Intelligent Wind Farm Data Automation Using IEC Standards

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Abstract— **Wind power as a green and renewable source of energy is growing very fast. Governments and utilities around the world have encouraged over the last years the commissioning of wind farm projects—using wind as a clean power source. This led to the development of new standards and architectures to make wind farm data available and meet the requirements for wind farm monitoring.**

In this paper, we propose a novel approach to automate wind farm data. The solution processes collected data and generates non-operational information that will serve for production and wind power forecasting as well as operational information, such as turbine status, turbine counters, active power of each turbine and total power of the wind farm. Using the IEC 61400 protocol and IEC 61131-3 automation languages embedded in a data concentrator, our solution communicates with various components and concentrates the data to make it available to different clients. In addition, the collected data will be processed to generate statistical information (periodic, minimum, maximum, average and standard deviation) and key indicator information (availability counters, power) thanks to a customized automation module.

Index Terms—**Automation, Renewable Energy, Forecast, Statistical Calculation, IEC 61400-25, IEC 61131-3, Wind Power.**

I. Introduction

Goverments and utilities around the world have encouraged over the last years the commissioning of wind farm projects—using wind as a clean power source. This led to the development of new standards and architectures to make wind farm data available and meet the requirements for wind farm monitoring. Wind farm data is collected from several heterogeneous data sources. Indeed, the new generations of wind farm communications systems are mainly based on three types of data sources: wind turbines, weather stations and substation data. Substation data is essentially gathered from Intelligent Electrical devices (IEDs). Second, the collected data needs to be communicated to several clients such as Supervisory Control and Data Acquisition (SCADA) systems deployed at control centers (CC), substation local Human Machine Interface (HMI), and off-site data historians. Third, wind farm data is collected in a raw format and may not be helpful for the decision-making process. Therefore, it will be necessary to perform advanced operations, such as data correlation between different data sources, and advanced calculations to help end-users in forecasting and making decisions. The IEC 61400-25 has been introduced as an emerging protocol extended from IEC 61850 to allow communication with wind turbines. It allows to have monitoring and control solutions as separate parts, and to use a system to store, analyze and present wind power information. Despite these capabilities, current implementations of this protocol generate an important amount of turbine status data. This is not suitable for the decision making process, because the end-user needs to have a clear information about the turbine availability. Furthermore, current implementations do not offer aggregation mechanisms to provide a number of wind farm indicators such as the global availability/non availability and other status turbine counters related to specific conditions (as turbine stopped for low temperature conditions).

In this paper, we propose a novel approach to automate wind farm data. The solution processes collected data and generates non-operational information that will serve for production and wind power forecasting as well as operational information, such as turbine status, turbine counters, active power of each turbine and total power of the wind farm. Using the IEC 61400 protocol and IEC 61131-3 automation languages embedded in a data concentrator, our solution communicates with various components and concentrates the data to make it available to different clients. In addition, the collected data will be processed to generate statistical information (periodic, minimum, maximum, average and standard deviation) and key indicator information (availability counters, power) thanks to a customized automation module.

II. Wind farm communication architecture

According to the project specification described in [1], the required data to be transmitted from the wind farm to the SCADA system is divided in four categories:

- Substation data (statuses, alarms, meters, etc...)
- Weather towers data
- Turbines data
- Production data.

To achieve these requirements, a wind farm communication system has been proposed as described by Fig. 1. A data concentrator collects the data from multiple sources using TCP/IP or RS232/485 connections. The wind turbines and weather towers are connected to the substation using optic fiber connection. The wind turbines are either connected to a proprietary server which is connected to the data concentrator or directly connected to the substation network. In addition, the data concentrator collects the information of intelligent electrical devices such as meters, protection equipment and power quality modules. The collected data will be subsequently published to different data clients such as distribution grid SCADA, historian servers and local HMI.

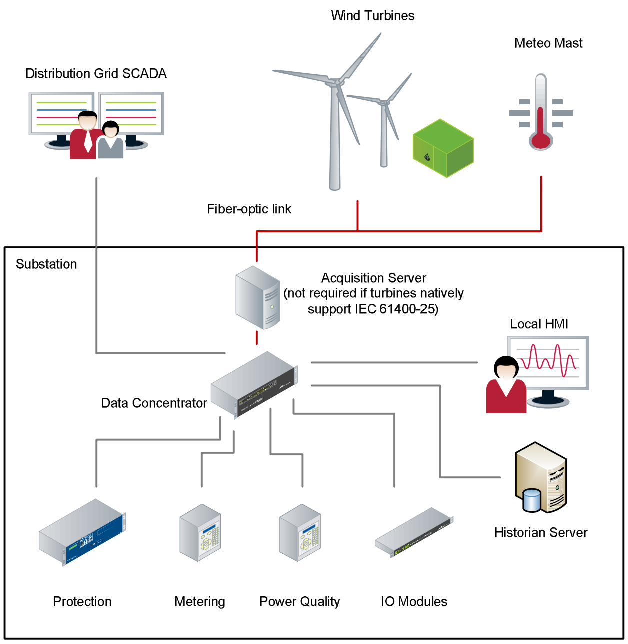

Fig. 1. Typical wind farm architecture

Furthermore, the data described above can be delivered to end users in two different forms: *real time data*, which is basically a simple transmission of the acquired information from all the devices in the substation or computed from this data (for key indicator information as availability turbines counters, availability power at the wind plant, etc.) and *statistical data* which is calculated from real time data and transmitted periodically to SCADA systems [1]. This data is used by the utility to build up an historical database which is used for forecasting and impact analysis purposes [3]. Tables 1 and 2 give some examples of data which can be generated from a wind farm automation system.

Statistical Value	Period of calculation
Minimum	10 minutes
Maximum	10 minutes
Average	10 minutes
Standard deviation	10 minutes

Table. 1. Statistical data calculated from wind farm data

Data	Sampling Rate	Transmission Period	Units
Active power	1/5 Hz	10 minutes	MW
Available power of turbines	1/5 Hz	10 minutes	MW
Substation available power	1/5 Hz	10 minutes	MW
Number of turbines stopped - low wind	1/5 Hz	10 minutes	-
Number of turbines stopped - high wind	1/5 Hz	10 minutes	-
Number of turbines stopped – icing conditions	1/5 Hz	10 minutes	-
Number of turbines stopped - low temperature	1/5 Hz	10 minutes	-
Number of turbines stopped - high temperature	1/5 Hz	10 minutes	-
Number of turbines in operation	1/5 Hz	10 minutes	-
Number of turbines available	1/5 Hz	10 minutes	-
Number of turbines in production	1/5 Hz	On change	-

Table. 2. Statistical data and counters which can be calculated from wind farm data

III. IEC 61400-25: A BRIEF OVERVIEW

According to IEC61400-25 User Group [2], the IEC standard series 61400-25 provides a solution for access to wind power plant information with standardized data names and semantic. It gives possibilities to procure monitoring and control solutions as separate parts, and to use a single system to store, analyze and present wind power information. In addition, the standard opens up for control and monitoring of information from different wind turbine vendors in a homogeneous manner.

The use of a standard communication solution is beneficial for all parties - vendors, system integrators as well as the customer. The additional cost of developing and maintaining vendor specific solutions are costly for vendors, system integrators and the customer. A standard communication solution lowers the cost of integration and maintenance for all parties involved. In addition, vendors have the opportunity to focus their core business - creation of facilities for efficient and optimized operation of wind turbines by including a standard communication solution in their product portfolio [2].

Fig.2 depicts a breakdown example of a wind turbine into logical nodes (LN). Each wind turbine model includes a list of mandatory logical nodes (in green boxes). This list can be variable from one turbine vendor to another but it is always recommended to keep all the logical nodes in the turbine model. The detailed name of each logical name can be found in [2].

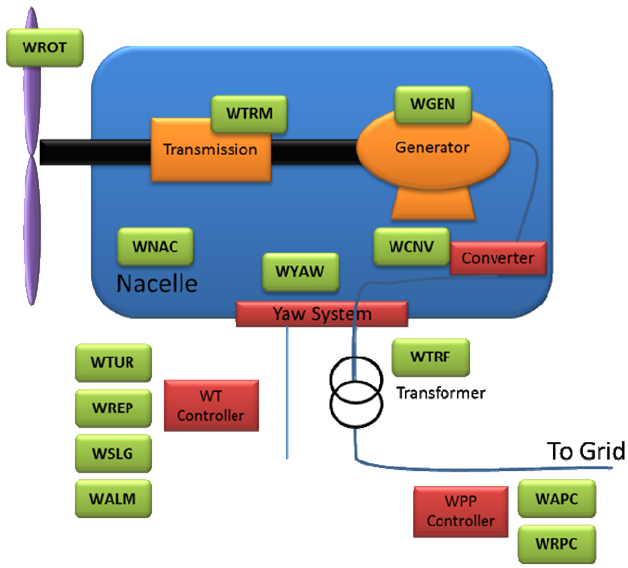

Fig. 2. Modeling a wind turbine using IEC 61400-25 Standard

Although the defined data model allows providing a large number of information to the end user, some of the required information detailed in the previous sections (such as wind farm counters) cannot be provided by the current implementations. Furthermore, some of the calculated counters require additional information from devices other than the wind turbines. For example, the total number of turbines available in the wind farm is based on the turbine availability. Both are calculated by the following rules:

Rule 1: Turbine availability:

If Turbine Status is "Running" And the Feeder Status is "Active"
Then
Turbine is Available.

Rule 2: Total number of turbines available in the wind farm:

Number of turbine available = Sum of turbines with status "Available"

The above rules show that the turbine availability is calculated by considering the turbine status and the feeder status which is provided by IEDs. This information will be transmitted as a real time value to end user and will be also stored in a local memory to calculate the 10 minutes statistical values. To accomplish these requirements, we propose to use advanced processing capabilities offered by IEC 61131-3 automation language. The proposed architecture will be detailed in the next section.

IV. WIND FARM DATA AUTOMATION ARCHITECTURE

Using the IEC 61131-3 automation language, we proposed a software solution that allows processing the information gathered from wind turbines, weather towers and IEDs. Fig. 3 depicts the different parts of the architecture.

The calculation of counters is handled by the rule base module which uses the turbine statuses (using IEC 61400-25) and the electrical equipment statuses (using various number of communication protocols such as DNP3, IEC61850, Modbus). These calculated counters will be transmitted in real time to utility SCADA and historian servers and they will be displayed in the local substation HMI. They will be also stored in a temporal memory managed by the statistical module. This one will use the stored data as well as other information gathered from weather towers, wind turbines and IEDs to calculate 10 minutes statistical data. The data concentrator will take this information, convert it to a specific communication protocol and send it to all the subscribed systems.

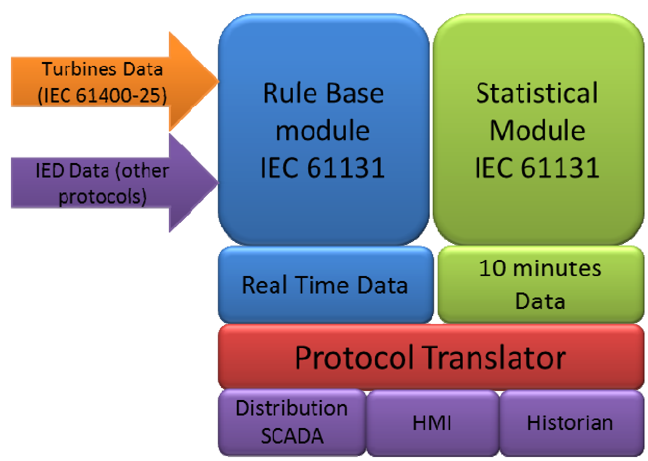

Fig. 3. Proposed Wind Farm Data Automation Architecture

V. CONCLUSION

As discussed in several technical papers and utility workshops such as in [3], the availability of wind farm data such as turbine data as well as meteorological mast data, allowed the development of automated reports to retrospectively analyze the impact of specific weather conditions on the farms' generation, or the time periods with particularly bad weather forecasts (ramping amplitude and phase errors for instance). Such information is necessary to reduce the cost of integration of wind farms since it provides better tools for data analysis and energy production forecasting. This information has to be retrieved from the wind farm in a reliable way and according to custom specifications which are not supported by the current definition of IEC 61400-25. We proposed this solution to respond to such requirements and to reduce the data bandwidth since all the statistical calculation is performed on the field and communication between the wind farm and the SCADA system occurs every 10 minutes instead. Therefore, only operational information is transmitted in real time.

References:

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[1] [2] IEC 61400-25 User Group. http://www.use61400-25.com/

[2] [3] V. Balvet, J. Bourret, J-E. Mubois, SAGIPE: A Real-Time Data Acquisition System for the Massive Integration of Wind Generation in Hydro-Québec's Power System, CIGRÉ 2009, Calgary, Canada.

VI. Biography

Foued Barouni is a Product Application Engineer at EATON. He manages sales projects in automation and cybersecurity solutions for the utility industry. He is active in numerous projects involving standard protocols. His work experience includes design and engineering of telecommunication and SCADA systems for distribution, transmission and generation assets. He has special interests in renewable energy, substation automation and communication protocols. Foued Barouni is a graduate of Computer Science Engineering from the INSAT Institute of Tunisia (Bachelor) and Université Laval of Québec, Canada (Master and PhD). He is also member of CIGRÉ Canada and IEC TC57 Technical Expert.