phases of harmonics, inter harmonics and sub-harmonics in the motor drive systems. Once identified, the harmonics, inter harmonics and sub-harmonics can be eliminated by means of passive filtering or self-tuning active filtering. The reactive and active power consumption graph is shown in Figure 5.



**FIGURE 5.** Reactive and Active Power Consumption Graph

THDU (n)- are the coefficients of the harmonic components of the voltage determined by the expression (in equation 1)

# THDU (n)= (1)

# The improved power factor leads to lower apparent power demands and enhanced voltage stability in the conveyor system. Infrared imaging and continuous temperature tracking revealed that using filtering solutions decreased heat dissipation in cables and motors by a range of 12% to 18%. Motor drive systems have several unwanted harmonic components to their current waveforms due to the makeup of these systems. Motor drive systems usually are made up of an induction machine which has two different frequencies associated with it and hence is likely to cause current harmonics. Also, motor drive systems contain power electronic devices such as rectifiers and inverters. As was stated earlier power electronics devices such as rectifiers and inverters are known sources of harmonic distortion. Furthermore, wave form distortions (5th and 7th harmonics) were reduced, thus minimizing electromagnetic interference and extending the life of VFDs and motors. In conveyor-based industrial setups, harmonic distortions and reactive power impact not only adjacent motor drives, but also spread throughout the whole distribution grid. If reactive power isn't counter acted, it causes large apparent power, resulting in oversized equipment tannin creased losses. Harmonic currents, especially 5th, 7th, and 11th order, generate voltage notching and wave form distortion, which disrupt delicate devices. Under lighter burdens, harmonic effect sire present, but are les shameful. Simple passive filter should suffice. With medium to high loads, hybrid systems (passive + active) provide ideal performance. Power factor improvement corresponds with diminished kVA demand, allowing fort herself smaller capacity transformers and cables. In conveyor-based industrial systems, the coupling go flare synchronous motors and variable frequency drives (VFDs) creates nonlinear electrical condition.

# ADVANTAGES

The initiatives and methods discussed highlight the essential need to manage reactive and active power effectively. By implementing extensive strategies for reactive power compensation, optimizing network setups, boosting maintenance practices, and utilizing advanced technologies, utilities cannot ice ably reduce waste and enhanced he dependability of electrical networks. A focus on continually improving the quality of electricity delivered to consumers ensures that contemporary energy systems operate efficiently and meet evolving needs. Table III presents THD improvement before and after filtering.

**TABLE 3.** THD Improvement Before and After Filtering

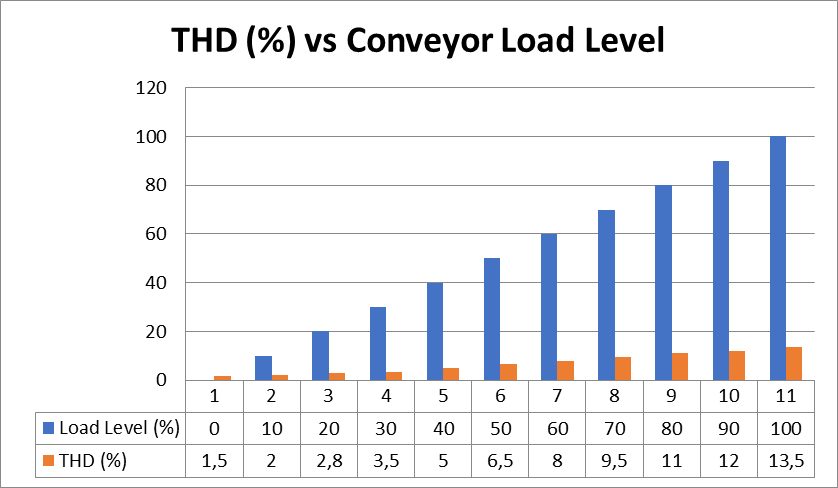
|  |  |  |
| --- | --- | --- |
| **Load Level (%)** | **THD Before Filtering (%)** | **THD After Filtering (%)** |
| 25 | 12.1 | 5.2 |
| 50 | 14.3 | 6.4 |
| 75 | 18.7 | 7.1 |
| 100 | 22.6 | 8.0 |

Table 4, presents power factor before and after compensation.

**TABLE 4.** Power Factor Before and After Compensation

|  |  |  |
| --- | --- | --- |
| **Load Level (%)** | **Power Factor Before** | **Power Factor After** |
| 25 | 0.89 | 0.96 |
| 50 | 0.85 | 0.95 |
| 75 | 0.79 | 0.93 |
| 100 | 0.72 | 0.91 |

Capacitor batteries, often utilized in conjunction with thermistors, play a crucial role in transverse compensation, providing necessary reactive power support and enhancing voltage stability within power systems. While the use of thermistor-diode circuits can reduce costs, they also introduce challenges related to delay and voltage fluctuations. Advanced control strategies and real-time monitoring solutions are critical for ensuring the safe and efficient operation of reactive power compensation systems. These technologies are not only valuable for improving performance but also for enhancing grid reliability and resilience in the face of increasing demand and a growing reliance on renewable energy resources. This combined system exemplifies the innovative solutions being explored for reactive power compensation. By seamlessly integrating thermistor-controlled reactors, capacitor banks, and harmonic filters, this system provides a sophisticated and efficient method for addressing the challenges of power quality and grid stability. The alteration in the THD metrical diverse conveyor load stages is shown in Figure 6.



**FIGURE 6.** The Alteration in the THD Metrical Diverse Conveyor Load Stages

# APPLICATIONS

The classification of filter compensation devices was considered as follows, analyzing their structure, control methods and methods of connecting to a compensated network. The main methods for managing active filter compensatory devices were considered, with Park-Clark's phase changes, incorporating Acai’s instantaneous power theory, showing their characteristics, advantages and disadvantages. Recommendations were made to use various methods and means of improving the quality of electricity in industrial power supply systems based on the power value of the non-linear load on the power of the transformer in the power supply system. A generalized algorithm for analyzing and modeling non-sinusoidal modes has been developed for rational selection of technical tools, or solutions have been provided to improve the quality of electricity for industrial power supply systems with non-linear loading and capacitor devices. In the direct power control system of an active rectifier, the influence of switching tables is very large on the current characteristics at the input of the rectifier. In the process of selecting the state of the voltage vector, this will lead to a change in the active and reactive power directly at the input of the rectifier. The frequency of the asynchronous motor of the electric drive system is controlled using scalar, vector, discontinuous and sliding (direct torque control system) and other control algorithms. Frequency converters with diode rectifiers are commonly used in conveyor electric drive systems. These converters consume reactive power power from the mains, causing significant distortion of the mains current and voltage at the input of the rectifier. When the motor is operating in regenerative mode, the recovery energy is not returned to the grid, but is dissipated in the resistor elements of the converter, which limits the use of the converter in the mine conveyor system. Conveyor speed control reduces the width of the belt during design, as well as reduces belt wear and energy consumption. There are two methods of tape speed control: continuous and discrete. The discrete control method, based on the amount of measured load, changes the conveyor speed discretely when a certain threshold value of the load is reached, as required by the technology. With the continuous control method, the conveyor speed changes in proportion to the load flow.

# CONCLUSION

The thorough assessment of reactive power and harmonic distortions in contemporary conveyor systems discloses not able hurdles and possibilities for refining power quality and system efficiency. As conveyor systems are more commonly driven by non-linear loads such as variable frequency drives (VFDs), the metrics of harmonic distortion (particularly THD) often increase with load, possibly causing equipment over heating, decreased efficiency, and disruption of control systems. In the direct power control method of the active rectifier, the influence of switching tables on the characteristics of the current at the input of the rectifier is very great. In the process of selecting the state of the voltage vector, this will lead to a change in the active and reactive power directly at the input of the rectifier. A promising approach to improving the operating mode of the direct power control method is to use switching tables of keys to select the optimal control voltage vector. The efficiency of the direct power control method of the active rectifier is increased by analyzing several voltage switching tables to select the optimal control voltage. The analysis and assessment of conveyor electric drive systems at mining enterprises were performed. Options for selecting the structure, equipment and control algorithms for the electric drive system were proposed. A new structural diagram was proposed, which is a multi-motor conveyor electric drive system with a frequency converter consisting of an active rectifier and several voltage inverters. An algorithm for direct control of the torque of asynchronous motors was used. The result is high-quality speed and torque control with overshoot (no more than 5%), a soft start and soft braking process, and a decrease in higher harmonic components of the current consumed by the power source. The conveyor electric drive system ensures a high level of electromagnetic compatibility. In the direct power control method of an active rectifier, the influence of switching tables is very large on the current characteristics at the input of the rectifier. In the process of selecting the state of the voltage vector, this will lead to a change in the active and reactive power directly at the input of the rectifier. A promising approach to improving the operating mode of the direct power control method is the use of key switching tables to select the optimal control voltage vector. The study of switching tables with direct control of the power of the active rectifier ensures strict character in the selection of control voltage vectors. The choice of a switching table has more advantages for building electric conveyor drives. Increasing the power factor, reducing harmonic distortion of the current in the network.

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