6.0 DISTRIBUTION SYSTEM ACTIONS

Reduction in GHG emissions through improved electric distribution systems is a worthwhile goal. As electric service is extended into every home and business in the world, the efficiency of the distribution network takes on a greater impact as a contributor to GHG emissions.

In a well-run system, total transmission and distribution system losses are on the order of 9%, and of this 2-3% are in the distribution system. In the developing world equivalent numbers are total losses of 15% and distribution losses in the 5-7% range. Given the immense number of kilometers of electrical conductors installed throughout the world it is clear that if electric resistance losses can be reduced by even a portion of one percent then there will be a dramatic impact on the total amount of generation, and subsequently GHG emissions.

Distribution system reliability and quality of service also play a role in GHG reductions. Consumers will adopt alternative energy strategies when distribution reliability is poor. When alternatives include small generators driven by internal combustion engines, then there will be a contribution to GHG. The contribution is all the more dramatic when a non-polluting generation source, such as hydropower, is replaced by an internal combustion engine.

This section presents a collection of discussions about basic technical segments of electric distribution technology. GHG effects are directly related to reduction in electrical resistance losses. However, there are also significant improvements that can be accomplished through improved reliability and quality of service.

6.1 REDUCTION IN REACTIVE POWER LOSSES

CHARACTERISTICS

The use of electric motors requires that the distribution system deliver a form of power known as "reactive power". This is generally not a problem for residential power distribution, due to the limited number and small size of motors. Commercial and industrial users often require large quantities of reactive power, which increases current and energy losses. Connecting capacitors to the distribution system compensates for the reactive power, and reduces current and energy losses back through the system, since transmission losses are related to current and line resistance.

When reactive power-related losses are minimized, generation demand and the corresponding GHG emissions are reduced.

SIZE: Power factor correction capacitors for application on primary distribution feeders are commercially available for use on the full range of voltage levels and in practical kVAr sizes.

FEATURES: Power factor correction capacitors can be installed with switches and relays that sense low and high voltage. The insulating fluid used in early capacitors contained PCB, but new insulating fluids are now in use.

COST: The cost of power factor correction capacitors installed on primary distribution feeders in close proximity to low power factor loads is in the range of $12-20 per kVAr.

CURRENT USAGE: Power factor correction capacitors are in common use on primary distribution systems through out the world.

POTENTIAL USAGE: Every utility can benefit from installing more efficient capacitors.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Customers are reluctant to correct their own power factor, especially where rate tariffs do not allow a penalty for large users.
- Possible negative impacts on power quality.
- Energy loss reductions alone do not offset the capital costs of required new equipment.
- There are operating and maintenance (O&M) costs associated with many dispersed capacitor installations, and failure of accessory (fuses, switches, etc.) equipment is common.
- The VAR control function can be optimized under the Distribution System Automation Option.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- When losses are reduced, GHG emissions are also reduced due to the accompanying reduction in demand for generation.

EMISSION ESTIMATE: Varies according to the fuel mix used in generation.

COST-EFFECTIVENESS: Total losses of 9% are attributable to transmission and distribution from the point of generation to the point of use. From 2-3% of the total can be assigned to losses in feeder conductors and transformers.

SECONDARY EFFECTS: Varies according to the generation fuel mix.

RESOURCES

- The U.S. Department of Energy sponsors a *Real Time System Control Program*, that awards contracts to utility consultants, manufacturers and universities.

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6.2 UPGRADING AND AUTOMATION OF DISTRIBUTION INSTRUMENTATION AND CONTROLS

CHARACTERISTICS

Distribution automation refers to a system that enables an electric utility to remotely monitor, coordinate and operate distribution components in a real-time mode. Automation components include remote switch control, integrated volt-var control, service restoration, feeder configuration, trouble call, fault location and isolation, load checks and safety checks. Customer automation options include remote metering, load control, load shedding and shaping, economic operation, cold load pickup, remote connect/disconnect, trouble call and tamper detection.

Together, these services help optimize line power flow and increase system efficiency (and reduce cost), which reduces generation demand and the emission of greenhouse gases, while providing the same level of service.

Work on superconducting technology (and other products) is underway that is expected to further increase efficiency of distribution controls.

SIZE: The most widely-used distribution voltages are 12.47, 13.2 and 13.8 kV although complete range is from 4.16-34.5 kV. A primary distribution system uses transformers that step the primary distribution voltage down to voltages in the range of 120-600V.

FEATURES: Automation components include remote switch control, integrated volt-var control, service restoration, feeder configuration, trouble call, fault location and isolation, load checks and safety checks. Design lifetime of transformers is 30 years.

COST: Varies with the voltage (higher voltage systems are more expensive). Cost of developing communications systems is relatively expensive.

CURRENT USAGE: In the U.S. and other countries, a number of companies have automated their distribution systems.[1]

POTENTIAL USAGE: Automated distribution systems can be used in every country.

[1] The Karnataka Electricity Board (KEB) has a pilot Distribution Automation project to improve energy efficiency in its 192,000-mile distribution system. This pilot will use automatic control hardware including a complete line of capacitor controls and a state-of-the-art auto-reconfiguration system for automated switching requirements. KEB anticipates that automating distribution will make significant contributions to KEB's operating efficiency.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Conventional utility accounting may not justify implementing a distribution automation system.
- There is a high cost associated with developing the required communication system, together with the equipment and electronic database maintenance. However, as communication systems and distribution automation hardware costs decrease, expansion of distribution automation systems will become increasingly viable.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Distribution (and transmission) do not directly produce carbon emissions, but indirectly impact GHG emissions.

EMISSION ESTIMATE: Varies according to the fuel mix used in generation.

COST-EFFECTIVENESS: N/A

SECONDARY EFFECTS: Varies according to the generation fuel mix.

RESOURCES

- Several U.S. utilities have undertaken projects to improve distribution systems. More information on their projects is available in the U.S. Department of *Energy Climate Challenge Options Workbook. http://www.eren.doe.gov/climatechallenge/*
- The Electric Power Research Institute is sponsoring a research project to address distribution system impacts of dispersed energy systems and technologies.
- EPRI has prepared *Guidelines for Evaluating Distribution Automation* to assist firms in determining the costs and benefits of various automation options for distribution systems. More information is available at *http://www.epri.com/pdg/products/.*
- Tepel, R.C. et al., 1987, *Customer System Efficiency Improvement Assessment: Supply Curves for Transmission and Distribution Conservation Options*, Battelle Pacific Northwest Laboratory, PNL-6076.

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6.3 REDUCING CONDUCTOR LOSSES

CHARACTERISTICS

Losses in distribution feeder conductors are the result of current flow through electrical resistance of the conductors. The resistance a conductor offers to the flow of electricity is inversely proportional to its cross-sectional area — i.e., the larger the diameter of the conductor, the less resistance the current will encounter.

Resistance is also a function of the type of material of which the conductor is made. Thus, by replacing a conductor with one of a larger diameter or changing to a material that offers less resistance, power loss can be reduced when the same current is flowing through the conductor. Lower resistance losses will reduce generation and decrease GHG.

Distribution feeder losses can be minimized by upgrading existing feeders with larger-size conductors, reconnection of customers, and sectionalizing feeders with switching. On single phase systems there is also a need to balance loading among the three phases. Segmenting shield wires can also eliminate losses associated with loop flows through this path.

SIZE:	Conductors are aluminum and range in size from 35-240 sq.mm., and operating voltages range from 2,400 Volts to 69 kV.
FEATURES:	Distribution feeders can be overhead or underground. Overhead distribution uses aluminum conductors; cables use either copper or aluminum.
COST:	Costs to upgrade vary according to size of conductor, type of feeder (overhead or underground) and length. Feeder construction costs can vary from $15,000-50,000 per km.
CURRENT USAGE:	Feeder loss reduction is a regular part of distribution system operation and maintenance.
POTENTIAL USAGE:	With distribution automation, demand-side management, and time-of-use pricing there will be more sophisticated methods by which feeder resistance losses can be controlled.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Requires accurate load information and estimates of type and number of consumer connected. Installation of demand metering on primary distribution feeders is a necessary data source.
- A modular standard approach to feeder design is essential — this necessitates use of computer software to optimize feeder sectionalizing
- Reconductoring existing lines is generally only cost-effective when a thermal capacity increase is needed, but existing load flow models or regional models for economic evaluation of conductor losses can be developed.
- Pole, tower, and cross arm strength are a concern for existing lines. Most distribution

facilities are built and designed to the size of the conductor on the line. A larger conductor adds greater windage, weight, and ice loading levels which may exceed the design capability of the tower equipment. Therefore, in many cases, increasing the line capacity requires a complete rebuild of the line, not just reconductoring.

- Environmental permitting can be extensive, especially where structure rebuilding is necessary. Environmental regulations are often unclear for this type of project. Lengthy permitting processes and costly conditions in permits may preclude consideration of or implementing a reconductoring project. Examine ways to clarify and simplify environmental permitting, taking into account the advantages of using an existing transmission corridor and the fact that line losses would be reduced.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Avoids the emission of greenhouse gases indirectly by reducing generation demand.

EMISSION ESTIMATE: Varies according to the fuel mix used in electricity generation.

COST-EFFECTIVENESS: Total losses of 9% are attributable to transmission and distribution from the point of generation to the point of use. From 2-3% of the total can be assigned to losses in feeder conductors and transformers.

SECONDARY EFFECTS: Varies according to the generation fuel mix.

RESOURCES

- Institute of Electrical and Electronics Engineers, 1992, *Tutorial Course: Distribution Planning*, PES publication 92 EHO 361-6-PWR.
- Institute of Electrical and Electronics Engineers Computer Application, 1995, *Distribution Engineering Tool Features a Flexible Framework*, Power Magazine, (July), pp.21-24.

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6.4 INSTALLING MORE EFFICIENT TRANSFORMERS

CHARACTERISTICS

Transformers are the devices that change the voltage of an AC electric circuit. They are most commonly used to reduce the voltage from the distribution level of 4-69 kV to the level required by the customer. However, whenever the transformer is energized, regardless of load, an electrical loss known as "core loss" occurs. Of the 9% total losses attributable to transmission and distribution from the point of generation to the point of use, 2-3% of the total can be assigned to losses in feeder conductors and transformers.

There are significant numbers of distribution transformers in the electricity supply system. The minimization of core and winding losses through the use of more efficient transformers reduces generation demand and the emission of greenhouse gases.

Significant advances have been made in reducing core losses, through improved manufacturing and treatment of steel cores, and through the development of amorphous metals (including steel). Decrease in winding loss, which is a function of the transformer load, is also possible.

SIZE: 5 kVA to 500 kVA single phase distribution transformers and 15 kVA to 1,500 kVA three phase distribution transformers.

FEATURES: Most commonly used is the oil-filled transformer, transformers are installed on poles, in surface level distribution centers and in underground vaults. Design lifetime is 20-30 years.

COST: Distribution transformer costs vary from $10-25 per kVA. Maximum efficiency designs may not be the most economic, since increasing the efficiency usually results in an increase in capital cost of the transformer.

CURRENT USAGE: Conventional transformer designs are based on steel core oil filled transformers.

POTENTIAL USAGE: Development of amorphous core distribution transformers offers the prospect for reduced excitation losses.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- The high cost of new transformer equipment may not be offset by the reductions in energy loss.
- There is only one supplier of amorphous core material (in the U.S.).

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Produces no carbon emissions directly, but more efficient operation will reduce demand for electricity.

EMISSION ESTIMATE: Varies according to the fuel mix used to generate electricity.

COST-EFFECTIVENESS: Depends on the size of transformer. The most efficient size may not be the most cost-effective size.

SECONDARY EFFECTS: Varies according to the generation fuel mix.

RESOURCES

- The Electric Power Research Institute (EPRI) has sponsored a study as part of which Minnesota Power has installed 25 amorphous core distribution transformers. Another EPRI collaborative research project with Potomac Electric Power Company to demonstrated a cooling design for forced-oil/air-cooled transformers with advanced winding technology involved installation of a low loss transformer at a distribution substation in 1994.
- Approximately 55% of the distribution transformers purchased by the New England Electric System in 1993 were of the amorphous core design.
- The U.S. Environmental Protection Agency sponsors an *Energy Star Transformer Program*, whose participating utilities agree to purchase qualifying transformers and to institute early replacement where economically warranted.
  http://www.epa.gov/appdstar/transform/utility.html

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6.5 REDUCING FORCED OUTAGES AND STABILIZING LINE VOLTAGE

CHARACTERISTICS

Electric energy is supplied to customers at a utilization voltage that is maintained within prescribed limits to insure proper operation of customer equipment. Maintaining the voltage as close to the standard as is practical controls electrical losses and contributes to improved system efficiency. Careful engineering of distribution system components and the use of voltage-regulating equipment are required. Connecting single-phase load in a careful way eliminates losses associated with residual current flow. These reductions in distribution system losses in turn reduce generation demand and GHG emissions.

SIZE: Applicable to all voltages.

FEATURES: Voltage regulation is accomplished by adjusting the turns ratio of transformers and by the control of reactive power. Automatic control of transformer taps and shunt capacitors and shunt reactors can be accomplished with Supervisory Control and Data Acquisition (SCADA) and automation systems.

COST: The cost of the voltage control function is bundled into the overall cost of SCADA and automation systems.

CURRENT USAGE: Power factor control capacitors are installed on primary distribution feeder circuits.

POTENTIAL USAGE: Advances in distribution automation will allow improved control over voltages on distribution feeders.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Voltage regulating equipment has high capital costs, and increases the equipment operating & maintenance costs. Savings due to energy loss reductions may not offset the costs of new equipment or replacement of existing line and terminal components; voltage upgrades are generally only cost-effective when done to increase capacity.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Reducing distribution system losses reduces generation demand and GHG emissions.

EMISSION ESTIMATE: Varies according to the source of electricity generation.

COST-EFFECTIVENESS: Improved reliability means that consumers will not use GHG producing alternative energy sources.

SECONDARY EFFECTS: Improved reliability through reduction in forced outages will have a secondary benefit in the form of fewer hours of lost production and a higher quality of life for customers.

RESOURCES

- The National Rural Electric Cooperative *Association Closed-Loop Voltage Control Project* (RER #91-8) led to the development of a new system to control voltage regulators remotely, achieving a better voltage profile on distribution feeders.
- National Rural Electric Cooperative Association, 1991, *The Distribution System Loss Manual*.

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6.6 DISPERSED ENERGY STORAGE SYSTEMS

CHARACTERISTICS

The integration of dispersed generation, particularly renewable energy technologies that are intermittent generators (i.e., solar and wind power) is facilitated by dispersed energy storage systems. Energy storage systems use electricity during non-peak hours or from intermittent sources to convert water to ice or chilled water (for cooling), or to store energy in batteries. During peak periods, this stored energy can be converted back to electricity for use.

The use of these systems, in addition to filling the traditional role of meeting peak demand needs, increases overall system efficiency and reduces total system losses. A reduction in generation demand and GHG emissions results. The utilization of dispersed energy storage systems also reduces GHG emissions by allowing greater use of local low- or non-carbon fueled generation systems at the local level.

Use of dispersed storage systems will enable utilities to lower costs through deferrals of upgrades and new construction, supply new generation to customers, and improve reliability. The use of dispersed energy storage systems throughout the distribution system will improve dynamic operating capabilities and asset utilization, allowing existing generation to function more efficiently and improve the overall efficiency of the system. Emerging energy storage systems, which can be dispersed throughout the distribution system include batteries, flywheels and superconducting magnetic energy storage (SMES).

SIZE:	Uninterruptible Power Supplies and other forms of disbursed storage and generation range from a few kilowatts to several hundred kilowatts.
FEATURES:	Chilled water or battery storage systems
COST:	Installed costs of such units must be competitive with the low end of alternative forms of supply with installed costs under $450 per kW.
CURRENT USAGE:	Many companies are using dispersed energy storage systems. For instance, the U.S.-based Southern Company will begin to use dispersed energy storage (with a number of other T&D system upgrades) and expects to reduce distribution losses by about 15,000 MWh per year by the year 2000.
POTENTIAL USAGE:	Development of these systems is key to successful and widespread deployment of renewable energy systems.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Dispersed energy storage equipment has a high capital cost, and low energy capacity is available from existing dispersed storage technologies.
- Energy storage systems dispersed throughout the system may require additional dispatch and control systems.

- There is a lack of planning practices that fully assess the value of dispersed storage and generation.
- Dispersed resources may not all be under the ownership of a single company. This poses challenges in the control, protection, operation, and maintenance of distribution systems.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Unless the source of power to charge storage devices is non-carbon fueled generation, use of storage would actually increase, not decrease, emissions of greenhouse gases as the overall efficiency of a generator and a storage device is lower than the straight generator itself.

EMISSION ESTIMATE: Varies according to fuel source of the charging device.

COST-EFFECTIVENESS: N/A

SECONDARY EFFECTS: Varies according to the fuel source of the charging device.

RESOURCES

- Demonstration projects underway include the Electric Power Research Institute (EPRI) Battery Storage Project at Southern California Edison; the Puerto Rico Electric Power Authority (PREPA) 10 MW battery storage system, with Sandia National Laboratories assistance on performance testing; and a Metropolitan Edison/GPU study to determine if a battery storage facility to "shave" peak load for a specific application is feasible and/or practical. This dispersed storage project would reduce transmission losses in addition to peaking requirements.
- The U.S. Department of Energy sponsors an Energy Storage program to aid in the transfer of dispersed storage technology to utility systems.
- EPRI's *Engineering Handbook for Dispersed Energy Systems on Utility Distribution Systems* (TR-105589) provides a summary of available information on methods and tools for evaluating dispersed energy systems from economic, reliability, and power quality perspectives. The handbook identifies the costs and benefits, integration and engineering requirements, and projected performance of expansion options and also includes general background on development, methods for including dispersed energy sources in distribution planning, and application issues such as system protection.

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6.7 IMPROVING CUSTOMER SERVICE

CHARACTERISTICS

Improved customer service can be described in terms of improved reliability. Service reliability is measured in terms of frequency and duration of outages. Other measures of service include prompt and accurate billing and payment procedures, as well as providing information to users. In the case of commercial and industrial customers, service assistance may include energy audits and surveys. Some service programs include assistance in conversion to energy efficient lighting.

SIZE: N/A

FEATURES: Can consist of a variety of programs, for example: reducing outages, institution of easy-to-use payment procedures, provision of customer assistance programs, etc.

COST: Improving service reliability is the cost to upgrade and improve protective relaying, and repair feeders, and may be bundled into the cost of distribution maintenance activities.

CURRENT USAGE: Utilities in the U.S. and other countries are instituting programs to improve customer service.

POTENTIAL USAGE: Every utility can benefit from customer service improvement programs. Especially in countries where competition is being introduced, maintaining and improving customer services is essential to profitability.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Need to establish "benchmark" values for acceptable and unacceptable service performance.
- Rates must be adjusted to provide adequate funding to repair and maintain feeders and substations at a proper level.
- Need to build a database of outage events recording of details of each service interruption.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- There is no guarantee that improving customer service will result in reduced energy use.

EMISSION ESTIMATE: Will vary according to the generator's fuel mix as well as to the nature and duration of the program.

COST-EFFECTIVENESS: Improved service performance is measured in the reduction in energy not served as maximum revenue.

SECONDARY EFFECTS: Varies.

RESOURCES

- The Energy and Utility Partnership Programs, sponsored by the U.S. Agency for International Development and the U.S. Energy Association has sponsored a number of programs teaching customer service.

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6.8 COMPUTER SOFTWARE SYSTEMS AND MODELS

CHARACTERISTICS

In modern utility systems, distribution system engineering and operations are highly computerized. Several comprehensive distribution engineering workstations are available that can accomplish all distribution system operating steps including load forecasting, feeder design, sectionalized switching and fuse and protective relay coordination studies. There have also been significant developments in the combination of automated mapping systems with geographical information systems and field operations. Supervisory Control and Data Acquisition (SCADA) and other distribution automation systems are also being adopted by more utility companies. Improved service efficiency and reliability will translate into lower losses and reduced GHG emissions.

SIZE:	Techniques can be applied to large and small distribution service areas.
FEATURES:	Software provides for load forecasting, feeder design, customer databases, transformer load management, and control of voltage and power flows.
COST:	Cost depends on the total area and number of customers. Costs for distribution control systems range from less than one million dollars for a small system to tens of millions for large, comprehensive systems.
CURRENT USAGE:	Industrialized countries need to automate because of demand for high reliability and to save on high labor costs.
POTENTIAL USAGE:	The introduction of expert systems, artificial intelligence and fuzzy set logic with more sophisticated computers is being studied for application to electric distribution systems.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- The cost of software and distribution control centers may be difficult to justify in cost benefit analysis, especially when combined with need for annual outlay to pay for new computer hardware and software maintenance fees.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Emissions are avoided indirectly though lower power losses, meaning less generation is demanded.

EMISSION ESTIMATE: Varies according to the fuel mix used to generate electricity.

COST-EFFECTIVENESS: The measure of cost-effectiveness is improved reliability, increased responsiveness to customer requests, and reduction in installed costs of feeders and transformer installations.

SECONDARY EFFECTS: Varies according to the generation fuel mix.

RESOURCES

- A number of vendors and consultants provide expertise on selecting and implementing appropriate computer software.

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