AGORA
ADVANCED GRID OBSERVATION RELIABLE ALGORITHMS

BENEFITS PROVIDED BY THE AGORA SYSTEM

The main objective underlying the AGORA System: Advanced Grid Observation Reliable Algorithms is to provide assistance to a transmission or distribution grid/ network operator during normal operation and incidents.

The development of automatic systems for real-time control and of decision support modules in electrical power systems requires the availability of intelligent observation and real-time monitoring of the grid as well as analysis and simulation tools with a degree of reliability and precision not guaranteed by the traditional methods used in the industry.

In 1992 AIA initiated development of an automatic system for electrical network restoration based on the concept of exploration of the state space. AIA rejected the classical line that was being used in similar systems: rule-based expert system. AIA's advances were made possible since it had already achieved a breakthrough innovation result in Load Flow algorithms: a non-iterative power Flow Algorithm capable of computing the network close to voltage collapse.

The AGORA on-line Observation and Monitoring Elements solves three basic problems:

Observation of the network state, updated every 30 seconds , resistant to the lack of information and coherent.

Simulation of maneuvers over the network in atypical conditions far from the normal working conditions such as voltage collapse, load-generation unbalance, etc.

Restoration of the network back to normal conditions after small incidents or large black-outs have taken place through an optimal plan of actions.

As a result of these very strict requirements, the development of new methodologies in the field of load flow and state estimation with superior convergence properties, has been essential.

Once the new methodologies were developed, a new suite of reliable algorithms supporting operations and planning have been created. Most of them constitute the different basic modules of AGORA as well as some of its optional product offerings.

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DIFFERENTIAL ASPECTS OF THE AIA SOLUTION

SIMULATION: LOAD FLOW

The classical methodology for solving the load flow problem is a second order iterative algorithm (Newton-Raphson) which uses an approximate updating of the Hessian matrix (fast decoupled, FDNR) in order to speed up the calculation.

This widely used algorithm is time efficient if provided with an approximate initial solution sufficiently close to the correct solution. Otherwise the convergence of this method cannot be assured as it does not always converge to the right solution. In many cases it can require the manual intervention of experts to effectively modify the problem stated. Consequently, the classified methodology is not acceptable in an automatic system.

The solution proposed by AIA uses procedures that are radically different. AIA's methodology:

- Is non-iterative (more related to perturbation).
- Does not require an initial solution.
- Finds solutions to the stated problem even in the vicinity of voltage collapse.
- Provides indications on the static stability of the solutions.

The algorithms are based on non-iterative methodologies sustained by mathematical theory of AGORA. guaranteeing the correct solution.

Mathematically highly superior to the FDNR, AIA's method is very efficient regarding time, as it uses the ultimate advances in terms of representation and organization of sparse matrices.

OBSERVATION: STATE ESTIMATOR

The estimation of electrical states based on field measures offers convergence and stability problems for the algorithms in use ("state of the art") of the same type as in the case of the load flow. The state estimation algorithm developed by AIA extends the methodology used in the load flow to the case of the minimization of the error function adequately weighted by the quality of the observed measures.

The methodology is robust and is protected from the existence of large regions without information, adequately reconstructing in a plausible and coherent manner the values for which no measure is available. The AIA algorithm works directly with the complete network and does require two or three step estimation procedures. Two or three step estimation procedures may be required by alternative methodologies, including an initial load flow and external model computation with low observable characteristic followed by an internal model estimation.

The new AIA methodology inherits the characteristics of efficiency and correctness (attaining the physical solution) from the load flow algorithm, allowing estimates of networks of a significant size every few seconds with a rate of convergence close to 100%.

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FUNCTIONALITIES THE AGORA INSTALLATION

The AGORA system is an *On-Line Real Monitoring and Simulation System* and it provides any SCADA or EMS with a whole set of new functionalities:

Under Normal Network Conditions: One of the chief advantages of the AGORA system is the set of functions used for the day-to-day management of the network. Those functions have a double impact quite profitable to the operator. First, it provides him with a set of high quality tools based on the same mathematical savvy that allowed for the development of a Load Flow and a State Estimator of an un-paralleled convergence quality capable of observing the grid close to voltage collapse. Second, it allows for a continuous contact with the system, ensuring that when difficult situations occur the operator will be completely familiar with the system and its maneuverability. The following list gives an idea of those functions:

- **System overview**. Specialized displays provide the operator with a global view of the system actual conditions, and give a natural complement to his SCADA MMI (Man Machine Interface). The information presented can be metered directly from the field or from the powerful State Estimator.
- **Security analysis tools.** They are based on the powerful and unique Load Flow algorithm developed by the AIA research team. They allow the study of the network conditions and the proposal of changes in any of the network parameters, including its topology.
- **Simulation tools.** They allow for an easy and maneuverable way of testing new contingency measures, defense plans, and/or any system operation strategy designed by the network operators of the company.
- **Powerful study mode.** By obtaining images: estimated real-time snapshots of the online situation of the network (State Estimation output) it can generate a reliable historical database of cases for off-line or on-line study. On-line studies have included the study of contingencies or maintenance line clearances work. Disturbances for which the system provides optimal solutions, can be studied as well as the suggested solving plan in an environment that allows testing by the network operator.
- **Training tool.** A specific part of the system allows for the training of operators in the mastering of the system when close to its limits.

Under Disturbed Network Conditions: Restoration Plans are generated. Here lies a unique functionality of the AGORA System which to this date is unmatched in the market. When a disturbance is detected over the network, be it a topology disturbance or a distortion (under-voltage, over-load, etc..) condition, the AGORA System produces:

- **Field alarm's information.** There is a filtering and analysis process of the field alarms allowing the system to present the operator with the relevant information for the restoration process, with regards to equipment availability.
- **Dynamic Restoration optimal plan.** The AGORA SYSTEM provides the operator with the plan of operations (breakers operation, active and reactive generation, taps changes...) that need to be performed on the network in order to bring it back to its normal state of activity. The sequence proposed is optimal, and consistent with the weights set to represent the system restrictions and priorities. If the situation changes a real-time monitoring of the evolution of states triggers new plans to be generated on-line.
- **Restoration intermediate states.** The AGORA SYSTEM verifies all intermediate states of the proposed restoration sequence and makes that information available to the operator in a way that is both simple and easy to understand and follow. >For this a very reliable and fast Load Flow is needed.

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- **Generation of automatic reports**. The AGORA SYSTEM also generates reports automatically. The reports can be triggered by time or by events, and can be customized to meet specific needs (regulatory requirements, general public etc.).

Under Strong Simulation Environment: The AGORA simulation environment with the load flow underneath and a strong graphical interface can emulate the field and SCADA, supporting any load, generation and topology. It has been specially designed for training Operators on the knowledge of the grid behavior as well as for allowing the reproduction and design of massive generation of disturbances to evaluate and validate the restoration strategies. It has the following functionalities:

- **Base case generation.** The Simulator can use stream input files to generate the base case, with data extracted from the real time environment. The image transmitted to this environment contains the current topology, analogue values and the network model. The topology and values can be modified.

- **Topology changes.** The base case topology can be modified, as needed using the breakers and isolators included in the network model. The changes can be performed using graphic or text editing environments. The system provides Help facilities. Data are obtained directly from the Database, which can be consulted on-line (breakers, isolators, relay alarms, etc.).

- **Load and generation changes.** Both load and generation can be changed individually or scaled. To produce distortion disturbances, the active and reactive load and generation can be scaled independently.

- **Protection Relays.** The system takes into account the effect of the protection relays in case of over voltage, under voltage and overloads.

- **Disturbance generation.** Any change in the topology, load or generation can be manually generated to simulate a disturbances of any kind. A high level language enables the user to produce topological changes with massive disturbance generation. This information is transmitted to the system via commands such as "zero-substation", or "zero-bus-bar" in order to produce any disturbance or collection of disturbances to be submitted to the AGORA on-line real time monitoring or simply to compute the final system status after such disturbances. The disturbances are simulated and the results visualized in a graphical environment.

- **Restoration evaluation.** A s soon as the AGORA system restoration module has found the way to solve the disturbance, the solution is transmitted to the Simulation environment. The solution is then evaluated and stored for further analysis. Also in the real-time system a simulation environment with reduced functionalities is also available. The evaluation criteria use a heuristic similar to the one used during the restoration path calculation. To analyze the impact of each factor in the final solution the system displays in an orderly manner the penalties for each one. The same heuristic can be used to evaluate alternative plans, manually generated by the operator.

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CENTRAL FEATURES

Added value from the very first day
Monitoring the Grid: Robust Load Flow and State Estimator:

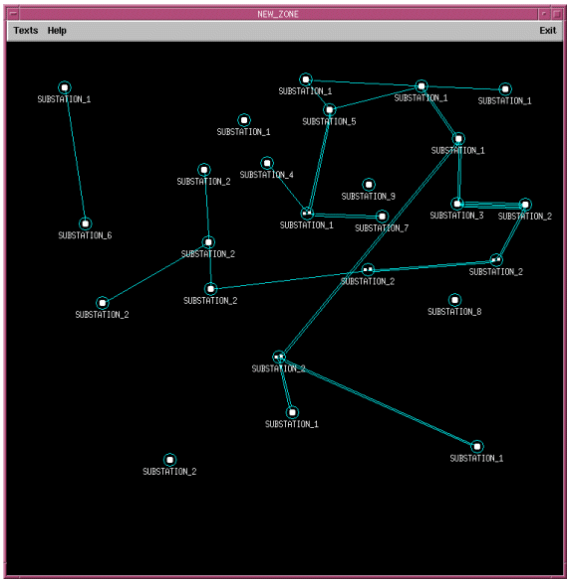
- Assessment Network model validation
- Field measurements quality control
- Cases library (RT Snapshots) generated & exported standard formats (PTI, GE)
- Assessment of voltage collapse: Dynamic PV and QV curves generation
- Real time reactive margin analysis & new contingency metrics
- Losses and power cycles reactive control
- On-line optimal power flow
- On-Line powerful simulation: clearances, operators actions

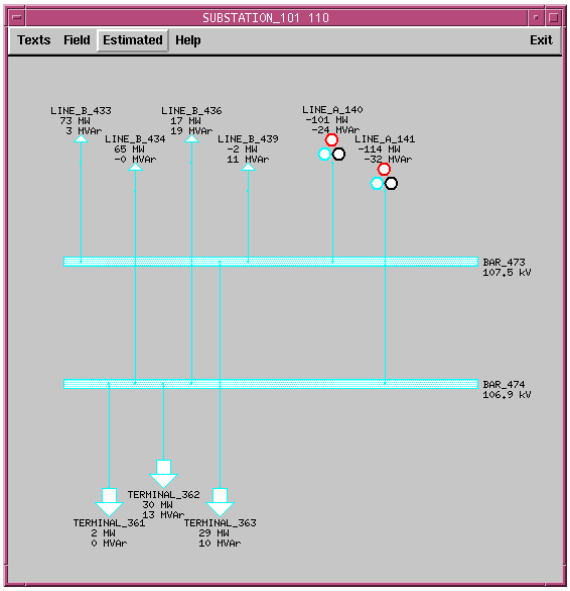
Added value from the very first weeks
Grid Intelligent restoration tool and powerful review environment:

- Dynamic restoration with flexibility also minor distortions back to normal
- Cero maintenance with all zoom levels:
  - Nodes
  - Substations
  - Lines
  - Breakers
  - Etc
- Easily editable desired rules: specific states, Black-Start triggering
- A* with proprietary heuristic: optimal restoration plan
- Zones and hierarchical restoration security coordination capabilities

Simulating the grid: robust network modeling and evaluation of restoration plans:

- Powerful field/SCADA simulator with AGORA RT transmitted snapshots allowing case strong graphical editing supporting any load, generation and topology
- Powerful massive disturbances simulation and AGORA restoration plans validation
- Powerful tool for operator training on network behavior and restoration
- Powerful tool for reliability and security regulatory procedure testing





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MAIN SYSTEM COMPONENTS

AGORA Real-Time Monitoring System (Basic Components):
Preprocessors and Communication
Network topology and connectivity
State Estimator
Load Flow
Man Machine Interface
Alarms / Equipment availability (*)

AGORA Off-Line Simulation Environment

AGORA Real-Time Monitoring and Simulation System (Independent Components)
Disturbance Recognition Module
Distortion Solving Module
Reporting Module
On-Line Simulation Module

AGORA Real-Time Restoration and Other System (Interdependent Components)
Restoration: Plan generation, by zone, black start
Review Module for Restoration Plan
Alternative Plan / Plan Editor
Hot-Backup

AGORA Complementary System Options
Optimal Power Flow (OPF)
Registering of Historical Network Snapshots
Contingency Analysis
Load Forecast
P-Q Curve Profile generation
Module for exporting estimated snapshots in GE and PTI format (**)

(*) This is the only module of the Basic License not installed in the EVALUATION/TEST Installation mode.
(**) GE and PTI are trademarks standing for General Electric and Power Technology Inc.

TECHNICAL INSTALLATION: SIMPLE AND EASY TO CONNECT

Another of the AGORA SYSTEM important characteristics is the relative easiness of implementation in a new installation. Existing SCADA and/or EMS databases provide all the information needed for the internal AGORA SYSTEM database.

When the system is online, all the information needed is obtained from the SCADA using a computer-to-computer communication link. Different protocols have already been implemented.

All displays are automatically produced and can be easily customized. The alarms database is generated automatically from the SCADA once preprocessor have been customized.

The AGORA SYSTEM runs on RISC workstations. Existing installations include both IBM and SUN workstations under UNIX Operating System. The system can also be called from any PC or WS using a LAN and UNIX emulation under DOS or Windows.