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An Equivalent Modeling Method for Multi-port Area Load Based on the Extended Generalized ZIP Load Model

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I. INTRODUCTION

To model the load area and simplify the electrical network, a multi-port area load equivalent modelling method (ALEEM) based on the extended generalized ZIP load model (EGZIP) is proposed. Different from the traditional ZIP load, the EGZIP load model incorporates the voltage magnitudes and voltage phase angles of all boundary buses, which can equivalently model the area load with multiple boundary buses more accurately. The load flow calculation considering the EGZIP is derived and analyzed. Also, based on the hierarchical and partitioning characteristics of the power grid, a multi-port equivalent strategy is proposed to reduce the number of parameters to be identified in the equivalent model. For parameter identification, the currents measured at varying operation conditions on the boundary bus are used to construct the least square estimation (LSE) problem. The interior point method is used to identify the model parameters. The simulation test conducted on the 87 bus system proves the equivalent model derived from the proposed ALEEM based on EGZIP has higher accuracy and the multi-port equivalence strategy can reduce both the number of parameters to be identified and the time consuming on equivalent process.

II. EGZIP LOAD MODEL

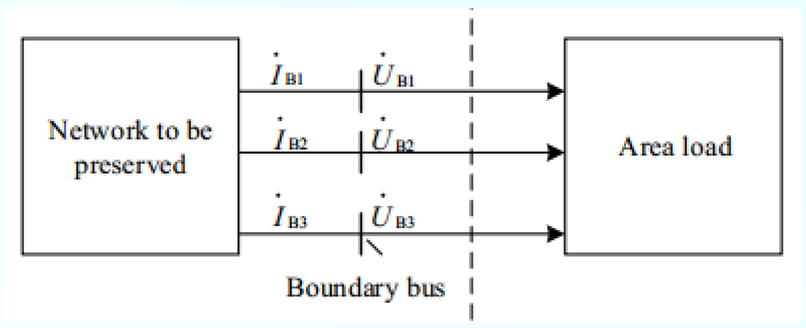


Fig. 1 The electrical network with area load

In the EGZIP load model, the equivalent load at each boundary bus is determined by the voltage magnitude and the differences of voltage phase angle between all boundary buses. Assuming that there are more than two boundary buses, the equivalent active load for boundary bus i is shown as follows:

$$P_i^{\mathrm{eq}} = \frac{1}{2}\begin{bmatrix} \boldsymbol{V} \\ \boldsymbol{\theta}_{\Delta} \end{bmatrix}^T \begin{bmatrix} \boldsymbol{A}_{\mathrm{VV}}^{pi} & \boldsymbol{A}_{\mathrm{V0}}^{pi} \\ \boldsymbol{A}_{\mathrm{V0}}^{pi\,T} & \boldsymbol{A}_{00}^{pi} \end{bmatrix} \begin{bmatrix} \boldsymbol{V} \\ \boldsymbol{\theta}_{\Delta} \end{bmatrix} + \begin{bmatrix} \boldsymbol{b}_{\mathrm{V}}^{pi} \\ \boldsymbol{b}_{0}^{pi} \end{bmatrix}^T \begin{bmatrix} \boldsymbol{V} \\ \boldsymbol{\theta}_{\Delta} \end{bmatrix} + c^{pi}$$

III. LOAD FLOW CALCULATION EMBEDDED WITH EGZIP

The matrix elements in the Jacobian matrix of the power flow equation should add the partial derivatives of active power with regard to voltage magnitude:

$$\partial P_i^{\mathrm{eq}} / \partial V_i = \boldsymbol{A}_{i\bullet}^{pi} \begin{bmatrix} \boldsymbol{V} \\ \boldsymbol{\theta}_{\Delta} \end{bmatrix} + b_{V_i}^{pi} \ ,$$

The partial derivatives of active power with regard to voltage phase angle:

$$\partial P_i^{\mathrm{eq}} / \partial \theta_j = \begin{cases} -\boldsymbol{A}_{(K+1)\bullet}^{pi} \begin{bmatrix} \boldsymbol{V} \\ \boldsymbol{\theta}_{\Delta} \end{bmatrix} - b_{\theta_{K(K-1)}}^{pi}, j = 1 \\ \boldsymbol{A}_{(K+1)\bullet}^{pi} \begin{bmatrix} \boldsymbol{V} \\ \boldsymbol{\theta}_{\Delta} \end{bmatrix} + b_{\theta_{K(K-1)}}^{pi}, j = 2 \end{cases}$$

IV. ALEEM BASED ON THE EGZIP MODEL

Fig. 2. depicts the equivalent electrical network with EGZIP load, which can substitute the original electrical network in Fig. 1.

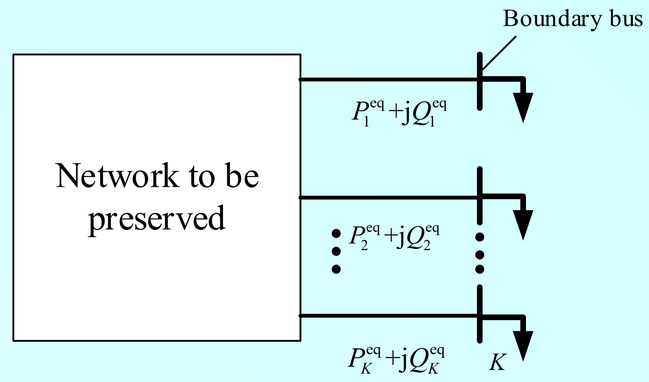


Fig. 2 The equivalent electrical network with EGZIP load

V. MULTI-PORT EQUIVALENCE STRATEGY

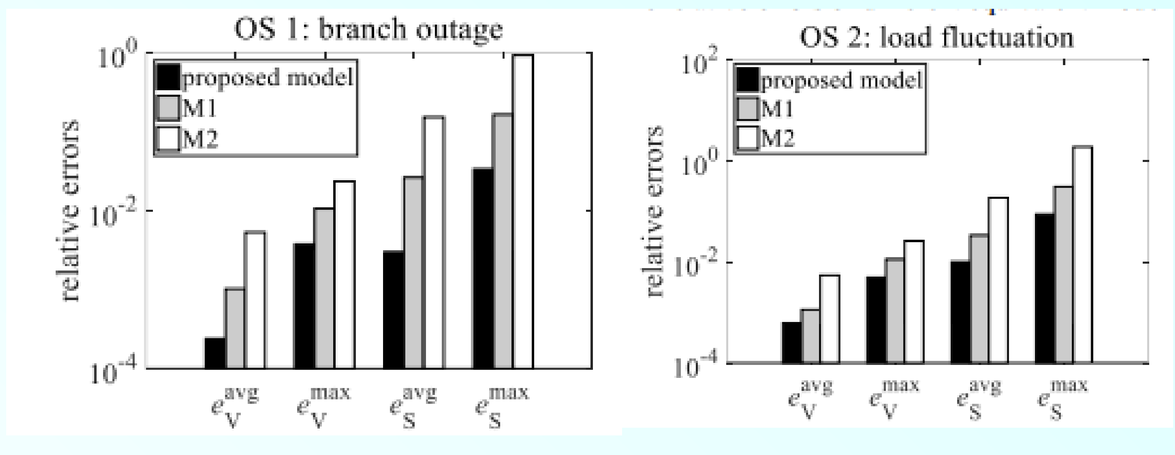
To diminish the unknown parameters, the multi-port equivalence strategy is adopted, the core of which are to equivalence different load areas separately. Accordingly, the dimensions of the unknown parameters is reduced greatly and the complexity of the least square estimation optimization model is assuaged.

VI. SIMULATION STUDIES

To demonstrate the effectiveness of the proposed model and the multi-port equivalence strategy, the simulation studies are carried out on the 87 bus test system.

THE EFFECTS OF EQUIVALENCE STRATEGY

Srategy	The number of parameters	Time (s)
combined	936	2.54687
multi-port	**252**	**2.06250**



VII. CONCLUSION

This paper proposes ALEMM based on EGZIP load model to construct the equivalent model of power system with area loads. Simulation tests are conducted on the 87 bus system. The test results demonstrate that multi-port equivalent strategy can reduce the parameters to be identified, thereby reducing the complexity of LSE problem and decreasing the consumed time on equivalent modeling. In addition, from the simulation tests under three operation states, it can be seen that the proposed equivalent model derived from ALEEM based on EGZIP has higher accuracy than other equivalent model in terms of the voltage magnitude and branch flow because EGZIP load model considers the mutual relationship of voltage between the boundary buses and it is the generalized version of ZIP load model.

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