Grid Architecture Component Class Specification

Component Class Designation: Grid Sensor

Summary Overview

Grid sensors are composed of two parts; a transducer that measures and converts a system state into a low voltage electrical signal, and an associated device which provides a means to process and transmit the state information. For the example of transmission line voltage, the transducer is a potential transformer that converts high voltage to a low voltage (typically 5V). It sends the low to a SCADA processing device, which converts it to a digital signal, adds meta-data (e.g. time) and transmits the data via a communications path.

Sensors provide state information about the grid to control devices, systems used for situational awareness, data repositories that are used for planning, disturbance analyses, market systems, and many other purposes.

~~Sensors are the devices that transduce grid and related variables into electrical signals and then (usually) into digital data for use by grid processes, including protection and control, analytics, planning, and market functions including forecasting and measurement and verification for settlement.~~

Definitions

Transducer- a device that takes a physical state measurement and creates a proportional low voltage output that can be used by an electronic device for processing and communicating. The measurement taken may be physical (e.g. force) or electrical (e.g. line voltage) but the outputs are nearly always low voltage, low current analog signals.

~~Smart ~~S~~s~~ensor – a device consisting of a transducer, signal conditioning, analog-to-digital conversion, some amount of local data processing capability, and a communications interface

Commented [RTG1]: Define smart and be consistent

Smart Sensor- a sensor which has embedded communications

~~Line sensor – a device that transduces circuit voltage or current to a signal; if the device is a smart sensor, it may calculate a variety of values, such as real and reactive power, RMS values of voltage and current, and harmonics of the power waveforms~~

Component Class Description

Purpose and Function

The purpose of a sensor is to measure a physical state variable and convert ~~a physical variable~~ it into a low voltage, low current analog or digital signal which can be easily stored and/or transmitted. The form of the variable largely determines the nature of the transducer whereas the characteristics of the processes or devices that will consume the sensor signal determine much about how the signal is converted to digital form, transported, persisted, and processed. The function of the sensor is to transduce the physical variable into a voltage (or current) signal, and the optionally convert it to digital form and provide the signal to other devices and systems. Table 1 below lists a number of standard grid sensor types.

Table 1 Typical Grid Sensors

Device Type	Comment
Relay, through which various instruments such as Voltage Transformers (VT's –used for AC voltage sensing) and Current Transformers (CT's –used for AC current sensing) are read	advanced digital relays may provide as many as a thousand different data points for readout
Substation instrumentation (i.e. weather stations, substation battery monitors, fire sensors, etc.)	can supply data on substation device/subsystem state, health, and sensor telemetry
Meters (residential, C&I, feeder, substation)	Usage data and some grid state variables; C&I meters may also provide waveforms and power quality data
Recloser, sectionalizer, and inter-tie switch controllers; capacitor, voltage regulator, and line drop compensator controllers; tap changer controllers and monitors	Can supply data from internal sensing elements on grid state variables and device health and status
Line sensors and their Remote Terminal Units (RTU's)	Line sensors have AC voltage and/or current sensing capability (through VT's and CT's attached to the power lines) plus local computation of derived quantities like real and reactive power
Faulted circuit indicators (FCI's)	Indicate if a fault current has passed through the sensing point
Substation RTU's	Act as gateways for substation sensor data in older substation designs; can also have control capability
Fault recorders (waveform recorders, digital fault recorders)	Record power waveforms related to circuit faults in detail for later analysis
Serial event recorders	Record grid events for later analysis
Power quality monitors	Record power waveforms in detail for later analysis of waveform conformity to standards
Transformer dissolved gas analyzers (power substation)	Asset health sensing
Transformer partial discharge monitors (power substation)	Asset health sensing
Transformer top oil temperature monitors (power substation)	Asset health sensing
Line sag/sway/Aeolian vibration monitors	Located on transmission lines or at towers
Line ice/snow load monitors	Located on transmission lines or distribution feeder lines
Bushing capacitance monitors (transformer and breaker) and cable tan delta monitors	Asset health sensing
Phasor Measurement Units (PMU's) for both transmission and distribution	Streaming data sources being widely deployed on Transmission; will move to Distribution as well
Cable temperature monitors incl. fiber/Raman backscatter transmission line temp measurement systems	Asset health sensing
Fuse and distribution transformer monitors	Asset health sensing

Device Type	Comment
Distributed Energy Resource (DER) controllers and gateways	Point of contact for aggregated DER data

<u>Key externally visible properties</u>

Output data rate –

Data acquisition mode – Power grid devices and sensors operate in one or more of five data acquisition modes:

- Polling – a polling master queries the device, which responds with the most recent values of the specified data points; polling is usually on a regular schedule and data volume per query is modest.
- Report by exception – the device pushes a data message to the master when the data changes by a specified amount.
- Streaming – a sensor sends a continuous stream of data, once streaming is initiated and until streaming is terminated by command or abnormal exit condition.
- Interrogation of stored files – the device maintains a log or data file; upon query, it transmits the log or file to the master. This differs from polling in terms of data size per query and frequency/regularity of the query.
- Asynchronous event message – the device uses internal processing to detect a specific condition indicated by the data, and spontaneously sends an event message to the master or any subscribing system. The message may or may not contain actual sensor data relevant to the event; the internal event can be a clock signal or countdown, so that the messages are sent on a regular basis, but initiated by the sensor, not a central controller. This method can and does result in message bursts and floods, due to multiple grid devices reacting to the same physical event. These bursts and floods can easily overwhelm the communications network and the application that is handling the messages.

Polling is common in grid control systems, but report by exception is used in some systems to reduce data volumes and therefore communication line bandwidth. Streaming is common for advanced sensors such as PMU-based wide area measurement systems (WAMPACS). Interrogation of stored data files is common for meters, data loggers and grid devices that collect records on a power waveform-triggered basis. Asynchronous event messages are becoming more common in devices that contain significant local processing and are therefore able to detect and report events.

Data classes – Table 2 below describes the set of data classes that can be produced by grid sensors.

Table 2 Grid Sensor Data Classes

Data Class	Description	Key Characteristics

Telemetry	Measurements made repetitively on power grid variables and equipment operating parameters; some of this data is used by SCADA systems	Constant volume flow rates when the data collection technique is polling; standard SCADA polling cycles are about 4 seconds, but the trend is to go faster; telemetry can involve a very large number of sensing points. Telemetry data usually comes in small packets (perhaps 1500 bytes or so). PMU data streams at anywhere from 30 to 120 samples per second per device.
Oscillography	Sample data from voltage and current waveforms	Typically available in bursts or as files stored in the grid device, captured due to a triggering event; transferred on demand for use in various kinds of analyses. For some kinds of sensing systems, waveform data is acquired continuously and is consumed at or near the sensing point to generate characterization values that may be used locally or reported out (e.g., converting waveform samples to RMS voltage or current values periodically); waveform sampling may be at very high rates from some devices such as power quality monitors.
Usage Data	Typically meter data, although metering can occur in many forms beside residential usage meters; typically captured by time-integrating demand measurements combined with voltage to calculate real power	May be acquired on time periods ranging from seconds to 30 days or more; residential metering may store data taken as often as 15 minutes, to be reported out of the meter one to three times per day
Asynchronous Event Messages	May be generated by any grid device that has embedded processing capability; typically event messages generated in response to some physical event; this category also includes commands generated by grid control systems and communicated to grid devices; may also be a response to an asynchronous business process, e.g., a meter ping or meter voltage read	For this class, burst behavior is a key factor; depending on the nature of the devices, the communication network may be required to handle peak bursts that are up to three orders of magnitude larger than base rates for the same devices; also, since many grid devices will typically react to the same physical event, bursting can easily become flooding .
Meta-data	Data that is necessary to interpret other grid data, or to manage grid devices and systems or grid data	Meta-data includes power grid connectivity, network and device management data, point lists, sensor calibration data, and a rather wide variety of special information, including element names, which may have high multiplicity

Interface descriptions

For most sensors, the transducer is generally interfaces through a Remote Terminal Unit (RTU) that provides signal filtering, conversion to digital form, and communication to systems that use the data. A wide variety of communication interfaces and protocols are used for grid sensors but generally, they are serial data in any of the data acquisition modes listed above. DNP3 is widely used in the US, but IEC

61850 protocols are gaining a foot hold. For streaming sensors (mainly PMUs) IEEE C37.118 and IEC 61850-90-5 are commonly used.

Table of relevant standards

Standard Name	Description	Version/Date
IEEE C37.118	IEEE Standard for Synchrophasor Measurements for Power Systems	
IEC 61850-90-5	Communication networks and systems for power utility automation - Part 90-5: Use of IEC 61850 to transmit synchrophasor information according to IEEE C37.118	
IEEE 1451	Standard for Smart Transducers	
IEEE 1379-2000	IEEE Recommended Practice for Data Communications Between Remote Terminal Units and Intelligent Electronic Devices in a Substation	

List of Attached Documents <list Visio drawing packages, Xcel spreadsheets, etc.; add rows as needed>

Document Name/File Name	Description	Version/Date

Version History

Action	Date	Description	Author(s)
created			