A PRACTICAL METHOD OF POWER QUALITY MONITORING AND MANAGEMENT

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ABSTRACT

Shanghai Municipal Electric Power Company has begun updating the technology and management standards of monitoring of power quality in 2010. Currently it has covered 305 monitoring points for the effective management.

Every month, we use up to 5 different aspects to assess the quality of power especially in the terms of voltage such as frequency deviation, voltage deviation, harmonics, unbalance degree of three-phase voltage and long term voltage sag and flicker.

Based on the above various indicators for monitoring results, we are drawing a relatively comprehensive assessment. We recorded its eigenvalue for those monitoring points which are defined to be relatively highly polluted. By measuring these high-pollution points in terms of waveform analysis, we can know several aspects of the voltage defects such as the time happened, duration, degree of pollution, phase sequence ,tendency and so on.

And, through a practical case, we can study specific monitoring data showed that the distribution of voltage dips, distribution of voltage amplitude in areas and other voltage defect parameters.

Key words*: monitoring, voltage defects, harmonic, sag and flicker, waveform analysis*

INTRODUCTION

This paper details the approaches taken in Shanghai Municipal Electric Power Company to setup a system to monitor and manage power quality.

The classical definition of power quality contains three elements which are reliability, frequency deviation and voltage deviation. However, with the expansion of the user needs, higher and higher demands of power quality have been proposed. It has been upgrading the management and measuring tool of power quality as well.

With the progress of the user demands, the definition of modern power quality has been proceeding as well. Nowadays, referring to the latest knowledge on power quality or definition, the 22nd Standards Committee of IEEE dealing with the treatment and research of the power quality standards and the other international commissions have recommended 11 kinds of special terminology, such as Interruption, Deviation, Sag, Swell, Spike, Voltage Fluctuation Flike, Notch, Harmonics and Inter-harmonics, Overvoltage, Undervoltage and so on[1].

However, the common definition of power quality should be divided into tow aspects which are supply quality and user quality. The supply quality mostly includes the voltage criteria such as deviation, sag, voltage harmonics, etc. While the user quality involves the indicators of the current quality which deals with harmonics and inter-harmonics, phase lead and lag, etc [2].

As we all know, the various kinds of the defect of power quality would cause different consequences. For several instances, harmonics will lead to mechanical vibration and resonances of power grid and three-phase imbalance will result in misoperation of the relay protection and automatic devices.

Thus, in 2005, China promulgated the national standard GB/T 19862-2005, known as *'General Requirements of power quality monitoring equipment'*, which provided the limits of voltage flicker, three-phase imbalance, harmonics and so on. As a result, the monitoring instruments have becoming increasingly demanding. Therefore, with the progress of modern detecting technology, the latest detecting technology must meet the following demands. First of all, it should quickly capture the transient waveform which disappears in microseconds as most interference occurs and fleet away within less than a second. Secondly, it should be capable of measuring the amplitude and phase of each harmonics and inter-harmonics. Thirdly, which is most important, it must have an effective analyse and recognition system which will reflect a variety of characteristics and regularity of the power quality indicators.

THE STEPS OF THE PROJECT

Main Purpose

In order to set up a system to monitor and manage power quality, Shanghai Municipal Electric Power Company had initiated the project since 2006 which started with a main station and other 109 monitoring points scatted in all voltage level and in nearly all districts in shanghai.

The principle of the project is to monitor the main network and the distribution network. As for the main network, we planned to learn about the general level of power quality of the grid. And by the way, we could detect the transient voltage quality and also the impact of HVDC[1], harmonics on the grid. And as for distribution network, we may make the statistics of the characteristics of different loads and provide evidence of the power defect both for the suppliers and the users. Thus, we could make further improvements of the governance and planning of the power grid.

To achieve these purposes, we need certain equipments and systems such as the LAN, Web servers, DB of the main station, general management station, communication terminals, user terminals, browsing terminals of the power

1 HVDC: DC transmission

company, and the system of load management [3].
The main content and construction scheme of the project are shown in Figure 1.

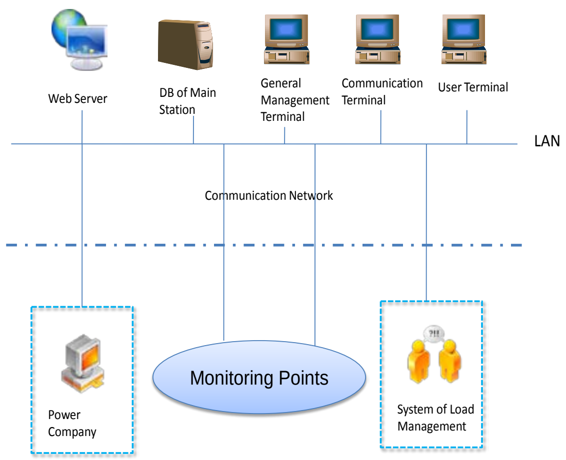

Figure 1: The main scheme and content of the power quality management system

Project progress

Since the start of the project on July 1st, 2006, Shanghai Municipal Electric Power Company had completed the establishment of the central lab and personnel system by the end of year. Meanwhile, we had also finished compiling the specification of function of the main station system and released it.
August, 2007, we determined the usage of the device called '*ION7650*' as the power quality meter and the software of main station analysis system, known as '*PQ view*' through bidding.
By the end of 2010, we have set up 305 monitoring points covering all districts and all voltage levels from 380V to 220KV to keep the power grid observed.
For the normalized management, we hold meetings to assess the quality of power dealing with five different indicators on every beginning of the month, such as frequency deviation, voltage deviation, harmonics, unbalance degree of three-phase voltage and long term voltage sag and flicker.
Through this management, we intend to apply the results of the monitoring system to many fields. For example, it could help to locate the harmonics and to analyse the cause of accidents, and furthermore, to draw a line of responsibility between power suppliers and users.

Analysis tool component

The system of power quality monitoring consists of the basic monitoring device known as ION7650 made by *Schneider*, the communication network, the monitoring center, and all clients including various terminals and Power Company detailed in Figure 2.

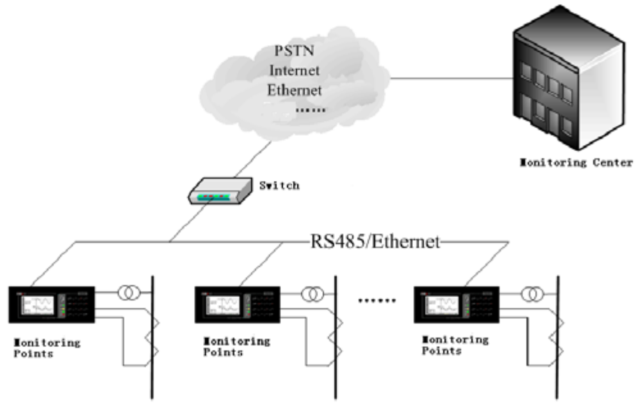

Figure 2: Depict of the structure of PQM

'ION7650', which is the element of PQM pictured in Figure 3, could monitor voltage and current data of steady and transient state. With an A-level sampling accuracy of harmonics, its sampling frequency is 12.8K (50Hz) and resolution is 16 bit.

Figure 3: The overview of the 'ION7650'

As for the monitoring of steady-state data, it updates the frequency and the harmonics every 3 seconds which is computed in RMS [2]. Simultaneously, *'ION7650'* would make judgements and record the incidents whose indicators exceed the limits with the updates of real-time data.
The indicators for judgement include voltage deviation, frequency deviation, three-phase imbalance, and harmonics which reported in magnitude and duration. The device will make statistics of real-time data of harmonics and save it as history at regular intervals which can be adjusted by users.
As for the monitoring of transient-state data, it could monitor the interruptions and over/under voltage with no gap at all. Once the voltage exceeds the threshold, it will trigger the function of transient waveform recording which should be revealed as alarm information for power engineers to analyse the cause of the accidents.

2 RMS: route mean square

NORMALIZED MANAGEMENT

Following the idea of the circulation of measurement, analysis and improvement, we arrange to hold meetings at the start of every month on which power quality status of the company will be reported. With the help of the engineers, we are able to locate those substations or users whose power qualities are disqualified. Then, we will continue to investigate into those certain cases to find out the cause of the pollution source and fix it by all means.

Moving our sight to the first line, the main centre do real-time monitoring with the software of *'PQ View'*, while users and engineers of Power Company can browse the net the access the history data through LAN or internet. Figure 4 overviews the map of location of monitoring points in Shanghai Electric Power Company.

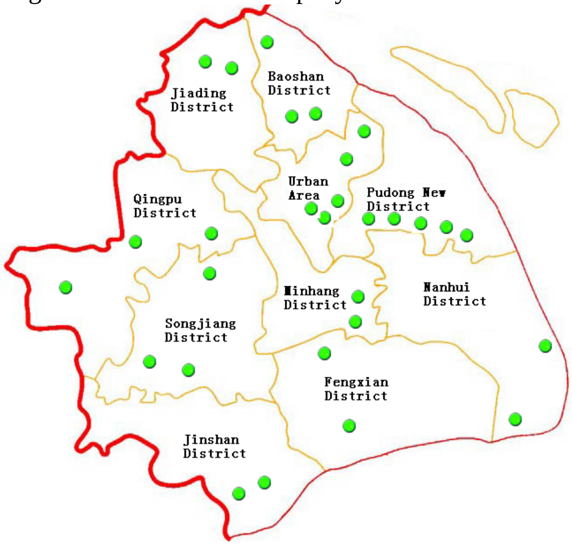

Figure 4: The overview location of monitoring points in Shanghai (parts of the points have been omitted)

With the effective of implementation of the project, Shanghai Electric Power Company has been monitoring the data of power quality of various substations and users since Oct, 2008. In other word, we have accumulated the history data of the monitoring points for over 2 years, and many long-term or short-term defects of power quality have been found and some of the problems have been successfully solved.

The following tables and images are some examples of the monthly report for the meetings dealing with power quality.

First of all, there will be a overall report including all monitoring points in each branch of the Shanghai Electric Power Company showing the general status of power quality in each district detailed in table 1(part of the districts omitted, time range: Nov, 1st ~Nov, 30th ,2010).

Summary of Power Quality in Shanghai Power Company							
Time Range: Nov 1st, 2010-------Nov 30th, 2010							
Qualification Indicators	Rate Threshold	Overall	EHV	Shiqu	Shibei	Pudong	...
System Frequency	99.50%	100.00%	100.00%	100.00%	100.00%	100.00%	...
Voltage Deviation	98.00%	100.00%	100.00%	100.00%	100.00%	100.00%	...
Overall Voltage Distortion Rate	98.00%	99.63%	99.50%	100.00%	99.20%	100.00%	...
2nd Harmonics Content Rate	98.00%	100.00%	100.00%	100.00%	100.00%	100.00%	...
3rd Harmonics Content Rate	98.00%	100.00%	100.00%	100.00%	100.00%	100.00%	...
5th Harmonics Content Rate	98.00%	99.92%	100.00%	100.00%	100.00%	100.00%	...
7th Harmonics Content Rate	98.00%	99.94%	99.87%	100.00%	100.00%	100.00%	...
9th Harmonics Content Rate	98.00%	100.00%	100.00%	100.00%	100.00%	100.00%	...
11th Harmonics Content Rate	98.00%	100.00%	100.00%	100.00%	100.00%	100.00%	...
13th Harmonics Content Rate	98.00%	100.00%	100.00%	100.00%	100.00%	100.00%	...
3 Phase Imbalance Rate	98.00%	100.00%	100.00%	100.00%	100.00%	100.00%	...
Long Term Voltage Flicker	99.00%	100.00%	100.00%	100.00%	100.00%	100.00%	...

Table 1: Overall Report of Power Quality in Shanghai Electric Power Company in Nov, 2010

Except for the overall report, users and engineers of Power Company also have access to the analysis report of each monitoring point which is concerned; therefore, some deeper studies and research would be led.

For instance, if we are interested in a certain monitoring point called 'QinXian 225', we could just log onto the Web server and download the report of its indicators including steady-state and transient-state at any range of time.(As shown in Table 2)

As we can see from the individual report of 'QinXian 225', nearly all indicators and criteria we concern about is listed in the table. The most important thing is that now we know it is in normal state as all conclusions about the indicators are *'qualified'*.

And, if we take a further step into the voltage deviation of the monitoring point, we could also draw the picture of voltage deviation within certain duration of time. (As shown in Figure 5)

Table 2: Overall Report of 'QinXian225' of July, 2010

Summary of Power Quality of Monitor Point										
Type :		Month-Sh					Time:	July, 2010		
Branch :		Shinan Branch		Location :		Qinzhou Substation				
Monitoring Name		QinXian 225								
Voltage			35	PT :		35000/100		CT :		400/5
Parameters		Three-Phase synthesis						Criteria		
		Max	Avg	Min	CP95	CP99	Conclusion	Max	CP95	CP99
Overall Vol		1.15	0.84	0.69	1.05	1.05	Qualified		3	
Voltage		5.87	2.97	1.2	5.58	5.58	Qualified		7	
Voltage		-0.01	-0.01	-0.01	-0.01	-0.01	Qualified		-3	
Frequency		0.041	0.018	0.002	0.036	0.036	Qualified		0.2	
Frequency		-0.04	-0.012	0	-0.037	-0.037	Qualified		-0.2	
Long Term Flick		0.155	0.088	0.071	0.155	0.155	Qualified	1		
Fundamental		21.384	20.781	20.975	21.108	21.261				
2~25th Harmonics Content Rate	2	0.07	0.01	0	0.04	0.05	Qualified		1.2	
	3	0.25	0.13	0.14	0.2	0.22	Qualified		2.4	
	4	0.04	0	0	0.03	0.03	Qualified		1.2	
	5	1.05	0.73	0.58	0.88	0.96	Qualified		2.4	
	6	0.04	0	0	0.03	0.03	Qualified		1.2	
	7	0.36	0.18	0.15	0.25	0.3	Qualified		2.4	
	8	0.04	0	0	0.02	0.03	Qualified		1.2	
	9	0.07	0.02	0	0.04	0.05	Qualified		2.4	
	10	0.05	0	0	0.03	0.03	Qualified		1.2	
	11	0.58	0.27	0.27	0.41	0.48	Qualified		2.4	
	12	0.04	0	0	0.02	0.03	Qualified		1.2	
	13	0.39	0.14	0.07	0.23	0.29	Qualified		2.4	
	14	0.04	0	0	0	0.03	Qualified		1.2	
	15	0.05	0.01	0	0.03	0.04	Qualified		2.4	
	16	0.04	0	0	0	0.03	Qualified		1.2	
	17	0.08	0.02	0	0.06	0.06	Qualified		2.4	
	18	0.05	0	0	0	0.03	Qualified		1.2	
	19	0.06	0.01	0.03	0.05	0.05	Qualified		2.4	
	20	0.04	0	0	0	0.03	Qualified		1.2	
	21	0.04	0	0	0.03	0.03	Qualified		2.4	
	22	0.04	0	0	0.02	0.03	Qualified		1.2	
	23	0.09	0.03	0.02	0.05	0.07	Qualified		2.4	
	24	0.04	0	0	0	0.03	Qualified		1.2	
	25	0.06	0.01	0	0.03	0.04	Qualified		2.4	

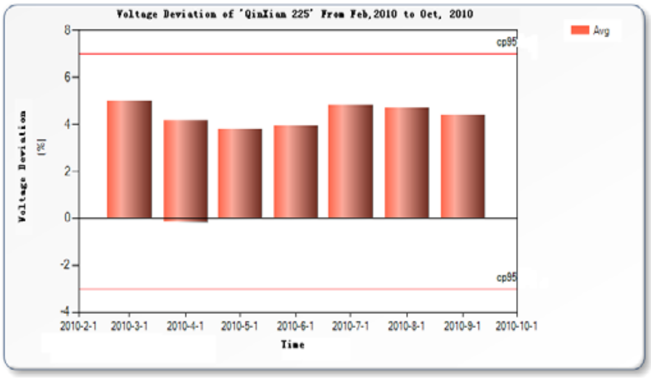

Figure 5: Picture of Voltage Deviation of 'QinXian225' from Feb, 2010 to Oct, 2010

Once a power defect like voltage flick or sag occurs, the alarm information would be triggered reminding the staff in charge of surveillance. And he could open and check the alarm information which is pictured in Figure 6, for example, to make the decision if further measures are taken.

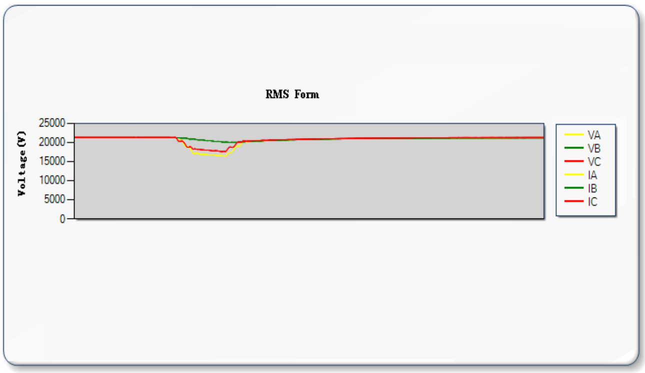

Figure 6: Picture of Voltage Sag in RMS Form

SPECIAL INVESTIGATION INTO A CASE

This part details one of the real incidents occur in our branch company and finally solved with the efforts of our staff of the power quality management.

As reported in June, 2010, one of our substations called 'Songyin Substation' was detected to exceed the limits of its 5^{th}, 7^{th}, 11^{th} harmonics content rate. The total distortion rate had surpassed 3.95 while the threshold was 3.0.

After the investigation on site, engineers found the source of pollution was on the side of users. Measures were taken immediately after the monthly meeting.

By installing the passive filtration unit on the user's side by the end of Nov, 2010, the 5^{th}, 7^{th}, 11^{th} harmonics content rate had been dropping since then and become normal in the report of Dec, 2010.

CONCLUSION AND OUTLOOK

With this online monitoring system, we are able to keep the power quality under surveillance. Also, it will help us find the defect of power quality and locate the source of pollution.

Thanks to the circulation of measurement, analysis and improvement as said above, it has gradually becoming a normalized management of power quality in Shanghai Municipal Electric Power Company.

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