Wireless Communications and Virtual Operator for Residential Electric Metering

Esteban Inga
Universidad Politécnica Salesiana, Quito, Pichincha, Ecuador, einga@ups.edu.ec
Juan Inga
Universidad de Cuenca, Universidad Politécnica Salesiana, Cuenca, Azuay, Ecuador, juanpaulinga@gmail.com

ABSTRACT
The Communication Network and Business over Smart Metering is an important stage of the Advanced Measurement Infrastructure-AMI. It can provide additional services to consumers such as cuts and re-connections for an agile and reliable electricity supply, as well as prepayment services, among others.

In that respect, this paper refers to the importance of the customers in the proposed Smart Grid, that seek efficiency and reliability of the grid in general, and including supply for renewable energy and their metering process. Initial projects have implemented Smart Metering using RFID, but it is possible to use the current telecommunications infrastructure to decrease the impact of electrical consumption and to avoid multiplying electronic devices, using other protocols of communication such as CDMA or GPRS-LTE. Furthermore, the Mobile Virtual Network Operator - MVNO introduces the possibility of several applications for Smart Metering as a junction element between the distribution enterprise and electricity consumers. MVNO permits to offer a type of business, a market strategy and collaboration with transactive energy.

Keywords: — Smart Grid, Advanced Measurement Infrastructure, Mobile Virtual Network Operator, Smart Metering, Home Area Network.

1. INTRODUCTION

THIS document is intended to provide a proposal about Smart Metering for applications in home area networks , building area networks and including renewable energy. Since the first concepts in Smart Grid, different utilities have created a route map for this application; therefore, it is necessary to answer the next question, what is Residential Electrical Metering?

According to the REDIE, Ecuador Smart Grid Program, a Smart Metering uses electronic devices called "smart meters" obtaining real-time measurements so that both the consumers and the distribution company are able to get information that contains conditions of service and use of energy. This is the linkage point for the Advanced Measurement Infrastructure [1].

So, the stage of Smart Metering inside of Smart Grid has great importance related to exchanging information that eases the demand management, obtains the characteristics of consumers and knows their behavior as well as the impact over energy systems [2][3]. In Smart Grid, it is necessary to be efficient, reliable and safe [4]. Then, it is also required to implement an efficient enough Smart Metering infrastructure to avoid using more electronic devices with an extra electric consumption. By reusing and optimizing the resources, it is possible to reach this goal [5].

In addition, optimizing the Smart Metering resources is possible by reusing the channel required for exchanging information which is the communication networks. These are implicit factors in the current smart meters; in fact, at this moment there are three options, RFID, CDMA, GPRS and in the future LTE. However, the first choice needs a specific mesh

for its application; in contrast, CDMA and GPRS are solutions that, for mobile communications, will be replaced by LTE. Then, there will be available a new option of applications using old solutions in Smart Electrical Metering, thus reducing costs and energy consumption [6][7].

Consequently an MVNO – Mobile Virtual Network Operator- deliveries the facilities to develop a new market for smart metering [8]. A service devoted only to this goal will allow consumers to link with distribution enterprises, reusing the entire current infrastructure the mobile communication enterprises have in a country. Other advantages will be low cost in comparison with other traditional operators and market diversification which implies new proposals and services options for clients who will be supported by trans-active energy.

2. REQUIREMENTS FOR THE SMART METERING SYSTEM

In this section it is showed a brief survey of the existing works about Smart Metering, assuming that RFID requires a new infrastructure for its implementation as a way to exchange information; therefore, it is not considered.

2.1 THE BENEFITS FOR CONSUMERS

The Smart Metering stage of Smart Grid will also help consumers save money. Consumers will be able to monitor their home energy usage by using smart meters. This will encourage them to use less energy and will reduce the amount of overall energy needed by the grid. Using less energy at times of peak demand saves money for the consumer. The energy produced in high demand has an increasing cost in times of low demand. When a user sees the consumption and its real-time price, he could limit his use. Reducing the demand in peak hours can reduce the effect of created pollution.

2.2 CELLULAR COMMUNICATION IN RESIDENTIAL ELECTRICAL METERING

In this section technologies of communications are considered in relation to companies that distribute or manage projects with smart meters. In this case the idea is re-use GPRS and CDMA for rural-urban zones.

3. COMMUNICATION IN SMART METERING

Through communications it is possible to generate a new concept about efficiency, reliability and responsible consumption; consequently, it is possible to have a grid in a similar condition as the internet grid. In this case, the grid analysis is required and essential for its management and managers.

Different concepts are involved in Smart Metering, among other ideas, efficiency and reliability on the electrical grid; therefore, it is necessary to consider a new concept of the network communication in order to communicate in each area; in fact, there are communications by Cellular Network; Wireless Network, Wire Network; but all types define a concept to check economic aspects and converge on accessibility, quality service, latency, among others[9].

The main idea is exchanging information among these enterprises and consumers, using an efficient protocol and proof, though. The mesh network provides data such as energy surveys, discharge, control and monitoring of the consumers, peak demand and connection. It is able to disconnect the energy supply when this type of action is necessary.

On figure 1 this network describes a mesh more sensitive to economic aspects; otherwise, it is not a good idea to set it up in real life. On the other hand, the information exchange also depends on events in communication such as latency (delay in ms by each package), and quality services (there are effects such as fading that attenuates the signal). The last topic is more important for some cases in which information requires a higher real-time control and monitoring. This situation does not provide a good management of electrical grids [10][11].

The differences that exist between Cellular Network and Wireless Network are given by different characteristics such as interoperability, service quality and time in information transmission in two ways, a mature concept of cyber security, among others. Therefore, in a wireless network it is possible to consider coverage, capacity, latency, and safety. The first step in this process is to choose the topology according to the system requirements. It cannot be forgotten that in the cellular network there must be coverage for a number of users over an extensive geographical area that is divided into multiple cells. But the cellular network has an advantage which is the use of a spectrum, as the radio channels that are reused in other cells.

On figure 1 it is possible to analyze the connectivity among distribution and generation substations, micro-generation (wind turbines and solar panels), smart metering in home/householder, even mobile workforce, fleets and mobile emergency units; furthermore, there is a connection between wireless backhaul, in each internet access with optic fiber, and other GPRS/CDMA that completes the connection with call centers and corporate offices.

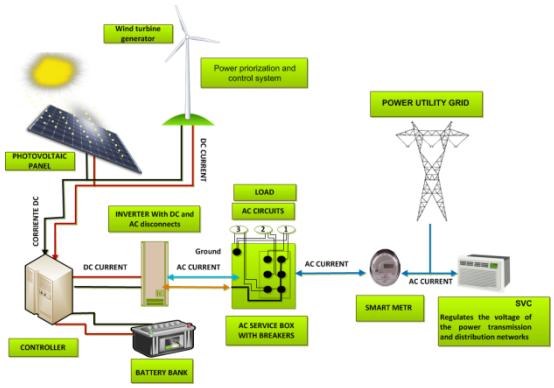

Fig. 1. Smart metering & renewable energy.

This picture permits to analyze the configuration of smart metering including renewable energy in the residences; from this level energy is distributed to different consumers such as distribution substations, solar plants, etc.

3.1 PROJECT MANAGEMENT IN TELECOMMUNICATIONS

In all projects of telecommunications networks, it is necessary to have a management project where there are a start, planning, execution, monitoring, control and closure; in fact, this project consists of those internally promulgated policies, procedures and practices to determine and use technology [12].

For example, in Guayaquil city (Ecuador) it exists in these moments the worst business in smart metering, named AMR – Advanced Measurement Reading, for not having a management plan of interoperability among smart meters brands. In a project, it is necessary to control and monitor all processes. The idea is to walk step by step and to set a vision into the future, especially about advanced technology, needs, and uses [13]. On figure 2 it is possible to analyze the first project in AMR reusing cellular communications as a protocol of communication to exchange information between electric distribution enterprises and the clients.

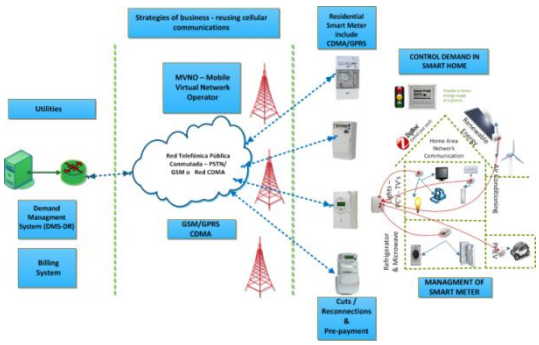

Fig. 2. Cellular Communications for Smart Metering.

The outage management system of residential consumers is considered for Smart Metering. When this type of events has occurred, there are several costs in relation to enterprises that offer different services such as: airlines, money exchange, on line transactions, etc. As a consequence, it is very important the quality on the grid. That is the reason why it is also necessary to prepare a specific task in such area; in fact, Smart Metering maintains this relation to analyze the demand and mitigate the use of energy in peak hours. The experience of large money losses due to failures in the system is real and however, it still has not been possible to control it.

For many enterprises related to power distribution, the most important aspect about getting a Smart Metering system and their first research include the concept of one-way distribution to charge. Thus, the consumers are given another position on the roadmap; as a consequence, there is not an optimal interchange of information, and the consumers do not receive other services, for example prepayment, low energy, distributed generation, real-time reading; in other words, it is actually, the need of managing demand from home.

The new research in smart metering looks for reliability, stability, efficiency, but also satisfaction for the consumer. The electric industry has neglected to provide other services or options to increase the efficiency at home. However, all these processes could allow users to reduce their consumption.

3.2 WIRELESS SENSOR NETWORK

A Smart Meter also offers another possibility for communications which has to do with the interior of a house. This feature is interesting in Smart Metering because of the facility to exchange information about electronic devices consumption, and through a smart meter, send data to the distribution company.

3.3 HOME AREA NETWORK-HAN

In this section, it has been analyzed how to connect, inside a house, some electronics devices with a Smart Meter. There are currently some options such as HomePlug or ZigBee[14][15] among others. With this solution it is feasible to be efficient at home. The home area network gives the possibility of transmitting data to the distribution company in order to be checked. It also allows simulating events and taking decisions over peak demand or simply demand. The demand response have an important state in smart grid, the figure 3 emphasizes this concept.

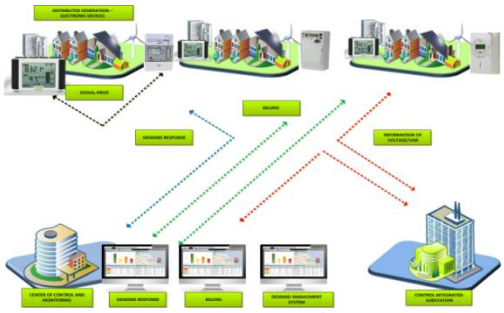

Fig. 3. Billing process of utilities.

4. CONSIDERATION

There are at the present time different governmental alternatives and agreements within this field; for example in Europe a plan has been launched for 2020. It is meant to increase the share of renewable energy into final energy consumption to 20 percent, and achieve a 20 percent increase in energy efficiency. On the other hand, in USA the department of energy has a different plan. It is about increasing wind energy generation in order to reach 20 percent of all the generated energy by 2030.

One of the most important features in smart grid is its capability to reduce peak loads with the manufacturing of more efficient electrical appliances or devices. In addition, some procedures have been proposed to reduce the user's consumption automatically.

In fact, this concept allows considering a new future in all the line of the energy system. The concept of being efficient is linked to time reduction or increasing the performance in electrical consumption; but it is necessary, at the same time, to control the whole electrical system and maintain the stability and an efficient use of electrical energy that will benefit everybody.

4.1 MOBILE VIRTUAL NETWORK OPERATOR - SMART METERING.

The smart grid requires Smart Metering, which in relationship with [16] and [17] generates benefits.

In addition, the implementation of digital technologies to obtain what is mentioned above implies that the Smart Grid sets up a Smart Metering system that reports about the state of the energetic use of every user [18] as it was previously remarked. Therefore, it is very important to determine the most adequate access for data transport from the smart meter to the enterprise that provides these services and related applications.

In this sense, given that electric energy smart meters have the capacity of getting integrated into wireless mobile communications systems as CDMA o GPRS/3G without the requirement of implementing additional infrastructure, it can be determined as an adequate solution, assuming each smart meter as a mobile device, but immovable. This means establishing a machine to machine service (M2M) between a smart meter and the electric distribution enterprise [19].

Considering each smart meter as a mobile device implies that a mobile network operator (MNO) is able to satisfy the Smart Metering specific needs. However, the planning, that among other issues, is required to carry out the implementation of the service will take more time than what was originally foreseen.

It could even mean a larger expense of both economical and network resources due to the need of generating a strategic planning and finding means and all the necessary logistics that this kind of business requires to maintain its previous operations and taking on the new ones that are usually produced when an activity, such as the Smart Metering AMR-AMI, is undertaken.

The Smart Metering implementation means that the operator entity or company gets a large specialization in managing M2M dedicated to the energetic sector. These services demand not only management applied to the data gotten from smart meters but they also need to generate services and additional applications for consumers based on the link between communication networks and the AMI stage.

Thus, in a saturated market or highly concentrated like the Ecuadorian one (an oligopolistic market) where the market stakeholders own their business niches very well marked off, a Mobile Virtual Network Operator (MVNO) will be the best solution because of its characteristic of getting completely committed to satisfying the client's needs and to the service that has to be implemented.

An MVNO can become a sub-brand or a department within an already established company in order to manage data distribution services. This information is related to the AMI stage in Smart Grids. It could also become a company determined to offer its services as a specialized telecommunications provider.

From what has been said so far, technical, economical and legal MVNO characteristics will be analyzed in order to start a Smart Metering business.

4.2 TECHNICAL AND ECONOMIC ANALYSIS

Implementing a Smart Metering employing M2M services requires many aspects to be taken into account [20]. By checking some related works, these following issues can be summarized:

- Safety levels on the network have to be highly developed.
- The standard choice must be adequate so that technical and economic benefits are maximized.
- The AMI infrastructure will need to be able to check and control remotely the energy employed in a house or business on real time.
- Home area networks design should ease communication among M2M destinations.

All of this will have to be taken on by the telecommunications provider agent. Graphic number 3 shows the scenario where the company in charge of telecommunications services management, is guided by a MVNO.

Due to the fact that information management does not have any relationship with voice services but, more specifically, with data services, the link between MNO and MVNO for 3G networks or the previous ones, will be given by the host operator's SGSN and the leaseholder operator's GGSN, this operation is illustrates in the figure 4.

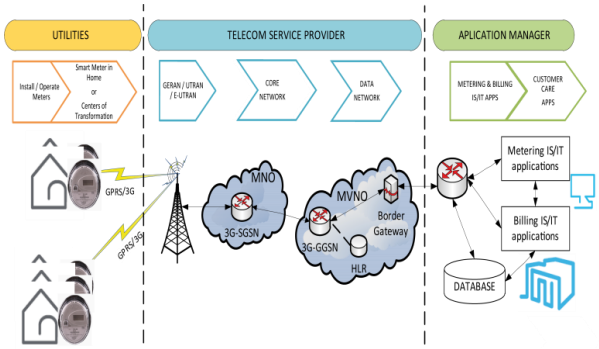

Fig. 4. Data Traffic Scenario with MVNO

From technical considerations, it is necessary to count on a type of technology able to meet technical and quality service conditions. But it is also important, for the sake of the business, to ensure the network scalability; and to generate applications for the consumers so that they are able to check and control their own consumption level easing the billing and payment process.

Technical issues will also enable agents to determine what technology is the most suitable according to demographic characteristics of the place where a Smart Grid is installed.

So on one hand, in Ecuador CDMA is adequate for rural zones access because the inhabitants' purchasing power is lower over there. As a consequence, the advanced applications of the service will be limited. On the other hand, GPRS, 3G or LTE are the most adequate standards for urban zones because they offer a larger number of developed applications and they allow the access to data more efficiently, such as the case of LTE.

Since the Smart Metering stage must be available for users through different operators, there is an inconvenient that comes up; the MVNO has to be kept connected with other operators. Therefore, the MVNO should boost flat rates for all grid users. This means the interconnection price will allow the MVNO to maintain a high earning level with the users of its host operator, who will resell network capacities wholesale [21].

The relation MNO-MVNO could be negotiated through access costs either by registered traffic or by a fixed fee that the virtual operator will have to pay to his host for the usage of the access infrastructure. However, these costs are considered similar to the interconnection ones that have been set out on the negotiating tables regarding this issue [22].

Scale economies must be essential in a telecommunications management model, and this kind of business is not is an exception to the rule. Therefore, economic models capable enough to determine the access fees in such negotiations, must be based on long term incremental costs because the project will have to be sustained on both medium and long terms [7].

The implementation of a Smart Metering system will improve its own benefits and those for its users [23]:

-- For the company

- It improves cash flow and financial management through a reduction of personal and charge costs.
- It reduces frauds.
- It equilibrates load balance

-- For the clients-consumers

- Power checking; customers see directly their energy consumption and thus their spending level.
- Convenient payment avoiding long lines and choosing when to pay.
- Reliable system.
- No billing errors.
- Improved supply quality.

4.3 REGULATORY ANALYSIS

The regulation is usually based on the delivery of a larger measurements volume that are read remotely through smart meters, but the main problem will be the MVNO[24] regulation.

That is the reason why it is necessary to count on clear rules that permit and foment the operation of MVNOs. These systems must be allowed to offer services not necessarily related to voice, such as the case of this research analysis.

Then each country should analyze under its own perspective whether it is necessary to determine rate ceilings or to let the market be self-regulated.

4.4 IMPLEMENTATION OF MVNOS FOR SMART METERING

In addition to what has been mentioned, it is considered that remote access to smart meters through a mobile network offers a larger feasibility in comparison to a RFID solution because of maintaining a simpler infrastructure [6][7].

Because of wireless mobile services and constant technological improvements of devices such as smartphones, reusing standards as GPRS or 3G is an ideal option. Latin America is not out of this trend. As a matter of fact, it showed a high degree of technological penetration average, which reached about 112% by the end of 2012 [25]. The possibility of implementing internet services is also growing and it is expected the M2M ones to increase outstandingly in the near future [20][26][27].

Considering MVNOs as a solution for data management is important because this will enable providers to get specialized in the clients' needs. They are consumers of energetic services and are served by utilities.

On the other hand, a MVNO helps reduce the impact on telecommunications infrastructures and lower implementation costs. It also fosters technological recycling, and even more important, electric consumption reduction in electronics devices used for smart metering.

5. CONCLUSION AND OUTLOOK

In relationship to the whole concept of Smart Metering, it is necessary to set up control, monitoring and management. But for this, there is only one way; the use of communication in all the different options analyzed on this paper.

Building new edifications and homes with renewable energy will need communication that allows customers to connect with distribution companies, and offers to consumers the alternative of selling their extra green generation. In fact, this design or route map has a social impact for future and current generations. However, this

concept also implies a large investment and the problem of facing a changing technology that gets obsolete quite rapidly.

Assuming that a MVNO is managing the Smart Metering telecommunications stage, it is possible that a monopoly of this service belonging to the provider company is established for being pioneer in a quite important sector.

This will mainly depend on State policies for the energetic sector. As a consequence, it could be possible for a public telecommunications company to create a sub-entity strictly devoted to provide the services at issue. Another possibility would be launching a bidding process in order to determine which company or companies are the best suited for offering these services.

It can be added that a monopoly could be avoided in a country through assigning several MVNOs to be responsible for Smart Metering management in different areas or regions. Nevertheless, this could lead to a company's dissatisfaction if it considers its assigned area does not produce higher profits due to geographical, demographic or ethnographic conditions.

Finally, telecommunications services linked to Smart Grids can be managed only if there is a clear set of rules to arrange their operability under free market conditions.

6. REFERENCES

[1] G. Meer, Conelec, Cenace, Celec, "Programa Redes Inteligentes Ecuador - Mapa de Ruta," Quito, p. 65, 2013.

[2] E. Inga, V. Orejuela, D. Arias, and J. Inga, "Comunicaciones celulares para medición inteligente de energía eléctrica en sistemas de distribución," 2013.

[3] E. Inga Ortega, "Redes de Comunicación en Smart Grid," *Ingenius*, vol. 7, no. Revista de Ciencia y Tecnología, pp. 36–55, 2012.

[4] M. Arian, M. Ameli, V. Soleimani, and S. Ghazalizadeh, *Intelligent migration from smart metering to smart grid*, vol. 2. IEEE, 2011, pp. 547–552.

[5] A. Molderink, V. Bakker, M. G. C. Bosman, J. L. Hurink, and G. J. M. Smit, "Domestic energy management methodology for optimizing efficiency in Smart Grids," *2009 IEEE Bucharest PowerTech*, pp. 1–7, 2009.

[6] S. T. Mak, L. F. Ieee, and E. International, "Synchronizing SCADA and Smart Meters Operation For Advanced Smart Distribution Grid Applications," 2011.

[7] D. Niyato, L. Xiao, and P. Wang, *Machine-to-machine communications for home energy management system in smart grid*, vol. 49, no. 4. IEEE, 2011, pp. 53–59.

[8] J. Inga Ortega and E. Ordóñez, "Análisis Técnico, Económico y Regulatorio para el Ingreso de un Operador Móvil Virtual en el Ecuador," Universidad Politécnica Salesiana del Ecuador, 2013.

[9] F. Bouhafs, M. Mackay, and M. Merabti, "Links to the Future: Communication Requirements and Challenges in the Smart Grid," *IEEE Power Energy Mag.*, vol. 10, no. 1, pp. 24 –32, Feb. 2012.

[10] Z. Fan, P. Kulkarni, S. Gormus, C. Efthymiou, G. Kalogridis, M. Sooriyabandara, Z. Zhu, S. Lambotharan, and W. H. Chin, "Smart Grid Communications: Overview of Research Challenges, Solutions, and Standardization Activities," *IEEE Commun. Surv. Tutorials*, vol. 15, no. 1, pp. 21–38, 2013.

[11] C. Wietfeld, H. Georg, S. Gr, C. Lewandowski, and J. Schmutzler, "Wireless M2M Communication Networks for Smart Grid Applications," *Energy*. VDE VERLAG GmbH, pp. 275–281, 2011.

[12] F. Hartman and R. Ashrafi, "Project management in the information systems and information technologies," *Manag. J.*, vol. 33, no. 3, pp. 5–15, 2002.

[13] K. Jugdev and J. Thomas, "Project management maturity models: The silver bullets of competitive advantage," *Proj. Manag. J.*, vol. 33, no. 4, pp. 4–14, 2002.

[14] D. Gislason, *ZIGBEE wireless networking*. Amsterdam: Elsevier/Newnes, 2008, p. 425.

[15] S. Farahani, *ZigBee wireless networks and transceivers*. Amsterdam; Boston: Newnes/Elsevier, 2008, p. 339.

[16] M. J. Booysen, J. S. Gilmore, S. Zeadally, and G. Van Rooyen, "Machine-to-Machine (M2M) Communications in Vehicular Networks," *KSII Trans. Internet Inf. Syst.*, vol. X, no. X, pp. 1–21, 2011.

[17] Schneider Electric, "Smart Metering. Xperience Efficiency," 2012.

[18] J. Liu, Y. Xiao, and J. Gao, "Achieving Accountability in Smart Grid," *IEEE Syst. J.*, pp. 1–16, 2013.

[19] G. Wu, S. Talwar, K. Johnsson, N. Himayat, and K. D. Johnson, "M2M: From mobile to embedded internet," *Commun. Mag. IEEE*, vol. 49, no. 4, pp. 36–43, 2011.

[20] Z. Fadlullah, M. M. Fouda, and N. Kato, "Toward Intelligent Machine-to-Machine Communications in Smart Grid," vol. 11, no. April, pp. 60–65, 2011.

[21] G. L. A. N. Fu, C. Yang, and G. W. O. H. Tzeng, "A MULTICRITERIA ANALYSIS ON THE STRATEGIES OPERATORS SERVICES," *Int. J. Inf. Technol. Decis. Mak.*, vol. 6, no. 1, pp. 85–112, 2007.

[22] S. Pattanavichai, N. Jongsawat, and W. Premchaiswadi, "A pricing model and sensitivity analysis for MVNO investment decision making in 3G UMTS networks," *2010 IEEE Symp. Ind. Electron. Appl.*, pp. 22–27, Oct. 2010.

[23] Nereo Business Consultants, "Smart Grid and MVNOs."

[24] J. P. Inga Ortega and E. Ordoñez, "Modelos de negocios para OMV en el Ecuador," *Ingenius*, vol. 9, no. Revista de Ciencia y Tecnología, pp. 50–56, 2013.

[25] Signals Telecom Consulting, "MVNOs en América Latina White Paper." 2012.

[26] Y. Benkler, “Open WIreless vs Licensed Spectrum: Evidence Form Market Adoption,” *Harv. J. Law Technol.*, vol. 26, no. 1, pp. 71–163, 2012.
[27] “Driving the energy sector towards the M2M-enabled smart grid :: Analysys Mason | Prepaid MVNO,” 2011. .

7. BIOGRAPHIES

Esteban Inga (M’1976-SM’08). He graduated from the Universidad Politécnica Salesiana. He is currently working toward a Ph.D. of degree in Engineering in the Universidad Pontificia Bolivariana- Colombia-Medellín. His research interest is cellular communications in advanced measurement infrastructure- smart grid. He is a professor of Universidad Politécnica Salesiana-Ecuador, director of Electric Engineering. Since 2011 is associated to group of research in Smart Grid

Juan Inga (M’1986-SM’08). He graduated from the Universidad Politécnica Salesiana- Ecuador as M.C. of the Telecommunications Management Program. He is professor of Electronic of Universidad de Cuenca - Ecuador and Professor and Telecommunications of Universidad Politécnica Salesiana - Ecuador.

Authorization and Disclaimer

Authors authorize LACCEI to publish the paper in the conference proceedings. Neither LACCEI nor the editors are responsible either for the content or for the implications of what is expressed in the paper.