SIRIS PLATFORM: GENERAL FEATURES OF THE FIRST INTEGRATED COMPUTACIONAL SIMULATOR OF SMART GRIDS IN DEVELOPMENT FOR BRAZILIAN ELETRIC UTILITIES

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ABSTRACT

There is no exact definition and concept of what Smart Grids (SG) are, but in short SG should be regarded as a technological convergence of many different technologies and actors. In other words, a SG is built upon the complete knowledge of many different processes, including the loads, communication systems, automation and software systems. In this way, SG are complex systems and it is a complex task to keep these systems stable, particularly when distributed energy producers are involved. For economical and safety reasons, large-scale field trials of new scenarios cannot be carried out. Therefore, modelling and simulation are considered appropriate means to test the overall system prior to deployment.

A R&D project, actually in development by NEO DOMINO and CELESC, is focused on the development and/or integration of several simulation tools under an integrated computational platform called SIRIS (Simulator of Smart Grids, in Portuguese). This includes the design of new grids or the expansion and upgrade of existing ones.

INTRODUCTION

There are many well-proven numerical simulators available in the market. The tools range from power system simulation to communication simulation and market analysis. Smart Grids are based on the convergence of several different technologies and actors (Figure 1); this means that some kind of collaboration among these technologies must be established. Each tool often use proprietary input formats, is dependent on some operating system or make use of third party libraries. Another issue with Distribution Networks is the large number of nodes, making the generation of the input files cumbersome and time consuming.

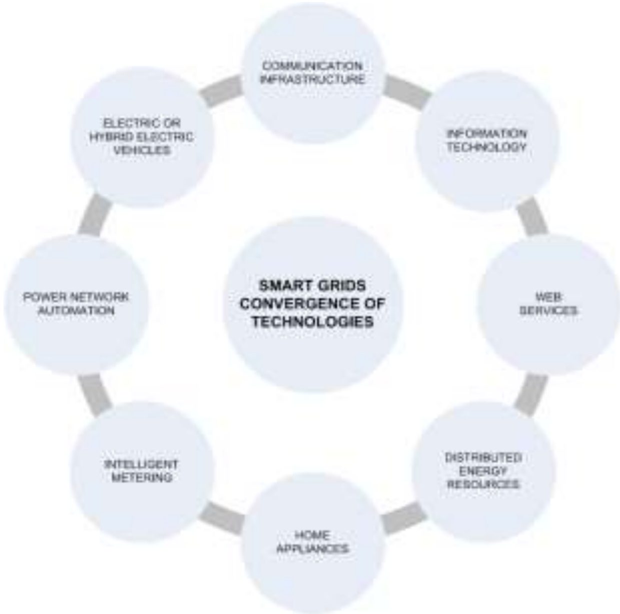

Figure 1. Electrical smart grids according to [1]

As Smart Grids involve many new issues, like stochastic demand response, distributed generation and electric vehicle chargers, and the large number of data to be taken into account in the planning and design phases of distribution networks, the need of computation tools is growing.

In this paper, SIRIS is described, a client-server simulation platform designed to overcome these limitations and provide, to the final user, a consistent tool that transparently make use of several simulation tools using one human-machine interface. The results are also presented in a user-friendly form.

This system aids the engineers in the design of power grids, from the concept to the validation, including the design of the automation system and the communication infrastructure. The cost figures can also be determined, as well as performance metrics. The system can be easily extended, as new tools or simulators become available.

SIRIS incorporates high-performance numerical algorithms for modeling of steady-state operation in different time scales and operational scenarios, simultaneously with the integration of traditional tools for analysis of power systems. Thus, it is possible to study previously the behavior of Smart Grids on various time scales and to simulate the response of various electrical phenomena with the energy market growth for different operational scenarios and seasonality. Additionally, its possible to test virtually the deployment or exchange of new devices (such as reclosers, voltage regulators, automatic switchgears, etc.) using the numerical model of the real distribution network under analysis to assess the impact on improving the operational efficiency of the electrical system against possible costs can be achieved implementation of those devices.

The main goals of SIRIS are: (i) Simulation of various communication technologies and systems used by utilities for the automation of distribution networks, considering three dimensional modeling of terrain, aspects of directionality and attenuation level of signal reception / transmission of messages; (ii) Integrated simulation of algorithms for unbalanced load flow, short circuit levels, automatic protective/maneuver schemes, optimal allocation of automation devices, micropower generation sources, distributed storage systems, electric vehicle charging stations and smart meters; (iii) Assembly of historical files of faults in a specific feeder, allowing determination of the effective contribution of each protection or maneuver device into global indices of continuity; and (iv) Forecasting of the consumption habits and load amount up to the level of final consumer to optimize its demand at each 15 minutes ahead and its response to new forms of pricing and supply arrangements.

The rest of the paper is organized as follows. In the next section an overview of the architecture of system is provided, including hardware and software requirements and the overview of the interoperation of the several software agents. In Section III some real use cases are presented.

SYSTEM ARCHITECTURE

The main goal of this project is the integration of several existing or in development simulation tools transparently to the end user. This means the use of one HMI (Human-Machine Interface) to access all the tools. Simulations may require a quite large processing power and the simulators may also run on different operating systems. Simulations also require power network data that are stored in some server. To take all these restrictions into account, the decision taken was to build a Client-Server architecture, as shown in Figure 2.

For simplicity, the Server is shown as one computer. It could also be a cluster, each node running a different operating system, or one computer running several server instances. The Apache web server is the entry point. The desktop applications do not drive the simulators directly neither manipulate data stored in the PostgreSQL RDBMS (also called SIRIS Database).

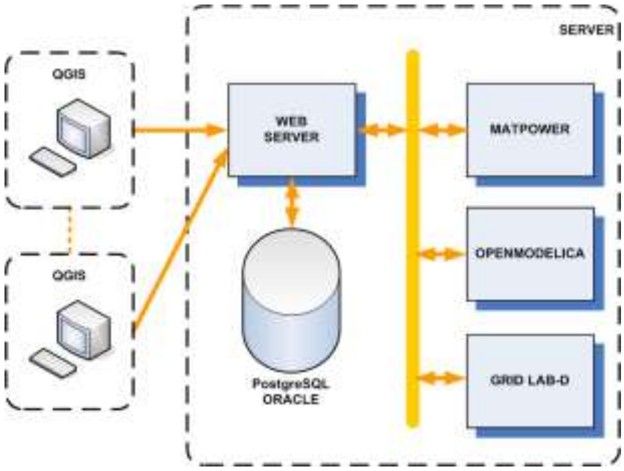

Figure 2. System architecture

The design of a power grid is a task that makes use of data from many different sources. The decision to use one HMI has lead to the decision to use a GIS (Geographic Interface System) as the HMI. The use of as many raster and vector layers as needed makes the GIS the ideal tool. The several simulation domains can be shown together in such an interface, a distinct layer to each simulator configuration or simulator results. The GIS also has to have tools to able the customization, be portable to several operating systems and preferably open source. The framework chosen to develop the GIS is called QGIS (see more details in www.qgis.org). It is an open source C/C++ framework developed using Qt. It can be extended by writing C/C++ or Python code. Figure 3 shows the QGIS main screen.

The GIS is composed by several layers. A layer can be a street map, a terrain map, or a satellite map. A layer can also show a feeder with its parts, like branches, poles, etc. A layer can also show the results of some simulation. The idea of using layers is to simplify the visualization, the end user can switch on or off any layers at any time.

The simulation scenarios are created and driven by plugins. There are several plugins to create the different simulation scenarios and to drive the different simulation tools. These plugin are written in Python and are dynamically loaded by QGIS, there is no need to recompile the QGIS software to include a new plugin.

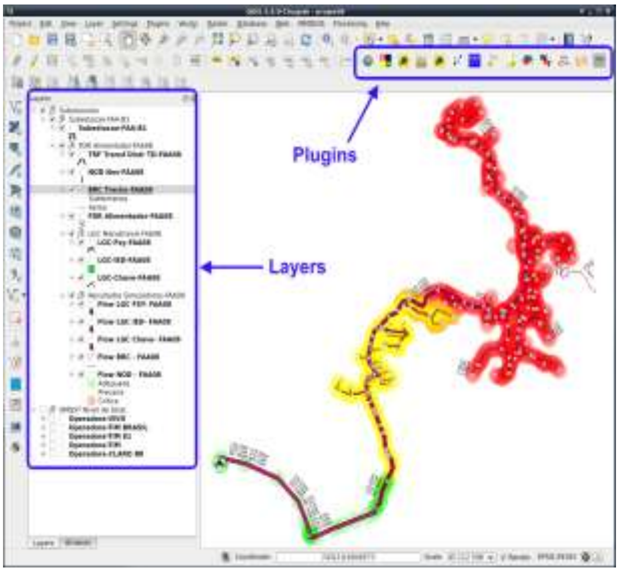

Figure 3. QGIS main screen

The plugins send and receive data from the Apache web server. They do not run any simulation, they just instruct the Apache web server to launch a module (applications launched by the Apache web server are called modules). The modules are also written using the Python language, and are called WSGI (Web Server Gateway Interface) modules. An specific module prepares the input data to launch an specific simulator, collects the resulting data and stores the data in the SIRIS Database.

The SIRIS Database has many database schemas to hold many different kinds of data. The distribution network is described as group of poles, equipments, cables, and they are placed in a map by using GPS data. The schema used to hold these data is called PostGIS and they are used to create a layer to show the power grid. These data are used by the WSGI modules to create the input data to the simulators, and they are also saved in the SIRIS Database.

The plugins launch simulations and wait for the results. When the results are made available in the database, the specific plugin creates at least one layer to hold the results and the process is finished. This process is sumarized in Figure 4.

To create a new simulation scenario the “New Project Plugin” is used. This plugin shows to the user the list of all available elements of the power grid. The user can then select, for instance, a particular feeder. A new layer is then created with the data of this feeder. As explained previously, the data are not created by the plugin. The plugin instructs the corresponding WSGI module on the server to create the data and store them in the database. Now the user can select a plugin for the desired simulation (Figure 5).

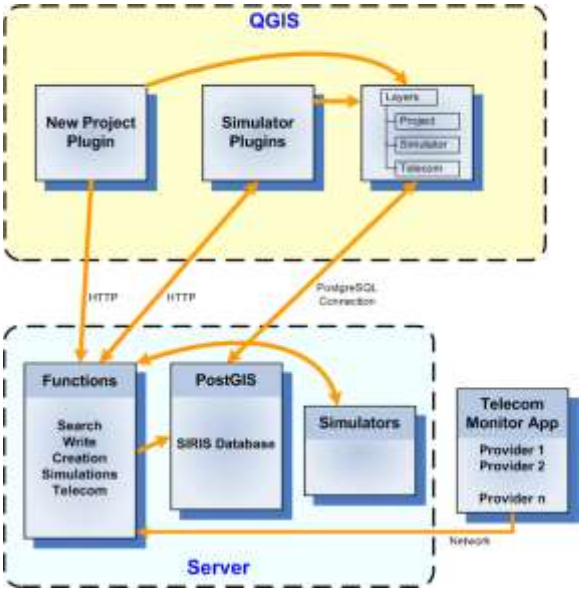

Figure 4. Software architecture

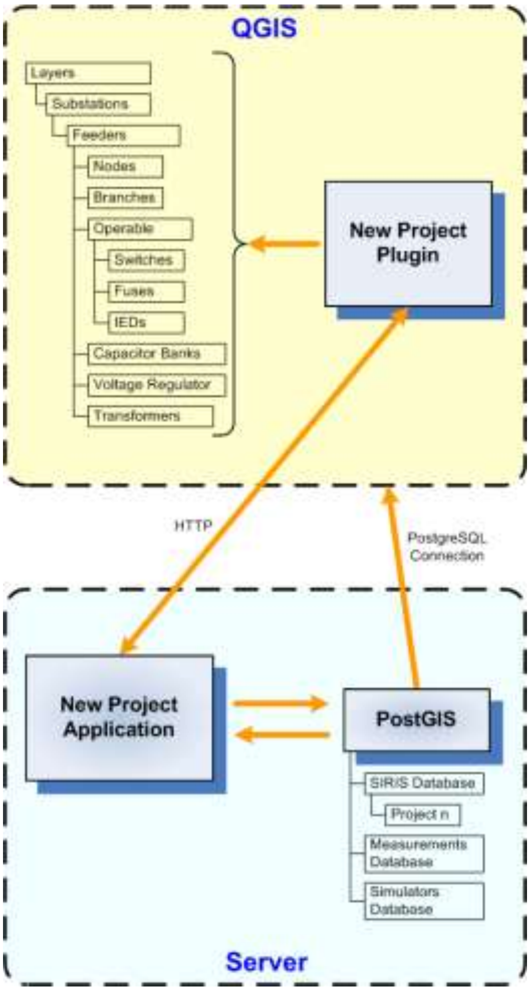

Figure 5. Creation of a new project

USE CASES

Power Flow

Power flow techniques are well known by engineers but they are mainly used for the analysis of transmission lines. Distribution networks have a high number of nodes making the configuration of the simulation scenario very difficult. Several power flow simulators also do not deal very well the high order matrices involved in the simulation of distribution networks.

GridLab-D (see more details in www.sourceforge.net/projects/GridLab-D) was designed to simulate both transmission and distribution systems. Some of the features are the unbalanced power flow simulation of three-phase systems and simulation of retail market systems. GridLab-D was adopted as the power flow simulation engine for power distribution networks because of its robustness in dealing with systems with a large number of nodes.

A plugin instructs a Python WSGI module on the server to use the data created by the New Project Plugin to create the input file for GridLab-D, and to lauch the numerical simulation. GridLab-D stores the results in CSV (Comma Separated Values) files. When the simulation is finished, the same WSGI module reads these files and writes the data to the SIRIS Database; and sends a message back to the plugin declaring that the simulation has ended. The plugin then creates the new layer with the results and shows the layer on the screen (Figure 6).

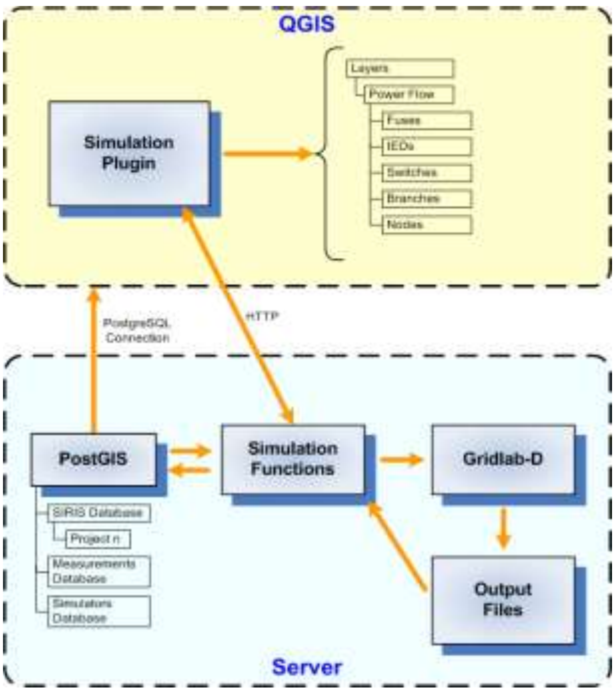

Figure 6. Simulation flow

Figure 7 shows an example of the powerflow simulation for a real feeder of CELESC utility. The colors represent the voltage levels on every node. Green means that the voltage levels are within the range, yellow is a warning level and red indicates that the voltages are either above the maximum level allowed or below the minimum level. The input voltage level was lowered to show the different colors. The simulation is performed using real load data. The user can select time and date to run the power flow. The load data also reside in the SIRIS Database.

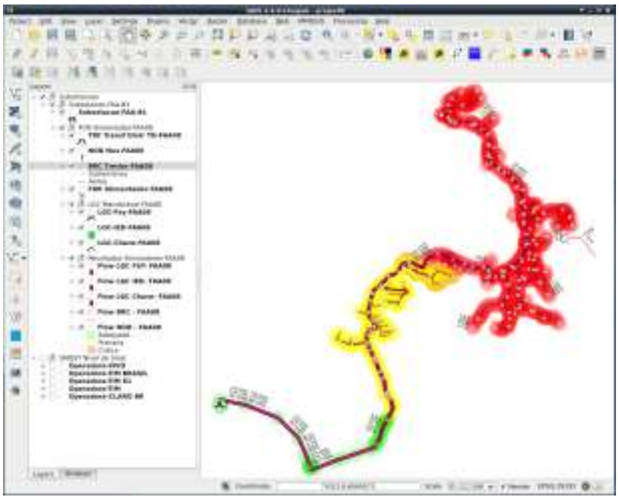

Figure 7. Power flow example

Mobile Data Communication Network

For the design of the automation system, the analysis of the communication infrastructure is also important. In this example the available mobile communication networks are shown. A Telecom App (Figure 8) is installed on mobile phones of the maintenance team to record the power level. The position, level, timestamp and name of the provider, with a resolution of 10 m is recorded and sent to the SIRIS Database as the communication becomes available. A specific Python WSGI module is used save the data in the SIRIS Database (see the ”Telecom Monitor App” block in Figure 4 and Figure 9).

The user can then have a view the status of the mobile networks using the same procedure used for the previous simulation. The “New Project Template” is used to create a layer and a database with the desired portion of the power distribution network and the Telecom plugin creates the layers, one layer for each provider, and instructs a Python WSGI module to include the data for the region selected. The colors represent the power level. Violet indicates a high level and red low level. An example is shown in Figure 10.

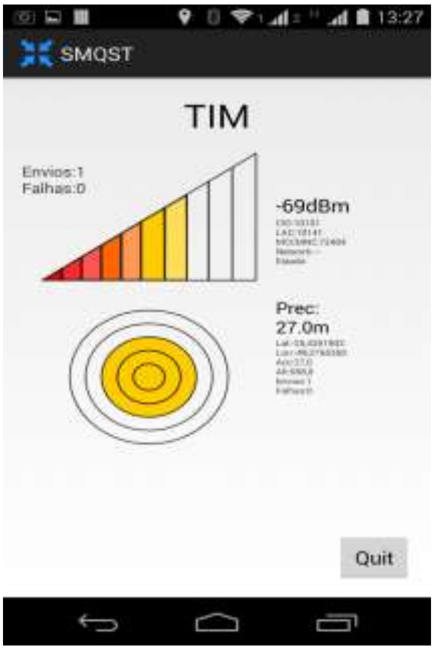

Figure 8. Android App

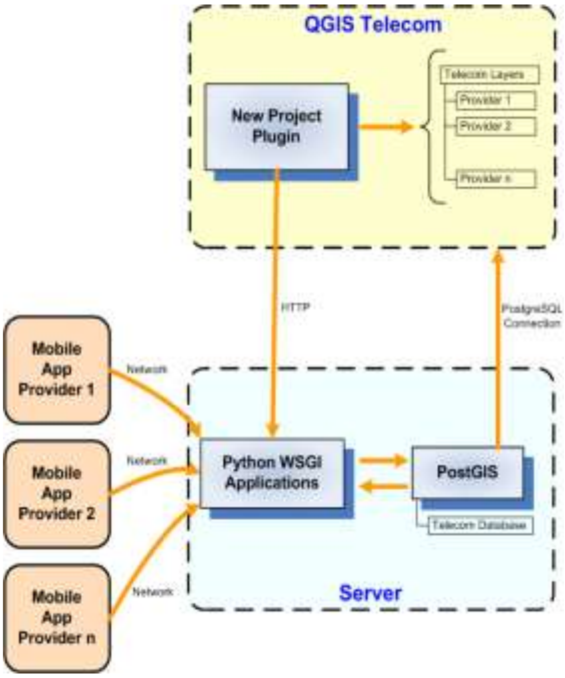

Figure 9. Creation of a mobile data communication layer

CONCLUSIONS

SIRIS has proven that it is a flexible power grid planning and design framework. One of its most important features is the combination of several simulation results already provided by others computational tools in CELESC in a same simulation environment, by the creation of distinct layers sharing the same geographic data. The visualization of the results by using colors and not only tables or number help the design engineer to rapidly focus on the problems of the network under simulation. The possibility of integrating virtually any simulator also an important feature, this makes the user more confident on the simulation results, by the use of well known simulators.

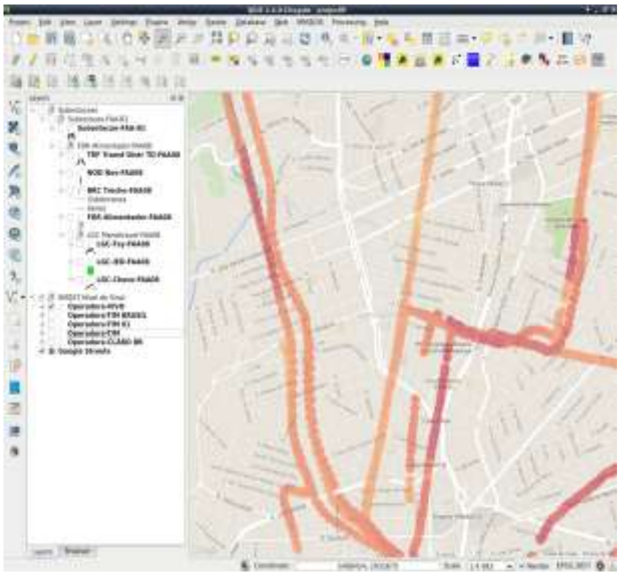

Figure 10. Mobile data communication networks

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