Digital Energy

Effective Inertia

High non-synchronous renewable penetration

Avoid major blackouts and financial (reputational) penalties due to ineffective management of system frequency

EFFECTIVE INERTIA Meter and Forecast to Master High Renewable Integration

KEY OUTCOMES

- Increase network resilience.
- Prevent potential blackout.
- Reduce curtailment fees and penalties.
- Lower frequency response services.
- Increase renewables penetration.

KEY FEATURES

- Nonintrusive metering.
- No engineering project to install expensive hardware required for signal injection.
- Regional and global inertia metering.
- Real-time metering.
- EMS and PMU PDC agnostic.
- Forecast from analytics.

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OVERVIEW

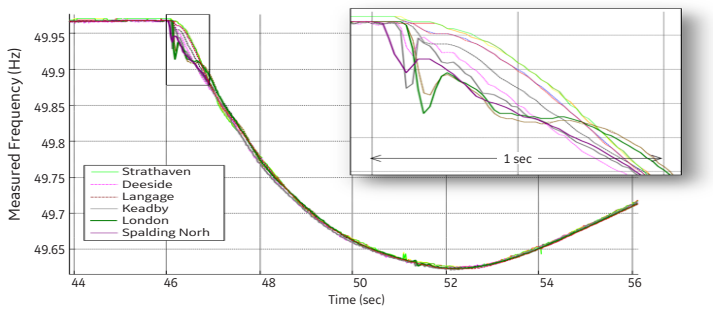
Effective Inertia: The Frequency Alert Indicator

The operation of the grid is continuing to grow in complexity, due to the growing volume of variable renewable generation. This has led to a massive displacement of system Inertia, with networks now requiring enhanced system visibility and understanding to deliver fast-acting response services. Analytics services now facilitates the measurement and forecasting of Effective System Inertia.

Effective inertia measures the combined inertia-like effects of rotating machines, passive load responses, and active generator controls. GE Effective Inertia metering is **nonintrusive**, with no injection of forced stimulation into the network. **WAMS data and analytics** measures effective inertia in each regional area of the power system in **real time**, and can combine them to a global value.

Metering real-time effective inertia **provides confidence to operators** about the margin and the risk on the current position, to make a decision on the appropriate frequency response service. Furthermore, the **Effective Inertia Forecast** allows forward planning to reduce the cost of services.

GE inertia metering and forecast is **agnostic of EMS and PMUs**; however, integration within the **GE Advanced EMS** Network, Generation and WAMS advanced applications maximize overall solution value.



- When inertia reduces, then load shed limits may be reached for governor response, resulting in a blackout.
- Frequency change takes time to propagate > Angles diverge > Stability risk.
- Frequency and RoCoF (Rate of Change of Frequency) varies substantially between locations in the first seconds.

Customer profiles

- Transmission System Operations (TSO)
- Regional Transmission Organization (RTO, ISO)
- Integrated utilities (generation, transmission, distribution)

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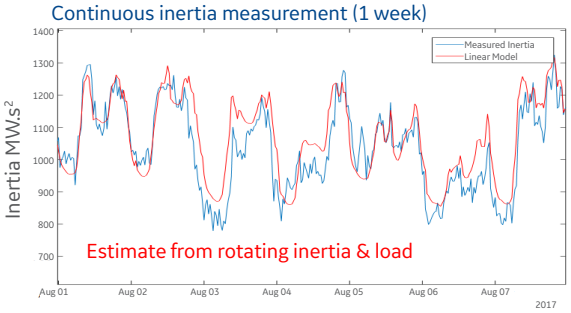
Avoid major blackouts from frequency drops - Lower frequency service costs

Effective Inertia Metering

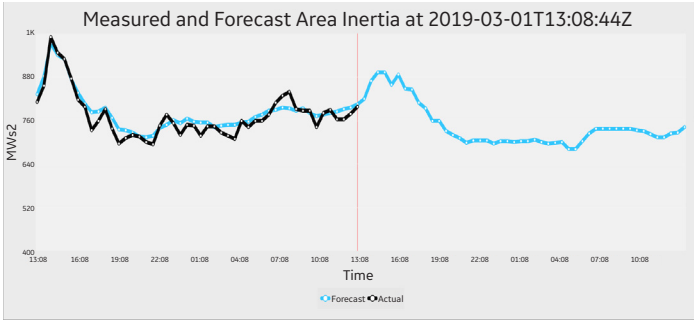
- The principle is built upon a proven PMU-based method for continuous metering at a regional level.
- The frequency is measured at selected points within the area, preferably close to main sources of real inertia.
- PMUs are located on all transmission circuits crossing the area boundary > summation of net power exchange.



Inertia metering versus model estimate

Effective Inertia Forecast

- Applying machine learning relates inertia to known and predictable values: conventional rotating inertia, load, solar power, wind power.
- Accurate inertia forecasting give the TSO confidence in a secure level of renewables penetration and associated reserve services.



Inertia forecast chart showing historical forecasts vs. actual metered inertia and 1-day ahead forecast

Fast Frequency Control: WAMS control to provide fast frequency service

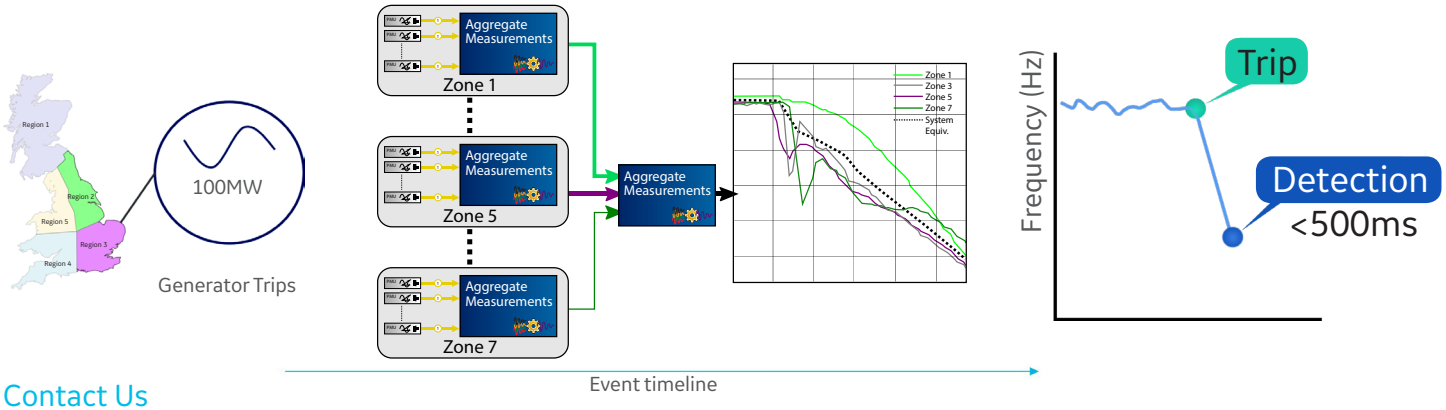
KEY FEATURES

- Fast detection.
- Real-time resource availability.
- Minimize the risk of system separation.
- Targeted and proportional response.
- Harness fast-acting resources in a reliable and safe manner.

WIDE-AREA MONITORING AND CONTROL SYSTEM

System split into a number of regions:

- Multiple distributed controllers.
- In each region, PMUs send data to aggregators.
- Aggregated signals broadcast to controllers.
- Resource information sent to a central supervisor.



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