Ambient-Frequency-Data Based System-Level Inertia Estimation Using Physical Equation and its Practice on Hawaii Islands

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Summary

In this work, a practical ambient-frequency-data based inertia estimation method using physical equation is proposed and validated by data from Hawaii island grids. With high renewable penetration, accurate inertia estimation is important and urgent. Ambient frequency oscillation always exists in power grid, so the proposed method has advantages of real-time inertia estimation and no need for additional disturbances. This paper first developed the physical equation for inertia estimation to offer clear mechanism for easy implementation in practice. To apply the proposed method in actual grids, a practical method to extract the ambient frequency oscillation from frequency measurement is further proposed. The inertia estimation using the physical equation is validated by KIUC simulation data and HECO field data, in which error rates are around 2% and 8%, respectively. Practical inertia estimation is challenging due to the large amounts of resources contributing to the power grid's effective inertia, but the method provided in this paper can offer a novel way for practical inertia estimation, which can help renewable penetration to boost carbon-free grid.

Process of the Ambient Based Inertia Estimation

(1) AFO feature extraction. The AFO is first extracted from the frequency measurements of FNET/GridEye. Then, the magnitude of the AFO is calculated;

(2) Equation model fitting. The extracted AFO magnitude, system load, and historical inertia, are used to fit the physical equation model to learn the quantitative relationship between the informative features and system inertia;

(3) Real-time inertia estimation. The above fitted physical equation is further implemented to estimate the system inertia using the real-time AFO measurements and system load.

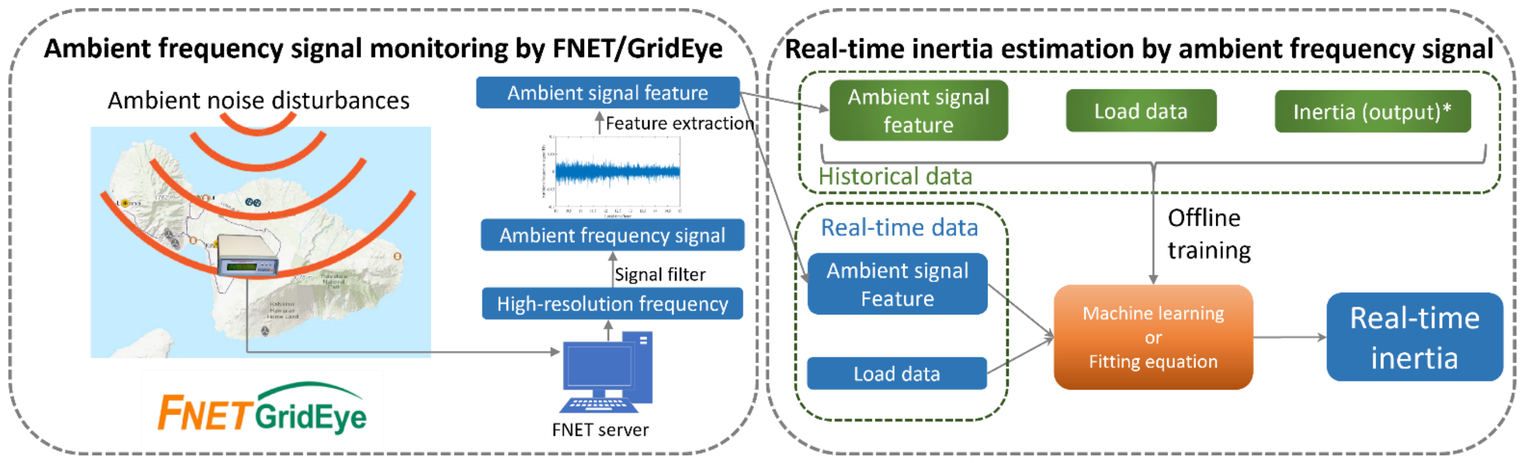

Figure 1 Progress of the proposed ambient-frequency-oscillation physical equation method.

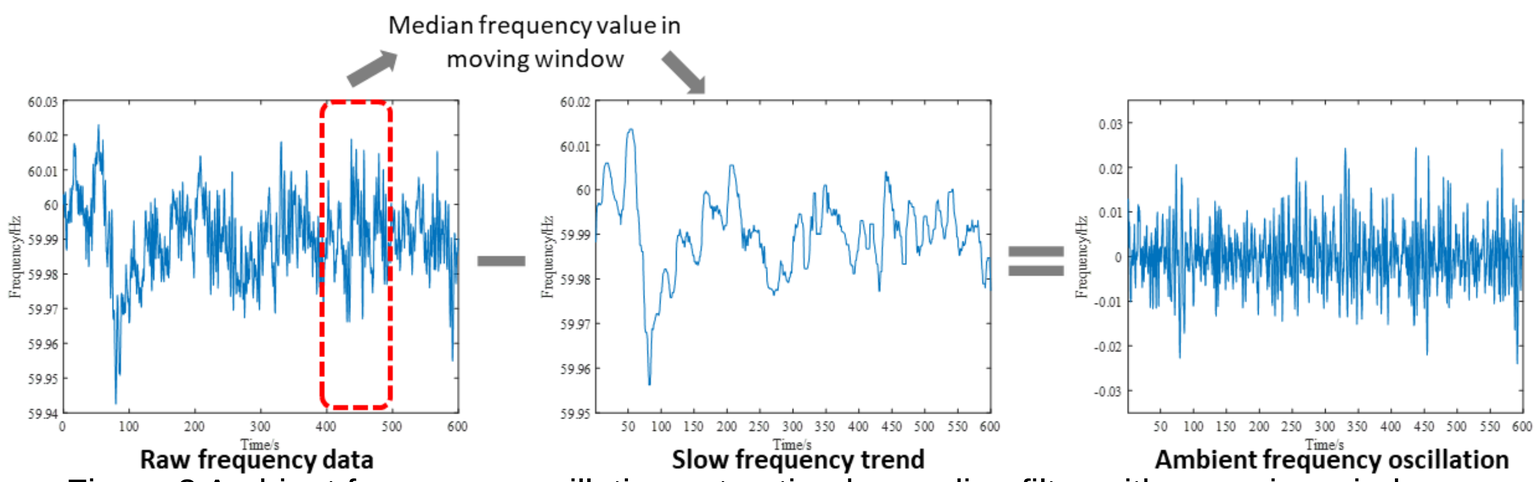

Figure 2 Ambient frequency oscillation extraction by median filter with a moving window.

Performance and Conclusion

The physical equation is derived for inertia estimation, which has the benefit of clear physical principles. A practical method of extracting the AFO from the actual frequency is also provided, which has advantage of easy implement. Then, a detailed process of using the proposed method in practice is proposed, which makes the proposed method can be used in real power system. The physical equation-based inertia estimation method is further validated using KIUC simulation data and the HECO field data, and achieved around 2% and 8% error rates, respectively. The results show that the proposed inertia estimation methods have satisfactory performance.

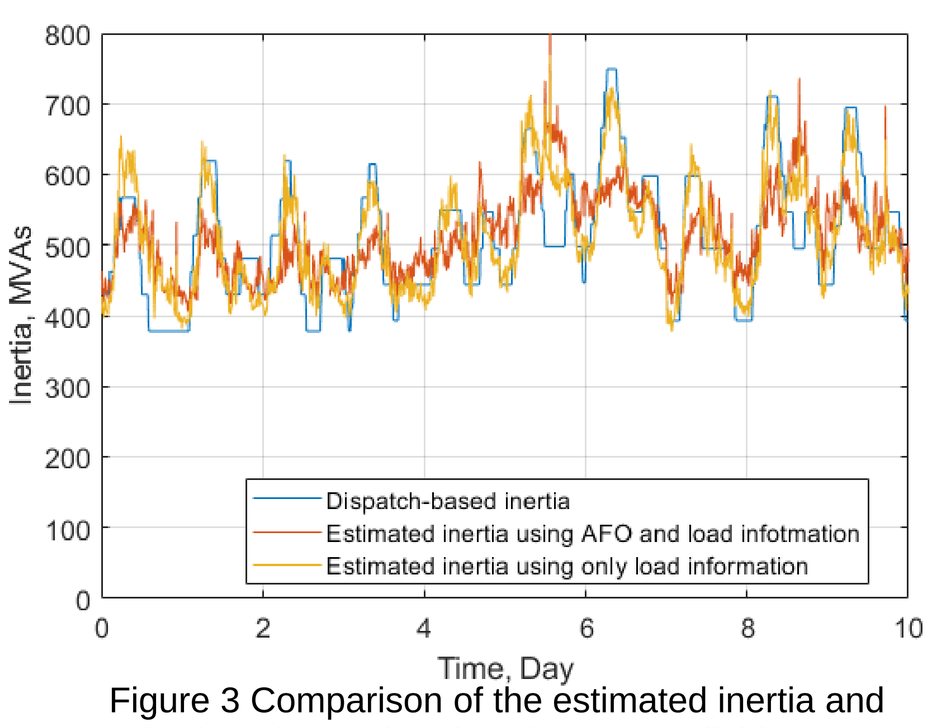

Figure 3 Comparison of the estimated inertia and the benchmark inertia using HECO field data.