

Distribution Fast Simulation and Modeling: from concept to reality

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Abstract –

As part of the Electricity Innovation Institute (E2I), the Consortium for an Electricity Infrastructure for a Digital Society (CEIDS) program is a major strategic goal targeting adaptive, “self-healing” electricity grid. To achieve this goal, the capability to model and simulate system behavior based on real-time data fast enough to anticipate changing system conditions is essential to support multiple automation/control capabilities. The purpose of the Fast Simulation & Modeling (FSM) system project is to develop the software platform to support this capability.

CEIDS solicited proposals on the development of the FSM requirements design via a Request for Proposal (RFP). The awarded project focused only on key transmission functionalities. However, distribution is facing fundamental changes, by the implementations of new types of devices, which permit new operational functions. The distribution system also needs FSM capabilities, and an efficient FSM suite of tool implies coordination between transmission and distribution operations. So the specification for the FSM suite of tools needs both transmission and distribution applications requirements to be complete.

The goal of this project is to design the requirements for the distribution applications of the Fast Simulation and Modeling suite of tool envisioned, and its coordination with transmission applications.

CEIDS General background -

Over the past two years, a group composed of domestic and international energy companies, federal and state agencies, and information technology companies, has come together with a visionary goal: to help today’s electric power system evolve into an intelligent infrastructure that integrates major changes in functionality and advances in communications, computing, and electronics to meet the energy needs of the digital society. This unique alliance is the Consortium for Electric Infrastructure to Support a Digital Society (CEIDS)—a public/private partnership managed by the Electricity Innovation Institute (E2I) and Electric Power Research Institute (EPRI).

To achieve its goal, CEIDS determined the needs of the electric value chain, drew a vision of the power system of the future and identified key attributes of the infrastructure.

The CEIDS vision of a new electric delivery infrastructure integrates advances in communications, computing, and electronics to meet the energy needs of the digital society.

To achieve this vision, CEIDS identified a critical need for fast and accurate computational methods to model and analyze the electric infrastructure.

As a matter of fact, today's power system operators work with computer models and data that only approximate generation sources, loads, and the connecting infrastructure. The state estimation of the power system is not always accurate because of data availability or accuracy. There is no real time tool to help operators in the decision making process, so critical decisions rely mostly on the excellent operator skills and experience.

The infrastructure of the future will develop much larger communication capabilities, and much larger complexity because of the emergence of new technologies and new functionalities. In the meantime, the multiplication of actors and energy exchanges, and the need for cost efficiency will oblige to operate power systems much closer to their operating limits.

Computer models and faster computation are needed to take data from many points on the Transmission & Distribution and end-use systems and quickly convert it into information that can be visualized and used to optimize or improve system performance, and reliability. Additionally, models providing faster than real-time, look-ahead simulations are required to anticipate and minimize disturbances, and then to evaluate optimum responses to the disturbances that take into account the characteristics of the end-use systems. Such models and fast computational speeds are key components of the envisioned intelligent grid, because they facilitate faster and optimized responses to outages, constraints, attacks, and other stresses on the system, as well as more efficient continuous operation of the system.

In a nutshell, the need for a faster than real time computer aided operational tool is increasing, particularly as the level of complexity to operate power systems is increasing, and as operating margins are decreasing.

The Fast Simulation and Modeling (FSM) Approach -

The FSM project is designed to provide mathematical underpinning and look-ahead capability for the electric infrastructure of the future, which is envisioned capable of automatically anticipating and responding to power system disturbances while continually optimizing its own performance. The "Integrated Energy and Communication System Architecture" project (part of the CEIDS R&D portfolio) provides the framework for fundamentally changing power system functionality. The FSM project will augment these capabilities by:

- Providing faster-than-real-time, look-ahead simulations, making it possible to avoid previously unforeseen disturbances;
- Performing "what if" analysis for large-region power systems from both operations and planning points of view; and
- Integrating market, policy, and risk analysis into system models, and quantifying their effects on system security and reliability.

Key Challenges for overall Fast Simulation & Modeling (FSM) on Transmission and on Distribution

Key players of the Power and Technological world contributed to a technological assessment study and helped define the necessary capabilities of the FSM system of tool and the phasing of the project:

- Phase1: design of the FSM functions requirements, data structure and Communication design document, and Verification & validation plan
- Phases 2 & 3: prototyping, and then software applications development and tests

The key issues and vital functional requirements identified were developed with the objective of specifying FSM capabilities allowing achievement of the following high level “self-healing” grid goals:

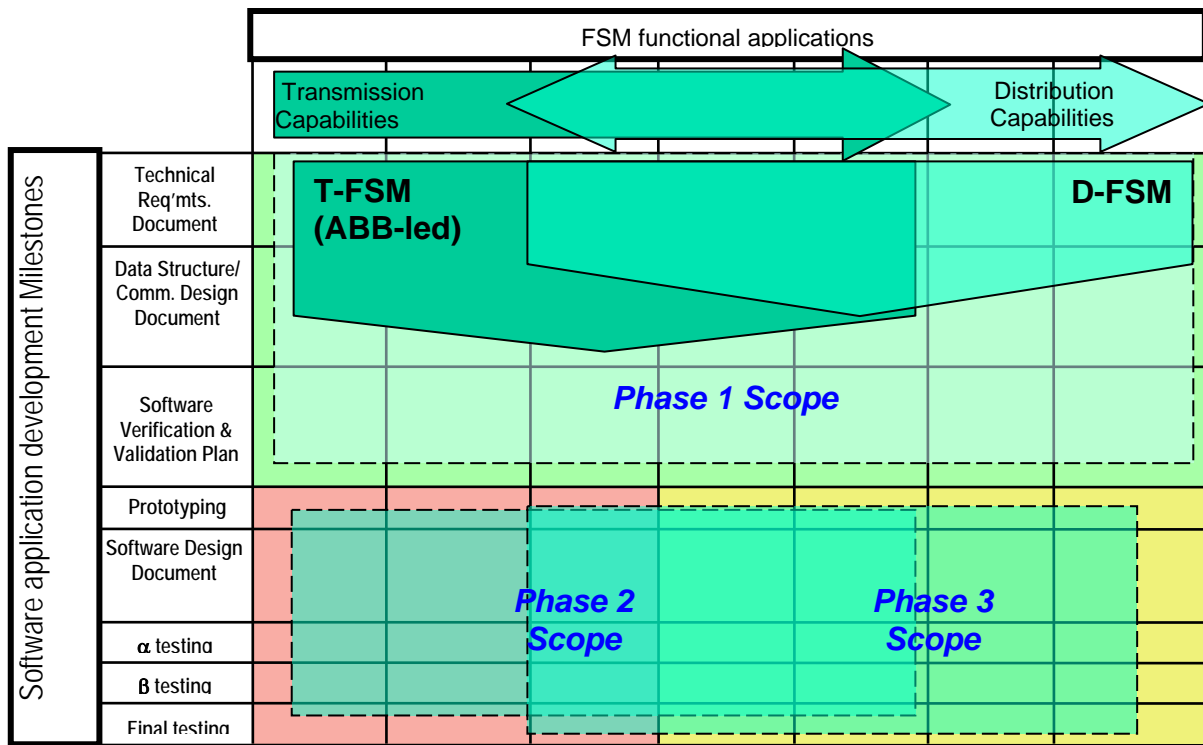
- For direct grid operations & management applications:
 - Predict model dynamic grid behavior.
 - Model grid over full range of physical and time domains.
 - Model grid behavior faster than real-time, allowing predictive modeling.
 - Interface with all existing off-line grid modeling systems
- Coupling of market data and engineering data to assess effects of different market rules.
- Support/substantially increase value of other key grid operations/management tools
- Generic application across all major stakeholders: RTO/ISOs, utilities, NERC, researchers. Build on “infrastructure” of existing capabilities {e.g. Common Information Model (CIM), Community Activity Room (CAR), CEIDS Integrated Energy Communications System Architecture (IECSA)}Help define technology needs in wide area grid monitoring/ measurement, automated grid control, communications, and markets.

The FSM request for proposal approach: ABB project

CEIDS solicited proposals on development of the FSM system via a Request for Proposal (RFP) in September 2003. The scope of the RFP was focused on the Transmission and Distribution key applications of the FSM suite of tools and referred to the technological assessment study.

Aided by the Project Advisory Group (selected stakeholders from utility, state agency and manufacturers), E2I has awarded a contract to ABB Team Project: the selected project is going to design requirements of key operation functions for large electric transmission grids, by the end of 2004.

The goal of the Distribution Fast Simulation and Modeling project (D-FSM) is to complement the scope of T-FSM and ensure reliability of the FSM phase 1.



The complexity to integrate those innovative capabilities and their need to consider several aspects of the current electric power system operations and planning in transmission as well as distribution are critical.

Indeed, if it is obvious that transmission systems need FSM capabilities to operate the grid in better conditions, it will be even more true for distribution systems, as most of the innovative technologies are going to affect distribution grids first.

Those innovative technologies include:

- **The widespread use of smart customer interfaces connected to the information system.** This will have an impact on the way the customers behave. The customers will have the ability to play an active role in the market. The management systems controlling the distribution and transmission grid will be required to manage this activity through sending market information between buyers and sellers, managing the effect these activities will have on load serving entities and transmission providers, managing congestion related issues and providing information regarding operations and customer related services between relevant parties. While much of this expected activity will not occur soon, it is important to begin developing the FSM capability to accommodate these new activities when customers choose to make use of them.
- **The penetration of new Information & Communication Technologies (ICT) in grid equipment** will give the distribution and transmission grid operators the opportunity to gather more data from remote places on the grid, build a more precise picture of the state of the grid for real time operation, and also improve asset management (including grid planning and risk management techniques).

- **The emergence of competitive Distributed Energy Resources (DER) solutions**, and the political push towards sustainable development will help the penetration of DER on medium (MV) and low (LV) voltage grids. This introduces new flexibility in the way both the high voltage and distribution grids are operated and developed, while offering the capability of placing generation at, or near, load. The grid operator will have new challenges to face in terms of voltage and frequency control, fault contribution and power flow.
- **The availability of advanced power electronic equipment** (that can be connected directly to the MV grid) such as Flexible AC Distribution Systems (FACDS) and Distribution Static Var Compensators (DSVC), and the emergence of storage devices (mainly for peak shaving), to name only two, will introduce new grid development alternatives for transmission organizations and utilities. Most development in the past has been driven by demand growth and this growth has been mainly addressed by investing in new lines, cables and transformers. Advanced power electronic equipment gives transmission companies more flexible, and possibly lower cost, options for managing access to and use of the grid. By holding persistently to the vision, the industry can ensure that the smart grid will emerge from these breakthroughs. The challenge of creating the smart grid will be in integrating a large scope of new technologies and the FSM system will be a central piece of the future infrastructure.
- **The emergence of open power markets.** Different kinds of market designs have been chosen in Northern America and throughout the world (New York Independent System Operator (NYISO), California Independent System Operator (CAISO), Korean Power Exchange, European power markets...). They are usually open first to large industrial customers and progressively to all customers. The degree of intervention of each stakeholder (customer and producer) depends on local regulation, the possibilities offered by grid automation, and the stakeholder interface with the grid and the market. The market mechanisms, the seam issues between region applying different market rules, or changing their rules is an important issue for the real time function of future grids.

These technological breakthroughs can't be managed and operated by the existing tools and require advanced capability in modelization, real time simulation and predictive capability, that is to say, distribution needs an adaptation of Fast Simulation and Modeling

Those Technological breakthroughs permit distribution grids to have new operation functions that will imply major changes on the way overall power systems are operated.

Those new capabilities include, for example:

- "Self-healing" grid reconfiguration capabilities,
- Reversed power flows,
- Islanding capability,
- Load management services,
- Demand-response,
- Power and VAR Supports from distribution,
- Wide area protection & Control...

Before any software development phase, such a complex and crosscutting project needs a serious effort on requirement design. The requirements of the FSM suite of tools for the overall system must not only be focused on transmission but also and surely consider distribution for the sake of the overall FSM success.

The DFSM Project Tasks and Deliverables

Here is a short description of the Distribution Fast Simulation and Modeling project four main tasks:

- **Task 0: Definition of the Stakeholder Engagement Plan.**
 - Organization and leadership of a distribution specific stakeholder group.
 - Interaction plan with on going CEIDS Projects.

- **Task 1: Distribution FSM High Level Requirements**
 - Technical review of existing simulation methods and tools,
 - Context and visions of the future,
 - Technological survey (present and future). High Level Requirement Document + Vision of the future Distribution System Operator functions

- **Task 2: Engineering Requirement Document for Distribution FSM**
 - Definition of the tool suite
 - Operational requirements document
 - Preparation of a mock-up showing an example of DFSM function

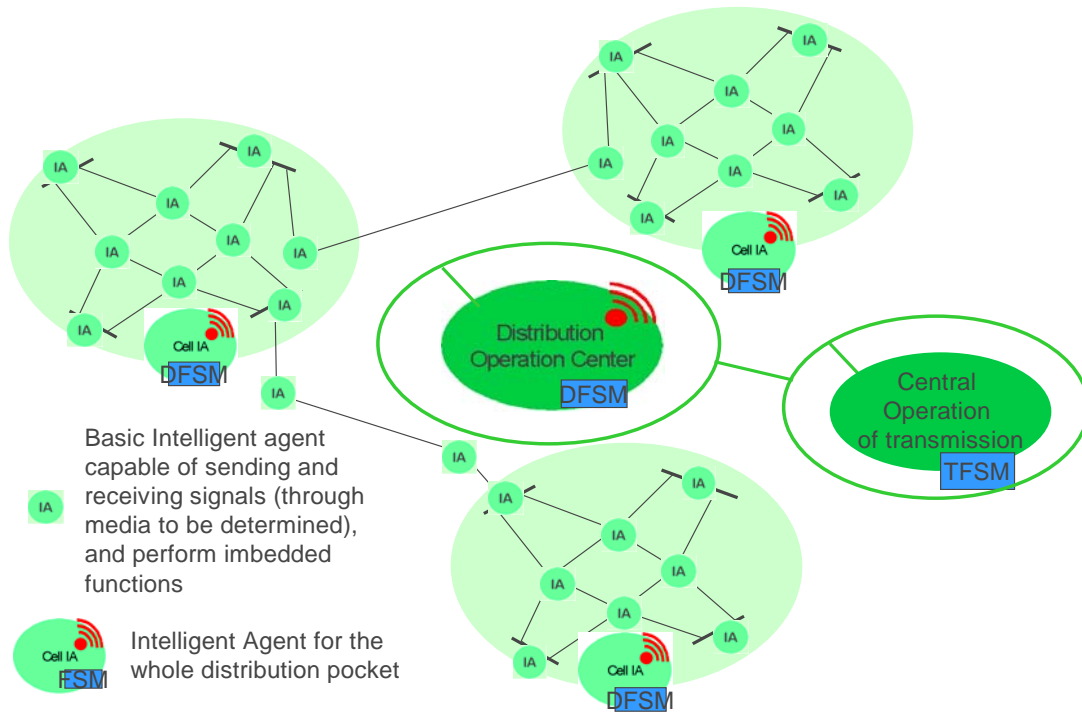
- **Task 3: Contribution to the Computing and Data Architecture Document**

Next step: development of Distribution Fast Simulation and Modeling application

The following phases of FSM will develop the suite of tools. This suite of tool is envisioned as a system that needs to process data from multiple sources (customers, generators, transmission grid, other distribution tools like SCADA, forecasting tools...). The Distribution applications specified in this project will be used at several distribution system levels, at least at the control center and substation.

The possibilities to invite DER and customers to participate in ancillary services, to change the electrical architecture (meshed, radial or loop) or to island an MV cell have strong impacts on the protection scheme, voltage control and power flows. Automation between substations and control centers is needed to accommodate operating the grid to its limits. This has been described in the literature as a MV cell or an adaptable MV micro-grid (see Figure 1). This leads to a multi-layer integration of intelligence each carrying their own functions; sometimes these functions are activated or de-activated.

Vision: The Information and Electrical Infrastructures



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Figure 1: The "Russian Doll" integration of DFSM and TFSM and the MV Cell concept

The DFSM suite of tools consists of three main components (see Figure 1):

- **The Core Grid Simulator** which contains
 - State estimator (in existence today on distribution grids: it filters faulty data and has the ability to solve non-synchronized sensor data issues)
 - Various grid simulation tools (time domain, power flow, optimized power flow, harmonic simulation...),
 - Statistical (probabilistic / predictive) tools to analyze results of thousands of simulations.
- **The Expertise Layer.** It contains all the real time functions that the grid level needs (for instance: protection scheme adaptation, voltage control, grid reconfiguration, dynamic voltage or frequency stability analysis...)
- **The Human Machine Interface.** The challenge for that area is to display in real time adequate information for the operators knowing the increase of complexity and the new constraints imposed by an operation closer to the grid limits.

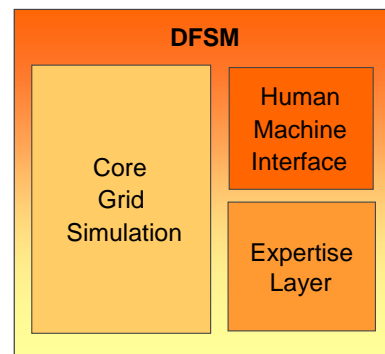


Figure 2: The three DFSM areas