CHANNEL REQUIREMENTS FOR LTE DUE TO MICROGRID MANAGEMENT SYSTEM IMPLEMENTATION

J.-I. CAIRO
Research Institute for Energy of
Catalonia (IREC) – Spain
icairo@yahoo.es

Albert RUIZ
Research Institute for Energy of
Catalonia (IREC) – Spain
aruiz@irec.cat

Andreas SUMPER
Dept. of Electric Engineering at
CITCEA (UPC) ETSEIB and IREC
asumper@irec.cat

ABSTRACT

This paper is presenting the repercussions that managing microgrids, when they are expanded within the power grid network, may take over telecommunication networks. In particular from secondary to tertiary control schemes, it is presented the kind of traffic that can be generated, and finally based on such traffic the capacity is calculated. Special interest in presented on the 4G LTE standard due to low latency and high data rate.

INTRODUCTION

The electrical power system, from generation, transmission and distribution, is facing a strong change in order to accommodate renewable energies of intermittent nature, together with the classical energies and the penetration of electric vehicles. All together is posing a strong challenge for the operation of such complex systems, and the communications requirements are one of the main topics in order to provide functionality.

Economic, technological and environmental incentives are changing the face of electricity generation and transmission. Traditional scheme based on centralized generating facilities and kilometric aerial cables are giving way to smaller, more distributed and closer to consumer generation. In the last decades, the interest for Distributed Generation (DG) and Distributed Energy Resources (DER) and their integration in the utility grid has increased significantly. These two concepts, together with Micrgrids, are usually confused. This is largely because there are no consistent definitions for them.

In this paper, an work on microgrids is presented, based in experiences from the real microgrid built at IREC laboratoeies [1] (based power structure) and communication needs are abstracted in order to finally concentrate on the communications by use of 4G mobile systems. The paper is organized as follows: First, a brief descripcion of microgrids is done, defining the microgrid concept as basic part of the smart grid (SG). Following several requirements are described for the control strategies of these systems. From the understanding of such control techniques, it is derived the amount of information that is required based on real physical measurements. With the previous information, it is explained in next paragraph the message exchange betwenn microgrids and those are reproduced by the IEC 61850. Finally in last sections of the paper, a description of the implementation of such communication requrements by means of the LTE technology and the real implemented work is descrived. At the ned, a list of related publications from the authors work is introduced.

MICROGRID MANAGEMENT

Micrgrids might be understood as small-scale grids. Nevertheless, depending on the type and depth of penetration of distribution resources (DR) units, load characteristics, power quality constraints and market participation strategies, the required control and operational strategies of a microgrid can be significantly and conceptually different than those for conventional power systems [2-4]. The main reasons are the following:

- Electronically coupled DR units barely have inertia. So, steady-state and dynamic response of these units are totally different than those of conventional large turbine generators.
- Microgrids are inherently subject to a significant degree of imbalance due to the presence of single-phase loads and/or DR units.
- A noticeable portion of supply within a microgrid can be from non-controllable sources (e.g. wind turbines, PV).
- Storage units can play a major role in control and operation of a microgrid.
- Economics often dictate that a microgrid must readily accommodate connection and disconnection of DR units and loads while maintaining its operation.
- A microgrid may be required to provide specific power quality levels or preferential services to some loads.
- In addition to electrical energy, a microgrid might be required to generate and supply heat.

ISA-95 is the international standard for the integration of enterprise and control system. ISA-95 defines some models terminology to determine which information has to be exchanged. The time frame at upper levels might be days, weeks, month, etc., while at lower levels it might be seconds or milliseconds.

As in [5], it has been identified and classified microgrid controls into:

- Level 3: to control the power flow between the microgrid and the grid. This control is referred as Tertiary control.
- Level 2: to control power flow of each DR within the microgrid. It also includes a synchronization control to connect and disconnect the microgrid to or from the grid. This control is referred as Secondary control.
- Level 1: to ensure that electrical levels into the microgrid are within required values. This one is the Primary control.
- Level 0: to regulate output voltage and current of each DR. This is the Inner control.

In reference [5] authors propose that Level 1 is responsible for power of each DR, and Level 2 is responsible for keeping electrical levels. Authors of the cited paper propose a different classification because their work focuses on droop-control for microgrids.

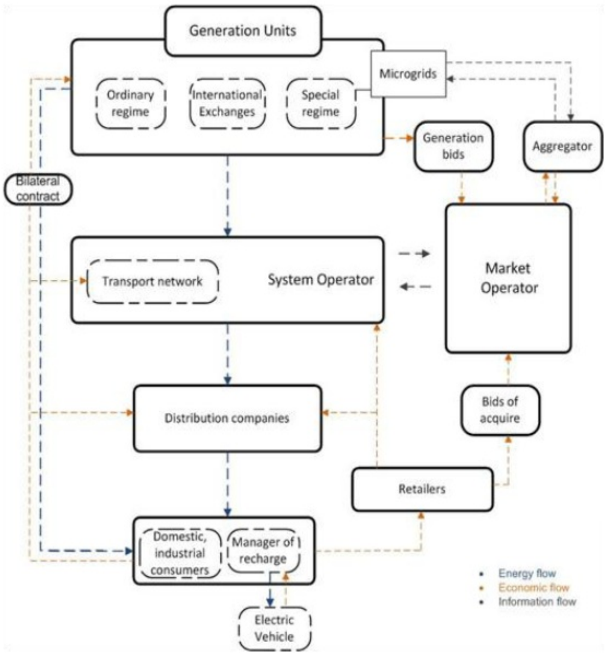
The droop method permits to control DR converters without using any critical communication [6]. In this method, active and reactive power of each DR depends on the frequency and voltage at the bus bar respectively. Actually, this method is usually referred as P -ω and Q - V.

In the droop method, active and reactive power, need to be calculated continuously because the electrical stability (frequency and voltage) depends on these values. The droop method achieves high reliability and flexibility. On the other hand, it has several drawbacks that limit its application. For instance, the conventional droop method is not suitable when the paralleled system must share nonlinear loads.

IREC's control for microgrid

In this section it will be presented a control algorithm for microgrids that interacts with utility company and the electricity market. The strategy of the algorithm is the scheduling of generation, storage devices and loads, from forecasting measures and economic issues. The algorithm uses optimization methods. These methods are beyond the scope of this paper but can be consulted in Reference [7]. The Spanish regulatory environment for microgrids has been taken as reference.

Currently, there are three main agents in the Spanish market: the generation company, the market operator and the retailer. More specifically, the aggregator would receive supply needs and generation offers from each microgrid then, with this information, could offer buying and selling bids in the different markets of the system by optimization of the overall benefit of the represented microgrids. After the participation in the market, the aggregator might communicate the set points for generation or buying of energy to each microgrid. In addition, the aggregator should provide the information about each microgrid to its corresponding distributor.



Figures 1 General diagram of Spanish Energy Market with micrograms.

Tertiary control

The Tertiary control has a scope of 48 hours with periods of 15 minutes. It has two objectives. The first one is the economic optimization using a program based on a Unit Commitment problem. The second one is to improve the profitability of the supply and demand balance by interacting with the grid. These aims are realized taking into account daily forecasts regarding weather, energy price and demand data. On economic optimization, the signals for the controllable units are calculated allowing the system to find out an optimal unit commitment considering future values by exploring the price differences between on-peak and off-peak periods during a day. The final result is a schedule of the power outputs for each period within the optimization range.

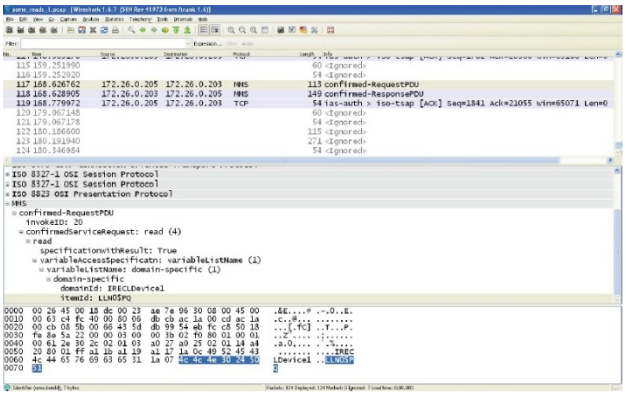
Secondary control

The secondary control runs each 15 minutes with periods of 30 seconds (more or less depending on the time range to obtain the real data available), and it is in charge of power quality optimization and to minimize the average of all deviations compared to the tertiary control program. To do so, the aggregator must take into account current weather data, operation data of generation units while ensures the exchanged power with the grid and storages states of charge programmed above. Every 30s, for each DR of the microgrid, the aggregator reads P and

Q measurements and sends P and Q set points.

According to IEC 61850-5, time transfer means the complete transmission of a message including necessary handling at both ends. Time counts from the moment the sender puts data content on top of its transmission stack up to the moment the receiver extracts the data from its transmission stack.

From the same IEC 61850 standard, message length may vary from 1 to 1024 bits length. Figure 2 shows a typical capture of power measurement message reading.



```
115 159.251990                                          60 <Ignored>
116 159.252020                                          54 <Ignored>
117 168.626762   172.26.0.205  172.26.0.203  MMS       113 confirmed-RequestPDU
118 168.628905   172.26.0.203  172.26.0.205  MMS       149 confirmed-ResponsePDU
119 168.779972   172.26.0.205  172.26.0.203  TCP        54 ias-auth > iso-tsap [ACK] Seq=1841 Ack=21055 Win=65071 Len=0
120 179.067148                                          60 <Ignored>
121 179.067178                                          54 <Ignored>
122 180.186600                                         115 <Ignored>
123 180.191940                                         271 <Ignored>
124 180.346984                                          54 <Ignored>
```

```
⊞ ISO 8327-1 OSI Session Protocol
⊞ ISO 8327-1 OSI Session Protocol
⊞ ISO 8823 OSI Presentation Protocol
⊟ MMS
  ⊟ confirmed-RequestPDU
      invokeID: 20
    ⊟ confirmedServiceRequest: read (4)
      ⊟ read
          specificationWithResult: True
        ⊟ variableAccessSpecificatn: variableListName (1)
          ⊟ variableListName: domain-specific (1)
            ⊟ domain-specific
                domainId: IRECLDevice1
                itemId: LLN0$PQ
```

```
0000  00 26 45 00 18 dc 00 23  ae 7e 96 30 08 00 45 00   .&E....# .~.0..E.
0010  00 63 c4 fc 40 00 80 06  db cb ac 1a 00 cd ac 1a   .c..@... ........
0020  00 cb 08 5b 00 66 43 5d  db 99 54 eb fc c8 50 18   ...[.fC] ..T...P.
0030  fe 8e 5a 22 00 00 03 00  00 3b 02 f0 80 01 00 01   ..Z".... .;......
0040  00 61 2e 30 2c 02 01 03  a0 27 a0 25 02 01 14 a4   .a.0,... .'.%....
0050  20 80 01 ff a1 1b a1 19  a1 17 1a 0c 49 52 45 43    ....... ....IREC
0060  4c 44 65 76 69 63 65 31  1a 07 4c 4c 4e 30 24 50   LDevice1 ..LLN0$P
0070  51                                                 Q
```

Figure 2. Capture of a “Read dataset P-Q” message.

LTE FOR MICROGRIDS

With the increasing demand for mobile broadband services with higher data rates and quality of service (QoS), in 2004 started the study of Long Term Evolution (LTE). The goal was to select a technology that would keep 3GPP's Universal Mobile Telecommunications System (UMTS) at the forefront of mobile wireless well into the next decade. Key project objectives where defined in the following areas:

- Peak data throughput
- Spectral efficiency
- Flexible channel bandwidths
- Latency
- Device complexity
- Overall system cost

Broadband wireless mobile communication technologies, such as 3G and 4G, have many inherent advantages. Both 3G and 4G are bidirectional communications systems with wide coverage, making them suitable for widespread terminal access and remote control. 4G systems are faster than previous 3G systems, allowing at least 50Mbps uplink, and 100Mbps downlink or more. Such high data rate should be fully capable to meet Smart Grid information transfer requirements. LTE is expected to provide smaller transmission and connection delays, increased bit rate (even at cell edge), better spectral efficiency, transparent mobility toward any network and reasonable mobile power consumption.

Some important systems/parameters to cope within LTE that can be modeled and specified for microgrids management are the scheduling schemes and the latency requirements.

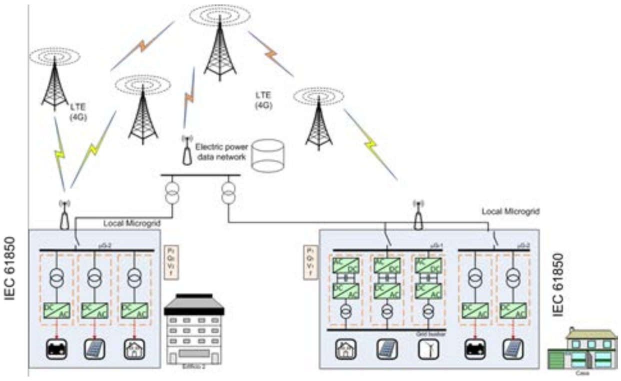


Figure 3. Communicating management units within microgrids using LTE subsystem.

Latency and channel requirements

Communication latency among distributed intelligent agents can have significant impact on high level capabilities of a smart grid installation, in particular any protection and coordination. Table I (from reference [8]) shows some requirements for a Wide-Area Measurement System for Data Delivery (WAMS-DD). It is remarkable that the network must be decoupled from the global Internet because it might not be able to meet the latency requirements of the SG. This would potentially result in security vulnerability for the SG. To be used for the second order headings.

LTE scheduling schemes

OFDMA selected for downlink (DL) radio access scheme due to its robustness to multipath fading, higher spectral efficiency and bandwidth scalability (bandwidth is divided in multiple sub-bands denoted as resource block (RBs), the minimum scheduling resolution in the time-frequency domain). Multiple access in DL OFDMA is achieved by assigning different frequency portions of the system bandwidth to individual users based in their channel conditions. In order to schedule resources to the different users on the DL, the base station (or eNodeB) needs channel quality reports from the individual users. The feedback reports from the individual terminal users to the base station are sent in the form of a *channel quality indicator* (CQI) that is obtained using reference signals trasnmitted from the base station.The packet scheduler at the base station uses the CQI feedback from individual users to perform an RB to user assignment every transmission time interval (TTI of 1 ms in LTE) according to the base station selected scheduling policy. The scheduler also determines the data rate to be used for each user in each subframe and can perform rate adaptation by using *adaptive modulation and coding* (AMC) in different subframes. Such fast channel depending scheduling in both time and frequency domain multiplexing is referred as *frequency-domain packet scheduling* (FDPS), which can improve by 40-60% the system capacity over time-domain only scheduling.

TABLE I
DIFFERENT LATENCY AND DATA SENDING REQUIREMENTS WITHIN THE DISTRIBUTION POWER GRID

Rate (Hz)	Latency (ms)	Quality	WAMS-DD	Deadline
120-720	5-20	Ultra High	Across grid or multiple ISOs	< 5s
60-120	20-50	High	Within an ISO/RTO	1 min
30-60	50-100	Medium	Between few utilities	1 hr.
1-30	100 – 1e3	Low	Within single utility	1 day
< 1	> 1e3	Very Low	Within substation	> 1 day

TEST SET-UP

The test on IREC labs, is conducted using LTE connectivity in the vicinity of the center. In less that 200 m straight line, there is the Telefonica tower. The modems are used to measure round trip time (RTT), connected into two computers via USB, by using the ping command. Pinging means the use of standard 4 packets of 64 bytes to the IP address specified.

Transfer speed from A to B is defined as the maximum quantity of data bits (payload) that can be transmitted from A to B with a HTTP connection over a TCP/IP during a unit of time (sec.). Control data necessary for the transmission such as TCP and IP heading are not included in this indicator. Latency between A and B is the required time in order to be able to send a packet, and is measured as the half of the time necessary to send and receive an ICMP (Internet Control Message Protocol) Echo/Reply between A and B. Such time includes the network necessary packet transport time as well as the processing time of the parquets between A and B

When considering a message average length of 200 bytes, a latency of 50 ms, and average sending message rate of 1 Hz, for an LTE uplink of 75 Mbps, we can transmit: 75 Mbps x 1s = 75 Mb or roughly 7,5 MB, and for a 200 byte message, we can have until 37.500 remote terminal units transmitting from the microgrids established in the coverage area.

Acknowledgments

This work was supported by the EIT and KIC-Innoenergy under the project KIC-INSTINCT.

CONCLUSIONS

In this work, it has been deployed within an nemulated microgrid at IREC facilities, a management algorithm that is sending consigns into the load, generation and storage units, that is the basis for obtaining the traffic requirements of their elements.

Several control options are being presented and one of the most faburable communication protocols is explained. Bsed on these premises, a volum of traffic can be estimated that needs to be feeted within the LTE estandard for future mobile networks. Latency is being presented as well as scheduling, and finally due to high data rate capacities is concluded that high volume of deveices could be managed.

REFERENCES

[1] Manuel Roman-Barri, “Experience on the implementation of a microgrid project in Barcelona” *IEEE ISGT Europe*, 2010

[2] T. Ackermann, “Distributed generation: a definition," *Electric Power Systems Research*, vol. 57, issue 3, pp. 195-204, April 2001.

[3] G. Pepermans, “Distributed generation: Definition, benefits and issues," *Energy Policy*, vol. 33, issue 6, pp.787-798, April 2005.

[4] R. H. Lasseter “Microgrid: a conceptual solution," *in Proc. IEEE 35th Annual Power Electronics Specialists Conf. PESC* 04, vol. 6, 2004, pp. 4285{4290.

[5] J. M. Guerrero, “Hierarchical control of droop-controlled ac and dc microgrids|a general approach toward standardization," *IEEE Transactions on indusctrial electronics* vol. 58, no. 1, pp. 158-172, 2011.

[6] Zhihao Zhang, “A load-shading control scheme for a microgrid with a fixed frequency inverter”, *Electric power systems research 80* (2010), 311-317.

[7] L. Igualada-Gonzalez, “Optimal managment of microgrids," *Master's thesis, Department of Statistics and Operations Research, UPC,* 2011.

[8] David E. Bakken, “Smart generation and transmission with coherent, real-time data”, *Proceeding of the IEEE,* June 2011, Vol.99, No.6