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Modeling a Microgrid that Integrates Renewable Energies in IEC 61850-7-420 and IEC 61400-25-3

Oscar Fernando Aviles Sanchez*, German Reina and Mauricio Mauledoux

Militar Nueva Granada University, Cr 11 No 101-80. Dp. Mechatronics Engineering

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Abstract

This paper explores a information model for a small electrical network (Microgid) that integrates renewable energies based in standard protocols. The information model of the micro network will be made up of a solar energy source, a wind energy source, an energy storage element, a non-renewable source such as a diesel generator. Each of the renewable sources is modelling based on the logical nodes of the IEC 61850-4-2, IEC 61850-7-420, IEC 61400-25-2 standards. The objective of this definition is select: logical nodes, variables and commands, required to achieve coordinated control. This interchange of information is required to develop more complex algorithm of distributed control resources. A control architecture based and structured in these standards will to allow interoperability between the controllers of the power sources of the network, regardless of who develops and manufactures the device. This work is intended to ensure that information can be exchanged to control the load flows in the electric network that integrates renewable energies. All communications between controllers will be based on these protocols that allow the exchange of information over ethernet networks for critical process.

Keywords: Renewable Energy, Smart Grids, Smart Grids, IEC 61850-7-420, Advanced Metering Infrastructure, distributed Energy Resource.

1. Introduction

This document develops an information model of an electrical network with renewable energy sources based in IEC 61850-7-420 y IEC 61400-25. It is a pilot project of apply standard protocols to define the information required to interchange the data between the regulators of the electric sources for a microgrid in a not interconnected zone grid. The variability of the grid and the fast reacting that now is required for maintain the balances between the load and the renewable energy sources is the motivation of this work.

The biggest challenge now is to mitigate the deficiency of development in technology and standards for be apply in projects with distributed controls that allows to integrate all the equipment connected to the network (Smart Grids and Microgids) for operate as coordinated system and maintain the balance of power in the grid. It is necessary to test and implement standard communication protocols that ensure interoperability between the specific controls of each agent connected to the grid.

One of the most used equipment for the implementation of renewable energies in the electrical AC grids are voltage inverters and DC-DC regulator AC-DC converters, Actually research is focusing on control strategies with multilevel inverters [1] with use less electronic components as the principal focus. Developments as advanced multilevel packed U Cell (PUC) Advanced [2] has been with successfully the reduction of the levels of transformer and the amount of power electric components in these inverters. This make possible the opportunity of develop a smart inverter more efficient and with a reduced cost. The controllers for this technology must be have interoperability as principal feature for a quick control response to maintain the balance of power in a micro grid.

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The controllers for this technology must be have interoperability as principal feature for a quick control response to maintain the balance of power in a micro grid. This paper explores a common information model for the develop of a new type of controller that make possible the interchange of information to be use in smart grids applications.

2. Smart Grid as Solution

The main characteristic of a smart grid is to use technology to acquire information instantaneously to achieve the balance between generation and demand, in this way it helps to make decisions based on the information received, and keeps the system operating with the highest efficiency. The technology can be applied in generators and consumers [3].

*E-mail address: oscar.aviles@unimilitar.edu.co
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Currently the traditional communications network must be updated and adapted for this. The communication network must be prepared to transmit the information of the electrical grid: As, for example: the price among other data to be delivered to the user, allowing to send connection and disconnection commands in addition to interacting with the demand response applications (Demand response -DR).

This advanced measurement infrastructure technology [2] allows renewable energies the following advantages:

1. It allows renewable energy sources to measure the energy delivered to the grid, including connection or disconnection of compensation, control and planning.
2. It allows serving as communications infrastructure to integrate distributed resources within distributed automation schemes.
3. It allows the use of advanced energy pricing schemes, which would improve the economy and investment returns of photovoltaic or wind farms.
4. Serves as a communication and platform to make use of Demand Response (DR) strategies, which allows a synergy with wind and solar renewable energies.

Other desired functions of controls for smart grid are, for example: Smart meters that can collect data on power quality, power outages, power factor, reactive power, voltage and frequency of the network. This information is transmitted to Distributed Automation (DA) systems. Information to the consumer that allows him to know the tariff and conserve energy or disconnect from the network at times when there are energy peaks or valley hours. Helping the consumer to choose the appropriate moment to connect to the network.

A microgrid is a section of an electrical network that can be connected to a main network and operate autonomously, feeding its own loads from its own sources of energy for some periods of time. When a microgrid is operating autonomously without connection to the main network, it is said to be operating in island mode ("islanded").

The microgrid is controlled by a real-time monitoring system that concentrates on regulating the voltage and frequency, this is achieved by controlling the different sources of energy and always seeking to balance the load and energy generated, as well as the energy injected from the main network. This controller should generally consider the load profiles, define an operating cost for each of the sources, estimate the amount of solar energy and wind energy.

All this application only can be possible If the different resources or multi agents in the network send and receive information to all the others. The interoperability is being useful to maintain the balance of load in the electrical network.

Smart grid will help to increase the level of penetration of renewable energies, IRENA (International Renewable Energy Agency) declare [4] [5] that with levels of penetration higher than 30%, this information exchange technology is essential for the proper functioning of electrical grids.

3. Why Use IEC 61850-7-420

The manufacturers of devices for smart networks and Distributed Energy Resource (DER), are working on the development of communication protocols and new standards, which allow to interconnect those systems to the network and provide users and providers with the possibility of monitoring and controlling these new technologies. [6]

New protocols are being developed from this need for standardization, one of this is IEC 61850-7-420 which seek to formalize the models of the sources and lay the foundations, procedures, guidelines for the interconnection and control of the DER. This standard basically defines four principles for effective communication: Information model, Services required by the model, Communications protocol, means of communication, which will be adapted and implemented as part of the project.

The idea of using the IEC 61850-7-420 standard is to take advantage of the object-oriented modeling developed by this protocol, towards the most well-known generation sources in figure 1 [3] show a schematic description.

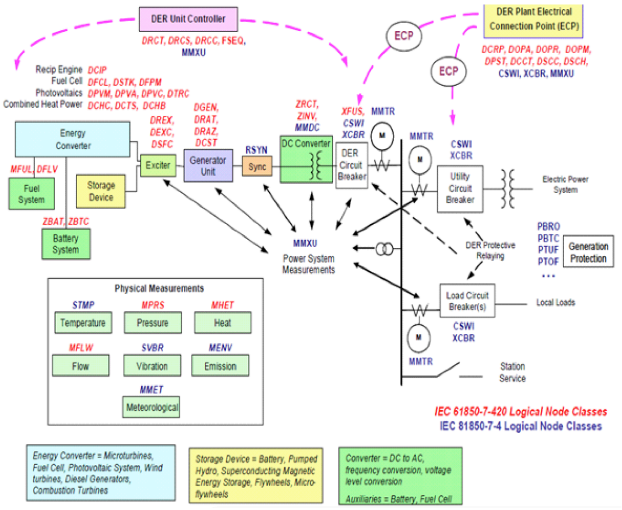

Fig. 1. Logical Nodes for Distributed Energy Resources (DER) in IEC 61850--7-420

This protocol was planned to define elements called "logical nodes" that define and describe the characteristics of the real world being defined abstractions of the elements that make up the source to connect in the network. This concept is currently used in the control and protection of substations and is being promoted to be used at higher control levels, waiting to be applied also by the SCADA and DCS control systems of the electric networks. The modeling was developed extensively in the IEC 61850-7-2 standard and the communications mapping in the IEC 61850-8 standard, in addition to the standard configuration systems SCL (System configuration language) for the DER plants (IEC 61850-6).

3.1 Virtualization and information modeling

The IEC 61850 standard is based on modeling the devices, the characteristics and describing the properties of each of the equipment at a real level Figure 2 [7]. This modeling is done by extracting the existing equipment, giving it a characterization by function. This description is made in a hierarchical manner: devices (Logical Devices LD), nodes (Logical Nodes LN), objects (Data Objects DO), common data classes (Common Data Classes CDC), common attributes (Common Attributes), standard data types (Standard Data Types).

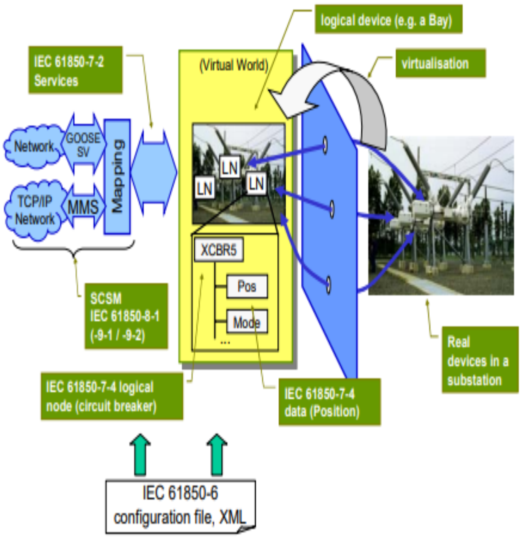

Fig. 2. Virtualization Concept in IEC 61850

The logical nodes, are the smallest part of a function that exchanges data, is an object that defines the types of data and methods. The set of logical nodes is converted into components that define different protection, control and monitoring equipment, as well as automation functions in the substations.

A real device can have different functions and more complex functionality. However, thanks to the model implemented in the IEC 61850 protocol, it can be represented regardless of complexity through the concept of logical nodes.

Each team, can be defined as a hierarchical functional description based on logical nodes Figure 3 [7], which we will explain descending way.

- The first level is the device known as IED (Intelligent electronic device) is an information server consisting of logical nodes that describe its functionality.
- The second level is the Logical Device (LD), which groups the different logical nodes that describe the functions that the IED has.
- The third level describes the nodes LNO, LNPD and function nodes, be they control protection, etc.
- The fourth levels describe the control functions and their sub functions.
- The fifth level describes the command data that the device can execute.
- The Sixth level describes the data that the device can deliver as measures or status data.

The concept of modeling the norm can be summarized as follows: Only the objects that should be visible for the communication network can be included, each class and node is designed for the exchange of information and defines the lengths of the variables data types and structure.

A simple way to understand the standard is by describing the Data Objects (DO). Assuming that we are going to measure the frequency of Phase B of bay 1 from the real world, this modeled in the norm would have the following form to be acquired.

Logical node: Class MMXU → MMXU1
Data Object: Class WYE → Type:A
Sub object of Data: Class CMV → phsB
Data Attribute: Class Vector → cVal
Magnitude of the data attribute: Class: Analogue Value: mag
Analog data type: Class FLOAT32: f

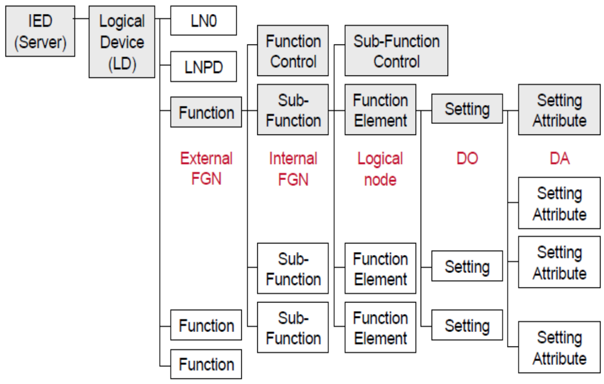

Fig. 3. Hierarchical functional description

All of the above is consolidated as a structured structure as follows: ***MMXU1.A.phsB.cVal.mag.f***

The figure 4 [8] shows how it is interpreted with protocol simulators. In general, the simulators show a tree on the left side where the device (Physical Device) has a unique network address. In this case the IED1 equipment, associated with this is the logical node, the XCBR associated with the model is used according to the norm of the switch. Inside the logical node is the data object, in this example POS, where is the value of the StVal (attribute) position and finally the information of the real position of the equipment (Open 1, Closed 2, intermediate 0 or in invalid state 3.)

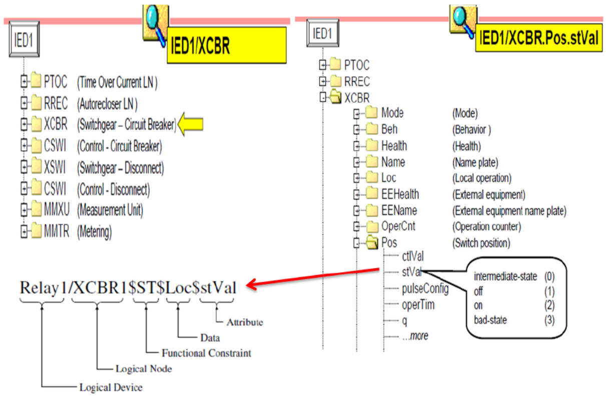

Fig. 4. Breaker example of virtualization Concept in IEC 61850 in a simulator of protocol.

The standard virtualize the real-world equipment and describes it in the virtual world (model), using previously defined data types and characteristics according to the variables that the team has in the real world, the information they send or receive to control systems. All this model allows exchanging information with other systems. This modeling is also planned to use standards communication channels. If we can model the generating sources and define the variables to be exchanged; We can then ensure that the communication, as well as the interoperability of the devices that integrate the network is guaranteed.

3.2. Communication Architecture for the Smart Grid

The network architecture for communication must be designed to allow the exchange of information from devices such as smart meters, controllers and other equipment that compose it. The exchange of information need to be implemented on the ethernet network model because this is a robust model independent of the medium of transmission or the speed of the channel, in addition to this, it is assured that it will have long-term support. The main advantage of the use of ethernet networks in the project is that it is a widely used model and allows to change the communications interface without modifying the communication models of the upper layers. For do this we use the communication protocols for ethernet networks implement and compatibles [9] with the IEC 61850 standard. In addition, it allows communication using media such as fiber optic or GPRS radios (General Packet Radio Service - GPRS) via cellular network among others, which are widely used by network operators.

The communications chapter of IEC 61850-7-4 allowed the implementation of high availability networks using Parallel Redundancy Protocol (PRP) and Highly-available Seamless Redundancy (HSR) protocols, written in the IEC 62439-3 standard. Basically, these improve the availability and recovery of faults in rings, exceeding the times obtained by other protocols such as Spanning Tree Protocol (STP) and Rapid Spanning Tree Protocol (RSTP), which are not suitable for critical systems applications.

The PRP and HSR protocols are an option for the design of the elaboration of the topology of the network. Basically, we can associate the operation of the network as two independent networks connected to each device interconnected with high reliability and availability and without delays. It is a process bus for critical applications. Use a PRP network will guarantee that the communication equipment will not delay in recalculate the topology of the communication network when a failure occurred in the fiber, this means we do not lose critical events that are circulating in the network. The advantage of use a fiber optics is that it can be laid along transmission lines in guard cables and allows equipment to be interconnected over long distances.

For the design of the network show in the Figure 5 we will have the possibility of using this type of technology especially in critical processes, the information should flow as if the network were an information bus with high availability where each controller sends and / or receives the required information to the control. In the micro network we will suppose that we will have redundant fiber optic between the different places and facilities, we will use one of the advantages that the equipment has in PRP networks, which is that in case they are limited or do not have this protocol because they are existing, in the future they could be integrated using a device called "redbox" that allows them to behave as if they had native PRP even if they do not have this characteristic.

The topology allows to support faults in one of the ports of the equipment, either due to fiber failure or due to equipment problems and to continue working without losing the information through network B. This design will allow us to work in critical processes such as the frequency and power control in the network, then redundancy with n + 1 capacity to support faults is implemented. The interaction of the elements of the micro network will be through the Ethernet network in PRP protocol. Another basic component of the network will be the switches that must have high availability and be compatible with GOOSE messages, MMS and process bus.

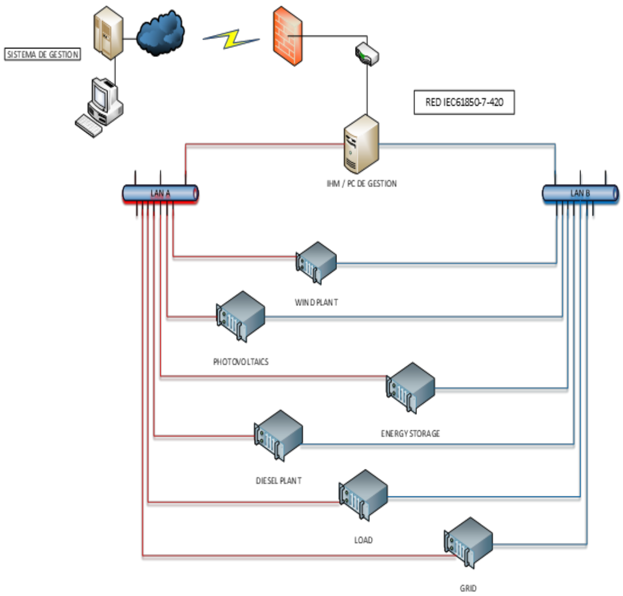

Fig. 5. Smart grid communication architecture in PRP protocol

4. Information Model for the Microgid

Each source was described using the language of selection of logical nodes that are associated to the components that make them up. The logical nodes of each source can be consulted in each of the control associated with each source, which will contain the information acquired either through physical inputs or exchanging information in the network.

The information model implemented with the logical nodes is directly related to the transmission of information to other devices, basically that is the object of this logical description. The complete abstraction of the network can be consulted in the figure 6.

The micro grid on which this project is developed is made up of: a solar energy source, a wind energy source, an energy storage element, a non-renewable source such as a diesel generator set and the electricity grid. With these different sources of electrical energy, we will feed a residential type load

All the sources are connected through an energy exchange bus, where the voltage and frequency parameters must be kept within the limits. Each source, user and regulation system have the option of disconnects operating the switch under load (circuit breaker XCBR), the data of contribution or consumption are detected by the energy meter (MMXU). The main components are:

- Energy sources: A wind power plant (Wind turbine), A Solar power plant (Photovoltaics), a Diesel plant, the electrical network (Grid).
- The consumption elements are: The load (Load) represented by the users.
- An energy storage element.

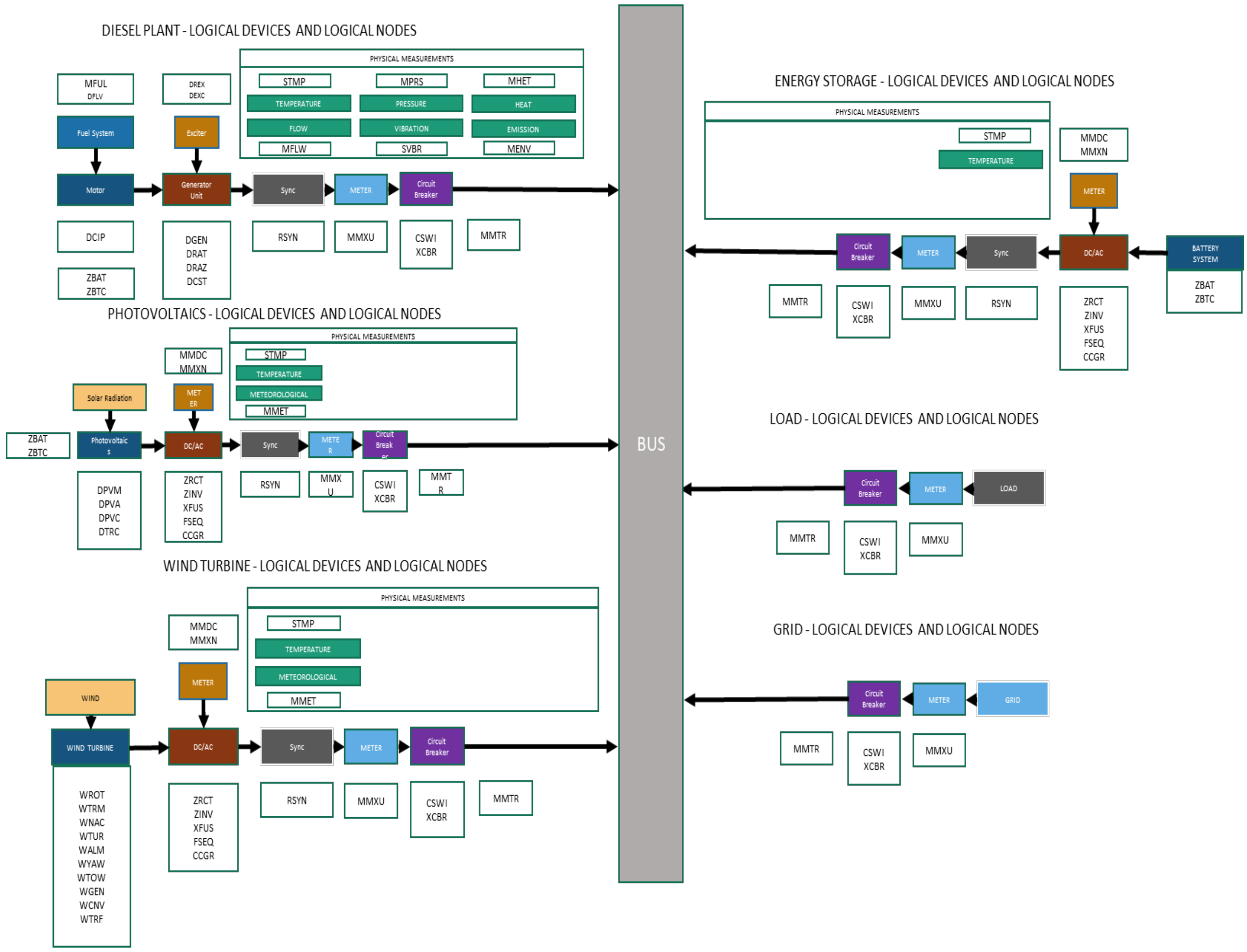

Fig. 6. Model of a Microgrid in IEC 61850-7-420 and IEC 61400-25-3

The choice of generation sources is made by recreating the Colombia scenario, which has several interconnected and non-interconnected areas that can make use of renewable resources and could be implemented in these areas in the future. The generator set is chosen to be able to search for a scenario that allows to simulate and propose as a control criterion reducing fuel consumption. As it really happens in the non-interconnected area of Vichada and simulate the future micro-network that may have the capacity to include renewable energies. The choice of the wind energy source is taken from the potential of the department of La Guajira in which at night they have a very large potential with this renewable resource and during the day it has large solar radiation rates. From this privileged area you can also take advantage of solar energy, so this type of energy source will also be used.

To achieve the stability of the small energy network it is important to explore energy storage systems and although their operating costs do not allow their use on a large scale, it is expected that as the penetration of renewable energies continues to increase its use it will be increasingly necessary.

The stability of the frequency through the power flows becomes the most critical factor to control in this type of network. A decrease in frequency then implies that more power must be delivered to the network to maintain the balance between the load and the energy generated.

The main objective is to develop a common language of interchange of information for future designs that guarantee the operability of the controllers. We include the information that must be have each logical node that represent the real device. Other purpose is to guarantee the availability of variables required for the control on case of a distributed control system.

If the information is flowing by the network the distributed controller can read it and perform control actions aimed at balancing the load and regulating the frequency and decreasing the use of the generator fuel or minimizing the consumption of electrical energy that is taken from the network, maintaining within the limits the electrical parameters in the end user of a micro grid.

4.1 Wind Plant A Case Especial

The logical nodes that describe and model the turbine are developed by the IEC 61400 standard and is limited to a wind turbine process, but is not designed to be used in exchange of information with other distributors in an electrical network [10], so it must be complemented with IEC 61850-7-420. The two standards are fully compatible in the structure and way of defining the logical nodes, so for this project we will assume that they can exchange the information without any problem. This standard is fully compatible with the descriptions of IEC 61850-4 and IEC 61850-410, so for this modeling we will use the two standards.

4.2 Inside the Logical Node

Each logical node has some optional variables, command, setpoints on other information. Hove ever the model for this project we include only a selection of the information required for a control of the microgrid. Each possible information to be interchange was selected and define for interchange. An example of the level of definition is show in figure 7.

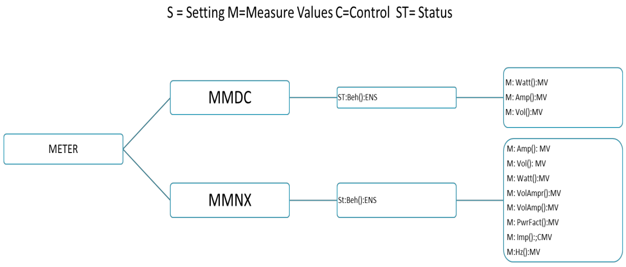

Fig. 7. Information selected in each logical node example MMNX and MMDC.

One of the main challenges of this modeling is to leave it as general as possible, because we want to use it in different types of networks regardless of size. We tried not to lose the generality and apply it in different schemes as in small networks with sources in DC generation that do not have inverting equipment. As well as regardless of whether they were one or groups of wind turbines and solar cells.

Each source has basically three equipment of measurement, the first represented by the MMXU node that is responsible for sending the other sources electrical parameters such as voltages, currents, power among others so that other sources know in particular the power imported and exported to the system. The MMTR is responsible for billing and accounting for the energy imported and exported to the network. Finally, the MMET is in charge of monitoring, in particular for the renewable energies, parameters such as solar radiation, temperature, wind speed.

There are also logical nodes associated with each power source and load as CSWI and XCBR that are only associated with the maneuvering equipment, which allow opening, closing or triggering the sources in case of failure. The nodes associated with the ZRCT, ZINV, CCGR inverters are generic and they are very important in all renewable energies, especially since all of their basic elements generate DC direct current and that must be delivered to the load usually through an inverter in alternating current in AC. The nodes associated with each power source are selected so that the parameters or commands for the frequency and power control equipment can share the information and / or receive the commands from the other sources.

5. Conclusion

Renewable energies are becoming the main sources of generation of electricity in the grid. It is expected that its inclusion in traditional networks will reach more than thirty percent before 2025, which forces current networks to update and prepare to regulate the effects they generate on existing power grids.

The centralized control technology and the current media infrastructure must be adapted to these changes. In this paper, an application of existing standards was presented to exchange information among the different sources of generation. The development of new technologies for renewable networks must apply these definitions to ensure the interoperability of the distributed controllers that are developed.

This paper was presented and defined a proposal for a common language, which can be applied to technologies that are developed in the future for the control of distributed generation networks.

It shows that there is the possibility of modeling all renewable energy sources through logical nodes and developments in standards IEC 61850-4, IEC61850-7-420, IEC 61400, as proposed in this paper.

The topology of the communications network is so important and critical that the IEC 62439-3 protocols are available to develop the high-speed process buses that allow the controllers to be applied in critical tasks with the speed required to regulate the network. This paper proposes a network that meets these requirements. Advanced measurement equipment requires smart grid equipment to use this technology. In addition, they must be equipped with the ability to receive and send information in both directions from the user and network operators.

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