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REAL-TIME POWER SYSTEM HARMONICS DETECTION WITH MOBILE MONITORING SYSTEM

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ABSTRACT

Nowadays power quality has become a great concern for both utilities and customers. With increasing use of nonlinear load being connected to the power system, more studies on the effects of harmonic penetration in power distribution system are needed. In this paper measurement techniques of voltage and current harmonics in the mobile power quality monitoring systems of the Turkish electricity transmission systems have been discussed. In order to exhibit the capabilities and usefulness of the mobile monitoring system developed; sample measurement results are also given in the paper.

Keywords: Power quality (PQ); Harmonics; Measurement

1. INTRODUCTION

In the electrical distribution systems under normal operating conditions, voltage and current waveforms must produce in sinusoidal forms with 50 Hz frequency. The deviation of a waveform from its perfect sinusoidal is generally expressed in terms of harmonics. As far as an electrical signal is concerned, a harmonic is defined as the content of the signal whose frequency is an integer multiple of the fundamental system frequency. The harmonic analysis is the process of calculating the magnitudes and phases of the fundamental and higher order harmonics of such an electrical signals [1].

In the 1920s and 1930s the analytical techniques for studying power system harmonics caused by static convertors were developed in Germany. During the 1950s and 1960s study of convertor harmonics was conducted in high voltage direct current transmission systems. Nowadays, the power system harmonic study is still a subject of concern for power engineers [2].

Today, however, increased industrial and consumer dependence on equipment with non-linear components is aggravating the situation. Harmonics in a power system can result in communication interference, transformer overheating, or the malfunction of the solid-state devices, and so on [3, 4]. Current harmonics induced by non-linear power electronic loads also present inefficient operations of local and global power supply systems.

Harmonic measurements in industrial power systems are essential to achieve three objectives. Firstly, for the identification of the sources and characteristics (magnitude, frequency and location) of the harmonics; secondly, for the design and installation of a filtering system to reduce the harmonic impacts to the power systems; thirdly, to ensure that total harmonic distortion, after compensation, will be in compliance with the regulatory requirements such as IEEE Standard [5].

In this paper inside a special mobile monitoring system used to take nationwide snapshots of all power quality (PQ) parameters specified in IEC 61000-4-30 [6], over the Turkish Electricity Transmission System, we will investigate the corresponding instrumentation and measurement technology applied to measure voltage and current harmonics separately.

The mobile PQ monitoring system described in this research work has flexible signal algorithms such that problem and location specific algorithms can be added into the system, wherever and whenever needed. PQ parameters specified in IEC 61000-4-30/class-B are computed and in case of any updates in the standards, it is possible to update the presented mobile systems. It is also possible to modify the software to produce outputs in such a way that any required analysis reporting is achieved such as event detection, monitoring, specific PQ parameter collection, or raw data collection. This system has also a lower cost when compared to the commercially available PQ monitoring systems. Moreover, since the system is composed of discrete components as observed in Fig. 1, easy and fast repairing is possible in case of any failure of the system. In addition, the time synchronization module provides event propagation analysis and indirect analysis of unmeasured points using the data collected by different mobile PQ monitoring systems [7].

2. MOBILE MONITORING SYSTEM

Each mobile monitoring system consists of: National Instruments DAQ Card 6036E (16 bit precision, high quality data acquisition), National Instruments SC-2040

S/H Card, 3 Current Probes, Voltage Divider, Laptop Computer, NI Labview Software, uninterruptible power supply for current probes, and isolation transformer, as shown in Fig. 1. It collects the raw data in accordance with IEC 61000-4-30/Class B, and carries out on-line data processing according to IEC 61000-4-7/Class B, IEC 61000-4-15/Class B, and IEEE Std. 519-1992 [5]. On-line PQ analysis software is as illustrated in Fig. 2.

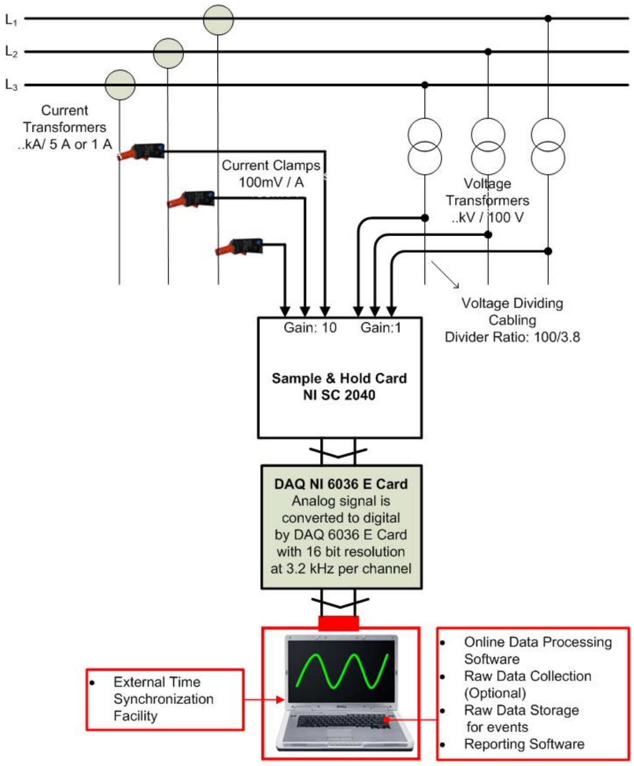


Fig. 1: Block diagram of PQ monitoring set-up

Reporting is made in view of IEEE Std. 1159, and Electricity Transmission System Supply Reliability and Quality Regulation (Turkish Std., 2004). Turkish Std., 2004 makes also necessary monitoring of reactive power flow in addition to power quality parameters, and imposes penalties on reactive energy demand of distribution companies, and large industrial plants.

3. HARMONICS MEASUREMENT TECHNIQUE

The mobile systems collect 3 phase current and 3 phase-neutral voltage waveform data at a rate of 3200 sample/sec/channel in accordance with IEC 61000-4-30/Class B. The collected raw data is carried out on-line data processing with the national PQ analysis software based on National Instrument Labview software in laptop computers according to IEC 61000-4-7/Class B, IEC 61000-4-15/Class B, and IEEE Std. 519-1992. 3200 samples per second are divided into five times 10 cycles because the power system frequency in Turkey is 50 Hz. A harmonic analysis technique is applied in 10-cycle time windows which correspond to a frequency resolution of 5 Hz. By this way, 640 samples participate in each 10 cycles due to the rate of 3200 sample/sec/channel.

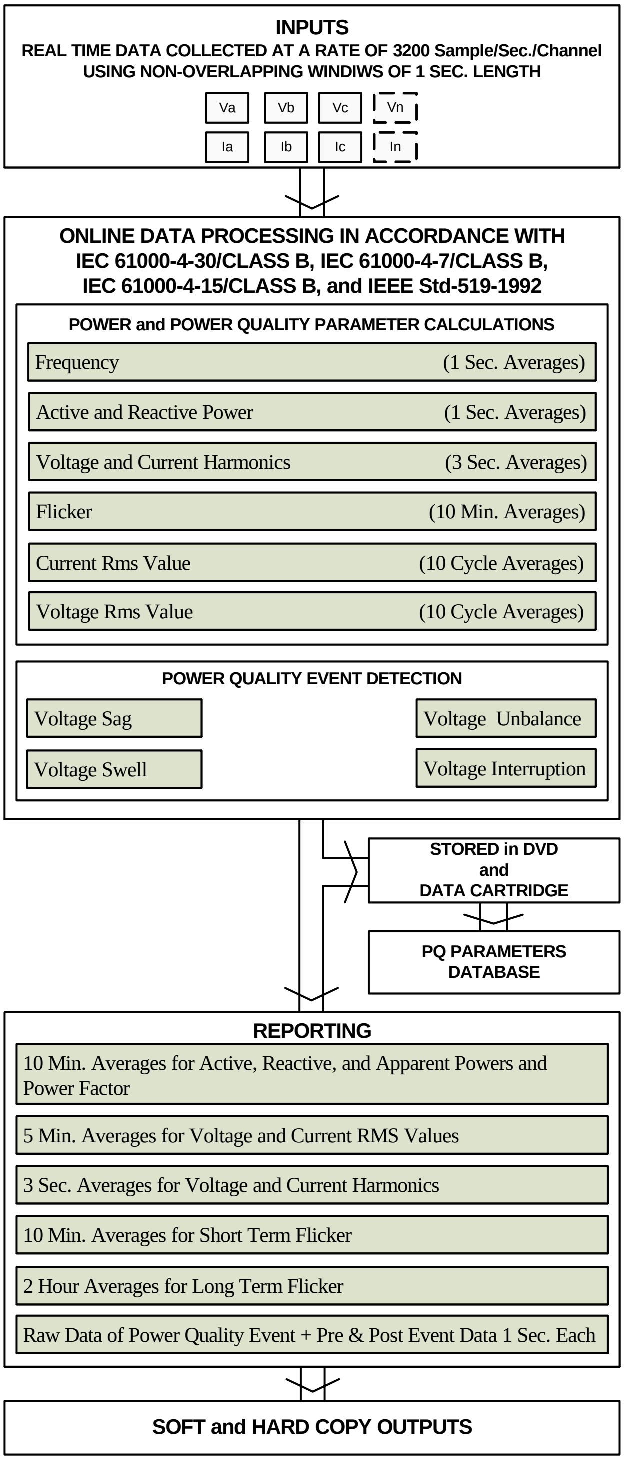


Fig. 2: On-line PQ analysis software

According to IEC 61000-4-7/Class B, if the number of samples in the time window is not an integer power of 2, DFT algorithm must be applied instead of Fast Fourier Transform (FFT). Therefore, the harmonic analysis on the software is achieved by using DFT block. Before DFT-processing, the samples in the time window are weighted by multiplying them with a Hanning window so that any amplitude of frequency components can not diminish after leaving from DFT block (Fig. 3). Amplitudes of all frequency components are found up to 31^{st} order by this technique. After the DFT-processing, 10 cycle root-mean-square (RMS) values of frequency components are calculated by using the amplitudes of which found from DFT block. Afterwards 10 cycle RMS values are averaged for every 3 seconds and recorded on the local discs of laptop computers according to IEEE Std. 519-1992. To be illustrated of current harmonic variations of measurement points with the help of graphs, the percentage of 3-sec average RMS values of frequency components according to the load current (I_L) defined as the maximum value of 15-max average fundamental current components in IEEE Std. 519-1992 are calculated. To do that for voltage harmonic variations, 3-sec average voltage fundamental rms values corresponding to each 3-sec average voltage rms values of frequency components are used.

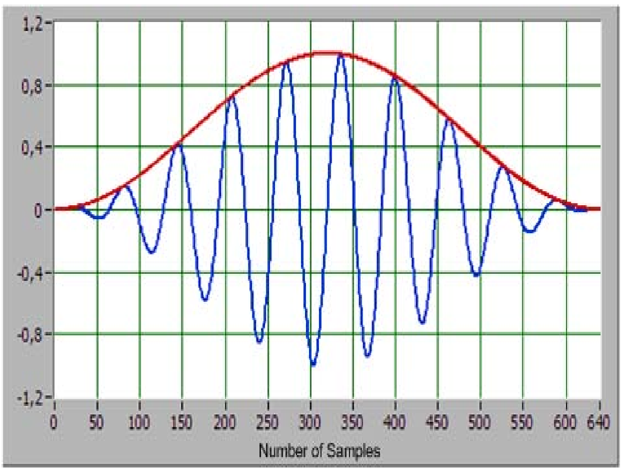


Fig. 3: Hanning window (red) and the 10 cycles signal multiplied with the hanning window (red)

3-sec. average voltage fundamental rms values corresponding to each 3-sec. average voltage rms values of frequency components are used to find the percentage values of voltage harmonics as denoted in IEC standard 61000-4-7. The calculated 3-sec.average voltage rms value of voltage harmonics are divided by the 3-sec.average rms value of fundamental component belonged to it, and multiplied with 100. Therefore the percentage values of voltage and current harmonics respected to fundamental components are ready to be presented as ones of PQ parameters.

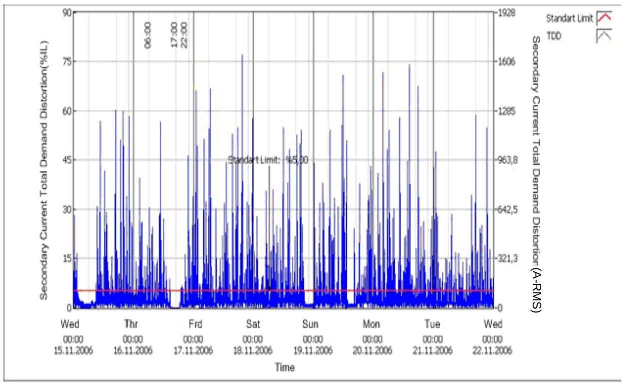
4. HARMONICS MEASUREMENT RESULTS

PQ measurements have been carried out at 59 transformer substations, 205 incoming and outgoing feeders. All measurement points are classified in Table 1 on the basis of the load types (heavy industry, industry + urban, urban only), and operating voltage level (medium, high, and extra-high).

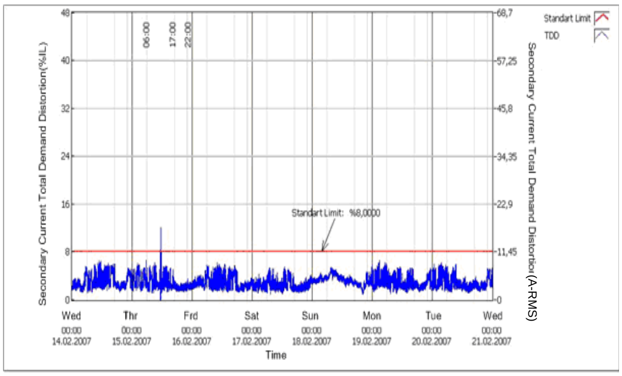
According to measured current harmonics values during one week, percentage of current total demand distortion (TDD) of different loads during one week is shown in Fig. 4, separately.

Table 1: The Number of measurement point
NB: Number of busbars, NF: Number of feeders

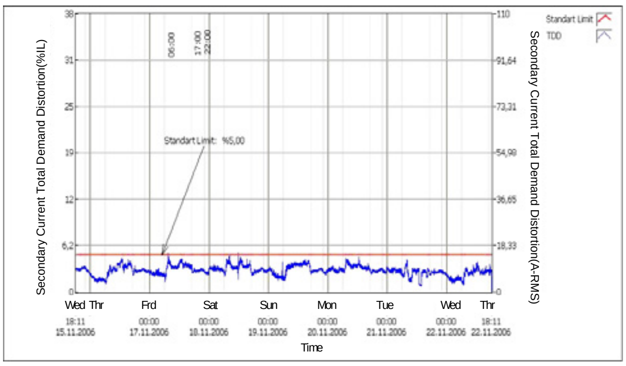
Number of Measurement Points								
Voltage Levels	Load Type							
	Heavy Industry		Industry + Urban		Urban Only		TOTAL	
	NB	NF	NB	NF	NB	NF	NB	NF
33 kV	11	19	56	89	20	24	87	132
154 kV	4	6	31	39	10	11	45	56
380 kV	2	2	9	14	1	1	12	17
TOTAL	17	27	96	142	31	36	144	205



(a)



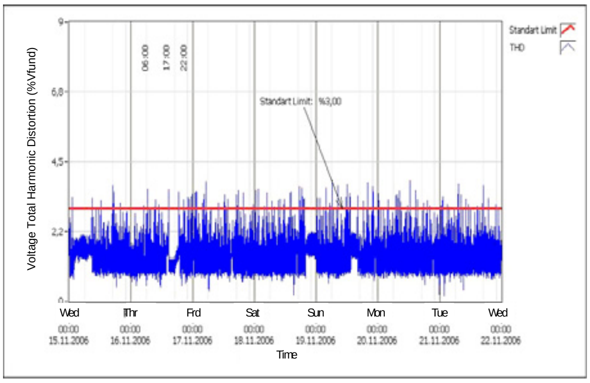
(b)



(c)

Fig. 4: (a) Heavy industry current total demand distortion (%I_L); (b) Urban + industry current total demand distortion (%I_L); (c) Urban current total demand distortion (%I_L)

And also with respect to measured voltage harmonics values, percentage of voltage total harmonics distortion of different loads during one week, are depicted in Fig. 5, separately.



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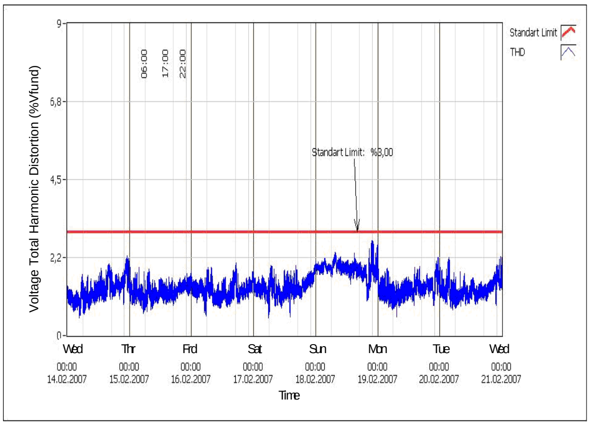

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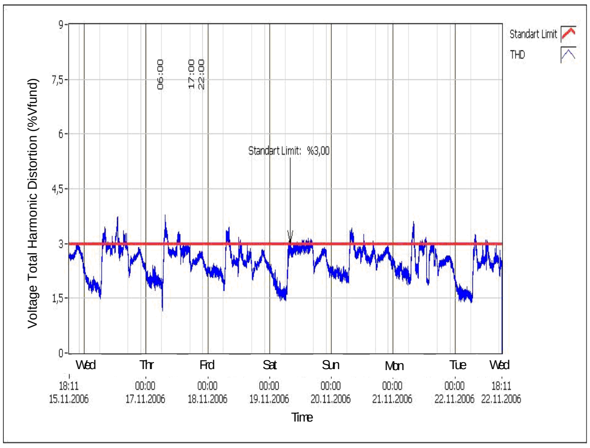

(c)

Fig. 5: (a) Heavy industry voltage total harmonic distortion (%V_{fund}); (b) Urban + industry voltage total harmonic distortion (%V_{fund}); (c) Urban voltage total harmonic distortion (%V_{fund})

The standard current TDD limits and voltage THD limits of different loads are shown in figures 4 and 5, according to IEEE 519-1992. Also percentage of measurement points at which voltage THD (Total Harmonic Distortion), and current TDD (Total Demand Distortion) problems are observed, are as given in Fig. 6.

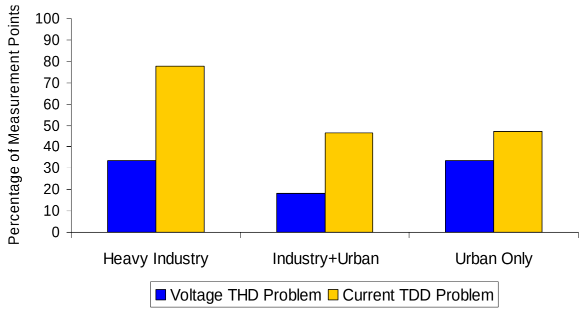

Fig. 6: Distribution of voltage THD, and current TDD problems for all measurement points according to IEC 61000-4-15, and Electricity Transmission System Supply Reliability and Quality Regulation, Turkish Std. 2004.

5. CONCLUSION

In this paper under national power quality project of turkey, real time measurement techniques of voltage and current harmonics in mobile power quality monitoring system of the Turkish Electricity Transmission System have been explained. According to the current harmonic values of different loads, variation of Current Total Demand Distortion of heavy industry load are very high with respect to urban + industry and urban loads and also percentage of current TDD of heavy industry load always exceeds its standard values during one week measurement. The same phenomenon is also obtained for voltage THD of the heavy industry load, but the percentage of voltage THD values of heavy industry loads, are near standard value during one week measurement. According to current and voltage harmonic measurement results of heavy industrial loads, approximately 80 percents of that loads have current TDD problems, so one of the important aim of this project is to monitoring the behavior of heavy industry loads like arc furnaces and etc, in the Turkish Electricity Transmission System and impose some external power electronics circuits to solve that problems simultaneously.

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REFERENCES

[1] K. W. Louie, P. Wilson, R. A. Rivas, A. Wang, P. Buchanan, "Discussion on Power System Harmonic Analysis in the Frequency Domain", TDC'06 IEEE/PES Transmission and Distribution Conf., Caracas, Venezuela, pp. 1-6, Aug. 2006.

[2] J. Arrilaga, D. A. Bradley, P. S. Bodger, *Power Systems Harmonics*, John Wiley & Sons, New York, pp. 5-135, 1985.

[3] H. C. Lin, "An Intelligent Neural Network Based Adaptive Power line Conditioner For Real- Time Harmonics Filtering", IEE Proceeding, Generation Transmission and Distribution, Vol. 15, No. 5, pp. 561-567, Sep. 2004.

[4] Y. M. Chen, R. M. O'Connel, "Active Power Line Conditioner with a Neural Network Control", IEEE Trans. Ind. Appl., Vol. 33, pp. 1131-1136, 1997.

[5] ANSI/IEEE Standard 519, IEEE *Recommended Practices and Requirements for Harmonic control in Electrical Power System*, 1992.

[6] IEC 61000-40-3-, *Testing and Measurement Techniques- Power Quality Measurement Methods*.

[7] T. Demirci, A. Kalaycıoglu, Ö. Salor, et. al, "National PQ Monitoring Network for Turkish Electricity Transmission System", IEEE Instrumentation and Measurement Technology Conf., Poland, May 2007.

[8] H. C. Lin, "Power System Harmonics Measurement Using Graphical Programming Tool", IEEE Conference on Cybernetics and Intelligent Systems, Singapore, 1-3 Dec. 2004.

[9] D. M. Said, N. Ahmad, A. A. M. Zin, "Power Supply Quality Improvement: Harmonic Measurement and Simulation", National Power Engineering Conf., Bangi, Malaysia, pp. 352-358, Dec. 2003.

[10] Ö. Salor, B. Gultekin, S. Buhan, et.al., "Electrical Power Quality of Iron and Steel Industry in Turkey", Industry Applications Conf. IEEE 42nd IAS Annual Meeting, pp. 404-423, Sept. 2007.