Development and application of measurement data pre-processing tools for parameter identification considering q-axis voltage

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Abstract: At present, when model parameter identification is carried out, measurement data from phase measurement units or fault recorders are generally used directly. These two types of devices can directly provide the fundamental positive sequence quantities required for parameter identification, but cannot output the dq components. If these measurement data can be fully utilized for parameter identification, it is very beneficial to improve the model accuracy. In this paper, according to the engineering needs of load model parameter identification, the extraction method and variation law of dq components are studied, and the data pre-processing tool is developed and put into use.

1. Introduction

When performing power system calculations, inaccurate load models can make the power system potentially dangerous and wasteful when making development plans. And in order to improve the accuracy of the simulation simulation, a more accurate mathematical model must be used. An accurate model consists of two aspects, one is the correct model equation, and the other is the accurate model parameters[1-2]. Since the principles of the power equipment in the power system are clear, the model is generally considered to be correct, without considering the errors in the model structure. As for the model parameters, it is difficult to find all the parameters required for the simulation calculation from the nameplate or manual of the equipment, so the parameter identification method is usually used to determine them.

In the practical model of induction motor, the practical model considering the q-axis voltage component can identify the load model parameters more accurately than the practical model without the q-axis voltage component, and the q-axis voltage component has an important influence on the accuracy of load parameter identification. Therefore, this paper studies how to extract the dq component and apply it to the load model parameter identification, which has important practical value.

2. Calculation method of dq component

The stator abc three-phase winding is spatially symmetrical, after passing current in space will be synthesized into a composite magnetic potential vector \( \vec{F} \). It can be synthesized either by the abc magnetic potential vector or by the dq magnetic potential vector, i.e.
The resulting Pike transform is obtained as follows

\[
\vec{F} = \vec{f}_d + \vec{f}_b + \vec{f}_c = \vec{f}_d + \vec{f}_q
\]  

(1)

\[
\begin{bmatrix}
f_d \\
f_q \\
f_0
\end{bmatrix} = \frac{2}{3} \begin{bmatrix}
\cos \theta & \cos(\theta - 120^\circ) & \cos(\theta + 120^\circ) \\
-\sin \theta & -\sin(\theta - 120^\circ) & -\sin(\theta + 120^\circ) \\
\frac{1}{2} & \frac{1}{2} & \frac{1}{2}
\end{bmatrix}
\]  

(2)

Write the matrix form

\[
f_{dq0} = Pf_{abc}
\]  

(3)

It should be noted that the Park transformation, although derived from the magnetic potential synthesis, is applicable as a mathematical transformation to various variables and their various variations.

2.1. Choice of speed

The first thing to note is that synchronous motors generally take the rotor speed, while asynchronous motors generally take the speed of the stator rotating field \( \omega_s = 2\pi f_s \). During the dynamic process after a fault or disturbance (strictly speaking the power system is always in a dynamic process), there are a total of 4 speeds. The first is the rotor speed \( \omega_r \), the second is the integrated vector \( \vec{F} \) speed \( \omega_F \), the third is the dq coordinate system speed \( \omega_S = 2\pi f_S \), and the fourth is the system common coordinate system speed \( \omega_n = 2\pi f_n \) where \( \omega_r \) and \( \omega_F \) are strictly time-varying in the dynamic process; \( f_s \) represents the frequency of the stator three-phase cross-flow, which is also strictly time-varying in the dynamic process, \( f_s(\tau) \); and \( f_n \) represents the system-side rated frequency, which is constant in the dynamic process, i.e. \( f_n = 50Hz \).

2.2. Selection of angle

As shown in Figure 1, 2 main angles are used.

One is the spatial angle, which is the angle of the d-axis leading the a-axis and varies with the rotation of the dq-axis.

\[
\theta(t) = \int_0^t \omega_s(\tau) \, d\tau + \theta_0
\]  

(4)

When \( \omega_s \) called the stator frequency \( f_s \) is constant

\[
\theta(t) = \omega_t + \theta_0
\]  

(5)
Where \( \theta_0 \) represents the initial angle.

Second is the electrical angle \( \alpha \), which is the angle of the integrated vector \( \mathbf{F} \) leading the a-axis of the stator, varies with the rotation of the integrated vector \( \mathbf{F} \).

\[
\alpha(t) = \int_0^t \omega_F(\tau) d\tau + \alpha_0
\]  

(6)

When the rotational speed \( \omega_F \) of \( \mathbf{F} \) is constant

\[
\alpha(t) = \omega_F t + \alpha_0
\]  

(7)

In equation (7), \( \mathbf{F} \) can represent the magnetic potential, voltage, current, etc. and \( \alpha_0 \) represents the initial value of the electrical angle of phase a.

Assumption 1: If the speed of rotation is the same as that of the d-axis, i.e., then, the angle between the two relative to each other at rest, is a constant value, and subtract formula (4) and formula (6) to get:

\[
\theta(t) - \alpha(t) = \theta_0 - \alpha_0
\]  

(8)

Assumption 2: Usually set \( t = 0 \) time, the d-axis coincides with the a-axis, that is \( \theta_0 = 0 \). From formula (8), we can get:

\[
\theta(t) = \alpha(t) - \alpha_0
\]  

(9)

That is, the angle \( \theta(t) \) is equal to the actual angle of the three-phase AC a-phase minus the initial angle of the a-phase. As seen in Figure 1, the initial angle affects the projection on the dq axis when \( \theta_0 = 0 \). Substituting equation (9) into equation (2), it can be mathematically deduced that

\[
\begin{align*}
\hat{f}_d(t) &= F \cos[\alpha(t) - \theta(t)] = F \cos \alpha_0 \\
\hat{f}_q(t) &= F \sin[\alpha(t) - \theta(t)] = F \sin \alpha_0
\end{align*}
\]  

(10)

Assumption 3: If we let the d-axis coincide with \( \mathbf{F} \) at time \( t = 0 \), i.e., \( \theta_0 = \alpha_0 \), then we have

\[
\theta(t) = \alpha(t)
\]  

(11)

It is important to note that:

1) The projection on the abc axis is the cos function of a instead of the sin function, so the three-phase electrical quantity adopts the cos function. If the angle given by some literature or measurement corresponds to the sin function, then b should be subtracted by 90 degrees.

2) Assumption 1 \( \omega_F = \omega_s \) is the premise of formula (9), and its condition is that the abc three-phase AC variable is fundamental and symmetrical, that is to say, it does not contain noise, harmonics, negative sequence, etc.

3) Assumption 2 is often used, and assumption 3 holds in special cases.

3. Development and application of preprocessing tools

The application scenario faced by this article is the parameter identification of the load model of a certain power grid considering the q-axis voltage. The measurement data is the instantaneous measured value of the three-phase voltage, which comes from equipment such as power quality monitors, and needs to extract the fundamental positive sequence quantity and dq component.

3.1 Development of data preprocessing tools

Make full use of various calculation modules provided by Matlab to build a preprocessing system in Simulink environment. The overall structure of the pre-processing system built is shown in Fig.2. The blue box on the left of Fig.2 is the input terminal of the measurement system, the green background module is the phase-locked loop module, key modules on orange background is “Discrete 3-phase PLL-Driven Positive-Sequence Fundamental Value”.

\[
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\]
3.2 Validation of the validity of data pre-processing tools

This subsection will use Matlab to generate simulation data for verification.

![Fig.3 Comparison curve of voltage dq axis](image)

(a) Voltage d-axis component  
(b) Voltage q-axis component

![Fig.4 Comparison curve of current dq component](image)

(a) Current d-axis component  
(b) Current q-axis component

The data preprocessing tool developed in this paper has a voltage d-axis component curve error of 0.056%, a voltage q-axis component curve error of 0.062%, a voltage d-axis component curve error of...
0.121%, and a voltage q-axis component curve error of 0.311%.

3.3. Measured data processing results of the power grid
The data used in this section is the measured data of a certain power grid, first extract the fundamental positive sequence quantity, then calculate the dq component, and calculate the active power and reactive power at the same time.

![Fig.5 Positive sequence voltage](image)

![Figure 6 Voltage dq axis components](image)

![Figure 7 Power curve](image)

4. Examples of load model parameter identification
At present, the motor part used for load modeling research and practical engineering application adopts practical models. Theoretical analysis shows that the practical model considering the q-axis potential can well identify the load model parameters[3]. Next, a practical model that considers the q-axis potential and a practical model that does not consider the q-axis potential will be used to identify the load parameters of the power grid measured data[4]. At the same time define the amount of error Err:

\[
Err = \sum_{i=1}^{n} \sqrt{(P_n(i) - P_m(i))^2 + (Q_n(i) - Q_m(i))^2}
\]  

(12)
Among them, \( n \) is the number of data points, \( P_o(i) \) is the actual value, and, \( P_m(i) \) is the output value after identification.

![Graph](image)

(a) Active power  
(b) Reactive power

Fig.8 power fitting comparison curve

| Sequence number | \( P_{MP} \) | \( R_S \) | \( K_I \) | \( X_D \) | \( Err \) |
|-----------------|-------------|---------|---------|---------|--------|
| Do not consider q-axis voltage | 0.100 | 0.166 | 0.224 | 0 | 320.042 |
| consider q-axis voltage | 0.123 | 0.155 | 0.270 | 0.003 | 317.809 |

From the results, the fit of active power is better when the q-axis potential is considered and the q-axis potential is not considered, and the fit without power is relatively poor. The power fitting error is smaller when the q-axis potential is considered than when the q-axis potential is not considered.

5. Conclusion

The data preprocessing tool for parameter identification developed in this paper is highly versatile and can be applied to the preprocessing of three-phase instantaneous measurement data of voltage and current to achieve the extraction of fundamental positive sequence and dq components. In addition, the extraction function of the dq component makes up for the shortcomings of the existing measurement equipment and enriches the available data for parameter identification.

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