Synchronized real time data: a new foundation for the Electric Power Grid.

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Conjecture: Synchronized GPS based data time stamping, high data sampling rates, phasor measurements and increased accuracy are leading to major improvements in grid reliability and security; as well as, substantial reductions in distribution losses and real time congestion relief: a direct effect on utility company profits.

Currently installed systems include over 40 phasor measurement units (PMUs) feeding highly available standard off the shelf real time data centers. These centers will rapidly scale to 100s of PMUs, such at those currently being installed in China. A few applications based on these new data are outlined below.

Benefits

Prevention of Blackouts

Early detection of grid problems

Real time calculation of grid stress metrics alert operators of the likelihood of grid failures. This information helps operators stiffen the grid, in many cases by adjusting the PSS devices on the offending generators or modulating loads. Metrics are based on real time computation of FFTs, wavelets, matrix pencil, and real time Prony damping analyses.

Early location of disturbance

Identification of the location of disturbances provides means of preventing propagation of grid disturbances: such technology includes computing real time multi-dimensional complex FFTs.

Real time power islands

Real time information necessary to form power islands will help prevent blackouts from cascading to wider areas. More efficient load flow solution methods based on distributed processing architectures are being used in these calculations.

More efficient use of assets

Congestion relief

Maximize throughput of existing lines by means of accurate synchronized measurements.

Equipment condition monitoring

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Real time assessment of aging equipment: transformers, capacitor banks, breakers, switches, and relays.

Demand Response

Time of use billing

Shift load peaks to reduce spinning reserve requirements. Reduces overall cost of supplying power.

Virtual Power Generators

Modulate residential loads (refrigerators and air conditioners) in real time providing energy for use in critical infrastructure applications. Over six million meters with up to eight remotely controlled relays are being installed in Denmark.

Outage management

Reduction of restoration time based on real time synchronized measurements combined with real time distribution network models. This includes real time use of smart residential meters for improved outage management.

Loss minimization

Transmission losses

Improved three phase models calibrated using real time phasor data.

Distribution losses

Real time control of circuit topology to minimize thermal losses.

Distributed generation

Use of distributed generators to reduce loss and control the distribution network.

Renewable generation

Wind power injections

Better models of connections between wind generation and the connected distribution grid combined with sophisticated feedback control using PMU devices.

Residential solar power injection

Improved control of distribution networks to handle large solar loads. Aggregation of solar power for market trading. Loads of one MWh can bid into wholesale markets. Both wind and solar aggregators will need improved forecasting algorithms.

Approach

Improved accuracy

Digital control of the power grid requires accurate measurements of the fundamental forces that drive the grid: voltage and current. The basic sensors to perform these

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measurements should be improved to provide at least 0.2 percent accuracy. From the fundamental measurements, other key variables are derived including: real power, reactive power, power factor, frequency, phase angle, flicker, etc.

Time synchronization

Grid measurements should be time synchronized to an accuracy of 1 microsecond. A continuous time system should be used. The current IEEE Standard specifies UTC time which is discontinuous. This can cause serious problems at every time transition (4 times yearly).

Standards based

New devices installed in the grid should meet the IEC 61850 and related standards. This provides interoperability between vendor equipment.

Integrated System Model

Improved network models running on distributed loosely coupled clusters, supporting larger and more accurate models. These will operate across voltage levels, and multiple phases. The models should run in near real time and be coupled with real time data.

Improved graphics

With far more variables being measured, operators will need better ways to view the data.

Proposed architecture

Common real time data center

High performance secure steaming databases will be used to provide a common data access to both streamed and transactional data. These provide a common naming system for all variables. The data centers will support thousands of simultaneous connections all requesting high volumes of historical and real time data.

High data rates

Power system equipment protection requires very high speed data for control and blackout prevention. For real time control (such as adaptive relaying or wide area protection), typically 30 or 60 samples per second for each variable along with an accurate time stamp are required, with the control action occurring in 100 to 500 mS. The time stamp accuracy should be better than 1 microsecond and the samples should be synchronized based on IEEE standards. A typical modern measurement unit would include up to 100 variables each sending 60 samples per second, or over 6000 samples per second from each meter. Sophisticated data compression technology will be used to reduce the volume of data without loss of information. Compression algorithms only filter out random noise: no process information is lost, a common misconception about data compression method.

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Large data volumes

Data volumes will be very high. Typically in the 10's of terabyte range for small applications. Larger applications, such as a National grid monitoring system will require petabytes of on line storage.

Common access to data

A service oriented architecture will support client requests for data. These secure calls will support web standard WSDL queries so that applications can determine how to request data from the servers.

Security

Two factor authentication, optimized data center architectures, along with physical security of the data centers provide state of the art secure access to authorized clients. Datastream security is essential to provide data access protection from inside attack. Each datastream will have multiple levels of security controlled via single sign-on technology.

High Availability

Data centers will include high availability architectures. Multiple servers form a "collective" to which clients connect. Role based access to the data is supported with two factor authentication controlling access to information in the database. Servers in the data center can be maintained without loss of data, and with no measurable impact on client response times.

Certified measurements

The accuracy of the primary measurements as well as dependent variables should be certified. Current standards, for example the C37.118, define only static accuracy: but, dynamic accuracy is also required so that the measurements remain accurate during transients in the grid.

Feedback control

The real time data center information will be used for multiple types of feedback control. Initial applications include wide area protection soon followed by adaptive relaying and real time voltage stability control.

Fast simulation modeling

A new generation of load flow algorithms will solve very large network problems in real time. These will be direct methods that do not require matrix inversion. The solution speeds of these new algorithms are directly proportional to the number of processors used. The model used will be the integrated system model as outlined below.

Integrated system modeling

There will be only one model used within a utility. This will support all departments requiring models: operations, maintenance, transmission, distribution, outage management, asset management, planning will use single integrated system model. The model will be distributed over cities, regions, provinces and state grid corporations.

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Improved graphics

Animation

Operator screens will make extensive use of animation. Some of this will be based on concepts from computer gaming area.

3D objects

Substation 3D models will be used for maintenance as well as real time control.

3D data surfaces

In order for humans to interpret these new high volumes of data, new method of data displays will be required. Surface charting of these data will be a common method of display.

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