XXII Seminarium

ZASTOSOWANIE KOMPUTERÓW W NAUCE I TECHNICE' 2012

Oddział Gdański PTETiS

Referat nr 34

ANALYSIS OF POWER TRANSFER PERFORMANCE IN INDUSTRIAL POWER PLANT BASED ON REACTIVE POWER COMPENSATION

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Abstract: This paper describes the single one week of three phase measurements of power quality parameters with the focus on flow of reactive power. The measurements were conducted in real LV distribution network in order to match the new capacitors bank with operating conditions of supply station. The measurements were done under rated voltage (three-phase, 230/400V) in the LV switchgear at small factory near Cracow. The main objective of the measurement was to assess power quality during long-term operating conditions as well as find out about quantitative benefits of reactive power compensation.

Key-words: reactive power compensation, measurements, case study

1. INTRODUCTION

Reactive Power is present in the AC network, but its transmission is adversely affecting network performance. The solution is the compensation of reactive power, which is not a new issue, but the selected problems which influence the quality of electrical energy is still up-to-date. Production of reactive power should be as close as possible of its consumption. Reactive power consumed by the lower voltage network devices and end-user should be covered in the basic parts from local sources (batteries, capacitors) [1]. In general, the measure of reactive poweramount in a given point of network is a Power Factor (PF), which determines the ratio of active power to apparent power. Low value of PF means transmission of more reactive power in the system, what is unfavourable.

Low PF value is generally caused by the prevailing number of inductive receivers at the network. The solution is installation of capacitive elements – first of all power capacitors. By that means, the spread of reactive power is changed and the PF increased. On the other hand, if capacitive reactive power predominates the inductive reactive power then it comes to overcompensation, which can be dangerous since it may lead to an excessive voltage rise in the network.

Demand for capacitive reactive power at a given network point is variable throughout the day. Therefore, a variable number of capacitors must be switched on, depending on the actual reactive power demand, to keep the PF value in a given range.

2. MEASUREMENT DESCRIPTION

2.1. Measurement device

Measurements were being performed using a three phase Power Quality Recorder (PQR). It is a portable instrument for the analysis of utility and industrial power distribution systems. The instrument provides the flexibility to customize thresholds, algorithms, and measurement selections. It captures the most comprehensive details on user-selected parameters and allows for later analysis. The device is equipped with 8 programmable channels dedicated to voltage (4) and current (4) probes. The PQR is Class-A standard and compliant to IEC 61000-4-30.

2.2. Installation place of measurement device

The measurement has been carried out at a MV/LV supply station of small factory near Cracow. The measurement points were located on the secondary side of a supply distribution transformer 400kVA, at the phase-to-phase voltage level U_{RMS}=0.4kV. The measurements of power quality, to be considered as authoritative, had to be recorded in a continuous mode in a period of at least one week.

The parameters of power quality had been measured and recorded in the test object before and after the installation of new capacitors bank.

Because original (already installed) old capacitor bank could not be switched off (economy reasons), the PQR was connected to the main low voltage switchboard busbars between old capacitor bank and the new capacitor bank. As a result the old capacitor bank and two feeders were overlooked and not involved in measurements. On the other side, these two feeders have no influence on power flow because one was not loaded, second is the spare connection (which was opened) with spare transformer. The point of measurement is illustrated in Fig. 2. When the new capacitors bank was connected to the supply circuit it was included to the measurement by PQR and old capacitor bank was switched off.

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2.3. Details of measurement

The three phase current of load and the current of L1 phase of capacitor bank are measured by all four available current channels (probes). The three phases voltage (voltage to ground) are measured as well. The remaining physical sizes are calculated by the software delivered together with the PQR.

In order to assess power quality during long-term operating conditions of supply station, the measurements were executed in 2 stages.

Stage 1. Before the installation new capacitor bank. During this stage all receivers are included by PQR measurement. Electrical parameters of energy quality were being recorded for analyses over one month. On the basis of recorded data, analyses and calculations the new capacitors bank was matched up with operating conditions of supply circuit of the factory.

Fig. 1. PQR connected to main switchgear in a power station

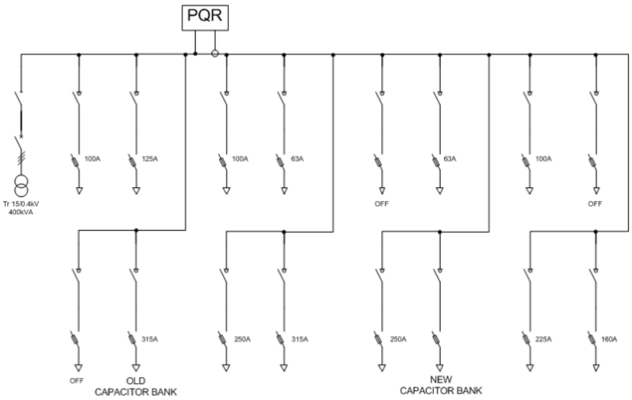

Fig. 2. Single line diagram of main switchgear

Fig. 3. The new capacitors bank connected to the LV busbars by the cell (bay) of switchgear in power supply station of factory.

Stage 2. During reactive power compensation. Next the new capacitors bank was connected to the same busbars and original old capacitor bank was turned off. The new capacitors bank was connected to the circuit which was included into measurement. Therefore the measurements, which are compared in following document, were executed in two different weeks. From this point of view the results might be underestimated. On the other hand, based on the weekly cycle of factory operation that is regularly repeated variation of the load (Fig. 4), the results of two different weeks could be compared with each other.

3. RESULTS

3.1. Normal operating conditions

The measurement results are gathered in the form of tables and charts, which included average values of 10 minutes periods of given physical quantities. The software, which is delivered with PQR, serves for communication with this data recorder as well as analyses and presents data. Data can be exported to format file of popular spreadsheet.

Results of measurements of the most important parameters are graphically presented in following charts in Fig. 4, Fig. 5, Fig. 6.

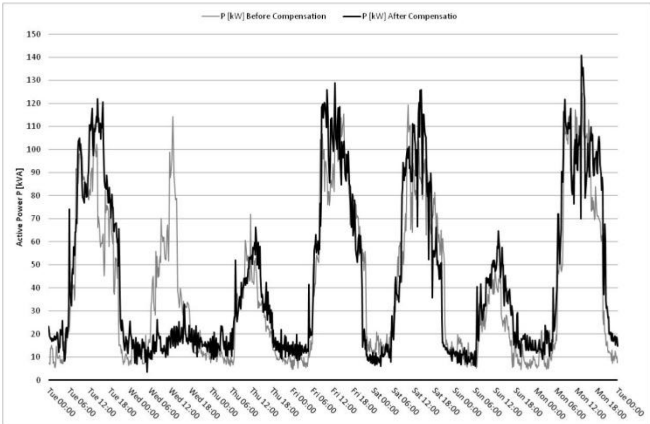

Fig. 4. Output Active power P [kW] measured on the main busbars of switchgear before and after compensation

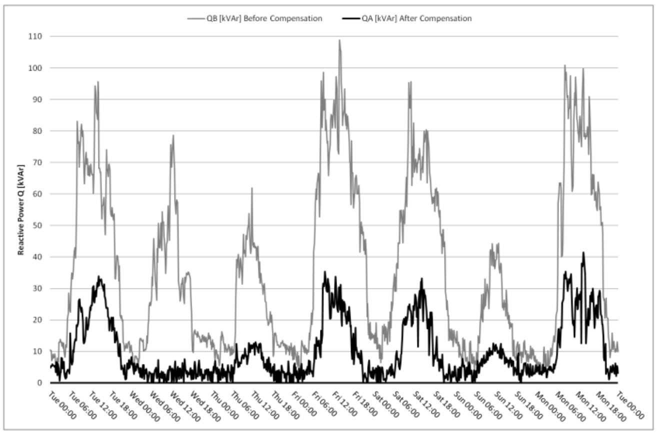

Fig. 5. Output reactive power Q [kVAr] measured on the main busbars of switchgear before and after compensation

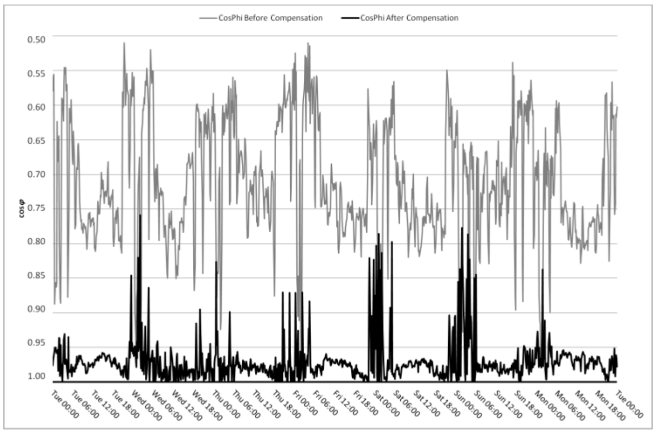

Fig. 6. Cosφ measured on the main busbars of switchgear before and after reactive power compensation

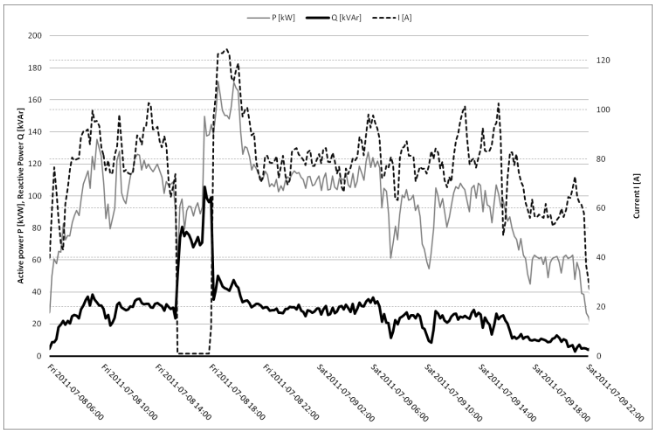

Fig. 7. Changes in demand for active and reactive power by dairy factory when PFC is switched off

From the charts on the figures it can be seen that despite of demand of active power on the same level (the same receivers were operating), the consumption of reactive power was reduced significantly. This was done through compensation of reactive power, which was incorporated in the measurement during the second week.

The new capacitor bank controller calculated the value of PF. If the measured PF is below 0.93 ms the microcontroller turns-on one more capacitor step. If the measured PF exceeds 0.99 the microcontroller turns-off one more capacitor step. The switching actions are taken every 5 seconds which was match up with system of capacitors discharging time.

The average cosφ before reactive power compensation amounts 0.713(ind.). The average cosφ after reactive power compensation amounts 0.935(ind.).

The energy losses only in windings of one supplying distribution transformer 400kVA are estimated on the basis of duration time of maximum losses τ and amounts about 317kWh in case of no reactive power compensation. For the stage 2 the energy losses are estimated on the level of 185kWh.

Therefore the energy losses related with the load losses in the transformer windings were reduced about 42%. It is the effectiveness of active power losses reduction by compensation of reactive power.

3.2. Capacitor banks shuted down

Next time the experiment was performed during which the device for reactive power compensation was turned off for a few hours. The experimental results are presented in graphs Fig. 7 and Fig. 8. At these figures it can be seen during the period when the PFC was turned off (PFC Current amounts 0), the demand for reactive power increased significant and it was taken from the supply network. Expression of the worsening conditions of supply and quality of electricity is also the low value of cosφ (Fig. 8)

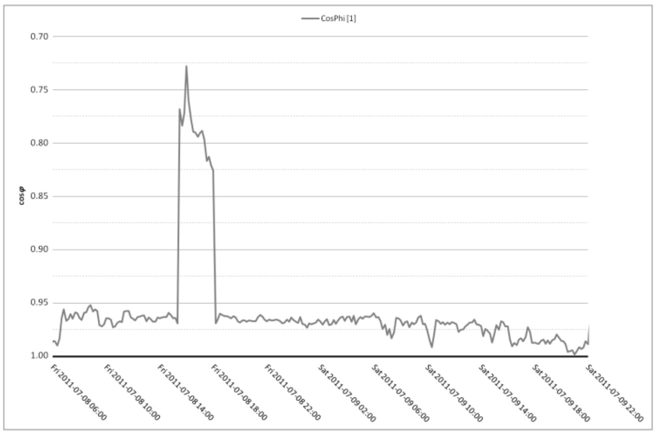

Fig. 8. Changes in cosφ of load in tested factory when the new capacitor bank was switched off

4. SUMMARY

Reactive power is necessary for the proper operation of alternating current devices and network, but its transmission is adversely affecting network performance. Therefore production of reactive power should be as close as possible of its consumption.

The simplest solution and well known is compensation of reactive power. Changing the parameters of the network by installing the appropriate equipment for power factor correction provides a number of benefits, from improving the technical conditions for power flow and work equipment after reduction of energy loss and lower energy bills.

In particular, such benefits as following can be distinguished:

- Losses reduction in power system via dynamic reactive power compensation
- Increase the transformer lifetime due to average temperature reduction
- Correction of power factor PF (cosφ),
- Improvements of voltage conditions in network,
- Reduction in the cross-section of the power cables or more transmission of active power

5. REFERENCES

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ANALIZA WYDAJNOŚCI PRZESYŁU MOCY W STACJI ZASILAJĄCEJ ZAKŁAD PRZEMYSŁOWY NA PODSTAWIE KOMPENSACJI MOCY BIERNEJ

Słowa kluczowe: kompensacja mocy biernej, pomiary, analiza przypadku

Dokument traktuje o wynikach pomiarów parametrów jakości energii elektrycznej ze szczególnym uwzględnieniem przepływu mocy biernej w określonym czasie w wybranym zakładzie przemysłowym. Pomiary zostały wykonane w rzeczywistej sieci rozdzielczej 230/400kV w celu dopasowania nowej baterii kondensatorów do warunków działania stacji zasilania. W artykule przedstawiona jest analiza jakości energii elektrycznej podczas długotrwałych pomiarów w normalnych warunkach eksploatacyjnych, a także ocena ilościowych korzyści płynących z kompensacji mocy biernej.