EPRI Intelligent Universal Transformer

Risk Appraisal and Project Plans

1012434

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Technical Update, December 2006

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This document describes research sponsored by the Electric Power Research Institute (EPRI)

This publication is a corporate document that should be cited in the literature in the following manner:

EPRI Intelligent Universal Transformer: Risk Appraisal and Project Plans. EPRI, Palo Alto, CA: <2006> <1012434>.

REPORT SUMMARY

Background

The vision of the EPRI ADA Program (Program 124) is to create the technology basis for the distribution system of the future by transforming traditional single-function distribution systems into multifunctional power and information exchange systems with increased reliability, improved performance (lower system losses), better economics, better power quality, and more customer service options. Achieving this vision will require capturing the benefits of new capabilities in power electronics, information technology, distributed computing, and simulation. EPRI Project 124.003 is targeted at developing the first-generation EPRI intelligent universal transformer (IUT). The IUT will be a power electronic and communication system that replaces conventional distribution transformers. It will be a multifunctional device that is of immediate value in distributions operations as a transformer replacement and of even greater value in its role as a strategic component that is an interoperable part of ADA and the distribution system of the future.

Objective

The overall objective of this multi-year project is to develop and test a first-generation IUT, working in conjunction with a major equipment developer who has the necessary research, technology development, and commercialization skills in power electronics, communication systems, distribution automation, new product business development, and other disciplines needed to develop and bring a complex new technological product to commercial reality.

Approach

The following tasks were performed as part of the 2006 effort:

- Interviews and presentations with prospective developer contractors
- Exploratory meetings with prospective new funders for the IUT
- Development of a statement of risks for developing and commercializing the IUT
- Development of future work plans for the project
- Presentations to promote the IUT at major conferences and workshops

Results

The report presents the following:

- An updated description of the development status and the role that is sought for the IUT in the distribution system of the future
- A description of the development and commercialization risks for the IUT
- An initial development plan for the IUT

- An initial applications research plan for the IUT

The latter part of the development and test phase may overlap the onset of the applications research phase, depending on interest and funding from the sponsors. These plans will be updated in conjunction with a commercial developer after one is put under contract and then kept current over the duration of the project to reflect the discovery coming from the work.

EPRI Perspective

EPRI Project 124.003 is part of EPRI Program 124 on Advanced Distribution Automation (ADA), which has the objective of creating the technology basis for the distribution system of the future. The scope of project 124.003 is to develop and test a first-generation IUT. The IUT is to be a power electronic and communication system that provides the functionality of conventional wound inductive transformers and a number of added functions not available from conventional transformers. To have maximum compatibility with utility communications systems, the equipment developed in Program 124 will be made compatible with IEC standards (the most robust case) and backwards compatible with less robust legacy systems now in use. The projects in Program 124 are correctly viewed as components of a coordinated body of work to evolve the distribution system of the future, rather than as standalone activities. The whole is greater than the sum of the parts.

Keywords
Intelligent Universal Transformer, Advanced Distribution Automation, Distribution System of the Future, Distribution System Monitoring and Communications

ACKNOWLEDGEMENTS

The author would like to acknowledge the following individuals and their organizations for their continuing inputs and support of the IUT in 2006:

- Raymond Litwin, Northeast Utilities, who has made significant contributions to helping clarify the value proposition and business issues for the IUT.
- John (Bill) Cox, Salt River Project
- Mike Gevaza, OG&E Electric Services
- Jorg Stangl, BC Hydro
- Greg Stewart, Tennessee Valley Authority
- Emil Turek, Lincoln Electric System
- Charles Wallis, Alabama Power Company

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1 INTRODUCTION

This report provides a description of the status and plans for the EPRI project that is targeted at developing the intelligent universal transformer (IUT).

Sponsorship

Sponsorship of the past work on the IUT has been provided by electric utilities. It is envisioned that sponsorship in future work (larger phases) will be a combination of funding from electric utilities, a cost sharing development contractor, and possible other sources, such as government funding. The term “sponsors” is used in the report to be inclusive of all these prospective funders.

Organization of This Report

This report is organized in four sections. Section 1 provides an overview of the report and a description of the anticipated role of the IUT in advanced distribution automation (ADA) and the distribution system of the future. Section 2 provides a description of the risks associated with the development of the IUT. Section 3 presents the development plan for the IUT. Section 4 discusses the possibilities for applications research related to the IUT during the later stages of development and after commercial release of a first-generation IUT product.

Role of the IUT in Utility Distribution System Operations

In order to illustrate the role of the IUT, the following sequence of figures will describe the vision for ADA and how the IUT is seen as contributing to it. This understanding of the role of the IUT is essential to understanding the development risks, the development and commercialization plan, and the applications research plan, which follow in subsequent sections of this report. To begin, consider Figure 1-1 which simply illustrates three radial feeders as may be typical of those into today’s power distribution circuits. A random distribution of feeder loads is shown.

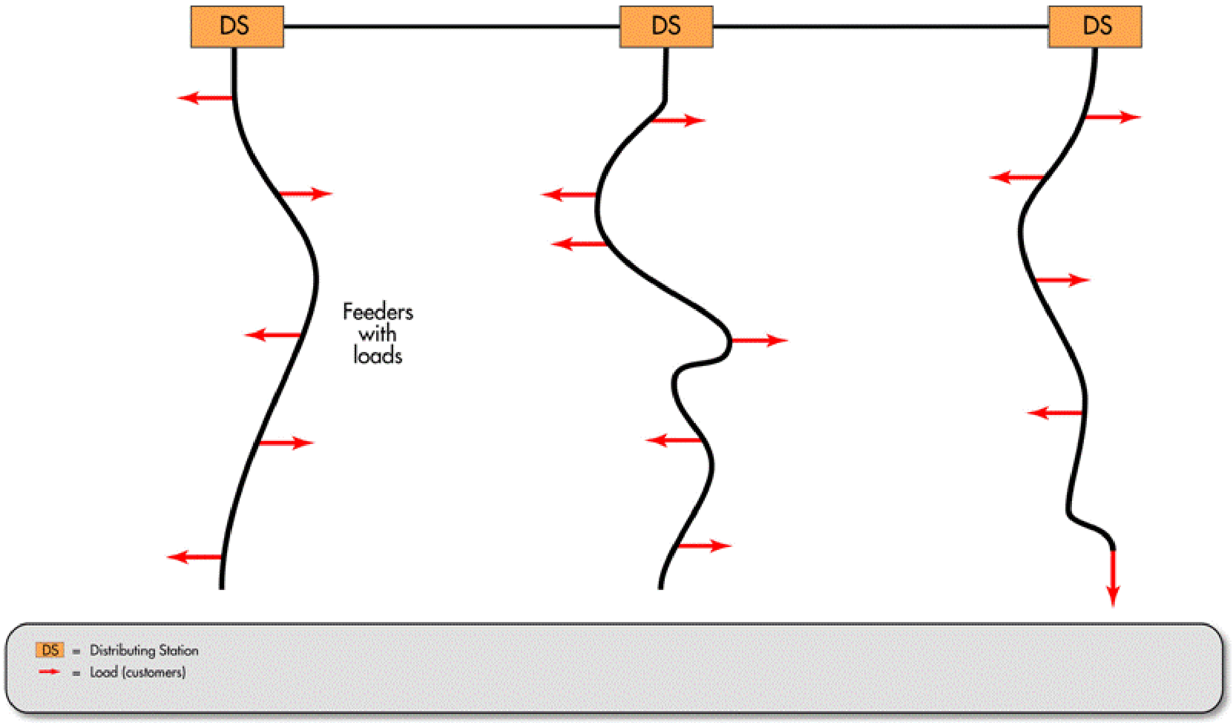

Figure 1-1. Conceptual view of distribution circuits

Figure 2-1 shows the same feeders as the last figure but with the addition of a variety of "intelligent" electrical and electronic components. Here intelligent signifies remotely controllable and having programmable automatic control, such as may be achieved with a microprocessor. There is, of course, no true intelligence in the equipment, but the term will be used here for convenience. Intelligent equipment of this type is making inroads into distribution systems and is expected to continue doing so. This would include both existing products and new products like the IUT. These new components will enable a variety of new capabilities and benefits in the distribution system of the future.

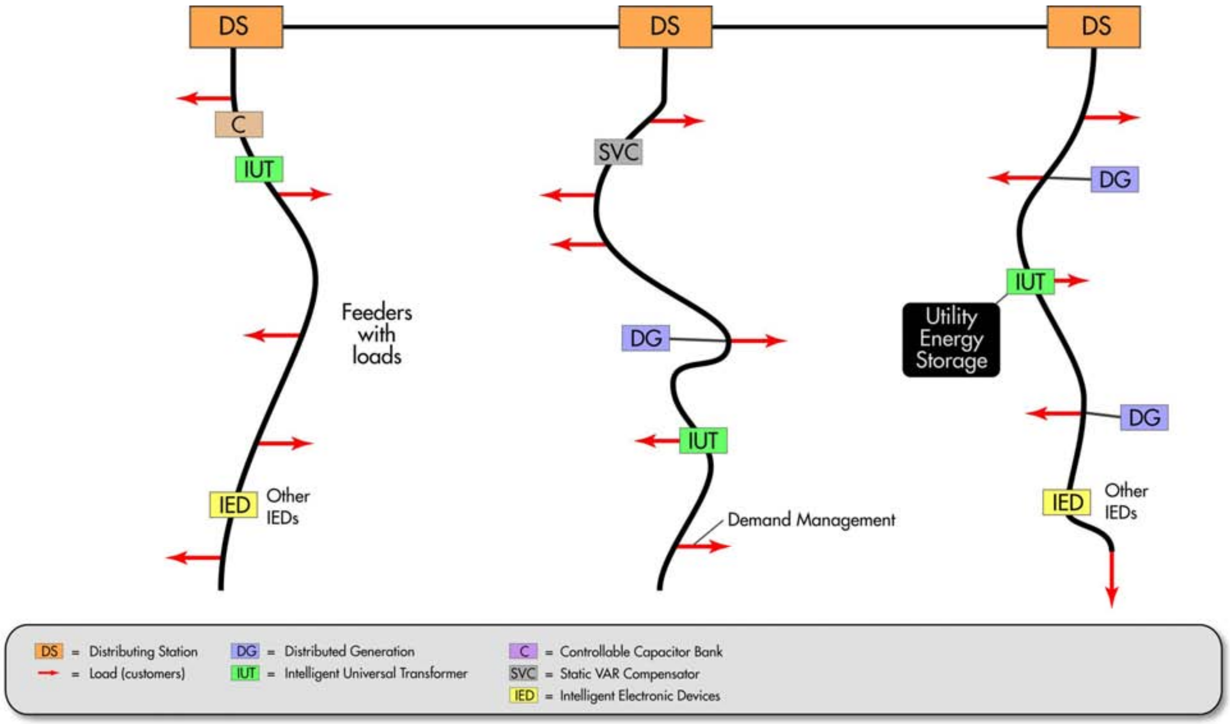

Figure 1-2. Conceptual view of distribution circuits with a variety of intelligent electrical and electronic components added

Figure 1-3 shows the addition of monitoring capabilities into the distribution circuits. These include discrete sensors and sensing functions embedded in other equipment. Because discrete sensors are expensive and only provide the function of sensing, it is desirable to take advantage of the fact that other components often need to monitor voltage, current, power factor, and temperature to operate themselves. With a remote communications link, the information could be extracted from the devices as knowledge of the distribution operating conditions at the site of each device. Hence, the device plays the role of a sensor, in addition to its primary function. The IUT will be used in this manner, in addition to its primary function of stepping voltage.

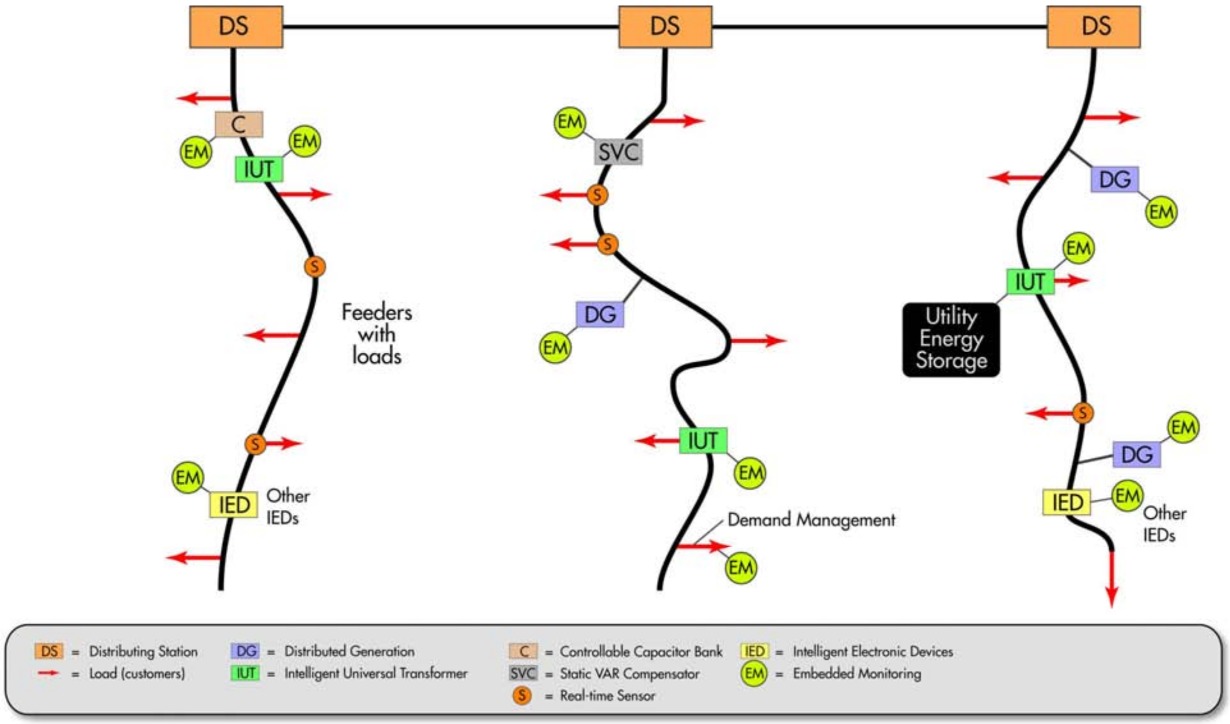

Figure 1-3. Conceptual view of distribution circuits with monitoring components added. The monitoring components can be either discrete sensors (S) or embedded monitoring (EM) capabilities in electrical and electronic components.

Figure 1-4 shows a communication and control system overlaid on the distribution circuits. This capability will allow data to be collected from the monitoring devices and processed by the control system. Based on predetermined algorithms, the control system will govern the various devices in a coordinated way to achieve voltage regulation, VAR management, power quality enhancement, outage mitigation and other system operating capabilities that improve system operations and the quality of service seen by the customer. All devices under such control must have a suitable communication interface and in the long run conform to IEC 61850, which is a body of international standards under development for open-systems communication architecture. The IUT must have such a suitable communication interface.

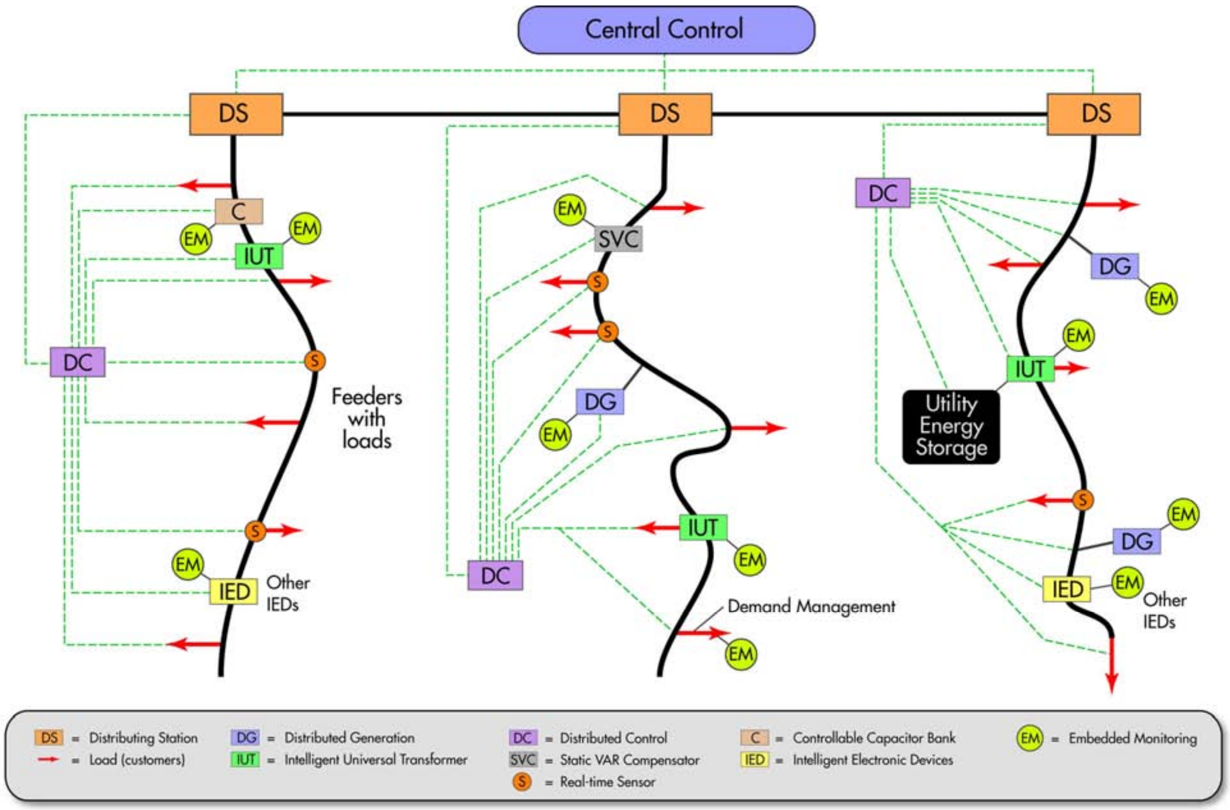

Figure 1-4. Conceptual view of distribution circuits with overlaid communication and control system.

Figure 1-5 shows possible reconfiguring capabilities that could be achievable in a more intelligent distribution system. Via control actions such as those described above, the feeder on the right might be islanded in emergencies by reducing demand and dispatching distributed generation on the feeder to a point where there is a balance between demand and generation. This type of capability is sometimes called a "microgrid", but the term suffers from widely varying definitions of what it means. On the left, another reconfiguring capability is shown in which two feeders are connected at the tail ends when there is a fault in one of them. This allows a faulted segment in one of the feeders to be isolated without losing the whole feeder. These are just two of many possible configuring and reconfiguring capabilities that would come with a more intelligent distribution system.

These changes will not all occur at once. The transition to ADA will be based on *revolution by evolution*. The changes will come gradually, but in synchronism with a long-term vision for the end result that is being sought. The IUT will be a cornerstone of this vision of future evolution of distribution systems. The IUT capabilities will contribute to system monitoring, voltage regulation, VAR management, power quality enhancement, new customer service options, and other aspects of ADA—in addition to providing the voltage stepping function of conventional transformers.

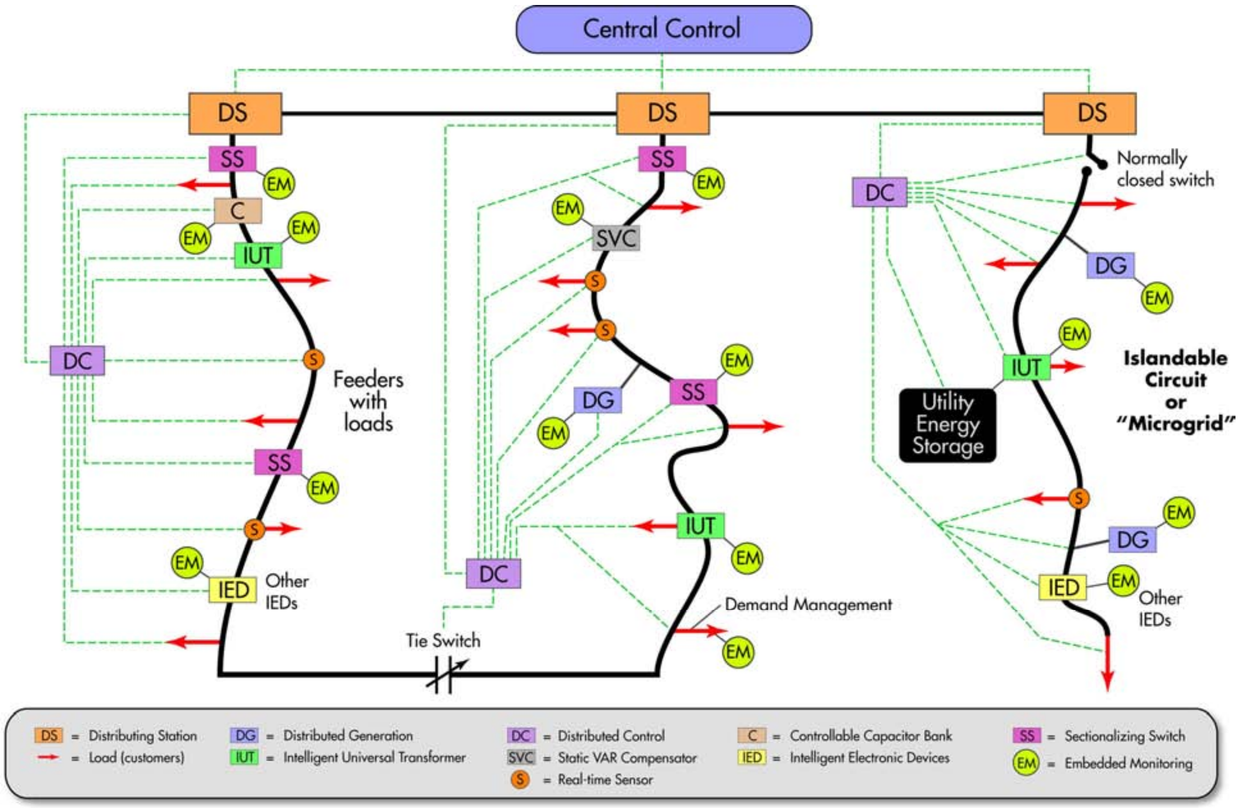

Figure 1-5. Conceptual view of distribution circuits with new configurations and reconfiguring capabilities enabled by the features illustrated in the earlier figures.

Status of IUT Project

A laboratory bench model of the main power conversion circuit for the IUT has been developed and tested. This serves as a point of departure for the future work plan in this report. More information on past history of the IUT is provided in Section 2 of this report. Figure 1-6 shows the IUT main power conversion circuit bench model under test in a laboratory and Figure 1-7 shows the overall test set-up.

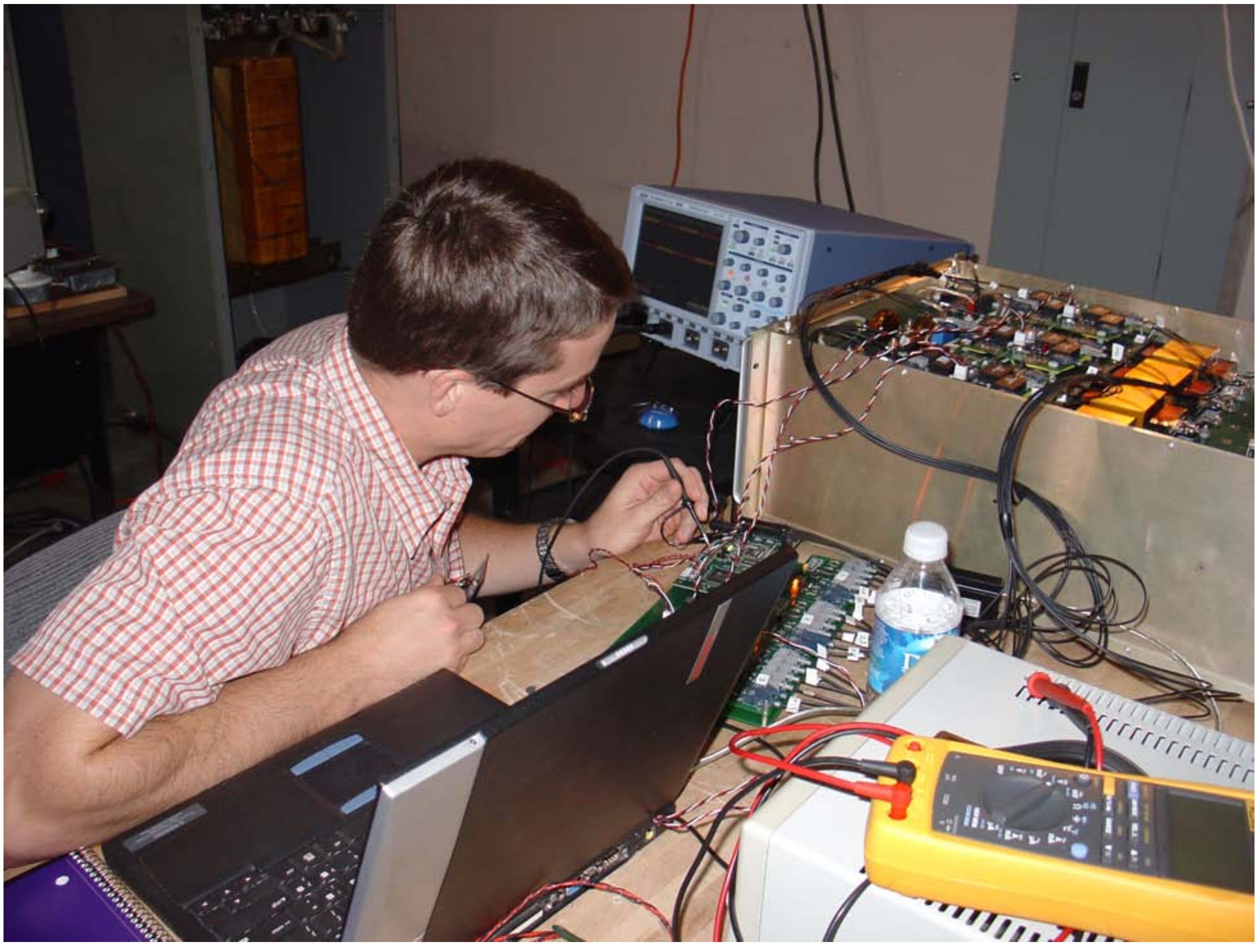

Figure 1-6. Testing the laboratory bench model of the main power conversion circuit for the IUT. The IUT circuit under test is in the upper right part of the picture.

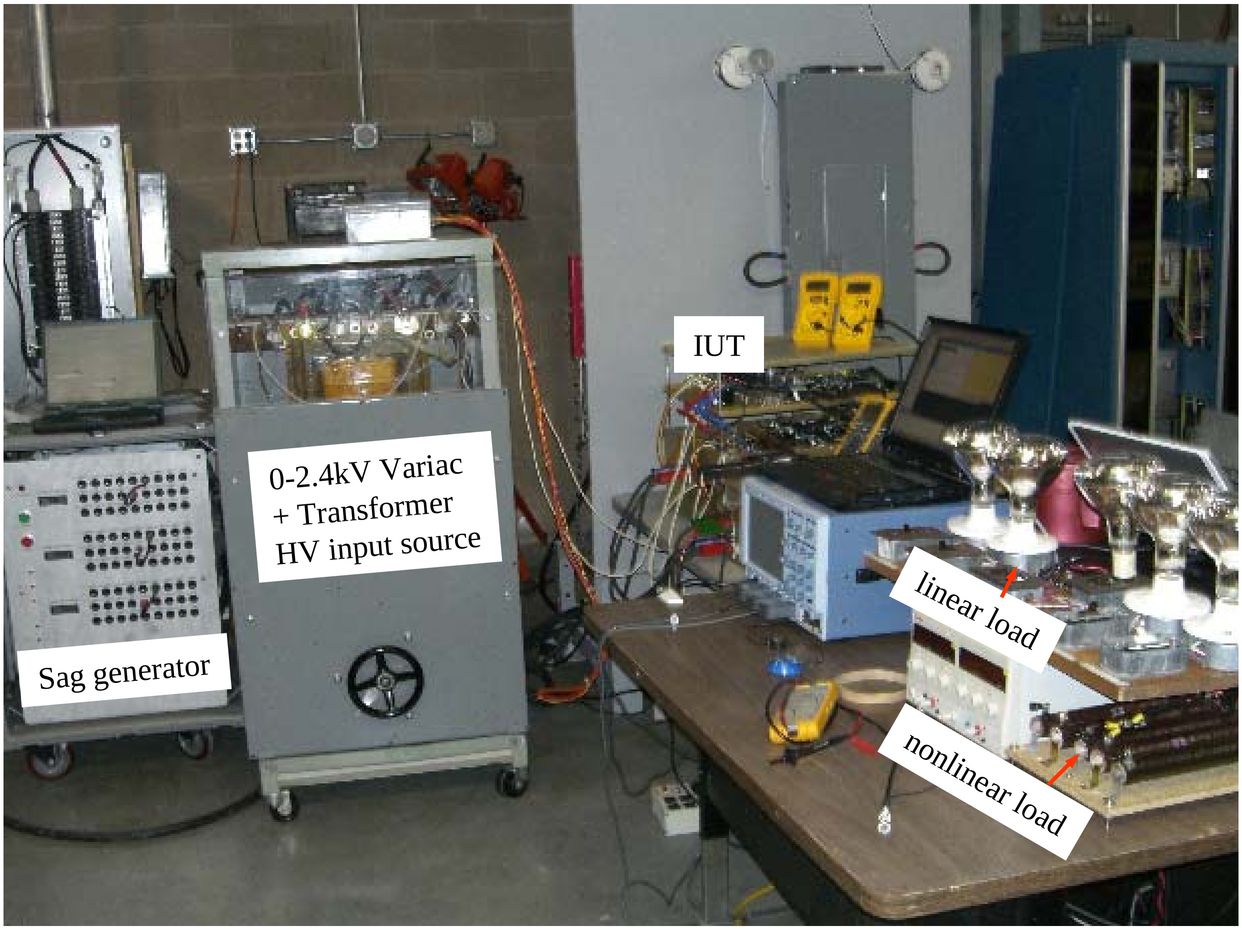

Figure 1-7. Laboratory set-up used in testing the laboratory bench model of the main power conversion circuit for the IUT.

2
INITIAL RISK STATEMENT FOR EPRI INTELLIGENT UNIVERSAL TRANSFORMER RESEARCH AND DEVELOPMENT

This section provides an assessment of the development risks that must be considered in developing the IUT. It provides perspective to help understand the plans for development and applications research in Sections 3 and 4, respectively.

Past Work and Current Status

Past work on the IUT has included the following steps:

- A feasibility assessment including technical feasibility, market potential appraisal, and cost/benefit study [1]. This feasibility concluded with a gate which was a decision point at which the sponsors could decide on the continuation of the project at the end of 2002. Based on the results of the feasibility study, it was decided to continue on to the next phase and focus on an all-solid-state design as the preferred path in which a true technology revolution was possible.
- A design analysis of the main power conversion subsystem [2]. Due to limited funding availability, a planned competitive procurement for an industrial developer was deferred and the design analysis was done by the feasibility study team. The scope was limited to the main power conversion system only, with a deferral of work on other subsystems due to limited funding availability. However, this phase did help pinpoint the requirements for an all solid state design and did help flush out an initial intellectual property (IP) position. IP protection was sought for both an all solid state IUT and a hybrid or cascade concept in which a power electronic system is cascaded on the back of a conventional transformer. The latter is similar to the prior EPRI DVRIT concept, except that it uses a more advanced power conversion system. It was determined to protect both approaches, but to stay focused on the all solid state approach in subsequent phases. The completion of the design analysis was another gate at which a decision was to be made on whether or not to proceed to the next phase—development of a laboratory bench model of the IUT. A decision was made to proceed.
- A proof-of-concept laboratory bench model for the main power conversion subsystem [3]. Due to limited funding availability, competitive procurement was again deferred. This was a key gate for the project. It had to be decided whether to proceed with the reduced funding that was available, if so, what path to take. Three options were given to sponsors when the reduced EPRI base funding availability for 2004 became known. The options were (1) stopping the project and going no further, (2) doing a partial bench model, rather than a complete bench model by getting some supplemental funding to add to the base funding, or (3) putting the project on hold and trying to raise enough funding for a full bench model phase and then resuming the project. A sponsors' meeting was convened and the second

option was selected with a number of sponsors agreeing to provide the supplemental funding needed. The partial bench model was a two-year phase. It was successful in proving the workability of the high-voltage power electronic circuit topology that had been chosen for the main power conversion circuit. The close of this phase was another decision point on project continuation. A workshop was convened, the bench model was demonstrated, and a decision was made to proceed with further development of the IUT.

In all cases the scope of past work has been limited by funding availability. The project is now at a juncture where the scope of work becomes larger and the risks become larger. Additionally, the research and development must now shift to an industrial developer with the resources to develop the IUT, to work through the testing and debugging of experimental field prototypes, to develop a commercially releasable product that resolves any problems from the experimental prototypes, and to stay with the product in commercialization. It would have been desirable to have teamed with a developer in the earlier work (from the project inception), but that was not possible due to the slow funding cash flow.

The development risks associated with moving forward are summarized below. It is important that these be articulated and understood as we move to the larger, riskier development of a field prototype. A commitment from sponsors is needed to take us through this process and the extent of that commitment needs to be clear. There will be additional gates (decision points) at which options for continuation will be examined with the sponsors.

Table 2-1 summarizes the status of IUT development at the close of the laboratory bench model phase. The table helps to put into context the discussion of risks that follows. It is important for the reader to realize that the overall IUT status is early in its development cycle. The IUT is a complex, multi-functional power electronic system. The development risks looking forward into the experimental field prototyping and beyond are significantly greater than looking backward into the pre-prototype work.

Table 2-1
Status of IUT Development

Development Steps	Status
Pre-prototype work	
• Initial Feasibility Analysis	Completed
• Design Analysis	Completed
• Proof-of-Concept Bench Model for Main Power Conversion Circuit	Completed
System Integration Studies	
• Fault Current Analysis	Not started
• Interoperability—Utility Electrical System (Stability, Equipment Interaction and Coordination, Etc.)	Not started
• Interoperability—Utility Communication System	Not started
• Incorporation of IUTs as Nodes in Monitoring System for ADA	Not started
Update Cost/Benefit Study	Not started
Updated Market Study	Not started
Sponsor Survey on Desired Design Characteristics and Functional Priorities for Field Prototypes	Initial discussions held at bench model demonstration. Formal survey not started.
Identification of Developer for IUT	Discussions with two prospects have been held. Suitable vendor not yet identified.
Development of field prototypes	
• Main power conversion system refinement	Not started
• Communication subsystem	Not started
• Auxiliary electronic subsystems	Not started
• Connection access to high voltage dc bus	Not started
• Power semiconductors	Trial units from one source obtained for bench model
• High-frequency transformer	Experimental unit from one source obtained for bench model
• Thermal management design	Not started
• Design of packaging	Not started
Identification of hosts and host sites for experimental field prototypes	Not started
Development of test plan for field prototypes	Not started
Operational and staged testing of field prototypes	Not started
Debugging field prototypes	Not started
Development of first-generation IUT product for commercial release	Not started
Development of a commercialization plan	Not started
Applications work (user group, technical support, trial in new applications, field experience assessments, etc.)	Not started

Risks in Future Development Work

The following is a description of known risks in the future development and commercialization of the IUT. It is not necessarily intended to be an exhaustive list.

Financial

There is a risk of not having enough financial resources to complete the development and being forced to stop the development.

The actual development cost of the IUT is not known at this time. An initial estimate was made at the time of feasibility assessment. This estimate needs to be updated working with a specific developer based on a specific design. The IUT development cost needs to be broken out in terms of parts, engineering and development, testing, debugging, and refinement into a commercially releasable product.

The development cost needs to be broken down in terms of cost per number of field prototypes tested. The testing costs need to also indicate what will be done by the developer as part of the contract work and what test support is expected from the host utility.

The cost of associated utility system integration, market and cost/benefit studies also needs to be taken into account. It would be possible to refine the current cost estimate prior to selection of a developer. But a final estimate will still need to be done working with the actual developer.

Contractual/Development Team

An industrial firm qualified to develop and commercialize the IUT and to provide the significant cost sharing that will be required on top of EPRI's sponsor funding may not be found. It is a tall order in that the developer is being asked to share a significant part of the risks. The firm must be willing to stay committed to the long-term development process and subsequent commercialization.

There may delays in performing the work that stem from difficulties in negotiating a contract and possible licensing agreement with the developer. This negotiating risk is greater in a large complex project such as this one.

Deficiencies may occur in the skills of the developer team. Principal needed technical skills are in the areas of power electronics, communications media and architecture, packaging design, and utility distribution system design and operations. If the team is found to need strengthening, the needed skills can be obtained by contractor new hires or added subcontracts. This may add cost.

Technical Risks

Electrical/Electronic Subsystems

The main power conversion subsystem has been designed and a proof-of-concept laboratory bench model was built and tested. The circuit must be debugged and further developed for a field prototype.

The development of auxiliary power circuits, such as a connection point at the high-voltage dc bus, a low-voltage dc output port and other output ports, has not yet been started. These subsystems must either be sourced to a vendor or developed from scratch by the overall IUT developer.

The IUT must deliver acceptable quality of electrical power and must perform its functions properly to meet the specifications that are developed on a function-by-function basis.

The IUT must be designed with a suitable first-level redundancy that allows the unit to keep operating with a failed module (such as an internal circuit card or power semiconductor mount assembly). The IUT would send failure information via its communication link to the system operator so that the failed module can be replaced prior to a second failure.

The IUT must be designed to be parts-wise repairable to enable quick remedy of problems without replacement of an entire IUT unit.

Communication Subsystem

This part of the development work has not yet been started. Whereas it was originally intended to be part of the bench model phase, it was deferred to the field prototype phase due to the limited funding availability. Next to the basic IUT power conversion subsystem, the communication subsystem is the next most important subsystem. Together these two subsystems comprise the minimum parts that should be developed in the field prototype phase. Other subsystems that add more functionality to the IUT could be deferred if necessary.

The primary risks associated with the development of the communication subsystem are assuring its accurate performance and conforming the information model to IEC standards, which are still under development. The information model should also be backwards compatible with major proprietary systems in use today such as Distributed Network Protocol (DNP3). The information model can be developed and implemented in parallel with making it available to the appropriate IEC working group for standardization.

Components

Non-Standard Components

The power semiconductor devices needed for the high-voltage power electronic circuit topology used in the IUT are not yet commercially available. A custom power semiconductor package for the IUT was developed by Powerex, at their cost, and trial samples were made available to EPRI for the laboratory bench model. Some problems with these samples were encountered. The overall IUT developer will have to work with Powerex and other power semiconductor vendors to assure that a proven line of power semiconductors meeting the IUT developer’s specification for use in the IUT is available from first and second sources.

A suitable high-frequency transformer for the IUT bench model was not commercially available. An experimental model was custom made for the bench model by a vendor. The overall IUT developer will have to work with vendors to assure that a proven line of high-frequency transformers meeting the IUT developer's specification for use in the IUT is available from first and second sources.

Standard Components

All standard off-the-shelf components will need to be specified and first and second sources identified.

Mechanical and Environmental

The IUT packaging will need to be designed for durability and safety comparable to that of conventional transformers in both padmount and polemount configurations. The IUT must be capable of successful operation in all climatic and environmental conditions in which conventional transformers would normally operate.

The IUT must afford safety from electrical hazard to humans comparable to that of conventional transformers. The IUT must be protected from failure due to animal and vegetation contact. The IUT must be designed for acceptable levels of audible noise and EMI emissions in the environments in which it will operate.

The IUT must be designed for modularity in two respects. First, the various auxiliary subsystems must be configurable as optional modules so that only those modules that are needed are included in a specific installation, according to which IUT functionalities are needed at the that location. Second, the IUT must be modular with respect to power level. It is intended that, by use of a varying number of modules, different distribution transformer power levels can be configured. This will result in greater economies of volume production for the product and will make multiple unit ratings serviceable from the same spare parts inventory (versus having to stock separate spares for every rating of transformer in use by a utility, as is now done with conventional transformers).

Thermal

Heat dissipation is a key design issue that must be addressed in the field prototype phase. The various IUT subsystems and the packaging must be designed with suitable passive cooling (no liquid coolants) to keep the IUT from overheating in a wide range of climates in which it will be designed to operate. Managing the thermal design will be particularly challenging given that the IUT subsystems will be confined to a relatively small package for a power electronic system of this size.

Testing Risks

The field prototypes will be experimental units and subject to staged testing, failures, repairs, and all the issues associated with developing a new state-of-the-art electronic/information technology product. The field prototypes should be developed in padmount class first and pole-mounted units would come later. The padmount units would provide the easier access needed for the test and debugging activities.

Utility host sites will be needed for the testing in which there is not a risk of adverse customer reaction from power interruptions or power quality disturbances during the testing. Ideally, this would be in a circuit where the loads are a utility's own facilities. This would also reduce the risk of complaints about the noise and other temporary inconveniences that may be associated with the testing.

There are safety risks associated with testing new electrical equipment that will need to be addressed to avoid injury during the testing.

Conforming to Standards

The IUT will need to conform to all applicable standards (building, safety, electrical, emissions, etc.). This will likely include all the standards that apply to conventional transformers (from an external terminal standpoint) and additional standards that may be evoked by the added functionality of an IUT relative to a conventional transformer. The developer will need to attempt to identify all applicable standards working with utilities and local standards setting organizations.

Commercial Risks

There will be a need to win acceptance of the IUT as a commercial alternative to conventional transformers.

There is the risk of emergence of a new competing product based on power electronics. In other words, someone else could bring an IUT-type product to market.

If the business volume is inadequate, the commercializer will be forced to abandon the IUT business.

Market/Economic Risks

The potential market for the IUT is huge, including both replacement of aging transformers and new installations. However, the market entry process will have risks and must be carefully designed to identify high-value niche opportunities to create a track record and production volume with gradual movement to larger market segments.

Conventional transformers have been relatively inexpensive and reliable, but limited in functionality. On the other had, utility sponsors have recently noted that conventional transformer materials (copper and iron) have been skyrocketing in price. This has flowed through to a significant increase in conventional transformer costs, which has narrowed the gap on the cost target that the IUT must meet for competitiveness with conventional transformers.

Utility System Integration Risks

The ability to use the various functions of the IUT will require coordinated operation with other distribution equipment. The IUT must be interoperable with other components in a distribution circuit, such as other IUTs, distributed generation, capacitor banks, voltage regulation equipment, and protection systems. This will mean upfront analysis of system integration issues, such as stability, fault currents, and interaction with and coordination with other equipment operation. Interoperability must also be achieved in the communication infrastructure of the distribution system. The upfront study results must be properly reflected in the design of the field prototypes. The test host will need to be willing to work with the development team to assure proper integration with other controllable devices in the chosen test circuit.

These risks make it desirable to begin with basic functions in the field prototype and then proceed to more complex functions in a phased process. This would be commensurate with phased funding to alleviate the amount of funding needed for initial field prototype work.

A key issue for the developer will be whether to use a hybrid system consisting of a power electronic circuit cascaded on a conventional transformer as an interim step toward an all solid state solution. Front-end system integration and market studies will help make this decision.

Conclusion

The risks for developing the IUT are significant. The potential payoff is also significant. It is important to understand the risks and to have a development path with the proper checkpoints to manage the work and control the risks and to provide a framework for key decisions on scope and continuation at key project junctures.

Key issues as the project moves to the field prototype development and testing phase are the need to update supporting studies on system integration, market entry, and cost/benefit analysis and which of these can be updated separately in parallel while continuing efforts to select a developer.

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3 PLAN DESCRIPTION FOR EPRI IUT DEVELOPMENT

Background

This section provides a description of work to be performed in the next phase of the project which addresses the following:

- Updating the studies pertaining to business case and distribution system integration of the IUT
- Development, testing, and debugging experimental IUT field prototypes
- Development of a specification for a commercially releasable first-generation IUT
- Development of a commercialization plan for the IUT

This work description will be used as a basis for procurement of contractors to do the work and for development of work statements to go in any needed requests for proposal and contacts. It will also be used as a guide for setting priorities with sponsors to program the work flow in accordance with funding availability. Accordingly, this plan is a living document that will be updated as needed throughout the development work described for the IUT. Although the work plan description is written in task form, this plan is not a verbatim work statement for the contracted efforts.

Flexibility is being retained on development team structure. It is a given that a large major power electronic equipment developer is needed to pick up where the prior bench model phase left off and proceed with the development and testing of the field prototypes. This developer should also have other skills, as described below and may need to have subcontractors to acquire the needed skills. It is expected that the main developer will also be the ultimate commercializer and will provide significant cost sharing to the project.

It is desired to keep the contractor team structure from getting too complicated with too many players while assuring that all the needed skills are on the team. However, flexibility is retained to have some of the supporting studies that are described done by contractors other than the main developer. Sponsor concurrence will be sought on a case-by-case basis. It is expected that the team members who developed and tested the main power conversion system in the last phase of the project will be retained either as EPRI consultants or subcontractors to the main developer to aid in transitioning the knowledge base from the prior work to the main developer. Irrespective of the final team structure that is arrived at through EPRI procurement processes, this group of contractors is referred to as the “contractor team” in subsequent discussions.

This plan is a living document and will be updated as needed to reflect results coming from the IUT research and development work and based on input from the sponsors.

Development Team Requirements

The IUT development will require a versatile team to address the many technical facets of the IUT development and to follow through in commercialization.

During the prior project phase which was focused just on the laboratory bench model development of the main power conversion system due to budget limitations, the team skills were kept limited to just the task at hand—development and test of an advanced power electronic circuit topology.

Going forward the team skill set needs to be filled out (originally planned, but not possible with past funding levels). In addition to picking up and filling in the missing pieces that were left out of the laboratory bench model phase, the added skills are also needed to address the development and commercialization requirements of future phases.

A description of skills needed on the team is provided below.

Business development skills

The development team shall have the skills needed to perform the background studies related to the business case. This will include assessing the expected market growth for the IUT and a cost/benefit analysis update for the IUT that is synchronized to the development of the IUT in phases. The market and cost/benefit analyses must be aligned with the sequenced development of IUT functions. In other words, the business case must reflect the fact that the budget may not allow development and entry into the market with all the planned IUT functions in the first-generation product.

The team is also expected to monitor other worldwide efforts to develop power electronic replacements for transformers (when information can be obtained) and determine their relevance to and implications on continued development of the IUT.

Technology skills

Power electronic expertise is needed to continue the development of the power conversion system. This expertise must be capable of addressing both the power electronic circuit topology development issues and the new component development issues that are included in the work plan description.

Communication system expertise is needed to develop the communication interface for the IUT. This skill set must include knowledge of both the physical media and the protocols needed to create the communication interface. Additionally, the skill set should include familiarity with the status and plans for IEC standard 61850, in that ultimately the IUT must conform to this standard and the part of the standard that would apply to distribution feeder equipment is yet to be developed by an IEC working group.

Conventional transformer technology expertise is needed on the development team so that the developer can assess and understand the various technical standards that are now in place for conventional transformers and align the IUT development with conformance to these standards. As an example, the impact of the Department of Energy's proposed rule on energy conversion efficiency for distribution transformers [1] on IUT development needs to be considered. However, it also is important to note that to achieve commercial success the IUT is intended to be marketed internationally, and therefore the impact of international standards must also be considered in its development.

Utility distribution system expertise

Distribution system expertise is needed on the team. This includes expertise on distribution electrical design and emerging trends in distribution automation. The IUT must be properly integrated into distribution system operations. It must be able to operate as a standalone device to replace conventional distribution transformers in the simplest case without adversely affecting operations. In more complex cases, especially those involving use of the added functionality of the IUT, it must be capable of successful interoperability with other components of the distribution system. This successful interoperability means that there are not adverse interactions in the distribution electrical system environment and that the IUT is successfully integrated into distribution communication and control systems.

IUT Development Plan Description

The following is a description of the tasks to be performed in the next phase of the IUT project which will encompass the field prototype testing and debugging, the refinement of the field prototype design into a specification for a first generation commercially releasable product, and the preparation of a plan for commercialization.

Task 1: Distribution System Integration Studies for IUT

Task Objective

The objective of this task is to perform distribution system integration studies for the IUT and determine the consequence of the results on IUT design.

Task Approach

Fault current

The issues pertaining fault current and the IUT need to be assessed. This includes both the impacts of fault current on the IUT and the impacts of the IUT on fault clearing operations. It will be possible to get some inputs on these issues from prior work on integration of inverter-based distributed generation, static VAR compensators, dynamic voltage restorers, DSTATCOM, and other power electronic components used in distribution systems. The bottom line of the work will be to understand the implications of fault current problems for the IUT design and the extent to which other changes in the distribution system may or may not be needed to enable use of IUTs.

Interaction with Other Equipment and with Distribution Communication and Control

The issues pertaining to interaction of the IUT with other equipment in the distribution system need to be considered. First of all, the electrical interaction of multiple IUTs in the same distribution circuit needs to be understood. Will this interaction cause electrical instabilities that lead to outages or that are deleterious to power quality delivered to customers? Secondly, the interaction of IUTs with other power electronic components (DG inverters, static VAR compensators, DVRs, etc.) needs to be examined for same reasons. Finally, the interaction with other components like protection systems, voltage regulators, and switched capacitor banks needs to be examined.

The interaction of various remotely controlled components in the distribution system also needs to be understood from the standpoint of their interoperability in the communication and control system.

The results of these studies will be used in developing the design for the IUT field prototypes and in determining if changes to distribution circuits are necessary in order to enable use of IUTs. A goal will be to try to incorporate changes into the IUT that make its introduction into distribution systems as seamless as possible. Changes to distribution circuits to accommodate IUTs would be made only as the last resort.

Task Output

The output of this task will be special topical study reports on the utility integration studies.

Task 2: Update Business Case Studies

Task Objective

The objective of this task is to update business case work done during the past feasibility phase of the project.

Task Approach

The market study will be updated. An initial market study was done as part of the feasibility phase of the project. This study needs to be updated.

The cost/benefit studies for the IUT will also be updated.

These study efforts may be done internally by EPRI, sole sourced, or competed, depending on budget availability, schedule, and knowledge of suitable contractors. In any case, objective contractors will be required who can do the work, provide the needed information, and not try to turn the study into an effort to make more work for themselves.

Task Output

The output of this task will be special topical study reports on the business case studies.

Task 3: Procurement of Developer Contractor for IUT

Task Objective

The objective of this task is to procure a development contractor to develop, test, and debug the IUT in field prototype form and to follow through in refining the field prototypes into a commercially releasable form.

Task Approach

The following steps will be performed:

- EPRI will prepare a request for proposal (RFP) including selection criteria and bidders list. The RFP will define the goals of the development project, the desired results, the tasks, the skill set that is desired, and the required management program. The content of the RFP work description, deliverables, and schedule will be an amplified version of the work description below. The sponsors will be given a chance to review the RFP in draft form, before it is revised into final form.
- The RFP will be released to bidders. The bidders will be asked to propose the work in incremental stages to give us flexibility to adapt the schedule if the funding falls short of that needed to meet their proposed schedule.
- Teaming will be encouraged so that bidders can take steps to create a team with all the skills needed to meet the requirements set forth in the RFP.
- A presentation will be prepared on the IUT, including a summary of past work and salient features of the RFP, for presentation and discussion in a bidders' conference. A bidders' conference will be held to address questions on the RFP and other issues raised by the bidders. The bidders' conference may be held by web-casting.
- EPRI will receiver bidder proposals and evaluate them in accordance with the selection criteria. Sponsors will be given the opportunity to have representatives on the proposal review team. From among the responsive proposals, one or more finalists will be selected. If none of the proposals is responsive, an alternative course of action will be recommended by EPRI to the sponsors.
- If needed, EPRI will interview finalists to aid in making a final selection. EPRI will negotiate a research development contract based on the work statement in the successful bidder's proposal and a licensing agreement for background intellectual property. Ideally, it would be desirable to have an award to the best proposal and keep the runner up as a fallback in case negotiations with the first award are not successful.
- Work on the development of the IUT will then be initiated by the development contractor under EPRI management.

Task Output

The output of this task will be an RFP, contractor award, and negotiated agreements for the contracted work that is described below in the development discussion.

Task 4: Field Prototype Design Specification: Initial Interface with Sponsors and Utility Industry

Task Objective

The objective of this task is to prepare a design specification for the field prototypes and refine it with utility input to assure it conforms to their needs.

Task Approach

The developer will work with EPRI to organize a design workshop to lock into a final specification for the IUT field prototype and first-generation IUT. The developer will review all EPRI reports on the IUT and any relevant papers, patents and other information identified in a literature search. The developer will prepare a straw-man specification for the first-generation IUT. The developer team will include functions in the IUT that they believe to be achievable within the expected budget availability that is foreseen for the future of the project at that time. They will also specify optional functions that they believe are achievable through added work, if more funding were to become available.

To aid in developing this specification, the developer will develop a questionnaire to survey sponsors and other utilities, as needed, to get a reading on the preferences and trends in distribution transformer ratings and other characteristics for conventional transformers now in use. The draft specification will be completed and provided by the developer to EPRI. EPRI will circulate the specification the sponsors prior to the workshop.

The workshop will be convened to critique and finalize the design specification. This workshop may be held by web-casting. All sponsors will be invited to participate in the workshop. Other participants may be invited whose input is deemed vital to finalizing the specification before launching the actual development process.

In the workshop, it will again be necessary to assure that the functional priorities for the first-generation IUT are properly aligned with the expectations for future project funding. As a minimum, the first-generation IUT will have the following features:

- Ability to step voltage
- Ability for real-time voltage regulation
- Communication interface for remote monitoring and control

Other functions can be added as optional work items for inclusion in development up to the limit of expected available funding. The sponsors will be asked to set final priorities for these optional items at the workshop.

Task Output

The output of this task will be a final design specification for proceeding with the IUT development. The results of this task will be used as the design basis for steps in the development and test of field prototypes and subsequent refinement into a commercially releasable first-generation IUT.

Task 5: Development of Field Prototype Configurability and Packaging

Task Objective

The objective of this task is to design the configurability and packaging of the IUT.

Task Approach

The developer will design the configurability and packaging of the IUT, including the following issues:

The IUT packaging will be designed for both padmount and polemount applications. The first field prototype units will be padmount units to allow easy access for testing and debugging them in the field. But the design work should address both padmount and polemount versions for the first generation commercially releasable IUT. The IUT packaging shall be designed to last the life of the product and support use of the IUT in all climates in which conventional transformers would be used.

The IUT will be designed for repairability. The IUT will be designed to lessen the chance of catastrophic failures which may cause total loss of a unit such as occurs with conventional transformer. In other words, the IUT will be designed with redundancy in the circuits and repairability to keep a unit in service with minimal interruptions. The redundancy should provide a backup circuit in the power electronics so that if a main power semiconductor or its drive circuit fails, a back up is switched in automatically and diagnostic information is sent via the communication system to alert operators to dispatch a repairman to replace the failed component. The IUT control system should be continually self-diagnosing the IUT and sending status and condition information back to the control system. Problems should trigger an alarm to alert an operator that service may be needed.

The IUT layout will be configured for modularity. The modularity must address two key issues. First, the IUT will be a multifunction system in which not all functions are needed in every application. Hence, the product should be configured in modules where the main power conversion system is the anchor product and the other functions, such as providing a dc output port, are optional modules that can be purchased and used with the anchor product as needed. The anchor product should include the abilities to step voltage, regulate voltage, act as a distribution monitoring node, and link to the distribution communication and control system. The other functions should be addressed one by one to determine whether they should be part of the anchor product or a separate module. This step of the design should also address the availability of an alternative set of modules for selling the IUT in overseas markets that may be 50-hertz rather than the 60-hertz norm for North America.

Second, the IUT should be designed for voltage and kVA rating modularity. The goal is not to have a separate IUT anchor product for every existing conventional distribution transformer voltage level, but rather to have a modular approach in which many different voltage and kVA ratings can be met by a single anchor product that can be built up modularly to the different voltage and kVA levels in question.

Task Output

The output of this task will be a design for the packaging and configurability of the IUT field prototype and the first generation commercial IUT.

Task 6: Development of Main Power Electronic Circuit Topology

Task Objective

The objective of this task is to develop and test the main power electronic circuit topology for the IUT.

Task Approach

The developer will evaluate the main power electronic circuit topology from the laboratory bench model phase of the project and determine what refinements are needed to make it compatible with the design specification for the field prototype IUT. The developer is encouraged to improve the power electronic design. However, in the end a compromise must be made between adapting the earlier design to meet the field prototype needs and major changes which are beyond the ability of the project schedule and budget to bear. The power electronic system will then be developed for the field prototype. This will likely include laboratory work on the main power electronic circuit before placing it into the actual field prototype units. The power electronics will be designed to operate reliably in all climates in which IUTs will be deployed. The development of the main power conversion circuit must be closely coordinated with the development of the control system discussed in the next task. The two must be compatible.

A bench model main power conversion system was developed in the last phase of the project to establish proof of concept. This power electronic system performed successfully in the bench model testing. This is the starting point for the further development of the IUT main power conversion system going forward. The following steps will be taken to develop it:

- Review the bench model power electronic design for suitability to meet the needs of the field prototypes and subsequent first-generation commercial IUT.
- Develop the power electronic design to close any gaps relative to these needs.
- Develop a main power conversion system that is not only compatible with the needs of the functionality that is chosen for inclusion in the first-generation IUT, but also adaptable to additional functions that may be added later.
- Develop, test and debug the main power conversion system in a laboratory as needed.
- Incorporate the main power conversion system in the field prototypes.

Task Output

The output of this task will be a fully developed main power conversion system for the IUT field prototypes.

Task 7: Development of Control System

Task objective

The objective of this task is to develop and test a control system for the IUT field prototypes.

Task approach

The developer will evaluate the control system design from the laboratory bench model phase of the project and determine what refinements are needed to make it compatible with the power electronic system design for the field prototype IUT. A determination will be made as to whether to use analog or digital control. The control system will then be developed for the field prototype. This will likely include laboratory work on the control system before placing it into the actual field prototype units. The control system will be designed to operate reliably in all climates in which IUTs will be deployed.

A bench model control system was developed in the last phase of the project. This control system performed successfully in the bench model testing of the main power conversion system. This is the starting point for the further development of the IUT control system going forward. It is important to note the bench model control system addressed only control of the main power conversion system and did not address integrated control of all subsystems and all functions of the IUT. The field prototype control system must address all functions and subsystems included in the first generation IUT, as per the earlier task to develop the design specification. The following steps will be taken to develop the control system:

- Review the bench model control system design for suitability to meet the needs of the field prototypes and subsequent first-generation commercial IUT.
- Develop the control system to close any gaps relative to these needs. A decision will have to be made on analog versus digital control.
- Develop an adaptable control system that is not only compatible with the needs of the functionality that is chosen for inclusion in the first-generation IUT, but also adaptable to controlling additional functions that may be added later.
- Develop, test and debug the control system in a laboratory as needed.
- Incorporate the control system in the field prototypes.

Task output

The output of this task will be a fully developed control system for the field prototypes.

Task 8: Development of Power Semiconductors for IUT

Task Objective

The objective of this task is to develop a suitable power semiconductor package to enable the realization of a commercial IUT product based on a high-voltage power electronic circuit topology and to establish first and second sources for the power semiconductors.

Task Approach

The laboratory bench model for the IUT used a specific advanced high-voltage power electronic circuit topology for the IUT. This circuit design was based on use of insulated gate bipolar transistors (IGBTs) as the type of power semiconductor switch in the circuit. The power range of the IUT requires a high voltage, low current IGBT, and there were not commercially available IGBTs in this range at the time of the bench model work. A power semiconductor supplier, Powerex, agreed to adapt a higher current product family to the current and voltage range desired for the IUT. Samples were made available for evaluation as part of the IUT bench model of the main power conversion subsystem.

As part of the field prototype development, the developer will prepare a final specification for the power semiconductors that is compatible with the IUT design and arrange first and second sources to manufacture and supply the power semiconductors. Units will be purchased for the field prototypes to validate the integrity of these components.

Task Output

The output of this task is a suitable power semiconductor switch type for use in both the IUT field prototype and the first-generation commercial IUT.

Task 9: Development of High-Frequency Transformer for IUT

Task Objective

The objective of this task is to develop a suitable high frequency transformer to enable the realization of a commercial IUT product based on a high-voltage power electronic circuit topology and to establish first and second sources for the high frequency transformer.

Task Approach

The laboratory bench model for the IUT used a specific advanced high-voltage power electronic circuit topology for the IUT. This circuit design required a small high-frequency transformer for electrical isolation of the input and output sides of the IUT. A custom transformer was wound using a suitably-chosen core material and supplied by a vendor for the bench model work.

As part of the field prototype development, the developer will work with a suitable vendor to develop a final specification for the high frequency transformer (including terminal properties, core, and windings) that is compatible with the IUT design. The developer will arrange first and second sources to manufacture and supply the high frequency transformers. Units will be purchased for the field prototypes to validate the integrity of these components.

Task Output

The output of this task is a suitable high frequency transformer for use in both the IUT field prototype and the first-generation commercial IUT.

Task 10: Development of Communication Subsystem for IUT

Task objective

The purpose of this task is to develop the communication subsystem for the IUT, including any needed hardware, software, information models, and protocols.

Task approach

The developer will design, develop, test, debug, and finalize the design for the communication subsystem. This subsystem will consist of an interface capable of providing operating information to the distribution system's control facility and receiving information from the distribution system's controller and it will also be capable of peer-to-peer communications with other equipment having a suitable communication interface. The communications subsystem design will include all aspects:

- Hardware
- Software
- Communications
- Conforming to applicable standards

This subsystem development was not addressed in the prior laboratory bench model phase and needs to be developed from scratch in the field prototype phase. Whereas it was originally intended to be part of the bench model phase, it was deferred to the field prototype phase due to the limited funding availability. Next to the basic IUT power conversion subsystem, the communication subsystem is the next most important subsystem. Together these two subsystems comprise the minimum parts that should be developed in the field prototype phase. Other subsystems that add more functionality to the IUT could be deferred if necessary.

The primary risks associated with the development of the communication subsystem are assuring its accurate performance and conforming the information model to IEC standards, which are still under development. The information model should also be backwards compatible with major proprietary systems in use today such as Distributed Network Protocol (DNP3). The information model can be developed and implemented in parallel with making it available to the appropriate IEC working group for standardization.

Task output

The output of this task will be a fully developed communication subsystem for use in the field prototypes.

Task 11: Development of Auxiliary Power Electronic Subsystems for IUT Prototype

Task Objective

The objective of this task is to develop all auxiliary subsystems for the IUT.

Task approach

The developer will develop or arrange to procure auxiliary subsystems needed for the IUT. Examples of such subsystems include:

- Power conversion system for producing a low-voltage dc output port.
- Output port for accessing the high-voltage dc bus internal to the main power conversion system.
- Output port for converting to 400-hertz ac output for communication applications.

The decision on which auxiliary subsystems need development will depend on the outcome of the design workshop and prioritization of functions for the first generation product that was discussed in earlier tasks.

Task Output:

The output of this task will be the developed auxiliary subsystems or agreements with the suppliers from whom they can be procured.

Task 12: Component Sourcing for the IUT Subsystems

Task Objective

The objective of this task is to source all components for the IUT to vendors who will supply the parts.

Task approach

The components for all subsystems in the IUT need to be sourced to vendors. This includes components for the main power conversion subsystem, the communication system, the enclosures, and all auxiliary subsystems. The sourcing of the power semiconductor switches and the high frequency isolation transformer have been discussed in earlier tasks. Any other non-standard components will be developed, tested, and sourced in the same manner as was discussed for those earlier non-standard components. This would include machining of the enclosures.

All standard components will be sourced to commercial vendors. First and second sources will be identified for each component. Evaluation of the components will be done as necessary in a laboratory to assure that they meet specifications. The standard components will be incorporated in the experimental field prototypes to assure their performance and compatibility with the IUT.

Task Output:

The output of this task will be a set of agreements with suppliers addressing the conditions for supplying all parts needed for commercializing the IUT.

Task 13: Assembly of Field Prototypes

Task Objective

The objective of this task is to assemble the components into testable field prototypes.

Task Approach

Using the results of the preceding development tasks, the field prototypes will be assembled for testing. These prototypes will be assembled as if they were commercial products. They will then be tested according to a prescribed test plan to identify any problems that need to be resolved in the design refinement work prior to commercial release. This assembly process will also test whether or not the agreements with parts suppliers are working or not.

Task Output

Field prototype units ready for testing.

Task 14: Development of Test Plan for Field Prototypes

Task Objective

The objective of this task is to develop a plan for testing and evaluating the IUT field prototypes.

Task Approach

The developer will write a test plan for evaluating and debugging the IUT field prototypes. The test plan will address actual field trials in a variety of climates in which the IUT is intended to operate. The test plan will be written as a draft for review and comment by EPRI and sponsors and then finalized for use in the actual testing and evaluation. The test plan will address both staged and operational testing to validate the satisfactory performance of the IUT functions, subsystems, and components and to identify design problems that need to be corrected.

The developer will specify the desired characteristics of the utility host sites for the IUT field prototypes. A plan for selecting host utilities will be written, including selection criteria. Input from sponsor utilities will be obtained to identify which of them have suitable host sites and would be willing to host a field prototype test.

The developer will clearly delineate the risks in the test plan so that participants can make the necessary preparations for safe testing and for testing with minimal customer impact. The delineation of risks will be a factor in determining which host sites the utility sponsors wish to offer for testing.

The costs per unit of the IUT field prototypes will be prepared by the developer, once the design is stable and the parts and assembly costs are known. The cost of each prototype unit is to be borne by the host utility. It is understood that these are experimental units and are not to be left permanently in service after the field prototype testing is completed.

The needed test equipment and data recording equipment will be specified. The expected roles and responsibilities of the test participants will be described, including the developer's role and the host utility's role.

Task Output

The output of this task is the test plan document. It will be used to test and evaluate the field prototypes and it will be incorporated as an appendix in the annual project report and the comprehensive final report for the project.

Task 15: Testing the Field Prototypes

Task Objective

The objective of this task is to test, evaluate, and debug the field prototype IUTs and identify changes that need to be made in the developing the final product specification for commercial release.

Task Approach

The test plan developed in the prior task will be implemented. The developer will work with EPRI to select the host utilities. The necessary concurrences to assume the host responsibilities will be obtained. This will take the form of a written agreement executed among the parties with content determined during the development of the test plan.

The units will be installed at the designated host utilities and tested as per the test plan document. Both the installation and testing will require close coordination between the developer and host utility. The problems encountered will be resolved in the field and testing continued wherever possible. Retesting will be done when necessary following any adjustments to the prototype design (hardware or software changes). Any issues that need further resolution in the commercial product finalization will be noted and addressed in the subsequent task dealing with development of a commercial product specification. All test results will be carefully documented and included in the comprehensive final report.

Task Output

The output of this task is the testing, evaluation, and debugging of the IUT field prototypes. The results will be used to develop the specification for a commercially releasable first-generation product and will be incorporated in the comprehensive final report.

Task 16: Development of Commercialization Plan

Task Objective

The purpose of this task is to develop a commercialization plan for the IUT.

Task Approach

The developer will prepare a commercialization plan. The plan will take into account the results of the studies done earlier in this phase pertaining to business case issues and utility system integration issues. The plan will describe the market entry path and the path for market growth over the long term.

The intellectual property items requiring negotiation of licensing agreements will be identified in the plan.

Task Output

The output of this task will be a plan for commercialization of the IUT upon commercial release of the first-generation product. This plan will be incorporated in the final comprehensive report for the development project.

Task 17: Development of a Commercially Releasable First-Generation Product

Task Objective

The objective of this task is to develop a specification for a commercially releasable IUT product.

Task Approach

The developer will refine the field prototype design into a final design for the first-generation IUT, taking into account the results and lessons learned in the field prototype testing. A product specification will be developed for use in setting up manufacturing, marketing, and other business elements for the IUT. The developer will prepare the product specification in draft form for review by EPRI and the project sponsors. The specification will be finalized, taking into account input from the reviewers. The final specification will address both padmount and polemount versions of the product.

Task Output

The output of this task will be a final product specification for commercial release of a first-generation IUT. This specification will be incorporated in the final comprehensive report for the project.

Overall Project Management and Reporting

Assuming the budget is sufficient to move more aggressively in the next phase of the project than in past phases, a more aggressive management and reporting process is planned. This process is expected to include the following elements:

Monthly progress reports

Monthly progress reports will be prepared by the EPRI project manager for the sponsors. These will give overall technical and financial status information on the project and will summarize key information in monthly reports that will be required from the contractors. The contractors will be asked to provide status and milestone information on a task-by-task basis for their work statements, to bring attention to problems and major accomplishments, and to provide financial tracking information.

Annual project status reports

Annual status reports will be published by EPRI. These will be written by the lead contractor for the development team, reviewed by EPRI and sponsors, and published by the EPRI publications group.

Special topical study reports

Special studies on utility system integration, market, and business case issues will be made available to the sponsors as they are performed. The decision to do any such studies will be done with sponsor input and guidance. The reports will either be made available to sponsors in unpublished form or published by EPRI, on a case-by-case basis. Publishing reports adds project costs, and so only the more important topical studies that the sponsors want to see published will be published. Others will be made available to sponsors in unpublished form. Sponsors will be given the opportunity to review and comment on these study reports in draft form.

Commercialization plan

The commercialization plan will be made available to the sponsors. It will be a living document and updated as needed.

Final report on field prototype development and test

A comprehensive final report will be published by EPRI at the conclusion of the field prototype development and test phase. Sponsors will be given the opportunity to review and comment on the comprehensive final report in draft form.

Quarterly project reviews with sponsors

It is expected that these will be set up as webcast meetings, except that the final review each year will be a face-to-face meeting. The status of the project will be reviewed in each quarterly meeting and input will be obtained from sponsors to aid in key project decisions.

In the interim, between formal reviews, EPRI management will work with the contractor team to manage the work and keep it focused on meeting objectives. If an urgent matter arises that needs sponsor input, it will be brought to the sponsors without waiting for the next quarterly review meeting.

Priorities for Deliverables

If funding is insufficient to meet all the planned deliverables, priorities for deliverables will be set by EPRI in concert with the desires of the sponsors in order to stay within the actual funding availability.

Intellectual Property

All foreground inventions will be disclosed to EPRI throughout the development work.

Straw-Man Schedule

The schedule for the work above is as follows:

- The IUT field prototype development and testing are expected to take 24 months from the date of contract start-up with the developer/commercializer.
- The IUT field prototype refinement into a final design specification after the testing is done is expected to take an additional 6 months.
- The supporting studies will be done as needed. Their duration will depend on the nature of specific studies. The sponsors will be given options to perform some of these studies in parallel via a separate team while the developer/commercializer is being procured.

The development schedule is subject to change based on what is proposed by bidders in the developer team procurement and based on realities of funding availability.

References

[1] Energy Conservation Program for Commercial Equipment: Distribution Transformers Energy Conservation Standards; Proposed Rule, Department of Energy, Office of Energy Efficiency and Renewable Energy, Docket Number: EE-RM/STD-00-550, Federal Register, August 4, 2006.

4
PLAN FOR APPLICATIONS PHASE FOR EPRI IUT PROJECT

Background

The applications phase is intended to provide an opportunity for EPRI to work with users of the IUT in pre-commercialization and post-commercialization activities. The work will be targeted at helping users to identify applications for the IUT, try the technology out in these applications, and evaluate and share the experiences among users. The work can begin in parallel with the IUT development work and therefore an applications plan should be developed from the outset and updated as needed. It is important to recognize that the actual implementation of the applications plan will depend on the availability of funding from sponsors who wish to see EPRI play a role in applications research and development for the IUT.

Applications research and development is distinctly different from the field prototyping research. In the field prototype development, experimental units are tested and refined as a key step in developing the product, prior to making it ready for commercial release. Applications research and development is focused on activities to support use of the product after commercial release, but can include preparing for product use in anticipation of commercial release. The applications planning needs to be coordinated with what is being learned in the field prototype testing.

EPRI Involvement in Applications of New Technologies

A project's applications research phase will vary in accordance with the nature of the project's product. The applications phase can begin prior to a product's release and continue after that release. For project's having multiple products, the project's plan should include an applications phase for each project. Even when a product is delivered by a vendor/manufacturer, an EPRI applications plan should exist that involves EPRI, the users, and the vendor/manufacturer in a process for follow-through on applications. The applications work should help encourage use of the product, help introduce the product into all major applications that have been identified for the product, evaluate the experiences with the product in these applications, and provide feedback to aid in product improvement or development of a next-generation product. Table 4-1 provides representative activities.

Table 4-1
Representative Activities During A Project's Applications Phase

Activity	Description	When/Participants
Applications field experience assessment	Conduct applications workshops with users and, in some cases, vendors to examine experience with applications for the product, possible new applications for the product, and issues for improving the product or developing a next-generation product.	After commercial product release
Training forums	Conduct forums (face-to-face, webcast, video, web training, etc.) to introduce prospective users to a product and/or train their staff on procedures for adoption and maintenance. The training may include basic familiarization with the core technologies as well as the product. Training can begin in advance of the product release and continue after product release.	During development and after commercial product release
Periodic technology transfer workshops	Workshops in which the only topics are recent EPRI products (not industry issues, or vendors). These aren't training courses, per se, but there is enough detail to provide an appreciation for the technology. These would typically be done for an entire program or higher level grouping of products, rather than an individual product.	Periodic, e.g., annually or biennially, depending on number of products coming out in a given area
User site coordinators	Select user staff members as site coordinators. Part of their job is to encourage use of the EPRI product within the user's organization.	During development and after commercial product release
Subscriber-requested assistance as part of base program	A provision that allow use of a small percentage of base program funding to have EPRI staff visit sites who need help implementing EPRI technology. It is a quick way to start including implementation into the base program, but it is prompted by a user calling EPRI.	After commercial product release
Webcasts following product release	Increased emphasis on webcasts following product release. Program 104 uses this approach effectively. Significant resources are invested in preparing and giving these webcasts for each maintenance guide they produce. Participation is very strong, particularly by plant staff (end-users) that never travel to EPRI meetings.	After commercial product release
Testimonials and documentation of applications experience	Tools that can be used are Testimonials, EPRI Innovators, Success Stories, EPRI Journal articles, EPRI annual report, and the Applications Scorecard. These are most often done after a product exits, but there are situations in which testimonials and success stories can be documented with user input during the development phase of a project (for example to celebrate and recognize a key interim deliverable being achieved).	Whenever a customer has valuable experience to share
Applications workshops	Conduct applications workshops with users and, in some cases, vendors to examine experience	After commercial product release

	with applications for the product, possible new applications for the product, and issues for improving the product or developing a next-generation product.	

Prospective User Engagement During Prototype Hardware Development and Testing

Objectives of engagement

The objectives are to test the hardware in pre-commercial field prototype form and to identify and resolve flaws or user problems with the product before commercial release. Normally, the field prototype phase will follow a laboratory bench model phase. As such, the field prototype has had a first level of debugging in the laboratory phase. The laboratory test could be considered an "alpha test" and the field prototype a "beta test". However, the field prototype phase not only includes corrections to problems identified in the laboratory test phase, but also includes testing the packaging for the first time.

Approach

During the design and laboratory phases of the project, prospective users (utilities) with a high level of interest in the product should be identified and arrangements should be made with them to host the testing of one or more field prototypes. This may involve setting up a supplemental funding arrangement for them to receive the prototype hardware. The number of field prototypes to be tested depends on the level of customer interest, the complexity of the technology under development, the number of possible applications of the technology in which field prototyping is deemed essential, and the available project budget. The statement of work should describe the test plan in detail. Utility engagement in development of the test plan is essential.

Desired results

The field prototype phase is intended to produce the following results:

- Assure the product is on track to meet the user expectations.
- Get customer input to improve the product.
- Identify problems to be resolved in finalizing the product and packaging for commercial release.
- Engage the users in pre-commercial use of the product. This is intended to encourage them to become early adopters of the commercial version of the product. It will also help identify application and commercialization issues to aid EPRI and any vendor partners in actual commercialization processes.

User Engagement after Product Release

In the past, EPRI engagement in applications after product release has been minimal in most cases. There have been some exceptions. The primary reason for lack of EPRI post-development applications work with users was that the users were unwilling to pay for applications work after the product development was completed. It is desirable to increase the level of applications work at EPRI. Most EPRI staff would like to see increased engagement of both users and EPRI during the commercialization of a product that may have been under development for several years. It is disconcerting to have to hand off the product to an outside vendor and leave it to the vendor to achieve successful engagement with the users after product release. Ongoing EPRI involvement in applications work after commercial release addresses these issues. However, the great challenge to increasing EPRI/user engagement after product release will be to secure the user funding needed to make it happen. Only then, can such post-delivery engagement happen in a significant way. Figure 4-1 illustrates the engagement process schematically.

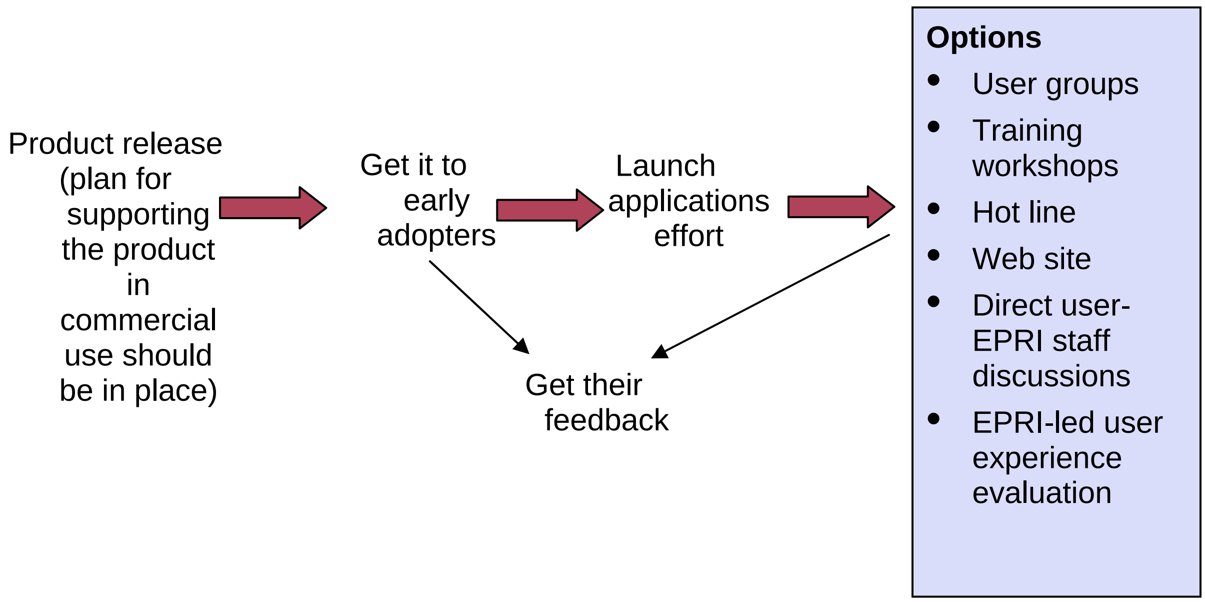

Figure 4-1. Conceptual View of EPRI Involvement in Applications Research for a New Hardware Product.

One goal is to help users see ways to use new EPRI products and to encourage them to adopt them more quickly. Hardware products are usually “handed over the fence” to a vendor for commercialization via a license agreement. It could be an exclusive license to a single vendor or multiple licenses to multiple vendors. It is desirable for EPRI to remain involved with the product after commercial release to encourage use and new applications and to identify needs for next-generation product development. However, there is usually no funding to do so.

The best practice is to have discussions on EPRI involvement after commercial release with the sponsors throughout the product development phase. An effort should be made to identify early adopters and in which applications it would be desirable to try the product first. The EPRI role in the early commercialization should be identified early in the project and well before commercialization begins. A collaborative field experience evaluation research project could be set up to try out the product and share the experience among the participants. The users try the technology in various applications and fund EPRI to develop a shared experience database. This approach has worked in the past. Such field experience evaluations have even been used with non-EPRI products, when there was a group of utilities interested in testing and sharing experiences with a specific new product or family of new products.

Initial Applications Plan for the IUT

With the above background in mind the following initial applications research and development plan is given for the IUT. It will be updated as needed over the project life cycle, based on sponsor need and interest.

IUT User Group

An IUT user group will be organized. The user group will be supported by user group member fees. EPRI will provide leadership of the user group to the extent that the user group members desire. The user group will exists as long as the members deem it necessary and support it. Options will be considered for merging the IUT user group concept with other user groups for other technologies and products developed by the EPRI ADA program and possibly with select non-EPRI technologies where there is synergy and a clear reason to do so.

IUT Applications Development

EPRI will work with the IUT user group and the developer/commercializer to identify new applications for the IUT and to try the technology out in these applications. The experience will be evaluated and the results used to either encourage more use of the IUT in specific applications (where it works well) or to guide the development of the next generation IUT to make it more suitable for these applications (where it does not work well for the current generation IUT).

IUT Field Experience Assessments

EPRI will lead the development of field experience assessments of the IUT in various commercial applications. The performance history of specific IUTs in specific applications will be tracked and reported. Lessons learned will be documented. EPRI has done a considerable amount of this type of work in various technologies over the years. This activity will require not only a sponsorship source for EPRI to do the work, but also IUT users willing to share field data and experiences.

IUT Educational Forums and Technical Publications

EPRI will lead in the organization of educational forums and in writing technical publications for utility engineers and other potential adopters of the IUT to provide outreach activities on:

- Technical understanding of the IUT—what it is, what its functions are, and what its roles in current distribution infrastructure and the distribution system of the future are.
- Interaction of the IUT with other distribution equipment.
- Guidance on distribution design for use of the IUT and integrating it into distribution system operations.

Other support aids, such as a hot line, will also be considered. These activities will be planned and conducted in conjunction with the IUT users group, other IUT interests groups, and even individual utilities. In all cases the group wishing support in these areas will bear the costs.

IUT User Training Workshops

EPRI will lead the organization of training workshops to train utilities who have committed to use the IUT. The aim is to help utilities build the new skills that will be needed to engineer systems with increasing penetrations of IUTs, to install IUTs, and to maintain IUTs. This work will be done working in close coordination with the developer/commercializer. These activities will be planned and conducted in conjunction with the IUT users group, other IUT interest groups, and even individual utilities. In all cases the group wishing support in these areas will bear the costs. In some cases the developer/commercializer will bear the costs as a part of their business development efforts.

IUT Information Dissemination

EPRI will disseminate information via various media such as news releases, web site postings, technical papers, and success story documentation to the extent such efforts are sponsored by the user groups or another source.

Conclusion

The applications research described in this initial plan will require sponsor input to determine which of the activities in it they would like to develop and support. Some of the activities can be started in the latter stages of the development of the IUT, and others would not be started until after commercial release of a product. The ability for EPRI to do any of these things depends on receiving sponsor support. It is expected that EPRI and the developer/commercializer will team in the performance of some of these activities. It is likely that some of the activities (like educations forums) could address multiple ADA products and services and not be solely focused on the IUT, depending on the specific activity.

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