ONS - Brasil New Control Center Architecture Conceptual Design

J. M. Ordagci, H.C.T. Santos, S.R. Morand, R.Céspedes, *SM IEEE*, R.Mano, and D.Cáceres, *M IEEE*

***Abstract*--The Brazilian National Power Grid Operator – ONS – has successfully completed the design and specification of the next generation set of four SCADA/EMS systems that will support the real-time operation of the Brazilian power system. The main goal of this new concept is to provide a unique and synchronized platform architecture (named REGER, Energy Management Network in Portuguese) for all five control centers that are located in the cities of Brasilia, Rio de Janeiro, Recife and Florianopolis.**

This paper presents the conceptual design of this integrated platform and its interfaces with the corporate and IT services of other ONS divisions using the Service Oriented Architecture (SOA). A full set of applications supporting the various tasks that the different real-time and corporate users may require are also part of REGER. The design includes development and simulation platforms that complement the real-time operating platform and the integration of Synchrophasors Measurements and Applications. Details about the implementation plan and the expected benefits from this future-oriented project are presented as conclusions.

***Index Terms*-- Power System Real Time Operation, SCADA, Energy Management Systems, Hierarchical Control Center Structure, Open Market, Open Systems, PMU.**

I. Introduction

ONS was created to substitute the previous cooperative structure and collegiate entities for operation coordination, which had shared utility responsibilities. The new model institutes ONS as the Brazilian Independent System Operator (ISO) in charge of the over 90,000 MW National Interconnected Power System. Figure 1 presents a schema showing the main characteristics of the organizational model that is operational in Brazil.

A. *ONS Responsibilities*

ONS has the following responsibilities as per the Law from May 27, 1998:

- Operation Planning and Scheduling and the centralized generation dispatch in order to optimize the interconnected power and energy systems

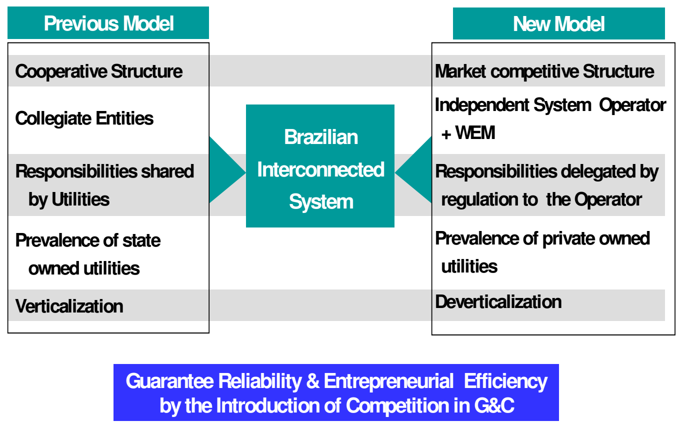

Fig. 1. The Brazilian Power Sector Restructuring Overview

- Supervision and coordination of the power system Control Centers
- Operation monitoring and control of the national interconnected power and energy systems and international interconnections
- Administration of the electric energy transmission services and respective access conditions, as well as administration of the ancillary services
- Propose to ANEEL, the Brazilian regulator, the expansion of the transmission basic network as well as grid reinforcements
- Definition of transmission operating rules related to the interconnected system base network.

A hierarchical structure of control centers is used to operate in a global and integrated way the "Operation Network". This network is the union of "Basic Network", the "Complementary Network" (facilities which impact the Basic Network,), and the integrated power plants. Fig. 2 illustrates the Brazilian Power System including High and Extra High Voltage Transmission Lines only.

B. *ONS Existing Control Center Structure*

ONS has the following Control Centers:

CNOS– National System Operation Center: the higher level one hierarchical is responsible for the coordination, supervision, and control of the basic and complementary network.

J. M. Ordagci, H. C. T. Santos, and S. R. Morand, are with Operador Nacional do Sistema Elétrico (ONS), Brazil

R. Céspedes, R. Mano, and D. Cáceres are with KEMA, Inc.

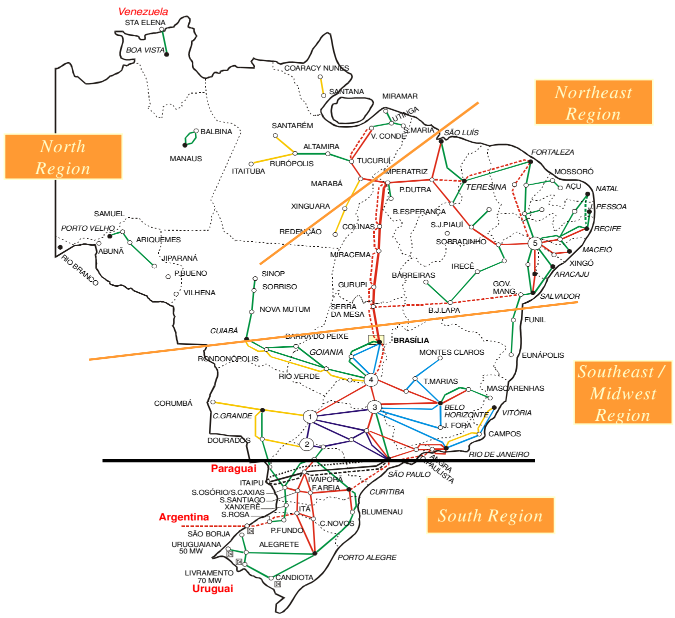

Fig.2. The Brazilian Power System

COSR– Regional System Operation Center: Four centers owned by ONS (South located in Florianópolis, South-East in Rio de Janeiro, North located in Brasilia, and North-East in Recife), for coordination, supervision and control of the regional/ local basic and complementary network, control of generation dispatch of independent power producers (IPPs), and command and dispatch execution of power plants under AGC.

II. ONS REGER PROJECT

The ONS objectives for the REGER project for the implementation of the next generation of control centers at the National and Regional level are summarized below:

- Provide a state-of-the-art integrated SCADA/EMS network to monitor and control Brazilian Electric Power System in a secure, reliable and economic fashion
- Allow faster and organized power system recovery in the event of major failures
- Provide an extensive Corporate/External User System (CEUS) facility that will serve the various users within ONS, by allowing access to the real time and historical information and thereby improving the efficiency of the entire organization
- Provide for the maximum upgrade and expansion capability of the REGER to serve the long-term needs of the ONS.
- Provide modern, distributed Data Acquisition Nodes - NADs that allows the implementation of the Agents information acquisition independently of the amount and physical location of the SSC Real-Time Nucleus and facilitates the support and transition of the existing Agents communications installations with ONS.

Figure 3 presents a general overview of the main REGER components identifying the regional control centers and users. REGER will provide ONS with four Supervisory Control Systems (SSC) as follows: SSC-BSB in Brasilia supporting the CNOS and the North & Central West (NCO) regional control centers, the SSC-RIO supporting the South East (SE) regional control center, the SSC-REC supporting the North East (NE) regional control center and the SSC-FLN supporting the South (S) regional control center.

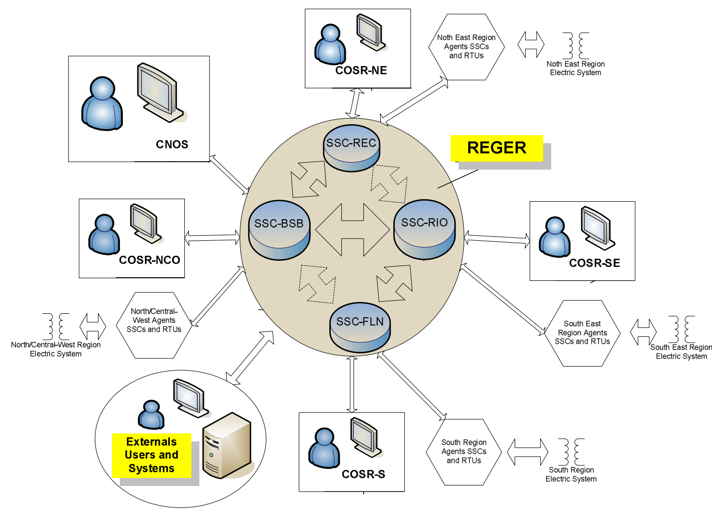

Fig. 3. REGER – General View

A. *System Architecture*

The architecture selected for REGER will support the implementation of the following corporate initiatives:

- Development of an integrated Service Oriented Architecture (SOA) that guides all aspects of creating and using business processes, defining and provisioning the IT infrastructure that allows different applications to exchange data and participate in business processes regardless of the operating systems or programming languages underlying those applications,
- Interface the REGER platform applications and ONS corporate environment with SOA for all practical purposes,
- Integration with the existing ONS technical data base (Base de Dados Técnica, BDT) so that all applications requiring for example power network modeling data have consistent data derived from a single data source throughout the entire organization,
- Provide standardized methods for applications integration to and from the real-time REGER platform,
- Implement a highly available and secure IT environment in compliance with sound cyber

security practices.

Figure 4 presents the general approach designed for the ONS REGER implementation. The four control systems for Brasilia, Rio, Recife and Florianopolis are integrated and synchronized using the provided REGER network-wide synchronization, replication and administration functions.

For each control system two environments are shown: the REGER and the Corporate environments. The REGER environment of each control system shows the main functions supported in the real-time LAN (SCADA, Automatic Generation Control – AGC, Network Analysis – NA, Information Storage and Retrieval – IS&R) and demilitarized (DMZ) zones where additional functions are supported (Operating Training Simulator – OTS, Historical Information System – HIS, Quality and Development System – QADS).

ONS developed applications will be implemented in the real-time LAN, in particular the ORGANON (ORG – ONS voltage stability and dynamic stability real-time assessment) will be tightly integrated with the rest of the real-time applications.

A high speed service bus shall provide for the local internal secure communications for all REGER provided applications that use intensively the power system data provided by SCADA and the REGER synchronization function.

A second bus, the Enterprise Service Bus (ESB) will support the SOA implementation in REGER. It is required that the SOA approach be implemented in the DMZ while it is very desirable to extend this concept into the rest of REGER. The SOA services will comply with the ONS implemented approach for the corporate environment.

Other ONS applications located at the corporate LAN of each control system will also be integrated using the SOA services defined with ONS. These functions include:

- Hydraulic Simulator - SH
- Short Term Load Forecast –ANSTLF
- Technical database – BDT
- Daily production scheduling - PDP
- Data Maintenance Management System – SGI
- Data Management System - SGD
- Phasor Measurement Unit System – PMU
- Wind Production Forecast – PPE
- Detection of Fire, Lightning and Metereological Information – DQDM

The REGER platform to implement will be highly modular integrating all necessary components to comply with the functions set forth by ONS, providing the flexibility to adapt to the future organizational changes and providing the necessary consistency in terms of source data, displays, real-time and historical data to all ONS users.

All SSCs shall have identical components although some SSCs may not include all components. The architecture will provide the flexibility to add or remove the modular components of a SSC in order to adapt REGER to ONS future organizational evolution.

The SSC-BSB will be modeled with all real-time information received and processed by REGER (100% of the real-time data points of all SSCs). The SSC-RIO being the backup of the SSC-BSB will share the same model and data.

B. REGER Operation

The conception of the REGER architecture is that all SSCs during normal operating conditions (including communications) shall operate as a network with functions that provide real-time data sharing and resources supporting the users regardless of their location. In this context, the real-time data received by one SSC shall be made available to any other SSC that requires this data and also to any user that may access any computer resource provided they own the required access rights and the necessary communications are available.

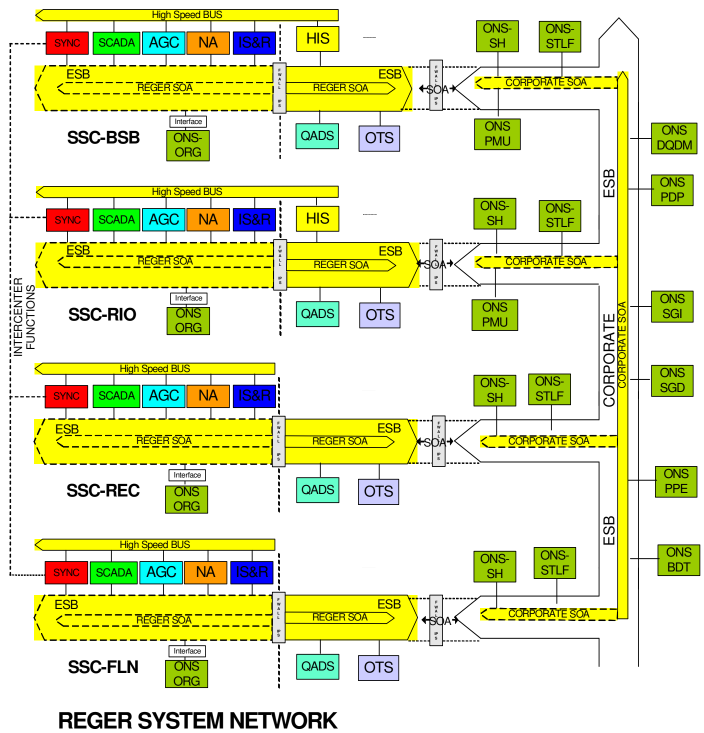

Fig. 4. ONS General REGER Architecture

When operating isolated from the REGER system (operation that will perhaps be limited to the initial startup and during special conditions upon communications failures) one SSC will be fully functional with all the functionalities of a control system, although depending on the contingency it may be without refreshment of data acquired from other control systems.

Each SSC has a main primary role of supporting its local control center as listed above. In addition the SSC-BSB and the SSC-RIO shall have the additional role of being the backup system of one or more control systems in case of a temporary or permanent failure of one SSC. The following lists the foreseen backup roles between control systems:

- SSC-BSB is the backup of the SSC-RIO and SSC-REC
- SSC-RIO is the backup of the SSC-BSB for the

CNOS functions and of the SSC-FLN

- SSC-REC is the backup of the SSC-BSB for those functions of the Control Center of the COSR-NCO.

The architecture will also provide the means to change these initially defined roles according to ONS organizational needs. For instance one SSC may be defined as backup of the remaining SSCs in the future if the communications with all NADs is provided.

III. REGER Conceptual Configuration

Figure 5 presents a general approach to the REGER conceptual configuration. In this configuration the following levels are identified:

Agents: they are all entities of the electric Brazilian sector that maintain an operational relationship with ONS.

Agent Communications Networks: these are the mainly regional networks that provide the means to transmit the Agents real time data to the ONS Data Acquisition Nodes (NADs) and vice-versa.

ONS Data Acquisition Nodes ONS (NADs): these are subsystems that collect data received from the Agents. Also the NADs are responsible for relaying the control commands and data distribution from the SSCs to the Agents. They work as regional data concentrators, performing the necessary protocol conversions, as well as sending data to the SSCs using a common protocol that will be adopted for the ONS operation communication network. Regional redundant NADs report during normal operation and normal communication conditions to the local regional SSC within the same region and simultaneously to the backup SSC of that region.

One of the NADs of a region will be located at the control center facility together with the regional SSC; the second NAD due to reliability reasons will be located in a different facility thus providing the means to still report data to the REGER network in case of severe SSC or communication disturbance.

ONS Operational Communication Network: the communications network (WAN) which will support the real time data and voice transmission between the ONS SSCs and NADs.

ONS Processing Systems: comprise all the SSC necessary resources to support the functions required by the various local and remote user groups.

ONS Users: this level comprises Users that perform the following functions:

- SSC maintenance, operation users: database, display and other maintenance duties and power system operation and analysis,
- ONS Corporate users: these users will mainly access historical data and applications in a study mode, simulations and maintenance data. Due to security reasons these users will have limited access to SSC resources and will have access restrictions in compliance with ONS cyber security approach,
- External Users: these are agents that will be granted access to selected real-time data. These users will have restricted access to some historical published data using web tools.

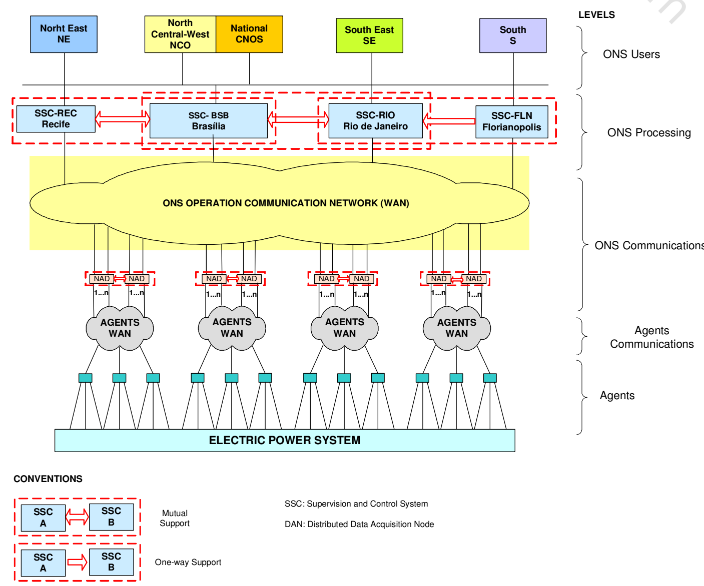

Fig. 5. REGER Conceptual Architecture

IV. REGER Functional Requirements

Each SSC within REGER is autonomous and independent in the network when operating isolated from the rest. However when interconnected they shall share Network functions. In general, REGER SSCs may have different hardware configuration (in their future evolution) and different data sets.

The requirements that need to be met by REGER as a whole that is beyond the normal SSC functions are:

1) Consistent source data maintenance in REGER: achieved by implementing a centralized Master Source database and the data model synchronization function of all SSCs from the Master Source,

2) Consistent real-time data (SCADA data, network analysis application data, scheduling, etc. in general all data modeled as part of the on-line database) maintenance in REGER: each SSC will acquire directly from its regional NADs its own regional data called hereinafter Information Area and thus it is defined to be the Real-Time Data Master (RT Master) for that Information Area data points. This data shall be distributed to other SSCs that require this data and thus there shall be a real-time data synchronization function at the Network,

3) Consistent historical data in REGER: each SSC will collect locally historical data to be used for operation and other purposes. This data shall be replicated to two central historical data repositories, one primary and one backup located at the SSC-BSB and SSC-RIO respectively, where consistent REGER wide historical data will be stored.

4) Consistent application source versions and run-time applications within REGER: each function such as SCADA,

Network Analysis, etc. that is operational in REGER shall have the same version and thus there shall be the means to ensure that all SSCs operate using the same software version. This requirement is applicable thus at the application source and run-time levels.

5) Remote access support of Users from one SSC to another SSC within REGER: users within REGER shall not be restricted to access only local SSC resources but they may access any remote resource in REGER. For this purpose REGER shall consider the administration of users granted access rights beyond their local SSC.

6) Operation under emergencies using the designated backup SSC: the transfer of responsibilities between one SSC and another that take over its functions under emergencies and the return to the normal operation is considered also a function at the REGER level that shall be implemented.

V. REGER Source Data Model Maintenance and Management

ONS is in the process to implement a central technical database BDT. This central database will be located at the corporate level and will encompass all types of technical data including the Power System Model data. The BDT, among other data, will in essence comprise similar as the CIM type of data in an ONS defined model structure which will be common with the Source Data required at the SSCs.

In order to preserve the data consistency principle, the source of the common data shall be ONS BDT. Users from the various SSCs and also corporate users will be responsible for the data maintenance task either locally or remotely. Figure 6 presents the envisaged data maintenance of the BDT showing users from all SSCs and corporate users. A CIM/XML standard import capability function will be implemented, including all hardware and software required, in order to implement a full functional import mechanism of the common data from the ONS BDT.

The implementation of this function shall include:

- Data validation and consistency check before imported to the Source Master DB
- Logging of all data changes with the possibility to audit the source data changes
- Interface to visualize the Source Data and data logs
- An Undo function that reestablishes initial conditions before the database change request shall be provided.

All SSCs within REGER shall derive their real-time database from the common Master Source DB. The source data shall be maintained at the REGER SSC Master which is defined to be the SSC-BSB, or the SSC-RIO in case of permanent failure of it.

Source data shall be modifiable only at the Master source DB by local or remote authorized users and distributed from there to all SSCs. The data that is defined to be part of one specific SSC is called the Information Area of that SSC.

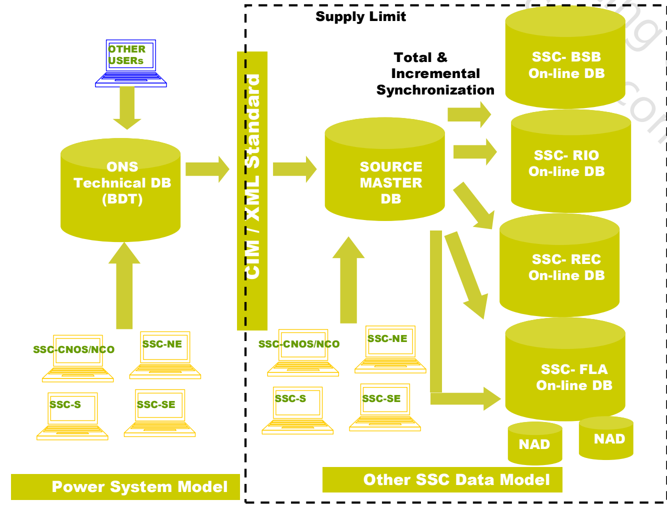

Fig. 6. REGER Source Database Concepts

All SSCs sharing the common Source Data shall have the same:

- Identification of SCADA data points that are defined to be part of the SSC,
- Complete Power network model or a subset of the complete model,
- Displays identification,
- Other required common naming and addressing needed as per Contractor's specific implementation.

A. *Data Maintenance and Model Synchronization*

For BDT changes that modify multiple data models the change shall also be propagated into the REGER Source Data Master by a single command. For instance the modification of a name in the BDT shall be propagated to all instances in the source REGER database and then applied to all real-time databases where the name is used. The modifications shall be passed using the CIM/XML interface and propagated to all tables using the modified parameter. Another example is the transfer of equipment from one substation to another without requiring the deletion of one instance and creation of a new one, but the direct change by modifying the initial database characteristic. In general all possible BDT alterations shall be supported in this form.

B. *NAD Data Model Management*

It is recognized that the NAD data model is an activity that requires permanent local SSC intervention in particular when implementing additional data links with Agents, modify the data points, perform testing activities on a new or existing data link, etc. All these activities are also further dependent on the type of protocol (network protocols such as TASE.2, IEC 60870-104 or any of the serial protocols to be supported by ONS).

VI. System Functions

A comprehensive set of applications will be part of REGER. The detail explanation of the scope of these functions is beyond the scope of this paper, but a brief explanation of the main functions is presented next.

The REGER functionality will be based on as much as possible off-the-shelf functionality ready available from the industry. Only limited customization will be introduced to some applications when needed. Customized applications will rather be developed by ONS and interfaced with the rest of the functions using the SOA services. The following is the list of main REGER functions that will be available at all four SSCs:

a. SCADA functions including data acquisition and exchange, data processing and monitoring, sequence of events, supervisory control and tagging, historical information management, and post-disturbance analysis

b. EMS functions encompassing:

- Network Analysis Model and Database Conversion
- Power System Model Maintenance Using CIM Tools
- Equipment Outage Scheduling (EOS)
- Real-Time Network Analysis
- Study Network Analysis
- Parameter Adaptation
- State Estimator
- Power Flow
- Study Comparison
- Contingency Analysis
- Optimal Power Flow
- Remedial Action
- Automatic Voltage Control
- Constrained Dispatch
- Schedule Validator
- Synchrophasor Measurement Applications
  - System Stress Monitoring (StressMon)
  - Closing a connection between two electrical islands (SynchAssist)
  - Closing a breaker in a loop in the transmission network (LoopAssist)

c. Generation Control and Scheduling including:

- Automatic Generation Control with Dynamic Bias Calculation , Interface with State Estimator (SE)
- Interchange Transactions and Scheduling - ITS
- Reserve Monitor
- Economic Dispatch
- Short-Term Load Predictor
- Production Cost
- AGC Performance Monitor with two possibilities using NERC Reliability Standards and Implementing ONS Procedures
- Generation Schedule Deviation Monitoring

d. Dispatcher Training Simulator (DTS) completely integrated and with capacity for simulating:

- Realistic Generation modeling and voltage control
- Load sensibility to voltage and frequency
- Long-term dynamic models for generating units, turbine control, and voltage regulators with static and dynamic limitations of active/reactive power loading

KEMA Inc. has assisted ONS in preparing a separate study for the Phasor Measurement System that will be developed in parallel with REGER. An initial interface between these two systems will allow the incorporation of PMU data into REGER for a limited set of initial functions as listed above. However, it is expected that this interface will evolve allowing ONS to take advantage of new PMU applications according to new expected developments.

VII. Project Implementation

The REGER project will change the entire control center infrastructure of ONS and thus a careful planning of the implementation phases has been developed in order to ensure that the operation of the Brazilian power system will not be impacted. Given the comprehensive nature of this project a phased approach has been selected. The first phase will be dedicated to replace one of the Regional Systems first. The selection of the site where this will occur depends on the obsolescence of the existing system and the needs to replace the existing platform in the next future.

Once the initial system is operational a second phase will deploy the REGER platform to the remaining sites until all four SSCs and their interfaces are fully operational. The planning will also involve the provision of the required communication means for supporting REGER. Given that ONS does not have its own communication infrastructure these services will be outsourced with the required contracting conditions to ensure the high availability of the entire REGER system.

VIII. Conclusions

This paper has presented an overview of the situation in Brazil related with the control center infrastructure supporting ONS, the Brazilian ISO operator. An overview of the organization and the market structure was presented, showing ONS's major responsibilities and relationship with other market agents. The main functionality and role of the control center systems that are being modernized has been shown together with traditional and new tools that will support the operation and control of the large power system of Brazil.

The REGER system of ONS has been presented at the architectural and conceptual levels. The envisaged architecture is believed to provide a better reliability in comparison with isolated systems with just data exchange as is the case in many hierarchical control system structures. Also the features for central database maintenance will certainly provide ONS the means to consolidate a more consistent set of control centers both for real-time and for historical data.

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X. Biographies

Jorge Miguel Jorge Miguel Ordacgi Filho is a Professional Electrical Engineer graduated from the Universidade Federal Fluminense. During his carrier as a protection engineer (1974 - 1998) with FURNAS Centrais Elétricas, Itaipu Hydro and ELETROBRÁS he worked on settings calculations, analysis, transmission line protection (up to 500 kV) and power plants. He later joined the Brazilian ISO managing the implementation of special protection systems and was later involved with Control Center Automation Systems, SCADA, and others. From 1975 - 1992 he taught Power System Protection at Universidade Veiga de Almeida in Rio. He is the Brazilian Member of CIGRÉ SC B5 - Protection and Automation. He used to play drums - jazz and bossa nova - just for fun. Now his free time is dedicated to his granddaughter Sofia and Persian cat Ico.

Hiram C. T. Santos graduated from Instituto Tecnológico de Aeronáutica – ITA of Brazil in 1971 and is working on supervision and control systems since 1976. He is working at ONS since 2000 and is currently the Project Manager of REGER

Sérgio Ribeiro Morand, is Brazilian with many years of experience in the developing of important infrastructure projects in Brazil and is currently with ONS assisting the development of critical IT projects including REGER.

Renato Céspedes received his Doctor of Engineering of the Polytechnique Institute of Grenoble in France. Dr. Céspedes is Executive Consultant of KEMA where he works since 1991 and is currently the head of the Latin America office located in Bogotá, Colombia. He has participated in a number of control center projects and power system related studies in the USA, Europe, Latin America, Africa and Asia. Dr. Céspedes is Senior Member of IEEE and Associated Professor of the National University of Colombia and has published numerous papers in international publications.

David Cáceres is a Principal Consultant of KEMA Inc., Pennsylvania (USA) office since 1995 who worked and lived in Brazil for ten years before. He graduated from the Engineering National University (UNI), Lima (Perú) in 1974, and since then has participated in several control center, hydro power plant, distribution and substation automation, Smart Grids, and communications projects all over Latin America and the Caribbean, USA, Spain, Canada, India and Vietnam. Mr. Cáceres has published a variety of SCADA/EMS papers in conferences and magazines.

Rui Mano graduated in 1971 as Electronic Engineer at the Universidade Federal do Rio de Janeiro, Brazil. Mr. Mano is a Principal Consultant of KEMA Brasil since 1998 and heads the Brazil office. He has participated in a number of SCADA/EMS projects in Brazil and South America and has also headed the software development of a complete DMS. He is Professor (licensed) of the Pontificia Universidade Católica – PUC, in Rio de Janeiro, Brazil and has several papers published in international conferences.