



Measurement and calculation of harmonics in distribution power system with connected small co-generation facility Etan

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Abstract Generation of electrical energy in large conventional plants (thermal, hydro, nuclear) in last ten years worldwide is being supplemented by small generation utilities. Etan is a gas refining facility. Power supply is provided by two turbo generators and each of them can independently cover the consumption of Etan. Etan usually works in insular operation, but it can also work parallel to the distribution system, especially in cases of maintenance of generator units. Etan is connected to the MV distribution power system (10 kV bus in substation 35/10 kV Ivanic Grad) through a 4,5 km long cable. Load in Etan consist mostly of induction motors. Power electronic devices are used for control of motor loads. The working process of the refinery is always the same so the load is not varying with time.

It is very important to know the influence of this kind of industrial consumers with distributed generation on power quality.

Power quality measurements were performed at three measurement points with the power quality analyzer ION 7650 of company Power Measurement.

The aim of this paper is to compare harmonic measurements and calculations at all three measuring points in different operating conditions depending on the production of generator in Etan.

Key words

Distributed generation, power quality, harmonic measurements, harmonic calculation.

1. Introduction

Etan now usually works in insular operation, but in the future, the refinery should operate parallel to the distribution system, with option of exporting energy to the power system. Turbo generators in Etan have rated power of 3,325 MVA each. They are connected directly to the 10 kV bus without power transformers. The generators always work separately. The maximum consumption of Etan is 1,6 MW, so one generator is more

than enough to cover consumption of the refinery. Load in Etan that consists mostly of induction motors is connected to the LV busses through two power transformers 10/0,4 kV of rated power 1,6 MVA each. Etan is through a 4,5 km long cable connected to 10 kV bus in distribution network's substation 35/10 kV Ivanic Grad (point of common coupling - PCC). Cable connection is reserved for power supply of Etan in case of generators' reconstruction. Etan facility is connected to the power transformer which has loaded tertiary winding. The rated power of the transformer is 8/4/4 MVA. Secondary and tertiary windings have separated busses. Etan – industrial consumer is connected to the secondary winding, and distribution loads like household consumers are connected to the tertiary winding. High percentage of motor loads and power electronic devices suggest that harmonics may represent a significant problem for all loads connected to distribution system, in case when Etan is working parallel to the distribution system. A major effect of harmonic voltages and currents is increased heating of power system elements like power transformers, motors, generators, cables, lines, etc. Except increased heating there is a possibility of system resonance that can destroy system elements like capacitor banks.

2. Measurement

The measurements were performed in order to determine of power quality parameters, especially harmonics, in the distribution power system. The measurements were performed in cases when Etan is not connected to the system and when Etan is working parallel to the system. In case when Etan is working parallel to the system, measurements were carried out for three different situations: with power generation of 1,9 MW (more than Etan's consumption), with power generation of 0,3 MW (less than Etan's consumption) and with power

generation of 0 MW (all consumption is covered by the distribution system). Measuring points in distribution power system and in Etan refinery are shown on figure 1. Instruments were set at three measuring points and measurements were taken simultaneously at all measuring points. First measuring point was on the 35 kV bus in substation Ivanic Grad - MT1, second measuring point was on the 10 kV bus in substation Ivanic Grad (secondary transformer winding) – MT2 and the third measuring point was on the 10 kV bus in Etan refinery – MT3. Power quality analyzers ION 7650 were used for the measurements.

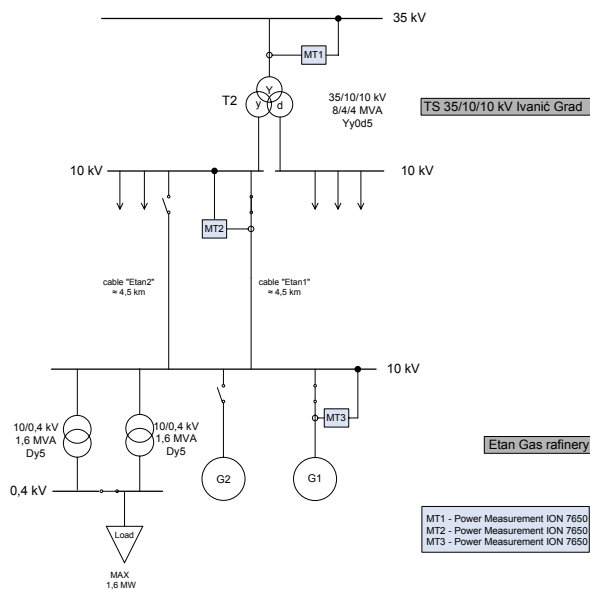


Fig. 1. Measuring points in distribution power system with connection of Etan refinery

Measurement results of harmonics (peak value in percentage of nominal voltage) on the 35 kV bus in substation Ivanic Grad (MT1) in case when Etan is working parallel to the system, for all three different cases: with power generation of 1,9 MW, with power generation of 0,3 MW and with power generation of 0 MW are shown on figure 2.

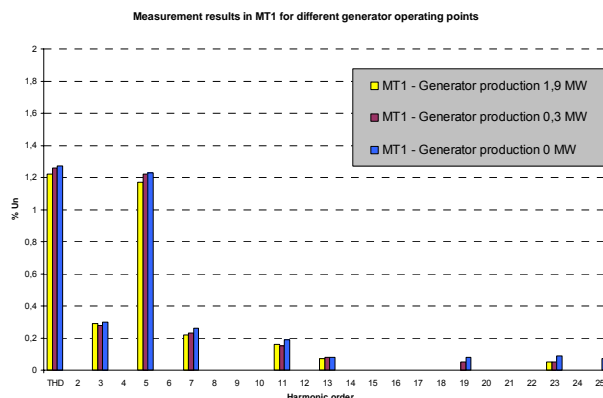


Fig. 2. Measurement results of harmonics on the 35 kV bus in substation Ivanic Grad (MT1) for three different cases

Measurement results of harmonics (peak value in percentage of nominal voltage) on the 10 kV bus in substation Ivanic Grad – on secondary transformer winding (MT2) in case when Etan is working parallel to the system, for all three different cases are shown on figure 3.

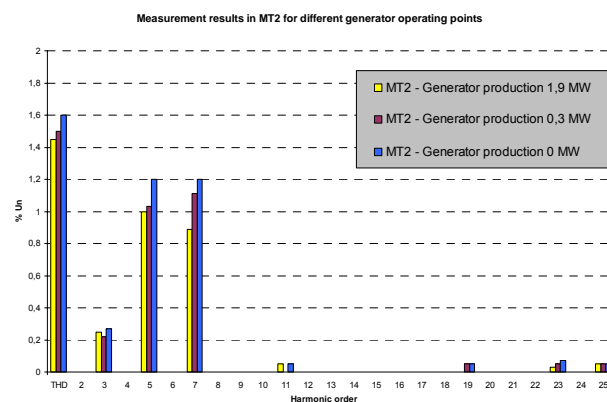


Fig. 3. Measurement results of harmonics on the 10 kV bus in substation Ivanic Grad – on secondary transformer winding (MT2) for three different cases

Measurement results of harmonics (peak value in percentage of nominal voltage) on the 10 kV bus in Etan refinery (MT3) in case when Etan is working parallel to the system, for all three different cases are shown on figure 4.

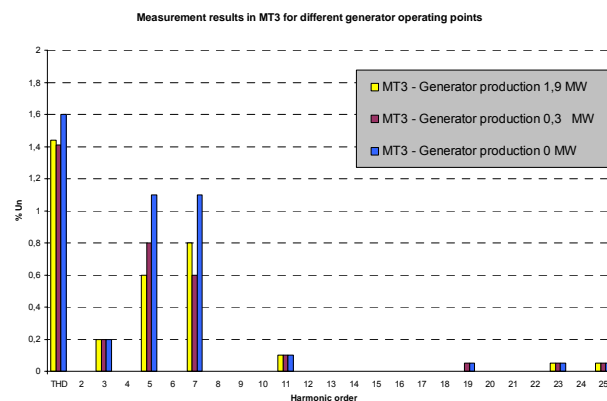


Fig. 4. Measurement results of harmonics on the 10 kV bus in Etan refinery (MT3) for three different cases

Harmonic measurement results analysis was carried out according to international standards and technical reports regarding power quality in distribution networks at medium voltage level and low voltage level [1] and [2]. The comparison with limits that are given for harmonics in international standards and technical reports was made for every measurement point.

Measuring period according to EN 50160 [1] should be one week, and 95% maximum weekly value of harmonics should not exceed limits given in EN 50160. The exception for this measurement is length of measuring period that was less than one week, because operation process that is not economically justified.

Maximum measured values were compared with those given in the norm (maximum 95% weekly values were not accessible). Maximum measured values were much lower than limits given in the EN 50160.

3. Calculation

Harmonic analysis was carried out using ETAP Power Station simulation software.

Simulation model for harmonic analysis of the distribution power system with connected Etan refinery is shown on figure 5.

In case when Etan is working parallel to the system, calculations were made for three different situations: with power generation of 1,9 MW (more than Etan's consumption), with power generation of 0,3 MW (less than Etan's consumption) and with power generation of 0 MW (all consumption is covered by the distribution system).

An indispensable precondition while carrying out calculation of harmonic propagation in power systems is good knowledge of the system parameters. Simulation model was made with data that was available at the time, while remaining data was assumed.

Data that was used for the calculation was partially known and partially estimated. 3-phase and 1-phase short circuit power on 35 kV bus in substation Ivanic Grad was known from short circuit calculations. Data for three winding power transformer in Ivanic Grad, cable Etan 2, generator in Etan and power transformers in Etan were known from the manufacturer. Estimated data was the load that is connected to the tertiary winding of power transformer in substation Ivanic Grad, and the load in Etan.

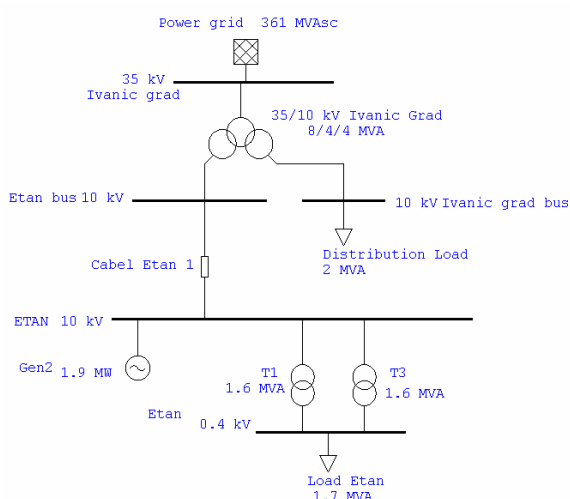


Fig. 5. Simulation model for harmonic analysis in distribution power system with connection of Etan

Simulation results of harmonics (in percentage of nominal voltage) on the 35 kV bus in substation Ivanic Grad (MT1) in case of Etan working parallel to the system, for all three different cases are shown on figure 6.

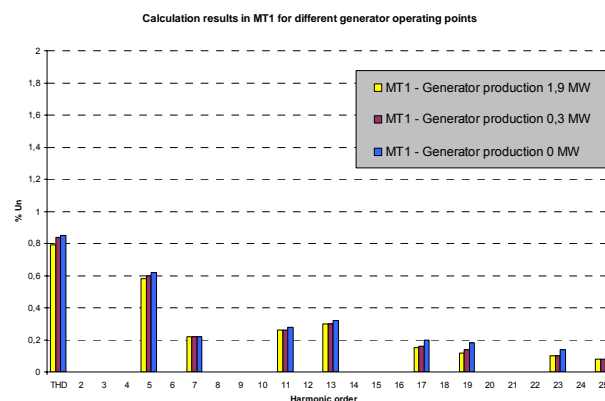


Fig. 6. Simulation results of harmonics on the 35 kV bus in substation Ivanic Grad (MT1) in three different cases

Simulation results of harmonics (in percentage of nominal voltage) on the 10 kV bus in substation Ivanic Grad – on secondary transformer winding (MT2) in case of Etan working parallel to the system, for all three different cases are shown on figure 7.

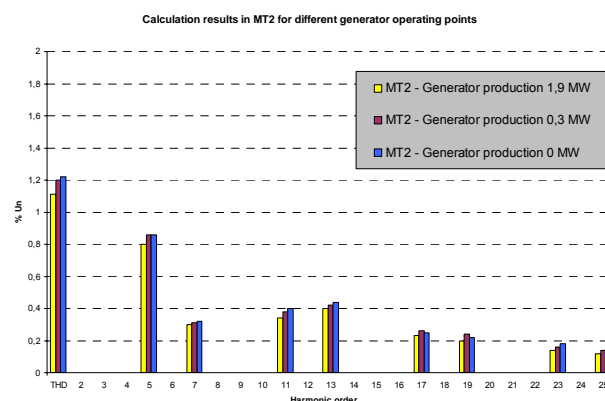


Fig. 7. Simulation results of harmonics on the 10 kV bus in Etan refinery (MT2) in three different cases

Simulation results of harmonics (in percentage of nominal voltage) on the 10 kV bus in Etan refinery (MT3) in case of Etan working parallel to the system, for all three different cases are shown on figure 8.

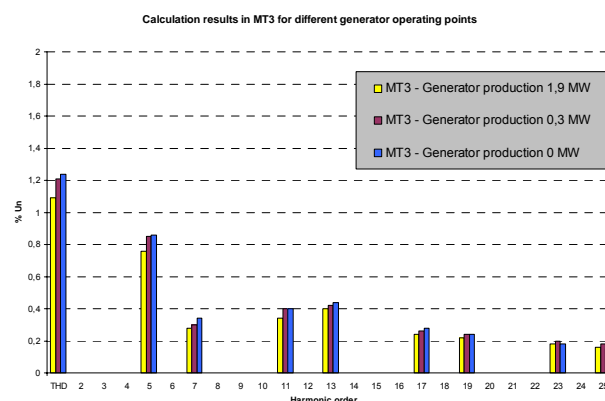


Fig. 8. Simulation results of harmonics on the 10 kV bus in Etan refinery (MT3) in three different cases

4. Conclusion

Simulation results of harmonic analysis were compared with harmonic measurement results, at all three measuring points and for all three different cases: with power generation of 1,9 MW, with power generation of 0,3 MW and with power generation of 0 MW in refinery Etan. Both results of measurements and of simulations are within the limits given by EN 50160.

Measurement results for voltage total harmonic distortion are consistent with values of the simulation for all three measuring points. There are small differences between results (measurement results are greater than simulation results) but all values are relatively small for distribution power system (according to EN 50160 the limit for THD is 8 %).

In both cases at all three measuring points, minimal values of THD appear when the power generation is 1,9 MW, and maximal THD appears when power generation is 0 MW.

Individual voltage harmonic values for all three measuring points differ from values of the simulation.

Differences in measurement and simulation results are present due to the lack of data. It is obvious that parameters of transformers, cables and lines are exactly

known. The load in the system however is subject to changes and cannot be represented exactly in calculations. Variation of the load, which is normal in power systems, is seen as an important part in the analysis. With good knowledge of the load connected to the part of power system, which is being observed and individual specifications, model for the simulation can be more detailed and therefore give better simulation results.

References

- [1] EN 50160: 1999, Voltage characteristics of electricity supplied by public distribution systems.
- [2] IEC/TR 61000-3-6: 1996, Electromagnetic compatibility (EMC)- Part 3:Limits - Section 6: Assessment of emission limits for distorting loads in MV and HV power systems – Basic EMC publication.
- [3] Power Measurement – ION 7650 user guide, www.eliteas.com/pml/PMLACFILES/7550_7650_userguide.pdf
- [4] Etap – PowerStation help manual, www.etap.com.