

## Modeling of Control Systems Dedicated to Dispersed Energy Sources

**Abstract.** The paper presents a modeling method for SCADA systems that considers service conditions, data acquisition and the applied communication standards. Modeling of the SCADA operation for dispersed sources can be realized various ways. Multi-variant modelling responds to varied expectations and tasks realized by the energy source depending on its installed power, kind of installation or the way of its operation. The model should include several cooperating modules that exchange information.

**Streszczenie.** Artykuł przedstawia sposób modelowania Systemów Sterowania i Nadzoru (SSiN) z uwzględnieniem właściwości eksploatacyjnych i informatycznych oraz zastosowanych standardów komunikacyjnych. Modelowanie pracy SSiN dla źródeł rozproszonych może być realizowane wielowariantowo. W modelu uwzględnić można szereg modułów współpracujących i wymieniających informacje pomiędzy sobą. (**Modelowanie systemów sterowania dedykowanych dla źródeł rozproszonych**).

**Keywords:** SCADA modeling, dispersed generation, communication standards.

**Słowa kluczowe:** modelowanie systemów SSiN, energetyka rozproszona, standardy komunikacyjne.

doi:10.12915/pe.2014.03.57

### Introduction

Technological developments and growing demand for low-emission power generation have considerably increased the significance of dispersed generation within energy policies. It entails a number of legal and technological problems, which need to be solved. Those problems are differently viewed by energy source owners and by system operators [1]. In order to solve those issues it is necessary to develop a proper environment for the cooperation between a dispersed energy source and the grid. One way to ensure safe predictable and efficient operation of the source is to equip this source with a well-fit system of supervision and control (SCADA). The mentioned system sets up an environment that supplies information about the source operation, its environment and the electric power system whereto it is connected. The SCADA system structures can be varied, depending on the needs of the source owner. Such systems make possible to develop intelligent networks, where the electricity source fully cooperates with the power network system [2].

A modeling method for SCADA systems that considers service conditions, data acquisition and the applied communication standards, has been presented. Modeling of the SCADA operation for dispersed sources can be realized various ways. Multi-variant modelling responds to varied expectations and tasks realized by the energy source depending on its installed power, kind of installation or the way of its operation. The model should include several cooperating modules that exchange information. The first element of that model is the energy source. For the sake of safety and reliability of the source operation, its control system has to be autonomous, which means that it should operate properly even if there is no data exchange with the remaining elements of the model. The second modeled element is the local process visualization that enables the human-machine communication (HMI) and provides current information about the energy generation process. The third required element is an electricity management module that visualizes the source-grid cooperation at the grid connection point. This three-module model can be developed by adding other modules such as a weather station, cooperation with the system protection, measurement and energy costs or data exchange with the SCADA of the grid operator. The modules to be included not necessarily need to be directly related to the source

operation, but can also concern the energy market or optimization of the grid operation [3].

Although in practice dispersed generation control systems are not very complex, the Authors have elaborated SCADA models based on the standards CIM and IEC 61850 [4] together with its extension that describes the operation of dispersed sources. Such an approach makes possible to describe SCADA models according to the recommendations for Smart Grids and enables cooperation with other elements that compose an intelligent system.

### Dispersed generation

Dispersed energy sources can be divided into three groups depending on their installed power:

- microsources – installed power range from 1 to 500 kW [5].
- small sources – installed power up to 5 MW,
- medium sources – installed power range from 5 to 50 MW,
- large sources – installed power range from 50 to 150 MW,

Typically, energy sources of higher installed power are connected to the medium voltage or high voltage grid. Typical small energy sources are:

- hydro-electric power stations,
- wind turbines and wind farms,
- photovoltaic power plants,
- diesel engines,
- piston and gas turbines.

All energy sources, even the smallest ones have to meet relevant legal requirements. The conditions are provided by the Energy Law and an ordinance of the Minister of Economy with more detailed rules given by the Operation and Maintenance Instructions for distribution grid operators.. Additionally, relevant regulations of construction law have to be met together with getting adequate licenses required by the law. As far as the connection terms are concerned realization of adequate metering and protection systems is of considerable importance. Legal and technical conditions affect the needs of dispersed source operators as they induce minimal functional conditions for the control systems of the sources.

According to the concept that dispersed generation is one of the elements that form a Smart Grid and in order to ensure compatibility of the dispersed source SCADA System with the SCADA of a Distributed System Operator

(DSO) it is necessary to select technical solutions that can be accepted by both sides. In documents, where the standardization process for smart grids is described [6] it is strongly emphasized that the grid structure modeling should be based on the CIM standard (IEC 61970) and that unconstrained data exchange based on standard IEC 61850 [5] should be possible.

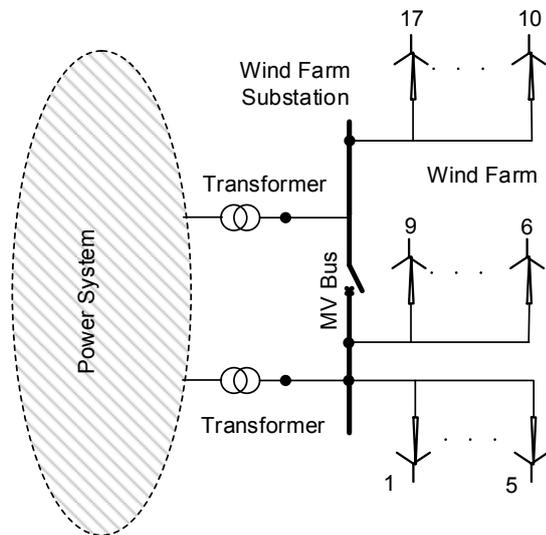


Fig.1. Interconnection scheme for a wind farm

Legal and technical conditions affect the needs of dispersed source operators, because they induce minimal functional conditions for control systems of the sources.

### Modeling of control systems dedicated to dispersed energy sources

At modeling of a dispersed energy source control system it is necessary to precisely define expectations for the source and its importance for the power system. Technical conditions to be strictly met should be recognized together with additional requirements that follow from the DSO's needs. When defining the additional requirements it seems to be purposeful to answer such questions as:

- What kind is the source ?
- What is the operation mode of the source (constant power i.e. biogas generator/ variable power – wind turbine)?
- Is it possible to control the source operation ?
- Will the source operation control be used for the optimization of the power system operation?
- Will the source operation control be used for the cost optimization at energy purchase/sale ?

Answers to the above questions lead to a conclusion that there can be a number of SCADA models that depend on the source character, its installed power or tasks realized for the grid or for the DSO. In order to avoid the SCADA system modeling for each kind of a dispersed source, the Authors propose a multi-variant model that consists of a number of modules cooperating with each other.

The modules can be analyzed into the following groups: Primary modules that are essential for controlling of the power generation process :

Energy source – the first and the most important element of the model. The source control module is autonomous, which means that it should operate properly

even if there is no data exchange with the remaining elements of the model.

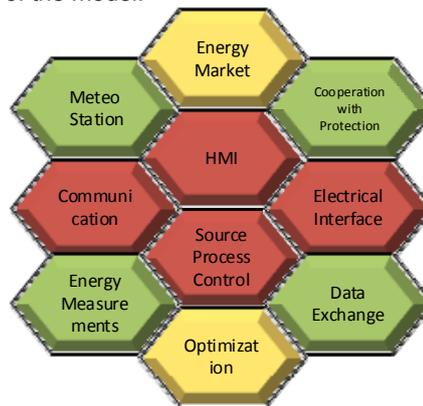


Fig.2. SCADA model. Primary modules (red), additional (green), optional (yellow)

HMI – Human Machine Interface – a local control SCADA station that enables the user-machine communication and presentation of the current data.

Electrical interface – describes the electric equipment and electric parameters of the required elements that cooperate with the source.

Communication – an interface that makes possible to define the way of data exchange between individual elements.

Additional modules supporting the source operation:

Meteo station – describes weather conditions in the source environment.

Module of cooperation with the system protection.

Energy metering module.

Module of data exchange with supervising systems or the DSO's SCADA.

Optional modules, used in large supervising systems, such as:

Energy market module,

Grid optimization module.

Except for the primary modules that are included in all control systems, additional and optional modules can be partially modeled.

### Wind Farm SCADA elements

Taking into account the variety of dispersed energy sources and their varied operational characteristics, the below considerations will be focused on one type of dispersed energy sources, that is on wind turbines. A twelve-turbine wind farm connected to the MV network system will be discussed (Fig. 1.).

In order to describe a SCADA model for the above mentioned sources terminology of the IEC 61850 [5] and of additional documents such as IEC 61850-7-420 describing dispersed generation and IEC 61400-25-2 [7] describing control systems of wind turbines has been used. The mentioned standards use an abstract hierarchical model of data for the description of individual system elements via the so called Logical Nodes (LN) that include their functions and attributes.

Such a description is stored in XML files that store data about individual SCADA elements and their attributes. With the application of the model elements described in the previous section, it is possible to assign to them the information stored in individual logical nodes (LN).

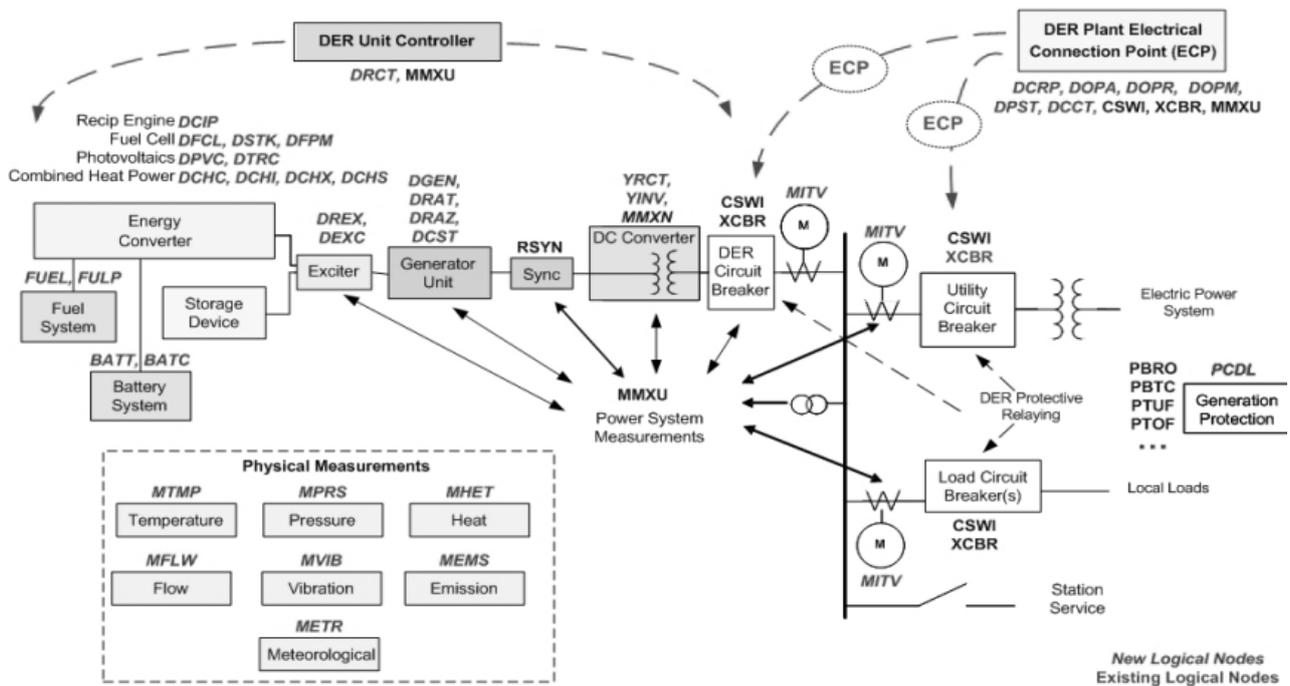


Fig.3. Logical devices and logical nodes for distributed energy resource (DER) systems [8]

### Energy source

Energy source as a single wind turbine can be described using a group of LNs that represent electrical and mechanical parts of the turbine. Logical nodes that describe the mechanical part are the following:

- Basic information about turbine (WTUR),
- Rotor information (WROT),
- Transmission information (WTRM),
- Nacelle information (WNAC),
- Yawing information (WYAW).

For the electric element modeling purposes, it is necessary to know what is the generator type and the energy conversion process in a single turbine. Fig. 3

presents a simplified diagram of the Enercon E82 wind turbine with a synchronous generator.

For the control of the electrical part the following nodes can be used:

- General information about turbine (WTUR),
- Generator information (WGEN),
- Converter information (WCNV),
- Generated active power information (WAPC),
- Generated reactive power information (WRPC).

In the case of a wind farm that consists of many turbines, individual logical nodes that describe the operation of each wind turbine have to be adequately numbered.

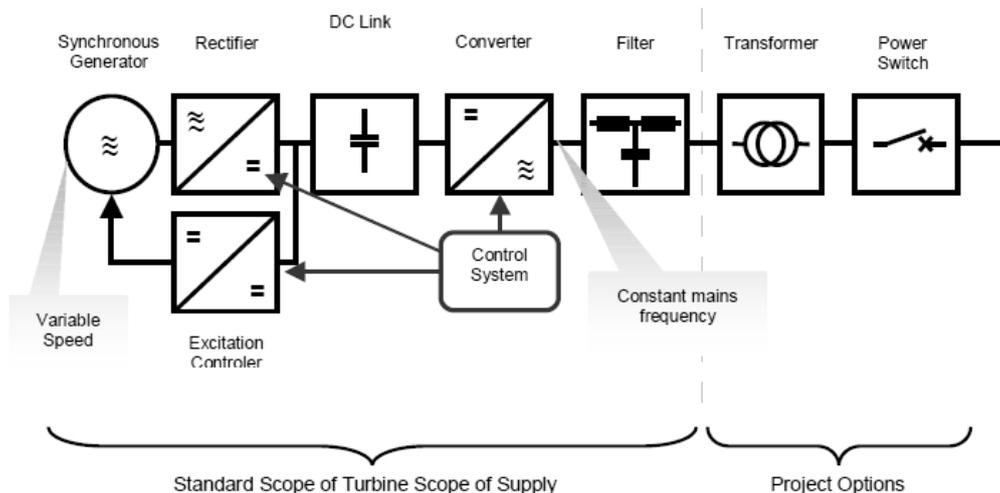


Fig.4. Energy evacuation scheme for the wind turbine Enercon E-82 [9]

### Human-Machine Interface

Human-Machine Interface functions as the system operator for a wind farm. Logical nodes that are assigned to it can be grouped into two categories that describe the operation of a single turbine and of all the system. These are the following nodes:

- Alarm information (WALM),
- Analog measurements (WSLG),
- Generated active power information (WAPC),
- Generated reactive power information (WRPC).

The above data translated through the SCADA system form a control application that shows the condition of a wind turbine for its operator.

### Electrical interface

The electrical interface is composed by elements that describe basic electrical equipment of individual turbines and of a MV switching substation that connects the wind turbine to the distribution grid. These elements are:

- Turbine transformer (WTRM),
- Circuit breaker (XCBR),
- Voltage measurement (MMXU),
- Current measurement (MMTR).

### Communication

The communication module is an element that is responsible for the cooperation and data exchange of the remaining SCADA modules. It can be realized various ways using various communication technologies and protocols. Different protocols can be applied to a local turbine controller and to the communication protocol for data exchange between wind turbines. The IEC 61850 standard imposes the application of a fiber optic network Fast Ethernet or faster. The protocol type used in that standard depends on the kind of exchanged data and the required transfer time.

### Additional modules

In dispersed generation sources, a module that functions as a meteo station can measure a number of parameters such as wind speed, temperature and atmospheric pressure. Those quantities are the most important measurements for a wind turbine. The Logical Node WMET or MMET can be used for that purpose.

One of the required protection elements is a set of overcurrent, under or overvoltage protection combined with over and under frequency generator protection. The mentioned protection elements make an autonomous device that can be assigned a set of logical nodes that correspond to individual protection functions i.e. PBRO, PBTUF, PTUF, PROF.

For the purposes of energy metering and energy purchase/sale settlements, documents that describe Smart Grid elements recommend application of the readout and processing standards used for electricity meters, such as DLMS or IEC 62056.

Implementation of a data exchange interface between supervising systems and the DSO SCADA requires a mutually accepted communication protocol. In the case of Smart Grids, it has been assumed that the IEC 61850 standard is to be used by all parties connected to the grid [6].

### Optional modules

The energy market module can be used only for large-scale dispersed sources or a few sources of considerable total power. For small sources, renewable energy measurements are sufficient to obtain an adequate license.

The system operation optimization module can be used, when the energy sources can be applied for the grid voltage regulation and for the control of active and reactive power generation. It requires cooperation and data exchange between the source control system and the grid management system.

### Conclusions

Models that describe operation of dispersed generation SCADA systems are elaborated in order to adjust the sources to the Smart Grid requirements and at the same time to adapt their technical potential to the source owner needs. Many manufacturers of energy sources offer installation-ready systems for their control. The alternative is to develop the own SCADA system based on Programmable Logic Controllers (PLC) or remote-control devices that use popular communication standards of electric power engineering. Manufacturers of the mentioned equipment offer a number of tools that enable flexible adjustment of individual system elements to the user needs. Ultimately, it is worthwhile to consider the application of devices that use the IEC 61850 standard and its supplements as both the PLC and remote-control manufacturers as well as the protection equipment producers declare their support for the standard.

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