POWER QUALITY ESTIMATION AT THE LOAD NODE SUPPLIED FROM GRID AND LOCAL POWER UNITS

N.R. Rahmanov, O.Z. Kerimov*, R.N. Rahmanov, Kamil Dursun*****

**CPEE Azerbaijan – Cleaner Production and Energy Efficiency Center,*

***BP-AIOC, ***Tekna-Norway*

E-mail: nariman@cpee.az

www.cpee.az

+(99412) 431 39 83

ABSTRACT

Efficient monitoring of Power Quality in main node of energy system containing different motor load and supplied from autonomous power plant is examined. By mean of long term monitoring of all power quality parameters it is established their conformity to international standard.

Estimation of power quality parameters at Sangachal sub-station node which GRID supply BP terminal at.

Keywords: monitoring, power, exploitation, transformers, frequency.

I. INTRODUCTION

Active exploitation of oil and natural gas fields at sea and mainland of Azerbaijan resulted by building a huge terminal for storage and transportation of hydrocarbons to Europe. Such unique installation was built at Sangachal by international company operated by BP. The terminal has connections with appropriate oil pipe-line Baku – Tiflis – Ceyhan and gas pipe-line Baku – Tiflis – Erzerum.

At present time Sangachal 's Terminal load (first stage of development) is including a set of powerful motors which drive pump, vacuum units and other oil industry gears and also other groups of consumers, which have electronic equipment with rectifier circuits, heating equipment, freezers, computers, air conditioners and some other techniques.

All this equipment is very sensitive to the quality of supplied voltage. For smooth start of asynchronous motors thyristor circuits are used and as a result there would be considerable distortion at current at the period of start. Despite it electrical driven motors even at steady state operational condition have distorted form of current.

From the other side, long term voltage increasing or decreasing resulting in a short life time of motors and their electronic power supply units. Low voltage condition has more negative effect, because of increased current. Long action of low voltage conditions may result in termination of computers and micro-controllers. According researches [1] total low voltage time period greater by 10-25% than time period of loosing power .

This paper deals with operational analysis of power quality main parameters for big oil-industry load node, which contains many different power motors having been supplied from local autonomous power station and also connected to big energy system (grid).

II. MEASURING CIRCUIT AND TECHNIQUES.

RMS values for voltage and current are calculated using expressions:

$$U_{AC} = \sqrt{\left(\frac{1}{N} \sum_{j=1}^{N} u_j^2 \right)}$$

$$I_{AC} = \sqrt{\left(\frac{1}{N} \sum_{j=1}^{N} i_j^2 \right)}$$

where U,I RMS values

u,i measured values for voltage and current

N number of measured values for 16 periods

Taking in consideration that Simeas Q digitizes voltages and currents with sampling frequency of 6400 Hz for 50 Hz networks during 16 periods of standard industrial frequency we have N=6400:50*16=128*16

The **frequency** is determined at input V_{phase1} of the device. Digitizing is realized with sampling frequency f_{sample}

$$f_{sample} = 128 \cdot f_{nom}$$

Active power could be calculated from

$$P = \frac{1}{N}\sum_{j=1}^{N} u_j \cdot i_j$$

where

u, i measured values for voltage and current

N number of measured values for 16 periods, i.e. N=128*16

Reactive power

$$Q = \sqrt{S^2 - P^2}$$

Power factor (cosφ)

$$PF = \frac{P}{S}$$

For calculating power in three wire system by the classic method there would be voltage balance and load balance as well as no harmonics (i.e. voltage and current functions are sinusoidal).

For three wire hv network we can use 2-wattmeter method. In that case total **active power**

$$P_{total} = P_{W1} + P_{W2}$$

Total apparent power

$$S_{total} = \frac{\sqrt{3}}{2} \cdot \left(U_{P1-P3} \cdot I_{W1} + U_{P2-P3} \cdot I_{W2}\right)$$

Total reactive power

$$Q_{total} = \sqrt{S_{total}^2 - P_{total}^2}$$

Power factor

$$PF = \frac{P_{total}}{S_{total}}$$

In presence of harmonics **total harmonic distortion** one can estimate from the expression

$$THD = \frac{0.01}{U_1}\sqrt{\sum_{n=2}^{40} U_n^2}$$

Where:

n - order of the harmonic

U - RMS value of the voltage

Apparent power

$$S = U_{AC} \cdot I_{AC}$$

There are different measuring equipment on the market today. Among them the most known in our opinion devices designed by Siemens (Germany), LEM and S&I (UK), MARS and PARMA (Russia) and some others. All measuring systems could monitor and record power quality values in real time scale and in accordance with GOST-13109-97 standards. From this point of view Simeas Power Quality Recorder devise by Siemens was chosen as having been more convenient and taking into consideration that protection and some control devices installed at Power Control Center are from Siemens.

Functions of Simeas Q Power Quality Recorder:

-Recording of electrical quantities, e.g. for analyzing power quality.

-Suitable for monitoring of single phase power supply systems and 3 and 4-wire three-phase power systems.

-Recording of limit violations.

-Transmission of recorded values via various communication channels (RS-232,RS-485,PROFIBUS DP)

The metering procedure was divided on three stages:

On first stage input circuit of the device was connected to current and voltage transformers using 2CT & 2VT (two wattmeter circuit). Averaging time base was accepted once as 1sec and in next metering cycle 1min. So we got 2 data basis- for short time period (5-7min.) and long time period (about 1 or more hours). Installed CT has transformation coefficient 1200/5A and VT – 220/0.1kV accordingly. In second case device was connected to CT and VT on 110kV side of 220/110kV transformer with transformation ratio 1000/5A and 110/0.1kV accordingly.

Generalized circuit of Azerbaijan Energy System (Grid) – is done on Fig. 2.1

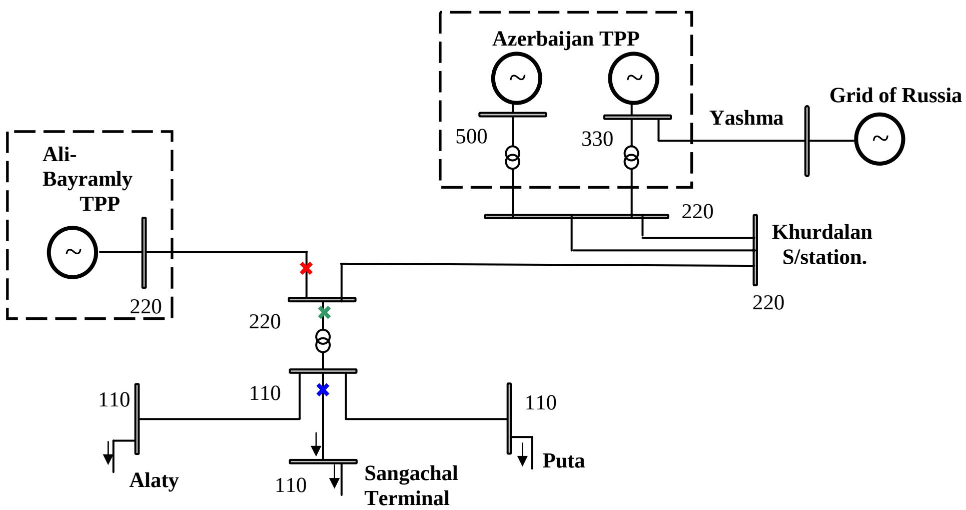

Fig. 2.1

III. RESULTS OF POWER QUALITY MONITORING AND ANALYSIS AT SANGACHAL – BP ENERGY TERMINAL CONNECTION NODE

In this chapter measured and evaluated values of power quality parameters on energy supplying part of grid (220kV buses at substation of Sangachal) and 110kV line supplying BP Terminal are reviewed. In accordance with International standards 13109-97 measured values of power quality were compared with established standards. Results of analysis for each parameter are done below.

A. 220kV Sangachal node substation – system side

Voltage deviation

On Fig.3.1 there are root mean square values for phase-to-phase voltage measured with 1min. time intervals. Steady state deviation for voltage could be evaluated from:

$$\delta U_S = \frac{U_S - U_{nom}}{U_{nom}} \cdot 100$$

The function δU_S is shown on Fig.3.2 was measured at different time of the day during 2 days. As it seen, means of δU_S do not exceed normal border limits of $\pm 5\%$ besides one case then deviation of voltage within one minute exceeds limit value (9,4%).

Frequency deviation

Frequency deviation for long period of monitoring is shown on Fig.3.3. It is seen that frequency deviation does not exceed acceptable bounds, i.e. 50,2 ÷ 49,8 Hz.

Non-sinusoidal character of voltage

This parameter is characterized by:
total harmonic distortion for voltage (THD)
- coefficient of n-harmonic component

THD function for phase to phase voltage is shown on Fig.3.4.

It is obvious from the picture that measured values of THD do not exceed normally admissible ± 2%.
Estimation of harmonics from third to eleven for voltage U L1 is done.
All measured values do not exceed normally admissible values determined by standard (table 3.1).
Comparative evaluation of measured values for harmonics (U) with their acceptable values according GOST-standards are shown below:

Comparison of harmonic values with standard levels.
table 3.1.

Harmonics	Swing of measured value, %	Normally acceptable, %	Limit, %
For 3d	0,3-0,4	0,75	1,12
For 5th	0,115-0,156	1,5	2,25
For 7th	0,113-0,160	1,0	1,5
For 9th	0,016-0,023	0,2	0,3
For 11th	0,16-0,25	1,0	1,5

B. 110kV Sangachal node substation – Terminal side

To have more detailed data during monitoring, measurements were done with two kinds of average time: 1min. and 1sec. Root mean square phase to phase voltage function with average measuring time 1sec is shown on Fig. 3.6 and other power quality parameters.
Voltage deviation on all three phases does not exceed acceptable bounds (104,5-115,5)kV. Phase currents for Sangachal-Terminal line (Fig.3.7) have stationary state with average mean of 22A .
Comparison of measured parameters with values determined in accordance with standards done below.

- Voltage deviation are in acceptable bounds (104,5-115,5)kV
- Frequency deviation (Fig.3.10). Max. and min. thresholds are 50,005 and 49,965Hz do not exceed limit values 49,8- 50,2 Hz

Measured value for THD is in interval of (0,6-1,0)%. It is also acceptable because THD value do not exceed ±2% level

- Voltage non-symmetry (Fig.3.11). Coefficient of non-symmetry is changing within 0,57-0,67 range That is lower than normally acceptable range of 2% stated by standards.

Comparative evaluation of measured values for harmonics (U) with their acceptable values according GOST-standards are shown below: Table 3.2

table3.2.

Harmonics	Value for harmonics component, %	Normally acceptable value, %	Limit value, %
For 3d	0,5-0,56	0,75	1,125
For 5th	0,02-0,156	1,5	2,25
For 7th	0,45-0,62	1,0	1,5
For 9th	0,002	0,2	0,3
For 11th	0,15-0,55	1,0	1,5

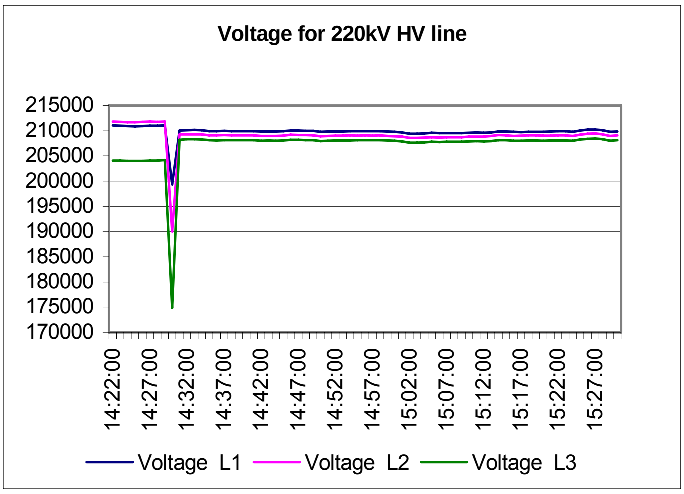

Fig.3.1

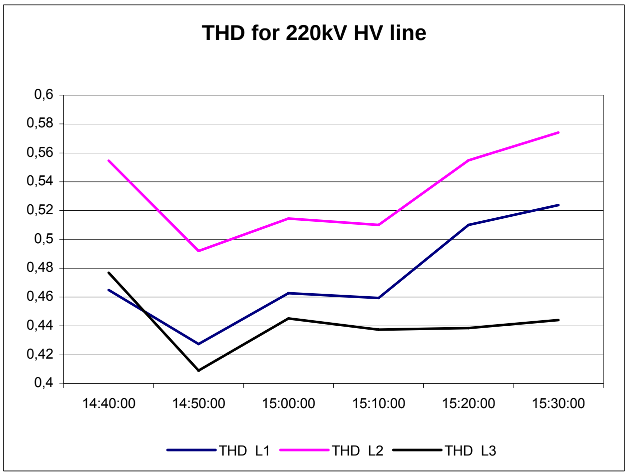

Fig. 3.4

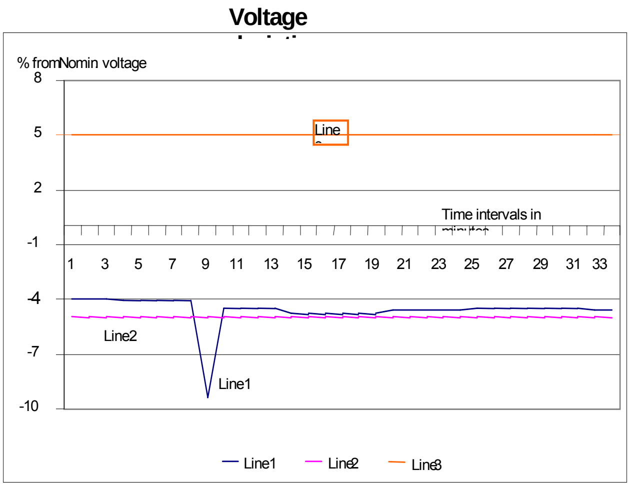

Fig. 3.2

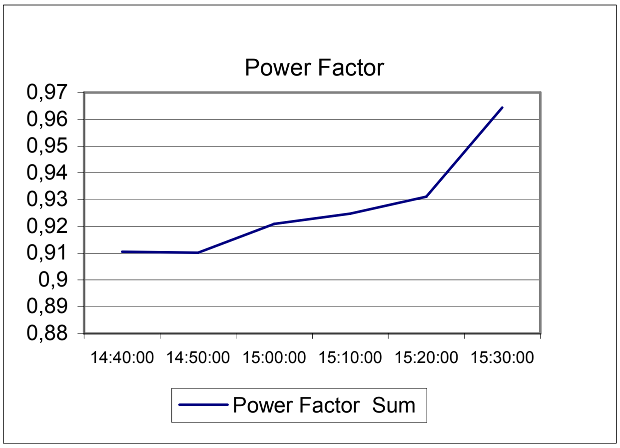

Fig.3.5

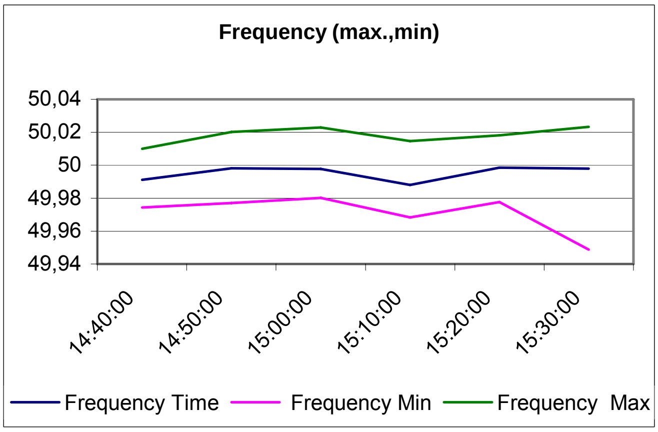

Fig. 3.3

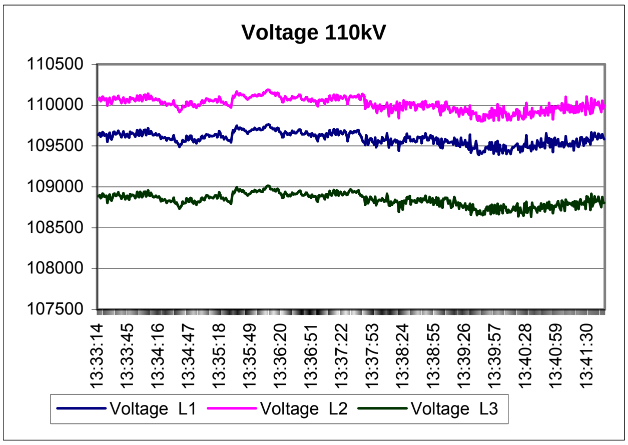

Fig. 3.6

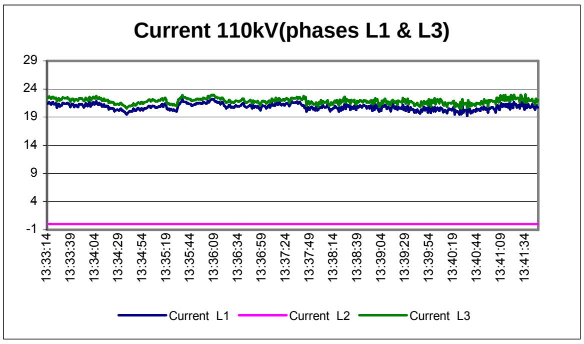

Fig. 3.7

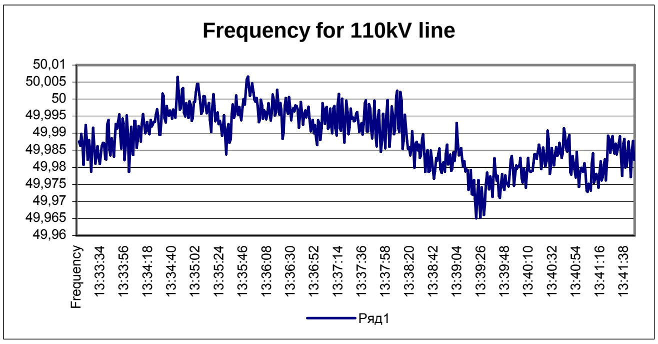

Fig. 3.10

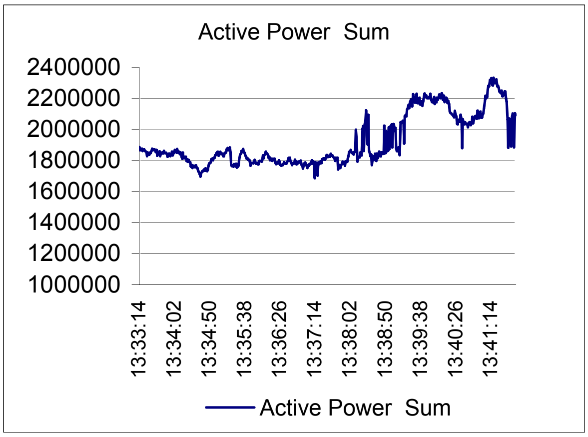

Fig. 3.8

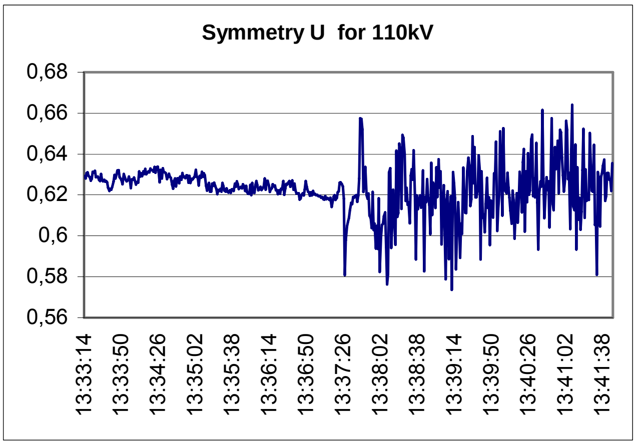

Fig. 3.11

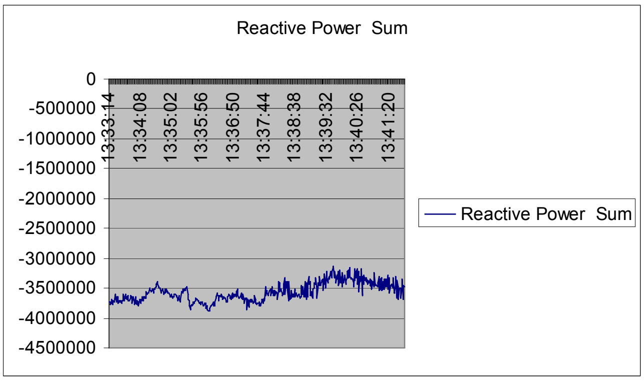

Fig. 3.9

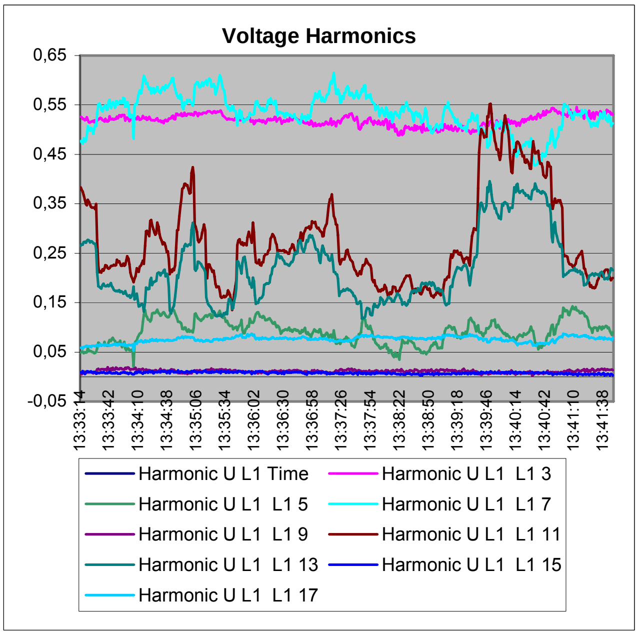

Fig. 3.12

IV. CONCLUSION

1. Monitoring of power quality parameters on 220kV Sangachal substation at System side as well as on 110kV Terminal side.

Measurements were done taking in consideration Grids state and operative conditions (Max. & min. load demands).

2. Comparing measured values of power quality with acceptable values recommended by standards, there can be determined:

- Coefficients for n-harmonic component for all measured harmonics are in admissible borders recommended by standard.

3. During power quality monitoring it was discovered that BP Terminal is consuming active power but on the other hand supplying Grid with reactive power. It is as Terminal could take part in voltage stabilization for Sangachal node of Grid.

- Frequency deviation in case of parallel work of Azerenerji with Russian Grid at max. load consumption hours occasionally exceeds normally acceptable values, i.e. 49,8-50,2 Hz
- Steady state value of voltage deviation is in normally accepted bounds, ±5%.
- THD for phase to phase voltage is different, but all values are in acceptable limits (2-3)%

4. Voltage variations on the Azenerji side (Sangachal substation) should be monitored in a long run to determine and predict some prospective difficulties in using Grid as supply source.

REFERENCES

1. D Daniel Sabin, Ashok Sundaran /Quality Enhoncement and Reliality/ Spectrum IEEE, 1996, Febrary