Simulation evaluation of capacitor bank impact on increasing supply current for aluminium production

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Abstract. DC current supply to power the electrolysis process in producing aluminium at PT Indonesia Asahan Aluminium (Persero) is about 193 kA. At this condition, the load voltage regulator (LVR) transformer generates 0.89 lagging power factor. By adding the capacitor bank to reduce the harmonic distortion, it is expected that the supply current will increase. This paper evaluates capacitor bank installation impact on the system by using ETAP 12.0 simulation. It has been obtained that by installing 90 MVAR capacitor bank in the secondary part of LVR, the power factor is corrected about 8% and DC current increases about 13.5%.

1. Introduction
Capacitor bank is widely used in electrical power system to improve the power factor. Capacitor is acting as a reactive load generator and connected in parallel to load compensating the lagging current [1-4]. Capacitor reduces reactive current and reactive power so that the power loss and dropped voltage decrease, and load voltage increases. Capacitor bank topology consists of grounded and ungrounded wye as shown in Figure 1.

![Capacitor bank configuration](image)

Figure 1. Capacitor bank configuration: (a) Grounded Wye, (b) Ungrounded Wye
This paper reports the simulation conducted when planning capacitor bank integration to PT Indonesia Asahan Aluminium (Persero) or PT. Inalum, to increase electrolysis current.

2. Research Method

Power flow calculation in existing condition is performed by modelling the electrical network within PT Inalum starting from generator, transmission system, smelter loads and the simplified interconnection with the public electrical operator (PLN) by using ETAP 12.0. The system states are based on the measured parameters using SCADA of PT Inalum [5]. Manual calculation is performed to determine the size of the capacitor bank.

The main station (Gardu Induk) of PT. INALUM has 4 units LVR. Each has 182 MVA capacity. The LVR adjusts and stabilizes output voltage for rectifier transformer [6]. Each electrolysis potline is served by a single unit LVR with 3 taps of NVTC (No Voltage Tap Changer). Each NVTC tap has 27 OLTC (On Load Tap Changer) taps. Tap works as a voltage regulator to anticipate load fluctuation. Figure 2 shows the model of the electrical system within PT. Inalum.

![Figure 2. Electrical network model of PT. Inalum](image)

3. Evaluation Results

3.1. Capacitor Bank Calculation

The reactive power generation in some conditions are approximated by using Equation 1 and 2.

\[
\text{Potline AC Power} = \text{Potline DC Power} \times \text{Conversion Constant} \\
\text{Potline DC Power} = I_{dc} \times V_{dc} \times P10
\]

The minimum current, the existing current, upgrade alternative 1 and 2 are plotted in Table 1. The alternative capacitor bank implementations are based on maximum and partly compensated capacitor bank values. The maximum current (6 x 37 kA = 222 kA) requires 89.9 MVAR reactive power. This research uses the capacitor bank of 2x45 MVAR as plotted in the maximum current of 222 kA. It is referred to as upgrade 1, while 45 MVAR is upgrade 2.
### Table 1. Reactive power requirement

| Condition | I dc (kA) | V dc | PIO | P dc / P L (MW) | P ac / P L (MW) | Q P L (MVAR) | S P L (MVA) |
|-----------|-----------|------|-----|----------------|----------------|-------------|------------|
| Min. Current | 130       | 4.4 V | 165 pot | 94.4         | 97.5           | 52.6        | 110.8      |
| Normal     | 193       | 4.4 V | 165 pot | 140.1        | 144.7          | 78.1        | 164.5      |
| Upgrade 1  | 210       | 4.4 V | 165 pot | 152.5        | 157.5          | 85.0        | 179.0      |
| Upgrade 2  | 222       | 4.4 V | 165 pot | 161.2        | 166.5          | 89.9        | 189.2      |

3.2. Power system model with capacitor addition

By integrating capacitor bank to model as in Figure 2, the integration model is shown in Figure 3. Capacitor bank is in grounded Wye model.

![Figure 3. Electrical network model of PT. Inalum with capacitor bank integration](image)

There are 3 pot lines shown in Figure 3, with 182 MVA MTR and 182 MVA LVR. The capacitor bank is parallel to STR and SR.

3.3. Impact on power factor and current improvements

Figure 4 shows impacts of capacitor bank integration. At normal condition, the power factor is slightly above 0.89. By adding upgrade 1 45 MVAR, power factor moves upward to about 0.96. By fully connecting all capacitors, power factor is stable in 0.99.

![Figure 4. Impact on power factor](image)
The reactive power decrement reduces secunder currents of LVR from 2930 A to 2727 A (upgrade 1) and 2587 A (upgrade 2). The LVR secunder current reductions increase the rating of electrolysis potline, so that the current can achieve 219 kA.

![Figure 5. LVR current decrement](image)

4. Conclusions
Based on the results of ETAP 12.0 simulation, a single 45 MVAR capacitor bank installation on the system increases the power factor from 0.89 to 0.95. The 2x45 MVAR capacitor bank installations improve power factor to 0.99.

Further, the LVR secondary current reduces from 2930 A to 2727 A (for 45 MVAR capacitor bank) and 2587 A (for 2x45 MVAR capacitor bank). This reduction enables the potline current capacity increases from 193 kA to maximum 219 kA. This increment is useful for increasing aluminium production.

References
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