CLEAN DEVELOPMENT MECHANISM

AM0118

Large-scale Methodology

Introduction of low resistance power transmission line

Version 02.0

Sectoral scope(s): 02

United Nations
Framework Convention on
Climate Change

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1. Introduction

1. The following table describes the key elements of the methodology.

Table 1. Methodology key elements

Typical project(s)	Introduction of efficient high voltage alternating current transmission line
Type of GHG emissions mitigation action	GHG mitigation through energy savings in power transmission lines.

2. Scope, applicability, and entry into force

2.1. Scope

2. This methodology covers installation of new and efficient low resistance high voltage alternating current (AC) power transmission lines (herein after project transmission line) or replacement of existing power transmission lines with project transmission lines providing the same or higher service as compared to baseline, thereby reducing the power losses and hence emission reductions.

2.2. Applicability

3. The methodology is applicable under the following conditions:

(a) The project transmission line system transmits electricity from the point of origin/supply to the point of receipt (i.e. two identified substations);

(b) There should not be any branching in between the proposed project transmission line;

(c) The direct current electrical resistance (ohm/km) of project transmission line is at least 5% lower than that of the conventional transmission line which otherwise would have been implemented in the absence of the project activity. This condition applies to projects activities using option 2 only (i.e., using simulation software to estimate baseline technical losses as per paragraph 22(b));

(d) The project transmission line possesses the same or equivalent mechanical characteristics, such as outer diameter, nominal weight and minimum tensile strength, with a variation of no more than +/- 20 per cent as compared to baseline power transmission line;

(e) The implementation of the project should not lead to changes in the design of steel lattice towers or modification and reinforcement of steel tower numbers and/or tower foundation;

(f) The project transmission line should have the same transmission parameters, such as voltage level, transmission capacity, distance, power transmission technology (e.g., alternating current) as compared to the baseline system;

(g) The project transmission line is produced and installed in conformity with national/international standards;

(h) The site specific conditions and/or regulations shall not mandate the implementation of the low resistance power transmission line.

4. This methodology is not applicable to the project activities of replacement of an existing alternating current power transmission line by a new direct current power transmission line. The approved methodology AM0097 may be explored for projects involving the installation *of high voltage direct current power transmission line*.

5. In addition, the applicability conditions included in the tools referred to below apply.

2.3. Entry into force

6. The date of entry into force is the date of the publication of the EB 97 meeting report on the 1 November 2017.

2.4. Applicability of sectoral scopes

7. For validation and verification of CDM projects and programme of activities by a designated operational entity (DOE) using this methodology, application of sectoral scope 02 is mandatory.

3. Normative references

8. This methodology is based on the following proposed new methodology:

(a) NM0374 “Introduction of low resistivity wire or cable to new or existing power line” prepared by Shanghai Zhixin Carbon Asset Management Co. Ltd. and SinoCarbon Innovation & Investment Co., Ltd.;

(b) Approved baseline and monitoring methodology AM0097: Installation of high voltage direct current power transmission line.

9. This methodology also refers to the latest approved versions of the following tools:

(a) Combined tool to identify the baseline scenario and demonstrate additionality;

(b) Tool to calculate the emission factor for an electricity system.

10. For more information regarding the proposed new methodologies and the tools as well as their consideration by the Executive Board please refer to <http://cdm.unfccc.int/goto/MPappmeth>.

3.1. Selected approach from paragraph 48 of the CDM modalities and procedures

11. “Existing actual or historical emissions, as applicable”; or “Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment”.

4. Definitions

12. The definitions contained in the Glossary of CDM terms shall apply.

13. For the purpose of this methodology, the following definitions apply:

(a) **Conventional power transmission line** - is the type of transmission lines that has been applied widely in the host country, such as aluminium stranded, steel-cored aluminium stranded transmission line;

(b) **Low resistance transmission line** - has smaller resistance values compared to conventional one with the same outer diameter and therefore reduces the transmission loss;

(c) **Transmission line losses** - include power losses (kW) due to passage of current in the conductors in the line. These do not include losses that take place in the equipment installed at the sub-stations/converter stations;

(d) **Station losses** - station losses are the losses that take place in the equipment installed at the substations (sending /receiving end). These include losses in transformers, switchgears etc., as applicable;

(e) **Technical losses** - technical losses are the summation of station losses and transmission line losses;

(f) **Point of origin/supply** - point of origin/supply is the site at which the project transmission line begins to transmit power. It could be at the substation in power plants or other transmission substation;

(g) **Point of receipt** - point of receipt is referred to as the point at which power is received at a transmission substation from the point of origin/supply, through the project transmission line;

(h) **Transmission capacity** - transmission capacity is the maximum allowed transmission power delivered by the power line under normal operating conditions.

5. Baseline Methodology

5.1. Project boundary

14. The spatial extent of the project boundary encompasses:

(a) The project transmission line from the point of origin/supply to the point of receipt including all the equipment (e.g., at substation) connected to it;

(b) Substations/converter stations connected between the terminals are also a part of the project boundary;

(c) The interconnected electricity grid to which the identified substations are connected is also included in the project boundary;

(d) The figures 1 and 2 below show the physical delineation of the project boundary.

Figure 1. Project boundary in baseline scenario

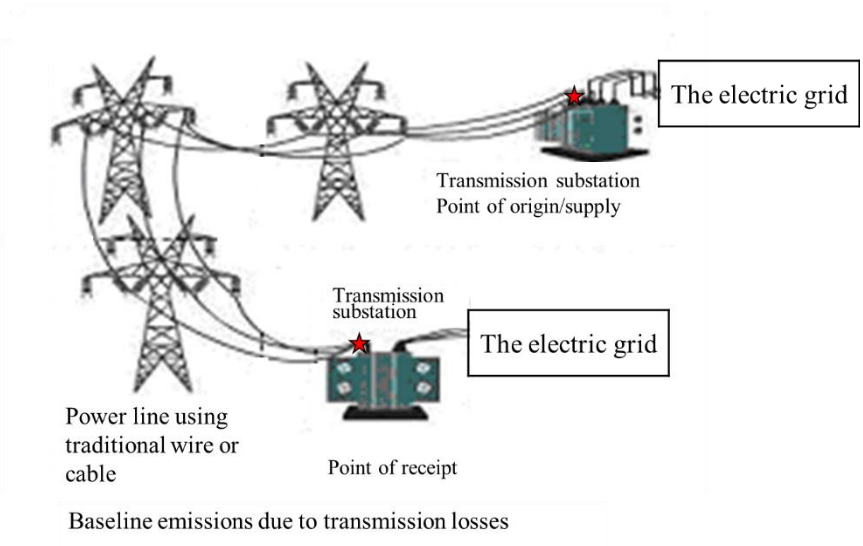
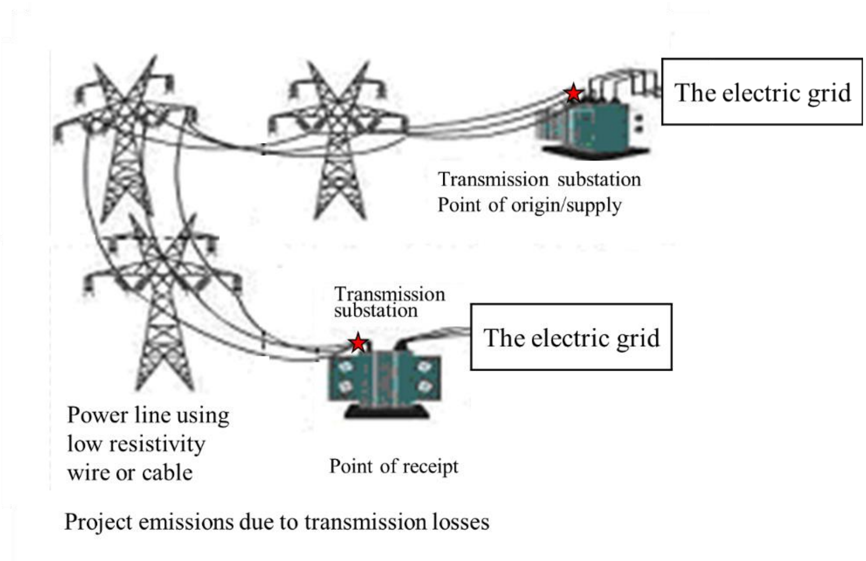


Figure 2. Project boundary in project scenario



15. The greenhouse gases included in or excluded from the project boundary are shown in Table 2.

Table 2. Emission sources included in or excluded from the project boundary

Source		Gas	Included	Justification/Explanation
Baseline	Transmission losses in the power line using traditional wire or cable identified in the baseline scenario	CO_2	Yes	Major source of emissions
		SF_6	No	These emissions cancel out each other under baseline and project scenario
		CH_4	No	No resulting CH_4 emissions
		N_2O	No	No resulting N_2O emissions
Project activity	Transmission losses in the power line using low resistance wire or cable in the project scenario	CO_2	Yes	Major source of emissions
		SF_6	No	These emissions cancel out each other under baseline and project scenario.
		CH_4	No	No resulting CH_4 emissions
		N_2O	No	No resulting N_2O emissions

5.2. Identification of the baseline scenario and demonstrating of additionality

16. Project participants shall apply the latest version of “Combined tool to identify the baseline scenario and demonstrate additionality” to identify the baseline scenario.

17. In applying Step 1 of the tool, the realistic and credible alternatives of the project activity are:

(a) B1: Implementation of project activity transmission line without being registered as CDM:

(b) B2: Implementation of power line based on the current trends/practices in the region or country:

(i) The project participant shall assess and consider all prevailing practices for power transmission in the region/country. The technologies and designs considered shall comprise those which are capable of meeting the technical requirements of the project scenario.

(c) B3: Continuation of power transmission using existing alternating current transmission line:

(i) This baseline alternative is available for CDM projects where an existing alternating transmission line is replaced by a project power transmission line, and where in the absence of CDM the existing transmission line would have continued supplying the electricity without any modification. The point of origin/supply and point of receipt shall remain the same;

(d) B4: Power transmission using the national or regional electricity grid:

(i) This alternative may be realistic and credible if the existing power transmission line is available at a comparative cost with respect to the proposed project power transmission line.

18. The methodology is applicable only if the most plausible baseline scenario identified using "Combined tool to identify the baseline scenario and demonstrate additionality" is B2 or B3.

5.3. Additionality

19. The latest approved version of the "Combined tool to identify the baseline scenario and demonstrate additionality" should be applied to assess the additionality of the proposed project activity.

5.4. Baseline emissions

20. Baseline emissions are calculated as follows.

$$BE_y = Q_{Line,BL,y} \times EF_{Elec,y}$$ Equation (1)

Where:

BE_y	=	Baseline emissions in year *y* (tCO_2e)
$Q_{Line,BL,y}$	=	Technical losses in the baseline scenario during year *y* (MWh)
$EF_{Elec,y}$	=	Emission factor of the electricity system that supplies power to the transmission line during year *y*, determined using the procedure provided in paragraph 30 (tCO_2e/MWh)

21. The baseline emissions are on account of the technical losses occurring in the power line identified as the baseline scenario. These include losses taking place in the transmission line (referred to as transmission line loss) and substations which are located between the point of supply and point of receipt (referred to as station loss). The total losses (i.e., transmission and substation losses) are referred to as baseline technical losses.

22. The baseline technical losses shall be determined using one of the following two options

    (a) Option 1: Using the actual power flow data during the crediting period;

    (b) Option 2: Using simulation software.

5.4.1. Steps to calculate baseline technical losses using Option 1

23. The project participants shall calculate the baseline technical losses by the following equation.

$$Q_{line,BL,y} = Q_{line,PJ,y} \times \frac{Rdc_{BL}}{Rdc_{PJ}}$$ Equation (2)

Where:

$Q_{line,BL,y}$	=	Transmission losses in the baseline scenario during year *y* (MWh)
$Q_{line,PJ,y}$	=	Transmission losses in the project during year *y* (MWh)
Rdc_{BL}	=	Direct current resistance of the baseline power line (@20 deg. C) (Ω/km)

Rdc_{PJ}	=	Direct current resistance of the project power line (@20 deg. C) (Ω/km)

24. For the purpose of an ex ante estimates for the PDD, the project participant shall use transmission line losses mentioned in equation (2) above using credible assumptions and such information shall be transparently documented in the PDD.

5.4.2. Steps to calculate baseline technical losses using Option 2

25. The technical loss in the baseline scenario is calculated as:

$$Q_{line,BL,y} = \sum_{H} P_{line,BL,H} + P_{station,BL,H}$$ Equation (3)

Where:

$Q_{line,BL,y}$	=	Technical losses in the baseline scenario during year *y* (MWh)
$P_{line,BL,H}$	=	Transmission line losses in the baseline scenario during the hour H of year *y* (MW)
$P_{station,BL,H}$	=	Substation losses in the baseline scenario during the hour H of year *y* (MW)
H	=	Each operational hour in year *y* (hour)

26. The project participant shall calculate substation losses and transmission line losses mentioned in equation (3) by using actual power flow data (i.e., electrical energy evacuated from the point of origin/supply and the net electrical energy received) in the project transmission line on a continuous basis during the monitoring period. The data over the monitoring period shall be used to construct the load curve of the dedicated transmission line plant during the same period. The actual loading conditions of the transmission line in the project scenario during the monitoring period shall be then used for the determination of technical losses using a simulation of the baseline transmission line during the same period using the actual loading conditions. This is to ensure that the same/actual loading conditions are used for computing transmission losses in both the project and the baseline scenarios.

27. The ex-post simulation of the baseline transmission line factors in the losses that would have occurred in the baseline scenario had it been operated on the same load profile as the project transmission line. The simulation that provides the value of the parameter $P_{line,BL,H}$ and $P_{station, BL,H}$ of the equation (3) above shall be calculated for each monitoring period and the value so obtained be used in the equation (1) to estimate baseline emissions.

28. For details about calculation of station losses and transmission losses using simulation software please refer to Appendix 1 and Appendix 2.

29. For the purpose of an ex ante estimate for the PDD, the project participant shall calculate substation losses and transmission line losses mentioned in equation (3) above as per the simulation of the power transmission line identified as the baseline scenario, using credible assumptions on the loading of the transmission line during the crediting period and such information shall be transparently documented in the PDD.

5.4.3. Determination of emission factor of electricity source $EF_{elec,y}$

30. Determination of emission factor $EF_{elec,y}$ depends upon the following two scenarios:

(a) If the point of origin/supply is the grid, the emission factor of electricity is the emission factor of the grid, i.e. $EF_{elec,y} = EF_{grid,y}$, determined using “Tool to calculate the emission factor for an electricity system”;

(b) If the point of origin/supply is one or several power plants, and the point of receipt is one or several specific users, i.e. the electricity will not be transmitted by the grid, the emission factor of electricity is the weighted average electricity emission factor of all the power plants in the sending point calculated using methods to determine average operating margin under “Tool to calculate the emission factor for an electricity system”. If all plants are renewable energy or nuclear plants, the emission factor shall be considered as zero.

5.5. Project emissions

31. Project emissions are calculated as follows:

(a) The emissions associated with the project activity are due to transmission losses occurring in the power line implemented in the project activity. The project emissions will then be calculated as the product of the technical losses and the emission factor of the electricity supplied through power line during the year.

$$PE_y = Q_{Line,PJ,y} \times EF_{Elec,y} \qquad \text{Equation (4)}$$

Where:

PE_y	=	Project emissions in year y (tCO_2e/yr)
$Q_{Line,PJ,y}$	=	Technical losses in the project scenario during year y (MWh)

5.5.1. Determination of $Q_{line,PJ,y}$

32. The transmission losses in the project scenario ($Q_{line,PJ,y}$) shall be determined using method 1 or 2 as follows. For project activity that applies Option 1 to determine baseline emissions, method 1 below shall be used. For project activity that applies Option 2 to determine baseline emissions, method 2 below shall be used (with method 1 used for calibration purposes):

(a) Method 1: the project transmission losses shall be calculated on the basis of the amount of the gross electrical energy evacuated from the point of origin/supply and the net electrical energy received at the point of receipt of the project transmission line as follows, taking into account uncertainty in a conservative manner[1]:

$$Q_{line,PJ,y} = \left(Q_{line,origin,y} - Q_{line,receipt,y}\right) \times (1 - U_{90}/100) \qquad \text{Equation (5)}$$

[1] The approach to estimate uncertainty is based on Equation 3.2 on page 3.28, Chapter 3 “Uncertainty” contained in “2006 IPCC Guidelines for National Greenhouse Gas Inventories”. It is redefined at 90 percent confidence interval instead of 95 confidence intervals applied in the IPCC guidelines.

With

$$U_{90} = \frac{\sqrt{\left(U_o \times Q_{line,origin,y}\right)^2 + \left(U_r \times Q_{line,receipt,y}\right)^2}}{\left|Q_{line,origin,y} - Q_{line,receipt,y}\right|} \times 0.82$$

Equation (6)

Where:

$Q_{line,origin,y}$	=	Gross electricity evacuated from the point of origin/supply of the power transmission line using the low resistance wire or cable built under the project activity during year y (MWh)
$Q_{line,receipt,y}$	=	Gross electricity received at the point of receipt of the power transmission line using the low resistance wire or cable built under the project activity during year y (MWh)
U_o	=	The percentage uncertainties associated with each of all the measurements *o* applied to determination of the parameter $Q_{line,origin,y}$
o	=	Source of variance in the electricity measurement (voltage and current) at the metering point of the sending end
U_r	=	The percentage uncertainties associated with each of all the measurements *r* applied to determination of the parameter $Q_{line,receipt,y}$
r	=	Source of variance in the electricity measurement (voltage and current) at the metering point of the receiving end
U_{90}	=	the overall percentage uncertainty in the measurement of *o* and *r* based on the 90 per cent confidence interval

(b) Method 2: The technical losses of the proposed project are determined by the same simulation software used in baseline scenario with the same calculation process, but using the project line parameters. The project proponent shall calibrate the model at least for the first year of the monitoring period by comparing the project losses determined using the method 1 with the project losses determined using the simulation in order to ensure that the simulation model correctly estimates the losses occurring in the project transmission;

Application of the simulation software for the calculation of station losses and transmission losses shall be in accordance with procedure provided in Appendix 1 and Appendix 2.

(c) An example illustrating the application of Method 1 is provided in the Appendix 3 to this methodology.

5.6. Leakage

33. Leakage is not considered.

5.7. Emission reductions

34. Emission reductions are calculated as follows:

$$ER_y = BE_y - PE_y$$ Equation (7)

Where:

ER_y	=	Emission reductions in year *y* (tCO_2e)
BE_y	=	Baseline emissions in year *y* (tCO_2e)
PE_y	=	Project emissions in year *y* (tCO_2e)

5.8. Changes required for methodology implementation in 2nd and 3rd crediting periods

35. It is required to address the validity of the baseline scenario at the start of the second period for a project activity. Baseline emissions have to be reassessed before the start of a new crediting period. Project participants shall refer to the methodological tool "Assessment of the validity of the original/current baseline and update of the baseline at the renewal of the crediting period".

5.9. Data and parameters not monitored

36. In addition to the parameters listed in the tables below, the provisions on data and parameters not monitored in the tools referred to in this methodology apply.

Data / Parameter table 1.

Data / Parameter:	L_{BL}
Data unit:	km
Description:	Length of the power line in the baseline scenario
Source of data:	For the project activity involving replacement of an existing line, one of the following sources shall be used as source of data (in preferential order): (a) Technical documents or operation records provided by the project owner in the baseline scenario; or (b) Project feasibility study report (FSR); or (c) Project documents submitted to the government authorities for applications for approval; or (d) Project documents submitted to financial institutions for appraisal; or (e) Project documents certified by registered professional engineers; For the greenfield projects, the length should be the same as the project activity
Measurement procedures (if any):	-
Any comment:	-

Data / Parameter table 2.

Data / Parameter:	***Rdc_{BL}***
Data unit:	Ω/km
Description:	Direct current resistance of the baseline power line (at 20 degrees C)
Source of data:	One of the following sources shall be used as source of data (in preferential order): (a) Test report issued by the third-party testing institutions; or (b) Product specification provided by the manufacturer or calculated by relevant parameters; or (c) Project feasibility study report (FSR); or (d) Project documents submitted to the government authorities for applications for approval; or (e) Project documents submitted to financial institutions for appraisal.
Measurement procedures (if any):	-
Any comment:	For projects that apply option 2 in paragraph 22 (b) (Simulation software), AC resistance shall be used instead of DC resistance of the project power line (@20 deg. C)

Data / Parameter table 3.

Data / Parameter:	U_o
Data unit:	-
Description:	The percentage uncertainties associated with each of all the measurements *o* applied to determination of the parameter $Q_{line,origin,y}$
Source of data:	Manufacturer's specification
Measurement procedures (if any):	
Any comment	

Data / Parameter table 3.

Data / Parameter:	U_r
Data unit:	-
Description:	The percentage uncertainties associated with each of the all measurements *r* applied to determination of the parameter $Q_{line,receipt,y}$
Source of data:	Meters manufacturer
Measurement procedures (if any):	
Any comment	

Data / Parameter table 3.

Data / Parameter:	***Rdc_{PJ}***
Data unit:	Ω/km
Description:	Direct current (DC) resistance of the project power line (@20 deg. C)
Source of data:	One of the following sources shall be used as source of data (in preferential order): (a) Measured according to IEC 60468 (Method of measurement of resistance of metallic materials); (b) Test report issued by the third-party testing institutions; or (c) Product Specification provided by the manufacturer or calculated by relevant parameters; or (d) Project feasibility study report (FSR); or (e) Project documents submitted to the government authorities for applications for approval; or (f) Project documents submitted to financial institutions for appraisal
Measurement procedures (if any):	
Any comment	For projects that apply option 2 in paragraph 22 (b) (Simulation), AC resistance shall be used instead of DC resistance of the project power line (@20 deg. C)

6. Monitoring methodology

37. All data collected as part of monitoring should be archived electronically and be kept at least for 2 years after the end of the last crediting period. 100% of the data should be monitored if not indicated otherwise in the tables below. All measurements should be conducted with calibrated measurement equipment according to relevant industry standards.

38. In addition, the monitoring provisions in the tools referred to in this methodology apply.

6.1. Data and parameters monitored

Data / Parameter table 4.

Data / Parameter:	***L_{PJ}***
Data unit:	km
Description:	Length of the power line in the project scenario
Source of data:	One of the following sources shall be used as source of data: (a) Technical documents or operation records provided by the project owner in the baseline scenario; or (b) Project feasibility study report (FSR); or (c) Project documents submitted to the government authorities for applications for approval; or (d) Project documents submitted to financial institutions for appraisal; or (e) Project documents certified by registered professional engineers;
Measurement procedures (if any):	-

Monitoring frequency:	Annually
QA/QC procedures:	By site review to check if there is any change in the project implementation.
Any comment:	-

Data / Parameter table 5.

Data / Parameter:	$EF_{Elec,y}$
Data unit:	tCO_2e/MWh
Description:	Emission factor of electricity system that supplies electricity to the transmission line during year *y*
Source of data:	As per the “Tool to calculate the emission factor for an electricity system”
Measurement procedures (if any):	As per the “Tool to calculate the emission factor for an electricity system”
Monitoring frequency:	As per the “Tool to calculate the emission factor for an electricity system”
QA/QC procedures:	As per the “Tool to calculate the emission factor for an electricity system”
Any comment:	Also refer to paragraph 30

Data / Parameter table 6.

Data / Parameter:	$Q_{line,origin,y}$
Data unit:	MWh
Description:	Gross electricity evacuated from the point of origin/supply of the power transmission line using the low resistance wire or cable built under the project activity during year *y*
Source of data:	Measured by the project participant
Measurement procedures (if any):	Electricity meter with accuracy class of 0.2s or 0.5s should be installed in the outgoing line of the transmission substation in the point of origin/supply.
Monitoring frequency:	Continuously
QA/QC procedures:	Measurement equipment will be calibrated annually for accuracy. Uniform class of meters for measurements shall be used, i.e. meters of similar accuracy class preferably from same manufacturer at both sending and receiving ends of the transmission line.
Any comment:	-

Data / Parameter table 7.

Data / Parameter:	$Q_{line,receipt,y}$
Data unit:	MWh
Description:	Gross electricity received at the point of receipt of the power transmission line using the low resistance wire or cable built under the project activity during year *y*
Source of data:	Measured by the project participant

Measurement procedures (if any):	Electricity meter with accuracy class of at least 0.2s or 0.5s should be installed in the incoming line of the transmission substation in the point of receipt.
Monitoring frequency:	Continuously
QA/QC procedures:	Measurement equipment will be calibrated annually for accuracy. Uniform class of meters for measurements shall be used, i.e. meters of similar accuracy class preferably from same manufacturer at both sending and receiving ends of the transmission line.
Any comment:	-

Data / Parameter table 8.

Data / Parameter:	H_y
Data unit:	hour
Description:	Each hour of operation time of the power line in the project scenario during year *y*
Source of data:	Operating records
Measurement procedures (if any):	-
Monitoring frequency:	Daily, archived monthly
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 9.

Data / Parameter:	***Load Curve***
Data unit:	-
Description:	Load curve for the project transmission line during year *y*
Source of data:	Monitored values of power evacuated
Measurement procedures (if any):	The power evacuated from the point of supply/origin shall be monitored on a continuous basis. Based on the power evacuated, the load curve for the year shall be developed
Monitoring frequency:	Real-time monitored and recorded
QA/QC procedures:	-
Any comment:	The load curve developed for the project case shall be used to compute the transmission losses, using simulation software, that would have occurred in the transmission line used in absence of CDM project. The process shall be repeated for every monitoring period

Appendix 1. General guidance on use of simulation software package

1. Evaluation of transmission line models

1. The calculation methods using simulation models are applied for planning, designing and managing operations in electricity transmission and distribution networks as well as industrial networks. Companies use simulation models of various designs of transmission lines as it is not possible to get existing data on the performance of the transmission lines exactly as per the desired configuration. The models may be available as software packages that are used by companies to evaluate various configurations of transmission lines before the final investment decision is taken. For the purpose of this methodology the project participants shall apply a model that is implemented as a software package. The software package shall meet at least one of the following standards and shall calculate technical losses with better than 5% accuracy:

    (a) VDE[1] 0102/1.90 – IEC[2] 909;

    (b) VDE 0102/2002- IEC 909/2001;

    (c) IEC 61363-1/1998;

    (d) ANSI[3];

    (e) Engineering Recommendation G74[4];

    (f) The national standards or industry standards of the host country.

2. The above requirement shall be confirmed by a third party chartered engineer.

3. The baseline scenario shall be simulated by a balanced load flow study of the power transmission line. The balanced load flow study is an effective tool for calculating operating conditions in electrical power networks. This calculation method determines the power flow from the point of supply to the point of receipt. Conservative assumptions shall be taken into account while carrying out simulation of the baseline transmission line e.g. no substation losses (except terminal substations) will be calculated for the estimation of baseline technical losses. The simulation results shall be confirmed by third party chartered engineer.

4. Software simulation is required to arrive at baseline emissions since the calculation of the power transferred from the point of supply to the point of receipt would involve a complex algorithmic approach. In addition, it will also require equations and procedures for

[1] Verband der Elektrotechnik, Elektronik und Informationstechnik, <www.vde.com>.

[2] International Electrotechnical Commission, <www.iec.ch>.

[3] American National Standards Institute, <www.ansi.org>.

[4] ER G74 sets out a procedure which requires a more detailed assessment of short circuit currents with a fuller representation of system pre-fault conditions and taking account of dynamic load fault circuit contribution.

calculations which will be very difficult to carry out manually. On the other hand, the simulation shall account for the losses that are otherwise difficult to quantify using calculation procedures.

5. The project scenario shall be simulated by the same processes.

2. Criteria for the selection of simulation software

6. The simulation software must be in compliance with accepted International Standards in electrical power transmission industry and follow any of the following algorithms for performing the load flow study:

   (a) Newton-Raphson method;

   (b) Gauss-Seidel method.

3. Functional Characteristics

7. The functional characteristics of the software package should include:

   (a) Load flow calculations should be able to handle more than one isolated network at the same time;

   (b) Required number of in-feeders and generators should be supported;

   (c) Voltage controllers should calculate the optimal tap position while automatically taking into account voltage ranges;

   (d) Load flow should handle phase shifting transformers;

   (e) Permissible operating ranges (P/Q) can be defined for generators and in-feeders. The software can also use a prescribed zone exchange power to calculate power transfer between different network areas;

   (f) Establishment and shutdown dates shall be defined for any equipment considered by the load flow calculations;

   (g) The software package load flow should support different load types.

8. The project participant shall use software that is reliable, is used by chartered engineers and is readily available.

4. Key input parameters for the software package

9. The key input parameters should include:

   (a) Voltage level of the transmission line (kV);

   (b) Length of the transmission line (km);

   (c) Operating system frequency (50 or 60 Hz as adopted in the application country);

   (d) Inductance of the transmission line (H/km);

   (e) Capacitance of the transmission line (F/km);

(f) Expected transmission line loading (MW);

(g) Substation spacing (km);

(h) Power factor of the power at the point of origin/ supply and connected to the transmission line during the hour H of year *y*.

10. Since the software is standardized, the simulation need not be performed by any third party, it can be either carried out by the technology supplier or by the project participant themselves. But the operation of the simulation software should be explained to DOE and the actual software shall be shared with DOE during validation. The DOE shall verify that the software used by the project participant is in compliance with International Standards in power transmission technology and as per standard industry practices.

11. The project participant shall simulate the model of the power transmission line that was or would have been installed in the absence of the project activity.

Appendix 2. Calculation of station losses and transmission losses using simulation software

1. The **station losses** comprise the following two types of losses:

   (a) **Transformer losses** (two components):

      (i) Core loss. Core losses are again comprised of hysteresis losses and eddy current losses. Hysteresis loss is energy lost by reversing the magnetic field in the core as the magnetizing Alternating Current (AC) rises and falls and reverses direction. Eddy current loss is a result of induced current circulating in the core;

      (ii) Winding loss. The winding loss is a result of the resistance of the windings and is proportional to the square of the current through the transformer;

2. The **transmission line losses** comprise the following losses:

3. Please provide definitions of these losses:

   (a) **Ohmic losses:** The passage of current through the conductors (of a transmission line) results in power losses due to resistance of the conductors. This loss is referred to as the ohmic losses;

   (b) **Reactive power flow losses:.** It refers to those losses which occur as a result of flow of reactive power in a system. The flow of reactive power results in the reduction of the power factor of the system, which in turn results in reduction of transmission of real power. Thus, the term reactive power loss refers to this reduction in transmission of real power.

4. The simulation software as described in Appendix I shall be chosen in order that the following parameters are used to compute station losses and transmission line losses:

   (a) **Rated power transformer voltage.** The voltage assigned to be applied, or developed at no-load, between the terminals of an untapped winding, or of a tapped winding connected on the principal tapping. For a three-phase winding it is the voltage between line terminals. This parameter is the key design parameter of a transformer, which in addition to the kVA rating is used to calculate the rated current of the transformer, and therefore, the losses that would occur during the course of operation of the equipment;

   (b) **Rated power transformer kVA.** The kVA rating of a transformer is the apparent power handling capability of the transformer. This is a conventional value of apparent power assigned to a winding which, together with the rated voltage of the winding, determines its rated current, which affects the losses that occur in the transformer during course of operation;

(c) **Power transformer ratio.** The power transformer ratio is the ratio of the number of turns in primary winding and secondary winding. This is same as the ratio of primary voltage and secondary voltage;

(d) **Percent exciting current.** The percent exciting current is the value (expressed as percentage of the rated current) of current which primary winding of the transformer draws to develop the magnetic flux sufficient to reach the rated voltage, secondary of the transformer being open circuited; Besides magnitude/absolute value in Amperes, the percent exciting current must have its power factor included. The no load current and exciting current are used interchangeably by the transformer industry. In the cases where information on no load current are available, no load current and no load power factor have to be treated as exciting current and exciting current power factor respectively.

(e) **Percent impedance.** Short-circuit impedance of a pair of windings is the percentage ratio of "voltage applied to primary winding to maintain rated current in the short circuited secondary winding" and the rated voltage of primary winding.

5. **Relevance of parameters under points a, b, c, d and e above.** All these design parameters are the characteristics of a transformer, and transformer no-load and load losses are dependent upon these design parameters. The transformer no-load and load copper losses comprise the total losses that take place in the transformer connected at the sub-station. Further, the transformer losses comprise the bulk of the losses that occur in a substation. The parameters listed above are required to compute the transformer losses at any point the transmission line is in operation.

(a) **No load iron test loss (Watts).** The no-load iron test losses are the power losses which are caused due to the hysteresis and eddy currents in the iron core of the transformer. These loads are always present in the transformer when energized irrespective of the loading:

(i) **Relevance.** These losses are present all the time; this has direct bearing on the terminal station losses;

(b) **Full load copper test loss (Watts).** These are the power losses which occur due to the flow of current in the copper winding and are proportional of the square of the current:

(i) **Relevance.** These losses vary with respect to the loading on the transformer, and have a direct bearing on the terminal station losses;

(c) **Resistance and reactance per unit length.** The resistance of the transmission line is the ohmic resistance of the line per unit of line length. This is evaluated after considering the proximity and skin effect. This is responsible for the power losses in the line and voltage drop across the line. The resistance is inversely proportional to the area of the conductor and directly proportional to the resistance of the conductor:

(i) The reactance of the line in combination with the resistance, contributes to the voltage drop across the transmission line;

(ii) **Relevance.** Ohmic losses are directly proportional to the resistance of the power transmission line. This forms major part of the transmission losses. Reactance contributes to voltage drop in the transmission line and is only indirectly related to the loss calculation.

6. Therefore, the parameters listed above allow for the calculation of losses that occur at the various stages of a power transmission system, i.e. substation and transmission line. The station losses and transmission line losses together represent the technical losses that occur during the transmission phase.

Appendix 3. Illustrative example using method 1 (paragraph 31(a) above) on determining project transmission losses taking into account uncertainty

1. Hypothetical Example (for illustration purpose only): 345 kV, 200 km transmission line

(a) Resistance of the base line transmission line: 0.0370 ohm /km

(b) Project transmission line = 0.0289 ohm /km

2. Power flow measurement at the given time for the transmission line in question

2.1. Baseline Scenario

(a) Power at the origin: 420 MWh;

(b) Power at the receiving end: 409 MWh;

(c) Losses in the line: 11 MWh.

2.2. Project Scenario

(a) Power at the origin: 420 MWh;

(b) Power at the receiving end: 411.5 MWh;

(c) Losses in the line: 8.5 MWh;

(d) Reduction in losses: 2.5 MWh.

3. Percentage uncertainty in power measurements employing 0.2s class meters

(a) For the variation of load current between 20% to 100 % of normal loading;

(i) Percentage error of energy meter: 0.3;

(ii) Percentage error of measuring transformer: 0.2;

(b) Combined or system error in percentage: 0.5.

4. Applying equation 6 of the methodology

$$U_{90} = \frac{\sqrt{(0.5x420)^2 + (0.5x411.5)^2}}{|420 - 411.5|} x0.82 = 28.36$$

5. Applying equation 5 of the methodology, Losses based on measurement with 0.2s class metering adjusted with uncertainty = (420-411.5) *(1 - 28.36/100) = 6.089 MWh

Note: The project transmission losses without adjusting uncertainty = (420-411.5) = 8.50 MWh. Hence the error in loss estimation because of metering uncertainty = 100 x (8.5-6.089)/8.5 = 28.36 per cent.

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Document information

Version	*Date*	*Description*
02.0	1 November 2017	EB 97, Annex 5 Revision to amend the requirements for eligibility thresholds. Adjustment to document title by changing resistivity to resistance.
01.0	4 November 2016	EB 92, Annex 4 Initial adoption.

Decision Class: Regulatory
Document Type: Standard
Business Function: Methodology
Keywords: electric power transmission, electricity generation