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Higher math suggests solution to transmission system woes

Physicist finds way to better manage power flow on nation's electric grid

Whether it's because of the aging infrastructure, increased congestion or actual blackouts, transmission and distribution companies, regulators, and policymakers are looking for ways to solve the nation's electric transmission concerns.

Now, a small European software development company has found one IT solution, it says, that can improve reliability, expand capacity, and offer quick restoration. The software is called Advanced Grid Observation Reliable Algorithms, or AGORA for short.

San Francisco-based Pacific Gas & Electric Co. (PG&E) recently became the first U.S. utility to purchase AGORA to help manage its huge transmission system. Reliability and power restoration are key priorities for PG&E, which serves about 13 million customers in northern and central California. Having experienced a devastating blackout that affected close to 1 million San Franciscans in December 1998 and another on June 14, 2000, the utility bought AGORA from San Francisco-based EleQuant, the newly established U.S. subsidiary of Grupo AIA of Barcelona, Spain.

Utility companies in Spain, including Red Electrica de Espana S.A. and Endesa Holding, have been using the highly complex software package at control centers in Madrid, Barcelona, and Seville since the early 1990s.

In brief, according to its developers and users, AGORA provides grid operators with the following:

- real-time monitoring and observation tools;
- voltage collapse assessment and optimal restoration analysis;
- a systemwide or localized disturbance restoration tool;
- a robust, reliable load flow and state estimator;
- a reliable grid modeling tool;
- a load forecast calculator;
- a contingency analysis tool.

Bob Stuart, manager of operations engineering, has worked for PG&E for more than 30 years and has experienced it all. He reports that after a four-month trial, PG&E decided to purchase AGORA in June 2002, and now it's fully operational. "We're fine-tuning some of the options, but it's doing what we need it to do. It's pretty phenomenal in my mind."

Before and after AGORA

What makes AGORA so phenomenal? Here's how Stuart explains it. "It takes the real-time data from our energy management system (EMS), crunches the numbers and models the system," Stuart explains. "Using the analogy of the highway system, AGORA knows exactly the amount of cars flowing on the whole highway system, including the interstates and state highways. It knows if a lane has shut down and whether that's a problem or not before it ever happens. And it will give you a plan for avoiding the traffic congestion."

Admitting that the highway description is "grossly oversimplified," Stuart says AGORA is a "very complex system." And, yet, it helps PG&E manage its 18,000 circuit miles of high voltage transmission lines in many climatic zones where "every minute's an adventure."

After working with AGORA for just a short time, Stuart says it helps PG&E to:

- operate its transmission system more reliably and closer to the margin;
- provide dynamic restoration to the system should anything unplanned occur; and
- provide more information and more flexibility in planning and maintaining the system.

While AGORA is highly sophisticated, Stuart tells *ECSR* that a PG&E engineer trained all of the company's operator / dispatchers. "Like any new tool, there's a bit of a learning curve and an intimidation factor. [But] the operators caught on very quickly and have even used it on their own," he says.

What was it like at PG&E before AGORA? Prior to 1998, California utilities like PG&E were in control of an integrated transmission and generation system. Consequently, utilities could control their generation to prevent transmission overloads. As a result of restructuring, however, utilities are no longer in control of generation, and their way of operating the system has completely changed.

"In the past we could predict dispatch patterns because they were based on our own system and economics. I don't think anyone's in denial anymore. The system has changed radically in how generation is dispatched. We must be able to react very quickly," Stuart says. "We must know exactly what the single worst contingency is or multiple contingencies, and know our plans and be able to react exactly to how the system is dispatched."

Furthermore, Stuart says, in the past the system was modeled with only a few snapshots, and the model was never absolutely certain. "Now we have something we can model with very great accurately, very robustly, in real time to take into account all the possible contingencies. Or if something bad happens, how to get back quickly. How much is that worth? Priceless, in my mind."

'Always works'

Underpinning the AGORA system is a brand new algorithm devised by **Antoni Trias-Bonet**, a Grupo AIA physicist. Also a co-founder and vice president of research and development, Trias-Bonet was looking for an "optimum restoration system for electric utilities" when he had his "eureka" moment in November 1999.

John Sell, EleQuant's director of sales, explains: "For about 40 years, utilities have used traditional SCADA or EMS tools, which have one thing in common: Newton-Raphson iterative mathematics to calculate the load in the transmission system. It's widely recognized that the Newton-Raphson approach has shortcomings, but nobody has been able to do anything about it. Until now.

"Grupo AIA came up with a definitive way to calculate loads in the transmission system that does not rely on Newton-Raphson iterative math. That proprietary algorithm -- discovered by Trias-Bonet -- is the heart of AGORA."

In fact, AGORA provides 100% convergence in normal operations, as well as near voltage collapse and during disturbances. By contrast, Newton-Raphson systems will provide 90% convergence in normal operations and no convergence in the vicinity of voltage collapse. "We have a load flow algorithm that always works," Sell states.

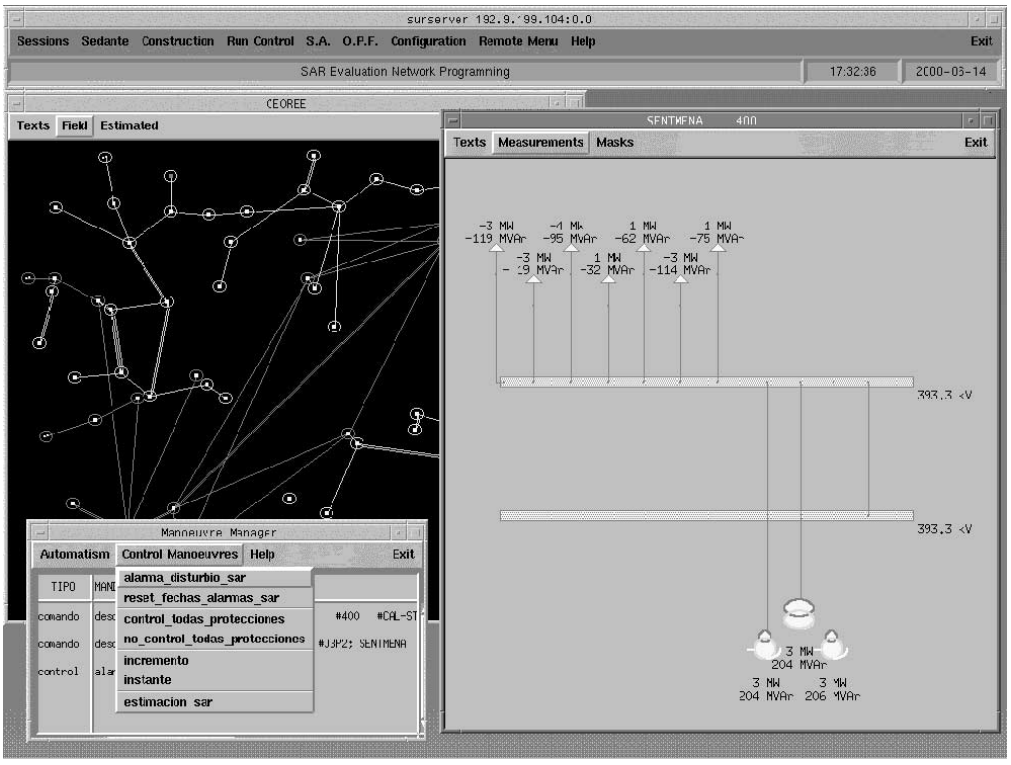
The system allows utilities to monitor the grid in real time, anytime, calculating the flow of the entire system and providing that information to the system operators. And the operators can see if they're approaching voltage limits. In short, operators know -- with much greater accuracy -- how far they can push the system without resulting in voltage collapse or other system disturbances.

Three applications

AGORA addresses three primary needs on the grid: monitoring, simulating, and restoring -- as represented in **Figures 1-3.)** Here, briefly, are the system's capabilities:

• **Monitor.** A robust load flow and state estimator, AGORA "guarantees" that grid operators never make decisions based on incorrect information, thus dramatically increasing reliability. With real-time information flowing in at all times and properly estimated, operators are able to react quickly to any changes in the grid -- often within

Figure 1: Monitoring



Source: EleQuant, Inc., San Francisco, CA.

minutes.

"Most state estimating systems converge maybe 90% of the time if you're doing well," Stuart says. "But they're not very robust if something goes wrong or you're trying to solve for contingencies. They oftentimes don't even solve when a solution is there. We believe very strongly that AGORA will do that. If there's a solution, it will find it." For instance, Stuart says AGORA will predict low voltage before it happens. And it will know how much margin is available. "It will predict those things, and put that information in the hands of the operators for them to take action and prevent low voltage problems from happening," Stuart says.

• **Simulate.** Providing network modeling and restoration evaluation, AGORA helps utilities plan their activities. Utilities regularly take equipment out of service for maintenance and must prepare plans to maintain the normal flow of power to customers. EleQuant estimates that utilities can reduce engineering staff time by 90%, and a small utility could save nearly $1 million annually by minimizing interruptions of power.

Stuart agrees: "When you have a huge system like PG&E, knowing when to take equipment out and maintain it so that it will be in the best economic interest to both generation and transmission folks is really important." Consequently, PG&E uses the simulation tool when it does planned or unplanned maintenance on the system that may affect the availability of assets. "We like to simulate that event and perhaps another to make sure we won't get into trouble if something unplanned happens while we're doing something planned," Stuart says.

• **Restore.** Using its proprietary algorithm, AGORA provides dynamic restoration of general blackouts with the capacity to bring minor disturbances back to normal. According to Sell, AGORA can "guarantee the optimum restoration solution to any event in the transmission system." Although optimum means different things to different utilities, he says, the company can take care of that from utility to utility during the initial installation phase. For instance, utilities can set priorities for locations -- such as hospitals, the mayor's house, or for the assets themselves -- and determine what's best for their particular situation. "Our algorithm takes all those inputs into [consideration] to determine the optimum procedure to restore power to the network," Sell states.

Both Stuart and Sell tell *ECSR* that had PG&E been operating AGORA during the 1998 blackout, the utility's restoration would have been four hours, instead of the actual 12 hours.

Questions, answers

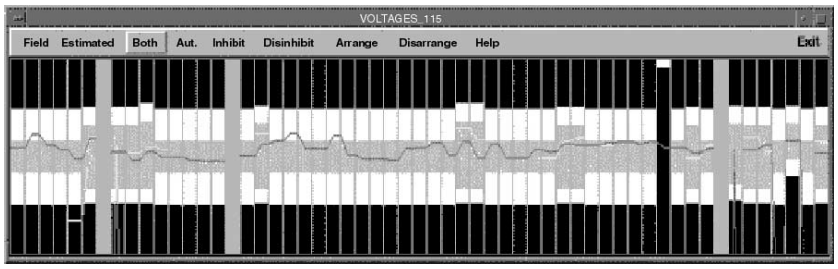
ECSR asked Sell and Stuart a few other questions about AGORA. Following are their answers:

• **Will current SCADA and EMS systems, which operate on Newton-Raphson iterative mathematics, become obsolete**? "We operate in parallel with other EMS systems," Sell explains. "Other EMS software providers are also providing SCADA systems as well, which are both hardware and software. Those systems are pervasive throughout the utilities, and they're not interested in replacing all that. Neither are we." **(See Figure 4.)**

• **What is the typical installation time?** Normally, Stuart says, it's about two to four months. **(See Figure 5.)**

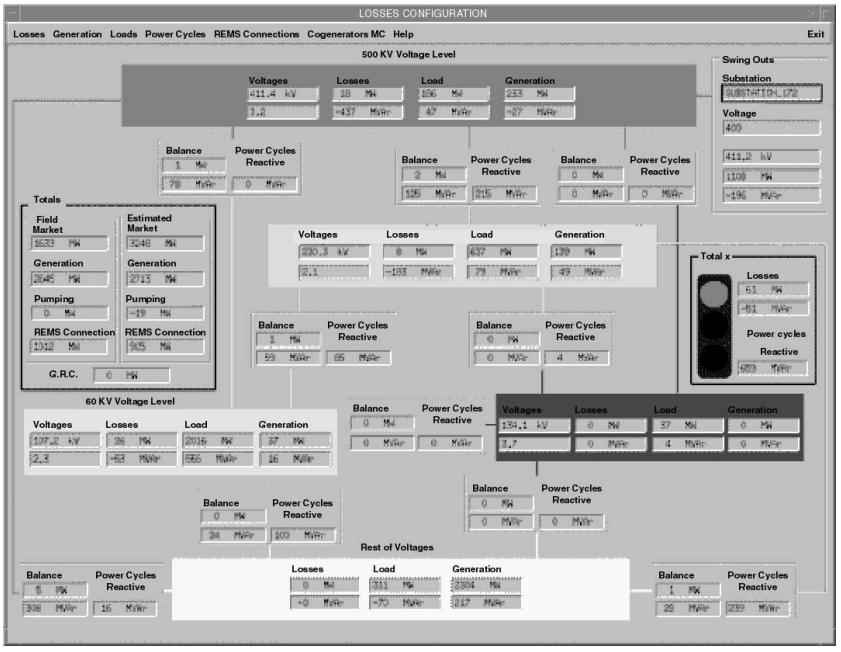
• **How much does AGORA cost?** From $2.5

Figure 2: Simulation



Source: EleQuant, Inc., San Francisco, CA.

Figure 3: Restoration



Source: EleQuant, Inc., San Francisco, CA.

million to $5 million, depending on grid size and functionality.

• **What is return on investment time?** "Utilities should see lower cost of operations because AGORA performs its job better. And with quicker implementation time, the savings are going to be larger as well. Utilities will see faster ROI. For example, PG&E, which does thousands of clearances a year, normally would spend several hours to do a single clearance before installing AGORA. Now it can take only a few minutes -- a tremendous man-hour improvement," Sell says.

• **What does AGORA do for the utility operating in a highly competitive environment?** "The key thing is they can assess accurately their existing transmission system. They can identify accurately and quickly where they're constrained. It lets them improve their investments at an appropriate level, improve reliability and system security, and reduce restoration times, which all benefit the transmission operator," Sell comments.

• **Is AGORA off-the-shelf or customizable?** "We generally customize it for customers. For instance, during installation we set up preferences specific to each utility, such as the restoration priorities, 'coloring' the load, what a zone is, what an area is, and so forth. Although we use the same graphics operators are familiar with in their existing systems, we have an interchangeable graphics library so we can make our screen and the screens they've been using as similar as possible. In short, it's highly customizable," Sell explains.

• **Can AGORA avoid installing new transmission lines?** "No, there's really no substitute for new wire," Stuart says. "But it does allow us to extend the life of the system. A certain amount of conservatism needs to be built into the transmission system, and most utilities and transmission owners have static readings based on conservative assumptions such as low wind speeds and high temperatures. Also, there's a fair amount of voltage or reactive margin. So you don't have to drop load or operate closer to the margin because you have this real-time tool to tell you how far away you are from the point of no return."

Sell adds, "We like to say *you can defer capabilities*. For instance, if you can't see exactly what your operating system is doing, you have to be conservative in your engineering. But with AGORA you can determine exactly how much capability you have. And using that information plus load forecasts -- based on economic forecasts -- AGORA can tell you exactly where you are. Therefore, you can use this as a tool to plan your investments more accurately, and perhaps defer investments.

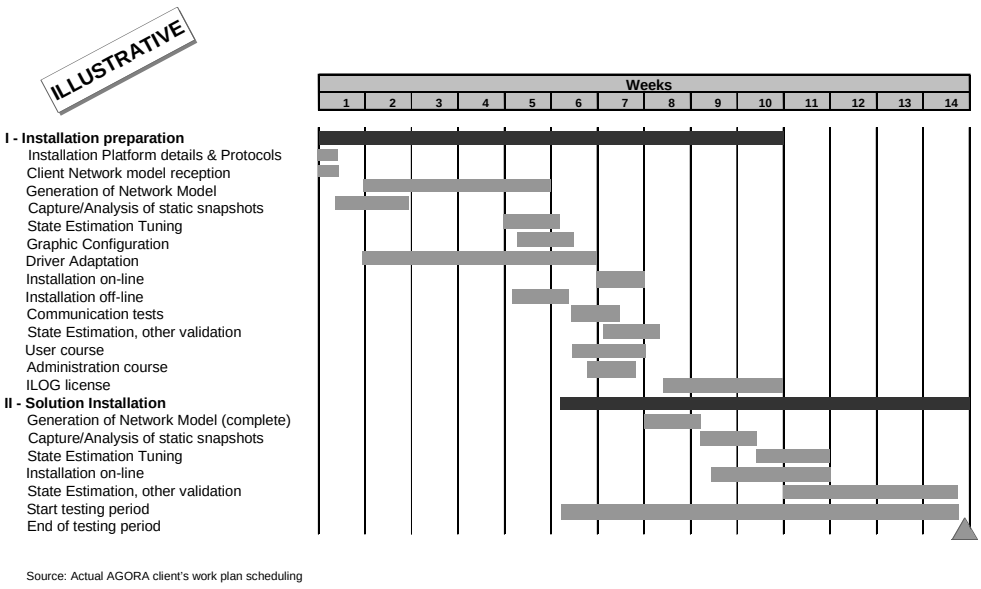
Editor's note: For more information about AGORA, contact John Sell at 415-981-7000, ext. 229. Go to EleQuant's web site at www.elequant.com for a detailed presentation of convergence issues with Newton-Raphson iterative load flow calculations. ✹

Figure 4: AGORA Ranks Best in Market Comparison

	AGORA (AIA-EleQuant)	OTHER*
Algorithms	New Paradigm	Legacy approach
Methodology	Non-iterative algorithm	Newton Raphson iterative
Convergence during normal state	100%	20% to 90%
Convergence through Voltage collapse	100%	0%
Real time 24:7	Yes	Partial
Functionalities	More extensive than competitive tools	Limited by methodology
Ease of model augmentation	Fully automatic	Manual
Multi-site capability	Full	Full
Investment needed for comparable installation sizes	One-site $2.5 to $5 million (final price depends on grid size and functionalities)	$8 to $15 million
Implementation schedule	2 to 4 months	1 to 2 years

Source: EleQuant, Inc., San Francisco, CA.

Figure 5: A Typical Work Plan to Install AGORA Takes 2 to 4 Months



Source: Actual AGORA client's work plan scheduling

Source: EleQuant, Inc., San Francisco, CA.