OPTIMIZATION OF REACTIVE POWER COMPENSATION, SOLUTION FOR INCREASING POWER DELIVERY EFFICIENCY

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1. INTRODUCTION

According with PE 120/94, valuable for electrical networks from Romania, the reactive power compensation is made using the technical-economic optimizations investments for Electric Power National System (ENS). From economically, point of view reactive power sources are installed if there are justified, meaning the decreasing of the active power losses in the network [1,2].

Technically we verify if, on ENS dimension criteria [3], resulted reactive power compensation systems on economically criteria, respect the voltage limits of normal conditions.

The specialized reactive power sources used in SEN are:

- capacitors banks installed in MV (Medium Voltage) network and LV (Low Voltage);
- synchronous compensator installed in provider's networks for reactive power compensation and voltage regulation in transport electrical network 220/400kV;
- static compensators which substitute synchronous compensator installed in the nods of the network which need automated reactive power compensation.

2. REACTIVE POWER COMPENSATION IN MV AND LV POWER DELIVERY NETWORKS

The capacitors banks can be installed in MV or LV networks and are fixed and variable. The variable one can be manual or automated for steps connection. The choosing of the type capacitor banks is made using the load curve, in the installing point of the capacitor banks and using the results of economical calculus.

The increasing of power factor in provider's electrical networks can be made naturally. This is recommended with priority (power transformers interchanging, the reconfiguration of networks).

After we finish all the natural possibilities for increasing the power factor, it can be considered to install specialized sources of reactive power (capacitors banks, harmonics filters).

The reactive power which must be compensated by specialized sources is also determinate (considering the regulations) to assure the neutral value of power factor to the maximum point of load curve and the minimum point of load curve too [4,5,6].

Capacitor banks will be utilized like a specialized way to compensate the reactive power. They are more economically than synchronous compensators and static compensators and they have simply conditions of use.

The capacitor banks with more steps are used in the situations where the variations of reactive load imposes an adaptation following the load curve, so for low loads states the consumer do not have to delivery reactive power back in the system.

The different capacitor banks fractions are conditioned by the circuit-breaker possibilities to cut the reactive current. Usually, LV capacitor banks under 250kvar and MV (with power under 1000kvar) must have manually possibility to interrupt, using a circuit-breaker and had to be protected for short-circuit.

If the capacitor banks are installed in the networks where the variations of reactive load are important and in the cases where the MV power capacitor banks is greater than 1000kvar, usually, automated capacitors banks will be chosen, correlated with the reactive power.

The LV capacitors banks with power under 100kvar can be connected directly to the consumer, like a fixed capacitor bank, without a special connection system; this type of capacitor banks can be used for load compensation reactive power in case of power transformers, in the follow conditions:

- the power of capacitor bank will not be greater than 20% of power transformer;
- the transformer will have circuit-breaker on the MV side.

The location of capacitors banks is calculated using technical-economical criteria, with the follow considerations:

- the capacitors banks are first installed on buses which are supplied by circuits with great load, so the results of compensation is first of all the increasing of active power flow and second important decreasing of losses;
- for having important decreasing of losses, the capacitor banks are installed as possible as close to the consumption;

- the automated capacitor banks are installed in the buses with an important consumption; the step power will be maximum 250kvar on LV and between 1000kvar – 4800kvar on MV;

- the LV capacitors banks are usually installed inside; the MV capacitor banks is recommended to be installed outside.

3. STEPPING THE CAPACITOR BANKS

In stepping capacitor banks is necessary to take in consideration that the consumer must not sent back reactive power in electrical system. If the load curve has important variations, we must choose more steps.

Tacking in consideration that the power of capacitor bank is chosen to obtain for a period of time (month, trimester, year) a medium value for power factor close to neutral value, it is necessary that the periods of over-compensation and under-compensation to be eliminated. For this goal, the capacitor banks must to have a step number, each step having equipment to connect and brake which can be controlled manual and automated using some criteria.

To make possible this control it has:

a) the capacitor bank must to have more steps following the load curve;

b) to connect and to brake a step automated.

In the case that the capacitor banks are automated, we can admit some criteria of steps selection: variation of voltage domain, load current, change of reactive power with the system, operating time.

In supply stations where the load have an important variation during the day, like we observed in the analyzed region, the load variation is accompanied by the reactive power variation, the power capacitor bank control is made using the network current. To follow closely the load curve, is necessary that the capacitor banks, in the maximum area, to have a big number of steps of low power.

The control of capacitor banks using the direction of reactive power to or from the reactive supply is not very used. The control of capacitor banks using the operated time is mostly used because the daily load curve have important variations which permit to establish the exact time of operation [4].

The advantages which results using the control of capacitor banks give the necessity that the capacitor banks to operate with independent steps. Generally, to choose the number and the power of steps must permit the reactive power flow in the system to follow the reactive power load curve. The control efficiency is increasing with the number of steps, the power factor is better, but the fractionation from a number of steps forward is not economically, because complex equipment for steps connections had to be used.

Usually, the capacitor banks to 1000V have 4-5 steps, and from 1000V forward the capacitor banks have 3 steps, rarely 4 steps [4, 5, 6].

4. LOAD CURVES FOR TRANSFORMER STATIONS

Daily active and reactive power load curves were made using a data base with summer 2004 measurements, in 6/0.4kV transformers's secundary from the nominated transformer stations proposed for compensation.

Measurements were made in seven consecutive days and were considered the average values on temporal landing corresponding to five working days and two days of weekend, as it is recommended in special literature [2, 3, 4]. We concluded that important for the active and reactive power flow is the load curve for one working day. In weekend, power flow is lower than in working days.

Measurements were made at 1 minute or 15 minutes period and resulted 96, respectively 1440 daily measurements. One minute period measurements were made for transformer stations with an important armonic regime, for determining the parameters of this regime, but this is a problem who will be the subject for another paper. For that it was utilised the QUALISTAR electrical power analyzer.

In Figures 1 and 2 are presented the daily curves of active and reactive power on two transformer stations proposed for compensation, using the realised measurements data base.

Results concerning optimal solution of compensation systems for the analyzed region are presented in the final table 1.

5. CONCLUSION

Considering the optimal compensation solution we can obtain the greatest economic benefits for a ten observation time. This result is explained because energy loss reduction is bigger in this case considering all the transformer posts from the analyzed feeders PA 12, PA 3, PA 14. Another explanation is the following: the compensation system is bigger, because all the transformer posts are compensated and also reactive power losses from the transformers are included in the compensation system.

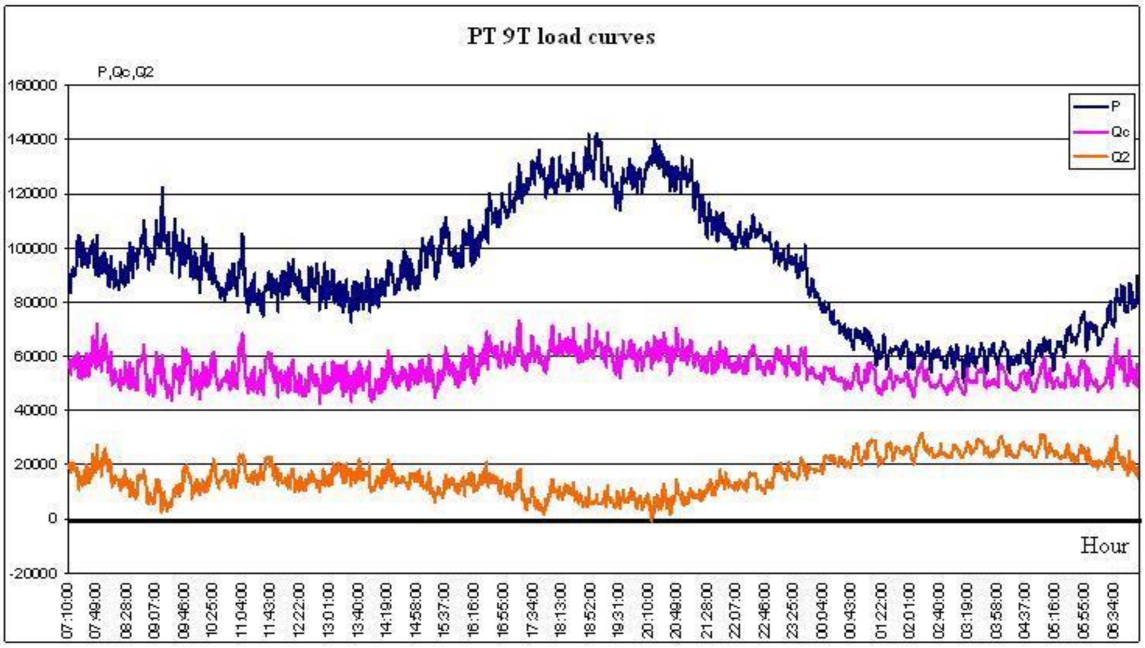

Figure 1. PT9 one working day load curve (T 9) – Feeder 3 – Station10 – 6/0.4kV.

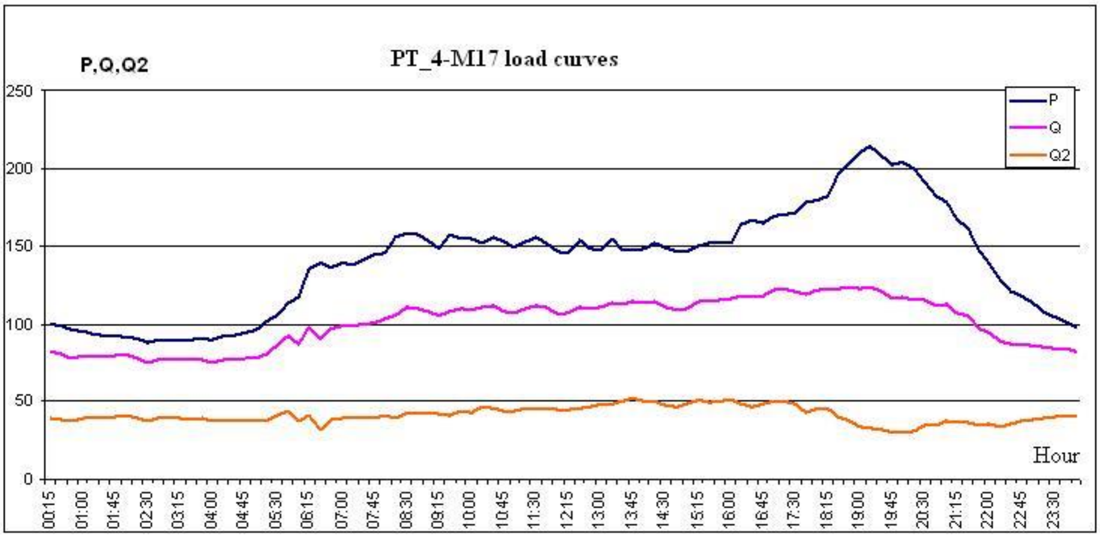

Figure 2. PT76 T4 M17 one working day load curve - Feeder 14 - Statios 10 - 6/0.4kV.

Table 1. Optimal solution of the compensation systems.

No.	TR. Stations for compensation	Reactive power Q for compensation [KVAR]	Reactive power steps according to PE 104 KVAR]	THD [%] PE 143 Uthd Athd	Observations
1.	PT11 T11	20,83…22,79	20,83 21,75	1.6…4.4 4.5…84.2	Supplied from Station 10, PA 12
2.	PT18 B4	11,2…16,24	11,2 13,32 15,33	2.1…4.4 7.3…24.5	Supplied from Station 10, PA 12
3.	PT29 E5	25,2…57,51	25,2 31,75 43,02	1.8…5.5 5.8…33.9	Supplied from Station 10, PA 12
4.	PT163	9,7…16,58	9,7 12,58 15,09	1.9…4.6 7.8…33.4	Supplied from Station 10, PA 12

5.	PT4 T4	7,89…20,19	7,89 10,9 14 17,7	1,5…4,4 3,9…22,3	Supplied from Station 10, PA 3
6.	PT5 T5	7,46…25,41	7,46 12,8 16,4 20,5	2,7…3,7 5,9…13,2	Supplied from Station 10, PA 3
7	PT9 T9	9,36…22,71	9,36 12,56 14,9 18,44	1,5…3,8 3,8…23,3	Supplied from Station 10, PA 3
7.	PT15 T15	30,2…36,94	30,2 33,1	2,7…4,4 7,3…14,8	Supplied from Station 10, PA 3
8.	PT56 T1 M16	9,06…23,62	9,06 15,75 18,97 20,71	1.9…4.9 5,9…14,2	Supplied from Station 10, PA14
9.	PT61 T3 M16	5,6…20,95	5,6 13,07 17,8	2,5…4,4 3,9…20,3	Supplied from Station 10, PA 14
10.	PT74 T2 M17	13,86…25,07	13,86 16,21 19,46 21,6	1,3…5,4 5,9…18,3	Supplied from Station 10, PA 14
11.	PT75 T3 M17	8,46…28,71	8,46 16,96 20,61 24,66	1,7…4,8 5,9…25,3	Supplied from Station 10, PA 14
12.	PT76 T4 M17	30,22…52,27	30,22 38,15 40,8 46,09	2,5…5,4 2,9…21,3	Supplied from Station 10, PA 14
13.	PT141	0,37…16,02	5,06 8,9 11,8	2,9…4,8 6,3…14,6	Supplied from Station 5, PA 14

Simulation of shunt capacitors application to the primary distribution feeder is an economically beneficial measure to utilities. The advantages include:

1. releasing a certain KVA at the substation used to feed additional loads along other feeders;
2. electricity suppliers charge their customers in terms of both KWh (energy consumptions) and KVA (power demand);
3. decreasing of KVA at the substation leads to cost saving;
4. improving power factor at the substation;
5. boosting the load level of the feeder, so that additional loads can be carried by the feeder for the game of maximum voltage drop.

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