6. Transmission and Distribution[1]

Highlights

- *Through 2020, Ameren Missouri has a total of 13 transmission projects, at an estimated cost of $82.6 million, which have been approved by the Midwest ISO Board of Directors.*
- *Ameren Missouri assumed a $25 billion MISO Multi-Value Project (MVP) system expansion over the next 25 years in addition to the approved reliability and market efficiency projects.*
- *Ameren Missouri has initiated a Voltage Control Pilot Project to enhance operational capabilities and evaluate Conservation Voltage Reduction as an energy and demand conservation measure.*
- *New high-efficiency distribution line transformers may provide cost-effective energy savings beyond new efficiency standards.*
- *Ameren Missouri views the Smart Grid as more of a direction than a destination; this is evidenced by our continuous infusion of technology into the electric grid over the past 30 years – with plenty of work yet to be done.*

Ameren Missouri is continuously maintaining or replacing aging infrastructure in order to provide safe and reliable service. Rapid growth during the 1960s and 70s due to a housing boom and the advent of air conditioning resulted in a replacement of the previous vintage infrastructure and an even larger new system. As growth has slowed over time the infrastructure has not experienced appropriate turnover. This lack of asset turnover means our existing grid is heavily populated with 40-50 year old equipment that is at risk for failure, obsolete, and inefficient compared to modern equipment. Ameren Missouri has proactively begun to address this issue, and plans to make significant investments to replace its aging grid infrastructure to improve overall system reliability and efficiency. In doing so, Ameren Missouri will incorporate cost-effective advanced technologies on an opportunistic basis that provide enhanced energy services and mitigate future obsolescence.

Ameren Missouri has evaluated a range of transmission and distribution options as part of a 2009 End-to-End Efficiency Study[2] performed with the assistance of EPRI. The study helped identify some promising opportunities including Conservation Voltage Reduction, Reactive Power Optimization, and High-Efficiency Transformers. In fact, Ameren Missouri has initiated a Voltage Control Pilot Project to enhance operational

[1] 4 CSR 240-22.040(7)
[2] EO-2007-0409 – Stipulation and Agreement #16; EO-2007-0409 – Stipulation and Agreement #17; 4 CSR 240-22.040(7)

capabilities and evaluate Conservation Voltage Reduction as an energy and demand conservation measure. Many of the conclusions from the EPRI study were based on generic data and therefore need further analysis. However, Ameren Missouri has included 100 MW of peak-time voltage reduction in its capacity planning based on its long history of experimentation with this resource.

Ameren Missouri has a total of 13 projects which have been approved by the Midwest ISO Board of Directors. Nine of these projects are Baseline Reliability Projects which are required to meet NERC TPL reliability standards and have an estimated cost of $58.5 Million. The remaining four projects are needed for a variety of other reasons including generator interconnections, providing supply to new load connections, etc., and have an estimated cost of $24.1 Million. Ameren Missouri also has three projects, totaling over $320 Million, in the Candidate Multi-Value Projects (MVP) list and which would be allocated across MISO according to the approved cost allocation method recently approved by FERC. Ameren Missouri assumed there would be a $25 billion MVP build-out over the next 25 years across the entire Midwest ISO territory, which would effectively eliminate any transmission barriers to wind resources. It is expected that approximately 8% of those costs would be passed on to Ameren Missouri's customers.

6.1 Transmission

6.1.1 Existing System

Ameren Missouri owns and operates a 2,944 mile transmission system that operates at voltages from 345 kV to 138 kV. The system is composed of the following equipment:

- 1,284 miles of 138 kV transmission circuits
- 717 miles of 161 kV transmission circuits
- 943 miles of 345 kV transmission circuits
- 24 extra high voltage substations with a maximum voltage of 345 kV
- 26 substations with a maximum voltage of 161 kV
- 34 substations with a maximum voltage of 138 kV

The system has been developed over many decades to provide reliable and economical transmission of electrical energy from power plants to where our customers work and live.

6.1.2 Regional Transmission Organization Planning

Since 2004, Ameren Missouri has been a member of the Midwest Independent Transmission System Operator, or Midwest ISO, a Regional Transmission Operator (RTO). The Midwest ISO was approved as the nation's first RTO in 2001 and was created as an independent, nonprofit organization that supports the delivery of wholesale electricity in 15 U.S. states and the Canadian province of Manitoba across nearly 94,000 miles of interconnected high voltage power lines. A key responsibility of the Midwest ISO is the development of the annual Midwest ISO Transmission Expansion Plan (MTEP). The MTEP identifies solutions to meet regional transmission needs and to create value opportunities via the implementation of a comprehensive planning approach. The MTEP development process also serves as a mechanism to evaluate and help coordinate the transmission plans developed by Midwest ISO Transmission Owners. This evaluation insures that transmission plans developed by the Transmission Owners are coordinated across the Midwest ISO territory and identify potential alternative solutions that could address multiple system needs. The result of the MTEP process is the compilation of transmission projects that are needed to address system reliability requirements and/or provide specific system benefits as delineated in the Midwest ISO Tariff. These projects are listed and described in the MTEP Appendix A.

The projects in MTEP Appendix A have been reviewed and approved by the Midwest ISO Board of Directors (BOD). Each MTEP document is identified by the year in which it was completed. The MTEP10 document is the culmination of more than 18 months of collaboration between Midwest ISO planning staff and stakeholders. Each MTEP cycle focuses upon identifying issues and opportunities, developing alternatives for consideration, and evaluating those options to determine effective solutions. The primary purpose of the MTEP process is to identify transmission projects that:

- Ensure the reliability of the transmission system.
- Provide economic benefits such as increased market efficiency and resultant lower energy cost.
- Facilitate public policy objectives such as integrating renewable energy.
- Address other issues or goals identified through the stakeholder process.

The MTEP10 Appendix A contains 230 new approved projects located throughout the Midwest ISO territory representing an incremental $1.2 billion in transmission infrastructure investment through 2020. These projects fall into the following five (5) categories:

- **Multi-Value Projects (One [1] project, $510.0 million):** Projects providing regional public policy and/or economic benefits. This project was reviewed and approved by the Midwest ISO Board of Directors on August 19, 2010.
- **Baseline Reliability Projects (37 projects, $94.3 million):** Projects required to meet North American Electric Reliability Corporation (NERC) reliability standards. These standards impact facilities of a voltage greater than 100 kV and represent the minimum standard applied across the Midwest ISO's footprint.

- **Generator Interconnection Projects (Six [6] projects, $6.85 million):** Projects required to reliably connect new generation to the transmission grid.
- **Transmission Service Delivery Projects (Two [2] projects, $3.9 million):** Projects required to satisfy a Transmission Service Request. The costs of these projects are always direct assigned to the requestor.
- **Other Projects (184 projects, $569.9 million):** A wide range of projects, such as those designed to provide local economic or similar benefit but not meeting the threshold requirements for qualification as Regionally Beneficial Project/Market Efficiency Projects, and projects required to support the lower voltage (less than 100 kV) transmission system.

With the addition of the recently approved transmission projects contained in the MTEP10 Appendix A, the total number of approved projects in the Midwest ISO territory is now 613 which represents an estimated investment of $4.7 billion through 2020. When completed, the projects will result in approximately 4,200 miles of new or upgraded transmission lines throughout the Midwest ISO territory.

6.1.3 Ameren Missouri Transmission Planning

Ameren Missouri's transmission strategy is centered upon meeting the changing requirements of our customers and the evolving utility industry. Successful implementation requires our involvement in a multitude of planning activities including:

- Local area planning considering load growth and system development requirements,
- Participation in NERC reliability standards development,
- Participation in SERC regional planning activities,
- Participation in EIPC Eastern Interconnection planning activities,
- Participation in regional generation interconnection evaluations
- Coordination with the Midwest ISO to improve overall regional operations,
- Participation in the Midwest ISO MTEP development process, and
- Engagement with the Midwest ISO on Tariff issues and Business Practice Manual issues.

Our goal with this high level of involvement in these many transmission planning processes is to maintain a reliable and efficient transmission system while meeting the current and future needs of our customers.

Ameren Missouri routinely performs rigorous analyses of the Ameren Missouri system throughout a one- to ten-year planning horizon. These studies consider the effects of system load growth, the adequacy of the supply to new and existing substations to meet local load growth, the selection of sites for new generation resources, the changing regional use of the bulk electric system (BES) and the resulting impacts on the reliability of the Ameren Missouri transmission system. In the event that these studies forecast reduced reliability, additional studies evaluating all practical alternatives are performed to determine what, where and when system upgrades are required. These proposed solutions include applicable new technologies, e.g. Flexible AC Transmission System (FACTS) devices, high-temperature operation conductor, etc., as well as more traditional planning solutions. The total cost for maintaining system reliability is considered for the expansion options.

Ameren Missouri is an active participant in the Midwest ISO annual MTEP development process. We work with the Midwest ISO to coordinate and pursue activities associated with the planning, operation, and maintenance of the transmission system. Participation in the Midwest ISO MTEP process is the method by which Ameren Missouri's local transmission plan is "rolled-up" as a portion of the annual MTEP document and projects included in MTEP Appendix A. The MTEP process provides the opportunity to evaluate regional solutions that may more cost effectively resolve multiple local issues. Through these activities with the Midwest ISO, adjacent Transmission Owners, and stakeholders, Ameren Missouri works to provide a reliable system throughout the Midwest region and to ensure that opportunities for system expansion make sense and would provide the required system benefits while seeking a balance between regional and Ameren Missouri goals.

Ameren Missouri also participates in regional generation interconnection studies for proposed generation interconnections inside and outside of the Ameren Missouri footprint. Ameren Missouri responds to requests for proposals from Midwest ISO and performs studies of proposed generation interconnections to the Ameren Missouri system or alternatively, Ameren Missouri participates in the ad hoc stakeholder groups that oversee these studies. Participation in these activities ensures that the studies are performed on a consistent basis and that the proposed connections are integrated into the Ameren Missouri system to maintain system reliability. Powerflow, short-circuit, and stability analyses are performed to evaluate the system impacts of the requested interconnections. If system deficiencies are identified in the connection and system impact studies, additional studies are performed to refine the limitations and develop alternative solutions.

Ameren MTEP10 Projects (Appendix A)

Ameren Missouri has a total of 13 projects (six new projects in MTEP10 Appendix A) which have been approved by the Midwest ISO Board of Directors. These 13 projects have a total estimated cost of $82.6 Million. Nine of these projects are Baseline Reliability Projects which are required to meet NERC TPL reliability standards and have a total estimated cost of $58.5 Million. The remaining four projects are needed for a variety of other reasons including generator interconnections, providing supply to new load connections, etc., and have a total estimated cost of $24.1 Million. Major projects include a new bulk substation and 161 kV supplies in the Troy area, addition of a second 345/138 kV transformer at Gray Summit Substation and reconductoring portions of the Sioux-Huster 138 kV lines. The complete Midwest ISO MTEP10 document and the list of Appendix A projects that have been approved by the Midwest ISO Board of Directors are available on MISO's website: www.MidwestISO.org. For convenience, the full MTEP10 report is contained in the electronic workpapers as "MISO MTEP10.pdf".

Ameren MVP Initiatives

Ameren Missouri is an active participant in the Midwest ISO initiative to identify major transmission projects which provide broad benefits across the Midwest ISO territory. The projects currently being analyzed are expected to be classified as Multi-Value Projects (MVPs). In order to be classified as an MVP, a project must meet the following criteria as defined in the Midwest ISO Tariff, Attachment FF:

A Multi Value Project must meet one of the three criteria outlined below:

a. Criterion 1. A Multi Value Project must be developed through the transmission expansion planning process for the purpose of enabling the Transmission System to reliably and economically deliver energy in support of documented energy policy mandates or laws that have been enacted or adopted through state or federal legislation or regulatory requirements that directly or indirectly govern the minimum or maximum amount of energy that can be generated by specific types of generation. The MVP must be shown to enable the transmission system to deliver such energy in a manner that is more reliable and/or more economic than it otherwise would be without the transmission upgrade.
b. Criterion 2. A Multi Value Project must provide multiple types of economic value across multiple pricing zones with a Total MVP Benefit-to-Cost ratio of 1.0 or higher where the Total MVP Benefit-to-Cost ratio is described in Section II.C.6 of this Attachment FF. The reduction of production costs and the associated reduction of LMPs resulting from a transmission congestion relief project are not additive and are considered a single type of economic value.
c. Criterion 3. A Multi Value Project must address at least one Transmission Issue associated with a projected violation of a NERC or Regional Entity standard and at least one economic-based Transmission Issue that provides economic value across multiple pricing zones. The project must generate total financially quantifiable benefits, including quantifiable reliability benefits, in

excess of the total project costs based on the definition of financial benefits and Project Costs provided in Section II.C.6 of Attachment FF.

To be classified as an MVP a project must meet additional specific criteria that are also contained in Attachment FF of the Midwest ISO Tariff.

The Midwest ISO and stakeholders are currently analyzing an initial set of transmission projects that have been identified as the Candidate MVP Portfolio. At this time the following transmission projects are included in the Candidate MVP Portfolio that would impact the Ameren Missouri transmission system

- Thomas Hill – West Adair – Ottumwa 345 kV line (105 miles): Expected to be in-service by June 1, 2016 with a preliminary cost estimate of $195 MM. The preliminary cost estimate includes both the Missouri and Iowa portions of the line.
- West Adair – Palmyra Tap 345 kV line: Expected to be in service by June 1, 2018 with a preliminary cost estimate of $100 MM.
- Palmyra Tap – Quincy IL 345 kV line: Expected to be in service by June 1, 2018 with a preliminary cost estimate of $27 MM. The preliminary cost estimate includes both the Missouri and Illinois portions of the line.

These projects will improve the efficiency of the transmission system by reducing losses, enhancing delivery of existing generation, and reducing congestion both within Missouri and between Missouri and the rest of the Midwest ISO. The analysis of these projects is expected to be completed during 2011 with the results documented in the Midwest ISO MTEP11 report.

6.1.4 Cost Allocation Assumptions for Modeling[3]

For modeling purposes, Ameren Missouri assumed the construction of projects necessary for the continued reliable and efficient operation of the transmission system. This included the assumption that the Midwest ISO analysis would determine that the full set of Candidate MVP Portfolio projects meet the criteria to be classified as MVP projects and subsequently would be approved by the Midwest ISO Board of Directors. The costs of MVPs would be allocated per the Midwest ISO Tariff and not be assigned to specific generation projects. Therefore, as the transmission interconnection costs of new generation facilities have been estimated, only the direct transmission interconnection costs have been included by assuming any relevant transmission backbone will be part of the MVPs.

Ameren Missouri assumed there would be a $25 billion MVP build-out over the next 25 years across the entire Midwest ISO territory with the investments hitting customer rates in $5 billion increments every 5 years. Adjusting for known changes in MISO

[3] 4 CSR 240-22.040(6); 4 CSR 240-22.040(3); EO-2007-0409 – Stipulation and Agreement #14

membership, Ameren Missouri's load is 7.85% of MISO load, and Ameren Missouri's generation is 8.6% of MISO generation. It is also assumed 10% of costs will be assigned to generators and 90% of costs will be assigned to load. Overall, Ameren Missouri expects approximately 8% of the MVP costs to be assigned to its customers. For modeling revenue requirement impacts a 16% fixed charge rate was used.

It is noteworthy that the IRP analysis was completed before FERC approved MISO's cost allocation method for the MVP projects in December 2010. The FERC approved method assigns 100% of the costs to the load. In the IRP analysis only 10% was allocated to the generators, and since Ameren Missouri's load and generation share of MISO are similar, the change in method would slightly reduce the amount allocated to Ameren Missouri compared to the assumptions at the time of the IRP analysis. Furthermore, these costs are common to all resource plans and therefore do not affect relative plan performance.

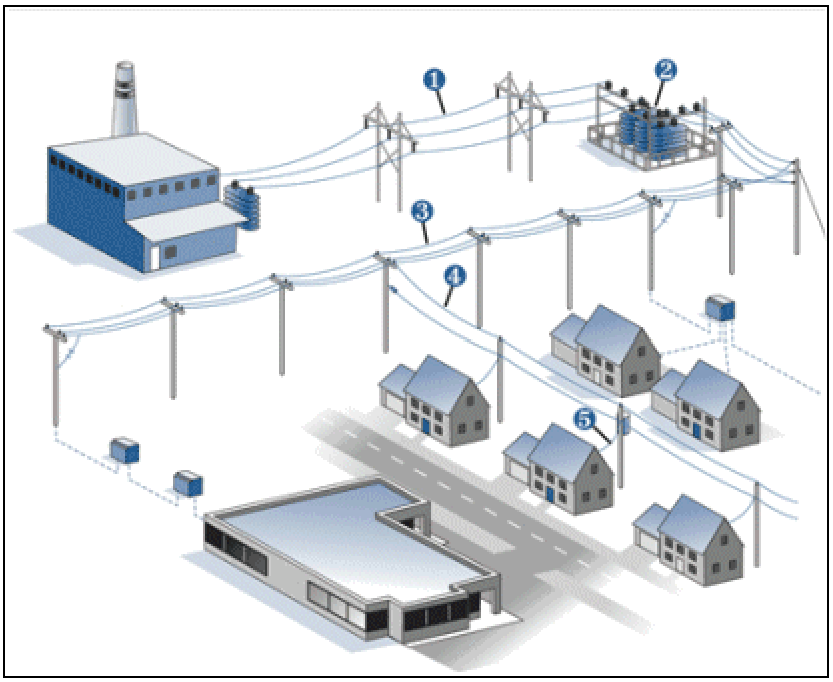
6.2 Distribution

6.2.1 Existing System

Ameren Missouri delivers electricity to approximately 1.2 million customers across central and eastern Missouri, including the greater St. Louis area, through distribution system power lines that operate at voltage levels ranging from 2,400 volts (V) through 69,000 V. Ameren Missouri has 33,000 circuit miles of electric distribution lines, which move electricity into the 63 counties and more than 500 communities where businesses operate and people live.

Approximately 70% of Ameren Missouri's distribution system operates at 12,470 V, 11% operates at 34,500 V and 12% operates at 4,160 V, with the remainder operating at other levels. (See graphic depiction of the Distribution System in Figure 6.1 for further detail.)

Figure 6.1



Here's how the power flows from a power plant to an electric customer:

1. Electricity travels from the power plant over high-voltage transmission lines.
2. At a substation, the electricity's voltage is lowered so that it can travel over the distribution system.
3. Main distribution power lines, typically 3-phase circuits, bring electricity into communities.
4. Local distribution power lines serve neighborhoods and individual customers.
5. Service drops carry electricity from pole-mounted or pad-mounted transformers - which lowers the voltage again - to customer premises.

Much of the distribution system in rural areas is supplied from a single substation source (#2 in Figure 6.1 above) that does not connect to other substation sources. Often, rural areas are supplied by long power lines that may serve several isolated communities. To counteract voltage drop and maintain proper voltage levels along lengthy circuits, the company installs capacitors or voltage regulators.

The distribution system in urban areas typically is interconnected, with customers able to receive power from more than one substation source (#2 in graphic above). At any given point in time each customer is served by a single power source, but by opening and closing switches, the company can re-configure the interconnected system to maintain service to customers via alternate sources and routes when portions must be de-energized to perform maintenance or complete repairs. Capacitors are generally used to maintain adequate voltage levels and power factor.

Finally, a portion of the distribution system is networked, which means customers are continuously connected to more than one source. Examples include the 120/208 V underground distribution network in downtown St. Louis and the 69,000 V network that supplies communities throughout central Missouri, including Jefferson City, Kirksville, Moberly and Montgomery City.

Ameren Missouri's distribution system includes both overhead and underground power lines at the low and medium voltage distribution levels. Underground lines (22% of the total) are more aesthetically pleasing and less vulnerable to weather-caused damage, but they take longer to repair upon failure and are significantly more expensive to install and replace.

6.2.2 System Inspection

Ameren Missouri assesses the age and condition of distribution system equipment with regular inspection, testing and equipment replacement programs, as described below.

Circuit and Device Inspections

Ameren Missouri inspects all distribution circuits (4,160 V to 69,000 V) at least every six years, in compliance with Missouri PSC Rule 4 CSR 240-23.020, to protect public and worker safety and to proactively address problems that could diminish system reliability. The program includes follow-up actions required to address noted deficiencies. Inspections include all overhead and underground hardware, equipment and attachments, including poles. Wooden poles are treated every 12 years as appropriate for purposes of life extension. Inspectors may also measure impedance of the grounding system. Through this program, Ameren Missouri also inspects all line capacitors, reclosers, and regulators on an annual basis. Any inoperable cells are repaired or replaced, helping to ensure optimal power factor system-wide. Ameren

Missouri also replaces a number of transformers each year with higher efficiency units when corrosion, oil leaks or other visually detectable issues occur.

Underground Cable Replacements

Sections of single phase or three phase direct buried cable are replaced when the failure history of the cable or cable section is excessive. Once a cable qualifies for replacement, a local engineer studies its performance, as well as the performance of the lateral on the other side of the “normal open” if it is looped, in order to determine how much cable (if any) will be replaced.

Cables that have failed but do not satisfy any of the criteria also may be replaced based on local engineering judgment, with Ameren Missouri personnel making the case for replacement based on field observations and other necessary investigations.

Substation Asset Management

Ameren Missouri schedules substation maintenance to maximize reliability of equipment, and selectively performs various diagnostic tests to obtain meaningful data to predict and prevent failures. Many tests, such as infra-red scanning to detect abnormal equipment heating, can be performed with the equipment in-service. Corrective maintenance is scheduled largely on the basis of diagnostic data, with the intent of restoring equipment to full functionality. When it is no longer practical to make repairs, old equipment is replaced with new, with an emphasis on efficiency and reduction of losses.

Conversion of Dusk-to-Dawn and Municipal Street Lighting

Ameren Missouri has replaced all mercury vapor lights with more efficient high-pressure sodium lights (or metal halide for color sensitive applications). The company continually monitors the development of more efficient lighting technology and is currently participating in an EPRI test of twelve LED luminaries in St. Louis County. More discussion of this pilot program can be found in Chapter 7 (Section 7.6.5).

6.2.3 System Planning

Ameren Missouri assesses system capacity, efficiency and losses through seasonal distribution system planning studies.

Annual Load Analysis and System Planning Process

Ameren Missouri records summer and winter peak load conditions (power, power factor, phase balance and voltage levels) at bulk and distribution substations. Distribution loads are temperature-corrected to represent 1-in-10 year maximum values using multipliers derived from statistical analyses of historic load data for several types of area load characteristics. Temperature adjustments for bulk substations are derived from historical temperature vs. loading profile curves for each particular bulk substation.

Engineers also calculate bulk substation loads using a power flow computer model that simulates the electric power delivery system. Using temperature-corrected distribution substation loads and current equipment ratings as inputs, the software calculates bulk substation loads. These are compared to temperature-corrected values and used to evaluate what, if any, diversity factors apply at each bulk substation.

After verifying the validity of the system model, engineers conduct seasonal planning studies of winter and summer peak conditions, evaluating worst case single-contingency failure scenarios for all bulk substations, 34,500 V and 69,000 V circuits, distribution substations, and distribution circuits. These studies pinpoint system limitations and enable engineers to identify upgrades required to maintain adequate system capacity. The evaluation of distribution system losses and maintenance of adequate system voltage levels are included in these analyses.

Planning system upgrades to withstand single-contingency outage conditions ensures that load levels will remain within circuit capabilities for such events. Under normal conditions (the majority of the time) individual circuit elements operate at lower load levels with correspondingly lower losses.

An integral part of the entire load analysis process is the establishment of equipment ratings and/or loading limits. Ameren Missouri evaluates transformer and conductor losses as part of the methodology used to establish distribution equipment ratings.

Distribution System Engineering Analyses

The Transformer Load Management (TLM) System relates customers to the distribution transformers serving them, allowing Ameren Missouri to predict transformer peak demand and apparent power from the customers' total monthly energy usages. Ameren Missouri uses this information to analyze distribution circuits and to reduce distribution losses through the more efficient loading of transformers. Additionally, customer meters are automatically read during peak load periods to confirm the transformer peak demands calculated with the TLM system.

EPRI's Distribution Engineering Workstation (DEW) software and Siemens PTI PSS/E software are used to analyze distribution circuits, ensuring reliable, safe, and efficient operation of the distribution system. DEW or PSS/E is used for: load estimation, power flow analysis, protective device coordination, fault current calculation, voltage flicker, phase balancing, and capacitor placement. Both software systems allow engineers to analyze existing, alternate, or proposed configurations for over/under voltages/currents, line losses, appropriate conductor sizing, and optimal capacitor placement.

SCADA (Supervisory Control and Data Acquisition) is used to remotely monitor and control the electric distribution system. Engineers use SCADA data to ensure that system models properly reflect real distribution system conditions, therefore enabling better planning of future system development.

Capital Project Evaluation

Ameren Missouri assesses the feasibility and cost effectiveness of potential system upgrades or expansion projects on an ongoing basis. Although potential capital projects are identified by various operating, engineering and planning personnel, all bulk substation, power line, and distribution substation projects are reviewed by Distribution System Planning prior to consideration for funding.

All projects are compared using the Integrated Spending Prioritization (ISP) tool, an application that evaluates both the costs and benefits of each potential project in order to establish funding priorities. Key to this evaluation is a reliability-based prioritization metric called the Service Availability Cost Factor (SACF) - a calculated index that facilitates ranking projects on a common cost-benefit basis. In its simplest form, SACF represents the cost per unit risk where risk is measured as customer load in kVA multiplied by hours of outage. Cost per kVA-hr saved, then, represents the investment required to avoid an outage to one kVA of customer load for one hour. By giving preference to projects with the lowest SACF scores, Ameren Missouri ensures that system reliability will be enhanced as fully as possible through proper prioritization of capital investments.

6.2.4 System Efficiency

Ameren Missouri regularly pursues opportunities to improve distribution system efficiency through ongoing activities and projects, including those listed below:

Periodic System Loss Study

Ameren Missouri evaluates the efficiency of its overall electric delivery system on a periodic basis by performing a comprehensive loss study. Losses in each portion of the system are calculated under peak load conditions using the computer software noted previously. Loss data from these evaluations are used in ongoing system planning activities and as supporting information for Rate Case Filings.

System Upgrade and Expansion Projects

By their nature, many types of energy delivery upgrade and expansion projects improve system efficiency by reducing load current, I^2R losses, or both. Examples of such projects include:

- Constructing new circuits or rebuilding existing circuits that make use of higher operating voltages, as in the conversion of power lines from 4 kV to 12 kV or the migration toward 138kV-fed distribution substations
- Constructing new circuits or rebuilding existing circuits with larger conductors

- Reconnecting single phase loads on three phase circuits to achieve balanced system phase currents
- Upgrading existing substations or strategically placing new substations to serve areas with increasing load density; and
- Reconfiguring distribution feeders as appropriate when connecting new customers

Reactive Power (VAR) Optimization

Customer loads consume real power (measured in watts), however AC power systems also require reactive power (measured in volt-amperes-reactive, or VARs) to deliver energy. Delivering VARs consumes distribution circuit capacity and can create undesirable levels of voltage drop. Ameren Missouri installs capacitor banks to maintain overall power factor near unity, thereby releasing as much system capacity as practical. Maintaining a power factor near unity reduces the current flows through the system that are necessary to satisfy its real power requirements. This in turn lowers line losses (I^2R losses) and reduces conductor heating, ultimately helping to prolong equipment life.

Because the amount of reactive power that customers need varies with load, a controlled but variable source of VARs enables optimal system performance. Ameren Missouri employs automatic and remotely controlled capacitor banks to stabilize system voltage as loads are cycled on and off. As recommended in the 2009 Ameren Missouri End-to-End Efficiency Study, performed with assistance from EPRI, Ameren Missouri plans to increase its focus on optimizing reactive power flow in the system. The company has budgeted to install a fleet of new capacitor bank controls for deployment from 2011 through 2015. These new controls will replace aging equipment and improve system performance, power factor and distribution system efficiency.

Volt/VAR Optimization Supporting Conservation Voltage Reduction

Because customer electric demand and energy consumption vary in proportion to the supply voltage, distribution system voltage adjustments (narrowing and lowering voltage ranges) can reduce total power consumption.

As noted in the 2009 Ameren Missouri End-to-End Efficiency Study conducted by EPRI, the results of industry Conservation Voltage Reduction (CVR) studies indicate that for every 1% reduction in delivered utility voltage, customer energy consumption may drop as much as 0.6 - 1.0%. Recognizing that CVR should be limited by what can be tolerated operationally by customers, and beyond that has to be limited by the minimum acceptable voltage level allowed by Missouri PSC standards, Ameren Missouri is interested in some controlled experimentation with CVR on its distribution system.

Ameren Missouri has initiated a Voltage Control Pilot Project to enhance operational capabilities and evaluate CVR on selected distribution power lines. Most circuits to be studied are part of a distribution automation project in St. Louis County; others are located in a more rural setting northwest of the metropolitan area. Design and construction of the pilot project are planned for 2011, with operational testing planned for late 2011 and 2012. Potential distribution energy savings, and the costs to achieve them, will be determined upon the project's conclusion.

Loss-Evaluated Distribution Transformer Purchasing

Ameren Corporation currently purchases transformers based on Total Cost of Ownership (TCO), including acquisition cost plus the evaluated cost of no-load and load losses, capitalized over a 30-year life. By purchasing high-efficiency distribution transformers that meet the US Department of Energy efficiency requirements, Ameren will gradually reduce total circuit losses in a cost-effective manner. Ameren conservatively projects an annual demand savings from replacing ~17,000 transformers yearly in Missouri and Illinois of 0.22 MW, and an annual energy savings of 1,634 MW-hrs.

Ameren evaluates the option to purchase high-efficiency, amorphous core transformers as they become available in volumes required. Although amorphous core transformers presently carry an additional purchase premium, the corresponding reduction of no-load losses can lead to a favorable TCO and an improvement in system efficiency to the long-term advantage of rate payers.

6.2.5 Peak Demand Reduction via Voltage Control

For over 20 years, Ameren Missouri has had the ability to reduce demand at selected distribution substations by reducing load tap changer (LTC) voltage setpoints at the time of peak system demand. This is a short-term strategy that has been limited to emergency situations.

As part of Ameren Missouri's alternative resource plan, the company includes 100 MW of demand reduction at the time of system peak. The 100 MW represents current system capabilities and therefore does not include any potential effects of Conservation Voltage Reduction evaluated earlier in this chapter.

Estimating demand reduction due to voltage control begins with identifying substations with appropriate LTC equipment. Ameren Missouri has identified 260 substations capable of implementing voltage control. The magnitude of potential demand reduction has been estimated based on substation demand data gathered from July 2008 through June 2009, a test year used to support weather normalization modeling.

It is estimated that 70% of the summer distribution system peak demand, or approximately 5,400 MW, is served by substations with voltage control capability. Although higher levels of voltage reduction are possible, this study assumed voltage reduction would be limited to 2.5%. Based on Ameren Missouri experience, load decreases by approximately 0.84% for every 1% reduction in voltage. Furthermore, experience indicates not all LTC equipment responds when signaled to reduce voltage. It is assumed that 90% of the equipment will respond properly. On this basis, Ameren Missouri can achieve approximately 100MW of demand reduction via voltage control at the time of system peak.

6.2.6 Distributed Generation

Ameren Missouri does have some interest in distributed generation (DG) as a means of deferring distribution system expansion projects. Potential projects can be analyzed on a case-by-case basis; however, the scope of potential candidates tends to be small. Furthermore, other factors that tend to exacerbate potential DG installations include noise and/or emissions ordinances, operational complexities associated with fuel availability, equipment maintenance, etc., and the fact that traditional system expansion projects usually provide secondary benefits like improving reliability.

Typically customer-owned generation is non-dispatchable; therefore this type of resource is not included when performing load analysis and system improvement justifications. Chapter 7 explores distributed generation as a demand-side resource.

6.3 Smart Grid

6.3.1 Smart Grid Overview

There have been many technological, operational and societal benefits identified in association with the US Department of Energy's vision for the Smart Grid. Ameren Missouri's Smart Grid vision focuses on the continued pursuit of service reliability, operating efficiency, and asset optimization, and on building a secure, robust energy delivery infrastructure as a means of enabling other Smart Grid elements. Among these elements are emerging technologies owned and operated by customers who are motivated by the prospect of becoming more active participants in energy-related decisions.

Ameren Missouri views the Smart Grid as the infusion of technology – communications technology, automation technology, and end-device intelligence – into the otherwise passive system of poles, wires, cables, transformers, switches and meters comprising the electric infrastructure. From a practical standpoint, capabilities like communicating with end devices, controlling them remotely, configuring them to operate automatically, receiving reports back on what they did, and the central control and back office systems necessary to integrate and support these functions, all represent features of an intelligent grid.

Ameren Missouri views the Smart Grid as more of a direction than a destination. Given the digital nature of the technology being referenced by the term and the frequency with which it turns over relative to the more robust hardware it attempts to automate, the Smart Grid will never represent a discrete state of existence that, once arrived at, signals the end of the effort. Simply put – in the same way that few people will ever have their “last” cell phone or their “last” personal computer, the electric grid will likely never achieve what can be considered a “final state” of automation or intelligence.

Ameren Missouri’s current activities in electric infrastructure technology are driven by deliberate and intended benefits associated with its adoption of the Smart Grid. These intended outcomes are summarized below:

Reliability Improvement – Deploy smart technologies across the energy delivery infrastructure in order to improve electric service reliability for Missouri customers.

Efficiency, Optimization and Integration – Improve the operating efficiency and asset optimization of the energy delivery infrastructure and further integrate Ameren’s existing Smart Grid applications, allowing for the flexibility, scalability, and extensibility of these and future applications.

Customer Enablement and Use of Technology – Provide the necessary resources to both prepare the electric grid for emerging customer technologies and enable motivated electric customers in Missouri to make use of those technologies and become more active participants in energy decisions.

Ameren Missouri sees its communication role as one of leading its employees, customers, regulators, and other stakeholders to a greater understanding of Smart Grid concepts, applications, and potential benefits, as well as Ameren Missouri’s specific plans for the future. Internally, Ameren Missouri fosters an environment of continuous learning for leaders and subject matter experts around Smart Grid topics through its participation in pilot installations and research projects, its participation with other utilities and industry groups on the development of Smart Grid concepts and standards, and the engagement of external consultants and industry experts. Additionally, there will be opportunities to partner with property developers and large customers in active demonstrations that showcase Ameren Missouri’s Smart Grid applications.

6.3.2 Ameren Missouri's Smart Grid Plan

6.3.2.1 Reliability Improvement

Automated Switching Applications

Ameren Missouri's strategy for automating subtransmission circuits (34kV and 69kV) is to install smart switching devices in order to limit the load dropped due to a single line contingency to 10 MVA or less in those cases where the existing circuit topology supports the restoration of unfaulted line sections to an alternate or paralleled source. Up to 200 automated switches could be required in addition to the 220 already in service to fully deploy on this strategy over the next 10-15 years.

Ameren Missouri's strategy for automating 12kV distribution circuits is to install smart switching devices at 12kV (at least one bisecting the feeder backbone and at least one tying it to a different feeder) in order to limit the load dropped due to a single line contingency to roughly half the feeder's peak load or less in those cases where the existing circuit topology supports the restoration of unfaulted line sections to a different feeder. Up to 1,600 automated switches could be required in addition to the 160 already in service to fully deploy on this strategy over the next 20-25 years.

Ameren Missouri plans to deploy on these smart switching strategies annually by circuit, substation, or group of adjacent substations as appropriate, according to the greatest combined customer density and potential reliability improvement for the cost. Substation and circuit candidates for switching solutions are identified through the standard annual contingency analysis studies conducted, as well as through periodic reliability reports of worst-performing feeders, worst performing high customer-density substations, etc.

Smart Substation Technologies

For many years Ameren Missouri has been building substations that are considered "smart" by today's standards. As a means of ushering in the next generation of substation intelligence in the industry, Ameren Missouri is incorporating combinations of winding temperature sensing, bushing power factor monitoring, water and dissolved gas content monitoring, and multi-function temperature sensing into the standard design of capital substation projects. These projects include the construction or re-build of entire substations as well as the installation or replacement of substation transformers. Additionally, mobile substation transformer purchases going forward will feature a combination of these types of sensors.

Industry data indicates that over the long term, the capture and trending of substation transformer diagnostic sensor data can reduce substation outage events due to unforeseen transformer failures and extend the average operating lives of these large assets. The premium for the sensing technology involved is less than 5% over all construction scenarios. Ameren Missouri plans to install this sensor technology on substation transformers over time as an integral part of its capital substation projects going forward, including those undertaken for reasons of load growth, reliability upgrade, or condition-based maintenance.

Ameren Missouri's strategy for substation relaying is to upgrade up to ten transmission terminals (above 100kV) annually to microprocessor-based relaying from the existing electromechanical and solid state technologies, based on a current population of 350 terminals and an estimated protection system design life of 30 to 40 years. Ameren Missouri also plans to upgrade up to four subtransmission network terminals (69kV) annually based on a current population of 90 terminals.

A single microprocessor relay package combines the functionalities of several pieces of legacy equipment, resulting in fewer points of failure and less control wiring. Self-diagnostic checks remotely alert personnel of their own operating condition, reducing the need for periodic maintenance and allowing for intervention before failure or misoperation occurs. Trip check maintenance is also greatly simplified, further reducing periodic maintenance.

The current plan is to have electromechanical and solid state relays extinct from Ameren Missouri's transmission system in the next 10-15 years. Ameren Missouri plans to convert as many of these as possible in association with other substation expansions, line maintenance activities and remote terminal upgrades. The remainder will be converted programmatically based on obsolescence, with priorities placed on relays found inoperable during routine maintenance followed by those with histories of uncorrectable misoperations.

6.3.2.2 Efficiency, Optimization, and Integration

Multi-Layered Network Architecture

Currently several isolated and overlapping networks are operating today in support of AMR meters, radio-controlled line capacitors, substation SCADA and automated switching, none of which is sufficient for the long-term expansion and widespread use of intelligent end devices. It's anticipated that more capacity will be required for ultimate end device populations in the tens of thousands, and more speed could be required to support large file transfers from remote diagnostic sensors in substations.

In response to this Ameren Missouri has developed and is deploying a multi-layered network architecture intended to support existing smart applications and enable future applications – a Wide Area Network (WAN) backbone for backhauling large amounts of field application data, Local Area Networks (LANs) for aggregating intelligent end device data (typically at substation locations), and Field Area Networks (FANs) for supporting communication with field end-devices beyond and downstream from the substation.

Ameren Missouri is developing a WAN that leverages various industry-proven transport systems such as fiber, digital microwave, and common carrier leased services, and likely features a mix of private and non-shared public infrastructure of either a wired or wireless nature. WAN infrastructure additions over time will focus on the connection of substations and other key network entry points, the delivery of information to the control center(s), and the application of necessary security layers throughout the network architecture.

Ameren Missouri is deploying LAN technology over time at substations as their specific locations are identified as effective aggregation points for planned feeder deployments of intelligent end devices like automated line switches, capacitors and regulators. Since these devices are being deployed on the distribution system by circuit or substation, the already owned or leased substation site becomes the preferred choice for this aggregation. Targeting these deployments at “smart” substation sites also allows for communications consolidation and maximizing the impact of the LAN infrastructure investment.

In some areas of the Ameren Missouri service territory the FAN will feature a radio frequency (RF) mesh network that is both self-organizing and self-optimizing, dynamically routing data communications amongst a diverse set of paths that wirelessly interconnect multiple end devices. In other areas, the FAN will feature a more traditional point-to-multipoint RF network or a cellular-based alternative, depending on the application and its inherent reliability and latency requirements. Ameren Missouri plans to adopt the use of intelligent end devices with open architectures as endorsed by National Institute of Science and Technology (NIST) standards, regardless of the smart applications involved and the other technology choices made.

Advanced Distribution Management System (ADMS)

Ameren Missouri is implementing an Advanced Distribution Management System (ADMS) as a means of providing an integrated suite of software applications with which to manage the electric distribution system. It is a highly integrated system of applications that provides distribution system operators a common user interface with which to monitor and control the distribution system on a daily basis. It not only replaces existing applications like outage management, switching orders, and Supervisory Control and Data Acquisition (SCADA), it features new applications such as dynamic circuit modeling, switching and restoration simulations, and a distribution system dashboard.

ADMS is foundational to future Ameren Missouri Smart Grid planning since it enables advanced applications that rely on the integration of functions formerly separate and distinct. In addition, ADMS allows for growth and scalability that is not feasible on the current platforms in use and provides the flexibility to add and integrate future applications. Current Ameren Missouri plans call for the ADMS platform to be implemented by the end of 2012.

Supervisory Control and Data Acquisition (SCADA)

Ameren Missouri's strategy for substation supervisory control and data acquisition is to programmatically introduce remote load monitoring at existing substations lacking such capability, for purposes of improving daily operations and facilitating the long-term planning of substation assets. Remote outage detection and supervisory control features will be introduced at existing substations lacking such capability on an opportunistic basis in association with other capital projects.

Ameren Missouri's 30+ years of experience in this area has shown that continuously updated load information on substation components can defer or eliminate previously justified capital projects, quickly identifies unforeseen overloads, releases capacity by allowing for daily operation closer to margin, and greatly enhances outage restoration activities. Remote metering also enables automatic transfer capability in smart switching applications and enables feeder level optimization via phase balancing and the operation of line capacitors. Supervisory control of switching devices further enhances operations by allowing for real-time outage notification and immediate intervention by dispatchers in restoration scenarios.

Of Ameren Missouri's 525 distribution substations, there are approximately 190 without remote metering capability. Ameren Missouri's plan is to upgrade a prescribed number of these substations annually on a programmed basis according to the preferences of operating and circuit planning entities, and align these upgrades as appropriate with smart switching and smart capacitor deployments that are planned on associated feeders.

There are approximately 250 Ameren Missouri distribution substations without outage detection and supervisory control capability. Ameren Missouri's plan is to convert these substations opportunistically over time as other capital projects are undertaken to replace their switching devices.

Capacitor Control and Volt-VAR Optimization

Smart line capacitor operation has helped Ameren Missouri maintain a consistent 98% distribution system power factor over the last twenty years. However, the capacitor control technology available today allows for feeder level efficiencies and degrees of optimization that were never before possible. The use of Volt-VAR Optimization as an advanced distribution system application not only helps achieve these levels of efficiency and optimization, but also more effectively controls customer end-use voltages, and more reliably supports the reactive requirements of the transmission system. Ameren Missouri's intent is to leverage new ADMS system capabilities to integrate substation load monitoring with "smart" line capacitor operation for the first time in order to achieve these goals.

Ameren Missouri's first step as part of this automation strategy is the deployment of the next generation of "smart capacitor" technology on the distribution and subtransmission systems. Ameren Missouri will leverage the need to replace the existing 25-year old line capacitor control system in operation today in the St. Louis metro area for this deployment. To this end, all 2,300 of these capacitor controls will be upgraded over an accelerated period of five years due to the unavailability of legacy controls and the fact that no other hardware replacements are necessary as part of these upgrades.

Additionally, Ameren Missouri will be installing "smart" capacitors in place of the remaining 1,100 non-fixed units in the service territory. This deployment will take place over time by circuit, substation, or group of adjacent substations, coincident with the deployment of automated switches in order to maximize the associated communications investment.

After ADMS is implemented, Ameren Missouri will begin controlled experimentation with Conservation Voltage Reduction (CVR) as an energy and demand conservation measure. This will take place on a substation (or substation unit) basis as its distribution feeders are outfitted with "smart" capacitors and as degrees of voltage flattening and power factor optimization are confirmed. As Ameren Missouri validates the CVR application over time, consideration will be given to expanding it over wider areas of the service territory and over different times of day and seasons of the year. As this application is enabled with the ADMS platform and matures, more programmatic approaches can be adopted.

Dynamic Transmission Equipment Ratings

The daily transmission interchange activity generated from Ameren Missouri's geography and high degree of national grid connectivity results in its transmission facilities experiencing wide load swings all year round as opposed to just seasonally. The periodic recalculation of transmission equipment ratings based on the combination of equipment sensor outputs and meteorological data improves daily operations and solidifies contingency plans amidst heavy MISO and interchange sales activity.

In support of this, Ameren Missouri plans to outfit transmission substation transformers with comprehensive analysis monitors as a supplement to the winding temperature, bushing power factor, and dissolved gas sensors also being deployed, for purposes of using their outputs to dynamically rate these units. This will be incorporated into the standard design of capital projects involving the construction or re-build of entire transmission substations as well as the installation or replacement of transmission substation autotransformers.

Ameren Missouri is also expanding the existing Phasor Measurement Unit (PMU) footprint on its transmission system to provide for more seamless operation across Regional Transmission Operator (RTO) boundaries. PMUs are high-resolution voltage, current, and frequency monitors outfitted at strategic locations on the transmission system. PMUs sample these electrical parameters many times a second, enhancing wide-area situational awareness for Transmission Operators and offering a more dynamic visibility into and synchronization with the rest of the nation’s grid.

Ameren Missouri was able to negotiate with MISO for participation in its DOE-funded investment grant project, in which PMUs will be added at four Missouri system locations – Labadie Power Plant, Sioux Power Plant, and the Montgomery and Kelso transmission substations.

6.3.2.3 Customer Enablement & Use of Technology

AMR (Automated Meter Reading) vs. AMI (Advanced Meter Infrastructure)

Ameren Missouri will continue to evaluate the cost-effectiveness, timing, and applicability associated with a migration to Advanced Metering Infrastructure (AMI) technology from the Automated Meter Reading (AMR) technology currently deployed. Initial investigation indicates a full conversion to AMI would cost approximately $300 million with an additional annual operating cost of $10 million. Table 6.1 supports Ameren Missouri’s position that most of the operational benefits of AMI are already being realized with the AMR system currently in operation. The few exceptions include two-way communication, remote connect and disconnect capability, remote meter programming, and advanced support for demand-side resources.

Ameren Missouri believes that today the benefits of an AMI conversion do not outweigh the costs. However, Ameren Missouri has been following AMI industry trends as well as exploring options for providing energy usage and pricing information to interested customers through means other than “smart” metering. Ameren Missouri is also tracking the degrees of success and ancillary issues associated with other utilities’ deployments of “smart” meters around the country as a means of keeping current.

Table 6.1 Comparison of AMR vs. AMI Functionality

Feature/Functionality	AMR	AMI
Automated meter reading	✓	✓
Demand metering	✓	✓
Time-of-use metering	✓	✓
Interval data collection	✓	✓
Two-way communication	✗	✓
Demand response & critical peak pricing (15min)	✓ (Limited)	✓
Demand response & critical peak pricing (TOU blocks)	✓ (Limited)	✓
Home area networks/in-premise connectivity	✓ (Limited)	✓
In-home control of "Smart Appliances"	✓ (Limited)	✓
Outage management	✓ (Limited)	✓ (Limited)
Remote connect & disconnect	✗	✓
Revenue protection, theft detection	✓	✓
Asset monitoring/distribution automation	✓	✓
Prepaid metering	✓ (Limited)	✓
Online energy management	✓	✓
Automated load cycling or limiting	✓ (Limited)	✓
Improving customer service/satisfaction	✓	✓
T&D asset optimization	✓	✓
Future products/service offerings	✓ (Limited)	✓
Workforce optimization	✓	✓
Remote meter programming	✗	✓
Detection of meter problems and wiring errors	✓	✓
Improved locating of orphan meters	✓ (Limited)	✓ (Limited)

Note: *"Limited" designates ability to provide the functionality with work-arounds and additional capital*

Emerging Customer Technologies

Ameren Missouri continually follows the advancements and industry trends associated with emerging customer-owned products and technologies, especially as they influence the planning around their eventual penetration on Ameren's distribution system – these include electric vehicles, small-scale distributed generation and energy storage, smart appliances and Home Area Networks.

Ameren Missouri has taken a particular interest in the emergence of electric vehicles and is currently investigating opportunities for contributing to the region's overall preparedness. Ameren Missouri is studying the potential penetration of electric vehicles in the service territory and the resultant impact of vehicle charging on the distribution system. We are identifying the various business models possible in association with electric vehicles, including the utility interface, ownership of charging stations, and possible rate structures associated with charging of these vehicles at home, at work, and in public places.

Ameren Missouri is also participating as a corporate member of the St. Louis Regional Clean Cities Plug-In Readiness Task Force as a means of following the initial discussions around being plug-in ready and identifying possible community partnering opportunities for technology promotion. Internally, Ameren Missouri is taking receipt of four PHEV bucket trucks in 2011 associated with an EPRI Demonstration project and is making arrangements with vehicle manufacturers for the early acquisition of EV/PHEV sedan models they plan to launch in Missouri. These activities are being pursued as a means of self-education and preparation for the energy advisor role Ameren Missouri is expecting to assume in this area with inquiring customers. Ameren Missouri is likewise taking active steps to render its own campus and operating centers plug-in ready, both for the sake of its growing electric fleet and its early-adopting employees.

AMI Impacts on DSM Programs

Integration into an AMI system allows DSM programs to communicate with the customer or their HAN (home area network) over one consolidated infrastructure, reducing the cost of program administration, marketing, and implementation. Without the AMI system, DSM programs will need to establish their own data infrastructure and their own method of communicating to customers; be it RF, pager, Internet, or other; thus reducing program cost-effectiveness. The particular DSM programs that would stand to benefit are Demand Response programs and Direct Feedback Energy Efficiency programs that involve an in-premise display device. It should be noted that these additional cost savings have been incorporated into the AMI evaluation. In addition, the demand-side analysis detailed in Chapter 7 includes an assumption of full AMI deployment starting in 2015.

6.4 Compliance References