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Testing of a Filtered Compensation Device under Industrial Conditions

J.N.Tolipov, Sh.I Murtazov

Institute of Energy Problems of the Academy of Sciences of the Republic of Uzbekistan

ABSTRACT: This article presents the results of testing filter-compensation devices with active converters in the power supply system of the yarn spinning workshop within "Sulton Tex Group" LLC. The main objective of the research is to develop a methodology for selecting the installation location of filter-compensation devices with active converters in networks with nonlinear loads, to improve their structure and algorithmic support, and to experimentally verify theoretical results related to improving power quality based on the theory of power supply complexes.

Experimental tests were carried out in a 0.4 kV power network using a single prototype of a parallel active filter (PAF). The nominal current of the PAF was 400 A, and an active-capacitive filtering circuit (R = 0.1 Om, C = 100 pF) was installed at its output. During the tests, variations in voltage, current, and harmonic distortions were analyzed under different operating modes of the control station and the parallel active filter. According to the obtained results, when the PAF was activated, the waveforms of current and voltage improved, while reactive power and high-frequency harmonics were significantly reduced. Based on the data in the table, the voltage unbalance coefficient decreased by up to 93.5%, and the current harmonics were reduced by up to 58%. The results of industrial tests confirmed the validity of the developed theoretical principles and modeling results. Furthermore, it was determined that equipping parallel active filters with output filtering circuits of various configurations plays an important role in improving power quality and eliminating resonance phenomena.

KEYWORDS: power supply system, filter-compensation device, parallel active filter, active converter, harmonic distortion, power quality, reactive power compensation.

I. INTRODUCTION

The industrial tests of filter-compensation devices with active converters were conducted under the conditions of power supply systems of existing industrial enterprises to achieve the following main objectives:

- To develop a methodology for selecting the installation location of filter-compensation devices with active power converters in geographically distributed networks with nonlinear loads;
- To identify directions for improving the structure, component composition, and algorithmic support of filter-compensation devices equipped with active converters;
- To validate and test theoretical studies and mathematical modeling results on the use of active converters and filter-compensation devices for improving power quality within the framework of the theory of power supply complexes.

II. OBJECT

In the first stage, a single active converter in the form of a parallel active filter was tested in the 0.4 kV distribution networks of the power supply system of the yarn spinning workshop within Sulton Tex Group textile company.

A parallel active filter was selected for the tests. Its nominal current is 400 A, and an active-capacitive filtering circuit (R = 0.1 Om and C = 100 µF) is installed at its output. As a nonlinear load, the control station of the centralized yarn spinning workshop installed at the yarn spinning factory was used.

The frequency converter is connected to a 250 kVA transformer, after which electrical energy is supplied to the 140 kW centralized yarn spinning workshop through a step-up transformer. The parallel active filter is connected to the control station, where the following parameters are indicated: Uc – phase voltage of the network; Ic – phase current of the supply transformer on the 0.4 kV side; Ibs – phase current of the control station; Ipaf – phase current of the parallel active filter.

In this case, the 10 kV overhead line supplying the yarn spinning workshop transformer has a length of 500 m, with a reactive impedance of 0.34 per unit. The reactive impedance of the yarn spinning workshop

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transformer is 0.045 per unit (based on the base values: 35/10 kV substation, 6300 kVA, 10 kV), while the power of the yarn spinning workshop is 0.02 per unit.

III. KEY FINDINGS AND ENERGY CONSERVATION OPPORTUNITIES

Since the given ratios are also typical for other yarn spinning workshop power supply systems, the obtained results can be considered adequate and applicable to other cases as well.

The studies were carried out based on the presented methodology by analyzing the parameters of voltage and current harmonics under the following operating modes:

•The parallel active filter and the control station are turned off;

•The parallel active filter is turned off, and the control station is turned on;

•The control station and the parallel active filter are connected, with the characteristics of the filtering circuit at the output of the parallel active filter modified;

•The parallel active filter is turned on, and the control station is turned off.

The network is supplied with energy at 0.4 kV through a transformer. When the electrical consumer (control station, BS) operates, reactive power and harmonic distortions are generated. These distortions cause the current to become non-sinusoidal. The parallel active filter (PAF) detects these distortions and generates a compensating current (I_{PAF}) in opposite phase. As a result, the total current in the network (I_{BS}) becomes clean, sinusoidal, and correctly phased. This device is used to compensate for reactive power and harmonic distortions in the electrical network.

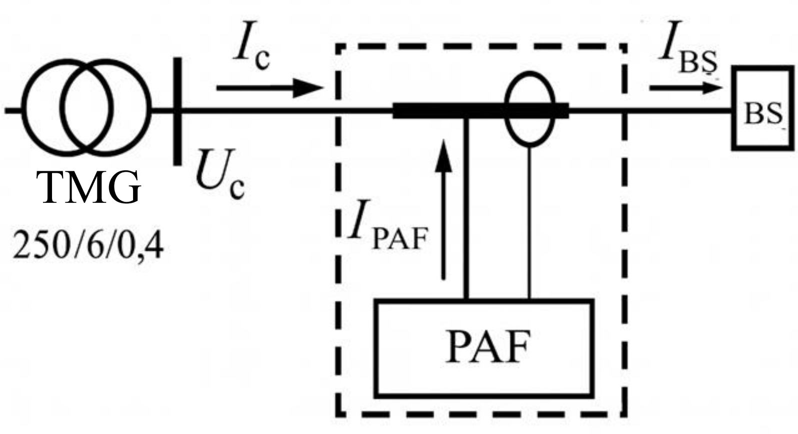

Figure 1. Diagram of experimental studies of the parallel active filter in the yarn spinning workshop within "Sulton Tex Group"

IV. METHODOLOGY

Table 1 presents values reflecting the performance of the parallel active filter for different configurations of its output filtering circuit. In this case, variations in the network voltage Uc are evaluated relative to the nominal value, while changes in the voltage unbalance coefficient kU are assessed with respect to the initial level of high harmonics when both the control station and the parallel active filter are turned off.

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Table 1

Assessment of the Parallel Active Filter's Performance

Parameter	Control Station and Parallel Active Filter Turned Off	Control Station Turned On, Parallel Active Filter Turned Off	Operation of the Parallel Active Filter Output Filtering Circuit Without a Resistor		Operation of the Parallel Active Filter Output Filtering Circuit With Resistors	
U_c, V	238	232	238	+3%	237	+3%
k_U, %	5,5	10,1	7,7	-52%	5,8	-93,5%
I_c, A	-	270	227	-26%	235	-13%
k_I, %	-	22,5	15	-33%	7,5	-58%

Thus, the experimental studies and industrial tests conducted in the yarn spinning workshop of "Sulton Tex Group" LLC confirmed the validity of the developed theoretical principles and identified patterns, and also made it possible to draw the following conclusions:

The results of the industrial tests demonstrated the necessity of equipping a conventional parallel active filter with output filtering circuits of various configurations. This is important not only under resonance conditions but also to ensure effective improvement of power quality. These results confirm the conclusions obtained through theoretical studies and mathematical modeling.

V. CONCLUSION

The results of the experimental studies conducted in the yarn spinning workshop of "Sulton Tex Group" LLC indicate that filter-compensation devices based on active converters effectively reduce reactive power and harmonic distortions in power supply systems and significantly improve power quality. During the tests, the harmonic composition of the network voltage and current was studied under various operating modes of the parallel active filter (PAF). The results showed that when the PAF was activated, the voltage unbalance coefficient decreased by up to 93.5%, and the current harmonics were reduced by up to 58%. This led to an improvement in current and voltage waveforms, a reduction in phase angle, and an increase in energy efficiency within the system.

The research results confirm the developed theoretical models and mathematical analyses. They also demonstrate the necessity of equipping parallel active filters with output filtering circuits of various configurations. Such a solution is crucial for preventing resonance phenomena, ensuring load stability, and improving power quality.

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