An Improved Compensation Current Detection Method of Static Synchronous Compensator

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Abstract. When the load current check point and compensation injection point of the Static Synchronous Compensator (STATCOM) are at different positions and there are differences in phase and amplitude, there will be a detection difference. To solve this problem, this paper proposes an improved STATCOM compensation command current detection method based on the ip-iq algorithm. This method can eliminate errors and improve detection accuracy by setting the preset phase angle and proportional integral (PI) controller according to the voltage phase and amplitude difference between the check point and the compensation point, thus breaking through the traditional ip-iq. The algorithm is only applicable to the situation where the detection point and the compensation point are at the same position, which improves the accuracy of detection. Theoretical analysis and simulation results show the effectiveness of the method.

1. Introduction

STATCOM can automatically perform real-time dynamic compensation of the power grid, which is the representative of the latest technology in the compensation field [1-5]. STATCOM can quickly and accurately dynamically track compensation according to the command current detection method, so people have proposed a variety of detection methods [6-7]. The harmonic current detection method based on adaptive interference cancellation theory has adaptive tracking detection ability, but the dynamic response is slow and there exists a time delay [5-6]. The accuracy of the detected reactive current is very important to the compensation effect. At present, the traditional ip-iq algorithm is only suitable for the load current detection point of STATCOM and the power compensation injection point are at the same position. Therefore, there are certain restrictions on the reference current detection of the complex structure STATCOM. These methods of detecting reactive current have the disadvantages of large amount of calculation, complicated process and complicated structure [10-14].

In this paper, an improved compensation current detection method is proposed. This method introduces the voltage phase information of the detection point and the compensation point. By setting the phase preset angle and the PI controller, the detection error is eliminated and the detection accuracy is improved [15], it breaks the limitation that the traditional ip-iq algorithm is only applicable to specific situations. The purpose of the detection point and the compensation point at the same location is to provide a fully balanced and sinusoidal power supply current under unbalanced and...
distorted power supply conditions. In order to verify the correctness and feasibility of the method, a simulation analysis was carried out using MATLAB. The obtained results show that the improved compensation current detection method is more effective and more real-time than the traditional method.

2. Improved low-voltage reactive power compensation method

Using the STATCOM multiplexing structure, when the load current detection point and the STATCOM compensation injection point are at different voltage levels, the voltage phase and amplitude between the detection point and the compensation point will have a certain deviation. However, the traditional ip-iq algorithm is only applicable when the detection point and the compensation point are at the same voltage level. When the amount of information has a large deviation, it cannot be directly used for compensation. This paper improves the traditional ip-iq algorithm, and proposes an improved ip-iq algorithm to detect the STATCOM compensation reference current.

First, suppose that the three phases are asymmetrical, the positive sequence voltage components $U_a^p$, $U_b^p$, $U_c^p$ in the voltage can be expressed by:

$$
\begin{bmatrix}
U_a^p \\
U_b^p \\
U_c^p
\end{bmatrix} =
\begin{bmatrix}
(U_a - U_b)/2 - U_c/2 - (U_a - U_c)/2j2\sqrt{3} \\
(U_b - U_c)/2 - U_a/2 - (U_b - U_a)/2j2\sqrt{3} \\
(U_c - U_a)/2 - U_b/2 - (U_c - U_b)/2j2\sqrt{3}
\end{bmatrix}
$$

(1)

According to the difference between the load detection point voltage and the compensation injection point voltage, a preset phase angle is set in the detection circuit to eliminate the error caused by the phase difference detection. The positive sequence voltage $U_a^p$, $U_b^p$ under the available coordinates is:

$$
\begin{bmatrix}
U_a^p \\
U_b^p \\
U_c^p
\end{bmatrix} =
C_{32}
\begin{bmatrix}
U_a^p \\
U_b^p \\
U_c^p
\end{bmatrix} =
\begin{bmatrix}
\bar{U}_a^p + \tilde{U}_a^p \\
\bar{U}_b^p + \tilde{U}_b^p \\
\bar{U}_c^p + \tilde{U}_c^p
\end{bmatrix}
$$

(2)

In the formula, $U_a^p$, $U_b^p$, $U_c^p$ corresponds to the fundamental voltage of the three-phase voltage $U_a$, $U_b$, $U_c$, $\bar{U}_a^p$, $\bar{U}_b^p$, $\bar{U}_c^p$ are the fundamental voltage components of the three-phase voltage after clark transformation. $\tilde{U}_a^p$, $\tilde{U}_b^p$, $\tilde{U}_c^p$ are the harmonic voltage components of the three-phase voltage after Park transformation.

Although the compensation point voltage and the detection point voltage are in different phases, it cannot be directly used as an inverse conversion signal to show the phase of the detection point.
voltage. Here, the initial phase angle of the voltage at the detection point is set to 0, and the difference between the initial phase angle of the voltage between the detection point and the compensation point is , and the relationship of the transformed voltage components is as follows:

\[
\begin{bmatrix}
\cos \omega t \\
\sin \omega t
\end{bmatrix} = \begin{bmatrix}
-\frac{U_p^a}{\sqrt{(U_p^a)^2 + (U_p^\beta)^2}} \\
-\frac{U_p^\beta}{\sqrt{(U_p^a)^2 + (U_p^\beta)^2}}
\end{bmatrix}
\]

(3)

The results of equation (3) have the same frequency and phase as those of \( U_p^a \)、\( U_p^\beta \), and after passing through the low-pass filter (LPF), \( i_p \) and \( i_q \) are obtained by Prak transformation, as shown in the equation:

\[
\begin{bmatrix}
i_p \\
i_q
\end{bmatrix} = C \begin{bmatrix}
i_a \\
i_b \\
i_c
\end{bmatrix} = CC_{32} \begin{bmatrix}
i_a \\
i_b \\
i_c
\end{bmatrix} = \frac{2}{3} \begin{bmatrix}
\sin \omega t & -\sin(\omega t + \pi/3) & -\sin(\omega t - \pi/3) \\
-\cos \omega t & \cos(\omega t - \pi/3) & \cos(\omega t + \pi/3)
\end{bmatrix} \begin{bmatrix}
i_a \\
i_b \\
i_c
\end{bmatrix}
\]

(4)

The difference between the three-phase current signal and the basic current signal is the harmonic current. The sum of the harmonic current and the basic reactive current can be obtained by disconnecting the iq channel, and the active current \( i_a \)、\( i_b \) can be obtained through inverse transformation. The relational formula is shown in equation (5). The obtained current signal is used as the compensation reference current of STATCOM, which can realize load compensation.

\[
\begin{bmatrix}
i_{af} \\
i_{bf} \\
i_{cf}
\end{bmatrix} = C_{32}^{-1} \begin{bmatrix}
t_p \\
0
\end{bmatrix} = \frac{2}{3} \begin{bmatrix}
\sin \omega t & -\cos \omega t \\
-\sin(\omega t + \pi/3) & \cos(\omega t - \pi/3) \\
-\sin(\omega t - \pi/3) & \cos(\omega t + \pi/3)
\end{bmatrix} \begin{bmatrix}
t_p \\
0
\end{bmatrix}
\]

(5)

3. System Simulation

3.1. Simulation model

The simulation in this paper uses the power system simulation library (PSB) of MATLAB to construct the detection module of STATCOM, in order to prove the correctness and effectiveness of the improved ip-iq compensation current detection algorithm of STATCOM proposed in this paper. The simulation experiment was carried out in the SIMULINK simulation software in MATLAB.

![Figure 2. Traditional ip-iq compensation current detection simulation model.](image-url)
3.2. Simulation analysis

Figure 3. Improved ip-iq compensation current detection simulation model.

Figure 4. Three-phase voltage and current simulation diagram at the public connection point before connecting to the STATCOM device.

Figure 5. Three-phase voltage and current simulation diagram at the common connection point after connecting the STATCOM device.

Figure 4 and figure 5 are the current simulation waveforms of the traditional detection method and the improved detection method respectively. Through comparison, it can be clearly seen that the traditional detection method has a poor compensation effect on the grid current waveform, moreover, the harmonics are relatively large and the current waveform is poor. In this paper, the harmonic components of the grid current compensated by the improved detection method are better suppressed, and the current waveform is greatly improved, which is very close to a sine wave. The simulation results verify the feasibility and effectiveness of the method.
4. conclusion
Based on the theory of instantaneous reactive power, this paper deeply analyzes the basic principles of the ip-iq algorithm, points out the limitation of this method in the STATCOM command current detection, and proposes an improved command current detection method to set the phase compensation angle, and add a PI controller after the low-pass filter to solve the command current detection problem when the STATCOM detection point and the compensation point are at different positions. Through the analysis of the traditional ip-iq algorithm and the improved method, simulation experiments are carried out. The results show that the improved method can better detect the compensation command current and has a wider range of applications.

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