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Proposal for a Monitoring and Dispatch System for Distributed Micro-Generation of Renewable Energy in Virtual Energy Centers

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ABSTRACT

The creation and updating of ANEEL (National Electricity Regulatory Agency) regulatory resolution on distributed generation provided a new business environment for the electricity sector, as well as enabling consumers to generate energy. In this context, distributed microgeneration plants management is a challenge, mainly for electric power distributors and for the entire supply chain and services. In this sense, it is urgent to develop a monitoring and dispatch system in microgeneration plants, in order to optimize the capacity factor of the enterprises and to enable the creation of Virtual Power Plants (VPP). VPPs are part of a new dynamic of the energy sector's strategic environment, which strengthens distributed generation through smart meters capable of communicating with operational centers and thus influencing new business models already diffused by the known smart grids. Included in this scenario, this paper presents a proposal for a monitoring and dispatch system for distributed micro-generation of renewable energies, as well as the engineering solution for a final product focused on market expectations.

Key words: Distributed Micro-Generation; Electric Power Market; Virtual Power Plants.

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INTRODUCTION

The need to expand energy supply by 50% every 20 years presents a real challenge in the world. Associated to this is population growth, economic growth and poverty reduction. Thus, the increase in collective awareness with a focus on respect for people and the environment has forced countries to search for energy solutions with a focus on common well-being, such as the so-called Paris Agreement, recently held at the 21st Conference of the Parties (COP -21) of the United Nations Framework Convention on Climate Change in the French capital.

If twentieth century was the century of fossil fuels, the twenty-first is announced as Renewable Energy, which can be evidenced by high growth rate in the share of renewable sources, notably wind and solar, in electric energy generation. Nationwide, according to ANEEL (National Electricity Agency) data of 2016, published in Generation Information Bank (GIB)[1], Brazil currently has 4.587 power generation projects in operation. According to GIB, there are 207 projects under construction and 660 with uninitiated construction, which are expected to add more than 25GW in country's power generation capacity. It is worth mentioning that, according to Monitoring Report on Implementation of Generation Undertakings[2], published in April 2016 by the same agency, photovoltaic plants are responsible for 4.4% of matrix for implementation of new electricity generation projects. Another highlight in the document is the addition of some 441.5 MW of wind farms granted in 2016.

Although the data presented refer to National Interconnected System (NIS), based on Normative Resolution 482 of April 17, 2012, updated by Resolution 687/2015, distributed micro and mini-generation systems have gained interest from consumers that, generating their own energy with renewable sources, started to access the systems of distribution and net metering, and also gained prominence in the planning of expansion of the national electricity sector due to the supply of active power and fundamental ancillary services to the electric grid.

This new configuration, merging the roles of consumer and producer or the called *prosumers*, implies a strategic business environment completely different from that established decades ago in Brazil, where the isolated generation systems with few connections and many restrictions prevailed, as well as the interconnected ones, with broad territorial extension and essentially unidirectional. In this sense, what is currently seen are productive forces and governmental interest in expanding the modality of electricity production in the country by the creation of a distributed and connected electrical sector, with a diversified matrix, with a strong presence of distributed generation (DG) through the use of smart grids and with two-way power flow.

As a result of this new way of exploring the electricity sector market, there is a need to integrate these small generation sources in order to optimize energy resources. In face of this, several agents are emerging to bring knowledge about market trends with new information technologies and systems automation, in order to increase control over plants and increase financial return of these enterprises. Among these new agents is the Virtual Power Plants (VPP), which enable the said virtual operators of system to manage power generating units as if they were only one, that is, as a larger power generating plant[3].

Aligned to this new reality of national electric sector, this work presents two plants of generation of energy from renewable sources. One of these facilities refers to a mixed plant, built in the municipality of Foz do Iguaçu/PR in an area provided by Itaipu Binacional. This plant is made up of photovoltaic generation system with installed capacity of 3kWp and a biogas/biomethane production unit. The other facility refers to a photovoltaic generation plant installed at Instituto Federal de Rondônia (IFRO) with a capacity of 15kWp in the municipality of Porto Velho/RO. In addition, a monitoring and control system of these plants will be presented, with a view to the development and implementation of a VPP that will allow exploiting the potential of the projects in an efficient way.

MATERIALS AND METHODS

Virtual Power Plants

n practical terms, VPPs allow integration of various distributed energy resources and their interconnection with electric system. It operates in this way as a single agent in the energy market, aggregating various components that operate in DG. When VPPs incorporate energy storage capacities and responsibilities to meet the demands, it is allowed that microgeneration units act in dispatch of energy as larger plants[4].

Study of VPPs has been gaining prominence in the scientific environment, especially with its implementation in distributed systems[5,6,7], where technical and regulatory barriers that have yet to be overcome to expand this new concept are discussed. Other areas of research focused on VPPs are commercial[8], control[9], dispatch[10] and various technical requirements for implementation of these agents[11].

The literature[12] differs from two types of virtual power plants: Technical Virtual Power Plants (TVPP) and Commercial Virtual Power Plants (CVPP). In general, TVPPs have a local focus, since they manage energy resources and production costs. In addition, these entities are concerned with services provision to power grid, either as active power reserve or ancillary services. On the other hand, the CVPPs turn to energy market, whether offering service or participating in auctions.

In order to structure the creation and implementation of these plants, many efforts have been undertaken in the identification and standardization of services offered to power grid. In[13], for example, the authors propose a mapping of the services of these exchanges using the architecture model of smart grid or SGAM (Smart Grid Architecture Model)[14]. In this model, 5 layers or dimensions of interoperability are shown in Figure 1.

In general, the first tier or Business Layer refers to economic and regulatory policies of energy sector as well as business objectives. Second Layer, called Function Layer, comprises management and control systems of distributed energy resources. Information Layer defines the standardized data models exchanged between subsystems, while the Fourth Layer or Communication Layer deals with protocols and network technologies that meet operational requirements. Finally, Component Layer comprises basic components involved in VPP implementation and connectivity between them.

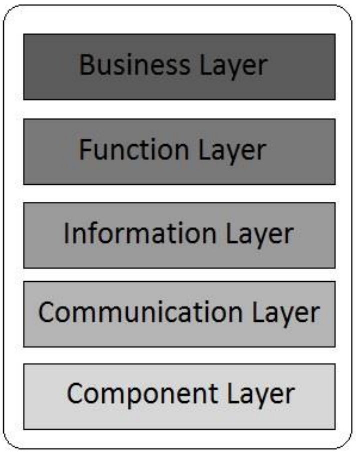

Figure 1- VPP Control Layers.

DISTRIBUTED MICROGENERATION PLANTS AND MONITORING SYSTEM

Overview

The project includes the following macro deliveries: i) to implement a solar generation complex using different energy generation and storage technologies at Itaipu Binacional and Instituto Federal de Rondônia. In both cases, systems will serve as backup for utility to facility lines and, in the case of Itaipu plant, may relieve its auxiliary service; ii) to automate a biogas/biomentane generation plant, installed in Itaipu, from biomass from restaurant sewage and grass pruning to supply vehicles powered by biomethane. Occasionally, as already happens in other installations, biogas can be used for electricity generation; iii) to develop a monitoring system capable of grouping data on plant status, production per period, and market information. Also, incorporate some remote commands that can work on these systems; iv) to create a portfolio of short-term, long-term, market-driven projects that attract funds through the Private Investment Fund / FIP or other business model. It is hoped to leverage projects in plant deployment regions, taking advantage of opportunities that are emerging in the distributed generation sector.

Biogas/Biomethane Generation Plant

Plant for biogas/biomethane production, which is being installed in Itaipu Binacional, is shown in Figure 2 and shall have the following characteristics:

- Biogas production capacity: 500 m³/day;
- Biomethane production capacity: 300 m³/day;
- Occupied area: 3.000 m²;
- Bioreactors number: 2;
- Power consumption: 6.5Mh / month

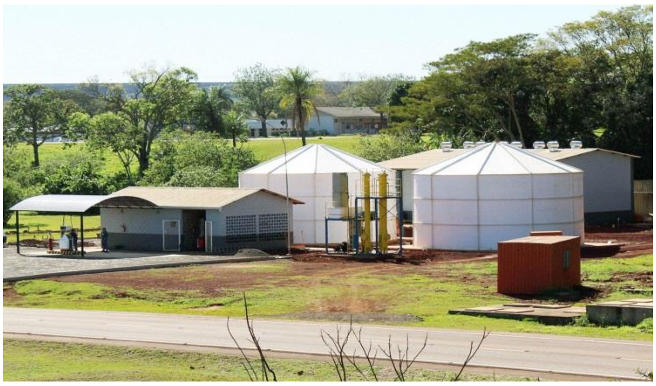

Figure 2 - Demonstration Unit (DU) of biogas/biomethane production. Installation in Itaipu Binacional.

When it comes into operation, the plant will process the following amounts of biomass:

- Sanitary sewage: 10m³/day;
- Grass: 1.200 kg/day;
- Organic waste: 600 kg/day;

The mentioned sanitary sewage originates from Itaipu production building, while grass will come from daily prunings in vegetation of broad green areas of plant. Regarding organic waste, material will come from restaurants installed in Itaipu Binacional complex, which are in the vicinity of the plant. In general, after receiving organic

residues, biomass preparation will take place, that is, the fractions of residues from grass and sewage will be added in order to obtain a mixture with 12% solids.
Initially, the plant will exclusively produce biomethane to supply a fleet of 60 Itaipu vehicles powered by this fuel. However, if the plant were used to generate electricity, 500m³ of biogas would account for approximately 21MWh/month.

Photovoltaic Generation Plant

Next, the study will present photovoltaic generation plants installed in Itaipu Binacional, in Paraná State, and in Instituto Federal de Rondônia.

Itaipu binacional installation

The photovoltaic generation plant to be installed in Itaipu Binational, shown in Figure 3, shall have the following characteristics:

- Installed power: 3.18kWp;
- Occupied area: 50m²;
- Panels/power per panel number: 12/265W;
- Inverters/power per inverter number: 1/3kW.

It is worth mentioning that this future installation is a demonstration unit for the purpose of preliminary studies of technical-economic feasibility and for validation of monitoring system under development. The plant will be connected to Itaipu's low voltage grid and will reduce the energy costs of biogas/biomethane plant.
With a view to production of clean and sustainable energy, it is intended to increase generation capacity of the photovoltaic plant and enable its direct connection to the biogas/biomethane generation system in order to close a cycle of production of electric energy and fuel from a renewable source that uses waste.

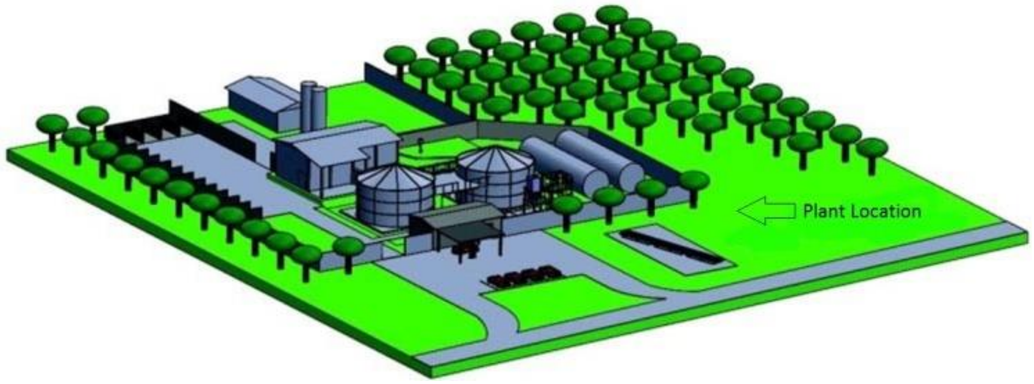

Figure 3 - 3D representation of the Demonstration Unit (DU) installation of biogas/biomethane production with installation of the photovoltaic power generation panel.

Installation Instituto Federal de Rondônia

Photovoltaic generation plant to be installed at Instituto Federal de Rondônia (IFRO), shown in Figure 4, shall have the following characteristics:

- Installed power: 15kW;
- Occupied area: 200m²;
- Panels/power per panel number: 56/265W;
- Inverters/power per inverter number: 2/8.2kW.

Figure 4 - Demonstration Unit (DU) of photovoltaic power generation highlighting the installation site at Instituto Federal de Rondônia (IFRO). Source: Google Earth. Consultation held on 09/2016.

When installed, the system will have two fundamental purposes: i) to serve as a laboratory with the institution for conducting research of students and teachers; ii) to enable technical-economic feasibility studies to expand this generation modality to communities with restrictions on access to electricity in the north of the country. The system will be connected to low voltage network through a substation installed inside the institute and will allow a reduction in cost of electric energy.

Monitoring System

For an effective implementation of a VPP, which integrates all information on available distributed energy resources, availability, production cost capacity of plants and energy market trends and tariffs, it is necessary to automate plants, a network of Communication, with online data collection and transmission services, such as a production history analysis and some level of remote control of generating units.

This integration between the VPP subsystems, from the low level, where production processes are located to high level, where purchases and sales of energy assets are made, is essential for decision making by the virtual operator. In this sense, the project presented in this work proposes a monitoring system that, if it does not yet include all the functionalities desired for the operation of a VPP, heads towards this objective.

The system developed is based on internet of things (IoT), which has been applied in several scenarios from business models for large companies to residential automation projects[15].

Figure 5 shows a vision of monitoring and control system developed for the project, where all information about generation units will be concentrated and from which it will be possible to carry out some interventions in the processes. The system can be accessed by the user through an interface for personal computers or mobile devices, such as tablets and cell phones. In addition, different user profiles will be defined to allow access levels with greater or lesser coverage to system.

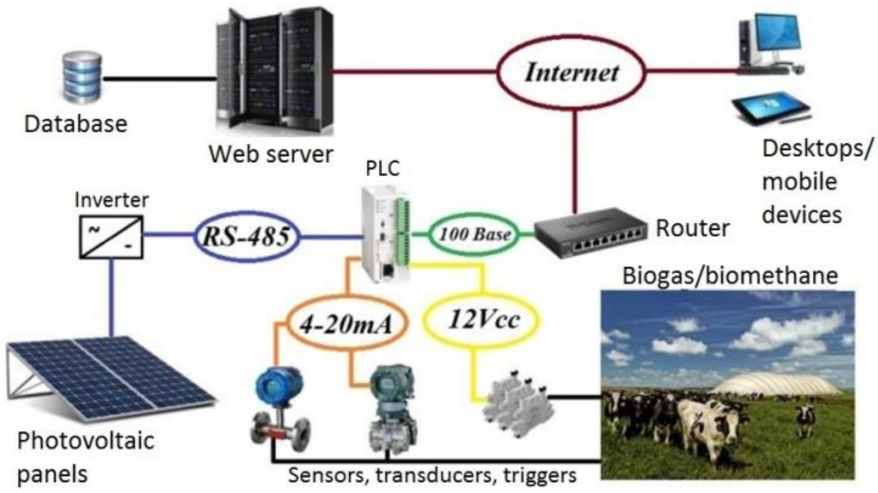

Figure 5 -. Diagram of the instrumentation and monitoring in development for integration of the generating units of energy.

Presence of web server and database is highlighted in the system, which will allow access both to online data and to the history of information about production unit in a period selected by the user. All information will be available through graphs and/or numerical values. Application will still have a dynamic character, allowing the user to register new plants, new monitored quantities and new equipment. Contextualizing with what was discussed in section 2, layers included in the design of monitoring system are: component, communication and information, since all logistics of supply and instrumentation of plants, network structure for collection and transmission of data and Support for the visualization of information by the user are being developed.
Among the quantities monitored in each system, we can highlight:

1. Photolvoltaic Plant:
a. Eletrical Current, Inverter input and output voltage
b. Electric power generated;
c. Power factor;
d. Irradiation, Wind speed, Temperature;
e. Quantity of energy produced, saved;
f. Local energy tariff and savings achieved;
2. Biogas/Biomethane Plant:
a. Amount of grass processed;
b. Sewage processed volume;
c. Organic waste processed volume;
d. Gas produced volume;
e. Volume of biomethane produced and supplied to vehicles;
f. Revenues.

For the photovoltaic system, all measured electrical parameters are supplied by the inverter, while meteorological parameters are from the sensors installed on site. With respect to the biogas/biomethane production plant, the instrumentation is more diversified and involves sensors of temperature, flow, pressure, triggers, transducers, etc. In this case, the programmable logic controller controls the plant and reads status of some equipment and sends data to the cloud, which makes this information available to the end user and updates the database for future reference. For locations where there are no internet available, mobile phones are expected to send data to the cloud.

For the evolution of system, remote control from applications that run on mobile devices are planned to be made available. In this way, the operator or owner can turn the plant on or off or direct the flow of energy produced.

RESULTS AND DISCUSSIONS

The purpose of the project detailed in this work can be understood from the feedback system, as shown in Figure 6, which, despite not including all subsystems of virtual power plant concept, already identifies in this model elements that point to the implementation of these entities.
As seen in section 3, plant 1 is located in the state of Paraná and refers to a mixed plant with photovoltaic generation and biogas/biomethane. Plant 2 is a photovoltaic generation system exclusively. However, it is through monitoring system and storing data that operators or users can visualize production levels, monitor targets, cost evolution, tariff policy, weather conditions, etc.
Thus, it is from the analysis of relationship between energy produced value, production costs and energy resources availability, that one decides on generating units operation.

To illustrate this, some scenarios can be created to illustrate how the systems work:

- *Scenario1:*
  Context*: Low biomethane demand and low biomass supply due to the holiday period at plant.*
  Action*: Focus on production or storage of photovoltaic energy for the purpose of compensation or provision of services to the grid.*
- *Scenario 2:*
  Context*: High demand for fuel and high electricity cost.*
  Action*: Focus on photovoltaic energy production for the purpose of compensation or exclusive supply to biogas/biomentane plant.*
- *Scenario3:*
  Context*: Control of biomentane production volume for the supply of vehicles and the production of biogas for cooking.*
  Action*: Focus on right proportion of production to maximize profit.*

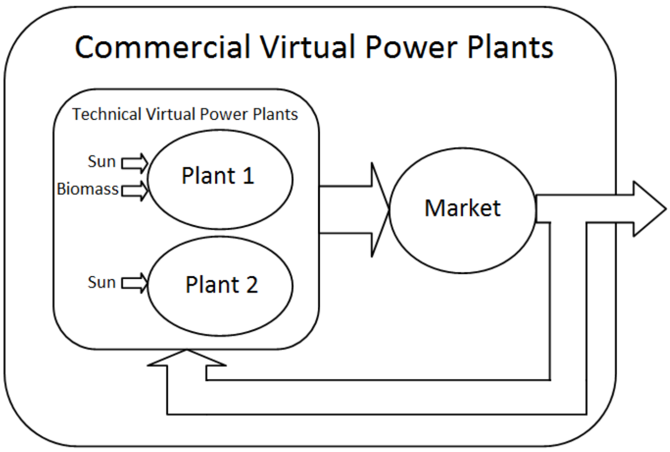

Figure 6 - Scheme of the Virtual Power Plant from microgeneration plants installed in Paraná (plant 1) and Rondônia (plant 2).

The aim of the system is therefore to provide information about generating units as well as energy market in order to enable the operator to operate on these units in an efficient manner and in line with market trends. This requires an increasingly high level of

automation and an adequate communication network infrastructure to enable online data collection and possible operation interventions.
It is also worth mentioning the continuous registration in database of all operation and production of generating units. This corresponds to a record, which can be accessed at any time for temporal analysis of plant behavior and productivity.
Considering the current stage of development, much still needs to be done. Among the main points to be advanced are:

- Expansion of the number of installed plants interconnected to the system;
- Raise the level of automation of processes;
- Allow storage of photovoltaic energy;
- Expand possibilities of remote intervention in plants;
- Standardize the system according to international standards;

CONCLUSION

The work presented the implantation stage of two microgeneration power plants installed in the states of *Rondônia* and *Paraná*. The first case is a plant that is exclusively photovoltaic and the second one is a photovoltaic and biogas/biomethane plant. In this sense, attention is drawn to a new look given to organic waste and sanitary sewage, which are treated as energy resources. The project follows the current trend of pulverizing energy production throughout national territory, promoting highly positive socio-environmental impacts and important services for the electricity sector at all levels.
A system where generation units are distributed requires, however, remote monitoring and management of energy resources and market evolution. For this, the presented monitoring system collects and makes available production data and plant generation availability both online and per period. Therefore, all infrastructure presented is aligned with the concept of a virtual power plant, an entity dedicated to the management of energy resources and dispatching of energy generation, which has been explored and developed in several countries. Although embryonic, the project reflects new business scenario that is opened in the electric sector and which will certainly require regulatory bodies to have a more inclusive legislation regarding the generation of distributed energy.

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