Observing the Power Grid by Real-time Frequency Data

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Introduction

The traditional power grid has been fairly opaque from a user perspective because of limited sensor data and/or data are classified, or unavailable for some users.

Future grid is transitioning from a centralized structure, with unidirectional power and data flow, to a distributed grid with increasing diversity in which users are no more than just data and power receivers. This change requires availability of additional data that need to be developed at users end. With synchrophasor technology implemented, the real-time data such as frequency and frequency patterns will be acquired by users. This frequency data can reflect instantaneous events as well as long-term patterns of the grid.

Therefore, in future smart grid when every user has access to frequency monitoring and reporting, the utility can easily and quickly get knowledge about frequency deviation in all local areas without gathering all the data. This user-participation can lead to a system with better stability and faster response time.

In our simulation, we use frequency data as feedback in load frequency control. Examples about how frequency deviation reflect the grid are also listed.

Background

Local frequency sampling devices

A frequency sampling device can acquire frequency data from users home outlet, as shown in Fig. 1.

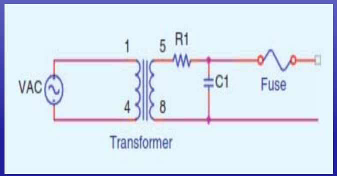

Figure 1. Circuit of sampling device

$$P_L = P_G + \frac{2H}{f_0}\frac{d}{dt}f_D + \beta f_D$$

Load frequency control equation

This basic equation describes the relation between grid frequency and generation-load balance. Frequency deviation is always related to power changes in the grid.

Method

We combine operational frequency pattern prediction with the event detection by local frequency measurement as shown in the block diagram in Fig. 2. When load frequency control is added as feedback in the block diagram as shown in Fig 3, the frequency stabilizes in its new steady state as shown in Simulink simulation result presented in Fig. 4.

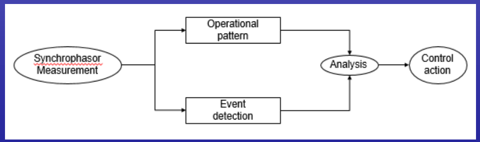

Figure 2: Control action development block diagram

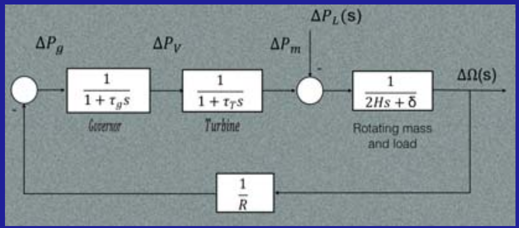

Figure 3: Isolated power system frequency control block diagram

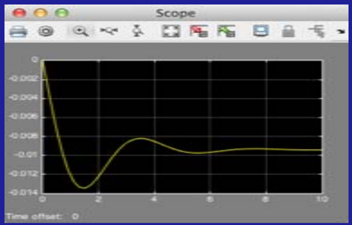

Figure 4: Frequency response in simulink

Frequency deviation patterns

Frequency data patterns characterize the operational characteristics of a grid by showing the average frequency deviation over a day, as shown in Fig. 5. Observing the periodical patterns results the information of changes in power flow or generation, due to market forces and human schedules.

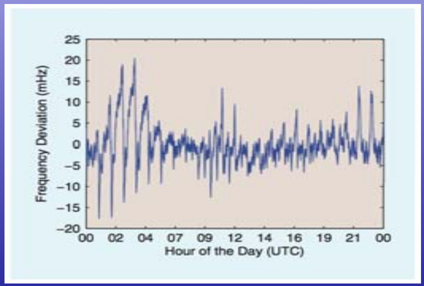

Figure 5: A stored daily frequency deviation pattern

Power grid events

In addition the instantaneous frequency deviation detected by widely available synchrophasor measurement technology provides information about the grid operations and events, such as generation loss shown in Fig. 6. Combining the operational patterns and instantaneous events' detection leads to timely discovering the events in the grid and taking the actions.

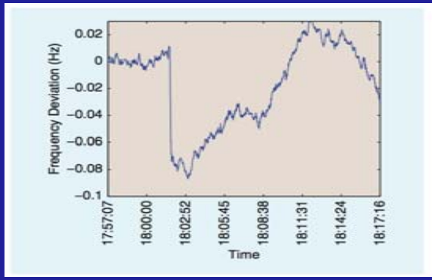

Figure 6: Instantaneous frequency deviation with sudden loss of generation

Conclusion

Frequency is strongly connected with power flow in the grid. By observing both the frequency deviation pattern and the instantaneous frequency deviation we can get knowledge about power flow in the grid and thus take actions to stabilize frequency. In smart grids, users will obtain frequency data by local sampling devices and get involved in event detection and frequency control, which results in better stability and faster response time of the power system

References

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