ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 11, Issue 10, October 2024

Improving Voltage Quality Using Filter-Compensating Devices

Taslimov Abdurakhim Dekhanovich, Sultanov Asror Nurali ugli, Muminov Vakhobiddin Uson ugli

Professor, Department of Power Supply, Tashkent State Technical University, Uzbekistan
PhD student, Department of Power Supply, Tashkent State Technical University, Uzbekistan
Assistant Professor, Almalyk Branch of Tashkent State Technical University, Uzbekistan

ABSTRACT: The increasing deployment of modern multifunctional measuring instruments (MIs) and electronic computing machines (ECMs) has enhanced the analysis and evaluation of electrical networks, particularly in addressing the non-sinusoidality of voltage and current. Non-sinusoidal waveforms, primarily caused by higher harmonics (HH), degrade the performance of electrical systems, reducing energy efficiency and stability. This study explores technical solutions, such as filter-compensating devices and LC filters, which are used to mitigate harmonic distortion and improve the power factor. The paper also discusses the role of passive and active power factor correction methods, focusing on the application of linear chokes and active harmonic conditioners (AHCs). These devices effectively reduce harmonic components in nonlinear load scenarios and improve the overall energy quality in transmission networks. The findings highlight the need for both passive and active filtering solutions to ensure efficient electricity transmission, reduce harmonic distortion, and maintain network reliability.

KEY WORDS: Electronic computing machines (ECMs), Non-sinusoidality of voltage and current, Higher harmonics (HH), Electricity quality (EQ), Harmonic distortion, Linear chokes, Three-phase bridge circuits, Passive LC filters, Uncompensated LC filter, Compensated LC filter, Active harmonic filters (AHF), Active harmonic conditioners (AHC).

I. INTRODUCTION

Recently, due to the emergence and spread of modern multifunctional measuring instruments (MIs) for indicators of electrical modes and electronic computing machines (ECMs), it has become possible to conduct a deeper analysis and take into account the impact of additional factors that were previously difficult to assess. Among the additional and poorly studied factors is the low quality of electricity (EQ), and in particular, the non-sinusoidality of voltage and current. The presence of higher harmonics (HH) reduces the performance of most elements present in electrical networks, which requires both technical and organizational measures to reduce the level of HH to a minimum.

Domestic and foreign specialists have developed many technical means to improve the quality of electricity according to indicators of voltage and current non-sinusoidality. One of the effective ways to reduce higher harmonic components of current is the use of filter-compensating devices [1]. The use of an LC filter to smooth out the ripples of rectified voltage can be called a method of passive power factor correction. The shape of the input current depends on the inductance of the choke and the capacitance of the filter capacitor. Since the frequency of the power supply network is 50 Hz, the filter elements will be large, which worsens the mass and size characteristics of the device. In this case, the power factor is in the range of 0.7-0.85. It should be noted that the use of inductance leads to overvoltages that occur on the output capacitance and the choke of the filter during abrupt changes in the load current [2]. Methods of active power factor correction [3] can be conditionally divided by conversion frequency into low-frequency and high-frequency methods [4]. As with most proposed methods, harmonics are eliminated only for individual electrical receivers.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 11, Issue 10, October 2024

II. MAIN PART

The simplest way to reduce the level of higher harmonics generated by nonlinear loads into the external network is the sequential connection of linear chokes (Fig. 1). Such a choke has a low value of inductive resistance at the main frequency and significant resistance values for higher harmonics, which leads to their attenuation [5,6]. At the same time, the amplitude factor (crest factor) k_a and the distortion factor k_i of the input current decrease:

$$k_a = \frac{I_a}{I}$$

Where I_a - current pulse amplitude; I - effective value of non-sinusoidal current.

$$I = \sqrt{I_1^2 + \sum_{n\geq 2} I_n^2} ,$$

Where I_1 - effective value of the fundamental (first) harmonic of current; I_n- effective value of the "n"-th harmonic of current.

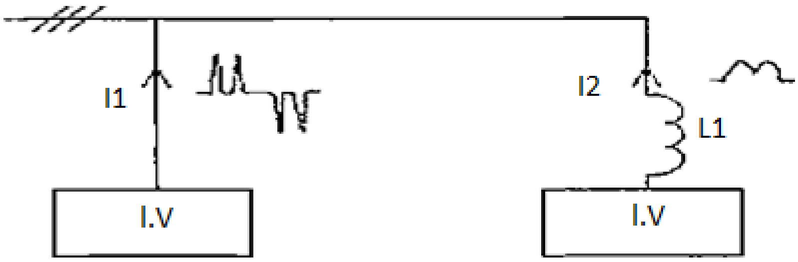

Figure 1 - Current curves of nonlinear loads: a) without choke b) with choke connected in series

This method of reducing the current distortion factor is used in three-phase bridge circuits [7]. The use of series-connected linear chokes in some cases does not allow reducing current harmonic distortions to the desired limits. In this case, the use of passive LC filters tuned to a certain harmonic order is advisable. Such filters have found wide application in systems with NSPS to improve the harmonic composition of the consumed current.

Connecting a filter at the input of a six-half-period rectifier under 100% UPS load reduces the current distortion factor to 8-10%. The value of this factor in the system without a filter can reach 30% or more. Figure 2 shows the implementation of a three-phase LC filter used as an optional device in three-phase NSPS.

The following types of passive filters are distinguished [7]:

- uncompensated LC filter; compensated LC filter; uncompensated LC filter with switch; three-phase version of the LC filter.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 11, Issue 10, October 2024

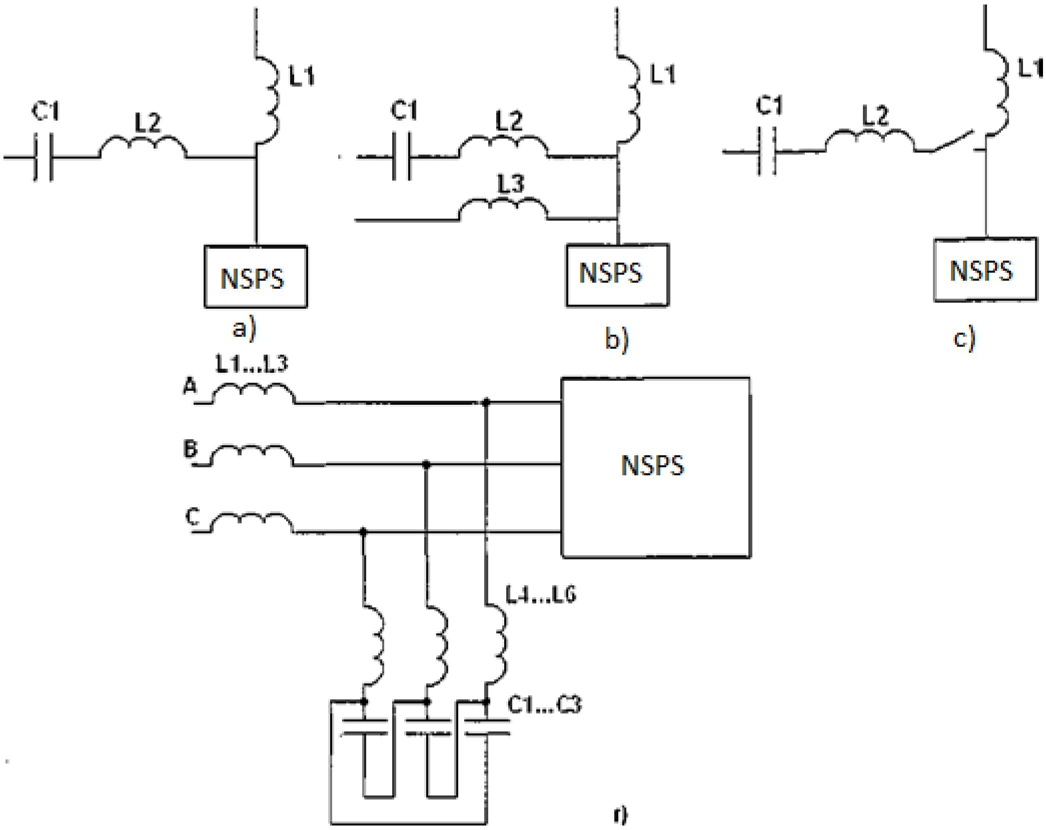

Figure 2 - Passive filters: a) uncompensated LC filter; b) compensated LC filter; c) uncompensated LC filter with switch; d) three-phase version of the LC filter.

An uncompensated filter contains a longitudinal inductance L1 and a transverse circuit consisting of a series-connected inductance L2 and capacitance C1 tuned to a certain harmonic (Figure 2a). If the filter is tuned to the 5th harmonic, the transverse circuit resistance is close to zero, and the current consumed from the source will not contain this harmonic.
A compensated filter contains an additional transverse inductance L3, which makes the filter inductive relative to the generator (Figure 2b). This reduces the capacitive component of the consumed current and facilitates generator operation in start-up and steady-state modes. However, the presence of the choke reduces the overall system power factor.

The uncompensated filter with a switch is convenient for use in circuits where its operation is required only at certain times. The transverse filter circuit is automatically connected only after the NSPS reaches nominal mode (Figure 2c).
One of the main disadvantages of such filters is the need to select chokes for a specific and constant harmonic power, which does not allow effectively combating them when the nonlinear load changes throughout the day. The use of chokes reduces the power factor, which negatively affects the energy efficiency of electricity transmission.
For such loads, active harmonic filters or active harmonic conditioners (AHC) can be used. AHC [891011] is connected in parallel with the nonlinear load (Figure 3).

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 11, Issue 10, October 2024

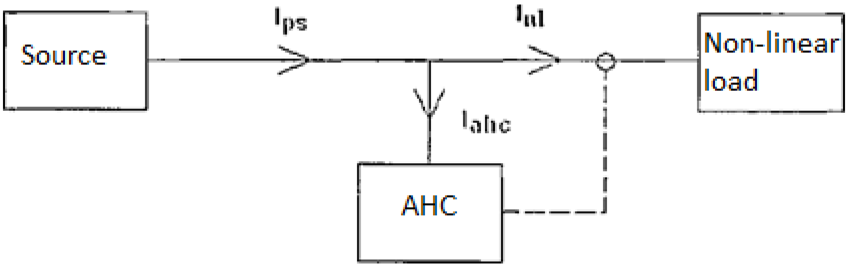

Figure 3 - Active harmonic conditioner connection diagram

The principle of operation of an active harmonic conditioner is based on analyzing the harmonics of the nonlinear load current and generating the same current harmonics but with the opposite phase into the distribution network. As a result, higher harmonic components of the current are neutralized at the point where the AHC is connected. This means they do not propagate from the nonlinear load into the network and do not distort the primary energy source voltage [12].
The nonlinear load current contains the main and higher harmonics:

$$I_{nl} = I_1 + \sum_{n\geq 2} I_n,$$

Where I_1 - is the effective value of the main (first) harmonic of the current;

I_n - effective value of the "n"-th harmonic of the current.

The AHC current contains the higher harmonics in counterphase to the load current:

$$I_{ahc} = -\sum_{n\geq 2} I_n,$$

Where I_n - is the effective value of the "n"-th harmonic of the current.
As a result, the current consumed from the source is almost sinusoidal, as it contains only the main (first) harmonic:

$$I_{ps} = I_{nl} + I_{ahc} = I_1$$

III. CONCLUSION

Thus, the source supplies only the main harmonic of the load current, while the AHC compensates for almost the entire spectrum of higher harmonics from the 2nd to the 25th. The AHC can be installed at any point in the distribution network and can compensate for higher harmonics from one or more nonlinear loads. Most AHC models can compensate for effective values of higher harmonics from 20 to 120 A.

REFERENCES

1. Taslimov A.D., Muminov V.U. "Evaluation of the Impact of Voltage and Current Non-Sinusoidality on the Functioning of Electrical Networks." Actual Problems of Power Supply Systems // Collection of papers from the International Scientific and Technical Conference. - Nukus, Berdakh Karakalpak State University, 2024. - pp. 302-306.
2. Labuntsov V.A., Zhang Daizhong. "Three-Phase Rectifier with Capacitive Filter and Improved Input Current Curve" [Text] / V.A. Labuntsov, Zhang Daizhong. - Electricity. - 2013. - №12. - pp. 45-48.
3. Ganelin A.M., Kostruba S.I. "Handbook of the Rural Electrician" [Text] / A.M. Ganelin, S.I. Kostruba. - M.: Agropromizdat, 2008. - 33 p.
4. Ivanov V., Panfilov D. "Standard Power Factor Correction Schemes" [Text] / V. Ivanov, D. Panfilov // Microchip News. - 2017. - №9-10. - pp. 38-45.
5. Dimitrios S. "Analysis and Study of a New Class of Power Filters for Three-Phase Industrial Networks of 380 V" [Text]: PhD dissertation in technical sciences / S. Dimitrios. - Moscow, 2001. - 162 p.
6. Passive filter design for harmonic reactive power compensation in singl-phase circuits supplying nonlinear loads. El-Saadany E.F., Salama M.M.A., Chikhani A.Y. IEE proc. Generat., Transmiss, and Distrib. 2000. 147.- №6.- P.373-380.
7. Bettega E., Fiorina J.N. Active Harmonic Conditioners and Unity Power Factor Rectifiers // Cahier Technique Schneider Electric, ECT 183, 1999.- 28 p.
8. Bernard S., Fiorina J.N., Gros B., Trochain G. THM Filtering and the Management of Harmonic Upstream of UPS *11* MGE UPS Systems, MGE 0246-2000.- 17p.

9. Bernard S., Trochain G. Compensation of Harmonic Currents Generated By Computers Utilizing an Innovative Active Harmonic Conditioner // MGE UPS Systems, MGE 0128, 2000.- 19p.

10. Jintakosonwit Pichai, Fujita Hideaki, Akagi Hirofumi. Denki gakkai ronbunshi. D=Trans. Inst. Elec. Eng. Jap. D. 2011. 121. - №3. - P.316-324.

11. Wang Qun, Yao Wei-zheng, Liu Jin-jun, Wang Zhao-an. Zhongguo dianji gongcheng xuebao=Proc. Chin. Soc. Elec. Eng. 2011. 21. - №2.- P. 16-20.

12. Li Kuang, Xiao Guochun, Wang Zhao'an (School of Electrical Engineering, Xi'an Jiaotong University, Xi'an 710048, China). Xi'an jiaotong daxue xuebao=J. Xi'an Jiaotong Univ. 2014. - №6. - P.632-635.