동적 부하모델 파라미터 추정을 위한 시뮬레이션 기반 최적화 기법 비교 연구

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Comparative Study on Proposed Simulation Based Optimization Methods for Dynamic Load Model Parameter Estimation

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Abstract - This paper proposes the hybrid Complex-PSO algorithm based on the complex search method and particle swarm optimization (PSO) for unconstrained optimization. This hybridization intends to produce faster and more accurate convergence to the optimum value. These hybrid will concentrate on determining the dynamic load model parameters, the ZIP model and induction motor model parameters. Measurement-based parameter estimation, which employs measurement data to derive load model parameters, is used. The theoretical foundation of the measurement-based approach is system identification. The main objective of this paper is to demonstrate how the standard particle swarm optimization and complex method can be improved through hybridization of the two methods and the results will be compared with that of their original forms.

1. INTRODUCTION

Optimization Methods are very much extensively utilized in applications in root finding of polynomials, systems of equations and in estimating the parameters of nonlinear functions [1]. The focus of this paper is determining the dynamic load model parameters, thus presenting a hybrid of complex method and PSO .

Identification of load model parameters, that properly depict load behavior during electric power system disturbances, enables proper power system planning, reliable prediction of prospective operating scenarios and provides for adequate control actions to be chosen in order to prevent undesired system behavior and ultimately system instability. The presence of parameter errors can lead to unreliable state estimation results [2]. Load models, which quantify real and reactive power responses to voltage and frequency disturbances, are generally divided in two groups: static and dynamic load models.

The purpose of this paper is mainly to discuss the estimation of parameters through proposed optimization methods in a hybrid model structure with static and dynamic.

The model includes a ZIP model for the static part and a induction motor for the dynamic part. In the load model representation, the 3rd order induction motor model is recommended with the state variables of rotor angular speed, d-axis and q-axis internal voltages.

Further, this paper aims to assess the effectiveness of Complex-PSO hybrid in comparison with the standard forms of complex method and PSO in minimizing the error of the outputs using the estimated parameters, which are obtained by numerical integration with Runge-Kutta 4th order method, from the time series data with measurement. To test the feasibility of the approach, this paper includes an example applying the algorithm to 23-bus test system.

2. OPTIMIZATION BASED LOAD MODEL PARAMETERS ESTIMATION

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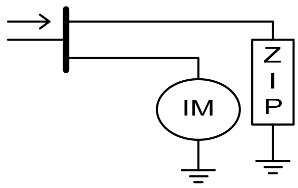
2.1 THE LOAD MODEL

The structure of the equivalent load models, considered in the paper, is mainly composed of two components; they are an induction motor and a static load as shown in Fig. 1 [3].



<Fig. 1> The model structure of interest

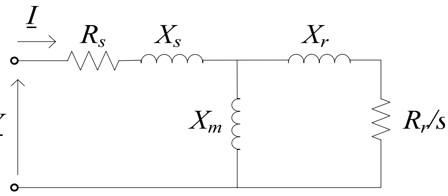
The static load model used in the paper is a ZIP model and active and reactive load demand, PZIP and QZIP, of the model can be expressed as follows:

$$P_{ZIP} = P_{ZIP0}[a_p(V/V_0)^2 + b_p(V/V_0) + c_p] \quad (1)$$

$$Q_{ZIP} = Q_{ZIP0}[a_q(V/V_0)^2 + b_q(V/V_0) + c_q] \quad (2)$$

where PZIPo and QZIPo are active and reactive load demand when voltage magnitude of the load bus is Vo as the reference. In (1) and (2), ap, bp and cp are the coefficients for the ratio of constant impedance (ap + bp + cp = 1), constant current and constant power portion to the active load, respectively; aq, bq and cq are those for the reactive load.

As for the dynamic load behavior, the 3rd order induction motor model [4] is employed. The equivalent circuit of the induction motor is shown in Fig. 2.



<Fig. 2> Equivalent circuit of an induction motor

In Fig. 2, Rs and Xs are the stator resistance and reactance, respectively; Xm is the magnetization reactance; Rr and Xr are the rotator resistance and reactance, respectively; V and I are the vector for the motor terminal voltage and current, respectively; s denotes the slip of the motor, which can be expressed as (wm-wo)/wo. wm and wo stand for the rotor angular velocity and its synchronous value. The detailed explanation on the induction model can be found in [4].

2.2 THE OBJECTIVE FUNCTION

For parameter estimation, this paper adopts the prediction-error approach for the two optimization methods. The fitness function is the summed error between the measured outputs, {P, Q}, and the simulated outputs, {P*, Q*}. The fitness function can be explained mathematically as follows:

$$f = \sum_{i=1}^{N_s} \frac{1}{2N_s} \left[(P_i - P_i^*)^2 + (Q_i - Q_i^*)^2 \right] \quad (3)$$

where Ns is the number of the sampling. In (3), the simulated active and reactive power, {P*, Q*}, can be obtained as follows:

$$P^* = P_{ZIP} + P_{IM} \quad (4)$$

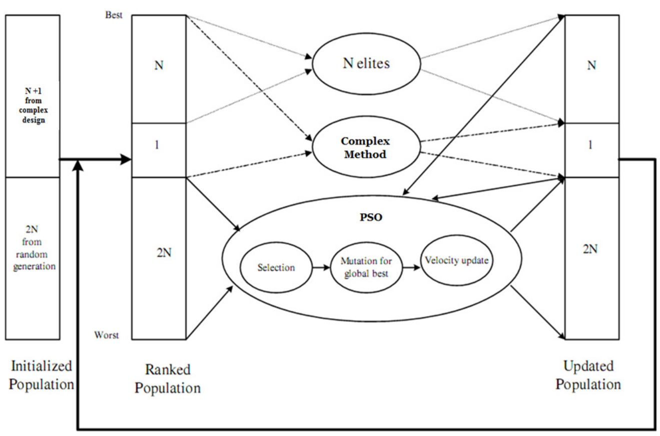
$$Q^* = Q_{ZIP} + Q_{IM} \quad (5)$$

2.3 THE COMPLEX-PSO HYBRID

The Complex Method is a general and powerful optimization algorithm that arose from the idea of applying simplexes to the optimization of either physical processes or mathematical functions (Spendley, Hext, and Himsworth 1962; Nelder and Mead 1965). As a direct optimization procedure, the Complex method does not require gradients of the objective function. Instead, it operates with information on the relative response rank associated with control levels [5]. Like simplex method, it undergoes reflection, expansion, contraction and shrinkage. However, complex method assures finding the better solution space by its added condition before accepting the reflection and expansion points.

PSO is a population-based and evolutionary in nature. It has memory in terms of the inertia weight, and then the social exchange information. A commonly observed social behavior, where members of a group tend to follow the lead of the best of the group, is simulated by PSO. As simple in concept and economic in terms of computational costs, PSO has a definite edge over other evolutionary optimization techniques. [6]

The proposed hybrid Complex-PSO will have three different approaches. The First approach is the application of PSO and the global optimum achieved will be subjected to Complex method in order to improve the best value. The second and third approaches takes 3N + 1 particles. Through this Complex Method will be executed first and followed by PSO. The initial swarm, N + 1 particles, is constructed using the random generated starting point to form an initial simplex, and additional 2 particles with opposite directions are randomly generated for each dimension. The additional swarm of 2N particles mentioned above may be a worthy investment as they could possibly bring about a great leap to the vicinity of the global optimum in the early iterations. Figure 3 below gives illustrates of the proposed hybrid.

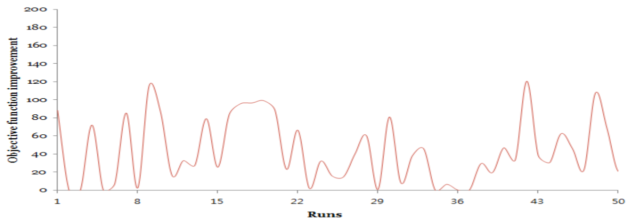


<Fig. 3> Schematic representation of the NM-PSO hybrid

As shown above the N+1 population will undergo complex and the resulting optimum will replace the (N+1)th particle only which is the second approach. While the third approach be replacing the entire N+1 population. Further these two methods will then be compared with that of the results of the original Complex and PSO methods.

3. Results

Below is the performance made by the hybrid using the first approach. The optimum value obtained by PSO was improved by the Complex method through lowering the objective function initially derived by PSO. Fifty runs were made in order to capture the effectiveness of the hybrid in obtaining better results.



<Fig. 4> Objective Function Improvement by Complex-PSO hybrid

<Table 1> Objective Function Improvement by Complex-PSO hybrid

	No. of runs that show improvement (out of 50 runs)	No. of runs that show no improvement (out of 50runs)	Average of Improvement for 50 runs	% chance of improvement	% chance of no improvement
COMPLEX-PSO HYBRID	45	5	43.62	90	10

4. Conclusions

This paper proposes the Complex-PSO Hybrid Optimization and compare its results with that of the original Complex and PSO methods. These methods were used to estimate the parameters for the load model structure including static and dynamic parts. This hybrid method can offer the synergistic effect of both the Complex's local optimum search ability and the PSO's global optimum search abilty . Because of the characteristic of PSO, it is said to capture the exact minima, but the initial application of the complex method in improving the best solutions of the population can overcome this disadvantage of the simulation based approach.

This hybrid presents a better and very effective solution compared with their original forms in determining parameters that will be used for load modeling and will be highly essential in power system stability analysis.

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