SCIENCE, TECHNOLOGY AND INNOVATION

MONITORING AND ANALYZING FEATURES OF ELECTRICAL POWER QUALITY SYSTEM PERFORMANCE

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Key words: Power quality, over voltage, under voltage, sustained interruption, interruption, voltage dips and swells.

Abstract: Power quality is a set of boundaries that allows electrical systems to function in their intended manner without significant loss of performance or life. The term is used to describe electric power that drives an electrical load and the load's ability to function properly with that electric power. Without the proper quality of the power, an electrical device may malfunction, fail prematurely or not operate at all. There are many reasons why the electric power can be of poor quality and many more causes of such poor quality power. Power quality of power systems, which affects all connected electrical and electronic equipment, is a measure of deviations in voltages, currents, frequency, temperatures, winding forces and torques of particular supply systems and their components. In recent years, a considerable increase in nonlinear loads has been experienced; in particular distributed loads, such as computers, monitors and lighting, and distributed sources. The aim of this paper is to display a way of monitoring and analyzing features of electrical power quality system. As a monitoring example is taken output from power transformer rated at 320 kVA, part of distribution grid of Durres City in Albania.

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Introduction

The main objective of this paper is to describe monitoring and analysis of electrical power system performance based on general requirements. A power producer may find this objective important if it has the need to understand its system performance and than match this system performance with the customers needs. Power quality monitoring is the process of gathering, analyzing, and interpreting collected of measurement data into useful information. The process of gathering data usually is carried out by continuous measurements of voltage and current during an extended period. The monitoring process time in this paper has taken for a period of 11 days. Data for power quality analysis of electrical parameters are taken from the outputs of power transformer with rated power 320 kVA and rated voltage 20/0.4 kV. Process of monitoring and analysis is referred to IEEE 1159 standard and international standard IEC 61000-4-30. General guidelines and definitions are provided from standards mentioned which provide a common language in describing power quality phenomena.

Electrical power quality monitoring standards

IEC standards for monitoring power quality phenomena are provided in a series or documents with numbers 61000-4-xx. The individual standards in this series cover specific requirements for each type of power quality variation or concern. For instance, IEC 61000-4-7 provides specifications for monitoring harmonic distortion levels. IEC 61000-4-15 provides specifications for monitoring flicker. The overall requirements for characterization of power quality phenomena are summarized in new standard IEC 61000-4-30.

a. Standard Requirements for Power Quality Measurement Equipment and for Assessment of Power Quality Measurement Data.

Mentioned standard provides detailed requirements for the measurement procedures and the accuracy requirements of the measurements and monitoring, such as:

- Capability to measure both voltage and current simultaneously, obtaining harmonic power flow information.
- Capability to measure both magnitude and phase angle of individual harmonic components, also needed for power flow calculations.
- Synchronization and a sampling rate, fast enough to obtain accurate measurements of harmonic up to 37th harmonic, (this requirements is a combination of a high sampling rate and sampling interval based on 50-Hz fundamental)

At the same time standard provides requirements for assessment of power quality measurement data that belongs to the stream off-line data analysis such as:

- Viewing of individual disturbances
- RMS variations analysis which includes tabulations of voltage sags and swells, magnitude - duration curves.
- Steady - state analysis which includes trends of RMS voltage and the current.
- Harmonic analysis where users can analyze voltage and current harmonic spectra.

Dedicated computer software is used for this purpose. The software is integrated well with monitoring equipment.

Single instrument measurement, monitoring and analysis

The process of monitoring is carried out by Power Sight Instrument, model PS250. Power Sight Instruments PS250 integrates functions such as data logger, on demand analyzer, harmonics analyzer and disturbance analyzer. PowerSight meters and power analyzers measure all: voltage, current, frequency and power (watts, VA, VAr, power factor, and energy in kWh); minimums, maximums, averages, and present values for individual phases, as well as harmonics spectrum and THD. It can save data for few days up to several months in continuously. Power Logger has four current and three voltage channels to directly measure all phases and neutral in three-phase.

The assessment of power quality measurement data is performed off -line at the central processing locations. Off-line power quality data assessment is carried out separately from monitoring instrument after downloading all data form PS250. Dedicated computer software is used for this purpose. The software accomplishes standard requirements, it is integrated with monitoring instrument. It is developed by the same company which has manufactured monitoring instrument model PS250, and this software is named PSM (Power Sight Manager). The software manages communication between PC and Instrument, configures, and analyses off - line data. The data can be downloaded to a PC in order to view graphical plots, waveforms, enabling off - line analysis.

Monitoring process is realized at secondary three phase power transformer which supplies residential and some commercial buildings with load. Figure 1, displays schema for connecting instrument to Multiple Single-phase Loads. It shows connections of instrument for unbalanced loads. The loads share the same neutral voltage connection. In this configuration, the voltage, current, and power of each load can be directly displayed or graphed on PC through PSM software.

Monitoring and analyzing for long term duration of voltage variations

Long terms duration voltage variations encompass root-mean-square (RMS) deviations of power during the for longer than 1 minute period. Those variations can be either over voltages or under voltages. Over voltage and under voltages are not generally results of system faults, but are caused by load variations on the system and system switching operations. Such variations are typically displayed as plots of RMS voltage versus time. In Figure 2 is shown three phase RMS voltage profile for time duration of 11 days during monitoring process, where a daily cyclical pattern is obvious. Here the load supplied is mostly residential; voltage profile is affected by day and night time. The monitoring process has started from date: 09.29.2009 at time 11:32, till date 10.10.2009 time 09:52. The process of monitoring in total is 15750 minutes. From monitoring process 1575 records were taken, each 10 minutes one record. Each individual record contains average data values of: RMS voltages and currents, power factor, active power, reactive power, total power, frequency and THD. Minimums, maximums, averages, and present values, for each measured values of each phase were recorded. Each record can be individually tracked up for waveform and RMS variations. Table 1 presents tabular form of voltage variations for each record, respectively phase voltages *V1n, V2n, V3n*.

1. Examination in records database for over voltages. An overvoltage is an increase in the RMS AC voltage greater than 110% of rated value. It correspondents to RMS value over 242 Volt, at the power frequency for duration longer than 1 minute. From examination in records database, Figure 2 c, result an overvoltage situation into records number 505 date 10/02/09 time 23:32:00 and record number 506 date 10/05/09 time 23:42:00. RMS value during this interval reaches highest peak value of 248 Volts at time 23:37:22. Overvoltage situation is present only for phase voltage *V2n* and its duration is 8 minutes and 35 seconds.

2. Examination in records database for under voltages. An under voltage is a decrease in the RMS AC voltage going under 90 percent of rated value or in absolute value it correspondents to RMS value under 198 Volt, at the power frequency for duration longer than 1 minute. Examination of records database does not show any under voltage situation.

3. Examination in records database for sustained interruptions. When the supply voltage has been zero for a period of time in excess of 1 minute, the long - duration voltage variations is considered sustain interruption. Voltage interruptions longer than 1 minute are often permanent and require human intervention for system repair and restoration. Examination in records database shows one sustained interruption, Figure 2b. Sustained interruption has occurred into record number 794 date 10/4/2009 time 22:42:53 and ends up into record number 796 date 10/4/2009 time 22:51:18, it is present for time 00:09:25. During this period which excess 1 minute voltage supply becomes zero volt for the three phases. In this case obtaining the date from records it is possible to analyze the causes of this sustain interruption.

Measurement / monitoring and analyzing integrated into one instrument

Monitoring and Analyzing Short - Duration Voltage Variations type can be designated as instantaneous, momentary, or temporary, depending on its duration. Short duration voltage variations are caused by fault conditions, the energization of large loads which require high starting currents, or intermittent loose connections in power wiring. Depending on the fault location and system conditions, the fault can cause either temporary voltage drops (sags), voltage rises (swells), or complete loss of voltage (interruption).

1. Examination in records database for voltage interruption. An interruption occurs when the supply voltage or load current decreases to less than 10 percent for a period of time not exceeding 1 minute. Interruptions can be result of power system faults, equipment failures, and control malfunctioning. The interruption is measured by their duration since voltage magnitude is always less than 10 percent of nominal. From examination in records database do not result any voltage interruption variation.

2. Examination in records database for voltage dips. A dip is a decrease to between 0.1 and 0.9 pu in RMS voltage at

the power frequency for durations form 0.5 cycle to 1 minute. In our case it correspondents between 198V and 22 V. From examination in records database result one voltage dip situation, shown at Figure 3. Voltage dip situation is traced at record number 17 date 09/29/2009 time 13:52:07. The RMS phase voltage *V3n* reaches the value 198 V and for other 32 seconds it remains below this value till moment 13:52:39. During this time interval it reaches minimal value of 189.5 Volt. Voltage dips are usually associated with system faults but can also be caused by energization of heavy loads.

3. Examination in records database for voltage swells. The swell voltage is considered as an increase to between 1.1 and 1.8 pu in RMS voltage or current at the power frequency for duration from 0.5 cycle to 1 minute. As with dips, swells are usually associated with system fault conditions, but they are not common as voltage dips. One way that a swell occur is from the temporary voltage rise on the unfaulted phase during single line ground fault. Swells are characterized by their magnitude, RMS value, and duration. From examination in records database do not result any voltage swell variation.

Monitoring waveform results and their analysis

In Figure 4 are displayed waveforms of secondary current and voltage at three phase power transformer. Two cycles of 50 milliseconds time duration are extracted and displayed. It corresponding of RMS colored values for three phase voltages waveform, *V1n, V2n, V3n,* three phase current waveforms *I1, I2, I3,* as well as neutral current, *In*. Table 1 shows calculated values for voltage, current and phase lag that belongs to waveforms displayed at Figure 4.

Total harmonic distortion (THD) represents a measure of the effective value of harmonic components of a distorted waveform. In Figure 5 is displayed evaluation of THD for the two waveforms cycles shown in Figure 4 , for current and voltage *V1n* and *I1* respectively. In table 2 is presented tabular form as well.

The variations of THD over a period of time often follow a distinct pattern representing nonlinear load activities in the system. Chat 6 shows the voltage THD variation over 11 days period where a daily cyclical pattern is obvious. It can be observed that that during weekend THD cyclical patterns are rarer than during the week days. The voltage THD shown in Figure 6 belongs to secondary of distribution power transformer. Mostly high - voltage THD occurs at night and during the early morning hours since the nonlinear loads are relatively high compared to the amount of linear load during these hours. From examining into database records THD voltage remains in nominal range.

Conclusion

A system for monitoring and analyzing the electrical power quality system performance was examined at power transformer rated at 320 kVA, part of distribution grid of Durres City in Albania. This power analyzer system measures all: voltage, current, frequency and power components; those minimums, maximums, averages, and present values for individual phases, as well as harmonics spectrum and THD.

From the evaluation process of recorder data: sustain interruptions variations, overvoltage variations for long duration category and voltage dip for short duration category are recorded during the period of 11 days.

Evaluation of THD is calculated based on the record measured on two cycles and for all the recorded period. The variations of THD over a period of time often follow a distinct pattern representing nonlinear load activities in the system. In general high - voltage THD values are recorded during the night and early morning. Database records examination shows that the THD voltage variation remains in nominal range.

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Annex

FIGURE 1. INSTRUMENT CONNECTION FOR UNBALANCED LOADS

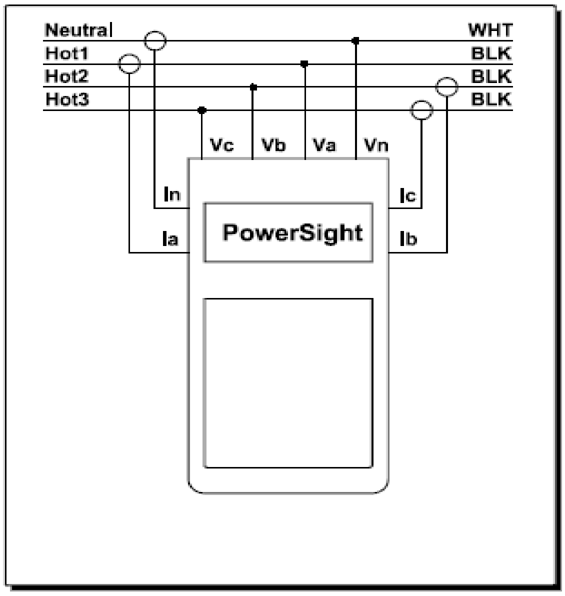

FIGURE 2.THREE PHASE RMS VOLTAGE PROFILE DURING MONITORING PROCESS A) COMPLETE PLOT OF MONITORING PROCESS B) SITUATION OF SUSTAIN INTERRUPTION VOLTAGE C) SITUATION OF AN OVERVOLTAGE INSTRUMENT CONNECTION FOR INBALANCED LOADS

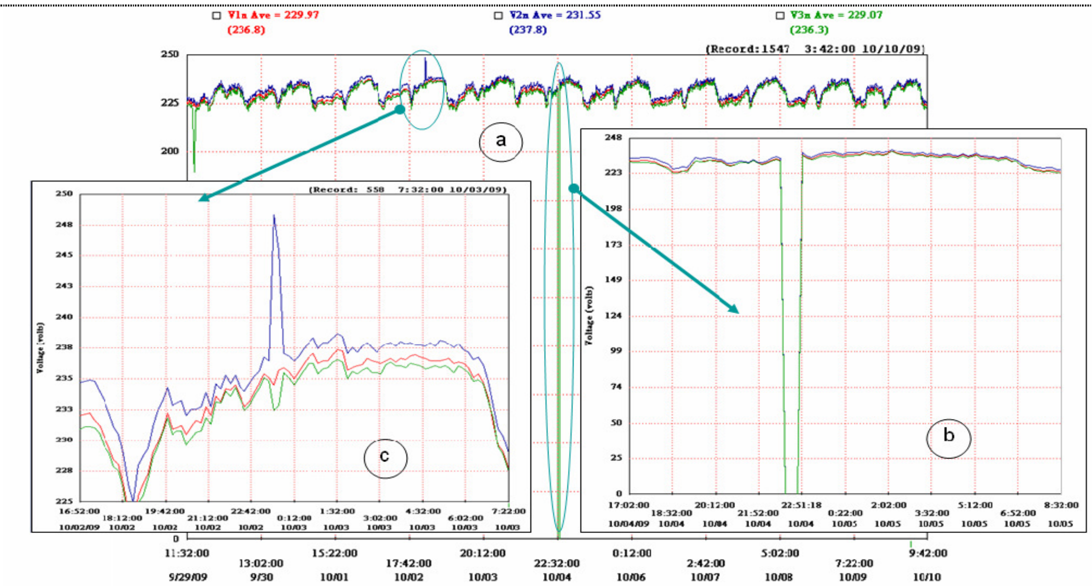

FIGURE 3. A VOLTAGE DIP SITUATION

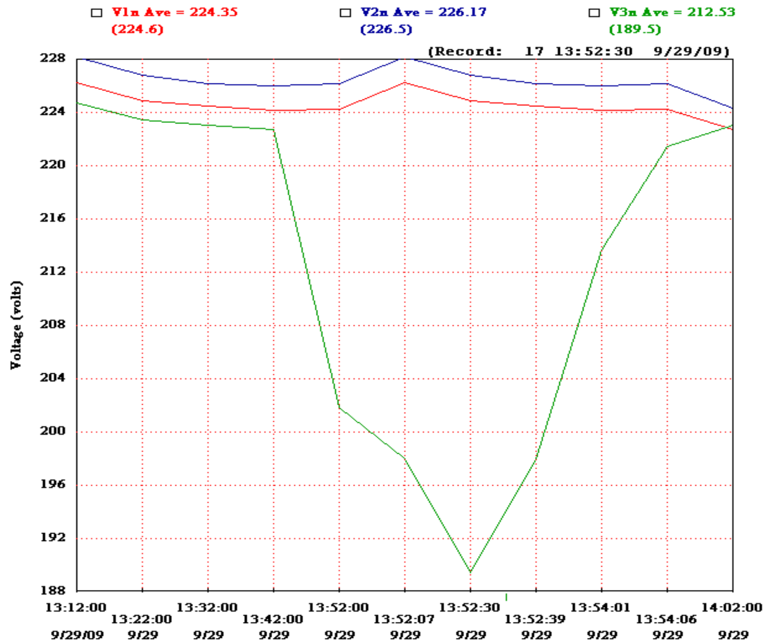

FIGURE 4. RMS WAVEFORM FOR CURRENT AND VOLTAGE OF THREE PHASE POWER SYSTEM

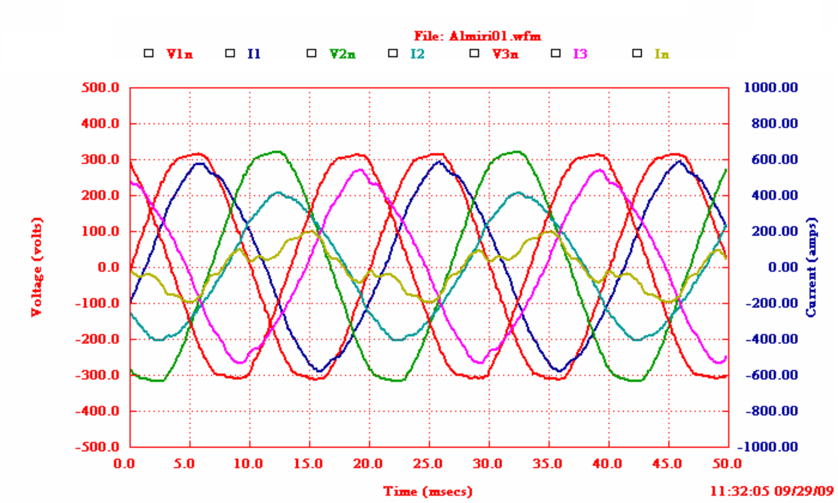

FIGURE 5. HARMONIC SPECTRUM FOR CURRENT AND VOLTAGE RESPECTIVELY V1N DHE I1

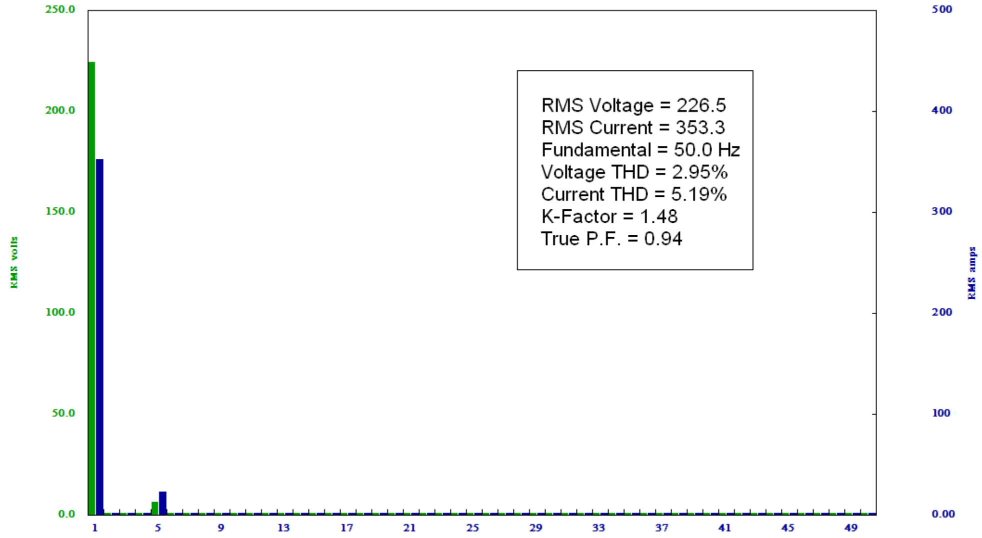

FIGURE 6. VARIATION OF THREE PHASE VOLTAGE THD OVER 11 DAYS PERIOD

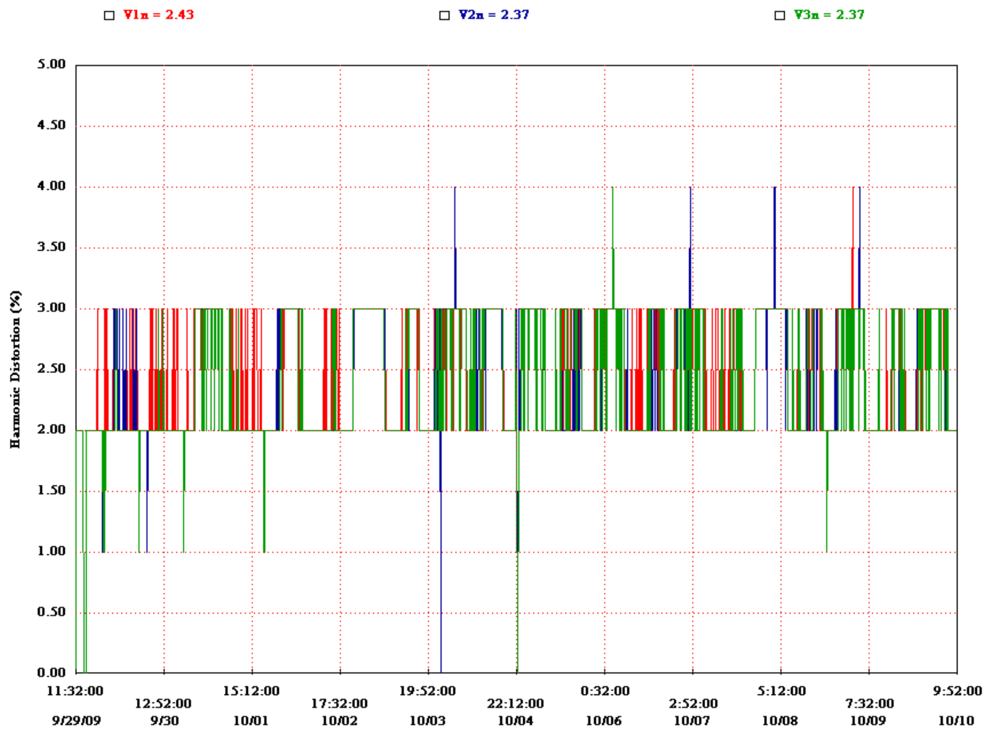

TABLE 1. TABULAR FORM OF RMS VOLTAGE VARIATIONS

Record Number	Date	Time	Three phase RMS Voltages									
	Format:	Format:	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	....
	M/D/Y	H:M:S	V1n	V1n	V1n	V2n	V2n	V2n	V3n	V3n	V3n	...
1	9/29/2009	11:32:00	226.1	226.7	225.3	228.1	229	227.2	225	225.7	224.5	…
2	9/29/2009	11:42:00	225.9	226.6	225	227.6	228	226.8	224.8	225.3	224.2	…
3	9/29/2009	11:52:00	225.1	225.7	224.4	227.1	227.6	226.1	223.9	225.1	222.8	…
i	……	……	……	……	……	……	……	……	……	……	……	…
1575	10/10/2009	9:52:00	225.4	226.2	222.6	226.8	227.6	223.7	223.8	224.4	221	…

TABLE 2. CALCULATED VALUES FOR THREE PHASE CURRENT AND VOLTAGE FOR TWO CYCLE WAVEFORM

Voltages				
RMS	V1n [V]	V2n [V]	V3n [V]	
RMS Value	226.5	228.8	225.5	
Crest Factor	1.4	1.4	1.4	
Imbalance	0.924%			
Currents				
	I1 [A]	I2 [A]	I3 [A]	In [A]
RMS Value	391.1	280.7	355.1	111.3
Crest Factor	1.5	1.5	1.5	1.8
Imbalance	17.976%			
Vpn, I, Phase Lag				
V1n, I1	20°			
V2n, I2	20°			
V3n, I3	20°			
True P.F	0.94			

TABLE 3. TABULAR FORM OF CURRENT AND VOLTAGE RESPECTIVELY, V1N AND I1

RMS Voltage = 226.5
Voltage THD = 2.95%
RMS Current = 353.3
Fundamental = 50.0 Hz

Voltage THD = 2.95%
Current THD = 5.19%

Hrm. Odd	Van RMS Voltage		Ia RMS Current		Hrm.	Van RMS Voltage		Ia RMS Current	
Hrm	Mag	Phase	Mag	Phase	Hrm	Mag	Phase	Mag	Phase
1	226.5	0.0	353.3	-54.4	2	0.20	0.0	0.010	59.1
3	0.54	-57.0	0.029	-45.3	4	0.17	0.0	0.010	-77.8
5	5.98	51.2	12.80	159.9	6	0.27	0.0	0.002	0.0
7	0.60	-81.4	0.048	-55.9	8	0.04	0.0	0.002	0.0
i-te	---	---	---	---	i-te	---	---	---	---
47	0.04	0.0	0.001	0.0	48	0.08	0.0	0.002	0.0
49	0.03	0.0	0.002	0.0	50	0.09	0.0	0.002	0.0