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Active Control Network Applied to Hydrogen and Ion Lithium Energy Storage Systems

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Abstract

The research of efficient renewable energy generation, storage and distribution technologies is an important step towards the implementation of continuous energy supply in an electric power grid, due to the intermittency of photovoltaic and wind generators microgrids. Supported by strategic research call of the Brazilian National Electric Energy Agency (ANEEL) the development of innovative Smart Grid Management methodologies employing predictive model analysis was proposed for a hybrid energy storage system consisting of a ion -lithium battery bank and hydrogen storage system using electrolysis fed by a set of photovoltaic plants with interconnected wind turbines as a micro energy network. The development of a robust system of instrumentation and control applied to the project contemplates the development and testing of a control mesh that includes the wireless integration and secure access with own point-to-point encryption applied. The quality and energy efficiency requirements can be verified in the experiments performed and behavioral models defined for the elaboration of representative mathematical models based on the predictive analysis of the collected data. In the context of increasing use of distributed generation, micro-energy and resource availability efficiently, it is expected to collaborate with the generation of tools from the predictive analysis as a basis for the prospective analysis enabling the development of control and monitoring systems appropriate to the expansion of the use of distributed renewable energy. The research is part of a structure that was started with the implementation of a photovoltaic and wind farm with investments by Companhia Energetica de Sao Paulo (CESP) in previous ANEEL research projects, and is now complemented with the energy storage and dispatch approach.

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Introduction

Looking for the smart cities electric power requirements [1], one basic objective is obtain cooperative operation in a structure composed of buildings with increasing deployment of distributed electricity generation systems, such as photovoltaic, wind turbines, solar and biomass systems, providing energy to devices, miscellaneous and lighting, with float load potential and demand. Microgrids have been used in order to organizing structures for a decentralized grid, but for this purpose storage systems need be used for supply a continuous and stable power flow. Some of the storage technologies selected for this research are lithium batteries and hydrogen fuel cell system. Power network control involves dispatching sources, storage systems and loads. Strategies for microgrid dispatching control with storage systems as hydrogen and ion lithium batteries are based in massive and continuous data acquisition of parameters into the microgrid looking for obtain a predictive model of power energy influence parameters. Establishing meters with distributed monitoring and data logging capabilities to allow estimation on strategic segments of the power grid will enable instantaneous consumption diagnostics, defining load shifting profiles and energy efficiency metrics for the analysis, operating as an integrated network of multiple Meter Data Colleting (MDC) [2]. Implementing a distributed meter network in a dynamic infrastructure subject to future expansion and change places modularity and adaptability as a requirement, employing wireless transceivers with modular, expandable and integrated technology and topology, including software defined radio experiments in this context. aiming to obtain frequency and modulation profiles suitable to the requirements of long distance and propagation constrains of smart cities data communication [3]. The major technological challenge and potential for innovation is to integrate available commercial off-the-shelf technology components for measurement, recording and telecommunications applications, where requirements such as physical and logical protocols are varied and most of them non-standard. The project has the premise of generating an integrated network employing different measurement and communication technologies through interfacing with integration modules developed when necessary, device parameterization and security encryption of transmitted data, as well as making the obtained and recorded data available to compatible applications. With mobile devices such as smartphones and tablets, enabling fast and appropriate remote access as decision support and network security support, which will be applicable to Smart Grid projects on a server acting as Meter Data Management (MDM). Collaborate with the generation of tools from the predictive analysis.

Techinical Description

Currently, research on efficient technologies for generation, storage and distribution from renewable energy sources (RES) is an important step towards the implementation of continuous power supply in a power grid, due to the intermittence and instability of the renewable energy sources. Photovoltaic and wind RES. From the Strategic R&D Call No. 21/2016 of the National Electric Energy Agency (ANEEL), it was started in july/2017 at the Sao Paulo State University "Julio de Mesquita Filho" (UNESP) project research of the São Paulo Energy

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Company - CESP P&D 00061-0054 / 2016 for the development of innovative Smart Grid Management methodologies employing predictive model analysis [3,4] proposed for a hybrid ion battery bank energy storage system - Lithium and hydrogen storage system by electrolysis powered by a set of photovoltaic plants and towers with wind turbines interconnected as a micro power grid [2] (Figure 1).

The development of the robust instrumentation and control system applied to the project includes the development and testing of a control loop that includes wireless integration and secure access with proper point-to-point encryption applicable to power microgrids as installations. The research is part of a structure that began with the implementation of a photovoltaic and wind farm with investments by Companhia Energetica de Sao Paulo (CESP) in projects of previous ANEEL calls, and is now complemented by the approach to energy storage and dispatch. The quality and energy efficiency requirements can be verified in the experiments performed and behavioral models defined for the elaboration of representative mathematical models based on the predictive analysis of the collected data. In the context of the increasing use of distributed generation, energy microgrids and resource availability efficiently, it is expected to collaborate with the generation of tools from predictive analysis as the basis for prospective analysis enabling the development of appropriate control and monitoring systems for expansion profile of distributed renewable energy employment [6]. The research objectives in the project are:

1. Provide potential responses to the technological challenge of innovation by integrating commercially available off-the-shelf technology components for metering, recording and telecommunications applications where requirements such as physical and logical protocols are varied and most non-standard.
2. Development of innovative Smart Grid Management methodologies using predictive model analysis proposed for a hybrid energy storage system consisting of lithium-ion battery bank and electrolysis hydrogen storage system.
3. Technological support the implementation of continuous power supply with high frequency and voltage stability while presenting low harmonic distortion in a micro power grid, due to the intermittence and installation of photovoltaic and wind RES through storage and dynamic control of dispatch.
4. Reduction of operating costs and potential risks to system control by possible intermittent fluctuations and fluctuations through predictive and preventive control supported by real-time monitoring.
5. Robust instrumentation and control system development applied to the project includes the development and testing of a control loop that includes wireless integration and secure access with self-contained point-to-point encryption applicable to power microducts as installations.

The basic diagram of the R&D project 00061-0054 / 2016 of the Companhia Energetica de Sao Paulo - CESP is showed in Figure 2.

In the concept of smart microgrids, one can see the existing structures composed of buildings with equipment and lighting distributed differently between them with varying loads and demands. Supervisory tools of monitoring by inverters and central meters

Figure 1: Experimental Microgrid Structure.

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don't allow to determine more precise details than the total demand consumed, estimated by point or cumulative readings. Establishing meters with distributed monitoring and data logging capabilities to allow estimation on power grid segments and potentially impacting points such as lighting systems and air conditioners will enable instantaneous consumption diagnostics, thereby obtaining consumption profiles and energy efficiency metrics in power plants applied to public or private companies building an integrated network of multiple Meter Data Colleting (MDC) [4]. Implementing a distributed meter network in a dynamic infrastructure subject with capability to future expansion and change places modularity and adaptability as a requirement, employing wireless transceivers with also modular, expandable and integrated technologies and topology, including software-defined radio experiments. In VHF and HF for applications or environments without the urban area with long distance and relief obstacles, without conventional means of data communication already installed. The major technological challenge and point of innovation is to integrate commercially available off-the-shelf technology components for metering, recording and telecommunications applications where requirements such as physical and logical protocols are varied and most of them non-standard. The project's target products will have the premise of generating support for the deployment of an integrated network employing different measurement and communication technologies through interfacing with integration modules developed when necessary, device parameterization and transmitted data security encryption, in addition to providing data obtained and recorded for mobile compatible applications such as smartphones and tablets, allowing for fast and appropriate remote access as decision support and network security support, which will apply to Smart Grid projects on a server acting as Meter Data Management (MDM).

The development will follow the PDCA (Plan / Do / Check / Action) cycle in an evolutionary and incremental manner, where the requirements at each phase and results will be reevaluated if necessary and improved as well as the models under development. The line will be the development of incremental systems from available Commercial Off the Shelf (COTS) technologies and their integration into modular dedicated systems. Microcontrollers, sensors and Field Programmable Gate Array (FPGAs) with embedded DSP (Digital Signal Processor) devices will be employed. that allow you to work with Radio Communication interfaces on the various technologies available including the description of Software Defined Radio (SDR) models. The proposed smart meters incorporate energy libraries that allow to extract individual parameters per phase such as Vrms, Vp, Irms, Ip, Pvar, Preal, Power Factor and three Total Harmonic Distortion (TDHIEC_F, TDHIEC_E and TDHIEEE) calculation methods, programmable sampling up to 8096 samples / second [9]. Understanding the influence of each constituent element of the network, factors of variation and type of load, interaction between distinct generation sources integrated in the network from the data acquired by the instrumentation will allow to develop mathematical and statistical behavioral representative models, as a basis for the development of innovative active control mechanisms that significantly reduce oscillations and anomalies arising from interactions in power grids. The use of automated instrumentation networking with network-compatible technologies in the design of IoT (Internet of Things) in wireless communication will also enable the development of smart meters tailored for detailed monitoring and control applications of renewable energy microgrids [1]. These meters can be used for current instrumentation Rogowski coils [9,10] technology that has advantage over other types of current transformers by the use of air core which unlike the iron core has a low inductance

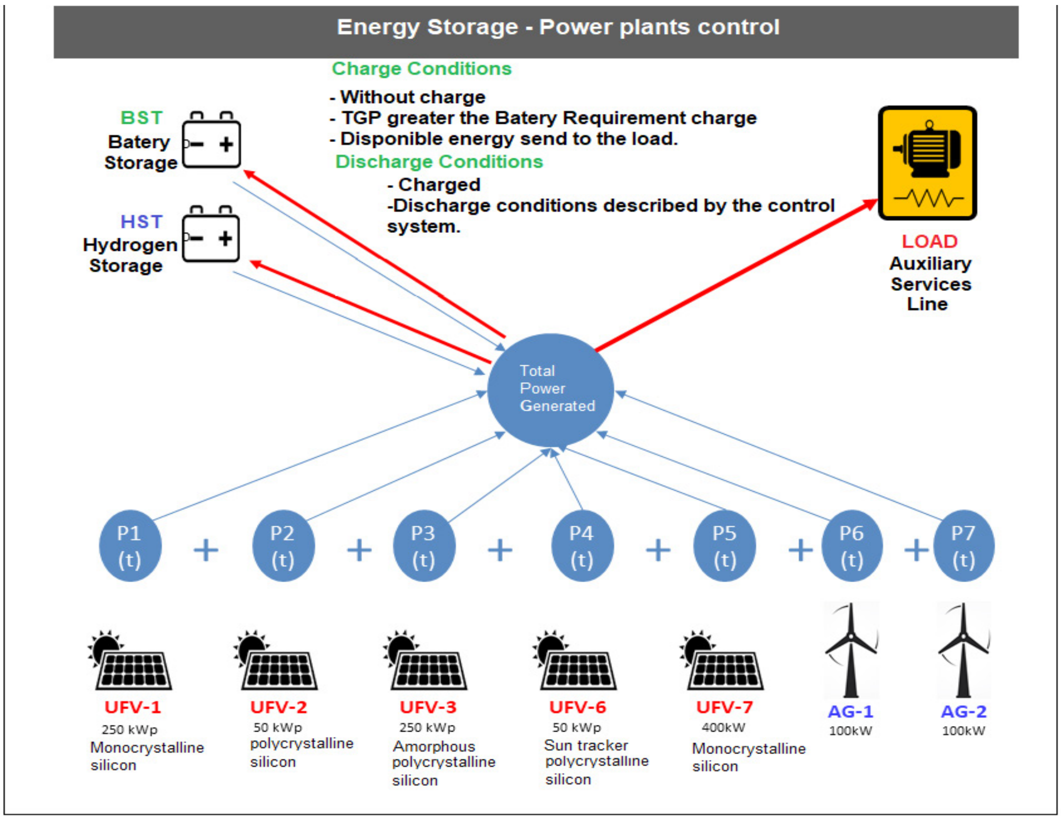

Figure 2: Basic control diagram of storage research.

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thus allowing response to rapid variations of electrical current or hall effect current sensors with higher frequency response. Another relevant factor is the non-saturation common to iron cores, being highly linear even when subjected to high current intensities typical in micro power grid applications. The system data communication network follows the pattern proposed by the Internet of Things (IoT) concepts where the constituent elements of the system are I/O access points, traffic points and data concentration (Gateways, Bridges). or Routers) or Internet access points (Cloud) all having commercial off-the-shelf components for implementing incremental and modular solutions as can be seen at Figure 3.

For the deployment of a data communication network, a prerequisite for system integration, different wired and wireless technologies will be employed, where the characteristics of consumption, range, propagation and susceptibility to interference are the most appropriate for each link. Access to monitoring and control data from power generation, storage and distribution systems is critical as it may compromise the safety of civil installations, so a line of ongoing research in the project is the development of point-to-point encryption embedded infrastructure. not just external access to the server. In this context, to achieve the objectives of remote access to project data, the system should allow the acquisition of information

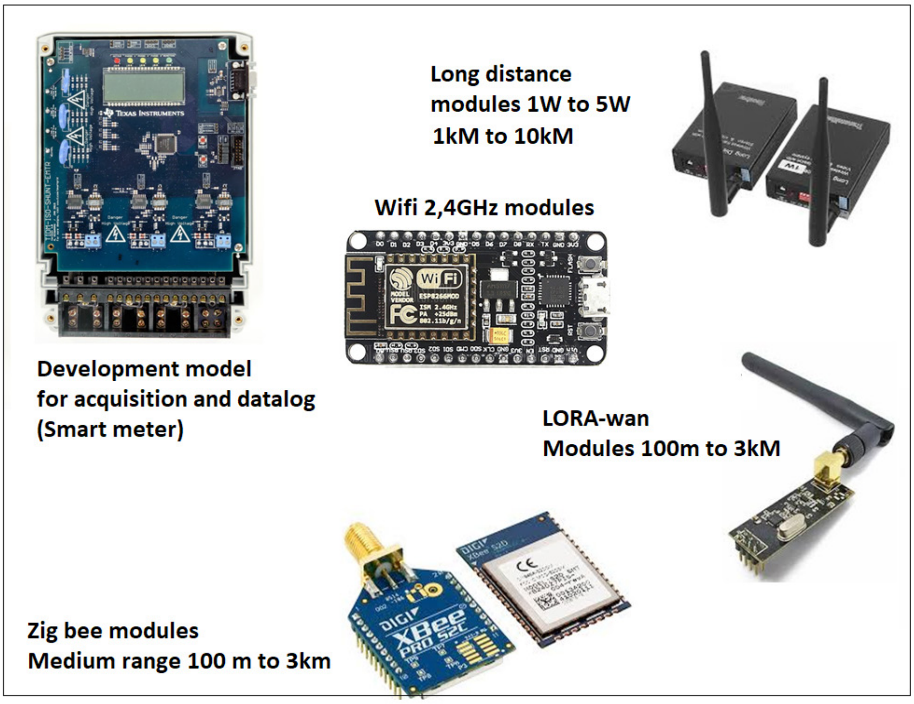

Figure 3: COTS Technologies used to acquisition and data link.

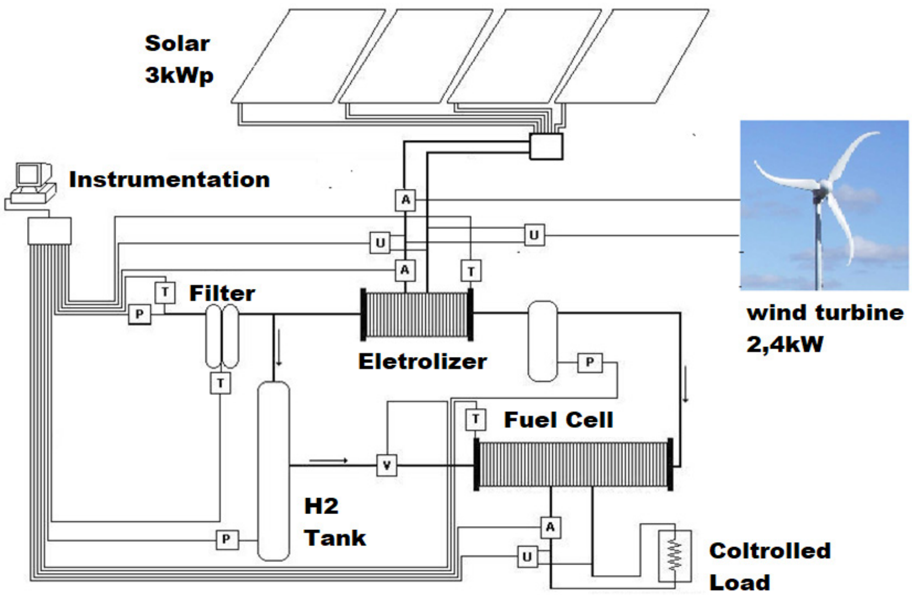

Figure 4: Smartgrid Bed Test Laboratory.

from instrumentation of generation plants, storage and distribution system of electricity, for data composition in relational database. The desirable and mandatory characteristics of the information to be obtained through monitoring serve as development rules followed in the later phases of the project's Relational Database Management System development and deployment process. The ability to integrate between systems will be addressed in lines of requirements, actions, methodologies and technologies to be employed to implement the complete instrumentation system.

As a full controlled bed test for determine parameters and critical conditions of use was implemented into the University an small laboratory facility with a microgrid using 3kWp photovoltaic solar power plant and 2,4kWp wind turbine with all of same storage technologies used into the real microgrid (Figure 4).

Final Coments

Adaptive models of instrumentation and hybrid data link structures are fundamental tools that allows to acquire data for support big data analysis in order to create predictive models of energy power system microgrids. Resources of security as peer to peer encrypt embedded firmware tools are essential to develop a strong and resilient control structure applied to microgrids with hydrogen and ion lithium storage included. Supported by the CESP R&D dedicated funds in a ANEEL strategic research for storage renewable energy research, this project received R$ 29.000.000,00 (≈ € 6.500.000,00) and will be used into new approaches for microgrids storage energy control.

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Competing Interests

The author declare that there is no competing interests regarding the publication of this article.

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