Simulated reality

A simulator to put network operators in control

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The electrical world is changing! Several power systems which had the reputation of being extremely reliable have experienced large scale blackouts in recent years. One of the keys to avoiding this is the thorough training of dispatchers, ie, teaching them how to deal with unexpected situations quickly and decisively.

An important component of dispatcher training is practicing on a simulator. For such lessons to be genuinely useful, the simulator's behavior must be as close as possible to that of the real system. Until now, simulators may have been very good at simulating certain phenomena, but less optimal at others. A Dispatcher Training Simulator (DTS), (known as FAST-DTS) jointly developed by ABB and Tractebel Engineering in Belgium, is using a completely new model to produce more accurate simulation results than ever before!

As part of the long term cooperation agreement between Tractebel and ABB, and following ABB's delivery of the Energy Management System (EMS) to the Belgian national and regional dispatch centers, it was decided to put the experience both partners had gained to good use. They proceeded to develop a simulator system that would provide ELIA[1] operators with the most advanced tools on the Market.

ABB's has contributed with the Network Manager‰ Platform which is characterized by its powerful database, training tools and infrastructure. Tractebel integrated its own FAST-DTS engine based on EDF-Tractebel EUROSTAG®, technology[2].

The result is the new dispatcher training simulator known as FAST-DTS.

Why do the power systems collapse?

Blackouts are nothing new: they have been a phenomenon since the first power line was built. However, several western countries have experienced exceptionally large-scale incidents in recent years. The simple explanation for this is that the electrical world is changing. Many changes include: deregulation of the energy market; generation and transmission businesses have been split; investments have been reduced or postponed; commercial transactions are causing unexpected flows; large fluctuating power sources have been connected; and

Footnotes

[1] ELIA is the Belgian grid operator.

[2] EUROSTAG is a software package for the dynamic simulation of electric power systems. It was developed by Tractebel Engineering and EDF.

high-voltage networks are increasingly operated close to their physical limits and under conditions that were not foreseen by their designers. In other words, the security margin is reduced to such an extent, that under certain conditions, a single contingency can lead to a large scale collapse. Thus, operators are facing increasingly complex and critical situations on an everyday basis and are compelled to use more and more sophisticated tools to control the network.

Teaching and training are the cornerstones of sound operating practice. Operators must widen their understanding of the physical phenomena and learn to react correctly in unexpected situations. Advanced training simulators are an essential part of this approach. Many people know that flight simulators have been used for many years to help train pilots, but simulators are now being used in other transport, marine and military applications.

Power systems are a special case due to their complexity. The phenomena that can occur in any system are completely diverse, ranging from the short to the long term and they can occur simultaneously or overlap. Modeling this process requires huge mathematical systems that need to be processed in real-time. Unfortunately, most of the currently available simulators have a restricted domain of use, and therefore only partially address the problem. Raising such restrictions is the challenge that FAST-DTS has undertaken.

FAST: a simulation engine that pushes back the limits

Most simulators are "phenomena oriented". This means they have been designed to simulate a given range of phenomena. The phenomena that take place in power systems can be classified according to various criteria, mainly their speed or whether they are related to active or reactive power. The phenomena that a given simulator is able to perform with accuracy define its scope, ie, its domain of use.

For instance, if a simulator is designed for long-term stability, it will be unable to properly simulate short-term phenomena. The rationale behind this approach is that the more restricted the scope, the simpler the mathematical model. And if the mathematical model is simple, the simulation engine can also be simple.

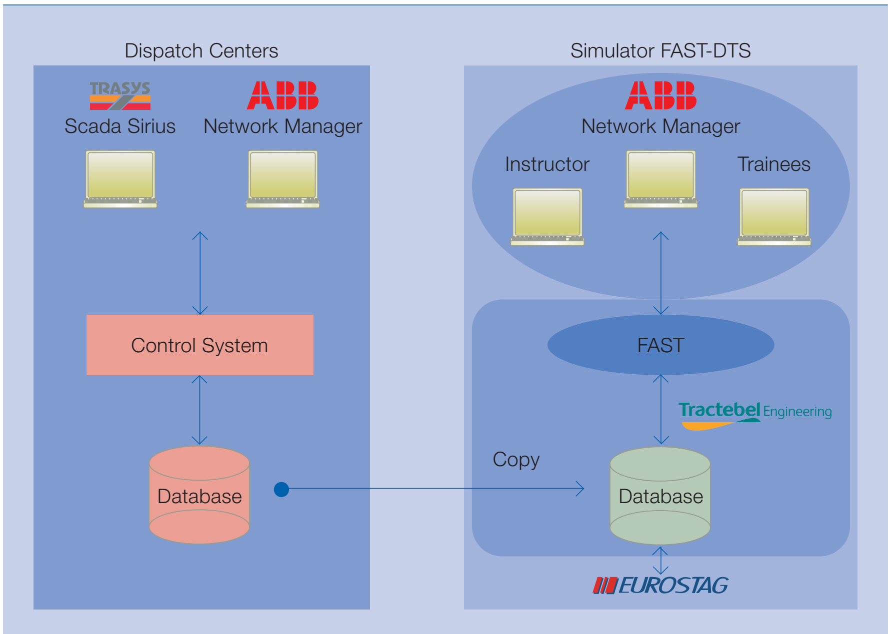
This approach has some limitations, the first of which is purely practical: if operators must be trained under various circumstances and contingencies, several simulators are required and this is often impractical. The main limitation, however, is conceptual: in power systems, nothing is independent. Short-term phenomena affect the long-term behavior of the network, active and reactive powers are not decoupled and phenomena of very different nature can occur at the same time. Even when a simulator is used within its domain, the behavior it computes may be questionable if it is systematically ignoring phenomena that are outside its domain! The only way to address these limitations is to base the design on a generalized model, ie, a model that is able to cope with all types of phenomena, regardless of their timescale, whether they concern active or reactive power, or whether they occur simultaneously or sequentially.

This is the type of model that was chosen for FAST-DTS. Of course such a model makes the simulation more complex, but the benefits are clear: The domain covered ranges from the generator's loss of synchronism (for example, due to a short-circuit) to the slow dynamics of the boilers and cen-

1 Classical dispatcher training simulators (DTS) versus FAST-DTS and its generalized model.

Classical DTS:	→	FAST-DTS and its generalised model:
✓ Quasi-static phenomena		✓ Quasi-static phenomena
✓ Long-term phenomena		✓ Long-term phenomena
✗ Short-term phenomena		✓ Short-term phenomena
✗ Electromechanical swings		✓ Electromechanical swings
✗ Loss of synchronism		✓ Loss of synchronism
✗ Simulation of protective devices		✓ Simulation of protective devices

2 The architecture of FAST-DTS



tralized controller actions. In other words, it models phenomena from 10 Hz to quasi-static ones. The developers believe that a detailed mathematical model, close to the physical phenomena and handled by a powerful solver[3)], is more robust than the simplified models usually used in simulators. This extensive model is able to simulate complex incidents up to blackout and remains quantitatively exact in situations where most simulators are just qualitatively approximate or defeating 1.

The architecture of FAST-DTS

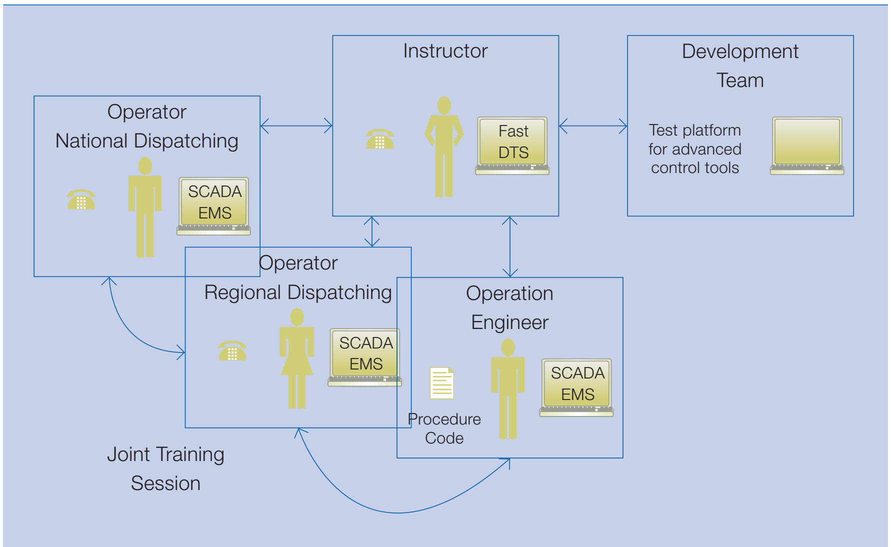
From the operator's point of view, the simulation engine of a training system basically replaces the real network, 2, in that it accepts commands from the control system and returns values to the analogue and digital telemetry points. This thinking holds true with respect to the architecture of FAST-DTS – the simulation engine is an independent system and is distinct from the control system. The two systems communicate using a common protocol (ELCOM) which is implemented in the communication layers of the Supervisory Control and Data Acquisition system (SCADA). To achieve as much flexibility as possible, FAST has been integrated into ABB's Network Manager system[4)].

This architecture has the following advantages:

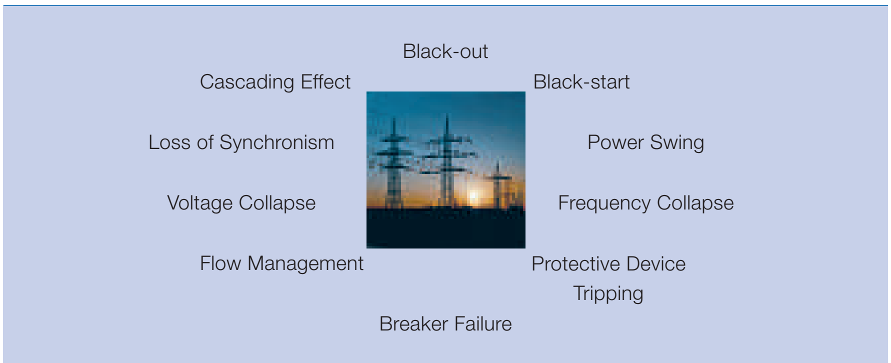
- The control system connected to the simulation engine is an exact replica of that in the control center. Operators handle it exactly as they would handle the real control center.
- The integration of FAST into the ABB Network Manager platform allows it to be used without replicating the control system tools. This feature is useful if a user wishes to have a lighter version of FAST-DTS in which the simulation engine and control system are not split.
- The ABB Network Manager platform also offers a state-of-the-art environment as simulation infrastructure for the instructor, allowing him to efficiently build and monitor the training sessions.
- The database for the simulation engine is not specific with respect to that of the control system, it is a copy. The database maintenance team does not have to do the same job twice when updating the database.
- ELCOM links can be multiplied if several control systems have to be connected to the simulation engine. This feature is very useful, for example, when training sessions involve coordinating actions from several operators or control centers. If the ELCOM protocol is respected, control systems of different types and different manufacturers can even be connected.

What about the data for the dynamic model? The generalized model of FAST requires some specific data that are not found in a standard control system database. In fact the model of FAST is fully compatible with EUROSTAG®. This feature allows the dynamic model to be tuned with the flexibility of a study tool and when it is well-tuned, it can be loaded into the main simulation engine database. The model compatibility allows a network state to be exported from the simulation engine and loaded into EUROSTAG®. Elements of a training session can be replayed and thoroughly investigated, for example to analyze dynamics that are not represented in sufficient detail under SCADA. Such analysis is not only of great value to trainees, but also to instructors when building new scenarios.

3 The structural view of FAST-DTS.



4 The phenomenological view of FAST-DTS.



Footnotes

3) This figure reflects CO_2 emissions caused by thermal process. The chemical process (calcination) produces several times this figure.

4) Network Manager is a control center solution, supporting a safe and efficient energy system operation. It is also an energy information system, providing decision makers with reliable process information.

FAST-DTS applications

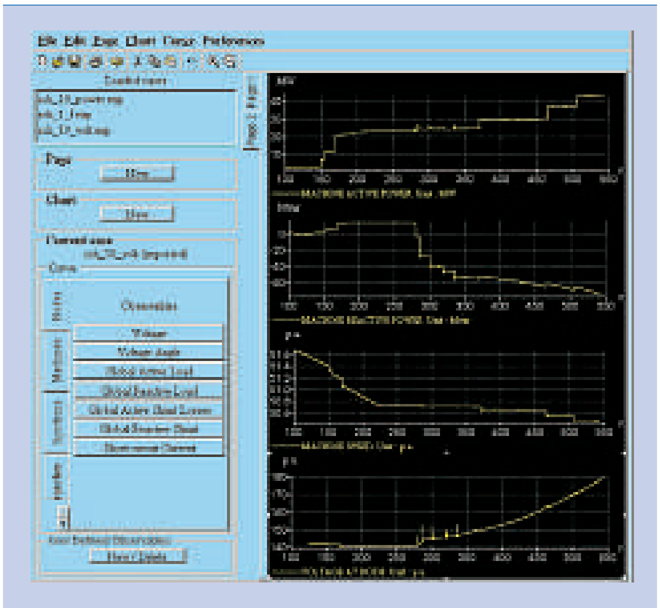
Concerning the field of application of FAST-DTS, it is necessary to consider two points of view: the structural and the phenomenological.

The structural point of view 3 follows on from the architecture of FAST-DTS. As already explained, it is possible to connect various control systems to the simulation engine. Thanks to this architecture, FAST-DTS supports training sessions that not only replicate the tools but also the hierarchy of the operation. This feature is of great value when analyzing critical interactions between operators and/or control centers in normal and emergency situations – especially when new operating procedures are being tested. The simulator is also an ideal platform for the on-line testing of advanced control tools such as security constrained dispatch or centralized voltage control.

The phenomenological appreciation 4 follows on from the dynamic model of FAST-DTS. The more general the model, the greater the scope of the events that can be simulated. The following list is not exhaustive:

- Line switching command.
- Short-circuit on a line, a transformer or inside a substation.
- Reactive power compensators
- Enable/disable a protective device or a regulation automaton.
- Change of a generator set point (active power and voltage).
- Enable/disable special functions of a generator governor.
- Enable/disable the control of a switch (breaker failure).
- Under load tap changer command.

5 A real-life scenario including an over-voltage and generator outage (post-session analysis).



The variety of the events that can be taken into account by FAST-DTS allows a network to be simulated in virtually any state.

Real-life scenario

The scenario shown in 5 illustrates how easily an operator can reach the technical limits of his power system. In this example, an over-voltage occurred because too many cables were connected during a black start and cascading effects rapidly led to a generator outage.

Tractebel Engineering training centre

ELIA uses the training centre of Tractebel Engineering for continuous training of its grid operators. FAST-DTS has been running since the beginning of 2004. The control system component of the simulator is configured as a full replica (SCADA plus EMS) of two control centers. The configuration is adapted according to the training scenario and/or the origin of the operators. The model includes 900 substations, 175 generators, 3,000 lines or transformers, 17,500 breakers and switches, and more than 6,000 protective devices. The simulation engine runs on a dual processor computer, and typical scenarios include flow management, voltage control and black-start.

An additional product for the Network Manager portfolio

The FAST-DTS simulator is considered another successful milestone in ABB's cooperation with Tractebel.
The simulator can be used as a stand-alone system, it can be integrated while upgrading an existing network manager or it can be used in addition to a new network manager.

In addition to the existing classical EPRI-based Training simulator, ABB will introduce this advanced training simulator into its Network Manager portfolio.

Further reading:

[1] **Stubbe, M., Bihain, A., Deuse, J, Baader, J-C.,** "STAG – A new unified software program for the study of the dynamic behaviour of electrical power systems"; IEEE Transactions on Power Systems 1989, vol. 4 n°1, pp. 129–138.

[2] **Stubbe, M., Bihain, J., Baader, J-C., A., Deuse,** "Simulation of the dynamic behaviour of power systems in short and long terms", CIGRE, Paper 38–03, 1988.

[3] **Vernotte, J-F., Panciatici, P., Meyer, B., Antoine, J-P., Deuse, J., Stubbe, M.,** "High fidelity simulation of power system dynamics", IEEE, Computer Applications in Power (CAP), January 1995.

[4] **Stubbe, M., Bihain, A., Gissinger, S., Stéphant M-Y.**, "An advanced Dispatcher Training Simulator"; 12th CEPSI Conference, Pattaya – Thailand, 2–6 November 1998.

[5] **Stubbe, M., Meyer, B., Jerosolimski, M.,** "Outils de simulation dynamique des réseaux électriques"; Techniques de l'ingénieur, Traité "Génie électrique", cahier D4 120, 1998.

[6] **Stubbe, M.,** "The Omases advanced simulation environment"; MED Power 2002 Conference, Athens – Greece.

[7] **Gissinger, S., Chaumès, P., Antoine, J-P., Bihain, A., Stubbe, M.,** "Advanced dispatcher training simulator", IEEE Computer Applications in Power, Vol. 13, No. 2, pp. 25–30, 2000.

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