Solutions for Governance and Suppression of Power Harmonic in Cities

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***Abstract*—Based on the current status of cities' power supply and distribution system, this paper conducts theoretical and experimental investigations over the generation, harzards as well as the restraining and suppression techniques of power harmonics. A solution of scheme selection for controlling and suppressing power harmonics suitable for the current power supply and distribution system of big and medium-sized cities is proposed. This study not only provides important implications for big and medium-sized cities, but also provides substantial reference value for controlling and suppressing power harmonics in the public utility system in China.**

Keywords-Power Harmonic; Governance and Suppression; Solution

I. INTRODUCTION

With the transformation and upgrading of industrial cities, the application of nonlinear load like converter, rectifier and inverter that use power semiconductor-cored insulated gate bipolar transistor (IGBT) and intelligent power module (IPM) has been widely used. While plenty of high power nonlinear converter equipments have their advancement and reliability in energy saving and controlling technology, its inherent characteristics will generate a large amount of harmonic, causing voltage and current waveform distortion in power supply system. [12] The consequence is that the power quality of utility grid is not up to standard or even worse, and the normal running and safety of utility grid and electrical equipment is badly influenced. Therefore, researches on the restraining and suppressing of power harmonics in urban utility grid have sound theoretical and practical values over improving power quality so as to better service the transformation and upgrading of the city.

II. CAUSE OF POWER HARMONIC

Power harmonic in city utility grid is mainly produced in the nonlinear load power equipment such as impact load, asymmetry load and the nonlinear load, with nonlinear load as the most important factor to produce electric power harmonic. [9] Inverter, uninterruptible power supply (UPS) and power converter equipment (such as rectifier and inverter), industrial computer and other high power nonlinear load are the harmonic source of utility grid. [7] With the transformation and upgrading of the inverter control in industrial control and other fields, the application of frequency converter is undergoing a wide spread. Therefore, inverter has become the main source of electric power harmonic in urban public grid.

III. HAZARD OF POWER HARMONICS

The harm caused by harmonic pollution of urban public power grid is reflected in many aspects. The main contents are as following.

1) Reducing the utilization rate of electrical equipment makes transformer, motor, power capacitors and other electrical equipments, as well as cables, Low pressure neutral line, busbar and other conductors working under the state of overload operation such as vibration, fever, abnormal sound, and etc. It shortens the service life of the electric power and increase electric energy loss.[13]

2) Interfering with relay protection, automatic devices and computer systems; Making the precision electronic equipment work abnormal, or even burn; Increasing the error of measuring and measuring instruments.[4]

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3) Reducing the quality of signal transmission and interfering communication system. Usually harmonics of 2000~5000Hz generates communication noise, while harmonics above 5000Hz lead to the disoperation of the signal of the telephone circuit. [8]

IV. GOVERNANCE AND SUPPRESSION OF POWER HARMONIC

In engineering, the governance and suppression of power harmonic in city utility grid is mainly divided into the following three types:

1) Series detuning reactor harmonic resonance amplifier is the main purpose of the measures to prevent because of reactive power compensation device (such as electric power capacitor, etc.) access to enlarge the excessive power harmonic and resonance occurs, but smaller filtering effect. [2-3]

2) Using passive power filter (PF) for harmonic governance. The passive power filter (PF) is a filter circuit that makes use of the combination of inductance, capacitance and resistance to filter out one or multiple harmonics. It Is currently the basic ways of city utility grid management and power harmonics restraining. Despite of its merits such as simple structure, low cost, reliable running and low-cost operating, still the harmonic governance effect is not ideal, and could lead to new problems such as oscillation of power supply and distribution system and harmonic amplification. [14]

3) Using active power filter (APF) for harmonic governance. The active power filter (APF) is a new type of special equipment based on modern power electronic technology and digital signal processing technology to govern electric power harmonics.[11] The basic principle of harmonic elimination is electricity generated during runtime equals the current amplitude of power harmonic, reversal polarity of harmonic current into the power supply system and compensate or offset the electric power harmonic current, and take the initiative to eliminate electric power harmonic. It has the merits of high control precision, fast response, good harmonic elimination effect and etc. Active power filter (APF) is a new research that enjoys a promising prospect in the field of future electric power harmonic governance and comprehensive optimization of power quality.

V. SOLUTION FOR GOVERNANCE AND SUPPRESSION OF POWER HARMONIC IN CITIES

A. About General Solution

With increasingly attention paid to the governance of electric power harmonic, related industries get fast development during the period of "China's 13th Five-Year Plan". There are a large variety of measures and products for the governance of electric power harmonic. Establishing reasonable selection schemes can guide technical personnel to choose measures and products according to the actual circumstance of electric power harmonic in power supply and distribution system. [15] Based on the harmonic voltage limit and harmonic current allowable value regulated in the utility grid national standard GB/T14549-1993 Utility Grid Harmonic Power Quality, [1] this paper sets the nominal voltage of 0.38 kV for example, and establishes a model selection scheme for the power harmonic governance and suppression of urban utility grid, as is shown in figure 1.

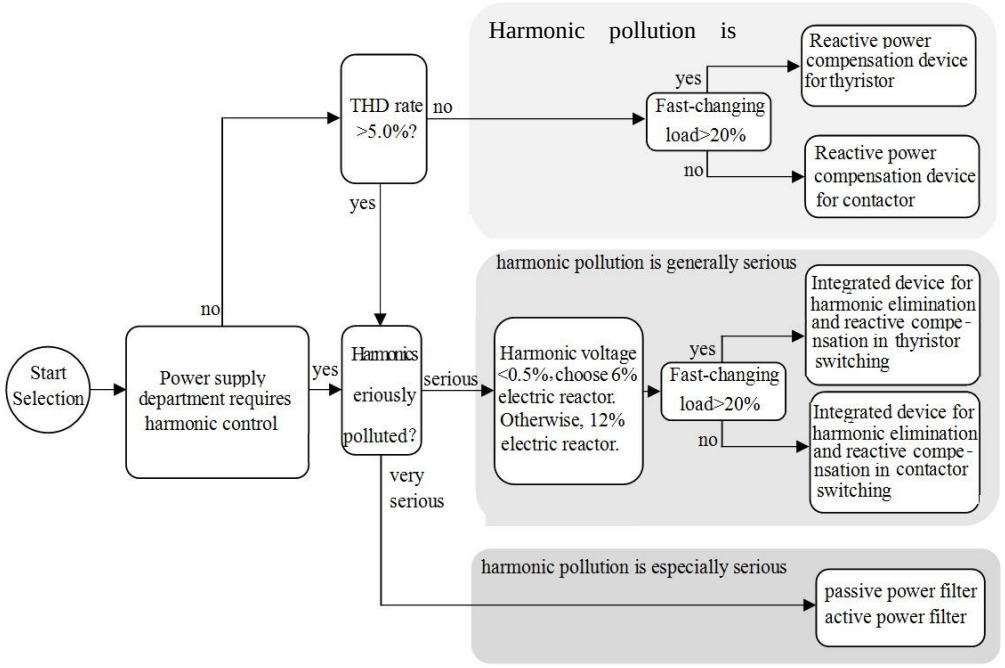


Figure 1. Model Selection for Power Harmonic Governance and Suppression

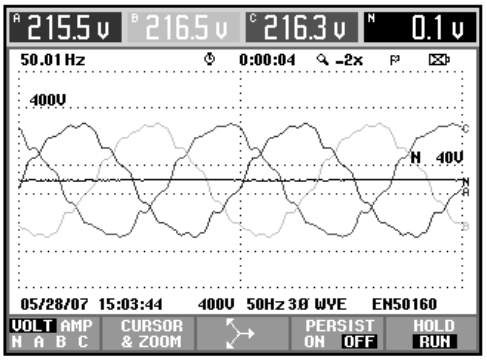
B. *Specific Solution for Power Harmonic Governance and Suppression*

By using technological upgrading projects as engineering case, this paper conducts researches on solutions for power harmonic governance and suppression.

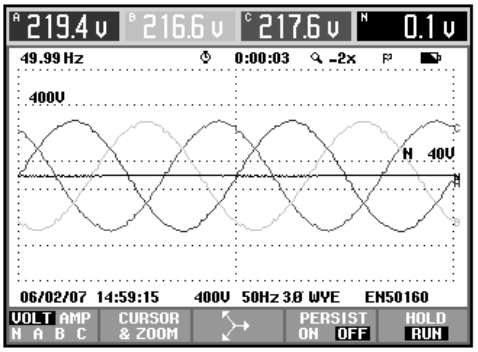
1) About technological upgrading projects: A utility grid in Hunan is mainly composed of one transformer S9-1250, equipped with 480 kvar PGJ type of reactive power compensation device. Load is composed of 2 sets of 200 kva UPS, switching power supply and air conditioning. When the system runs, output cable of the transformer reaches 45 degrees centigrade, cable vibration and electronic equipment interference become bigger. [10] Customer's technological upgrading requirements are as following: a) lowering the temperature rise of the cable and eliminating cable vibration; b) reducing interference of electronic devices.

2) Intended Solutions: Based on customer's technological upgrading requirements, the project group did a lot of resourcing work and field investigation to make sure the design rationality of this power supply and distribution system. Field test shows the distortion rate of voltage total harmonic was 7.8%, the distortion rate of current total harmonic was 68.9%. UPS and six pulse rectifier are the main nonlinear load that generate harmonics. Comparative analysis of these data proves that this project is under serious harmonic pollution and hazard. According to Figure 1, the choice of active power filter can effectively suppress the electric power harmonic. Detailed solutions are as following: a) retaining reactive power compensation device PGJ type 480 kvar; b) one set of LEAPF4200-0.4 active power filter installed into two sets of UPS respectively.

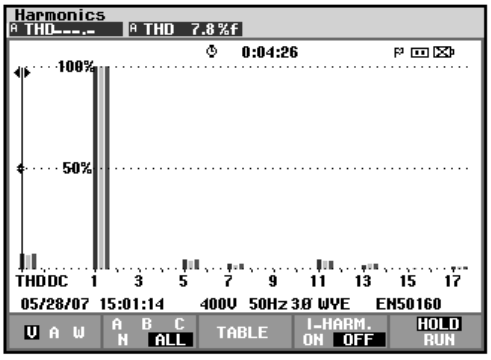
3) Verification: After installation and debugging, voltage, current waveform and harmonic analysis of the power supply and distribution system are tested on the spot, and data before and after the power harmonic control and suppression are shown in Figure 2 and Figure 3.



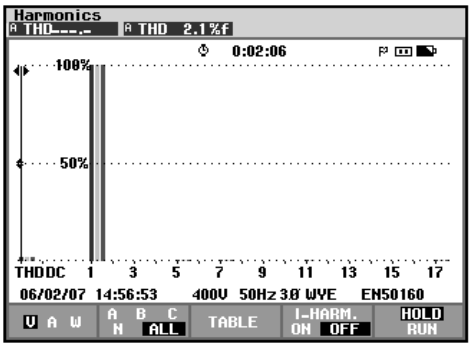
a) Voltage and current waveform-before



b) Voltage and current waveform-after

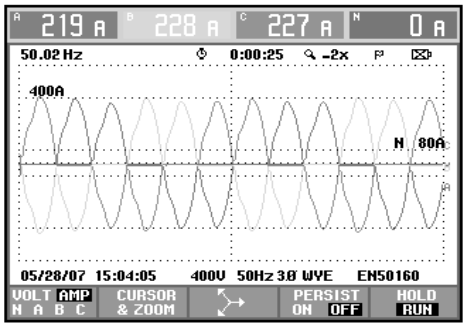


c) Voltage harmonic analysis-before

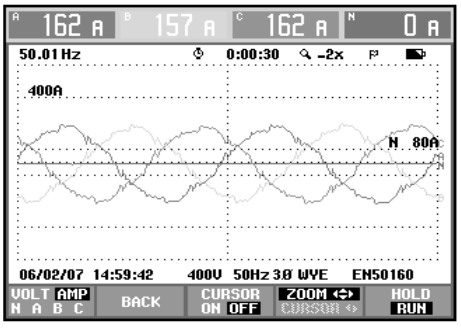


d) Voltage harmonic analysis-after

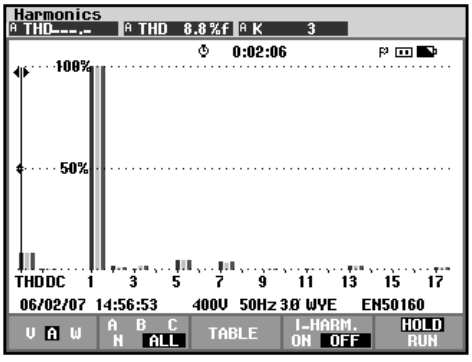
Figure 2. Voltage Waveform and Harmonic Analysis Before and After Power Harmonic Governance and Suppression



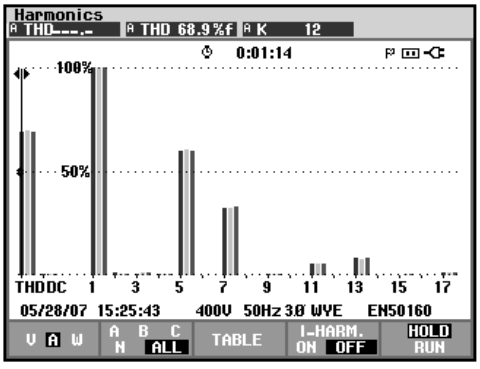
a) Current Rms and waveform-before



b) Current Rms and waveform-after



c) Current harmonics analysis-before



d) Current harmonics analysis-after

Figure 3. Current Waveform and Harmonic Analysis Before and After Power Harmonic Governance and Suppression

It can be seen from Figure 2 Figure 3 that after harmonic control and suppression, the total harmonic distortion rate of the power supply and distribution system is reduced to 2.1%; the total harmonic distortion rate of current is reduced to 8.8%; the temperature in output-end cable of the transformer is 37 degree centigrade when room temperature is 26 degree centigrade; the cable vibration and electronic equipment interference are eliminated. [5-6] After field tests and function verifications, the solution above turns out to be reasonable and achieves the intended goals.

VI. CONCLUSION

Based on the harmonic voltage limit and harmonic current allowable value regulated in the utility grid national standard GB/T14549-1993 Utility Grid Harmonic Power Quality, a model selection scheme for the power harmonic governance and suppression of urban utility grid is established after theoretical and experimental studies on the causes, hazards as well as the governance and suppression technology. By using technological upgrading projects as engineering case, this paper proposes a solution that uses active power filter (APF) as the core device. After field test and functional verification, the scheme proves to be both reasonable and practical. It is a reference for the power supply and distribution system design of urban utility grid.

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