Study of Power Quality Indexes and Consumption Regimes in Electrical Distribution System of "Albena" Resort

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Abstract – **In this paper are shown methods and technical solutions for determining of power quality indexes and consumption regimes in electrical distribution system of Albena Resort. The research proposes technical solutions for improving energy efficiency of electrical distribution system. Study gives assessment of effectiveness by application and installation of reactive power compensation systems in electrical distribution system of Albena Resort.**

Keywords – **Energy Efficiency, Power Quality, Electrical Distribution Systems.**

I. Introduction

To achieve the task of research, studying of electrical quantitative and quality indexes is made. Measurement system is used, based on network analyzers, which identify the values, ranges and deviation of different electrical parameters. On their base are evaluated some technical-economic indicators, such as relative increasing of active power loss caused by reactive, unbalance power and harmonic power. Based on the results some technical decisions are obtained for application of reactive power compensating systems. The research shows particular example, but the approach is applicable for similar objects and distribution systems.

II. Object Description

Last years, due to tourism sectors growth, in Republic of Bulgaria many new and reconstructed existing hotel resorts were built. They are very specific object as regards to electrical consumption, because they are directly related to annual loading and they use specific electrical equipment. The installed load of the largest, like Albena Resort is about 20÷50 MVA, which makes researches for improving power quality and energy efficiency reasonable. In the large hotel complexes, electrical equipment, determining the consumption regimes, can be divided into the following main groups, each of which has its specific characteristics:

- Main electrical installations – interior lighting and household equipment;
- Ventilation and Air Conditioning Systems (HVAC) in hotel rooms and public premises (restaurants, bars, fitness and spa centers, etc.);
- Technological equipment – hot and cold cooking, heaters, ovens, cold-storage rooms;
- Water supply and sewerage equipment - pumps, pressure boosting equipment, etc.;
- Exterior lighting – facade, street, park and security lighting, etc.
- Transport equipment – escalators, elevators, etc.

For each group, electrical equipment determines the performance of electric consumption and quantitative and quality indexes of power quality. Characteristics can be classified in the most general form as:

- Low power factor - a big part of interior lighting is made up of gas discharge lamps without compensation. The majority of HVAC facilities and water supply equipment using asynchronous motors without local compensation;
- Asymmetry of electrical power - caused by the random nature of the switching of single phase loads and single phase installations to three-phase network;
- Presence of harmonic currents - main source is HVAC systems, high power frequency inverters, lighting equipment, household appliances and motor drive equipment.

This shows the necessity of performing a research aimed defining of conventional power loss and reducing power loss in condition of non-linear and non-symmetrical regimes in resorts electrical distribution systems.

III. Practical Research

For 3 months, during the summer period (touristic season) in 2010, 22 electric power substations in the Albena Resort electrical distribution system registered various regimes of electrical consumptions and power quality.

Albena Resort Electrical Distribution System Topology

Electrical distribution system has triple "closed-loop" scheme on medium voltage 20 kV including 22 power transformer substations. The "closed-loop" scheme (three medium voltage feeders 'A", "B" and "C") are shown in Fig. 1, Fig.2 and Fig.3

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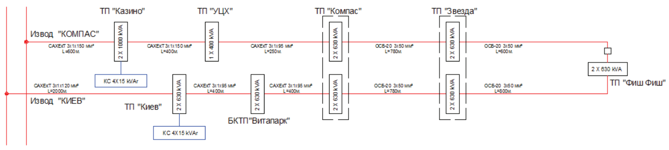

Fig. 1. Albena Resort Feeder "A" 20 kV

Fig. 2. Albena Resort Feeder "B" 20 kV

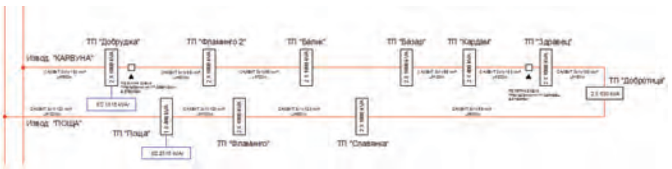

Fig. 3. Albena Resort Feeder "C" 20 kV

In order to achieve the task of studying is used specialized power meter production of ABB USA composed of the following components:

- ABB Power Plus type A1RL+ with accuracy class 0.2 with additional secured current and voltage circuits;
- IRDA to RS232 converter;
- portable PC;
- Power Plus Diagnostic Software (PPDS) v.1.08 developed by ABB Power T&D;

For the study purposes a specialized algorithm in MathCAD is used. System allows collaboration between other digital power meters after consultation of the source data format with the developed algorithm in MathCAD. In the case the starting file is DAT format with certain size. The whole file, containing the measured value is assigned as a matrix named "data" and after that values for analysis are derived from it. Therefore, only by a change in the matrix name, MathCAD automatically makes the analysis of a new study object. Defining variable *points* that show the *number* of measurement points for each file: *points = rows (data)*, but also counters j and v : *j=0…points-1 v=2.5 points-1*. Counter i is set from the second row of the matrix (the first is text showing the measured value) till the last one *(points -)* in tree values because the phase values for each measurement alternate by rows. Matrix contains values for the first harmonics of currents and voltages (Ia, Ib, Ic ; Va, Vb, Vc) and values to the fifteenth harmonic in percents of the first one. Moreover, the matrix contains the phasing angles PhAngB and PhAngC of the voltages Ub and Uc refer to Ua, phasing angles of the currents to appropriate voltages PFA, PFB and PFC reported from the first harmonic.

Calculating of the active power (P), non-symmetry power (mod N) and harmonic power (D) is possible by using of the primary indexes. Total power can be defined by Eq. 1 [1]:

$$S_j = \sqrt{(P_j)^2 + (Q_j)^2 + (N_j)^2 + (D_j)^2} \qquad (1)$$

Real power factor can be calculated by Eq. 2:

$$Km_j = \frac{P_j}{S_j} \qquad (2)$$

Then increase of partial power losses is given by Eq.2, Eq. 3 and Eq. 4 [1]

$$\Delta Pq_j = \frac{Q^2{}_j}{P^2{}_j} \cdot 100,\% \quad (3) \qquad \Delta Pn_j = \frac{\mathrm{mod}\, N^2{}_j}{P^2{}_j} \cdot 100,\% \quad (4)$$

$$\Delta Pd_j = \frac{D^2{}_j}{P^2{}_j} \cdot 100,\% \qquad (5)$$

$$Sum\Delta P_j = \Delta Pq_j + \Delta Pn_j + \Delta Pd_j \qquad (6)$$

$$DP_j = \left(\left(\frac{S_j}{\mathrm{mod}\, Sa_j} \right)^2 - 1 \right) \cdot 100 \qquad (7)$$

The index DP shows increasing of active power loss in conditions of non-symmetry and harmonics, compared to power loss in ideal regime.

Examples for these indexes and characteristics for a

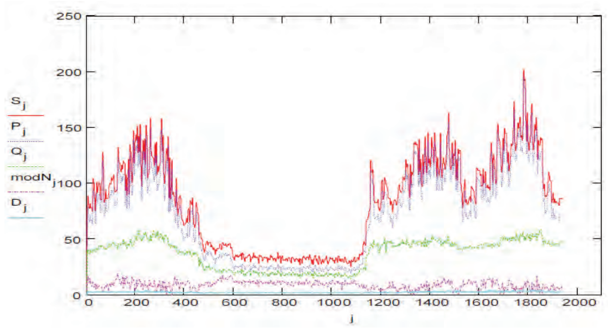

Fig. 4. LV/MV Substation – P, Q, modN, D and S for one day

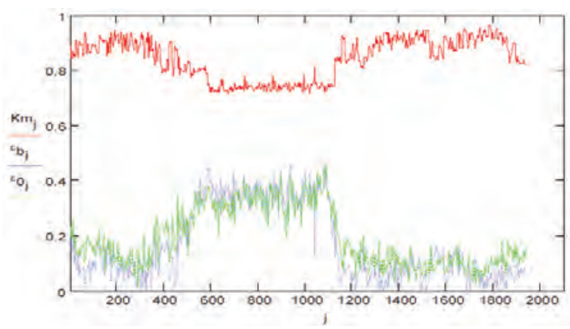

Fig. 5. LV/MV Substation – Km, εb and ε for one day

substation 1000 kVA are shown in Fig. 4, Fig. 5 and Fig 6.

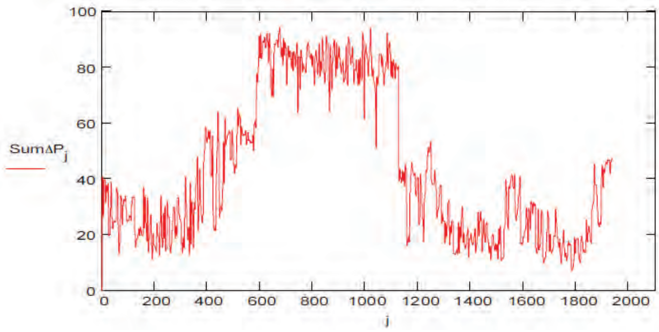

Fig. 6. LV/MV Substation SumΔP

Use of cosφ-P plan

The cosφ-P plan [2] is applicable for defining power loss in substation transformers in conditions of non-liner load and non-symmetry. Basic cosφ-P plan is given by Eq. 8

$$\delta(P,\cos\varphi)=\left[\frac{Po+\left(\frac{Pk}{S_H^2}\right)\cdot\left(\frac{P^2}{\cos\varphi^2}\right)}{P+Po+\left(\frac{Pk}{S_H^2}\right)\left(\frac{P^2}{\cos\varphi^2}\right)}\right]\cdot 100,\% \qquad (8)$$

In conditions of non-symmetry and harmonics, cosφ-P plan changes to Eq.9 [3]

$$\cos\phi_{ND}(P,\delta_{ND})=\sqrt{\frac{P^2\cdot k\cdot\left(1-\frac{\delta_{ND}}{100}\right)}{\frac{\delta_{ND}}{100}\cdot P+\left(\frac{\delta_{ND}}{100}-1\right)\cdot(Po+k\cdot N^2+kD^2)}} \qquad (9)$$

Where k is: $k=\frac{Pk}{S_H^2}=const$

Thus, in presence of D and N power, function will be a surface family with two variables (P,δ_{ND}) and two parameters (N, D). The horizontal section of surface family is curves family (Fig. 7).

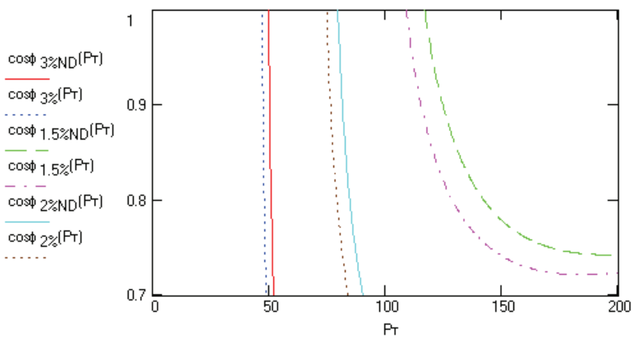

Fig. 7. Zones of δ for 1000 kVA transformer

The regime will be as more effective as the operation point is closer to the right top edge of diagram.

IV. Results

For the following research, an example for power ratio of a substation transformer is given in Fig 8.

Active power loss increase from low quality has three components ΔPq, ΔPn and Δ Pd respectively provoked by reactive power, non-symmetry and current and voltage harmonics in electrical grids. Total increase of conventional power loss SumΔP in Albena Resort electrical distribution system is about 21%. Fig. 9 shows that the major effect has ΔPq = 18,2% and the lowest one ΔPd = 0.9%

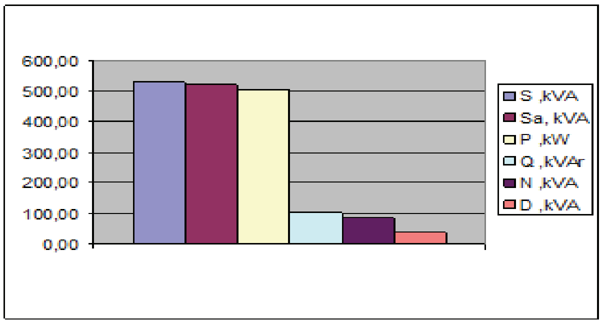

Fig. 8. Power ratio of one transformer in Albena Resort

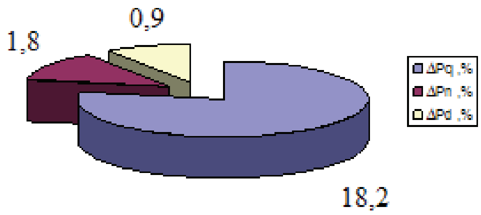

Fig. 9. Ratio of active power loss increasing in condition of non-symmetry and non-linear load

Conventional Δ P% losses represent active power losses in all units and elements associated with the transmission of electricity from power substation to consumer. They can be defined by deterministic methods and the average value is within ΔP% = (6.56÷10.31) % from total active power consumption.

V. Conclusion

Conventional losses depend on electrical distribution systems characteristics and reductions, are associated with changes in these features or system upgrades as a whole. This process is associated with serious capital investment, which recently made a very good efficiency in the Albena Resort.

As mentioned, the purpose of this study is to demonstrate the ability to achieve energy efficiency through influence on the regime parameters of the system.

Maximum economic effect can be achieved by minimizing the ΔSumP. The resultant reduction of active power losses is determined by the expression:

$$\Delta P_{TOTAL} = \Delta P \cdot \left(1 - \frac{Sum\Delta P_{AVERAGE}}{100}\right), \% \qquad (10)$$

The average economic effect of minimizing the negative components Q, N, D and reducing ΔPn, ΔPq, and ΔPd to achieve is saving of active power in the range of (1.32÷1.6)%.

Technical solution for minimizing the losses can be achieved through the implementation of universal compensators. In this case, due to the limited availability of harmonic power and ΔPd, compensation system in scheme “Soldatkina” can be used.

Total investment for application of compensation systems Soldatkina in 22 transformer substations in Albena Resort, low voltage distribution system, is about 150 000 euro. Nominal lifetime of these facilities is about 15 years. The return period for this type technical solution is about 5 years.

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