State of Ohio Energy Efficiency Technical Reference Manual

Volume IV: Transmission and Distribution

Including
Predetermined Savings Values
and Protocols for Determining Energy and Demand Savings

Prepared for the Public Utilities Commission of Ohio
by Vermont Energy Investment Corporation
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I. Protocols for Transmission & Distribution Projects

T&D Loss Reductions – Mass Plant Replacement and Expansion Analysis Protocol

This protocol defines the requirements for analyzing and documenting loss reductions due to installation of mass utility plant with lower losses than standard equipment, when that equipment is required due to failure, need for increased capacity, or connection of new loads. Where equipment is replaced prior to the end of its rated service life in order to achieve energy savings, the project is classified as Retrofit and the "T&D Loss Reductions – Mass Plant Retrofit Analysis Protocol" should be used to guide analysis.

Examples of mass plant include line transformers, secondary lines, service drops, and meters. For these common and generally small investments, determination of loads and losses for each installation will not generally be feasible or cost-effective. This protocol is intended to address the energy impacts of operating energy efficiency improvements of installed equipment on average over many installations.

This analysis protocol does not apply to equipment installed to serve interval-metered load in excess of 500 kVA. Those projects should be analyzed with the Large Customer Connection Analysis Protocol.

The Analysis Protocol is divided into four sections:
Section 1: Program Information
Section 2: Equipment Loading
Section 3: Base and Efficient Cases and Savings
Section 4: Screening Inputs

Section 1: Program Information

Program Title
Provide a unique title for the program so that it is easily distinguishable from other programs with similar scope. Example: "50 kVA 13.8 kV transformers specified for new connections".

Sites (locations)
Provide a list of the locations at which equipment was installed under this program. Locations may be identified by the customer addresses, pole numbers, transformer identification numbers, or similar identifiers.

Class/Sector/Industry Description
For each installation, specify the customer classes (residential, small general service, etc.) served by the equipment, and for non-residential customers, the sector (Industrial, Commercial, Institutional, Multi-family) and type of use (e.g., office, restaurant, dormitory, gas station).

Technology Description
Describe the type of equipment affected (e.g., line transformer, secondary, etc.), including the range of capacities, wire sizes, span lengths, or other descriptors affecting energy losses.

Describe the base-efficiency equipment that would be installed under current standard utility practice.

Describe the high-efficiency equipment installed in the program. Provide specific details (e.g., wire sizes, transformer loss specifications) relevant to loss computations.

Program Implementation schedule
Define the implementation schedule for the program, including number of installations by month.

Analysis Contact(s)
Provide contact information for the personnel responsible for tracking installations and for estimating loss reductions, including company name, individual(s) name, address, phone and email.

Section 2: Equipment Loading

For each type of equipment included in the program, provide (1) the estimated maximum load on the typical or average installation, (2) the estimated average load on the equipment on weekdays between 3:00 p.m. and 6:00 p.m., June through August (the coincident peak period), and (3) the estimated load-duration curve on the equipment.

Include the sources of the estimates, including utility load-research data.

Include any data on the variability of loads among installations, reflecting the number of customers served by the equipment (e.g., customers on a transformer or a span of secondary), the size of customer, and the customer class(es) (e.g., residential, street lighting, small commercial) served.

The load data should reflect the conditions prevailing in the year for which savings are claimed. Particularly for expansions of the distribution system, the loads in the year of installation may be less than loads in later years.

Where possible, the annual billed sales to the customers served by the equipment should be used as a check on the total energy usage assumed. Where these data are not available, describe the system configuration (e.g., secondary network) or database limitations that prevent such comparison.

Section 3: Base and Efficient Cases

Calculate and document energy losses for the efficient and base cases as outlined below.

Baseline-Case Losses
For each type of equipment included in the program, compute the annual losses per unit of equipment as

$$loss_{base} = \Sigma_t \, [kVA_t \div FLC]^2 \times FLLL_b + 8766 \times NLL_b$$

Where:

t = hour
FLC = full-load capacity
$FLLL_b$ = load losses at full load
NLL_b = no-load loss/hour

Compute the pre-project losses in the coincident peak period in kW as

$$peakloss_{base} = \Sigma_h \left\{[kVA_h \div FLC]^2 \times FLLL_b\right\} \div H + NLL_b$$

Where:

h = hour in the coincident peak period

H = number of hours in the coincident peak period

Provide manufacturer's specifications or standard-reference data for typical baseline equipment for FLC, FLLL, and NLL.

Provide the spreadsheet in which the base losses are computed.

Provide information demonstrating that the assumed base efficiency is in fact standard practice, including:

> Current Industry Practice – Document current industry practice using articles from industry journals, manufacturers' sales data, recent distribution standards from other utilities, and/or similar sources.
>
> Applicant Practice – Document the utility's own recent standard practices through purchase records, distribution standards, internal guidelines for linemen, and similar documents. Document the effect on equipment selection of allowances for growth, including new infill construction in expansion applications.

Efficient-Case Losses

For each type of equipment included in the program, compute the annual losses per unit of the efficient equipment as

$$loss_{efficient} = \Sigma_t \, [kVA_t \div FLC]^2 \times FLLL_e + 8766 \times NLL_e$$

Where:

t = hour

FLC = full-load capacity

$FLLL_e$ = load losses at full load

NLL_e = no-load loss/hour

Compute the post-project losses in the coincident peak period in kW as

$$peakloss_{efficient} = \Sigma_h \left\{[kVA_h \div FLC]^2 \times FLLL_e\right\} \div H + NLL_e$$

Where:

h = hour in the coincident peak period

H = number of hours in the coincident peak period

Provide manufacturer's specifications or standard-reference data for efficient equipment for FLC, FLLL, and NLL.

Provide the spreadsheet in which the efficient-case losses are computed.

Savings

Energy Savings = $(loss_{base} – loss_{efficient}) \times (1 + ULF)$

Where:

ULF = Upstream Loss Factor, the change in losses on the primary distribution and transmission systems per kWh reduction in secondary losses

Peak Savings = $(peakloss_{base} - peakloss_{efficient}) \times (1 + UPLF)$

Where:

ULF = Upstream Peak Loss Factor applicable to the coincident peak period

If the utility has estimates of load-related losses on the primary distribution and transmission systems, and uses those estimates in screening customer end-use efficiency measures, it may add those losses to the load reduction due to efficiency improvements in mass plant on the secondary distribution system. Provide the derivation of the estimate of primary and transmission losses, and demonstrate the consistency of the claimed losses with the loss values used for the savings behind the customer meter.

Section 4: Screening Inputs

Measure Life

Document the life of each type of added equipment, including reference to the utility's depreciation studies. The efficient case analysis is typically performed over the lifetime of the major components. Where some equipment has a useful life shorter than the analysis period, describe the rationale for the analysis period and assumptions regarding the replacement cost of equipment with lives shorter than the analysis period.

Discount savings with respect to existing equipment over time, to the extent that the utility would make this (or a similar) change in configuration in the foreseeable future to meet peak load or reliability requirements.

O&M Cost Effects

Include any foreseeable changes in O&M costs related to the changes in equipment and to any changes in operating practices.

Cost

Document the actual cost of the project, including equipment, internal and contract labor, allocated overheads, design, engineering, and permitting.

T&D Loss Reductions – Mass Plant Retrofit Analysis Protocol

This protocol defines the requirements for analyzing and documenting loss reductions due to replacement of existing mass utility plant with more efficient equipment, prior to the end of the existing equipment's useful life and in the absence of any need for increased capacity.

Examples of mass plant include line transformers, secondary lines, service drops and meters. For these common and generally small investments, determination of loads and losses for each installation will not generally be feasible or cost-effective. This protocol is intended to address the energy impacts of operating energy efficiency improvements of installed equipment on average over many installations.

This analysis protocol does not apply to equipment installed to serve interval-metered load in excess of 500 kVA. Those projects should be analyzed with the Large Customer Analysis Protocol.

The Analysis Protocol is divided into four sections:
Section 1: Program Information
Section 2: Equipment Loading
Section 3: Base and Efficient Cases and Savings
Section 4: Screening Inputs

Section 1: Program Information

Program Title
Provide a unique title for the program so that it is easily distinguishable from other programs with similar scope. Example: "Replacing 25 kVA 13.8 kV transformers with amorphous-core transformers".

Sites (locations)
Provide a list of the locations at which equipment was installed under this program. Locations may be identified by the customer addresses, pole numbers, transformer identification numbers, or similar identifiers.

Class/Sector/Industry Description
For each installation, specify the customer classes (residential, small general service, etc.) served by the equipment, and for non-residential customers, the sector (Industrial, Commercial, Institutional, Multi-family) and type of use (e.g., office, restaurant, dormitory, gas station).

Technology Description
Describe the type of equipment affected (e.g., line transformer, secondary, etc.), including the range of capacities, wire sizes, span lengths, or other descriptors affecting energy losses.

Describe the existing equipment that was replaced.

Describe the high-efficiency equipment installed in the program. Provide specific details (e.g., wire sizes, transformer loss specifications) relevant to loss computations.

Program Implementation schedule
Define the implementation schedule for the program, including number of installations by month.

Analysis Contact(s)

Provide contact information for the personnel responsible for tracking installations and for estimating loss reductions, including company name, individual(s) name, address, phone and email.

Section 2: Equipment Loading

For each type of equipment included in the program, provide (1) the estimated maximum load on the typical or average installation, (2) the estimated average load on the equipment on weekdays between 3:00 p.m. and 6:00 p.m., June through August (the coincident peak period), and (3) the estimated load-duration curve on the equipment.

Include the sources of the estimates, including utility load-research data.

Include any data on the variability of loads among installations, reflecting the number of customers served by the equipment (e.g., customers on a transformer or a span of secondary), the size of customer, and the customer class(es) (e.g., residential, street lighting, small commercial) served.

The load data should reflect the conditions prevailing in the year for which savings are claimed.

Where possible, the annual billed sales to the customers served by the equipment should be used as a check on the total energy usage assumed. Where these data are not available, describe the system configuration (e.g., secondary network) or database limitations that prevent such comparison.

Section 3: Base and Efficient Cases

Calculate and document energy losses for the efficient and base cases as outlined below.

Baseline-Case Losses
For each type of equipment included in the program, compute the annual pre-program losses per unit of equipment as

$$loss_{base} = \Sigma_t\, [kVA_t \div FLC]^2 \times FLLL_b + 8766 \times NLL_b$$

Where:

- t = hour
- FLC = full-load capacity
- $FLLL_b$ = load losses at full load
- NLL_b = no-load loss/hour

Compute the pre-project losses in the coincident peak period in kW as

$$peakloss_{base} = \Sigma_h \left\{[kVA_h \div FLC]^2 \times FLLL_b\right\} \div H + NLL_b$$

Where:

- h = hour in the coincident peak period
- H = number of hours in the coincident peak period

Provide manufacturer's specifications, test results, or standard-reference data for typical baseline equipment for FLC, FLLL, and NLL.

Provide the spreadsheet in which the base losses are computed.

Provide information demonstrating that the existing equipment could have remained in service.

Document that the existing equipment was functioning properly.

Provide certification that the existing equipment was adequate to meet anticipated loads.

Describe the disposition of the existing equipment. If the equipment has been or may be returned to service, explain how that return to service would not offset the claimed loss reductions.

Describe the manner in which equipment was selected for replacement (e.g., vintage, design, location), and provide documentation to demonstrate that the replacements were targeted for loss reduction, rather than actual or imminent failure.

Efficient-Case Losses
For each type of equipment included in the program, compute the annual losses per unit of the efficient equipment as

$$loss_{efficient} = \Sigma_t\ [kVA_t \div FLC]^2 \times FLLL_e + 8766 \times NLL_e$$

Where:

t	= hour
FLC	= full-load capacity
$FLLL_e$	= load losses at full load
NLL_e	= no-load loss/hour

Compute the post-project losses in the coincident peak period in kW as

$$peakloss_{efficient} = \Sigma_h \left\{[kVA_h \div FLC]^2 \times FLLL_e\right\} \div H + NLL_e$$

Where:

h	= hour in the coincident peak period
H	= number of hours in the coincident peak period

Provide manufacturer’s specifications or standard-reference data for efficient equipment for FLC, FLLL, and NLL.

Provide the spreadsheet in which the efficient-case losses are computed.

Savings
Energy Savings = $(loss_{base} - loss_{efficient}) \times (1 + ULF)$

Where:

ULF	= Upstream Loss Factor, the change in losses on the primary distribution and transmission systems per kWh reduction in secondary losses

Peak Savings = $(peakloss_{base} - peakloss_{efficient}) \times (1 + UPLF)$

Where:

ULF = Upstream Peak Loss Factor applicable to the coincident peak period

If the utility has estimates of load-related losses on the primary distribution and transmission systems, and uses those estimates in screening customer end-use efficiency measures, it may add those losses to the load reduction due to efficiency improvements in mass plant on the secondary distribution system. Provide the derivation of the estimate of primary and transmission losses, and demonstrate the consistency of the claimed losses with the loss values used for the savings behind the customer meter.

Section 4: Screening Inputs

Measure Life

Document the life of each type of added equipment, including reference to the utility's depreciation studies. The efficient case analysis is typically performed over the lifetime of the major components. Where some equipment has a useful life shorter than the analysis period, describe the rationale for the analysis period and assumptions regarding the replacement cost of equipment with lives shorter than the analysis period.

Discount savings with respect to existing equipment over time, to the extent that the utility would make this (or a similar) change in configuration in the foreseeable future to meet peak load or reliability requirements.

O&M Cost Effects

Include any foreseeable changes in O&M costs related to the changes in equipment and to any changes in operating practices.

Cost

Document the actual cost of the project, including equipment, internal and contract labor, allocated overheads, design, engineering, and permitting.

T&D Loss Reductions – Large Customer Connection Analysis Protocol

This protocol defines the requirements for analyzing and documenting loss reductions due to installation of distribution equipment to serve interval-metered load in excess of 500 kVA, where the installed equipment has lower losses than

- standard equipment, in the case of incremental improvements over equipment required due to failure, need for increased capacity, or connection of new loads, or
- existing equipment, in the case of retrofit of equipment solely for the energy savings.

Each project may include equipment serving one or a few customers, each with interval metering, at single location. The equipment may also serve small amounts of non-interval-metered street lighting and private area lighting, so long as the load shape of the outdoor lighting can be reasonably estimated.

Examples of distribution plant covered by this protocol include line transformers, secondary lines, service drops, and meters.

The Analysis Protocol is divided into four sections:
Section 1: Project Information
Section 2: Equipment Loading
Section 3: Base and Efficient Cases and Savings
Section 4: Screening Inputs

Section 1: Project Information

Project Title
Provide a unique title for the project so that it is easily distinguishable from other projects with similar scope. Example: "Install low-loss transformers and upgrade service drops for the Midway Office Park".

Sites (locations)
Provide a list of the locations at which equipment was installed under this project. Locations may be identified by the customer number, address, pole numbers, transformer identification numbers, or similar identifiers.

Technology Description
Describe the type of equipment affected (e.g., line transformer, secondary, etc.), including the capacity, wire size, span lengths, voltages, or other descriptors affecting energy losses. Provide a one-line diagram of the interconnection.

If this project consists of the incremental increase of efficiency for a new or replacement connection, describe the equipment that would be installed under standard utility practice. Demonstrate that the assumed base efficiency is in fact standard practice, including:

> Current Industry Practice – Document current industry practice using articles from industry journals, manufacturers' sales data, recent distribution standards from other utilities, and/or similar sources.
>
> Applicant Practice – Document the utility's own recent standard practices through purchase records, distribution standards, internal guidelines for linemen, and similar documents. Document

the effect on equipment selection of allowances for growth, including new infill construction in expansion applications.

If this project consists of the loss-driven retrofit of existing connection equipment, describe the existing equipment.

Describe the high-efficiency equipment installed in the project. Provide specific details (e.g., wire sizes, transformer loss specifications) relevant to loss computations.

Project Implementation schedule
Describe the implementation schedule for the project.

Analysis Contact(s)
Provide contact information for the personnel responsible for tracking installations and for estimating loss reductions, including company name, individual(s) name, address, phone and email.

Section 2: Equipment Loading

Provide the hourly customer loads at this location in the report year. If individual loads use only some of the equipment contributing to the efficiency improvement, disaggregate the loads so that load can be determined for each piece of equipment.

Determine

(1) the average load on the line at its input on weekdays between 3:00 p.m. and 6:00 p.m., June through August

(2) total energy delivered to the line.

Where possible, the annual billed sales to the customers served by the equipment should be used as a check on the total energy usage assumed. Where these data are not available, describe the system configuration (e.g., secondary network) or database limitations that prevent such comparison.

Section 3: Base and Efficient Cases

Calculate and document energy losses for the efficient and base cases as outlined below.

Baseline-Case Losses
Compute the annual base losses in kWh as

$$loss_{base} = \Sigma_t\, [kVA_t \div FLC]^2 \times FLLL_b + 8766 \times NLL_b$$

Where:

t = hour
FLC = full-load capacity or other convenient reference load
$FLLL_b$ = load losses at FLC
NLL_b = no-load loss per hour

Compute the pre-project losses in the coincident peak period in kW as

$$\text{peakloss}_{\text{base}} = \Sigma_h \left\{[\text{kVA}_h \div \text{FLC}]^2 \times \text{FLLL}_b\right\} \div H + \text{NLL}_b$$

Where:

h	= hour in the coincident peak period
H	= number of hours in the coincident peak period

Where various pieces of equipment are subject to different loadings (e.g., the transformer bank serves the entire load, while each section of secondary serves half the load), compute losses for each type of equipment or load grouping.

Provide manufacturer's specifications or standard-reference data for typical baseline equipment for FLC, FLLL, and NLL.

Provide the spreadsheet in which the base losses are computed.

Efficient-Case Losses

Compute the annual losses of the efficient equipment as

$$\text{loss}_{\text{efficient}} = \Sigma_t\, [\text{kVA}_t \div \text{FLC}]^2 \times \text{FLLL}_e + 8766 \times \text{NLL}_e$$

Where:

t	= hour
FLC	= full-load capacity
FLLL_e	= load losses at full load
NLL_e	= no-load loss per hour

Compute the post-project losses in the coincident peak period in kW as

$$\text{peakloss}_{\text{efficient}} = \Sigma_h \left\{[\text{kVA}_h \div \text{FLC}]^2 \times \text{FLLL}_e\right\} \div H + \text{NLL}_e$$

Where:

h	= hour in the coincident peak period
H	= number of hours in the coincident peak period

Provide manufacturer's specifications or standard-reference data for typical baseline equipment for FLC, FLLL, and NLL.

Provide the spreadsheet in which the efficient-case losses are computed.

Savings

Energy Savings = $(\text{loss}_{\text{base}} - \text{loss}_{\text{efficient}}) \times (1 + \text{UELF})$

Where:

ULEF	= Upstream Energy Loss Factor, the annual average change in losses on the primary distribution and transmission systems per kWh reduction in secondary losses

Peak Savings = $(\text{peakloss}_{\text{base}} - \text{peakloss}_{\text{efficient}}) \times (1 + \text{UPLF})$

Where:

UPLF = Upstream Peak Loss Factor, the change in losses on the primary distribution and transmission systems per kWh reduction in secondary losses in the coincident peak period

If the utility has estimates of load-related losses on the primary distribution and transmission systems, and uses those estimates in screening customer end-use efficiency measures, it may add those losses to the load reduction due to efficiency improvements on the secondary distribution system. Provide the derivation of the estimate of primary and transmission losses, and demonstrate the consistency of the claimed losses with the loss values used for the savings behind the customer meter.

Section 4: Screening Inputs

Measure Life

Document the life of each type of added equipment, including reference to the utility's depreciation studies. The efficient case analysis is typically performed over the lifetime of the major components. Where some equipment has a useful life shorter than the analysis period, describe the rationale for the analysis period and assumptions regarding the replacement cost of equipment with lives shorter than the analysis period.

Discount savings with respect to existing equipment over time, to the extent that the utility would make this (or a similar) change in configuration in the foreseeable future to meet peak load or reliability requirements.

O&M Cost Effects

Include any foreseeable changes in O&M costs related to the changes in equipment and to any changes in operating practices.

Cost

Document the actual cost of the project, including equipment, internal and contract labor, allocated overheads, design, engineering, and permitting.

T&D Loss Reductions – Substation Transformer Analysis Protocol

This protocol defines the requirements for analyzing and documenting loss reductions due to installation of efficient substation transformers in any of the following contexts:

- Incremental: installation of one or more high-efficiency transformers instead of a new standard-efficiency transformer
  - when a new transformer is required at a new substation,
  - to increase capacity at an existing substation,
  - to replace a failed or failing transformer
- Retrofit: replacement of an existing transformer with a more efficient transformer, which may be more efficient due to higher-efficiency materials (such as an amorphous core) or due to lower capacity (with lower core losses).

Addition of a transformer or substation to change power flow on the network should be analyzed with the System Reconfiguration Protocol.

The Analysis Protocol is divided into four sections:
Section 1: Project Information
Section 2: Equipment Loading
Section 3: Base and Efficient Cases and Savings
Section 4: Screening Inputs

Section 1: Project Information

Project Title
Provide a unique title for the project**.** Example: "Installation of low-loss amorphous-core transformers at the Midway 138-12.5 kV substation".

Location
Identify the location of the project, by substation name, number, and address.

Technology Description
Describe the transformer(s) affected, including voltages and capacity.

Describe the high-efficiency transformer(s) installed in the project. Provide manufacturer specifications.

If this project consists of the incremental increase of efficiency at a new transformer, describe the standard-efficiency transformer that would have been installed under standard utility practice.

If this project consists of the retrofit of a lower-loss transformer in place of an existing transformer, describe the existing equipment that was replaced.

Project Implementation schedule
Define the implementation schedule for the project, including the date at which the transformer(s) were energized by month.

Analysis Contact(s)

Provide contact information for the personnel responsible for tracking installations and for estimating loss reductions, including company name, individual(s) name, address, phone and email.

Section 2: Equipment Loading

Provide the hourly load the transformer or substation in the current year and identify:

(1) the maximum load on the equipment

(2) the average load on the equipment on weekdays between 3:00 p.m. and 6:00 p.m., June through August (the coincident peak period)

Section 3: Base and Efficient Cases

Calculate and document energy losses for the efficient and base cases as outlined below.

Baseline-Case Losses
For each transformer included in the project, compute the annual pre-project losses in kWh as

$$loss_{base} = \Sigma_t [kVA_t \div FLC]^2 \times FLLL_b + 8766 \times NLL_b$$

Where:

t	= hour
FLC	= full-load capacity
$FLLL_b$	= load losses at full load
NLL_b	= no-load loss/hour

Compute the pre-project losses in the coincident peak period in kW as

$$peakloss_{base} = \Sigma_h \{[kVA_h \div FLC]^2 \times FLLL_b\} \div H + NLL_b$$

Where:

h	= hour in the coincident peak period
H	= number of hours in the coincident peak period

Provide manufacturer’s specifications, test results, or standard-reference data for the baseline transformer for FLC, FLLL, and NLL.

Provide the spreadsheet in which the base losses are computed.

If this project consists of the incremental increase of efficiency at a new transformer, provide information demonstrating that the assumed base efficiency is in fact standard practice, including:

Current Industry Practice – Document current industry practice using articles from industry journals, manufacturers' sales data, recent distribution standards from other utilities, and/or similar sources.

Applicant Practice – Document the utility's own recent standard practices through purchase records, distribution standards, and similar documents. Provide data on peak forecasts for the substation, supporting the adequacy of the base equipment.

If this project consists of the retrofit of a lower-loss transformer in place of an existing transformer,

Describe the existing equipment that was replaced.

Provide information demonstrating that the existing equipment could have remained in service.

Document that the existing equipment was functioning properly.

Provide certification that the existing equipment was adequate to meet anticipated loads.

Describe the disposition of the existing equipment. If the equipment has been or may be returned to service, explain how that return to service would not offset the claimed loss reductions.

Describe the manner in which the equipment was selected for replacement, and provide documentation to demonstrate that the retrofit was undertaken for loss reduction, rather than actual or imminent failure or inadequacy.

Efficient-Case Losses
For each transformer included in the project, compute the annual post-project losses in kWh as

$$loss_{efficient} = \Sigma_t\,[kVA_t \div FLC]^2 \times FLLL_e + 8766 \times NLL_e$$

Where:

t	= hour
FLC	= full-load capacity
$FLLL_e$	= load losses at full load
NLL_e	= no-load loss/hour

Compute the post-project losses in the coincident peak period in kW as

$$peakloss_{efficient} = \Sigma_h\,\{[kVA_h \div FLC]^2 \times FLLL_e\} \div H + NLL_e$$

Where:

h	= hour in the coincident peak period
H	= number of hours in the coincident peak period

Provide manufacturer's specifications the installed transformer for FLC, FLLL, and NLL.

Provide the spreadsheet in which the efficient-case losses are computed.

Savings
Energy Savings = $(loss_{base} - loss_{efficient}) \times (1 + TELF)$

Where:

TELF = Transmission Energy Loss Factor applicable to the transmission system upstream from the project substation

Peak Savings = $(\text{peakloss}_{base} - \text{peakloss}_{efficient}) \times (1 + \text{TPLF})$

Where:

TPLF = Transmission Peak Loss Factor applicable to the transmission system upstream from the project substation

If the utility has estimates of load-related losses on the transmission system, and uses those estimates in screening customer end-use efficiency measures, it may add those losses to the load reduction due to efficiency improvements at distribution substations. For transmission substations, the utility may compute TLF as the portion of transmission losses attributable to voltages equal to or higher than those of the input voltage to the transformer.

Provide the derivation of the estimate of transmission losses, and demonstrate the consistency of the claimed losses with the loss values used for the savings behind the customer meter.

Section 4: Screening Inputs

Measure Life

Document the life of each type of added equipment, including reference to the utility's depreciation studies. The efficient case analysis is typically performed over the lifetime of the major components, in this case the transformers. Where some equipment has a useful life shorter than the analysis period, describe the assumptions regarding the replacement cost of equipment with lives shorter than the analysis period.

Where the utility would make a similar investment in the foreseeable future to meet peak load or reliability requirements, the analysis period should be limited to the period prior to that need date, and reflect the present value of the differences in capital costs.

Operations Effects

The estimates of baseline and efficiency case losses should reflect the operating practices expected to be in place for the base and efficient equipment.

O&M Cost Effects

Include any foreseeable changes in O&M costs related to the change in equipment (including the effect of replacing old equipment with new equipment) and to any changes in operating practices.

Cost

Document the actual cost of the project, including equipment, internal and contract labor, allocated overheads, design, engineering, and permitting.

T&D Loss Reductions – System Reconfiguration Analysis Protocol

This protocol defines the requirements for analyzing and documenting loss reductions due to changes undertaken to change network power flows and reduce losses, including (but not necessarily limited to) any of the following contexts:

- Addition of a substation or substation transformer.
- Addition of a new primary circuit or transmission line.
- Addition of capacitors.

The Analysis Protocol is divided into four sections:
Section 1: Project Information
Section 2: Equipment Loading
Section 3: Base and Efficient Cases and Savings
Section 4: Screening Inputs

Section 1: Project Information

Project Title
Provide a unique title for the project**.** Example: "Installation of new Midway 138-12.5 kV substation and reconfiguration of feeders K181 and K182".

Location
Identify the location of the project, by substation name, number, and address; line number and connecting substations; and/or other relevant identification.

Technology Description
Describe the equipment added, including voltages and capacity, and the major network elements (lines and substations) affected by the reconfiguration.

If the project includes the addition of capacitors, describe the connection of the capacitors (e.g., shunt, series), their kVAR capacity, and the levels to which they can be switched.

Project Implementation schedule
Define the implementation schedule for the project, including the date at which each major project element was put into service.

Analysis Contact(s)
Provide contact information for the personnel responsible for tracking installations and for estimating loss reductions, including company name, individual(s) name, address, phone and email.

Section 2: Equipment Loading

Provide the hourly loads on each of the major affected network elements for the last full year prior to the installation of the first element of the project.

For the current year, provide the hourly loads on

(1) each of the major affected network elements identified above

(2) each major element of the project (e.g., line, transformer or substation) in.

For capacitors, provide

(1) the hourly loads in the current year on the substation or other equipment to which the capacitors are attached.

(2) the hours in the current year for which the capacitors were activated at each kVAR level

Based upon the loading of the new equipment, identify N load patterns, such that each hour within the year is reasonably well represented by a load pattern and N is a tractable number for modeling and evaluation.

> At least one load pattern should represent typical power flows during the coincident peak period (weekdays between 3:00 p.m. and 6:00 p.m., June through August).
>
> The load pattern should be representative of the hours modeled, in terms of the direction of power flow, the level of power flow, and the operation of capacitors.
>
> Describe the load-pattern selection process.
>
> Identify the hours that are represented by each load pattern.
>
> Loss reductions in some hours may be zero or nearly so (e.g., hours in which capacitors are switched off, hours with very low flows on the affected equipment). These hours may be ignored, so long as any increase in no-load losses is also insignificant.

Section 3: Base and Efficient Cases

Calculate and document energy losses for the efficient and base cases as outlined below.

Baseline-Case Losses

Using computer software appropriate to the application, model the relevant portions of the distribution and/or transmission system for each load pattern *n* (where n = 1 to N). Compute $loss_n$, the sum of load and no-load losses in the study area for load pattern *n.*

Where possible, compare the transmission flows and losses modeled for the load pattern for the actual metered loads in some hours of the pre-project historical period. Where such comparisons are not possible, explain why.

Determine annualized base pre-project losses in kWh as

$$loss_{base} = \Sigma_n \; loss_{n,b} \times hours_n \qquad (1)$$

Where:

n = load pattern, n = 1 to N

$loss_{n,b}$ = total modeled base losses in the study area
$hours_n$ = hours in load pattern *n*

Compute the pre-project losses in the coincident peak period in kW as

$$peakloss_{base} = \Sigma_n\, loss_{n,b} \times hours_n \div H \qquad (2)$$

Where:
n = load pattern, for those load patterns representing the coincident peak period
H = number of hours in the coincident peak period

Provide the spreadsheet in which the base losses are computed.

Post-project Losses
Using actual metered data where available and modeling results otherwise (using the same software used in the base case), compute total load and no-load losses in the study area for each load pattern for the actual conditions in the report year, with the project.

Compute annual post-project losses as

$$loss_{efficient} = \Sigma_n\, loss_{m,n,e} \times hours_n + \Sigma_t\, loss_{a,t} \qquad (3)$$

Where:
$loss_{m,n,e}$ = losses in modeled load pattern *n* with the post-project actual configuration
t = hours in the year, excluded hours expected to have negligible loss reductions
$loss_{a,t}$ = actual losses in hour t in the report year

Compute the pre-project losses in the coincident peak period in kW as

$$peakloss_{base} = \Sigma_n \left\{ loss_{n,e} \times hours_n + \Sigma_h\, loss_{a,h} \right\} \div H \qquad (4)$$

Where:
n = load pattern, for those load patterns representing the coincident peak period
h = hour in the coincident peak period in the report year
H = number of hours in the coincident peak period

For comparison, provide the total modeled losses for the year and in the coincident peak period, with the post-project configuration.

Savings
Energy Savings = $(loss_{base} – loss_{efficient}) \times (1 + TELF)$

Where:
TELF = Transmission Energy Loss Factor applicable to the transmission system upstream from the study area

Peak Savings = $(peakloss_{base} – peakloss_{efficient}) \times (1 + TPLF)$

Where:

TPLF = Transmission Peak Loss Factor applicable to the transmission system upstream from the study area

If the utility has estimates of load-related losses on the transmission system, and uses those estimates in screening customer end-use efficiency measures, it may add those losses to the load reduction due to reconfiguration on the distribution system. For reconfigurations that affect flows on the transmission system, the utility may compute TLF as the portion of transmission losses attributable to voltages equal to or higher than those modeled in the study area.

Provide the derivation of the estimate of transmission losses, and demonstrate the consistency of the claimed losses with the loss values used for the savings behind the customer meter.

Section 4: Screening Inputs

Measure Life
Document the life of each type of added equipment, including reference to the utility's depreciation studies. The efficient case analysis is typically performed over the lifetime of the major components. Where some equipment has a useful life shorter than the analysis period, describe the rationale for the analysis period and assumptions regarding the replacement cost of equipment with lives shorter than the analysis period.

Where the utility would make this (or a similar) change in configuration in the foreseeable future to meet peak load or reliability requirements, the analysis period should be limited to the period prior to that need date, and reflect the present value of the differences in capital costs.

Operations Effects
The estimates of baseline and efficiency case losses should reflect the operating practices be expected to be in place in each configuration.

O&M Cost Effects
Include any foreseeable changes in O&M costs related to the additional equipment and to any changes in operating practices.

Cost
Document the actual cost of the project, including equipment, internal and contract labor, allocated overheads, design, engineering, and permitting.

T&D Loss Reductions – Voltage Conversion Analysis Protocol

This protocol defines the requirements for analyzing and documenting loss reductions due to increasing the voltage on an existing primary circuit or transmission line, where the voltage increase is not needed for additional capacity to meet load.

Where increasing the voltage on a primary circuit or transmission line is expected to significantly change power flow on the network, the effect on losses should be analyzed with the System Reconfiguration Protocol.

The Analysis Protocol is divided into four sections:
Section 1: Project Information
Section 2: Equipment Loading
Section 3: Base and Efficient Cases and Savings
Section 4: Screening Inputs

Section 1: Project Information

Project Title
Provide a unique title for the project. Example: "Increase Halfland-to-Midway transmission line from 69 kV to 115 kV."

Location
Identify the location of the project, by utility line number and names of substation(s) connected.

Technology Description
Describe the lines affected, including conductors, length, and pre- and post-project voltages.

Describe and enumerate the transformers connected to the line, both at substations and (for distribution projects) line transformers. Explain how each category of transformer was converted to the higher voltage (replacement, change in taps).

For any transformer replaced as part of the project, describe and provide manufacturer specifications for the original and replacement transformers.

Describe the required replacement of poles, insulators, sectionalizers, and other ancillary equipment.

Project Implementation schedule
Define the implementation schedule for the project, including the replacement of transformers and insulators, as required.

Analysis Contact(s)
Provide contact information for the personnel responsible for tracking installations and for estimating loss reductions, including company name, individual(s) name, address, phone and email.

Section 2: Equipment Loading

Identify whether power flow on the line is unidirectional or bidirectional, and if the latter, the share of hours of the report year in which power flowed in each direction.

For each interval-metered location along the line affected, provide the hourly loads in the report year and identify:

> (1) the average load on the line at its input on weekdays between 3:00 p.m. and 6:00 p.m., June through August
>
> (2) total energy delivered to the line.

Provide any available information regarding the distribution of load along the line, including

> (1) hourly load for large loads among the line (e.g., for distribution circuits, large commercial and industrial customers; for transmission circuits, substations, industrial customers and wholesale loads)
>
> (2) where hourly data are not available, the distribution of annual deliveries along the line

Include the sources of the data and estimates. Explain any corrections for misread or missing data.

Define segments of the line based on the location of large point loads and the density of smaller loads, so that within each segment either:

> (1) the current is constant within the segment, or
>
> (2) the change in current per mile is constant within the segment (i.e., uniformly distributed load).

(In either case, “constant” means “to the extent feasible given data limitations.)

Demonstrate that the power flows on the segments are consistent with one another and the power delivered to the line input.

Take hourly amperage directly from data logs or compute from power-flow data.

Section 3: Pre-project and Post-Project Cases

Calculate and document energy losses for the efficient and base cases as outlined below.

Pre-Case Losses
For each segment of the line, compute the annual pre-project losses in MWh as

$$loss_{pre} = \Phi \times k \times \Sigma_t A_{pre,i,t}^2 \times R \div 10^6$$

Where:

- t = hour
- $A_{pre,i,t}$ = amperage flowing into the segment
- R = resistance of the segment in ohms
- Φ = 1.73 for three-phase lines and 1.00 for single-phase lines
- k = 1.0, for segments with constant current
  = $(0.67 \times A_o + 0.33 \times A_i) \div A_i$, for segments with constant change in current per mile
- A_o = amperage flowing out of the segment

Compute the pre-project losses in the coincident peak period in kW as

$$peakloss_{pre} = \Phi \times k \times \Sigma_h A_{pre,i,h}^2 \times R \div 10^3$$

Where:

- h = hour in the coincident peak period
- H = number of hours in the coincident peak period

Provide manufacturer's specifications, test results, or standard-reference data for the conductor for R.

$A_{pre,i,t}$ will normally be equal to $A_{post,i,t} \times V_{pre} \div V_{post}$

Provide the spreadsheet in which the base losses are computed.

Post-Case Losses
For each segment of the line, compute the annual post-project losses in MWh as

$$loss_{post} = \Phi \times k \times \Sigma_t A_{post,i,t}^2 \times R \div 10^6$$

Where:

- t = hour
- $A_{post,i,t}$ = amperage flowing into segment *i* in hour *t*
- R_e = resistance of the segment in ohms
- Φ = 1.73 for three-phase lines and 1.00 for single-phase lines
- k = 1.0, for segments with constant current
  = $(0.67 \times A_o + 0.33 \times A_i) \div A_i$, for segments with constant change in current per mile
- A_o = amperage flowing out of the segment

Compute the post-project losses in the coincident peak period in kW as

$$peakloss_{post} = \Phi \times k \times \Sigma_h A_{post,i,h}^2 \times R \div 10^3$$

Provide the spreadsheet in which the efficient-case losses are computed.

Savings
Energy Savings = $(loss_{pre} – loss_{post}) \times (1 + TELF)$

Where:

- TELF = Transmission Energy Loss Factor applicable to the transmission system upstream from the project

$$\text{Peak Savings} = (\text{peakloss}_{pre} - \text{peakloss}_{post}) \times (1 + \text{TPLF})$$

Where:

TPLF = Transmission Peak Loss Factor applicable to the transmission system upstream from the project

If the utility has estimates of load-related losses on the transmission system, and uses those estimates in screening customer end-use efficiency measures, it may add those losses to the load reduction due to efficiency improvements on primary distribution lines. For transmission lines, the utility may compute TLF as the portion of transmission losses attributable to voltages equal to or higher than those of the input voltage to the project line.

Provide the derivation of the estimate of transmission losses, and demonstrate the consistency of the claimed losses with the loss values used for the savings behind the customer meter.

Section 4: Screening Inputs

Measure Life

Document the life of each type of added equipment, including reference to the utility's depreciation studies. The efficient case analysis is typically performed over the lifetime of the major components. Where some equipment has a useful life shorter than the analysis period, describe the rationale for the analysis period and assumptions regarding the replacement cost of equipment with lives shorter than the analysis period.

Where the utility would make this investment in the foreseeable future to meet peak load or reliability requirements, the analysis period should be limited to the period prior to that need date, and reflect the present value of the differences in capital costs.

Operations Effects

The estimates of baseline and efficiency case losses should reflect the operating practices be expected to be in place for the base and efficient voltage levels.

O&M Cost Effects

Include any foreseeable changes in O&M costs related to the change in equipment (including the effect of replacing old equipment with new equipment) and to any changes in operating practices.

Cost

Document the actual cost of the project, including equipment, internal and contract labor, allocated overheads, design, engineering, and permitting.

T&D Loss Reductions – Conductor Analysis Protocol

This protocol defines the requirements for analyzing and documenting loss reductions due to installation of efficient conductors in any of the following contexts:

- Incremental: installation of lower-resistance conductor instead of standard conductors
  - when a new primary circuit or transmission line is constructed,
  - to increase the capacity of an existing line,
  - when a line is relocated due to highway widening or similar conditions,
  - to replace aging conductor that is becoming unreliable due to mechanical stress
- Retrofit: replacement of existing conductor with lower-resistance conductor, where the replacement is not otherwise necessary to meet utility reliability standards.

For any of these contexts, the installation of the lower-resistance conductor must not be needed for additional capacity to meet load.

Addition of a primary circuit or transmission line to change power flow on the network should be analyzed with the System Reconfiguration Protocol.

The Analysis Protocol is divided into four sections:
Section 1: Project Information
Section 2: Equipment Loading
Section 3: Base and Efficient Cases and Savings
Section 4: Screening Inputs

Section 1: Project Information

Project Title
Provide a unique title for the project. Example: "Reconductor Halfland-to-Midway 69 kV transmission line from 3/0 ACSR to 336.4 ACSR".

Location
Identify the location of the project, by utility line number, names of substation(s) connected, and any other relevant geographical descriptors for the project (e.g., the roadways along with the relocation project is required).

Technology Description
Describe the lines affected, including voltages and length.

Describe the high-efficiency conductors installed in the project. Provide manufacturer specifications.

If this project consists of the incremental increase of efficiency for a new or replacement line, describe the conductor that would be installed under standard utility practice.

If this project consists of the loss-driven retrofit of existing conductor, describe the existing conductor.

Project Implementation schedule
Define the implementation schedule for the project, including the spans installed by month.

Analysis Contact(s)
Provide contact information for the personnel responsible for tracking installations and for estimating loss reductions, including company name, individual(s) name, address, phone and email.

Section 2: Equipment Loading

Identify whether power flow on the line is unidirectional or bidirectional, and if the latter, the share of hours of the report year in which power flowed in each direction.

For each interval-metered location along the line affected, provide the hourly loads in the report year and identify:

(1) the average load on the line at its input on weekdays between 3:00 p.m. and 6:00 p.m., June through August

(2) total energy delivered to the line.

Provide any available information regarding the distribution of load along the line, including

(1) hourly load for large loads among the line (e.g., for distribution circuits, large commercial and industrial customers; for transmission circuits, substations, industrial customers and wholesale loads)

(2) where hourly data are not available, the distribution of annual deliveries along the line

Include the sources of the data and estimates. Explain any corrections for misread or missing data.

Define segments of the line based on the location of large point loads and the density of smaller loads, so that within each segment either:

(1) the current is constant within the segment, or

(2) the change in current per mile is constant within the segment (i.e., uniformly distributed load).

(In either case, "constant" means "to the extent feasible given data limitations.)

Demonstrate that the power flows on the segments are consistent with one another and the power delivered to the line input.

Take hourly amperage directly from data logs or compute from power-flow data.

Section 3: Base and Efficient Cases

Calculate and document energy losses for the efficient and base cases as outlined below.

Baseline-Case Losses
For each segment of the line, compute the annual pre-project losses in MWh as

$$loss_{base,i} = \Phi \times k \times \Sigma_t A_{it}^2 \times R_b \div 10^6$$

Where:

t	= hour
i	= segment number
A_i	= amperage flowing into the segment
R_b	= resistance of the segment in ohms
Φ	= 1.73 for three-phase lines and 1.00 for single-phase lines
k	= 1.0, for segments with constant current
	= $(0.67 \times A_o + 0.33 \times A_i) \div A_i$, for segments with constant change in current per mile
A_o	= amperage flowing out of the segment

Compute the pre-project losses in the coincident peak period in kW as

$$peakloss_{base,i} = \Phi \times k \times \Sigma_h A_{ih}^2 \times R_b \div H \div 10^3$$

Where:

h	= hour in the coincident peak period
H	= number of hours in the coincident peak period

Provide manufacturer's specifications, test results, or standard-reference data for the conductor for R_b.

Provide the spreadsheet in which the base losses are computed.

If this project consists of the incremental decrease of resistance for a new or replacement line, provide information demonstrating that the assumed base efficiency is in fact standard practice, including:

Current Industry Practice – Document current industry practice using articles from industry journals, manufacturers' sales data, recent distribution standards from other utilities, and/or similar sources.

Applicant Practice – Document the utility's own recent standard practices through purchase records, distribution standards, and similar documents. Provide data on peak forecasts for the line, supporting the adequacy of the base conductor.

If this project consists of the retrofit of lower-loss conductor solely for loss reductions,

Describe the existing conductor that was replaced.

Provide information demonstrating that the existing conductor could have remained in service.

Document that the existing conductor was functioning properly.

Provide certification that the existing conductor was adequate to meet anticipated loads.

Describe the disposition of the existing conductor.

Describe the manner in which the line was selected for retrofit, and provide documentation to demonstrate that the retrofit was undertaken for loss reduction, rather than actual or imminent failure or inadequacy.

Efficient-Case Losses

For each segment of the line, compute the annual post-project losses in MWh as

$$loss_{efficient,i} = \Phi \times k \times \Sigma_t A_{it}^2 \times R_e \div 10^6$$

Where:

t	= hour
i	= segment number
A_i	= amperage flowing into the segment
R_e	= resistance of the segment in ohms
Φ	= 1.73 for three-phase lines and 1.00 for single-phase lines
k	= 1.0, for segments with constant current
	= $(0.67 \times A_o + 0.33 \times A_i) \div A_i$, for segments with constant change in current per mile
A_o	= amperage flowing out of the segment

Compute the post-project losses in the coincident peak period in kW as

$$peakloss_{efficient,i} = \Phi \times k \times \Sigma_h A_{ih}^2 \times R_e \div H \div 10^3$$

Provide manufacturer's specifications, test results, or standard-reference data for the conductor for R_e.

Provide the spreadsheet in which the efficient-case losses are computed.

Savings

$$\text{Energy Savings} = \Sigma_i(loss_{base,i} - loss_{efficient,i}) \times (1 + TELF)$$

Where:

TELF = Transmission Energy Loss Factor applicable to the transmission system upstream from the project

$$\text{Peak Savings} = \Sigma_i (peakloss_{base,i} - peakloss_{efficient,i}) \times (1 + TPLF)$$

Where:

TPLF = Transmission Peak Loss Factor applicable to the transmission system upstream from the project

If the utility has estimates of load-related losses on the transmission system, and uses those estimates in screening customer end-use efficiency measures, it may add those losses to the load reduction due to efficiency improvements on primary distribution lines. For transmission lines, the utility may compute TLF as the portion of transmission losses attributable to voltages equal to or higher than those of the input voltage to the project line.

Provide the derivation of the estimate of transmission losses, and demonstrate the consistency of the claimed losses with the loss values used for the savings behind the customer meter.

Section 4: Screening Inputs

Measure Life
Document the life of each type of added equipment, including reference to the utility's depreciation studies. The efficient case analysis is typically performed over the lifetime of the major components. Where some equipment has a useful life shorter than the analysis period, describe the assumptions regarding the replacement cost of equipment with lives shorter than the analysis period.

Where the utility would make a similar investment in the foreseeable future to meet peak load or reliability requirements, including the need to replace aging conductor, the analysis period should be limited to the period prior to that need date, and reflect the present value of the differences in capital costs.

Operations Effects
The estimates of baseline and efficiency case losses should reflect the operating practices be expected to be in place for the base and efficient conductors.

O&M Cost Effects
Include any foreseeable changes in O&M costs related to the change in conductor (including the effect of replacing old conductor with new conductor) and to any changes in operating practices.

Cost
Document the actual cost of the project, including equipment, internal and contract labor, allocated overheads, design, engineering, and permitting.