IMPACTS OF SINGLE PHASE CAPACITOR INSTALLATION ON REDUCING ENERGY LOSS

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ABSTRACT

In this paper, a method for reducing electric energy loss is introduced. For this purpose, we study the impacts of single phase capacitor installation on reducing energy loss. This study was done in two 13 days periods, before and after capacitor installation. Our test site was a 7300 square meters area with 431 residential consumers, 8 business junctions and 4 public junctions with a 800KV/A land transformer. We set the power factor to 0.97. With regard to this assumption; we endeavoured to calculate the capacity of the capacitors.
In our study at the end of the first period, the capacitor was estimated to 12µF. After capacitor installation, the power coefficient increased from 0.83 to 0.92. Furthermore, the voltage level improved from 205 to 228 volts. When the power factor improved, the expenditures decreased about 331US$ in 13 days after the capacitor installation. The results of our study suggest that capacitor installation is good technique for finance savings and reducing energy loss.

INTRODUCTION

In recent years, energy management consideration has been increased significantly. The most basic program in the electricity distribution industry is reducing conduction losses from power plant to consumers.
One reason for increasing energy loss is the existence of inductive loads on the electricity network. The existence of these inductive loads in the power plant has the following effects: 1) occupying transmission networks, 2) increasing the capacity of high voltage posts and distribution lines 3) increasing reactive flow 4) reducing voltage in consumer sites 5) decreasing power factor and finally 6) producing reactive power in power plants[5].
So reducing these reactive power loads is too important. It is widely accepted that capacitor installation is the best technique to compensate the reactive power and improve power factor. The aim of this study is determining the effects of single phase capacitor on reducing energy loss and it's financial saving.
Using capacitor installation, depending on amount of system power factor adjustability, we can improve the ability of Generators and Posts for extra loads, at least 30% and the voltage drop improved, almost 30% to 100%.
It is clear that installing a parallel capacitor at the consumer place, can improve reactive power. By means of capacitors, the load current is reduced. Furthermore, the power factor is improved which causes the reduction in the voltage drop.

DESCRIPTION

To implement the project, Hasht_Abad post region of Mashhad city was selected with the following features:

1. The area is approximately 73,000 square meters.
2. 431 domestic junctions, 8 business junctions and 4 public junctions.
3. Type of post: The type of land with 800 KV/A transformers.
4. Distribution panel with 1600A automated key that has 8 output low voltage feeder.

Figure 1 shows a view of the location test.

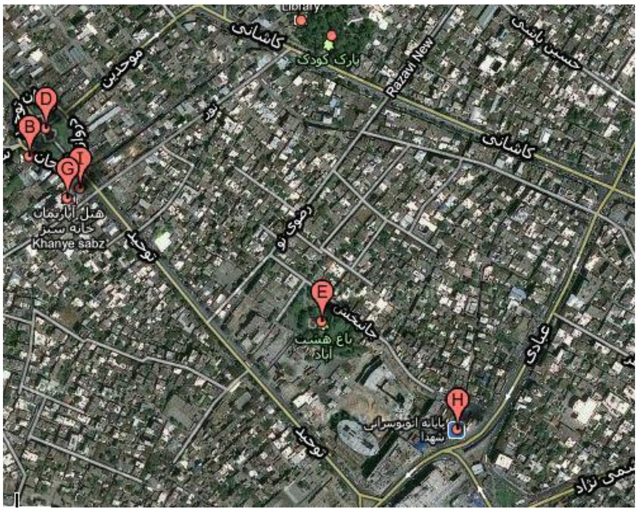

Figure 1) Hasht-Abad region post of Mashhad city

We evaluate the network in two parts, transformers and low voltage network [2]. For this purpose we use two DATA LOGGERs, a DATA LOGGER in the transformer's input and the other at the output of transformer.
To measure the voltage and the current of 20 KV networks, as the DATA LOGGER can't be connected directly to the 20 KV networks, we used CT & PT. So,

the output of CT & PT is connected to the DATA LOGGER.
Since this test procedure is time consuming and in the case of error, test repetition is very difficult, thus to enhance reliability, we place a Digital Meter in the path, series with TDL 101(DATA LOGGER).
We used ABB and ACTARIS digital meters at 20 KV network and low voltage side, respectively.

METHOD

Before doing experiment, all electric meters in the region were read and the DATA LOGGERs were started simultaneously to record the electrical parameters.
After 13 days, we re-read electric meters. Then we installed the capacitors on the meter during next 6 days. Before installation, we have to calculate the capacity of capacitor.
The gathered information from the both DATA LOGGERs is shown in table 1.

Table 1) Gathered information from DATA LOGGERs

Parameter	Value
Minimum reactive power	80Kvar
Maximum reactive power	188Kvar
Minimum active power	120KW
Maximum active power	320KW
Minimum power factor	0.75
Maximum power factor	0.9

To calculate the value of capacitors, we use the following variables [3]:

$Q_{3\varphi\min}$: Minimum reactive power (Kvar)

$P_{3\varphi\min}$: Estimated active power

PF_1 : Estimated power factor (Three-phases average)

PF_2 : Optimal power factor

Q_{cTotal} : Total capacity of capacitors (Kvar)

Using the gathered information from DATA LOGGERs shown in table1, the following results are obtained:

$Q_{3\varphi_{\min}} = 80K\text{ var}$

$P_{3\varphi_{\min}} = 120KW$

$PF_1 = 0.83$

$Q_{C_{Total}}$ is calculated using the following equation:

$$Q_{C_{Total}} = P_{3\varphi_{\min}} * (\tan\varphi_1 - \tan\varphi_2) \quad (1)$$

$\varphi_1 = \cos^{-1} PF_1$

$\varphi_2 = \cos^{-1} PF_2$

$Q_{C_{Total}} = P_{3\varphi_{\min}} * (\tan\cos^{-1} PF_1 - \tan\cos^{-1} PF_2)$

$P_{3\varphi_{\min}} = 120KW$

$PF_1 = 0.83$

$PF_2 = 0.97$

$Q_{C_{Total}} = 120KW * (\tan\cos^{-1} 0.83 - \tan\cos^{-1} 0.97_2)$

$\Rightarrow Q_{C_{Total}} = 50.5K\text{ var}$

After the installation of single phase capacitor, since a 37 Kvar capacitor was already installed on the network, it is necessary to remove this capacitor. Therefore the total capacity of capacitors is equal to:

$Q_{C_{Total}} = 50.5K\text{ var} + 37.5K\text{ var}$

$\Rightarrow Q_{C_{Total}} = 88K\text{ var}$

Considering the number of subscribers on the region (430 subscribers), the dedicated capacitor for each subscriber is equal to:

$$Q_C = \frac{Q_{C_{Total}}}{n} = \frac{88K\text{ var}}{430} = \frac{88000\text{var}}{430} = 204.65\text{var}$$

n : The number of subscribers on the region

Q_C : Required capacitor for each subscriber

The capacity of each capacitor is equal to[3]:

$$Q_C = \frac{U^2}{Z_C} = \frac{U^2}{X_C} \ \mu\text{F} \quad (2)$$

$X_C = \frac{1}{C.\omega}$

$Q_C = U^2 * C * \omega \ \mu\text{F}$

$Q_C = U^2 * C * 2\pi f \ \mu\text{F}$

$f = 50Hz$

$Q_C = U^2 * C * 100\pi \ \mu\text{F}$

$U = 230v$

$Q_C = (230)^2 * C * 100\pi \ \mu\text{F}$

$C = \frac{Q_C}{230^2 * 100\pi} \ \mu\text{F}$

$C = \frac{204.65}{230^2 * 100\pi} = 1.231 * 10^{-5} F$

$C = 12.31\mu F$

Q_C : Required capacitor for each subscriber

U : Voltage at the place of capacitor installation (Volt)

Z_C : Capacitor impedance

X_C : Reactance capacitor

C : Capacitance value (Farad)

f : Network frequency

Considering the type of capacitors available in the market and the possibility of reducing the network load in the winter and increasing the possibility of creation of Ferranti Effect in the network, we selected a 12 µF capacitor for each consumer.
Then, we installed 430 single phase capacitors at the consumer place. After 13 days, we measured energy

consumption and input energy to the transformer at the low voltage network.

After the installation of capacitor it has been seen that power factor reached to 1 while before installation it was 0.9.

Results shown in figure 2 confirm that capacitor installation has a positive effect on the power factor. Furthermore, similar improvement was visible in the low and high voltage network.

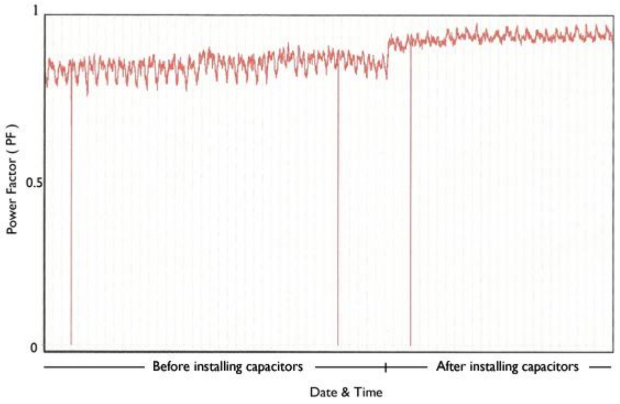

Figure 2)The value of Power Factor (PF) before & after capacitors installation

In figure 3, the total reactive power in the network is plotted versus date and time. Results confirm that installing capacitor has positive effect on the network.

It can be observed that the changes in reactive power before installing capacitors are between 100 VAR and 200 VAR. But after capacitor installation, there is a considerable reduction on reactive power. In this case the reactive power is varied between 50 VAR and 150 VAR.

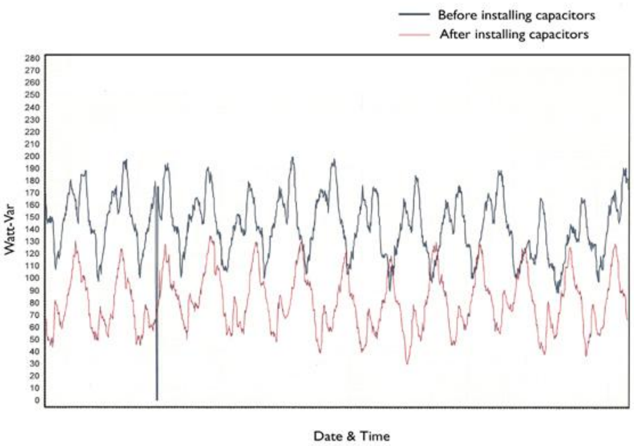

Figure 3)The changes of reactive power before and after installing capacitors

In figure 4, for both transformers and distribution network, the percentage of total system loss before and after capacitor installation is given. It can be seen that by installing capacitor the 6.84% reduction on the total system loss is achieved.

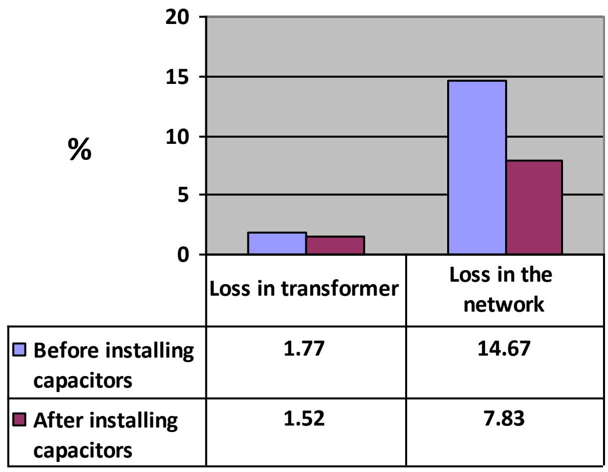

Figure 4) Percentage of total system loss

The results shown in figure 4, are obtained using the following calculation:

Calculation of the internal loss in the transformers before capacitor installation (in a 13 days period):

Input energy into the transformer in this interval: $W_{in} = 65678 KWh$

Output energy from the transformer in this interval: $W_{out} = 64515 KWh$

Therefore, energy loss in the transformer is equal to: $W_{Los} = W_{in} - W_{out} = 65678 - 64515 = 1163 KWh$

And percent loss is computed as follows:

$$\frac{W_{Los}}{W_{in}} * 100 = \frac{1163}{65678} * 100 = 1.77\%$$

Calculation of the loss in the network before capacitor installation (in a 13 days period):

Input energy into the low voltage network in this interval:

$W_{in} = 64515 KWh$

Energy consumption of the customers:

$W_{out} = 53690 KWh$

Energy used for lighting streets in 13 days:

$W_L = 1360 KWh$

Energy loss in the low voltage network is equal to:

$W_{Los} = W_{in} - (W_{out} + W_L) \Rightarrow$

$W_{Los} = 64515 - (53690 + 1360) = 9465 KWh$

The loss percentage is computed as follows:

$$\frac{W_{Los}}{W_{in}} * 100 = \frac{9465}{64515} * 100 = 14.67\%$$

Calculation of the internal loss in the transformers after capacitor installation (in a 13 days period):

Input energy into the transformer in this interval: $W_{in} = 68780 KWh$

Output energy from the transformer in this interval: $W_{out} = 67734 KWh$

Therefore, energy loss in the transformer is equal to: $W_{Los} = W_{in} - W_{out} = 68780 - 67734 = 1046 KWh$

The loss percentage is computed as follows:

$$\frac{W_{Los}}{W_{in}} * 100 = \frac{1046}{68780} * 100 = 1.52\%$$

Calculation of the loss in the network after capacitor installation (in a 13 days period):

Input energy into the low voltage network in this interval: $W_{in} = 67734 KWh$

Energy consumption of the customers:
$W_{out} = 61190 KWh$

Energy used for lighting streets in 13 days:
$W_L = 1237 KWh$

Energy loss in the low voltage network is equal to:

$$W_{Los} = W_{in} - (W_{out} + W_L) \Rightarrow$$

$$W_{Los} = 67734 - (61190 + 1237) = 5307 KWh$$

The loss percentage is computed as follows:

$$\frac{W_{Los}}{W_{in}} * 100 = \frac{5307}{67734} * 100 = 7.83\%$$

As mentioned earlier, by installing the capacitor we can reach to 6.84% reduction in total loss.

Cost saving:

After capacitor installation, we analyzed the cost saving due to reduction in energy loss in 13-days period. We considered 773 Iranian Rials per Kilowatt. The following results were obtained [1]:

1. Financial loss before installing capacitors: 8215444 Rials
2. Financial loss after installing capacitors: 4910869 Rials
3. Financial saving for 13 days: 3304575 Rials

If capacitors are installed for all subscribers (household, commercial and public) in the Mashhad city, the amount of financial saving would be as follows:

Electricity consumption in Mashhad city for one year: $2418926552 KWh = 2418926552 GWh$

Energy input into the network:

$$EnergyInput = EnergyOutput * (\frac{1}{1 - LossPercent}) =$$

$$2418926552 * (\frac{1}{1 - 0.1644}) = 2894 GWh$$

Energy saving = $2894 * (0.1644 - 0.935) = 205 GWh$

Financial saving = $205 GWh * 773 Riyals = 158$ Billion Riyals. In this case, with a little investment for each year, we can obtain over 200 megawatt hours of energy saving and 158 billion Rials financial saving in a year.

CONCLUSION

In this paper, we studied the impacts of single phase capacitor installation on reducing energy loss. Based on implementation results, we observed that, after installing capacitors the network power factor was in its minimum reactive power, about 0.83. Furthermore, cost analyzing confirm that if we install capacitor in all places in the Mashhad city, a huge money saving would be achieved.

The following benefits can be achieved after installing capacitor:

1. Power factor correction
2. Improvement in the voltage
3. Providing desired voltage for consumers
4. Loss reduction in the transformers
5. Loss reduction in the low voltage networks
6. Liberalization of network capacity and transformers (to delay investment to develop facilities)
7. Removal of establishments (for the purpose of reducing voltage drop)
8. Increase in energy sales due to improved voltage
9. Increase in lifetime customer equipment, due to the standard voltage
10. Increase in lifetime of network equipment and network facilities, due to load reduction on the network.
11. Reduction in the investment for power generation
12. Helping the environment (due to reduced losses and reduced heat generation and reduced fuel consumption in Power Plants)
13. Reduction in power outages in the network
14. Financial saving for electricity distribution companies

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