Explanatory note on MRV methodology "Installation of energy-saving transmission lines in the Mongolian Grid"

1. Eligibility criteria

In Mongolia, Aluminum Conductors, Coated-Steel Reinforced (ACSR) are commonly used for overhead transmission lines. Their specifications are determined as per Mongolian standard MNS 5870: 2008 shown in Table 1.

Table 1 Characteristics of ACSR used in Mongolia

Type of ACSR			—	ACSR 240/32mm^2	ACSR 300/39mm^2	ACSR 400/51mm^2
Cross-sectional area	Aluminum wire		mm^2	240	300	400
	Zinc coated steel wire			32	39	51
Construction	Aluminum wire	No. of wire	Nos.	24	24	54
		Diameter	mm	3.60	4.00	3.05
	Zinc coated steel wire	No. of wire	Nos.	7	7	7
		Diameter	mm	2.40	2.65	3.05
No. of layer	Aluminum wire		layer	2	2	3
	Zinc coated steel wire			1	1	1
Calculated cross-sectional area	Aluminum wire		mm^2	244	301	394
	Zinc coated steel wire			31.7	38.6	51.1
Outer diameter of conductor			mm	21.6	24.0	27.5
Diameter of steel core			mm	7.2	8.0	9.2
Direct current resistance at 20deg.C			Ω/km	0.1182	0.0958	0.0733
Minimum tensile strength			N	75,050	90,574	120,481
Nominal Weight	Aluminum wire		kg/km	673	830	1,090
	Zinc coated steel wire			248	302	400
	Total			921	1,132	1,490

The conductors shown above are used in major high voltage transmission lines (110kV and above) in Mongolia, being selected to meet required transmission capacity. Mongolia has a common design for steel lattice towers, and standard ACSR are installed on such steel lattice towers. Therefore, Low Electrical Power Loss Aluminum Conductors, Aluminum-Clad Steel Reinforced (LL-ASCR/SA) must be designed to have same mechanical characteristics (outer diameter, nominal weight and minimum tensile strength) as conventional ACSR used in Mongolia, to be able to be installed on Mongolian standard steel lattice towers without any modification and reinforcement of steel tower members and/or tower foundation.

Furthermore, to ensure a high standard of technology to be implemented, another criterion is introduced whereby electrical resistance (as defined as direct current resistance) of LL-ACSR/SA should be at least 10% lower than that of conventional ACSR that are currently operating in Mongolia. As a result, the eligibility criteria of the project transmission conductors are established as shown in Table 2:

Table 2 Eligibility criteria of project transmission conductors

Type of conductor (ACSR)		ACSR 240/32mm^2	ACSR 300/39mm^2	ACSR 400/51mm^2
Type of corresponding energy-saving conductor (LL-ACSR/SA)		Equivalent to LL-ACSR/SA 279/20mm^2	Equivalent to LL-ACSR/SA 337/27mm^2	Equivalent to LL-ACSR/SA 445/36mm^2
Outer diameter of conductor	mm	≦21.6	≦24.0	≦27.5
Direct current resistance at 20deg.C	Ω/km	≦0.1063	≦0.0862	≦0.0659
Tensile strength	N	≧75,050	≧90,574	≧120,481
Nominal weight	kg/km	≦921	≦1,132	≦1,490

2. Establishment of reference emissions: rationale of algorithm

As described above, energy-saving conductors, by possessing the same mechanical characteristics (outer diameter, nominal weight and minimum tensile strength) as conventional ACSR currently used, can substitute them while using the steel lattice towers of the same design (positional relation of installed conductors can be retained). Therefore, when calculating transmission loss, 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.

From the above, it follows that the transmission loss of currently used conductors is calculated as a product of transmission loss of energy-saving conductors (which is monitored) and ratio of transmission loss between current (reference) and energy-saving conductors, as follows:

$$LOSS_{RF,L,y} = LOSS_{PJ,L,y} \times \frac{Rac_{RF,L}}{Rac_{PJ,L}}$$

where

$LOSS_{RF,L,y}$	=	Reference transmission loss of transmission line L in the year y [MWh/y]
$LOSS_{PJ,L,y}$	=	Project transmission loss of transmission line L in the year y [MWh/y]
$Rac_{RF,L}$	=	Alternative current resistance of transmission line L using currently used transmission conductors.[Ω/km]
$Rac_{PJ,L}$	=	Alternative current resistance of transmission line L using energy-saving conductors. [Ω/km]

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 Rdc can be denoted as follows

Rdc(t) = Rdc(20deg.C) *(1+0.00403*(t-20))

Where the constant-mass temperature coefficient at 20deg.C 0.00403 is derived from the standard IEC 889-1987 (Hard-drawn aluminum wire for overhead line conductors).

Generally with ASCR as well as LL-ASCR/SA, alternate current resistance is more than direct current resistance due to "skin effect" derived from increased impedance in the inside of the conductor, and core loss (iron loss) and eddy current loss. This increase is calculated by the formula recommended by Conseil International des Grands Réseaux Électriques (CIGRE) based on the assumption that, with ACSR, electrical input is identical when the average temperature is identical, as follows:

Ratio of direct and alternate current resistance in three-layer aluminum conductor	$\frac{Rac}{Rdc} = 1.0123 + 2.36 \times 10^{-5} * Iac$
Ratio of direct and alternate current resistance in two-layer aluminum conductor	$\frac{Rac}{Rdc} = 1.0045 + 0.09 \times 10^{-6} * Iac$

Where

Rac = alternate current resistance (Ω)

Rdc = direct current resistance (Ω)

Since LL-ACSR/SA are designed two-layered aluminum and some of the ACSR currently in use are three-layered aluminum, the ratio of alternative current resistance between LL-ACSR/SA and ACSR is larger than the ratio of direct current resistance. Furthermore, conductor temperature is bound to be higher than ambient temperature due to power flow of transmission line, and conductor temperature rise and electrical resistance of conductor are positively correlated. Therefore, there is a further element of conservativeness by assuming that conductor temperature is identical to ambient temperature. These multiple levels of conservative assumptions ensures that the methodology achieves net reductions, which is probably about 6-8% of emission reductions calculated as per the methodology.

3. Establishment of reference emissions: data for calculating reference emissions.

As mentioned before, direct current resistance for the purpose of calculating reference emissions will be based on the Mongolian standard MNS 5870: 2008. It is possible that this standard is overachieved at present, resulting in deployment of conductors whose resistance is lower than what is prescribed in the standard. There are two possibilities for this to happen, namely a) the diameter of each strand is larger, and b) the conductivity of material is higher. The latter is deemed unlikely to happen since the conductive material is made from pure aluminum and there is very little room to vary conductance: therefore 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 IEC, etc., resulting in 2% reduction in resistance since resistance is inversely proportional to the cross-sectional area. Therefore, for the purpose of calculating reference emissions, the direct current resistance as prescribed in MNS 5870: 2008 is discounted by 2% to yield as shown in Table 3:

Table 3 Figures for $Rdc_{RF,L}$

Type of energy-saving conductor (LL-ACSR/SA)	—	Equivalent to LL-ACSR/SA 279/20mm^2	Equivalent to LL-ACSR/SA 337/27mm^2	Equivalent to LL-ACSR/SA 445/36mm^2
Type of corresponding conductor (ACSR)		ACSR 240/32 mm^2	ACSR 300/39 mm^2	ACSR 400/51 mm^2
$Rdc_{RF,L}$ (Direct current resistance at 20degC)	Ω/km	0.1158	0.0939	0.0718