

# Power Quality Analysis and Evaluation at Water Pumping Station Supplied by Medium Voltage

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## Abstract

Power Quality (PQ) related issues are of the most concern nowadays. The widespread use of electronic equipment, such as information technology, power electronics applications, programmable logic controllers (PLC) led to a complete change of electric loads nature. These loads are simultaneously the major causes of power quality problems. Due to their non-linearity, all these loads cause disturbances in the voltage waveform. This paper deals with the measurement, analysis and evaluation of the power quality parameters in a water pumping station with a medium-voltage level. Power quality parameters such as voltage, current, active power and harmonics are measured, analyzed and evaluated taking into consideration IEEE 519-1992 standards.

**Keywords:** Power Quality, Harmonic, Medium Voltage  
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## 1. Introduction

Power quality (PQ) has received a great deal of attention recently, since the increased use of power electronic devices such as converters in adjustable speed drives etc. Such devices are non-linear loads which draw nonlinear currents from the power supply. This causes distortion in the voltage and current wave form at the network [1-3]. Although there are many parameters affecting on power quality, harmonics are one of the major power quality problems in power systems. These harmonics result in some problems such as malfunctions in sensitive equipment, increased heating in the conductors and motors [4-10]. Harmonics can be described as the sum of several high-frequency sinusoidal signal components.

Given the importance of power quality, harmonics analysis and evaluation have been much more studied by researchers recently [11-13]. There are power quality standards that define the maximum allowable limit of distortion in voltage and current waveforms of the power supply. Many standards, guidelines and recommendations including IEEE standard 519-1992 and IEC 61000 series of standards have come into effect in this regard [1, 14]. Also, some indices like Total Harmonic Distortion (THD) and Total Demand Distortion (TDD), used respectively for voltage and current harmonics [1, 8].

In this study, an investigation is carried out to measure and evaluate the power quality in a pump station supplied by medium voltage level. This paper is organized as follows. Section 2 describes

the basic knowledge of harmonic and formulations; Section 3 presents brief technical properties of installed power plant; Section 4 establishes an evaluation power quality data; finally, conclusions of overall study are presented in Section 5.

## 2. Basic Knowledge of the Harmonic and Indices

Power systems are designed to supply and operate with pure sinusoidal voltage and current waveforms. In reality, small deviations from ideal supply conditions are generally experienced. The actual waveform is composed of a number of sine waves of different frequencies, including one at the power frequency, referred to as the fundamental component and harmonics. The term "harmonic", refers to any one of the above mentioned sinusoidal components. The frequency of these components is a multiple of that of fundamental one. The amplitude of a harmonic is generally a few percent of that of the fundamental [1-4]. Fig.1 shows a typical real, fundamental and harmonic current waveform in power systems.

Harmonic indices have been developed to assess the service quality of a power system with respect to the harmonic distortion levels. These indices are measures of the effective value of a waveform and can be applied to both the current and the voltage [5-7]. The IEEE-519 document has set limits on the level of allowable harmonics [14]. Several indices are available for harmonic analysis; however, the two most commonly used are the total harmonic distortion (THD) and the total demand distortion (TDD).

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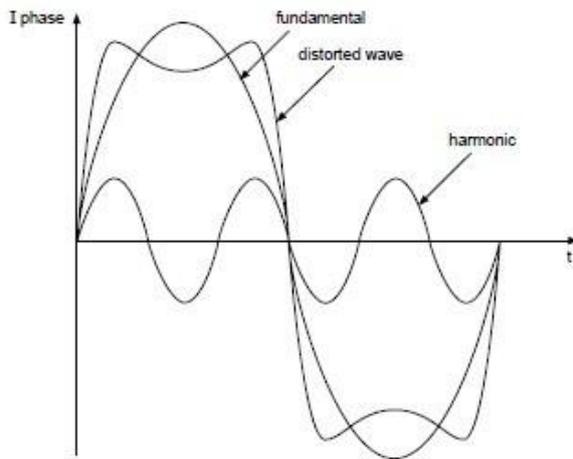


Figure 1. Typical distorted current waveform in electric power systems.

Mathematical formulations of (THD) and (TDD) for voltage and current are given in equations (1), (2) and (3) respectively [1,4,14]:

$$THD_V = \frac{\sqrt{\sum_{h=2}^{\infty} V_h^2}}{V_1} \quad (1)$$

$$THD_I = \frac{\sqrt{\sum_{h=2}^{\infty} I_h^2}}{I_1} \quad (2)$$

Where  $V_1$  and  $I_1$  are the RMS value of the fundamental, and  $V_h$  and  $I_h$  are the RMS value of the  $h$ -order harmonic component. Total Demand Distortion (TDD): Is the total harmonic current distortion defined by the ratio of the RMS value of the sum of the individual harmonic amplitudes to the maximum or rated demand load current  $I_L$  as shown in the following expression:

$$TDD_I = \frac{\sqrt{\sum_{h=2}^{\infty} I_h^2}}{I_L} \quad (3)$$

### 3. Technical Properties of Power Plant

Drinking water is pumped to the city by means of power plant under study. There is one piece induction motor which is the rated power of 1000 kW in the plant. Nominal operating voltage of the motor is 10 kV. Motor is supplied by one power transformer which is rated power of 5000 kVA.

Individual system compensation is performed in the plant. Total power of capacitor connected parallel to the network is 450 kVar. Short technical specifications of the motor, transformer and capacitor are given in Table 1.

Table 1. Technical specifications of the motor, transformer and capacitor.

<b>Transformer</b>		<i>Unit</i>
Secondary Voltage	(kV)	10
Rating	(kVA)	5000
<b>Motors</b>		
Operation Voltage	(kV)	10
Rating	(kW)	100
<b>Capacitors</b>		
Voltage	(kV)	10
Rating	(kVar)	450

### 4. Results and Discussion

In this study, power quality investigation has been performed in a plant supplied by medium voltage level. Voltage, current, active power and harmonics have been analyzed and evaluated based on IEEE 519-1992 standard [14]. All power quality parameters are measured and recorded while motor is loaded within nominal value and all capacitors are connected to network for full compensation.

Measurement was carried out by using AR5 type portable power analyzer. Voltage and current transformer already installed in the plant are used for this measurement. The measurement results are given and analyzed below in summary section. Fig. 2 shows the waveform of the three phase voltage measured from the network. As shown in Fig. 2, waveform of the voltage is not pure sinusoidal form but it has some distortions.

The single phase waveform of the voltage and current are also given in the Fig. 3. Maximum and minimum of the fundamental voltage rms value has been changed between 8500-8400 volt while current varies between 76620-75420 milliamper.

Fig. 4 and 5 Shows the waveform of the voltage and current during motor start up respectively. As can be seen from the figure, sudden change in voltage and current is observed during starting up the motor. It is called transient one and disappears after a short period of time. Motors should be started up with the help of soft start techniques in order to avoid any damage on the motor.

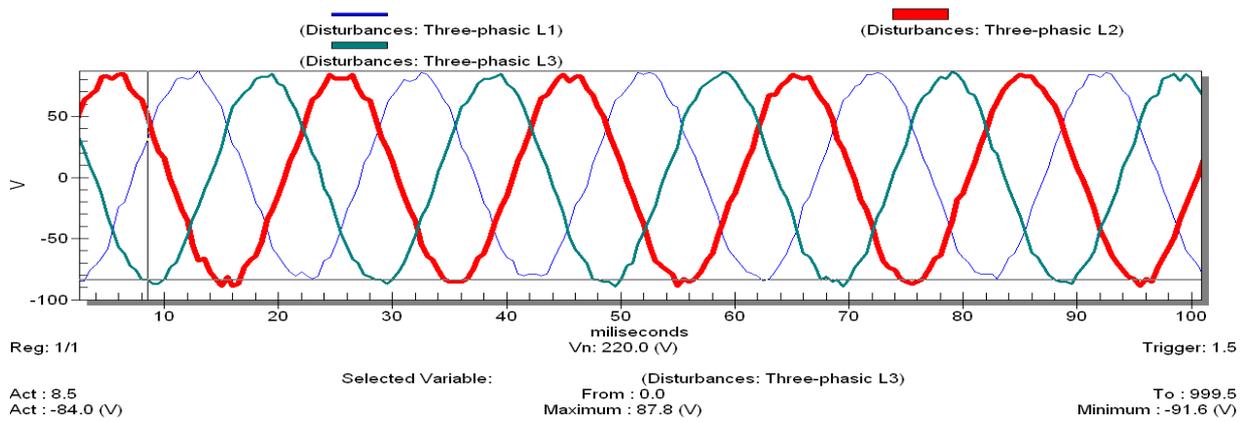


Figure 2. Voltage variations of three phases at grid.

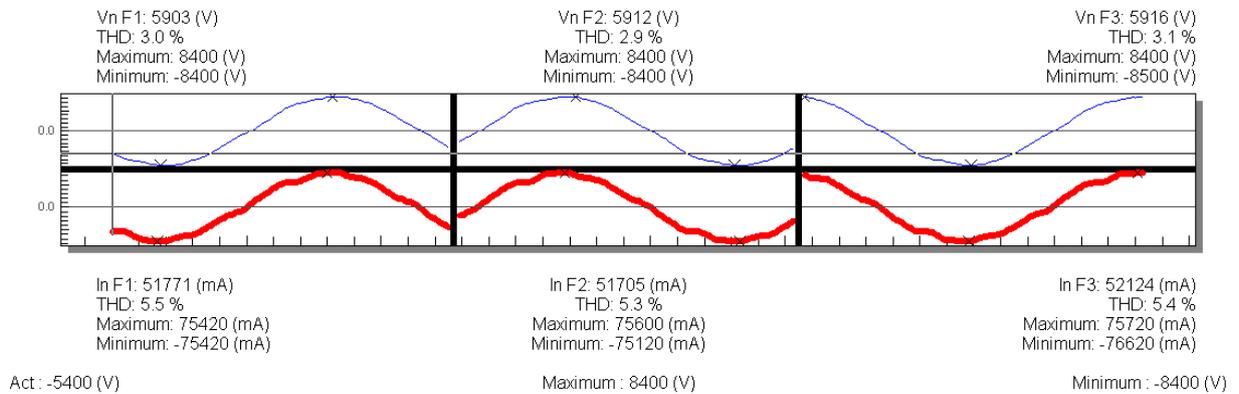


Figure 3. Single phase waveform of the voltage and current.

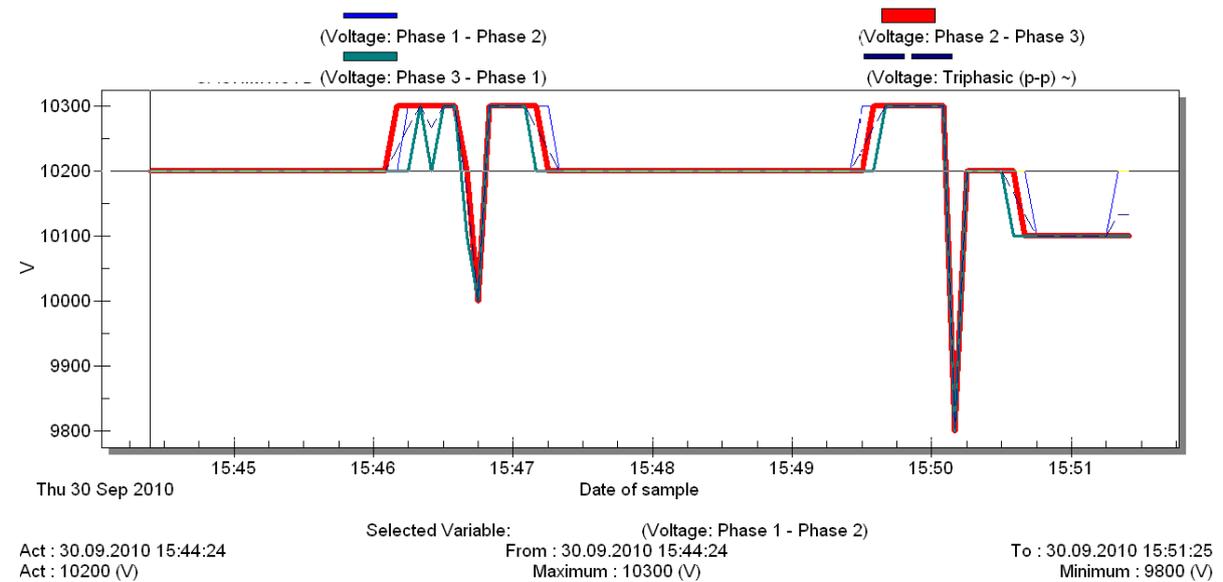


Figure 4. Voltage change of the motor during start up.

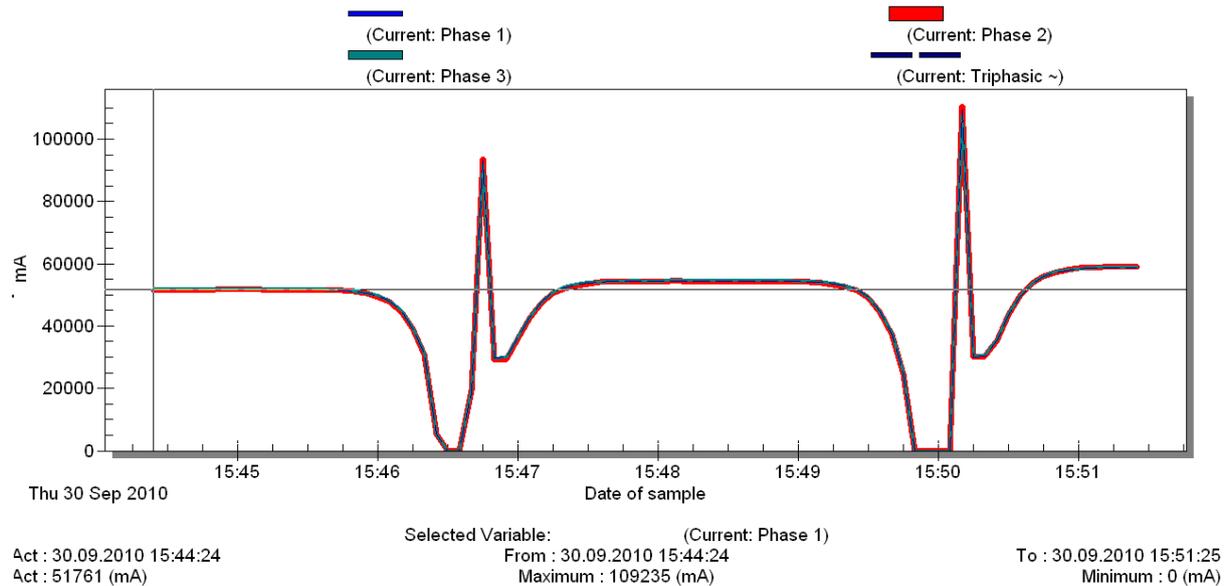


Figure 5. Current change of the motor during start up.

Additionally, waveform of the active power measured from the motor is given in Fig. 6

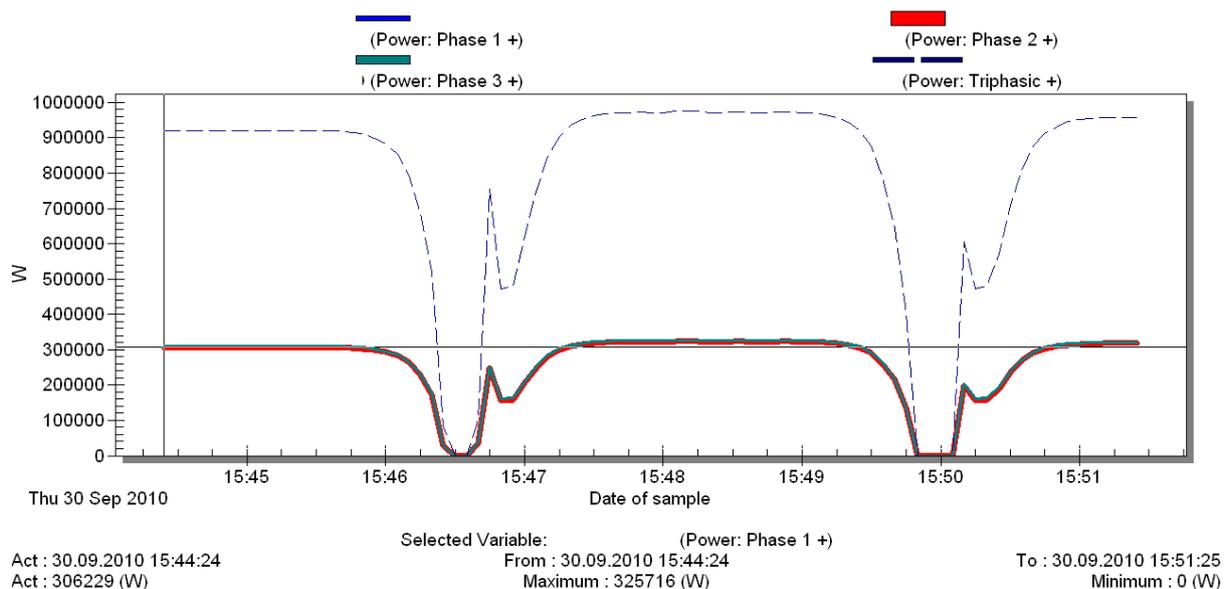


Figure 6. Active power change of the motor during start up

Total harmonic distortion (THD) value of the voltage and current obtained from the network buses are shown in the fig. 2. It can be seen that the fig. 2, maximum value of the voltage THD is 3.1% at bus while the maximum value of the current THD is 5.5% at bus. Table 2 and 3 shows the total distortion limits (THD) of voltage and current according to IEEE Std. 519-1992 respectively [14].

Considering the voltage and current THD, current value is high compared with the allowed standart values while voltage value is acceptable limit. The-

se values should be lowered using a proper filtering system. Fig. 7 shows the individual harmonic spectrum of voltage and current measured from power plant. There are 5<sup>th</sup> and 7<sup>th</sup> harmonics order for voltage spectrum while current harmonics have 5<sup>th</sup>, 7<sup>th</sup> and 13<sup>th</sup>. According to IEEE std. 519-1992, voltage harmonics order is within the acceptable level while 7<sup>th</sup> harmonic order exceeds the allowable limit.

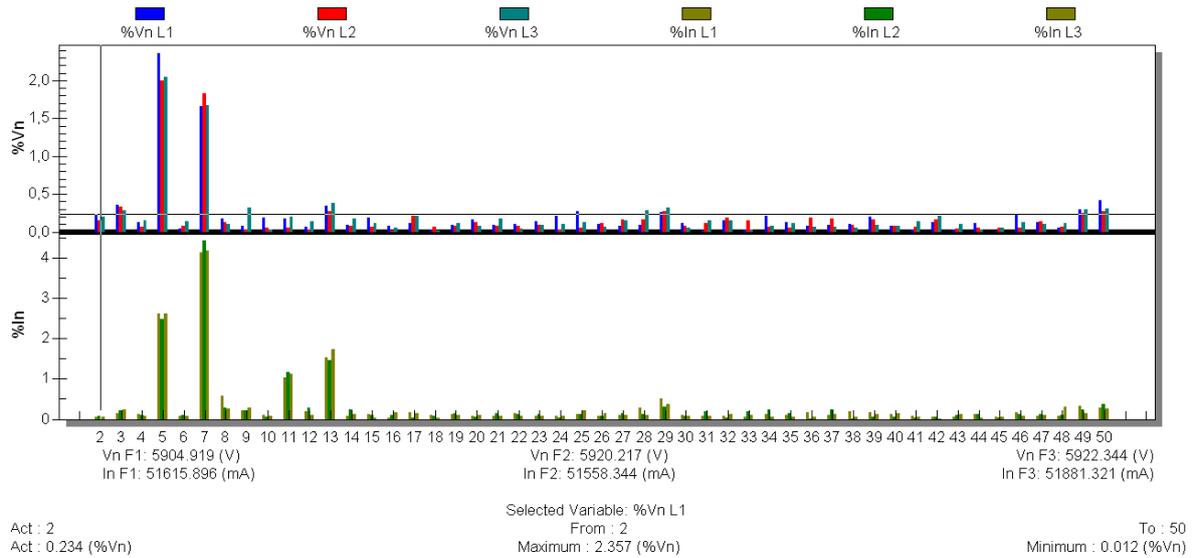


Figure 7. Individial harmonic spectrum of voltage and current at power plant.

Table 2. Voltage distortion limits for general distribution system.

Voltage Distortion Limits		
Bus Voltage at PCC	Individual Voltage Distortion THD (%)	Total Voltage Distortion THD (%)
69 kV and below	3.0	5.0
69.001 kV through 161 kV	1.5	2.5
161.001 kV and above	1.0	1.5

Table 3. Current distortion limits for general distribution system at medium and high voltage.

Current Distortion Limits for General Distribution Systems (120 V Through 69 kV)						
Maximum Harmonic Current Distortion in Percent of $I_L$						
Individual Harmonic Order (Odd Harmonics)						
$I_{sc}/I_1$	<11	11<h<17	17<h<23	23<h<35	35<h	TDD
<20*	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

5. Conclusions

In this paper, a power quality evaluation of the power plant supplied by medium voltage level under maximum loading condition is presented. Harmonics and power quality events such as voltage, current, active power have been measured, analyzed and evaluated based on IEEE 519-1992 standards. The investigations show that total harmonic distortion of current measured from the plant has slightly exceeded the limit while the voltage and other parameters are mainly good. A proper filter should be designed for harmonic elimination. After applying filters, harmonic distortions will be reduced considerably and that their maximum values are within the maximum allowable limits.

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