Simulation of the static synchronous compensator for the electrical system with non-linear load

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Abstract. This paper presents the STATCOM model in PSIM, which compensate reactive power and current harmonics from the non-linear load. Reactive power consumption and harmonics current of non-linear load given from measurement. The model of STATCOM is a multi-level voltage inverter. Constant system voltage, power factor and harmonics currents are controlled. All modes are realized and plots are plotted.

1. Introduction
STATCOM control strategy is categorized into primary control strategy and secondary control strategy. The primary control strategy offers device reactive power control, constant system reactive power control, power factor control, and constant system voltage control, while the secondary control strategy offers [4].

2. Simulation background
In order to verify the load compensation performance of STATCOM, a professional power electronic simulation software PSIM is used to build a simulation model for an electrical system with a non-linear load. The simulation model is shown below. According to the two different operation modes, two results of simulation schemes were presented to demonstrate the simulation results and STATCOM efficiency.

The rated voltage of the voltage source is 35kV. The non-linear load is connected to the 35kV bus bar. One set of ±130Mvar STATCOM is connected to the same 35kV bus bar. The main technical parameters of 130Mvar STATCOM are shown in table 1. The wiring diagram is shown in figure 2 and the electric circuit of STATCOM power cell are shown in figure 3.
Table 1. STATCOM Comparison total harmonic distortion before and after compensation.

| parameter            | value | unit |
|----------------------|-------|------|
| Rated capacity       | 130   | MVar |
| Rated current        | 2145  | A    |
| Rated voltage        | 35    | kV   |
| Wiring connection    | Delta |      |

3. Simulation model
Model of STATCOM with non-linear load is shown in figure 1-3.

Figure 1. Equivalent electric circuit model with STATCOM and non-linear load.

Figure 2. Model of delta connected STATCOM.
4. Non-linear load compensation simulation

4.1. Reactive power compensation
The simulation waveform of the 35kV bus voltage before compensation is shown in figure 4. The load active power $P$ and the reactive power $Q$ curve are shown in figure 6 (power is calculated as a 20ms average of one power frequency cycle).

Analysis of the above waveforms, the load reactive power fluctuations are large, the instantaneous power factor fluctuates between 0.78 and 0.99, and the average of the load active power is 105 MW.

After compensating with 130 Mvar STATCOM, the 35kV bus voltage simulation waveform is shown in figure 5. The grid active power $P$ and reactive power $Q$ curve are shown in figure 7 (power is calculated as a 20ms average of one power frequency cycle), and the average active power is 119MW.

![Figure 3. Model of one STATCOM power cell.](image)

![Figure 4. Grid voltage waveform, measurement results.](image)

![Figure 5. Grid voltage waveform after compensation, simulation results.](image)
Figure 6. Active and reactive power, measurement results.

Figure 7. Active and reactive power after compensation, simulation results.

After analyzing the above waveforms, after the STATCOM is put into operation, the reactive power fluctuation becomes smaller, the maximum reactive power is 4.71 Mvar, and the instantaneous power factor is higher than 0.998. The reduction of reactive power results in a significant reduction in grid voltage fluctuations, which in turn leads to an increase in active power and an increase in the active power of 13% for the non-linear load.

4.2. Harmonics compensation
After the STATCOM is started, the harmonic current in the load will be detected, and the currents of the same magnitude and opposite phase are compensated. The uncompensated load current spectrum is shown in figure 8. The compensated grid current spectrum is shown in figure 9. The STATCOM output current waveform is shown in figure 10.

Figure 8. Load current spectrum, measurement results.
Figure 9. Load current spectrum after compensation, simulation results.

Analysis results of the total harmonic distortion rate before and after the compensation at the STATCOM connected point are shown in table 2.

|                      | Before compensation | After compensation |
|----------------------|---------------------|--------------------|
| THDu                 | 5.5%                | 1.8%               |

Table 2. Comparison total harmonic distortion before and after compensation.

It can be seen from figure 8 that there is a large harmonic component in the STATCOM output current. After the compensation of STATCOM, the harmonic current in the load is basically canceled, and the harmonic distortion rate of the grid current waveform becomes low.

After the STATCOM started the operation. However, considering the filter quality factor and the partial harmonic design, the filtering effect is limited, especially for the second harmonic, it is difficult to have a good filtering effect.

Figure 10. STATCOM phase current waveform, simulation results.

5. Conclusions
For operating projects overview with given data from measurement, simulation verification for the two compensation mode of STATCOM is designed. The simulation results indicate that after compensation, the power quality at the STATCOM connected point could meet and exceed the site assessment requirements. The performance indicators that the simulation can achieve are as follows.

- Power factor ≥ 0.995
- Total Harmonic Distortion ≤ 1.8%
The simulation shows that after the compensation device is put into operation, the reactive power is reduced, the bus voltage fluctuation is reduced, and the stability of the bus voltage will cause the active power of the system to be improved.

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