



**The IntelliGridSM Consortium
Research and Development Plan
2005 - 2007**

February 1, 2005

The IntelliGrid Consortium Research and Development Plan

1. Introduction

In 2001, a diverse group of stakeholders—including domestic and international energy companies, federal and state agencies, and technology companies—came together with the goal of transforming today’s electric delivery system into an intelligent electric infrastructure for the future. This unique and far-reaching alliance was a public/private partnership initiated and managed by EPRI. Originally called CEIDS, it is now the IntelliGrid Consortium.

2004 marks the completion of the first multi-year phase of the IntelliGrid program. The focus of this initial phase was on forming the partnership, developing the vision of the power delivery system of the future, launching an integrated portfolio of R&D projects and developing the integrated energy and communication system architecture - IntelliGridSM Architecture (formerly known as IECSA). 2005 marks the beginning of the second phase of the initiative. It seems to be the appropriate time to rename the initiative the IntelliGridSM Consortium to better reflect its content and direction.

The purpose of this edition of 2005 Research and Development Plan is to define the objectives of the upcoming second phase of the program and describe the R&D activities that will be undertaken.

The IntelliGridSM Consortium is a public/private partnership that unites visionary thinkers and leaders to create a win-win situation, integrates and optimizes global research efforts, funds high-impact R&D on enabling technologies and on the integration of technologies to achieve the vision of the power delivery system of the future. The IntelliGridSM Consortium also leads an international effort to disseminate technical conclusions for the benefit of the public by promoting its adoption by others (standard groups, trade associations, etc.). Jointly designing, developing and finally “implementing the change”, the program will be very well positioned to facilitate the transformation of the industry.

The IntelliGridSM Consortium’s Partners laid out the vision for the entire industry emphasizing the need for integration of key stakeholder communities in the entire process to bring the future system to fruition. Vendors will build the components, utilities and energy service companies will integrate them into systems and various organizations will build services around the system. This vision also embraces key technical development and standards communities as important to manifest the overall vision. Figure 1 illustrates the vision of the “partnerships” that have key roles to play in the overall development of the future power delivery system. Starting with the description of new power delivery system’s functionalities as described in the CEIDS 2003 Master Plan, we are going to make sure to provide value to our Partners and to assist them in implementation of various aspects of our program. These efforts will lead to validate the attributes of the system of the future and to fulfill our mission.

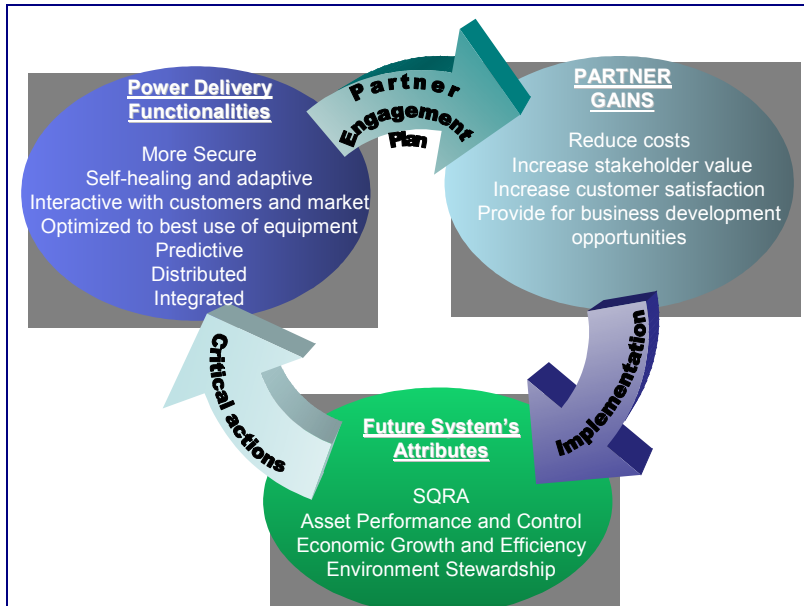


Figure 1 – Transformation of the Power Delivery with participation of the Partners

The IntelliGridSM Consortium’s role is to enable the effective integration of systems that can enable a variety of improved power system operations and consumer services functions. Our program will identify new science and technology developments needed as well as clarify key areas of uncertainty. This vision includes the potential to engage new industries that are not directly part of electric services today. That will be accommodated through jointly developed business cases for the new functionalities of the power delivery system of the future.

It is also important to note that the vision also respects the roles of the manufacturing community and the millions of components that will be required to implement the envisioned future. The vision foresees equipment built by a flourishing vendor community applying open systems based technologies. This vision does not preclude product differentiation but rather embraces the concept of open interfaces to enable interoperability between vendor products and systems.

The new R&D plan takes into consideration the first deliverables from Phase I: delivery and initial application of the IntelliGridSM Architecture and the specification of transmission-related Fast Simulation and Modeling project. Their arrival validates initial assumptions that were made and the overall program direction that has been taken with the guidance from the Partners. The other projects such as DER for advanced distribution automation as well as the Consumer Portal are well on their way to successful delivery of final results.

1.1 The value of the IntelliGridSM Consortium

The IntelliGridSM is actually the power grid of the future. Taken as a whole, reaching this vision will yield unprecedented benefits for the industry -- utility, vendors, consumers and society will all see rewards through increased reliability, reduced O&M costs, avoidance of new capacity, and increased customer satisfaction. Conservative estimates indicate a 5:1 benefit-cost ratio (Ref: Power Delivery System of the Future: A Preliminary Estimate of Costs and Benefits, EPRI, July 2004). Costs incurred to build the IntelliGridSM include purchase of automation equipment, communication networks, power electronic controllers, and simulation tools. The incremental cost over standard T&D upgrades is estimated to be \$165B for the industry over the next 20 years. However, the benefit from improved reliability alone is estimated at \$274B over 20 years (same Ref). However society will also benefit from deferred generation and capital investment, higher security, both physical and cyber, improved power quality and reduction in environmental impact.

The IntelliGridSM Consortium was created by EPRI to help the industry pave the way to the power system of the future. Such an evolution requires a resistance to the lure of easier short-term solutions made with a “silo” mentality – one without regards to the needs of other parts of the grid. The process is the key to our success. Success requires adoption by the industry. Adoption requires buy-in by industry leaders. Buy-in requires active participation by leaders at each step along the way. EPRI’s Consortium is defined by that process. It will ensure that the IntelliGrid Architecture is ultimately embraced by the utility industry and that, in turn, the industry is ready with products and tools to serve it.

The specific value of IntelliGridSM can also be assessed from the perspective of:

- Business development opportunity
- Enhanced customer satisfaction
- Increased shareholders value
- Regulatory compliance

2. The Vision, Mission and Strategy of IntelliGridSM

The Vision, Mission and Strategy define what IntelliGridSM is, what it does and how it does it, now and in the near future.

2.1 Vision

The Partners of the IntelliGridSM Consortium have collaboratively developed a vision for the power delivery system of the future. Its spirit and intention has remained unchanged since the start of the initiative. It is:

A new electric power delivery infrastructure that integrates advances in communications, computing, and electronics to meet the energy needs of the future.

The new intelligent electric delivery infrastructure will offer unprecedented flexibility and functionality; heightened levels of power security, quality, reliability, and availability; enhanced customer satisfaction and choice; and expansive opportunities for economic and business development. The power delivery system of the future will be integrated, self-healing, and electronically controlled—offering extraordinary resiliency and responsiveness.

Achieving this vision ultimately depends upon building strong technical relationships between industry participants including new types and levels of functionality into the power system. These needed capabilities will be 'enabled' in the broadest sense by several breakthrough innovations, including, but not limited to, the following:

- Integrating communications to create a dynamic, interactive power system as a new infrastructure for real-time information and power exchange.
- Improving methods for automating the distribution system to meet increased demands on for managing reliability and meeting changing customer needs.
- Digitally controlling the power delivery network by replacing today's relatively slow electro-mechanical switching with power electronic controls.
- Enabling the consumer to interact more dynamically with the electric energy enterprise of the future and providing more options for consumers and service providers alike.
- Integrating distributed energy resources as power system assets.
- Accelerating end-use efficiency through digital technology advances.
- Linking information technology with energy delivery. The concept of the smart-power delivery system includes automated capabilities to recognize problems, find solutions, and optimize the performance of the system.

The societal benefits of transforming the electricity/information infrastructure into the IntelliGrid include:

- Enabling significantly increased productivity and GDP growth rates,
- Substantially improving energy efficiency,
- Accelerating the rate of reduction in carbon emissions,
- Improving the security of the power system,
- Achieving greater electricity system functionality and consumer value, all while
- Reducing the total costs of infrastructure system upgrades and expansion.

The vision of the power delivery system of the future has been created in a joint effort with the IntelliGridSM consortium's Partners, based on the long-term vision outlined in the 2004 EPRI Electric Technology Roadmap and the U.S. Department of Energy (DOE) National Electric System Vision Document: Grid 2030. The vision is intended to be shared not only among our partners but with the entire industry and public agencies.

2.2 Mission

The program Mission has been refined over the three years that our consortium has been operating. The emphasis of the initial Mission was to develop the science and technology that would enable the envisioned power delivery system. The refined Mission is:

The IntelliGridSM Consortium will enable the development, integration and application of technologies to facilitate the transformation of the electric infrastructure to cost-effectively provide secure, high quality, reliable electricity products and services.

In the 2003 CEIDS Master Plan, the IntelliGridSM Consortium Partners and staff determined the key attributes of the power delivery system of the future - 1) security, quality, reliability, and availability; 2) economic efficiency and growth; 3) asset performance and control; and 4) environmental stewardship - and identified 19 critical gaps that are lacking in the existing electric power system that must be addressed in order to achieve these attributes. Seven of these gaps have emerged to form critical action items. These action items are shown in Table 1.

CRITICAL Action Items
1. Create communications infrastructure/open architecture interface
2. Develop fast and accurate computational methods to model and analyze the electric infrastructure
3. Characterize security, quality, reliability, and availability requirements of the infrastructure
4. Develop and implement cost-effective technologies to support automation, real-time monitoring, and control of the power delivery system
5. Enable distributed energy resources (DER) to play a role in energy markets
6. Develop effective forecasting tools for supply, load, and market data
7. Create high-value, cost-effective products and services to help consumers and companies control, optimize, and direct energy use in an environmentally acceptable way

Table 1 - Critical Action Item for Implementing the Vision – From the 2003 CEIDS Master Plan

In evaluating how to address these critical action items, certain technologies emerge again and again, and can be seen as foundational. Two of these *enabling* technologies are communications and distributed computing infrastructure. Enabling technologies are those that fundamentally change industry, business, or quality of life – often by making

other technology breakthroughs possible. In modern times, the most important enabling technology undoubtedly has been electrification. Widespread electrification has enabled the development of countless other breakthrough technologies.

Robust communication and distributed computing infrastructures will be needed to enable the new functionalities of the new electric power delivery of the future. Much of the base technology needed to create these infrastructures already exists. What is missing are the strategies, methods and mature open standards necessary to effectively integrate existing and emerging technologies to create the new functionalities demanded of the future energy services enterprise.

2.3 Strategy

The following strategy will be used to accomplish the programs Mission:

- **Creation of a shared Vision of the Future Power Delivery and Energy Services System.** The concept of the intelligent power delivery system has been initiated under CEIDS and will continue to evolve as work by IntelliGridSM Consortium and other organizations progresses.
- **Development of Open Platforms Around Critical Integrating Technologies.** A significant amount of the science and technology needed to create the new power delivery system already exists. What is missing is the integration of technologies to create the new functionalities. These open platforms will enable others to develop and deploy technology effectively and economically. The platforms have focused on two key areas: communications and computation.
- **Clarify Key Areas of Uncertainty.** Some aspects of the new electric delivery system are less clear than others. For example, there is a great deal of uncertainty about how distributed generation will be used in the operation of the power system. There is also uncertainty about the appropriate levels of reliability and quality needed by consumers in the future. Our program will conduct studies around these key areas of uncertainty to provide clarity and further refine the concepts described in the vision..
- **Develop Business Cases for the New Functionalities.** These studies will analyze the societal and business benefits that are derived from the new intelligent electric power delivery system. These studies will also help justify investments in creating the new power delivery system.
- **Identify New Science and Technology Developments Needed for the New Power Delivery System.** A guiding principle within the IntelliGridSM Consortium is to leverage existing and emerging technology advances made by others. When a technology gap is identified, our program will fund the necessary development effort.

- **Broadly Disseminate the Results of IntelliGridSM Consortium Work and Coordinate Activities with Other R&D Organizations.** The IntelliGridSM Consortium program will contribute the results of its work to other organizations and will track relevant activities by others.
- **Contribute to and Influence Relevant Standards Development Efforts.** Standards for implementing technology are critical for efficiently and cost effectively creating the new intelligent electric power delivery.
- **Inform Regulators and Policy Makers** of the advantages of and the requirements for the new power delivery system. Since many of the benefits of this infrastructure are societal, rather than directly benefiting the organization investing in the electric infrastructure, cost recovery methods will need to be developed and implemented.
- **Demonstrate Critical Aspects Of The New Functionalities That Make Up The Vision Of The New Power Delivery System.** Demonstrations are necessary for validating the technical feasibility and value proposition of the new functionalities of the intelligent electric delivery system of the future.
- **Assist Partners With Implementing IntelliGridSM Results.** The staff and its contractors will work with the Partners to implement the results of IntelliGridSM work.

2.4 Program Building Process

The 2003 CEIDS Master Plan identified – based on feedback from different stakeholder groups – the following key attributes of the power delivery system of the future are 1) security, quality, reliability, and availability; 2) economic efficiency and growth; 3) asset performance and control; and 4) environmental stewardship.

EPRI's Electricity Technology Roadmap (version 2003) reinforces these findings as described in Limiting Challenges:

#1: Transmission Capacity, Control, and Stability

#2: Infrastructure to Power a Digital Society

#3: Robustness and Security of Electricity Infrastructure

In our assessment and development of a research agenda, we have taken into consideration the U.S. Department of Energy (DOE) National Electric System Vision Document – Grid 2030, as well as EPRI-developed Electricity Sector Framework for the Future. Based on these documents and our own interaction with those who participated in stakeholder meetings associated with different IntelliGridSM Consortium projects, we have concluded that achieving the SQRA (security, quality, reliability and availability) and Enhanced Asset Performance and Control attributes should be our most immediate short-term goals. Thus it is reflected that way on the graph below. It also seems to us that reaching the environmental benefits will take the most of the time.

The rectangular boxes are describing critical action items that must happen in order to reach the final attribute. They are also going to serve as lead statements for new project definitions.

As described in the 2003 Master Plan, gaps analysis and critical actions have been identified to decide the future projects. Appendix B shows the extent to which these attributes are addressed by these projects.

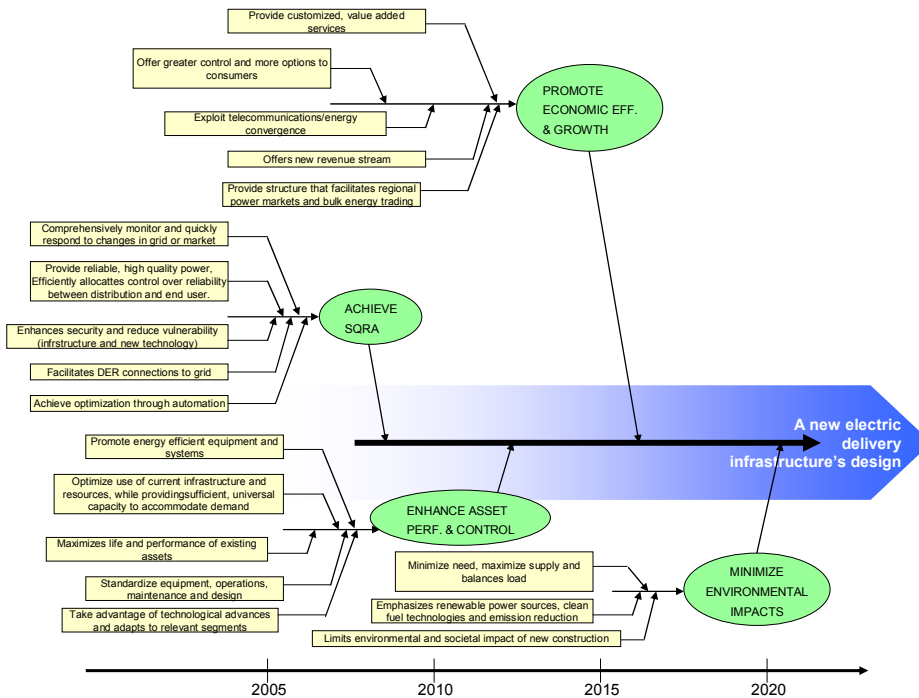


Figure 2 – Roadmap to key four attributes of the system of the future

Scoping studies play a pivotal role along the IntelliGridSM technology development path. Experience has shown that these studies can identify issues requiring further evaluation, improve the success of R&D and demonstration activities, and reduce uncertainties when assessing advanced technologies. Short-cycled and inexpensive, scoping studies provide valuable decision-making information on technical solutions being considered for funding.

Technologies will be identified for their contribution to the overall vision of the system. The IntelliGridSM Consortium-led industry mission is to provide integration methods and guides to enable the development of new and innovative functionalities. Sensors and new power electronics have already been identified as enabling technologies. Initial findings of phase 1 as well as new technologies will be developed in phase 2 to deploy them in the

three pilot projects. For example, peer-to-peer communication with innovative and low-costs sensors technologies, power electronics connected to Distributed Energy Resources could then be integrated in first industrial prototype of Portal in the Demand-Response program in California.

We also realize that there are a growing number of companies interested in playing on the “digital field”. Our initial screening has identified almost 100 companies worldwide (most of them residing in the USA) claiming research in the area of digital technology. We are eager to coordinate our effort with key participants to avoid unnecessary duplications as well as to maximize our joint resources. Our program is developing closer relationships with GridWise and the National Laboratories. The most recent efforts to create similar consortium by Navigant Consulting is of interest to us from the coordination and program development point of view.

3. Phases of the IntelliGridSM Program

The vision for the power delivery system of the future will not happen overnight. The timeframe to completely implement the IntelliGrid vision is estimated to be 2050. Because of the long-term, strategic nature of the program, IntelliGridSM Consortium partners are asked to commit their participation and funding for a four-year term. The IntelliGridSM Consortium program is envisioned as a series of multi-year phases. Figure 3 illustrates this approach. Each phase of the program will have well-defined goals.

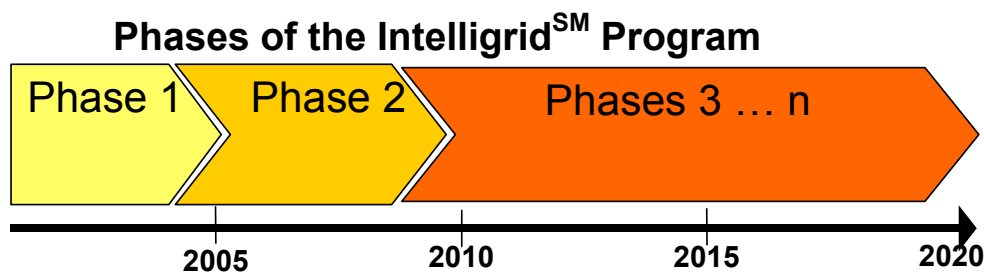


Figure 3 – Multi-Phase Approach for IntelliGridSM Consortium's Program

3.1 Objectives of the Phase 1:

The first phase was focused on organization, definition and launch. That is:

Organization of:

- The Steering Committee
- The Public Sector Advisory Committee
- The Digital Technology Advisory Council
- Project Advisory Groups

Definition of:

- The program Vision, Mission and Strategy to determine what research activity will be funded in its budget.
- The vision of the power system of the future (IntelliGridSM Architecture)
- The technologies needed to achieve the IntelliGridSM concept

Launch of:

- A set of interrelated, high-impact R&D projects:
 - Integrated Energy and Communications System Architecture (IECSA) (the project has developed methods, tools and recommendations to help utilities design communication infrastructure in an interoperable and flexible way, was delivered by fall 2004, and will be followed by a dissemination effort). The registered name of the project deliverable is IntelliGridSM Architecture.
 - Communications Architecture for Distributed Energy Resources in Advanced Distribution Automation (DER/ADA) (the project has developed communication “object models” for fuel cell and reciprocating engine and will have them adopted as international standard in 2007)
 - Fast Simulation and Modeling (FSM) (the first phase of the project will develop functional specifications and a computational architecture for both transmission and distribution.)
 - Consumer Portal - The Consumer Portal will establish two-way exchanges of communication between the consumer and the network. The Consumer Portal will enable the Consumer as an actor in the market and will allow the development of new services. (A scoping study, technology analyses, business case and project plan have been completed.)
- Several scoping studies, technology assessments and business cases
 - Power electronics scoping study, business case and technology assessment
 - Inventory of Utility Communications Technology
 - Infrastructure Quality and Reliability scoping study and technology assessment
 - Market forecasting scoping study
 - Sensors for Integrated Monitoring and diagnostics scoping study

3.2 Major Accomplishments and Milestones Reached During Phase 1 of the IntelliGrid Consortium Program:

Creation of the Vision of the Power Delivery System of the Future

- Developed a high level vision for the power delivery system of the future – *CEIDS Master Plan, July 2003*
- Developed a set of functional requirements for the power delivery system of the future – *Integrated Energy and Communications System Architecture Vol. II, Functional Requirements, August 2004*

Development of Open Platforms Around Critical Integrating Technologies

- Communications
 - Developed a set of requirements for the communications infrastructure needed to support the for the power delivery system of the future – *Integrated Energy and Communications System Architecture Vol. II, Functional Requirements, August 2004*
 - Developed a methodology and tools for utilities to use when designing communications systems – *Integrated Energy and Communications System Architecture Vol. I, User Guidelines and Recommendations, August 2004*
 - Developed recommendations for standards and technologies for utilities to use when designing and installing communications systems– *Integrated Energy and Communications System Architecture Vol. I, User Guidelines and Recommendations, August 2004*
 - Developed draft communications object models for fuel cells and reciprocating engines - *DER/ADA Object Model Report Final Draft, December 2003*
 - Initiated work to define the requirements for a communications portal that will enable consumers to participate in energy markets and to receive energy-related services.
 - State of the art and trends of communications in utilities systems *Inventory of Utility Communications, March 2004*
- Computing
 - Initiated work to develop the distributed computing architecture needed to support the IntelliGrid (*to be completed in November 2004*)

Clarify Key Areas of Uncertainty

- Developed a methodology for determining the appropriate level of quality and reliability for energy consumer – *Analysis of Extremely Reliable Power Delivery Systems – November 2002*
- Published a study that determines the cost of power outages and disturbances in the U.S. – *The Cost of Power Disturbances to Industrial and Digital Technology Companies, July 2001*
- Published a study on how distributed generation can be used in the operations of power systems under normal operating conditions – *Studies of Distribution Operations to Aid in Determining Object Models for Distributed Energy Resources, December 2003*
- Initiated a study on how distributed generation can be used in the operations of power systems under emergency conditions (*to be completed in December 2004*)

Development of Business Cases for the New Functionalities of the Power Delivery System of the Future

- Published business case analysis for power electronic-based power flow controllers - *Business Case Assessment for power electronic-based power flow controllers, December 2003*

- Published business case analysis for a consumer communications portal – *Business Case Assessment for Energy Service Portals, March 2004*

Identifying New Science and Technology Developments Needed for the Power Delivery System of the Future

- Published a technology analysis with a recommended approach for developing a consumer communications portal – *Energy Service Portal Development – Assessment and Recommendations, December 2003.*
- Published a technology analysis that identified key technology development activities needed for power electronic-based power flow controllers – *Advanced Power Electronics Technology Assessment – December 2003*

Influencing and Contributing to Relevant Standards Development Efforts

- Created IEC and IEEE working groups on communication, command and control of distributed energy resources

Demonstrations of Critical Aspects of the New Functionalities That Make Up the Power Delivery System of the Future

- Initiated several demonstration projects with Consortium partners implementing the methodology, tools and recommendations for installing communications systems

4. The Second Phase of the Program:

4.1 Objectives of the second phase

The first phase of the program created a vision of the power delivery system of the future for the industry, and launched four R&D projects that focus on critical enabling technologies. The second phase will continue the R&D efforts started in phase one and will launch new projects. The second phase will also address implementation of technologies to create new functionalities within the power delivery system. Figure 4 shows the activities of phase two. These pilot implementations will bring the industry closer to the vision of the future power delivery system.

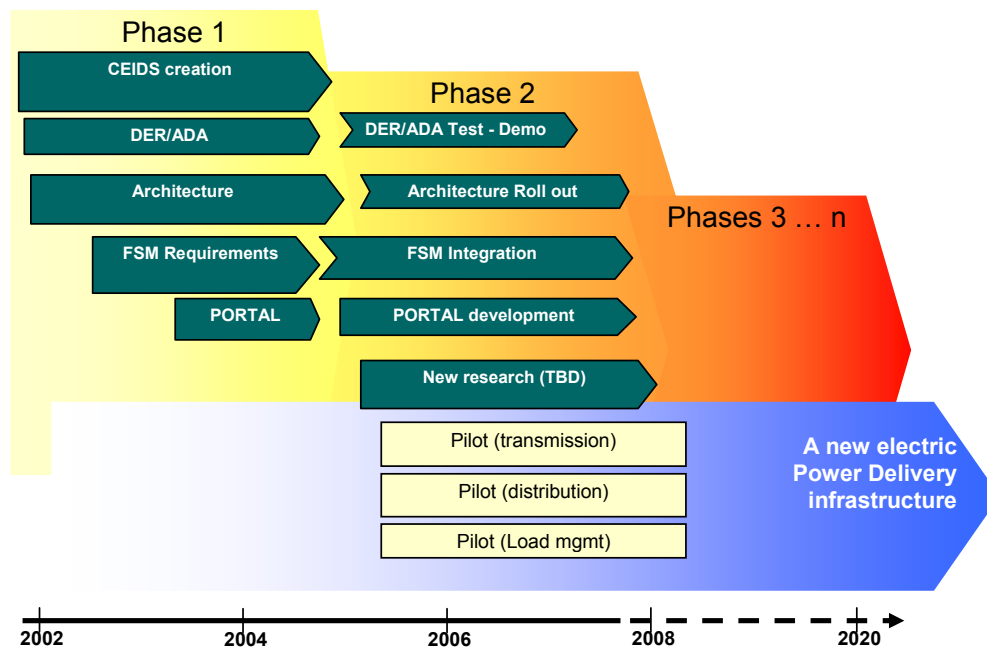


Figure 4 – Phases of the IntelliGridSM Consortium program

Elements of Phase 2 will include:

1. The IntelliGridSM Consortium will integrate the results of the projects with existing technologies and technologies being developed by others to launch pilot efforts that will demonstrate new functionalities of the power delivery infrastructure. These pilot programs will provide focus for the R&D program, raise visibility to enable better coordination with peer projects and demonstrate that the electric infrastructure is on the pathway towards being transformed into the power delivery system of the future.
2. Build upon the technical achievements of the first phase. For example, functional requirements for FSM were developed in phase one. Phase 2 will develop the FSM platform based on those requirements.
3. New research projects may be launched in phase 2 based on the results of scoping studies done in phase 1, such as Sensors or Cybersecurity.

More details on each program are provided in Appendix A.

(Note: This is what the IntelliGridSM Consortium targets to achieve. The reality of business and resources will be a determinant factor. The Business Plan and the Marketing Plan will explain in detail the resources and budget we need to achieve this goal, and how we plan to proceed to make it a reality)

4.2 Planned Pilot Areas

Market Response and Distribution

The IntelliGrid envisions a communications network that will link consumers to the electricity marketplace on a “24/7” basis, with a consumer communications portal enabling interactive, two-way exchanges—including price signals that flow from service providers to consumers and their array of “smart” appliances and equipment (including self-generation), and consumption patterns and other information that stream back to service providers and others.

Several utilities have programs to replace their existing electric meters with advanced meters that have two-way communications or pilot projects to demonstrate the value and technical feasibility of demand response. In parallel with these efforts, several regulatory bodies are pushing for the implementation of demand response programs and the creation of the communications infrastructure to support these programs.

IntelliGrid pilot projects in the consumer/market or distribution area could leverage an AMR or demand response system being installed by an IntelliGrid Partner to allow us to demonstrate the results coming out of the IntelliGrid Architecture and Consumer Portal projects. A pilot could demonstrate one or more of the following functionalities:

- Ability to give to the customer more information about his consumption, tariff, etc. (example : monthly billing, current status, advanced energy display)
- Simultaneous access to data (load profile) by different parties (customer, energy supplier, distribution system operator)
- Advanced pricing and real time pricing
- Remote connect, disconnect (control of maximum power allowed to the customer)
- Customer change of energy supplier (different retailers, selection of green power), of contract parameters
- Voluntary load reduction
- Emergency services using Demand Response as a virtual reserve capacity
- Import/export capabilities allowing customers to capitalize their local energy generation (green certificates)
- Outage detection and management
- Tamper detection, measurement of technical losses, theft
- Power quality monitoring
- Customer energy management determines optimal mix of current load, deferred load and distributed generation

A pilot should also illustrate important requirements, such as:

- new communication technologies that can support open two-way communication protocols (e.g. internet protocol)
- security issues – illustrate implementation of important security concepts using appropriate communication technologies and protocols
- data management issues demonstrating scalability (must be able to support very large and widespread deployment)
- interoperable aspects (as opposed to proprietary systems)
- specific applications that take advantage of the interoperable characteristics
- interfaces between the consumer portal and important consumer devices (e.g. thermostat, controllable loads)
- interfaces between the consumer portal and meters
- cost/benefit assessments creating a business case for consumer portal technology and applications
- systems integration of consumer portal functions (linking together different systems using interoperable design to achieve increased value) such as consumer portal interface to OMS for outage detection and notification
- new applications enabled by the consumer portal capabilities, such as advanced distribution operations or better use of distributed generation
- user interface functionality providing a new level of information for decision making to both the consumer and the utility
- legacy support demonstrating the ability to build on and interface with existing systems, such as AMR systems.

Transmission

A transmission pilot would leverage the work that has been done and continues being done in the WSCC and the Eastern Interconnection to develop phasor measurement networks. A pilot project would demonstrate the functionality of wide-area measurement and control. Contributions are already being made to the Eastern Interconnection Phasor Project (being sponsored by DOE) to apply the results of the IntelliGrid Architecture. In the future, the results of the Fast Simulation and Modeling project could be applied.

5. IntelliGridSM R&D Projects

The proposed R&D plan for IntelliGridSM is comprised of on-going work that was initiated in phase 1 and several new projects. The new projects have roots to scoping studies and technology assessments that were done in phase 1.

The projects that will be undertaken in the new phase are:

- IntelliGrid Architecture
- Communications Architecture for Distributed Energy Resources in Advanced Distribution Automation (DER/ADA)
- Fast Simulation and Modeling (FSM)
- Consumer Portal
- Options for new R&D such as sensor development and cybersecurity.
-

Descriptions, schedules and deliverables for these projects are provided in Appendix A.

IntelliGridSM will pursue work in Power Electronics mainly based on the proposal E2I/EPRI submitted to DOE in June 2004, as described in Appendix A.

It is expected that new scoping studies and technology assessments will be done in preparation for future program phases. Scoping studies may explore the following areas:

- energy storage
- intelligent agents
- advanced fault location and detection
- energy efficiency

The Steering Committee will approve the areas that the new scoping studies will cover.

6. Conclusion

In the three years since its inception, the initiative has grown into a very successful and significant program. With the current 14 founders, the IntelliGridSM Consortium has established an integrated R&D portfolio of high-impact projects that provide the technology foundation for the new intelligent electric power delivery of the future.

The intention of the IntelliGridSM Consortium is to do more than invent the next great thing. It is to create business processes that will make the Partners more competitive and innovative. With this in mind, the IntelliGridSM Consortium is eyeing the long-term horizon in year 2020, while targeting major research breakthroughs and key pilot projects to lead energy sector toward these advances.

Appendix A

IntelliGridSM Projects

IntelliGridSM Architecture

Overview

The goal for EPRI's IntelliGrid Architecture^(*) project (previously name IECSA) is to assemble an integrated energy and communications system architecture to support a self-healing grid. The architecture will provide the "building codes" for the data communications networks and intelligent equipment necessary to accomplish the vision of the IntelliGrid. The project was driven by industry need for an overall approach to the development and integration of advanced automation systems. The IntelliGrid Architecture also represents a desire for a clear expression of a guiding paradigm for distributed computing and advanced communications infrastructures that are robust in technical approach.

EPRI's roles in this program are a *facilitator*, involving all stakeholders (utilities, manufacturers, regulators, standards bodies), an *integrator*, assuring all aspects of the grid are addressed, and *executer of R&D* necessary to lay the foundation for utilities to adopt the IntelliGrid concept. The program's charter is to build on past research, development and standards work. In 2004, the project provided an initial framework and pathway for industry-level integration across a wide diversity of automation topics. The requirements investigated by the project have served to frame the architecture through a few of the most challenging applications.

Objectives of IntelliGrid Architecture for 2005

- I. **Education and Tech Transfer** – educate and obtain feedback from all stakeholders
- II. **Field Demonstration and Testing** – Identify and develop projects at utility sites that showcase the IntelliGrid concept, results and methods
- III. **Collaboration** with Key Industry Projects and Initiatives
- IV. **Perform technical work** necessary to complete key standards and integration methods of Ref 1 (see below in Accomplishments to Date).

Approach to Achieve Objectives

- I. Education and tech transfer includes tasks such as holding training workshops at utilities, publishing joint articles, speaking at industry events, developing tutorial materials, improving the usefulness of the IntelliGrid website and industry model, and providing examples of how to apply the results to specific industry applications. Feedback from first users of the architecture will be assembled and incorporated into the results. Integration with DoD and DoE work will continue.

- II. History has shown that the best technology and knowledge transfer is through field application at a host company. We will work with our utility and manufacturer partners to identify and plan projects that showcase one or more of the IntelliGrid Architecture recommendations. Initial engagements with utilities will be two-pronged: gaining corporate commitment to becoming an IntelliGrid showcase, and holding workshops to assist them in identifying candidate projects within their organization. This is followed by the development of a plan with key personnel from interested participating companies. Projects will meet the immediate needs of the host company as well as contribute to the resolution of one or more key technical issues remaining within the architecture. Examples of candidate projects may range from enterprise-wide integration development to a narrowly scoped automation project.

- III. This task includes coordination with and contribution to key industry projects and initiatives that can benefit from the use of IntelliGrid methods and can promote the adoption of IntelliGrid. Industry projects in this category include the Eastern Interconnect Phasor Project and the California Demand Response and Open Advanced Metering Infrastructure initiatives. This task will also include technical transfer and collaboration with Department of Defense and Department of Energy initiatives currently underway. Initiatives targeted for collaboration are the industry standards bodies such as IEC TC-57 Working Groups and the Gridwise Architecture Board.

- IV. Follow-on development of the architecture recommended in Ref (1) below will be defined by known gaps that exist, feedback from first users and recommendations from vendors and IT companies and std bodies. While some of the gaps will be addressed by partner demonstration projects, some technical issues are expected to remain.

Dates	Deliverables
2 nd quarter 2005	Issue Version 2.0 of UML design tool
4 th quarter 2005	Identify, define and begin 3 field demonstrations by end of 2005
4 th quarter 2005	Conduct training workshops at each utility partner site
4 th quarter 2005	Update and maintain Architecture website
4 th quarter 2005	Launch IntelliGrid subcommittee within UCA Int'l Users Group
4 th quarter 2006	IntelliGrid SM Architecture published through IEC

Key Accomplishments To Date From This Committee

Published final report recommending architecture for the IntelliGrid– Aug 2004

Volume I: IntelliGrid User Guidelines and Recommendations

Volume II: IntelliGrid Functional Requirements

Volume III: IntelliGrid Model and Design Tool

Volume IV: IntelliGrid Technical Analysis

Developed interactive website

Performed 7 training workshops at partner utilities

IntelliGrid Architecture used by California Energy Commission to develop reference design for demand response.

Published a study that determines the cost of power outages and disturbances in the U.S. – *The Cost of Power Disturbances to Industrial and Digital Technology Companies, July 2001*

Consumer Portal

Overview

Industry economics have resurfaced the need for a Consumer Portal that provides a communications gateway between energy providers and consumers for energy service functions. The functions enabled by the consumer portal will help the utilities reduce costs through more efficient operation, secure revenue from additional services and defer costs to accommodate load growth. Examples of Portal applications include AMR, demand response, real time pricing, theft detection, remote disconnect, energy management, DER interface and control, and outage detection. The Portal will be designed to accommodate the numerous protocols and standards that are in place today serving consumers for non-energy-related services. The wake of failed portal pilot projects left by this industry demonstrates the need for a standardized, open architecture and gateway to allow technology providers to develop equipment and applications that meet the evolving needs of utilities.

Deleted: Industry developments and previous work have demonstrated the need

Objectives of the Consumer Portal project for 2005

- I. **Create functional specifications and reference design** for the Consumer Portal
- II. **Collaborate** with industry consortia and relevant standards bodies
- III. **Demonstrate through Field Pilots** – identify and develop a portal at a utility site to demonstrate open architecture and compatibility with manufacturer’s products.
- IV. **Leverage current standard bodies** to get object models standardization

Approach to Reach Objectives

- I. Our work continues to incorporate the needs of our member utilities and the input from equipment manufacturers, system integrators and IT experts to assemble the specifications for each Consumer Portal function. In cases where market opportunity is driving the development faster, such as demand response in California, we will work with manufacturers to build from that specific application a more detailed reference design for the Portal. While the IntelliGrid Architecture represents the “building code”, the reference design will represent the “blueprint.”
- II. At this point in the Portal development, participation from all stakeholders is critical. Our utility partners supply the vision for future functionalities, our manufacturing partners provide the direction for compatibility and new technologies, and the regulators serve as the gateway to many near-term market opportunities. The Consumer Portal Advisory Group must encourage and embrace all facets to ensure adoption by the industry.
- III. History has shown that the best technology and knowledge transfer is through field application at a host company. We will work with our utility and manufacturer partners to identify and plan a project that showcases one or more

unique features of IntelliGrid’s Consumer Portal. The process will start with coordination between manufacturers and EPRI technical staff to define the profile of an acceptable demonstration. Initial engagements with utilities will be two-pronged: gaining corporate commitment to being an IntelliGrid showcase, and workshops to assist them in defining the project. This is followed by the development of a plan with key personnel from interested participating companies.

Date	Deliverables
2 nd quarter 2005	Assemble broad stakeholders group
2 nd quarter 2005	Create set of functional requirements
4 th quarter 2005	High level requirements of Consumer Portal
3 rd quarter 2005	Develop Use Cases for five high priority applications
4 th quarter 2005	Create reference design to support Consumer Portal’s demand response application
End of 2005	Identify, define and begin field demo
4 th quarter 2006	Create, reference design for a large set of functions
2 nd quarter 2007	Detailed requirements and object models for large set of functions from 2006
4 th quarter 2007	Get adoption of object models from International Standards Community

Accomplishments To Date From This Committee

Assessed state-of-the-art trends in communications used by utilities systems *Inventory of Utility Communications, March 2004*

Published business case analysis for a consumer communications portal – *Business Case Assessment for Energy Service Portals, March 2004*

Published a technology analysis with a recommended approach for developing a consumer communications portal – *Energy Service Portal Development – Assessment and Recommendations, December 2003.*

IntelliGrid Architecture used by California Energy Commission to create Portal solution to demand response.

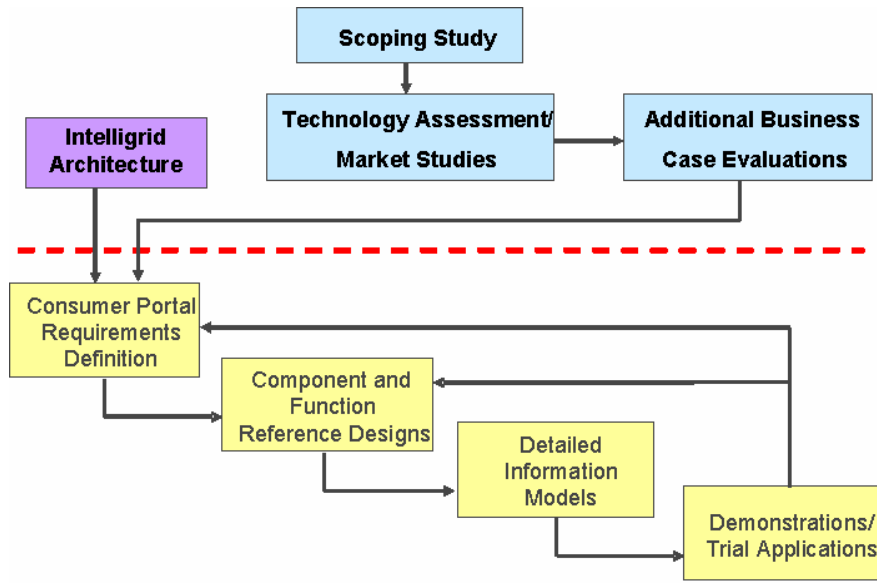


Figure A-1. IntelliGrid Consumer Portal Project Diagram

Fast Simulation and Modeling (FSM)

Overview

The Fast Simulation & Modeling (FSM) project is designed to provide the mathematical underpinning and look-ahead capability for a self-healing grid – one capable of automatically anticipating and responding to power system disturbances, while continually optimizing its own performance. It will provide a tool to aid in decision-making by permitting an operator to get an accurate state estimation of the grid in real time. This will allow the operator to optimize grid operations as well as predict grid behavior based upon historical and real time data.

The FSM project will develop an open platform for software. The steps follow the normal Requirements-Design-Development-Testing phases. EPRI's initial contribution occurs in the Requirements phase where we can leverage our utility advisors to create a robust set of functional requirements to support the follow-on design and development work. Subsequent work to develop algorithms and prototypes will benefit from the strength of the requirements phase.

During the requirement definition phase, the FSM project has been separated into two concurrent, connected activities: D-FSM, which focuses on distribution system operations and T-FSM, which concentrates on transmission system operations. The results from the two activities will be blended and harmonized during the second quarter.

To date, T-FSM has developed detailed functional requirements for one specific application -- Volt/VAr Management of transmission Power Systems. It applied to a computing architecture based on distributed intelligent agents.

Transmission Fast Simulation and Modeling (T-FSM)

Objectives of the T-FSM project for 2005:

- I. Complete a set of Functional Requirements
- II. Validate requirements through case studies done at member utilities
- III. Synchronize with the requirements developed in T-FSM and ensure compatibility with the IntelliGrid Architecture.
- IV. Collaborate with utilities, manufacturers and academia for design, development and testing to be completed in later phases
- V. Develop an FSM prototype of the Volt/VAr Management function to demonstrate the concept.

Approach to Achieve Objectives:

- I. Using input from utility partners, we can assemble and validate the functional requirements needed for T-FSM. These requirements can be refined by modeling the computational architecture system in simple use cases and will be reinforced through continuous iteration during the design stage. UML models of the identified functions will be developed.
- II. EPRI can leverage its relationship with its member utilities to develop a quantitative analysis of tangible benefits by applying the requirements to actual case studies.
- III. Although many tasks are done separately for Transmission and Distribution, the requirements must eventually be combined using the IntelliGrid architecture framework. This allows the future design and development of each system to accommodate functions that cross the boundaries between the two physical systems.
- IV. The eventual design of the FSM will require continual iteration and validation back to the Functional Requirements. EPRI's role in these later phases includes keeping all contributors focused on utility needs. Stakeholder meetings will be held during 2005 to present results and receive critical review.
- V. An FSM prototype will be developed that will be composed of software modules that would represent the layers of the distributed intelligent agents in the FSM hierarchical distributed computing architecture envisioned in T-FSM. Each module would consist of an algorithm that would operate the Volt/VAr management calculation by reusing as far as possible existing software (for power flows, or contingencies analysis, etc...) and interface with a standardized database. These modules would be integrated to an electric power system simulator and a CIM database of a representative power system, and would simulate electric grid events and how the FSM software reacts. It could eventually be linked to a real model of a Grid, and be operated by operators.

Distribution Fast Simulation and Modeling (D-FSM)

Objectives of the D-FSM project for 2005:

- I. Define the functional requirements for the distribution system of the future
- II. Synchronize with the requirements developed in T-FSM and ensure compatibility with the IntelliGrid Architecture.
- III. Collaborate with utilities, manufacturers and academia for design, development

and testing to be completed in later phases

- IV. Develop an FSM prototype of the Volt/VAr Management function to demonstrate the concept.

Approach:

- I. Using input from utility partners, we can assemble and validate the functional requirements needed for D-FSM. These requirements can be refined by modeling the computational architecture system in simple use cases and will be reinforced through continuous iteration during the design stage. UML models of the identified functions will be developed.
- II. Functional Requirements will be compliant with the IntelliGrid Architecture and the T-FSM computational architecture. Although many tasks are done separately for Transmission and Distribution, the requirements must eventually be combined using the IntelliGrid architecture framework. This allows the future design and development of each system to accommodate functions that cross the boundaries between the two physical systems. Also, maintaining a close relationship between the representative group of stakeholders and coordinating with other IntelliGridSM projects including T-FSM and IntelliGrid Architecture will assure the solution meets utility needs.
- III. The eventual design of the FSM will require continual iteration and validation back to the Functional Requirements. EPRI's role in these later phases includes keeping all contributors focused on utility needs. Stakeholder meetings will be held during 2005 to present results and receive critical review.
- IV. An FSM prototype will be developed that will be composed of software modules that would represent the layers of the distributed intelligent agents in the FSM hierarchical distributed computing architecture envisioned in T-FSM. Each module would consist of an algorithm that would operate the Volt/VAr management calculation by reusing as far as possible existing software (for power flows, or contingencies analysis, etc...) and interface with a standardized database. These modules would be integrated to an electric power system simulator and a CIM database of a representative power system, and would simulate electric grid events and how the FSM software reacts. It could eventually be linked to a real model of a Grid, and be operated by operators.

Date	Deliverables
1 st quarter 2005	T-FSM Functional requirements and computational architecture document
1 st quarter 2005	D-FSM Detailed functional requirements document (UML Model and Use Cases)
4 th quarter 2005	Integrated functional and IT requirements document for FSM
4 th quarter 2005	T-FSM Value Assessment Case Study
4 th quarter 2005	Computer based mock-up

1st quarter 2007	Infrastructure requirements document
4 th quarter 2007	Detailed FSM hardware specifications
1 st quarter 2008	Design document for selected functions and application prototypes
4 th quarter 2008	Innovative equipment compliant to FSM software
4 th quarter 2009	Commercial FSM Intelligent Agent software released
1 st quarter 2010	First site test of FSM

Key Accomplishments To Date From This Committee

“T-FSM High Level Requirements” – published Spring 2004
“D-FSM High Level Requirements” – published December 2004

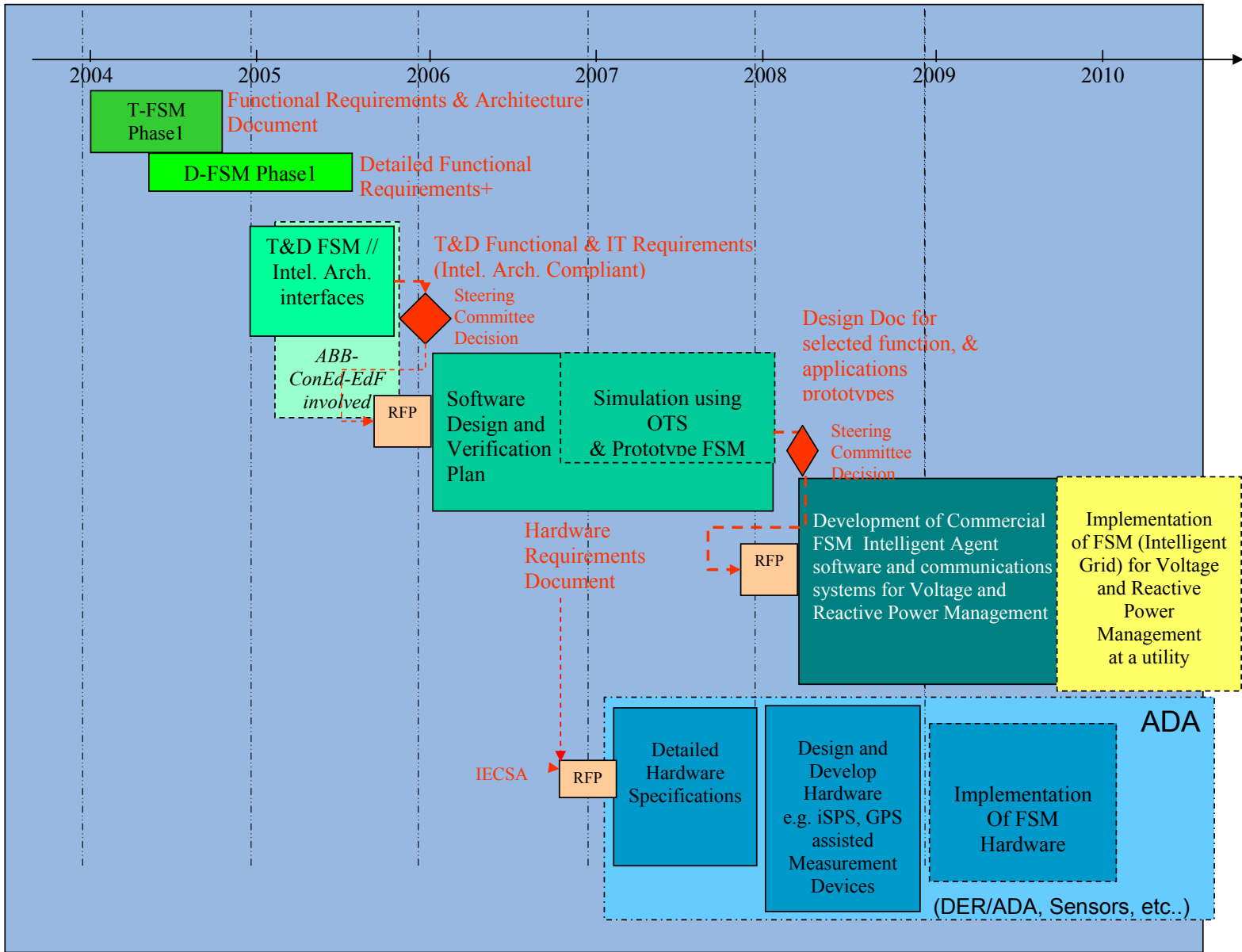


Figure A-2. Roadmap for the Fast Simulation Modeling Project

Open Communications Architecture for Distributed Energy Resources in Advanced Distribution Automation Project (DER/ADA).

Overview

Traditional distribution systems were designed to perform one function—distributing power to end-users. Advanced Distribution Automation will transform traditional systems into multifunctional systems that take full advantage of new capabilities in power-electronics, information technology, and system simulation. Realizing the advantages of these advanced automation functionalities will require improvements to today's distribution system, which has two major subsystems: the electrical subsystem and the communication/control subsystem. Through an evolutionary process, the electrical system can be made more flexible and the communication system can migrate to an open architecture standard. This intelligent evolution will allow new intelligent electronic devices (IEDs) to be easily deployed and managed as strategic resources, thus laying the foundation for the distribution system of the future. Integrating these distributed energy resources (DER) into electric power systems is a critical part of the wide-spread evolutionary advances going on in distribution automation. However, it will require the ability to seamlessly integrate DER into control system of an electric power system.

This project addresses one specific piece of the technology needed for Advanced Distribution Automation—object models for DER. It is part of a larger international body of work collectively sponsored by major players in the global electric power industry. These object models will:

- Increase the functionality (capabilities) and value of DER in utility distribution system operations
- Enable new system-level ADA options, such as microgrids
- Improve reliability and economics of power system operations
- Simplify DER implementation from a technical standpoint
- Reduce installation and maintenance costs

Objectives of the DER/ADA project for 2005:

- I. **Continue leadership on the IEEE and IEC working groups** (P1547.3 and TC57/WG17)
- II. **Reach consensus among stakeholders** on object modeling
- III. **Perform studies and field trials** that support the implementation of DER

Approach:

- I. The project will channel its work through the relevant IEEE and IEC Working Groups P1547.3 and TC 57/WG17. This will provide valuable input to the project from international experts and will also promote the work to the groups to facilitate

its ultimate adoption as standards.

- II. To ensure we develop a solution that is adopted by the industry, there must be participation from a representative group of stakeholders and a coordinated effort with other IntelliGridSM projects including FSM, Consumer Portal and IntelliGrid Architecture. The stakeholder group includes utilities, DER vendors, major DER users, key electricity end user and governmental agencies.
- III. This program will issue reports guiding how DER can be used in utility operations, in both normal and abnormal conditions. It will also provide testing of the vendors' software implementation. The first two object models selected were for fuel cells and reciprocating engines.

Date	Deliverables
All of 2005	Serve as Convener of IEEE 1547.3 Working Group to develop 2 nd draft of the guide
All of 2005	Serve as Convener for IEC TC57/WG17 to write the first committee draft of the standard
4 th quarter 2005	Report on abnormal condition studies and the significance for the object models
4 th quarter 2006	Final Draft of International Standard (FDIS) IEC Object Model
1 st quarter 2007	IEC International Standard DER Object Model

Key Accomplishments To Date From This Committee

Developed draft communications object models for fuel cells and reciprocating engines - *DER/ADA Object Model Report, December 2003*

*IEEE P1547.3 was launched under the leadership of the DER/ADA Project Manager
Draft One of the P1547.3 guide document was produced – December 2004*

IEC TC57, WG 17 was launched under the leadership of the DER/ADA Project Manager

Published a study on how distributed generation can be used in the operations of power systems under normal operating conditions – *Studies of Distribution Operations to Aid in Determining Object Models for Distributed Energy Resources, December 2003*

Produced detailed Test Plan for the developmental laboratory testing phase – July 2004

Technical Paper on IntelliGrid Architecture and DER/ADA Object Models presented at Brussels Conference – Dec 2004

Appendix B – Table of IntelliGridSM Projects corresponding to the four main attributes of the system of the future

ATTRIBUTES		PROJECTS				
		IECSA	FSM	DER-ADA	PORTAL	Sensors
SQRA	Provides reliable, high-quality power. Efficiently allocates control over reliability between distribution and end user.					
	Enhances security and reduces vulnerability (infrastructure and new technology).					
	Comprehensively monitors and quickly responds to changes in grid or market.					
	Facilitates DER connections to grid.					
	Achieves optimization through automation					
Asset Performance and Control	Takes advantage of technological advances and adapts to relevant segments.					
	Optimizes use of current infrastructure and resources, while providing sufficient, universal capacity to accommodate demand.					
	Maximizes life and performance of existing assets.					
	Standardizes equipment, operations, maintenance, and design.					
	Promotes energy-efficient equipment and systems.					
Economic Efficiency and Growth	Offers greater control and more options to consumers.					
	Provides customized, value-added services.					
	Exploits telecommunications/energy convergence.					
	Provides structure that facilitates regional power markets and bulk energy trading.					
	Offers new revenue streams					
Environmental Stewardship	Minimizes need, maximizes supply, and balances load.					
	Emphasizes renewable power sources, clean-fuel technologies, and emissions reduction.					
	Limits environmental and societal impact of new construction					