Additional Information for JCM Methodology

"Installation of energy-saving conductors for transmission lines in the Bangladesh grid"

1. Eligibility criteria

In this methodology, "The type of conductor used by the project is a family of HTLS" is set as one of eligibility criteria. High-temperature low-sag conductors (HTLS) are defined as conductors which have less sag at high temperatures, higher capacity and less energy loss compared to conventional aluminum conductor steel reinforced (ACSR) cables with cores made of steel alloys, composite-reinforced metal, or carbon fiber composite material. Examples of "a family of HTLS conductors[i]" is as follows;

GTACSR = Gap-type thermal aluminum conductor steel reinforced,
ACIR = Aluminum conductor invar reinforced,
TACIR = Thermal Aluminum conductor invar reinforced,
STACIR = Super thermal Aluminum conductor invar reinforced,
ZACIR = Super aluminum conductor invar reinforced,
ACSS = Aluminum conductor steel supported,
ACCR = Aluminum conductor composite reinforced,
ACCC = Aluminum conductor composite core, and
ACFR = Aluminum conductor fiber reinforced

[i] Source: Aniket V. Kenge, Sagar V. Dusane and Joydeep Sarkar (2016) Statistical Analysis & Comparison of HTLS Conductor with Conventional ACSR Conductor

2. Conservativeness of reference emission: Conductor temperature

Conductors are used in major high voltage transmission lines in Bangladesh, being selected to meet required transmission load. Bangladesh has a common design requirement for steel lattice towers, on which standard ACSR has been installed. Since such design requirement is applicable to all types of transmission line conductors, HTLS must be designed to have same mechanical characteristics (overall diameter, nominal weight and minimum tensile strength) as conventional ACSR used in Bangladesh, to be able to be installed on Bangladesh standard steel lattice towers without any modification and reinforcement of steel tower members and/or tower foundation.

When calculating difference of transmission losses between reference and project scenarios in Bangladesh, the only factor that needs to be considered is the resistance of the conductors themselves; there is no need to consider the difference in reactance and admittance caused by different diameter and distance between the conductors. This is because, as described above, the mechanical characteristics (overall diameter, nominal weight, and minimum tensile strength) are required to be the same in Bangladesh regardless of the type of conductors.

Therefore, the transmission loss of reference conductors can be calculated as a product of transmission loss of energy-saving conductors (which is monitored) and ratio of resistance between reference and energy-saving conductors, as follows:

$$\mathrm{LOSS}_{\mathrm{RE,L,y}} = \mathrm{LOSS}_{\mathrm{PJ,L,y}} \times \frac{\mathrm{R}_{\mathrm{RE,L}}}{\mathrm{R}_{\mathrm{PJ,L}}}$$

Where:

$\mathrm{LOSS}_{\mathrm{RF,L,y}}$	=	Reference transmission loss of transmission line L in the year y [MWh/y]
$\mathrm{LOSS}_{\mathrm{PJ,L,y}}$	=	Project transmission loss of transmission line L in the year y [MWh/y]
$\mathrm{R}_{\mathrm{RF,L}}$	=	Resistance of transmission line L using currently of reference transmission conductors. [Ω/km]
$\mathrm{R}_{\mathrm{PJ,L}}$	=	Resistance of transmission line L using project conductors. [Ω/km]

In addition, the ratio of direct current resistance between ACSR and HTLS at the same conductor temperature (20 deg. C) is applied in this methodology. Resistance of transmission lines is positively correlated with conductor temperature, which in turn is affected by the ambient conditions (temperature, wind velocity and solar radiation). For all type of conductors, the relationship between conductor temperature *t* and direct current resistance R_{DC} can be denoted as follows according to the standard IEC 60889-1987 (Hard-drawn aluminium wire for overhead line conductors) where the constant-mass temperature coefficient is at 20 deg. C:

$$\mathrm{R}_{\mathrm{DC}}(\mathrm{t}) = \mathrm{R}_{\mathrm{DC}}\ (20\ \mathrm{deg.C})\ \times (1 + 0.00403 \times (\mathrm{t} - 20))$$

3. Conservativeness of reference emissions: Overall diameter

To establish the reference emissions conservatively, this methodology predetermines the $R_{DC\_RF,L}$ (direct current resistance of transmission line L using reference ACSR at 20 deg. C [Ω/km]) as a parameter fixed ex ante, by using ASTM B232 with some adjustment. The $R_{DC\_RF,L}$ is set by discounting the direct current resistance of ACSR as prescribed in the ASTM B232 with 2% discount, based on the assumption as follows.

It is assumed that the diameter of each strand for reference conductor is 1% larger than its specification, which is the maximum allowable tolerance of major international standard such as the International Electrotechnical Commission (IEC). Since the resistance is inversely proportional to the cross-sectional area, the resistance of ACSR decreases by 2% (1% larger diameter results in 2% larger cross-sectional area).

> If overall diameter of a conductor is 1 % smaller than that of the specification of corresponded ASTM code (X mm), its larger cross-sectional are 2 % larger than that of ASTM code specification. When overall diameter of corresponded ASTM code is X mm, its cross-sectional area is $\frac{1}{4}\pi X^2$.
>
> $$\frac{1}{2}X \times \frac{1}{2}X \times \pi = \frac{1}{4}\pi X^2$$
>
> When overall diameter of a conductor is 1 % larger than that of corresponded ASTM code, cross-sectional area is $\frac{1}{4}\pi X^2 \times 1.0201$. Namely, 1% larger diameter results in 2.01% larger cross-sectional area.
>
> $$\frac{1}{2}(1.01X) \times \frac{1}{2}(1.01X) \times \pi = \frac{1}{4}\pi X^2 \times 1.0201$$
>
> Resistance of conductor (R Ω) is in inversely proportional to its cross-sectional area. Thus, when cross-sectional area is 2.01% larger, its resistance is discounted by 1.97 %.
>
> $$R \times \frac{1}{1.0201} = 0.9803R$$
>
> In this methodology, this discount is set as 2 % to avoid more complicated calculation.

As a result of the discount, the $R_{DC\_RF,L}$ values are determined as shown in Table 2 for six typical sizes (overall diameter) of ACSR conductors in Bangladesh. For instance, if the diameter of project conductor is 28.96 mm, Code “Mallard” is selected and $R_{DC\_RF,L}$ = 0.0702 (Ω/km at 20 deg. C) is used for calculation of reference emissions.

In case that the overall diameter of the conductor to be used in a project does not match any of the sizes in the Table 1, the logic explained above can be applied for other ASTM codes to determine the appropriate $R_{DC\_RF,L}$ for the project. In case that the overall diameter of project HTLS is not same as that of any ASTM code, a code with the most similar and smaller overall diameter than that of project conductor can be selected to set $R_{DC\_RF,L}$ for the project.

Table1: Example of default reference direct current resistance values

ACSR Code which has same overall diameter as one of project HTLS	Overall diameter (mm)	Direct current resistance standardized in ATSM B232 (Ω/km at 20 deg. C)	$R_{DC\_RF,L}$ (conservative direct current resistance) (Ω/km at 20 deg. C)[ii]
Flamingo	25.34	0.0856	0.0838
Crow	26.28	0.0799	0.0783
Mallard	28.96	0.0717	0.0702
Canary	29.52	0.0633	0.0620
Cardinal	30.42	0.0596	0.0584
Bluejay	31.98	0.0511	0.0501

[ii] The 98% of direct current resistance of reference ACSR