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Cost Savings for Nuclear Power Generating Stations Using the Power Factor Correction

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1. Introduction

Since separated from Korea Electricity Power Corporation on 2nd of April, 2001, the nuclear power company has been competitive with other power generating companies. In this situation, electrical power saving of domestic consumption is needed for the competitiveness of nuclear power plants.

Though the power factor correction is not new in the transmission and distribution systems, it is a useful method in the generation system for reduction of generating costs by decreasing the current. Comparison and cautions of the ways of the power factor correction are presented herein.

2. Methods and Results

The efficiency of electric equipment is related to the voltage, the current, and the power factor. The power factor of them is most useful because the rated voltage at the terminals of equipment is maintained. That is, the variation of the voltage at the terminals of equipment affects the performance and the operating life due to increasing current at undervoltage and increasing magnetizing current at overvoltage [1], [2].

The power factor of an alternating current electric power system is defined as the ratio of the real power to the apparent power. The power factor correction improving power factor (cosθ) to unity compensates for lagging reactive power by supplying leading reactive power.

Loads generally have lagging power factor. The term of 'Lagging' means that the current lags behind the voltage due to inductive reactance. Also, 'leading' means that the current leads the voltage due to capacitive reactance. Figure 1 illustrates phasor diagrams of leading and lagging currents. 90° lagging current flows through inductors such as transformers and motors, and 90° leading current flows through capacitors as shown in Figure 2.

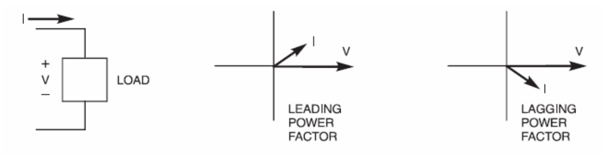

Figure 1. Phasor diagrams showing leading and lagging currents and power factors

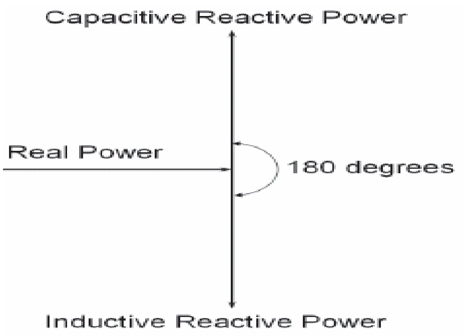

Figure 2. Capacitive and inductive reactance

Benefits of correcting power factor are reduction of electric utility billings, release of system capacity, voltage improvement, and reduced losses. Since the utilities surcharge for low power factor, improving power factor reduces billing charges. Also, total reduced current by supplying reactive power to loads closely results in decrease in conductor losses and voltage drops, and permits additional load to be served by the same system [3].

2.1 Power Factor Correction Options

There are several methods available for the power factor correction, including capacitors, static VAR compensators (SVC), and rotating synchronous condensers. Firstly, capacitors and synchronous condensers of them were considered because of costs of equipment. Then, after the characteristics of these facilities were compared, synchronous condensers were chosen. Although capacitors are cheapest, they have the properties of overvoltage and harmonic problems. Also, capacitors can not control fine adjustment because of controlling them by bank. Table 1 illustrates the comparisons of equipment [4].

Table 1 Comparison of power factor correction options

	Capacitors	Synchronous Condensers	SVC
Costs($/kVar)	08−10	30−35	45−50
operating Cost	Very low	High	Moderate
Harmonic Problems	Yes	No	Yes
Voltage Transients	Yes	No	Yes
Overload Capability	No	Yes	No
Maintenance	Easy	Easy	Complex
Speed of Response	Slow	Fast	Fast

2.2 Estimates of Power Factor Correction

In this paper, estimations for power factor correction were implemented by using the data of Wolsong nuclear power plants. 50% of the total domestic power normally received from grid through the station service transformer (SST) is 25 MW. The power factor of in-house loads is 80%, the % impedance of SST is 15.4% and its capacity is 79.2 MVA. Using these parameters, we got the values of Table 2 for improving the original power factor to required power factor.

Equations for obtaining the values in the Table 2 are as follows:

$$Q = p(\tan\theta_0 - \tan\theta_1) \quad (1)$$

$$\%\text{loss reduction} = 100[1 - (\frac{\cos\theta_0}{\cos\theta_1})^2] \quad (2)$$

$$\%\Delta V = \frac{Q \cdot \%Z_{tr}}{S} \quad (3)$$

$$\%\text{capacity} = 100[1 - \frac{\cos\theta_0}{\cos\theta_1}] \quad (4)$$

Q: Necessary leading reactive power for power factor correction
P: Active power
θ_0: Original phase difference between voltage and current
θ_1: Required phase difference between voltage and current
$\%Z_{tr}$: % impedance of transformer
S: The capacity of transformer

Table 2.Values of calculations based on the data of Wolsong Plants

pf Improvement	Amount(MVAR)	% loss reduction	% volt rise	capacity(%)
0.8	0.00	0.00	0.00	0.00
0.81	0.65	2.45	0.13	1.23
0.82	1.30	4.82	0.25	2.44
0.83	1.95	7.10	0.38	3.61
0.84	2.60	9.30	0.51	4.76
0.85	3.26	11.42	0.63	5.88
0.86	3.92	13.47	0.76	6.98
0.87	4.58	15.44	0.89	8.05
0.88	5.26	17.36	1.02	9.09
0.89	5.94	19.20	1.16	10.11
0.9	6.64	20.99	1.29	11.11
0.91	7.36	22.71	1.43	12.09
0.92	8.10	24.39	1.58	13.04
0.93	8.87	26.00	1.72	13.98
0.94	9.68	27.57	1.88	14.89
0.95	10.53	29.09	2.05	15.79
0.96	11.46	30.56	2.23	16.67
0.97	12.48	31.98	2.43	17.53
0.98	13.67	33.36	2.66	18.37
0.99	15.19	34.70	2.95	19.19
1	18.75	36.00	3.65	20.00

2.3 Estimates of cost savings after power factor correction

For improving the original power factor (80%) to the required power factor (95%), necessary reactive powers (Mvar) were 10.53 Mvar as shown in Table 2. Based on the quantity of reactive power, we can roughly calculate the costs of the synchronous condenser and saving money. Electric rates below 90% power factor apply surcharges per 1% and these over 90% power factor make a discount of per 1% up to 95%. The costs of a synchronous condenser include installing costs, and the future worth of these costs is not considered due to the short payback period. They are as follows:

- Synchronous condenser costs
  = 10530 kvar × 35 \$/kvar × 1026 ₩/\$
  = 378,132,300 ₩
- Saving after power factor correction (year)
  = 4500 ₩/kW × 43000 kW × 0.15 × 12
  = 348,300,000 ₩/year
- Payback periods applied to future worth factor
  = 378,132,300 ÷ 348,300,000
  = 1.085 year

3. Conclusion

The power factor correction is a useful method of energy saving. Especially, connecting capacitors or synchronous condensers close to loads is considered, and synchronous condensers for power factor correction are better than capacitors because of harmonic problems and switching transients.

The costs of a synchronous condenser can pay back within 1.1 year.

REFERENCES

[1] IEEE Std 241-1990, IEEE Recommended Practice for Power Systems in Commercial Buildings (IEEE Gray Book).
[2] IEEE Std 666-1991, IEEE Design Guide for Electric Power Service for Generating Stations.
[3] IEEE Std 141-1993, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (IEEE Red book).
[4] B. Kirby and E. Hirst, "Ancillary-Service Details: Voltage Control ORNL/CON-453" Oak Ridge National Laboratory, Oak Ridge, Tennessee, December 1997.