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A Novel Fuzzy C-means Clustering Algorithm to Improve the Recognition Accuracy

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Abstract. Using ambient excited data under PMU measurements to identify the low frequency oscillation mode and oscillation modes parameter information corresponding, has good prospects in power system analysis and control. This article discusses the applicability by using the natural excitation technique (NExT) in conjunction with the eigensystem realization algorithm for low frequency oscillation modes identification, then introduceds fuzzy C-means clustering algorithm to picked up the authenticity of the identified modal results automatically and improving the recognition accuracy. On the IEEE-11 and IEEE-68 bus test system numerical example shows that the proposed method has higher modal recognition ability and efficiency, and can meet the needs of online applications.

1 Introduction

With the interconnection of the power grid region and the weakening of the damp, the instable increasing oscillation has been a frequent occurrence of the system. Therefore, it is of vital importance and more difficult for the online monitoring of the power grid and the damping control to rapidly obtain the low frequency oscillation models and parameters [1].

With the all-around application of Phasor Measurement Unit (PMU) in the electrical power system and the gradual establishment of Wide Area Monitoring Systems (WAMS) based on PMU, the analysis of the system's low frequency oscillation based on the actually-measured tracks enjoys a promising prospect. According to different disturbance intensity, there are two categories of identification methods, namely the identification method based on the large signal disturbance signal and the identification method based on the small disturbance signal [2]. Currently, Prony has been the widely-used one among the low frequency oscillation modal identification methods based on the large oscillation disturbance. However, since the large disturbance signal might not exit all the time and the actually-measured signal is seriously impacted by the environment noises, the limits of Prony and the defects of data collected by it have been increasingly obvious. The modal identification methods based on the noise-like signal only adopt the real-time response signal in ambient excitation as the recognition input, and have no need to measure the input the drive signal. At the same time, it can avoid the complexity of

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manual excitation. Thus, methods of the kind are more applicable to the online monitoring and analysis of the low frequency oscillation model [3].

2 Selection of the reference channel

ERA is a MIMO time-domain overall modal parameter identification algorithm. Its input is the cross-correlation function matrix build by the reference channel vectors (multiple reference points), which can thus improve the accuracy and reliability of the identification results.

Under the environment excitation, the input drive signal of the electrical power system is similar to the white noise, and cannot be measured. In order to obtain the modal of a certain system, it is necessary to include all the signals measured by the electric generator's PMUs into the system's output column vectors. However, in fact, there is huge number of PMUs in the electric power system. It is extremely time-consuming to include the measured signals as the signals of the reference channels into $h(k)$ ($m\times1$) to form a Hankel matrix and conduct SVD. This might also hinders its online application. Therefore, it is an issue of great concern about how to quickly select signals with a high observability and representativeness from the mass data measured by PMUs as the signals of the reference channels.

The selection of the reference channels is based on a preliminary understanding of the system. First, derive the estimation methods of the dominant oscillation models based on the system's mathematical models; find the key fracture surfaces which might easily oscillate with the system through the analysis of the factors influencing the oscillation frequency; select the measured tracks on the fracture surface based on the oscillation increase amount of the state quantity [13]. After all these, the signals for the reference channels with a high observability towards the oscillation model can be confirmed.

Fuzzy clustering has a wide application in the intelligent classification of the statistical pattern identification, of which FCM is the one with the most mature application and theoretical system. Its principle is as below [16]: define an objective function, J; randomly select "c" initial cluster centers, $v_i(i=1,2,\cdots,c)$, from the sample set to be classified, $X=\{x_1,x_2,\cdots,x_n\}\subset R^p$; divide the samples to the category through the calculation of the Euclidean distance, d_{ij}, from the calculation samples to the cluster centers; and update and calculate cluster centers of every category at last. The iteration is repeated until the objective function can reach the minimum.

It also meets the following limiting conditions:

$$\sum_{i=1}^{c}\mu_{ij}=1,\forall j=1,2,\cdots,n(1\le j\le n) \tag{1}$$

Thus, it can be seen that the algorithm can realize the automatic identification of the system's modal parameters, and has a high calculation efficiency. Besides, the accuracy of the modal identification results is improved through the rectification of

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the authentic modal selection during the repetitive iteration process. The algorithm meets the requirements of online applications.

3 Auto pickup of modal parameters

After the introduction of the algorithm basis and the analysis of the key techniques, this part will present the specific implementation procedures of the algorithm. (See Fig. 1)

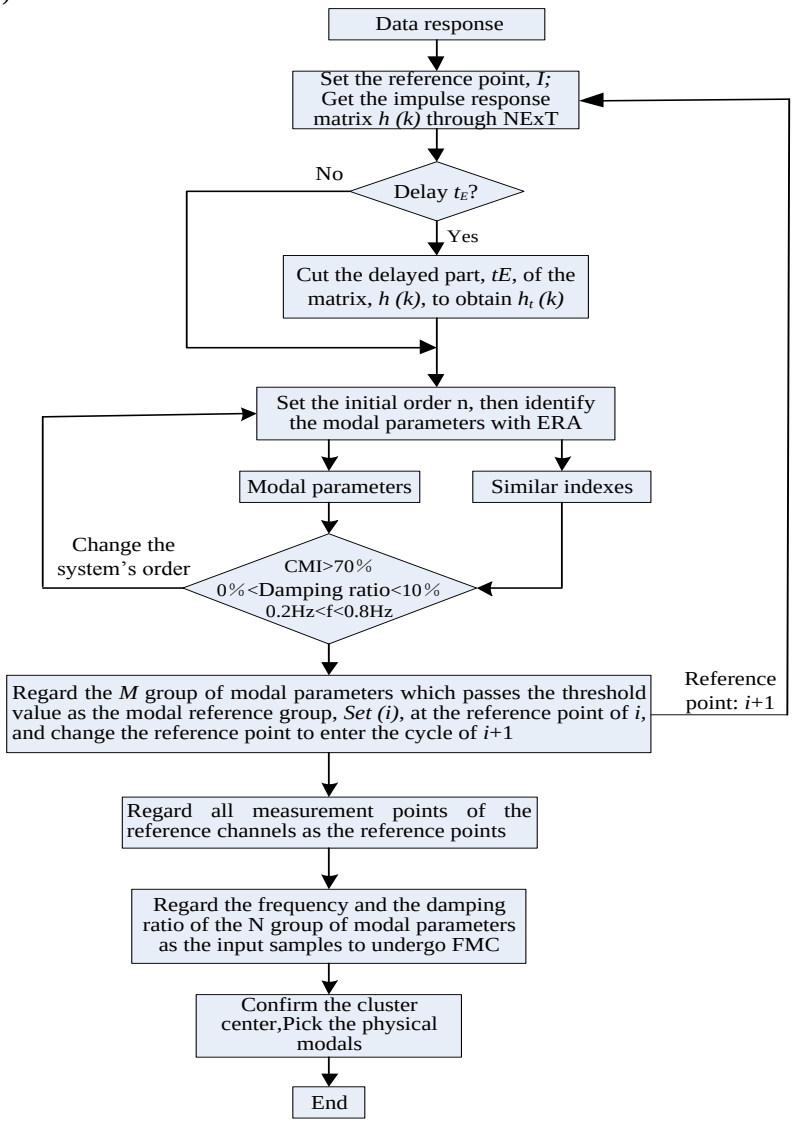

Fig. 1. The flowchart of automatic identification algorithm

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3 Conclusions

This paper puts forward the FCM-based NExT-ERA algorithm to conduct modal identification of low frequency oscillation noises. Under the environment excitation, the signals with a higher observability are selected from the data measured by PMUs as the signals of the reference channels. NExT is employed to obtain the cross-correlation function between signals so as to obtain the approximate pulse response function of the system. Then, ERA is adopted to conduct modal parameter identification of the pulse response at different orders. At last, the FCM algorithm is introduced to conduct automatic pickup of all identification results, which can not only identify the authenticity of modals, but also improve the parameter identification accuracy. The validity of the algorithm is verified through the simulation examples.

Besides, the algorithm put forward in this paper has advantages in the following four aspects:

1) The algorithm adopts the random loads generated by the electric power system as the natural excitation to avoid the complexity of the manual excitation. Besides, the parameters identified by it are more suitable for the operation conditions. Due to the limitation of algorithms, the modal identification in the previous literatures is mostly targeted at measurement signals based on large disturbance.

2) The algorithm has a sound noise resistant performance. When the Gaussian white noise is added into the signal, with the decrease of the signal-noise ratio (SNR) added, the algorithm can more accurately identify the modal parameters.

3) During the identification process of the authentic and false models, this paper introduces the FCM-based automatic identification algorithm, which improves the identification accuracy and the calculation efficiency. After setting some initial parameters, the algorithm put forward by this paper can achieve full automation and call for no manual intervention, so it boasts a promising online application prospect.

References

1. ZHU Fang, ZHAO Hong-guang, LIU Zeng-huang,et al. The Influence of Large Power Grid Interconnected on Power System Dynamic Stability. Proceedings of the CSEE, 27(1) , (2007) 1-7.
2. Ni J M, Shen C, Liu F. Estimation of the electromechanical characteristics of power systems based on a revised stochastic subspace methodand the stabilization diagram. Sci China Tech Sci, 55, (2012) 1677-1687.
3. Pierre J W, Trudnowski D J, Donnelly M K. Initial results in electromechanical mode identification from ambient data. IEEE Trans Power Syst, 12(3) , (1997) 1245-1251.
4. Wies R W, Pierre J W, Trudnowski D J. Use of ARMA block processing for estimating stationary low-frequency electromechanical modes of power systems. IEEE Trans Power Syst, 18(1) , (2003) 167-173.
5. D. J. Trudnowski. Estimating electromechanical mode shape from synchrophasor measurements. IEEE Trans. Power Syst, 23(3), p.p 1188–1195, Aug. (2008).
6. Zhou N, Pierre J W, Wies R W. Estimation of low-frequency electromechanical modes of power systems from ambient measurements using a subspace method. Proceedings of the North American Power Symposium, Rolla(2003).

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7. J. Thambirajah, N. F. Thornhill, and B. C. Pal. A multivariate approach towards interarea oscillation damping estimation under ambient conditions via independent component analysis and random decrement. IEEE Trans. Power Syst,26(1), (2011) 315-322.
8. G. H. James, T. G. Carne, and J. P. Lauffer. The natural excitation technique for modal parameter extraction from operating wind turbines. Sandia National Laboratories, SAND92-1666 UC-261. Albuquerque, NM, USA(1993).
9. J. Caicedo, S. Dyke, and E. Johnson. Natural excitation technique and eigensystem realization algorithm for phase I of the IASC-ASCE benchmark problem: Simulated data. J. Eng. Mech, 130(1) , (2004) 49-60.
10. Wan Ling, Hong Ming, Xu Junchen. Identification of modal parameters for model of a ship hull girder under ambient excitation based on NExT/ERA method. Journal of Ship Mechanics, 17(7) , (2002)774-784.
11. J. N. Juang and R. S. Pappa. An eigensystem realization algorithm for modal parameter identification and model reduction. J. Guidance Control, vol. 8, (1985) 620–627.
12. Li Huibing. Large engineering structures modal parameters identification technology. Beijing Institute of Technology Press: Beijing(2007).
13. WAN Qing, MIN Yong,ZHANG Yiwei. A New Algorithm of Oscillatory Active Power Increment Distribution in Low Frequency Oscillation Study.Automation of Electric Power Systems, 32(6) , (2008) 1-4.
14. Juang J N, Pappa R S. An Eigensystem Realization-Algorithm for Modal Parameter-Identification and Model-Reduction. Journal of Guidance,Control and Dynamics. 8(5) , (1985) 620-627.
15. Pappa R S, Elliott K B. Consistent-Mode Indicator for the Eigensystem Realization Algorithm. Journal of Guidance Control and Dynamics, 16(5) , (1993) 852-858.
16. Wu Chunli, Liu Hanbin, Wang jing. Parameter identification of a bridge structure based on a stabilization diagram with fuzzy clustering method. Journal of Vibration and Shock, 32(4), (2013) 121-126.
17. KUNDUR P. Power system stability and control. McGraw 2 Hill: New York , USA(1994).
18. G. Rogers. Power System Oscillations. Kluwer: Norwell, MA, USA(2000).

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