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Research on Power Load Modeling Based on Improved Perturbed Method

Shi Guoping*[1,2], Liang Jun[1], Liu Xiangsheng[3]
[1]School of Electrical Engineering, Shandong University, Jinan, 250061, China
[2]School of information and electrical engineering, Shandong Jianzhu University, Jinan, 250101, China
[3]Qingdao power supply company, Qingdao, 266002, China
*Corresponding author, e-mail: shiguoping@sdjzu.edu.cn

Abstract

This paper introduces a conventional synthesis power load model considering distribution network in PSASP, through analyzing the model structure and achieving process, proposes a power load model parameter identification method based on improved perturbed method. The paper gives parameters identification method of complete synthesis load model, including reactive power compensator parameters. The parameters identification method combines parameter identification process with sensitivity analyzing process together, not only can get model parameters but also can obtain the sensitivity of all parameters, which saves computing time and reduces the amount of calculation, the final simulation results prove the method is effective and feasible.

Keywords: *power system, perturbed method, load modeling, parameter sensitivity, synthesis load model*

1. Introduction

At the present time, digital simulation has been the major means in power system planning, designing, dispatching and analyzing [1-2]. The mathematical model of each circuit component is the basis of digital simulation experiment in power system [3]. The accuracy of load model will directly affect the simulation result of entire system and the final strategic decision [4-5].

This paper uses the conventional synthesis load model in PSASP [6], analysis the model structure and its achievement process in PSASP, proposes a parameter identification method based on improved perturbed method, the method combines parameters identification process with parameters sensitivity analyzing process, and reduce more computation and computing time, the simulation results proved its validity and feasibility.

2. Research Method

2.1. Complete Synthesis Load Model

The structure of the synthesis load model directly considering distribution network is shown as Figure 1 [5], the model includes the equal static load, the equal electric motor load, the equal distribution network circuit and compensator of reactive power, there is a virtual bus between bus bar and power load, and it is the equivalent impedance of the distribution network between virtual bus $\dot{U}_L$ and actual bus $\dot{U}_S$ [10].

Extended ZIP model can be denoted as:

$$\begin{cases} P_s = P_{s0}\left[P_Z(U/U_0)^2 + P_I(U/U_0) + P_P\right] \\ Q_s = Q_{s0}\left[Q_Z(U/U_0)^2 + Q_I(U/U_0) + Q_P\right] \end{cases} \tag{1}$$

Where P_s, Q_s, P_{s0}, Q_{s0} indicate active power, reactive power, the initial steady-state values of the active power and reactive power, P_Z , P_I , P_P indicate active power characteristics

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parameters, Q_Z, Q_I, Q_P indicate reactive power characteristics parameters, and satisfy $P_Z + P_I + P_P = 1$, $Q_Z + Q_I + Q_P = 1$, U and U_0 are bus voltage and bus voltage initial steady-state value.

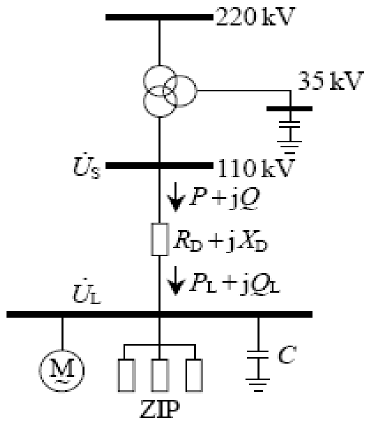

Figure 1. The Synthesis Load Model Structure Directly Considering Distribution Network

Dynamic part of the synthesis load model uses three-order induction electric motor model, the state equation and output equation of which show as below [7]:

$$\begin{cases} \dfrac{dE'_d}{dt} = -\dfrac{1}{T'_0}\left[E'_d + (X - X')I_q\right] + (\omega - \omega_r)E'_q \\ \dfrac{dE'_q}{dt} = -\dfrac{1}{T'_0}\left[E'_q - (X - X')I_d\right] - (\omega - \omega_r)E'_d \\ \dfrac{d\omega_r}{dt} = -\dfrac{1}{H}\left[(E'_d I_d + E'_q I_q) - T_L(A\omega_r^2 + B\omega_r + C)\right] \end{cases} \quad (2)$$

$$\begin{cases} I_d = \dfrac{1}{R_s^2 + X'^2}\left[R_s(U_d - E'_d) + X'(U_q - E'_q)\right] \\ I_q = \dfrac{1}{R_s^2 + X'^2}\left[R_s(U_q - E'_q) - X'(U_d - E'_d)\right] \end{cases} \quad (3)$$

The Equation (2) and (3) are the state equation and output equation of the induction motor's three-order electromechanical transient model [8]. U is the system input, I_d and I_q are the system output, ω is the system operating frequency. R_s and X_s are the equivalent resister and leakage impedance of the stator winding, R_r and X_r are the equivalent resister and leakage impedance of the rotor winding, X_m is the mutual inductance impedance between rotor winding and stator winding, and satisfy $X = X_s + X_m$, $T'_0 = (X_r + X_m)/R_r$, $X' = X_s + X_m X_r/(X_m + X_r)$. ω_r is the speed of rotation, T'_0 is the open –circuit transient time constant of the stator, H is inertia constant of induction motor, $T_m = T_L(A\omega_r^2 + B\omega_r + C)$ is the mechanical torque of the induction motor, $T_e = E'_d I_d + E'_q I_q$ is the electromagnetic torque, T_L is the load coefficient. A, B and C are the mechanical torque coefficient of the induction motor, and filled with $A + B + C = 1$.

K_{pm} is denoted as the rate of the equivalent electric motor over the total power load, which is defined as following:

$$K_{pm} = P_0^{'}/P_0 \tag{4}$$

In Equation (4), P_0 is the initial active power of the load test node, $P_0^{'}$ is the the initial active power of the equivalent electric motor.

M_{lf} is the rated initial load rate coefficient, which is defined as below:

$$M_{lf} = \left(\frac{P_0^{'}}{S_{MB}}\right) \bigg/ \left(\frac{U_0}{U_B}\right) \tag{5}$$

In Equation (5), S_{MB} and U_B are the rated capacity and rated voltage of the equivalent electric motor, U_0 is the initial voltage of the load testing node.

According to the structure of the complete synthesis load model, the reactive power compensation capacitor connects to the virtual bus $\dot{U}_L$ directly, so the voltage of the capacitor is $\dot{U}_L$, by definition, $Q_C = -I_C{}^2 X_C$, where $I_C = \frac{U_L}{X_C}$, arriving at $Q_C = -\frac{U_L^2}{X_C}$, following it,

$$C = -\frac{Q_C}{2\pi f U_L^2} \tag{6}$$

2.2. The Parameters of Synthesis Load Model Need to be Indentified

There are 15 parameters need to be identified in synthesis load model [8-9], including 8 electric motor parameters: R_s, X_s, X_m, R_r, X_r, H, A, B, 4 static model parameters: P_Z, P_I, Q_Z, Q_I and other parameters: K_{pm}, M_{lf} and X_c.

This paper identifies the model parameters by the method of Particle swarm algorithm [10-11], it is difficult and inaccurate to identify model parameters one by one, so this paper only identifies the parameters with high sensitivity according to sensitivity analyzing results set by improved perturbed method.

2.3. Sensitivity Analysis Based on Improved Perturbation Method

Given perturbed problems belong to a class of fixed problems including small parameters, just like differential equation: $\begin{cases} L(u, x, \varepsilon) = 0 \\ B(u, \varepsilon) = 0 \end{cases}$, where $0 < \varepsilon \le 1$ (7)

If the solution of Equation (8) can be described by a power series of ε: $u(x,\varepsilon) \sim u(x_0) + \sum_{n=1}^{\infty} \varepsilon^n u_n(x)(x \in \Omega)$, and is uniformly valid in Ω domain, then the Equation (7) is a canonical perturbed Problem in Ω domain, otherwise is a singular problem, singular perturbed method uses in solving the perturbed problems when the canonical perturbed method fails [11].

In short, perturbed method means adjust the value of one parameter fixing the others by certain step length in its value range, and analysis the response variation of the model.

This paper uses s an improved perturbed method in parameter identification, namely, fix one parameter with the typical value, and identify other parameters, if the curve fitting results are perfect, the parameter is considered rather low in sensitivity, otherwise, the parameter is considered rather high in sensitivity and need to be identified. The method can analysis the sensitivity of the model parameters and identify the parameter's value at the same time.

The identification process based on improved perturbed method is as follows:

Step 1: Set power network fault, obtain measured active and reactive power response under different fault.

Step 2: Fix one parameter with the typical value, identify other parameters of the complete synthesis load model using Particle swarm algorithm, if the identifying error is little, the parameter sensitivity is rather low, the value of parameter can be typical, then turn to step 3, in contrast, the parameter needs to be identified anew, repeat step 2.

Step 3: Choose another parameter with typical value, identify the rest parameters, if the identification results are perfect, the parameter sensitivity is rather low, the value of parameter can be typical, then turn to step 4, otherwise repeat step 3.

Step 4: On the analogy of this, the sensitivity of all the model parameters can be obtained one by one, the parameters with low sensitivity can use typical provided by EPRI directly, other parameters with high sensitivity need to be identified.

3. Results and Analysis

To take the EPRI-36 nodal system as an illustration in the Power System Analysis Package (PSASP), EPRI-36 nodal system is shown in Figure 2. The transient data of the complete synthesis load model can be gotten by PSASP, the dataset of each nodal point can be seen as field measured data from power fault wave recorders.

The typical parameters value of the complete synthesis load model is shown in Table 1

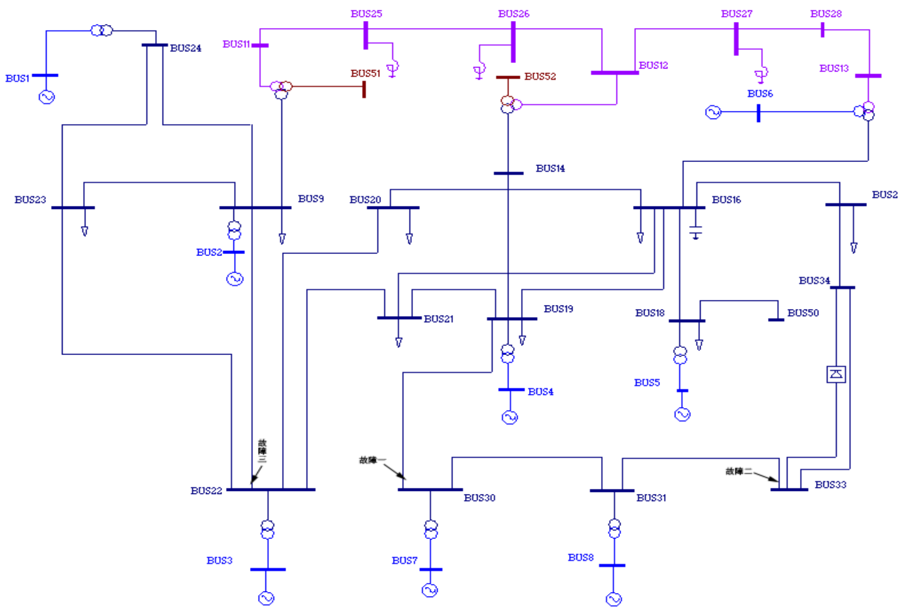

Figure 2. EPRI-36 Nodal Point System

Table 1. The Typical Parameters Value of the Electric Motor Provided by EPRI

	R_s	X_s	X_m	R_r	X_r	H	A	B	C
EPRI	0	0.120	3.5	0.020	0.12	2	0.85	0	0.15

3.1. Fix One Parameter, Identify other Parameters

Fix parameter X_m and set X_m=3.5, the curve fitting comparing the response of load model with measured response is shown in Figure 3.

It can be derived from Figure 3 that the parameter X_m take typical value, the simulation result is still very well, therefore, the sensitivity of X_m is rather low and need not to be identified. The sensitivity of X_m is high enough and needs to be determined on the contrary.

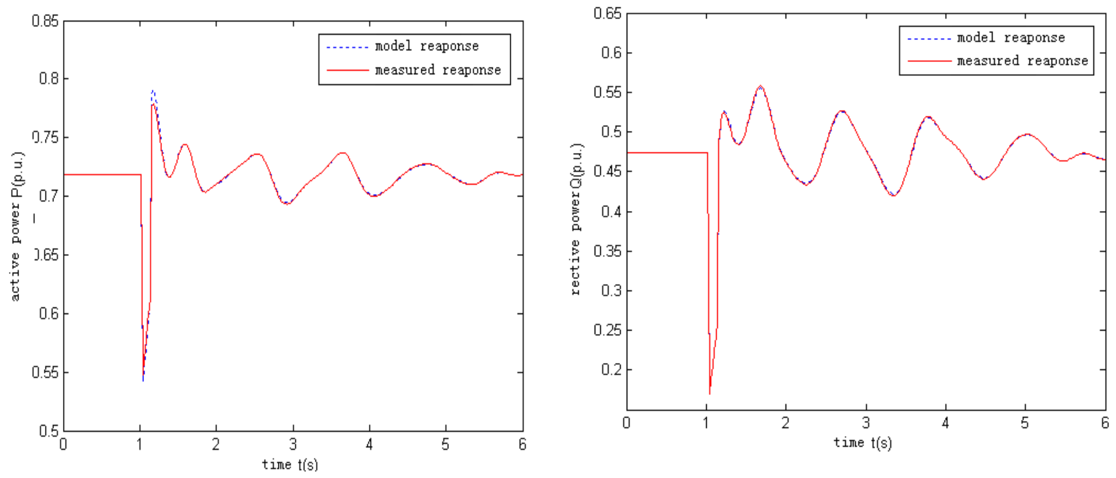

Figure 3. The Curve Fitting of Model Response Comparing with Measured Response (fix X_m)

3.2. Fix another Parameter, Identify the Rest of the Parameters

Parameter Xm and Xs take typical value, namely X_m=3.5 and X_s=0.18, identify the others, the simulation result comparing model response with measured response is displayed in Figure 4.

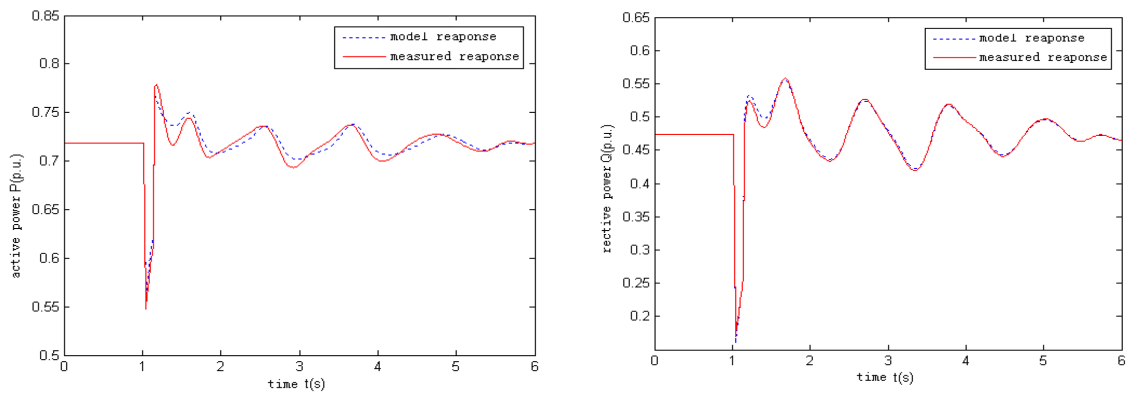

Figure 4. The Curve Fitting of Model Response Comparing with Measured Response (fix X_m and X_s)

It is clear from Figure 4 that when X_s takes typical value recommended by EPRI, the curve fitting is very bad, the model response is not in conformity with the measured response throughout the period, so the sensitivity of X_s is high, can not take typical value and needs to be determined renew.

3.3. Determine the Sensitivity of All Model Parameters One by One

According to the above-mentioned methods, the sensitivity of all model parameters can be gotten. The final conclusion is that the sensitivity of X_s, R_r, K_{pm}, M_{lf}, P_V, Q_V is high enough to need to be identified and the sensitivity of the others is very low to take typical value provided by EPRI.

3.3. The Verification of Improved Perturbation Method Sensitivity Analyzing Method

Take the BUS20 load under fault 1 for an example, the identification result is shown in Table 2. The curve fitting of model response only identifying 6 parameters comparing with measured response is shown in Figure 5. According to the results, the simplified identification strategy not only reduces computation, but also get better curve fitting of model response comparing with measured response, which will only identify 6 parameters, the identification result is not worse comparing with identifying all parameters, even better, and proves the identification strategy's validity.

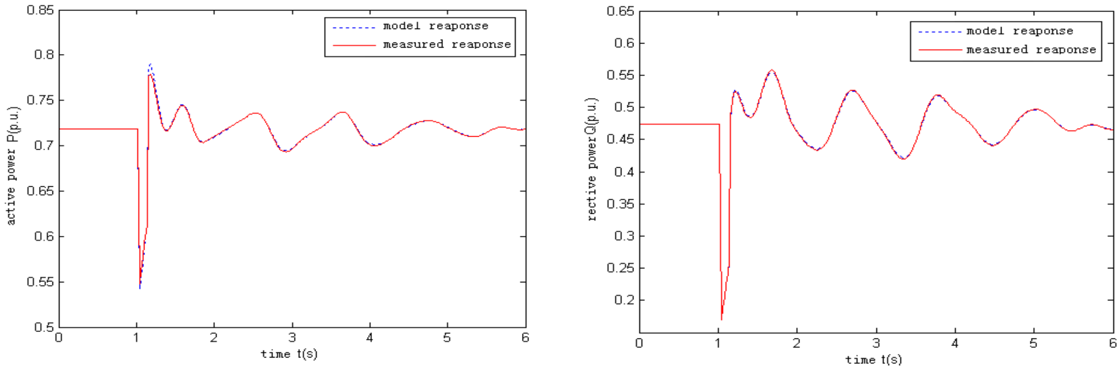

Figure 5. The Curve Fitting of Model Response Comparing with Measured Response (only 6 parameters)

Table 2. The Parameters Identification Result of BUS20 under Fault 1 Only with Determining 6 Parameters

	X_s	R_r	K_{pm}
F1B20	0.1993	0.0188	0.6139
M_{lf}	P_v	Q_v	Error J
0.5120	0.6273	0.2476	0.0034

4. Conclusion

This paper proposes a parameter identification method based on improved perturbed method, the method combines parameters identification process with parameters sensitivity analyzing process together, and reduce more computation and computing time, the simulation results proved its validity and feasibility.

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