Open systems for optimal integration of renewable energy

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***Abstract*— An alternative to the wide variety of proprietary communication protocols, which are often found in equipment for small-scale electricity generation, is the "best practice" to use a communication based on open standards. This presentation explains the benefits of using open systems based on ISO 14908 for optimal integration of renewable energy. Examples are presented of applications with some of the leading brands of inverters and control devices. Included is a discussion of the value of developing interoperable device level profiles to help facilitate better control and monitoring. An example is also given how this is further evolving to the Industrial Internet of Things.**

Keywords – communication; interoperable; control; monitoring; LonMark; Industrial Internet of Things; OpenADR

I. Introduction

Today, buyers of equipment for small-scale electricity generation often end up in a vendor lock-in situation, for example because the equipment uses a proprietary communication protocol. There are many such protocols, often one for each manufacturer. This can limit the owner of the equipment in many ways. For a more optimal integration of renewable energy, the best practice is to use a communication protocol based on open standards.

The LonWorks technology was originally developed by Echelon Corporation, based on an idea of the former Apple CEO Mike Markkula, and has over the years evolved into several standards, including ISO/IEC 14908-1. LonMark International is a global membership organization promoting open, multivendor control systems based on LonWorks technology. Some uses of the technology are:

- Buildings, for building automation
- Cities, in particular for control of street-lights
- Grids, such as Enel's remote metering
- Transportation, for example in trains

LonWorks is not dependent on Echelon any longer and it is possible to make LonWorks systems without using any product from Echelon, as you would expect from an open system.

Normally LonWorks is used for distributed control. Systems can contain many communicating nodes (devices).

II. Some of the LonMark benefits

A. *LonMark's nine questions for finding a long-term solution*

One of the key strengths of LonMark is to avoid vendor lock-in by enabling systems to be built in an open way. A true open system must pass the following test:

- Will my system be open to competitive bids after the initial installation?
- Can I install a system with multiple user interfaces from multiple suppliers?
- Is there built-in security at the low-level network-infrastructure level?
- Can I maintain my system by myself?
- Will I receive all the tools I need to fully maintain my system?
- Can I choose multiple bidders for my subsystems and have their products all integrated into one enterprise system?
- Is my system designed for only a small portion of my integration needs, or can it work with all of the components?
- Can I select products from multiple vendors and distributors and not be locked into a single vendor or source?
- Will all of the products that I select be guaranteed to work on the same network infrastructure?

B. *Power line communication*

In order to reach also small devices like load controllers, the option of being able to communicate over existing power lines is important. Unlike wireless communication, it is not blocked by metallic walls etc. LonWorks power line communication does not go through transformers, but this can be bridged by seamlessly using another media, e.g. for communication between two parts of a grid separated by transformer. Optional repeating available is a unique advantage, because it can – where needed – overcome some of the traditional limitations of power line communication.

This paper was presented at the 13th Wind Integration Workshop and published in the workshop's proceedings

C. No need to use strange naming

Industry standards related to IEC 61850, such as IEC 61400-25-2, unfortunately specify some designations that are identical with SI units but are used for other purposes, apparently without a thought of the confusion it can create. For example, Hz is sometimes used as a designation for frequency in general (not only as a unit of frequency). The strange naming conventions of such standards are not necessary to follow when working with the LonMark Interoperability Guidelines.

It would be welcome if the standards that use strange naming could be revised in the future, to address that, so their naming could become more attractive to use (perhaps also for LonMark). The International System of Units, abbreviated SI from French, has formed a basis for science and commerce for a long time and should prevail.

III. Examples of Applications

A. Small energy systems

Several systems for integration of small-scale renewable energy have been implemented using the open approach, integrating leading brands of inverters and control devices. It has thus been shown that it is possible, and very useful, to combine devices from different manufacturers, including:

- Studer Innotec's inverters in the Xtender range and compatible other devices
- SMA inverters with Data1 protocol
- ABB drives
- Morningstar's solar controller TS-MPPT-60
- Lufft weather stations
- Echelon's i.LON SmartServer
- Secyourit control devices
- Various electricity meters

Figure 1. An InnoVentum Dali PowerTower in the Philippines.

Some equipment can be delivered with an interface according to the corresponding LonMark Functional Profile, which is further explained below in section IV. That has been the case for example with ABB drives, which fulfill the Variable Speed Motor Drive Profile. To accomplish integration of components using proprietary communication protocols, some special drivers have been developed by TEROC, which provide protocol translation. Thus, even such components can be integrated in open systems, but the effort to develop the driver can be large (or only possible to do by the manufacturer, if the protocol is kept secret by them).

Earlier TEROC implemented the open approach for small-scale renewable energy applications in Sweden, Estonia, Bolivia and Brazil. Recently a hybrid system for power generation by wind and solar energy was commissioned at the Scandinavian Children's Mission in the Philippines by the Swedish company InnoVentum, in cooperation with TEROC. This site has grid connection, but power outages are common in some parts of the Philippines. With this system, the electricity is normally supplied partially by the grid and partially by wind and solar, when the grid is working, thus lowering the electricity bill from the utility and reducing the burden on the grid. When the grid is not working, some loads can still operate, because they are supplied by solar and wind in combination with a battery bank. The open approach of the control system enables the different components to function better together, including prioritization of the use of energy by load control (which leads to a longer power backup time for high priority loads when the power supply from the grid is not working) and remote monitoring (not only of one brand of equipment). The system is part of a broader InnoVentum initiative called Power to the Philippines, which targets also disaster relief. Reducing the burden on the grid can be especially important if the grid is operating close to its limits. Where there is no grid, the same type of systems can work autonomously.

Also the Fraunhofer Institute for Solar Energy ISE has used the i.LON SmartServer and devices for load control by power line communication [1]. The limitations they found could probably be overcome by repeating.

B. Wind turbine control for a weak grid

A project is under development on the northern side of lake Hjälmaren in Sweden, where there is plan to install a DirectWind 900 kW wind turbine next year. However, the grid is weak and the local utility would, with a traditional approach, allow only 700 kW maximum power to be installed to a 10.8 kV line there. This has to do with slow voltage variations from power flow calculations. They are concerned that during periods of low demand and high wind, a higher output from the wind turbine might raise the voltage for nearby customers above permissible limits.

TEROC has proposed an alternative solution using an active control system implementing Active Management Strategies (AMSs), which will allow a 900 kW wind turbine to be installed. This control system is based on extensive experience of control systems for hybrid power systems, including wind-diesel systems with very high wind penetration, deployed earlier.

The proposed control system will measure voltage on the local grid and communicate the data to an additional wind turbine controller, which sends a setpoint for reactive and maximum active power to the wind turbine's ordinary controller. The wind turbine would use active pitch control and variable speed with a full power converter, which means that the converter can adjust to these setpoints very quickly. Lowering the setpoint for active power can cause the turbine rotor to momentarily accelerate the rotational speed, but the rotational speed is prevented from exceeding its limits by the pitch control. In some cases, curtailing the maximum active power of the wind turbine will reduce the energy generation, but such losses are expected to be small.

Previous research performed by Chalmers University of Technology shows that up to twice as much wind power can be installed in a weak grid by implementing AMSs, compared to a situation without AMSs [2].

Just like for the previously mentioned controls for small systems, TEROC intends to use an open system based on international standards and LonMark guidelines. This provides a good basis for scalability to large systems.

C. *Buildning integration*

It is reported that the Wendelstein high school uses on-site generation by solar energy and a LonMark system where all systems like HVAC, energy data acquisition and lighting control are integrated. Approximately 1000 nodes are used in the building automation network of the high school. It is considered the most modern high school in Bavaria and already has won several awards [3].

IV. DEVICE LEVEL PROFILES

LonMark International is known for enabling multi-vendor interoperability through its Interoperability Guidelines. A key element of this document includes functional profiles that define device connectivity. Functional profiles contain the inputs and outputs of a device that enable products from multiple manufacturers to be connected together in a control network. The network inputs and outputs of a functional profile are provided by network variables and configuration properties. The network variables provide the operational data inputs and outputs for the functional block. The configuration properties configure the behavior of the functional profile. Each functional profile defines mandatory and optional network variables and mandatory and optional configuration properties.

The so called Standard Network Variable Types, used in functional profiles, are the core of interoperability. For example, a temperature variable using SNVT_temp is expected to use an integer between zero and 65535 that corresponds to a temperature between –274 and 6279.5 degrees Celsius.

LonMark International tests and certifies compliance with its Interoperability Guidelines, including functional profiles. There are over 500 certified products listed on the LonMark website, enabling open, interoperable systems.

As an example, a graphical summary of a functional profile of a Generator Set is shown in Fig. 2. Applications of this particular profile can be found e.g. in Cummins products.

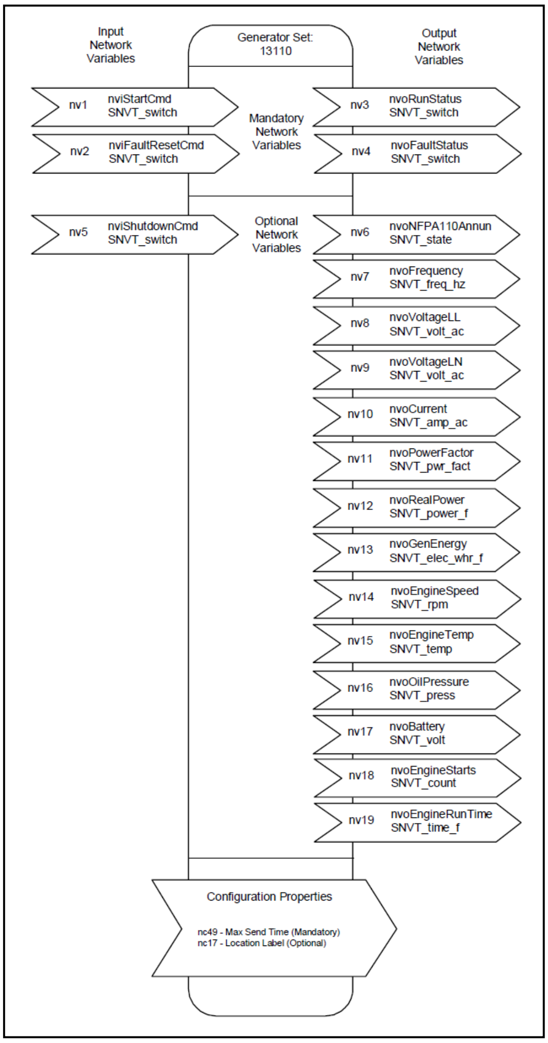

Figure 2. Generator Set functional profile.

Companies interested in the development of functional profiles for renewable energy are welcome to contact the author.

V. INDUSTRIAL INTERNET OF THINGS

Many application developers are talking about the Internet of Things (IoT). While there is a significant amount of hype over IoT, it is difficult to define since it means different things to different people. For the purpose of this paper, we will focus on a specific segment of the market known as the Industrial Internet of Things or IIoT. IIoT refers to industrial objects, or "things," that automatically communicate over a network – without human-to-human or human-to-computer interaction – to share information and take action, often autonomously. As these are largely non-consumer applications, they require a level of robustness, security and reliability not typically found in the general IoT solutions provided by consumer products.

Successful implementations of the IIoT will require an interoperability framework supporting multiple transport layers and multiple application domains. While the convergence on IPv6 is clearly moving forward, the MAC/PHY layers are on treadmill of continuous evolution. Recognizing the significant industry momentum behind IIoT, LonMark is updating its interoperable framework to include to support multiple standard transports, an Internet friendly representation standard for interoperable device profile definitions, and a markup structure for data encoding rules and object addressing.

VI. Integrating with OpenADR

Many utilities are turning to an international standard for automated demand response, called OpenADR or Open Automated Demand Response. OpenADR is an open and interoperable information exchange model that standardizes the message format used for Auto-DR so that dynamic pricing (e.g., hourly 'day-ahead' or 'day-of' real-time pricing) and reliability signals can be delivered in a uniform and interoperable fashion among utilities, DSOs, and customers' energy management and control systems.

OpenADR can be used to balance the grid during rapid changes in the availability of renewable energy resources by automatically shifting loads to balance supply and demand. OpenADR can also be used to implement price-based programs that use economics to drive customer consumption behavior.

Hundreds of companies are integrating the OpenADR profiles into a wide-range of residential, commercial and industrial products. This broad product offering provides and ideal opportunity to connect the smart grid to control systems complying to the LonMark interoperability standard.

Acknowledgment

Thank you InnoVentum and Julien Daligault for the permission to use the photo in Fig. 1.

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