Paper 0403

THE EFFECT OF SENSITIVE CONSUMERS ON POWER QUALITY IN 35KV POWER SYSTEM AND COUNTERMEASURES

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ABSTRACT: The Songjiang Sanzhuang substation mainly supplies large-capacity power consumers in 35kV and 10kV. Many of them are advanced electronics manufacturers and traditional metalwork and manufacturing enterprises. This paper is based on measurements of the consumers in various industries. By analyze the result of the measurements, this paper summarizes the characteristics of the sensitive consumers in 35kV (due to the length limitation, this paper take metalwork and electronics industry as an example), the effect on power quality (PQ) and the countermeasures.

0 Introduction

The idea power system supplies consumers with sinusoidal waveform and constant frequency under specified voltage level. In modern power system, due to the nonlinear equipments, the random changes of loads, the imperfect control means, faulty operation, external interference and various faults, there are many PQ problems. In recent years, the network operators and the consumers both concern about those issues, because the economic losses increased every year. In order to solve PQ problems, a measurement of the power quality of the consumers and the network should be done to analyze the reasons of PQ problems; then a reasonable solution that consider about various factors could be proposed and a post-evaluation of the solution is indispensable.

At present, many countries have done a lot of the work of PQ measurement, such as harmonic voltage and current detection of distribution systems and substation buses [2] and the PQ detection of consumer's internal network [3]. The main purpose of those measurements is to understand the PQ conditions of distribution systems at all levels and to understand the emission level of the large harmonic sources. Foshan city in China had measured the harmonic, and statistical analyze different industries' harmonic condition. All these efforts have played a positive role in understanding the nature of power quality and proposing a reasonable solution.

From the perspective of solving PQ problems, the general measure is evaluating the power quality, and then taking the targeted governance after the failure or the regulator had developed standards and implemented. It's useful for existing consumers. But the solution is specified for a particular consumer, non-standardized and non-standardized and cannot be widely used. And the method is too passive. It needs to negotiate with consumers about power cut, and then modify the equipments. It has increased the number of power cut in 35kV, affected the production, and reduced the reliability of power supply. For the different characteristics of various consumers, if a power quality solution which is approximate a standard for such industry could be proposed. The harmonic elimination device for certain type of consumers will be installed before the consumer is energized. That will reduce the the number of power failure caused by harmonic control. It will be meaningful in the improvement of the method of improving power quality.

There are lots of sensitive high-tech consumers in the district of Songjiang Power Supply company, SMEPC; many of them are advanced electronics manufacturers and traditional metalwork and manufacturing enterprises. The important features of the electronics industry are high added value and advanced technology, it occupies an important position in economic development of China. From the perspective of power quality, such consumers have a large number of high-precision automation equipments and high-performance test equipments. Higher requirements about power quality are indispensable, a little voltage fluctuation, harmonic and other PQ problems may damage the devices, even cause an accident. At the same time a considerable number of these devices with non-linear load characteristics, which are the power system harmonic sources. Such loads as the disturbance sources, not only bringing harm to the consumer's own sensitive equipments and causing adverse effects, but also may affect other consumers which connected to the same bus. Metalwork is a traditional industry which has been the mainstay of China's economic development. The main features of the metalwork industry is the mature technologies and equipments, but also relatively old. There are many electric furnaces which have a low power factor and serious loss. They are the disturbance source of harmonic distortion, would affect the other consumers' normal use of electricity under the same bus.

In order to improve the service for sensitive consumers and supply reliable high-quality electricity, from July 2010, Songjiang electric power company starting a detection of power quality of various consumers. Then analyze the power quality characteristics of these consumers, and worked out standardized measures to ensure a high level of power quality. The measures can provide technical basis to solve existing PQ problems and for the future design of new consumers.

This paper describes various types of electrical load characteristics, analyze the major PQ problems which are needed to detect, and summarize the situation of all types of consumers, come to power quality characteristics of various industries and countermeasures.

1 Characteristics of various consumers

1.1 Characteristics of electronics consumers and the main measuring aspects

Electronics consumers' main electrical equipment

generally include automated assembly line, automatic SMT production lines, plating and welding equipments, various types of signal generator and detection equipments, computers, environmental conditioning equipments, lighting equipments, uninterruptible power supply (UPS) and so on. To sum up, the characteristics are as following:

1) The loads are stable, no large electrical equipments: normally, there are no large equipments starting and stopping that cause voltage sag or swell;

2) Mostly single-phase equipments: causing unbalanced three-phase distribution load, the neutral point offset and phase difference between the asymmetric;

3) Many power switch equipments: high harmonic content, the main source is harmonic voltage, belong to capacitive loads;

4) Many non-linear inductive loads: high harmonic content and large reactive power, mainly various types of lamp ballasts;

5) Many servo control equipments: high harmonic content, main are various position control of automation equipments;

6) Many frequency equipment: high harmonic content, main are assembly lines and automation equipments whose control targets is speed;

7) Lots of equipments are sensitive to power quality. According to the literature [4]'s statistical results, short-term voltage drop or short-term interruption the most important factor.

From the above analysis, we can see the PQ problems of load current are the reactive power and harmonic, harmonic is a major problem. Therefore, measuring should be done focus on the harmonic current. Meanwhile, due to many equipments are sensitive to power quality and electronics industry is a high value-added industry, once malfunction or failure it will result in large economic losses. So the quality of the supply voltage should be long-term monitored, especially the voltage drop and short interruptions.

1.2 Characteristics of metalwork consumers and the main measuring aspects

Metalwork consumers' main electrical equipments are including various types of electric furnace, air compressor, water-cooled machines and so on. The difference between metalwork consumers and electronics consumers are:

1) There are a lot of large electrical equipments. Voltage swells or sags will be caused by the equipments' starting and stopping.

2) The equipments have certain sensitivity to power quality, but the sensitivity is lower than electronics consumers'.

The main problem of Metalwork consumers are harmonics, voltage and reactive power. Because of many large-scale electrical equipments, the voltage fluctuations is large. It will influence other consumers which connected to the same bus. Therefore, measuring should be done focus on the changes of harmonics and reactive power, and voltage fluctuation should be long-term monitored.

2 The choice of measuring points

In the choice of measurement points, the main principles are as following:

1) The selected manufacturers should be representative; the number of manufacturers can not be too small;

2) As one of the purposes of measurements is analyze the consumer's power quality characteristics, besides measuring the HV side of the transformer, the LV side also should be detected, this will ensure that the measurements are actual voltages on the loads;

3) For the steady-state PQ problems, the measuring time is 1 day, and the measurement should be ensured that covers the complete cycle of the load's work;

4) For transient PQ problems, monitoring devices should be arranged long-term monitoring.

Currently most metalwork consumers and electronics consumers of Songjiang District are in 35kV. Therefore the voltage and current in the substation feeders for each consumer should be measured, then according to national standards of power quality to assess the power quality. Measure point arrangement is shown in Figure 1. If within the consumer, the measuring point primarily in LV side of the transformer which is shown in Figure 2.

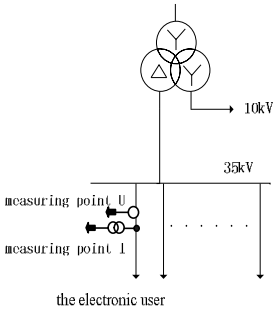

Figure 1 The measuring point in the substation

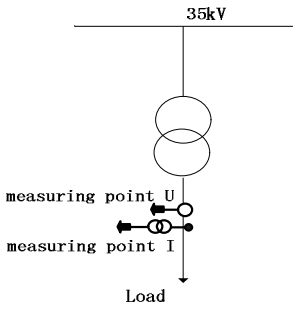

Figure 2 The measuring point within the consumer

3 Result analysis and harmonic sources locating

Power quality problems include reactive power, voltage deviation, flicker, three-phase voltage unbalance, harmonics and other issues. Among them, the harmonic problem is particularly important and prominent. To solve this problem and according to the "polluter pays governance" principle, it need to locate the harmonic sources through the measurement results.

If the grid voltage is qualified but the current harmonics is unqualified, then it needs to verify whether the locations of harmonic sources are in the network side or consumer side.

If there are more than one consumer connecting to the

same bus, when verifying the harmonic current, the harmonic current values of the national standard should be converted as following formula:

$$I_h = I_{GB}(S_r / S_j) \quad (1)$$

Where 'I_h' is the harmonic current limits of the point of common coupling, A; 'I_{GB}' is the harmonic current limits of the point of common coupling with reference capacity of short circuit, A; 'S_r' is the actual capacity of short circuit, MVA; 'S_j' is the reference capacity of short circuit, MVA.

The harmonic limits of the point of common coupling can be calculated by the following formula:

$$I_{hi} = I_h(I_i / I_t)^{1/a} \quad (2)$$

Where 'I_{hi}' is the corrected harmonic limits of each order, A; 'I_i' is the mean current per month of each consumer or the installed capacity, A or VA; 'I_t' is the mean current per month of the point of common coupling or the total installed capacity, A or VA; 'a' is the phase superimposed coefficient.

4 Countermeasure formulation

According to PQ problems of various consumers and considering the economic benefits, targeted power quality governance programs could be proposed, then studied the effect after treatment for validation.

5 case study

Through the early period investigations which have gotten dozens of consumer's load data, two typical consumers were selected. One is Shanghai Meadville Electronics Co., Ltd (electronics industry), the other is Shanghai Song Ya Steel Co., Ltd (metalwork industry). The data are as follows:

Table 1 Typical loads' power quality

		Meadville Electronics	Song Ya Steel	National standards	
Frequency deviation/Hz		+0.04/-0.04	+0.04/-0.05	±0.2	
Three-phase voltage unbalance/%		1.47	0.12	2	
short term severity/%	phase A	0.08	0.45	1.0	
	phase B	0.08	0.45		
	phase C	0.09	0.45		
voltage deviation/%	phase A	3.69	4.63	+10/-10	
	phase B	4.35	4.63		
	phase C	3.97	4.63		
Voltage distortion/%	2	0.01	0.12	Even: 1.2% Odd: 2.4%	
	3	0.09	0.43		
	4	0.01	0.07		
	5	0.75	3.13		
	6	0.01	0.06		
	7	0.27	1.69		
	8	0.01	0.07		
	9	0.02	0.10		
	10	0.01	0.07		
	11	0.26	1.81		
	13	0.05	0.95		
	17	0.06	0.51		
	21	0.02	0.05		
	25	0.02	0.17		
*THD*u /%		0.86	3.95	3.0	
				Meadville	Song Ya
harmonic current /A	2	0.13	0.60	0.70	10.26
	3	0.68	1.41	0.56	5.08
	4	0.40	0.29	0.36	5.27
	5	0.57	31.50	0.56	5.55
	6	0.01	0.20	0.24	3.49
	7	0.42	17.40	0.41	4.68
	8	0.20	0.23	0.18	2.60
	9	0.21	0.53	0.19	2.80
	10	0.04	0.27	0.14	2.12
	11	0.27	7.79	0.26	3.59
	13	0.23	6.33	0.22	3.12
	17	0.18	3.58	0.17	2.46
	21	0.09	0.74	0.08	1.23
	25	0.13	1.81	0.12	1.71

Note: the data are come from HV side; there are 2 to 25 harmonic voltage distortion and harmonic current limits in the national standards. Due to the length limitation, here is only a list of values of typical orders. The harmonic currents of Meadville Electronics are relatively small, because the measured data are from the measurement transformer side.

From the above table can be seen:

1) The electronics industry loads had a lot of PQ problems. The most serious is the harmonic problem. Harmonic was widely distributed and many harmonics (mainly odd harmonics) were over standard severely. This is mainly because the consumer has a lot of equipments using three-phase rectifier equipments as network interface, like inverters and UPS. The neutral line of the consumer was also detected significant amplitudes of 3rd harmonic and 9th harmonic. This is mainly be caused by a large number of single-phase electronic equipments, like computers, various types of electronic test equipments, etc. In addition, because of lots of single-phase equipments and loads unbalance, the degree of three -phase unbalance is high. During the measurement, the 4th and 8th harmonic are over standard, it may be caused by bending vibration of some devices' coupling.

2) Some orders of harmonic voltage distortion (5th, 7th and 11th) and total harmonic voltage distortion of metalwork consumers had exceeded the national standard, mainly because of the starting and stopping of large-scale electrical equipments. Because of a large number of non-linear devices, some orders of harmonic currents are relatively large, exceeding the national standards, especially 5th, 7th, 11th, 13th harmonic currents.

After the measurement, Shanghai Song Ya Steel Co., Ltd rectified and improved the power supply system, the effect is obvious. The 5th harmonic voltage distortion rate was 1.366%,the 7th harmonic voltage distortion rate was 1.634%, the 11th harmonic voltage distortion rate was 0.450%, the 13th harmonic voltage distortion rate was 0.930%, *THD*u was 2.155%, all were in line with the national standards. The 5th harmonic current was down to 8.720A, the 7th harmonic current was down to 10.320A, the 11th harmonic current was down to 3.040A. Although the 5th and 7th harmonic currents are still over the national standard, the values had been reduced by 2 to 4 times and the 11th harmonic current value was less than the national standard limit.

Shanghai Song Ya Steel Co., Ltd has installed the filters, 2% to 3% of the equipment loss and energy loss which caused by harmonic power flow can be saved, and the equipments' life are extended, the product quality and quantity are improved. The amount of reactive power compensation has increased, so that the voltage is more stable and higher. The compensation has increased 2% to 4% of the bus voltage, and increased the actual

productivity. The actual investment return rate is about 10 ~12%.

6 Conclusions

Through the analysis of the characteristics of electronics and metalwork consumers, electronics consumer's main PQ problems are harmonics and reactive, metalwork consumer's main problem are harmonics, voltage and reactive power, many measure results confirm it. Through the statistical analysis of a large number of data, the conclusions are as follow:

1) The harmonic of the electronics was serious, reflected in the frequency and the amplitude of over standard of odd harmonics (especially the 3rd harmonic). The degree of three-phase unbalance was large. The 4th and 8th harmonic of some consumers are over standard. Bending vibration was caused by badly centering of some devices' coupling.

2) The 5th, 7th, 11th voltage distortion and 5th, 7th, 11th, 13th harmonic current of metalwork consumer were over standard.

3) According to a large number of experience, filtering and reactive compensation equipment are usually installed for consumers. The investment can be returned in 10~12 months. It ensures the good quality of power supply of all the consumers on the same bus. So the investment is worthy.

This paper is only a small part of the measurement. Using this method, we can achieve some comprehensive and accurate understanding of PQ problems of various types of sensitive power consumers. It will provide a theoretical basis for improving the 35kV power system's power quality, reducing the failure rate of system's and the users' equipments, reducing impact of 35kV consumers on 10kV and low-voltage users, reducing the complaints of 10kV consumers and low voltage customers. A greater protection for the network operator will be provided and a greater contribution to the power marketing will be made.

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