

# Microgrid: Low Power Network Topology and Control

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**Abstract**—The network designing and data modeling developments which are the two significant research tasks in direction to tolerate power control of Microgrid concluded using IEC 61850 data models and facilities. The current casing areas of IEC 61850 include infrastructures in substation automation systems, among substations and to DERs. So, for LV microgrid power control, previously using the IEC 61850 amenities to control the smart electrical devices, we have to model those devices as IEC 61850 data models and design a network topology to maintenance all-in-one communiqué amid those devices. In adding, though IEC 61850 assists modeling a portion by open-handed several object models for common functions similar measurement, metering, monitoring...etc., there are motionless certain missing smithereens for building a multiplicity of functions for household appliances like tuning the temperature of an electric heater or refrigerator.

**Keywords**—IEC 61850, RCMC, HCMC, DER Unit Controller.

## I. INTRODUCTION

THE research objective of this paper is to use IEC61850 for Low voltage Microgrid power control. The goal is to apply the concepts of IEC 61850 to a different domain, the LV Microgrid, to perform power control of both energy consumption devices, e.g. smart household electrical appliances, and Distributed Energy Resources – DERs including the energy generators and energy storage. A good power control algorithm will help to utilize the available energy resources efficiently. The main objective above can be decomposed to 3 smaller objectives: A. designing a communication network topology in LV Microgrid B. Modeling LV Microgrid electrical components C. Applying IEC 61850 services for power control in LV Microgrid.

## II. NETWORK DESIGNING

In this measure, a modest but typical network will be designed to tolerate the communication between different thespians in a Microgrid which maintenance the routine of IEC 61850 data models and amenities for power control.

### A. Microgrid Power Diagram

A LV Microgrid involves of three building blocks: the DERs with energy distributed generators like PV panel and energy storage, and the electrical loads which devours energy. A LV Microgrid can operate in grid connected mode. The second is elect for this research. A typical LV Microgrid can

be shown in Fig. 1. Fig. 1 shows a typical LV Microgrid which consists of the Smart houses and the public Distributed Energy Resources (DERs). In this circumstance, the mechanisms of the LV Microgrid can be confidential to three types: energy consumers, energy generators and energy storages. The energy consumers are the household electrical appliances intimate the houses. The energy generators are the municipal Low voltage DERs such as wind turbine or PV panel and remote DERs in the Smart houses. The energy storages are controllable battery systems used to store the energy for imperative conditions or other future plans. A distinct module is the Electric vehicle (EV) which can be appreciated as together the energy consumer and energy storage.

### B. Network Topology for LV Microgrid Power Control

The current form of IEC 61850, the essential communication network setup consistent is Ethernet. So, we need to build an Ethernet-based communication network to connect all the equipment. Within this research, a network topology was designed for that resolution. This network was designed as a hierarchical topology in which all Smart houses was signified as a subnet and these subnets organized generated generous of field area network. The control part of the Microgrid here was the Regional Control and Management Center (RCMC) which was too connected to the field area network. Fig. 2 presents the communication network topology designed for LV Microgrid control and supervisory.

The all subnet and RCMC should connect to an Ethernet switch to establish so-called point-to-point links between RCMC and all subnet. Around could also be several municipal DERs, EV that should be achieved by the RCMC and then, they should have an Ethernet connection with RCMC done connecting to the Ethernet switch. Additional significant functionality is protection which is controlled by the protection device and the Circuit breaker (modeled by the XCBB logical node). Yet, as the messages for protection need to be very fast, they are handled by additional protocol (GOOSE) instead of the protocol for control drive (MMS). This research is around power control in LV Microgrid, the protection part is not analyzed. The protection device and circuit breaker in the subsequent Fig. 1 is impartial for design of a typical LC Microgrid with both control and protection purposes. As we can see in Fig. 2 inside a smart home, there is a Home Control and Management Center (HCMC) which is in charge of controlling all DERs and smart household appliances inside the house. HCMC can switch the Demand retort sent from RCMC to manage the energy consumption/production of the house. HCMC can control the household appliances to moderate their energy consumption

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and the DERs to modify their power production ability. RCMC is capable of monitoring and managing all HCMCs if it is permitted by the houses' owners to efficiently utilize the available energy of the grid.

### C. IEC 61850 Data Modeling

The core indication of IEC 61850 is to failure a physical device into logical devices, all of which will be additional wrecked down into logical nodes, data objects, and data features [1]. The Logical Device hosts communication access point of IEDs and connected communication services, and is introduced by a single IED. Yet, there's no regulation on how to arrange Logical Devices into a physical device which brings a great flexibility to the user. Logical Nodes are the minimum entities which are decomposed from the solicitation functions. Logical nodes are the building blocks of the ordinary since they represent the smallest functions of the device. Because the scope of this scheme is very different with

the unique scope of IEC 61850, various new functions could appear which necessitate to be modeled. This segment will designate how to model a new function as IEC 61850 logical nodes. Fig. 3 shows the principle of IEC 61850 data modeling. In this case, physical device IEDx is composed of a logical device LDx in which there are two dissimilar logical nodes XCBR and MMXU. XCBR1 and MMXU1 are the cases of the logical node period XCBR and MMXU which signify the circuit breaker and the measurement unit individually.

### D. IEC 61850 Data Modeling for Microgrid Components

There are 3 types of equipment to be modeled in a typical LV Microgrid: 1. Distributed energy resources (DER): Photovoltaic – PV panel, electric vehicle, energy storage. 2. Smart household appliances: LCD TV, electric heater, refrigerator 3. Control and management centers: Regional/Home control and management center.

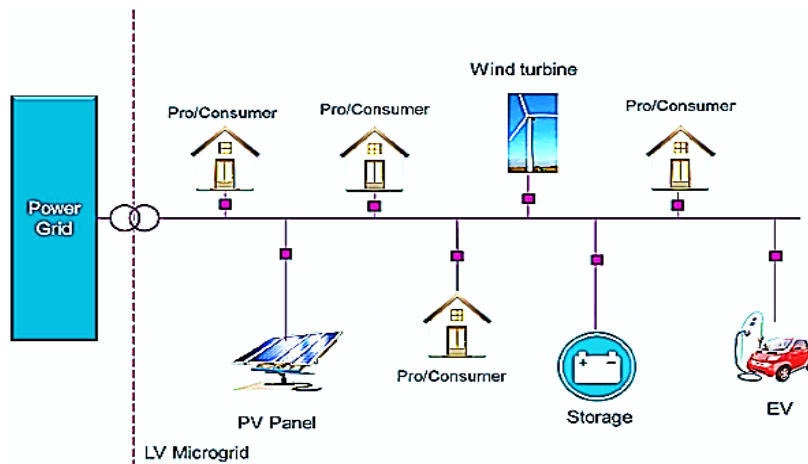


Fig. 1 LV Microgrid Diagram

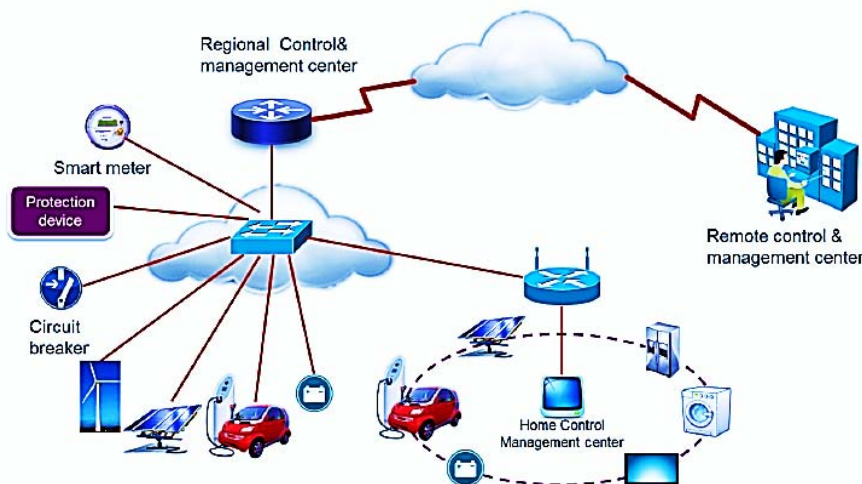


Fig. 2 Communication network topology for LV Microgrid power control

### E. Distributed Energy Resources

The extension rule for logical nodes overhead, we typically apply the existing logical nodes defined in the standard part 7-420 [2], the draft technical reports part 90-7 [3] and part 90-8 [4] for modeling the DERs. Also, the object models for wind turbine can be found in series IEC 61400-25: "Communications for monitoring and control of wind power plants". In Fig. 5, we can see that several existing logical nodes distinct for substation automation systems were applied for DERs, and too many new logical nodes were distinct to signify the new functions of DERs. There is no spartan rule on the arrangement of logical devices on physical device, it is not essential to implement all of the logical nodes in this figure to a DER. Essentially, depends on the exact locations and solicitation requirements of the DER, only respective logical nodes should be added. The PV panel is used as the distributed generator and the energy storage is the battery which too connects to the PV complete a hybrid inverter for charging resolution in the houses. The Hybrid Inverter allows the reverse flow of power from the PV and energy storage to the grid in situation of emergency or in retort to the Demand Response I distributed by RCMC to prevent peak load.

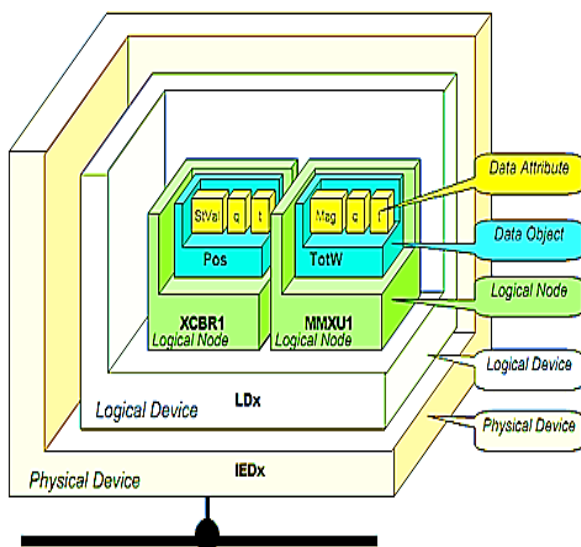


Fig. 3 IEC 61850 data modeling [1]

### F. Smart Household Appliances

The household appliances are the new devices to be modeled inside IEC 61850, the first step of modeling must be ascertaining their topographies. There are hundreds of different household appliances; so, we solitary take into interpretation the appliances that consume much energy.

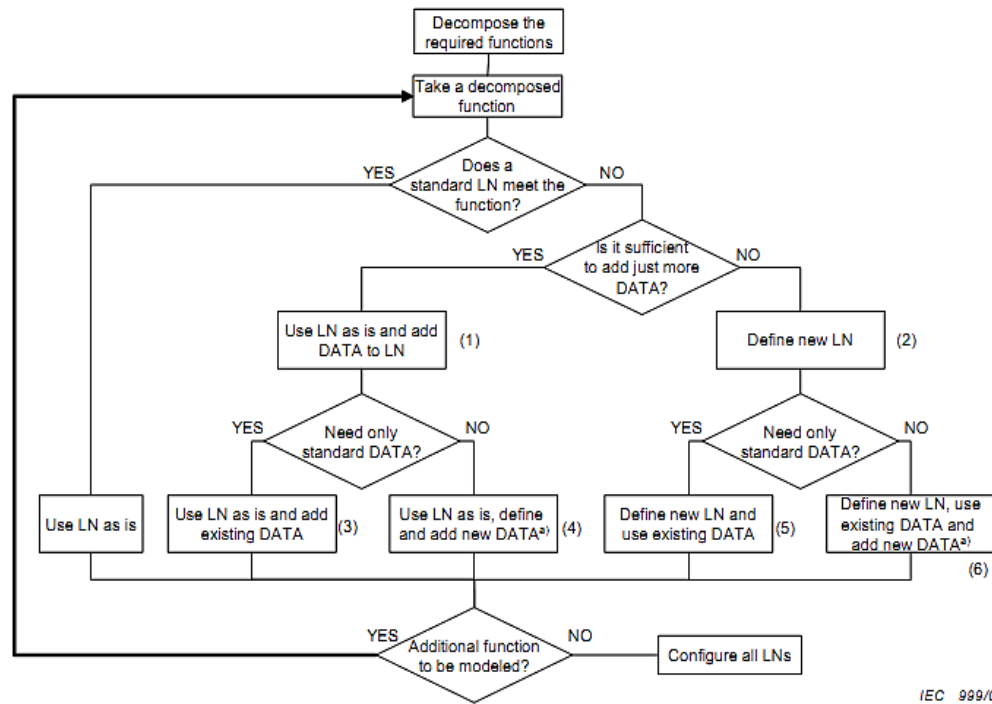
The appliances parameters recorded overhead, the basic functions required for control and management of household appliances are:

- \* Switching ON/OFF the equipment,
- \* Monitoring the device positions,
- \* Measuring/monitoring the energy-related parameters

- \* Monitoring other parameters (e.g. temperature),
- \* Moderating the energy consumption by alternating the operation modes of the devices

IEC 61850 delivers the two logical nodes MMXN and MMTN for measurement and monitoring of single-phase voltage, current, frequency and energy consumption [5]. We should apply these logical nodes to model the energy self-measuring and monitoring purposes of the household appliances. Secondly, for monitoring the devices in tenure of physical/product info, IEC 61850 outlines the logical node LPHD [5] involving of the physical information of the equipment which is obligatory for all IEDs. Then, with the Develop and report services it is potential to get this information. Also, for monitoring other operational parameters such as temperature, pressure, heat...of the devices, IEC 61850 too necessities the consistent logical nodes STMP, MPRS, MHET... [2]. While there are several logical nodes existing in the standard that are applicable, certain functions for household Appliances control has logically not been clear due to the modification in possibility amid substation automation systems and home automation systems.

Energy moderation is the maximum significant function to be modeled for power control but it is not involved in the standard. A new overall logical node for all smart appliances named *ZAPL* was defined as Table I. This logical node permits retrieving information about the operation status of the consistent appliance such as the operation status and operating mode i.e. the appliance working distinctly or subsequent an agenda or being manually controlled by the user. The user highest privilege to control or her appliances, if the users do not want disruption instigated by the telecontrol functions from HCMC, they can just switch the appliance to manual mode. Additional significantly, this logical node signifies the energy modulation function which is indispensable to control the energy consumption of the appliances. By situation the load target set-point, HCMC or the users can modulate the energy consumption of the appliances. The function turning ON/OFF the device is too modeled in *ZAPL* logical node since it is an elementary and mandatory Function for all devices. Yet finished setting the load target, HCMC can control the energy consumption of all smart appliances, additional technique to tune the energy consumption of a device is to directly change its operational threshold like changing the speed of a fan or temperature of a heater or refrigerator. There is a logical node called STMP defined in IEC 61850-7-4 for temperature supervision, and it is convenient to utilize this logical node and add more data objects to support the temperature modulation function. Table II shows the extension of the existing logical node STMP to support the function of temperature modulation. A temperature set-point was added to STMP class to control the temperature. Therefore, an instance of the STMP class with TmpSpt allows tuning the energy consumption of a heater or refrigerator by changing its output temperature.



<sup>a)</sup> New DATA based on existing or new CDC.

Fig. 4 Basic extension rules diagram

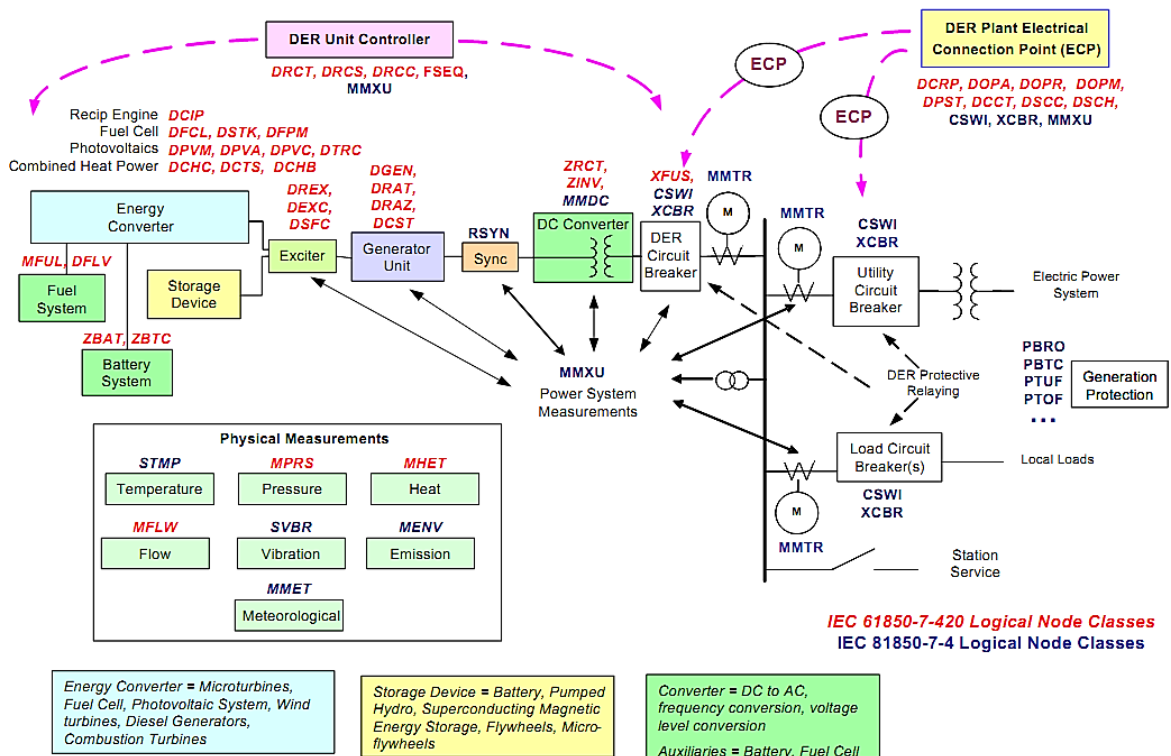


Fig. 5 Conceptual organization of DER logical devices and logical nodes

TABLE I  
ZAPL CLASS

Data Object Name	Common Data Class	Explanation	T	M/O/C
LNName		Shall be inherited from Logical-Node Class (See IEC61850-7-2)		
<b>Data Objects</b>				
EEHealth	ENS	external equipment health		O
EEName	DPL	external equipment name plate		O
OpTmh	INS	operation time		O
<b>Status</b>				
Oper	SPS	operation status of the appliance		M
OperMod	ENS	operating mode: 1-autonomous; 2-schedule; 3- manual		M
<b>Control</b>				
OperCtl	SPC	start/stop the appliance		M
AutoManCtl	ENC	sets operation mode to autonomous, schedule, manual		M
Schedule	ARY	the schedule for the lighting system		O
Setting				
LoadSpt	ASG	set load target %		O

TABLE II  
EXTENSION TO STMP CLASS

Data Object Name	Common Data Class	Explanation	T	M/O/C
LNName		The name shall be composed of the class name, the LN-Prefix and LN instance ID according to IEC 61850-7-2 clause 19		
<b>Data Objects</b>				
EEHealth	ENS	external equipment health		O
EEName	DPL	external equipment name plate		O
<b>Measured V</b>				
Tmp	MV	temperature		O
<b>Status Inf.</b>				
Alm	SPS	temperature alarm level reached		O
Trip	SPS	temperature trip level reached		O
<b>Setting</b>				
TmpAlmSptA	ASG	temperature alarm level set point		O
TmpTrSpt	ASG	temperature trip level set point		O
TmpSpt*	ASG	temperature set-point		O

\*New data attribute added to the standard STMP for setting the temperature

TABLE III  
ZHCM CLASS

Data Object Name	Common Data Class	Explanation			T	M/O/C
LNName		Shall be inherited from Logical-Node class (see IEC 61850-7-2)				
Data Objects						
EEHealth	ENS	external equipment health				O
EEName	DPL	external equipment name plate				O
OpTmh	INS	operation time				O
Status						
Oper	SPS	operation status of the home control and management center				M
OperMod	ENS	operating mode	value	explanation		
			1	autonomous		M
			2	controllable		
Setting						
MaxWh	ASG	set-point of maximum energy consumption				O

#### G. Control and Management Center

The scope of this research, communications in smart home systems and Demand retort are the key applications. For control in smart home systems, HCMC can apply IEC 61850 services for all control actions with the logical nodes in smart appliances. It is not required to outline a logical node for HCMC for control purpose. For Demand response, it is necessary to model the data and function of HCMC that

RCMC can access and implement the function to set the edge for energy consumption of the house in specific peak demand periods. A new logical node *ZHCM* was defined in Table III. In this logical node, there is a data object OperMod on behalf of the operating mode of HCMC.

If HCMC is configured to be controllable, RCMC can use the data object MaxWh to change the allowed maximum energy consumption of the house. If there is no fault and the

control function prospers, HCMC will then control the in home DERs and appliances to reduce the energy consumption in response to the Demand response signal sent from RCMC.

### III. RESULT

The two first objectives of the research: Objective 1 – Designing a communication network topology for power control in LV Microgrid; and Objective 2 – Modeling LV Microgrid electrical components for power control. A communications network topology is designed to tolerate the information transmissions between the LV Microgrid. Due to the current version of IEC 61850 that regulates Ethernet as the layer 2 protocol, this network is built over Ethernet. Though, it is too potential for future research to define mapping to other essential network protocols for transmitting the IEC 61850 information such as wireless or cellular networks. Those principles in preparation by modeling the LV Microgrid electrical components with IEC 61850 data objects, this paper too clear some new logical nodes to represent the very important power controls functions i.e. ZAPL and ZHCM logical nodes. Though, it is essential to realize that this research has utilized many existing logical nodes defined in IEC 61850 documents to model different components in a very different area with the substation automation systems. Thes indicates the great possibility of extending the scope of IEC 61850 to other area in order to provide interoperability to the future Microgrid.

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