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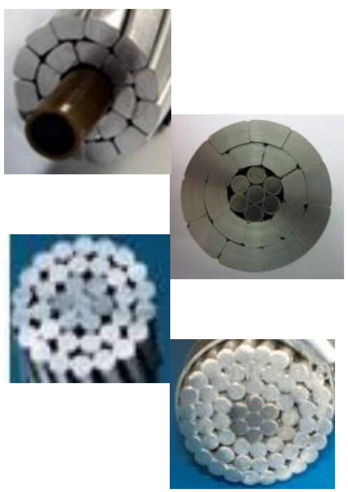
TNB Initiatives Towards Energy Efficient Transmission Lines



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TNB Initiatives Towards Energy Efficient Transmission Lines

Keywords : * Energy Efficient T/Line * Challenges * HTLS *

Transmission Line Construction

1. New rentice or Additional rentice.
2. Dismantling of existing overhead lines and replacing with new.

The Challenges

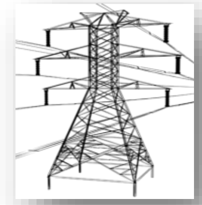
1. Landowners critical objections; land acquisitions and project delays can stretch over many years.
2. Cutting of trees (forest, oil palms, orchards) and disability of future land use when new rentice is acquired.
3. Significant costs in procuring rentice and access, and construction costs of new towers and foundations.

Conventional Overhead Line Conductors – The ACSR

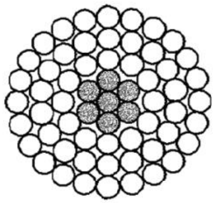
1. Typically ACSR is used : rounded aluminium strands with steel core and greased (between Al and steel).

2. Transmission losses when conventional ACSR is used for major grid and trunk lines.

3. Tall and robust tower structures are required to achieve ground clearances when crossing wide rivers and flat grounds (by virtue of the sagging properties of ACSR). Lightning arrestors may be necessary for tall towers.



21,469 cct-km



Typical ACSR

TNB Grid

TNB Road Map : Overhead Line Conductors

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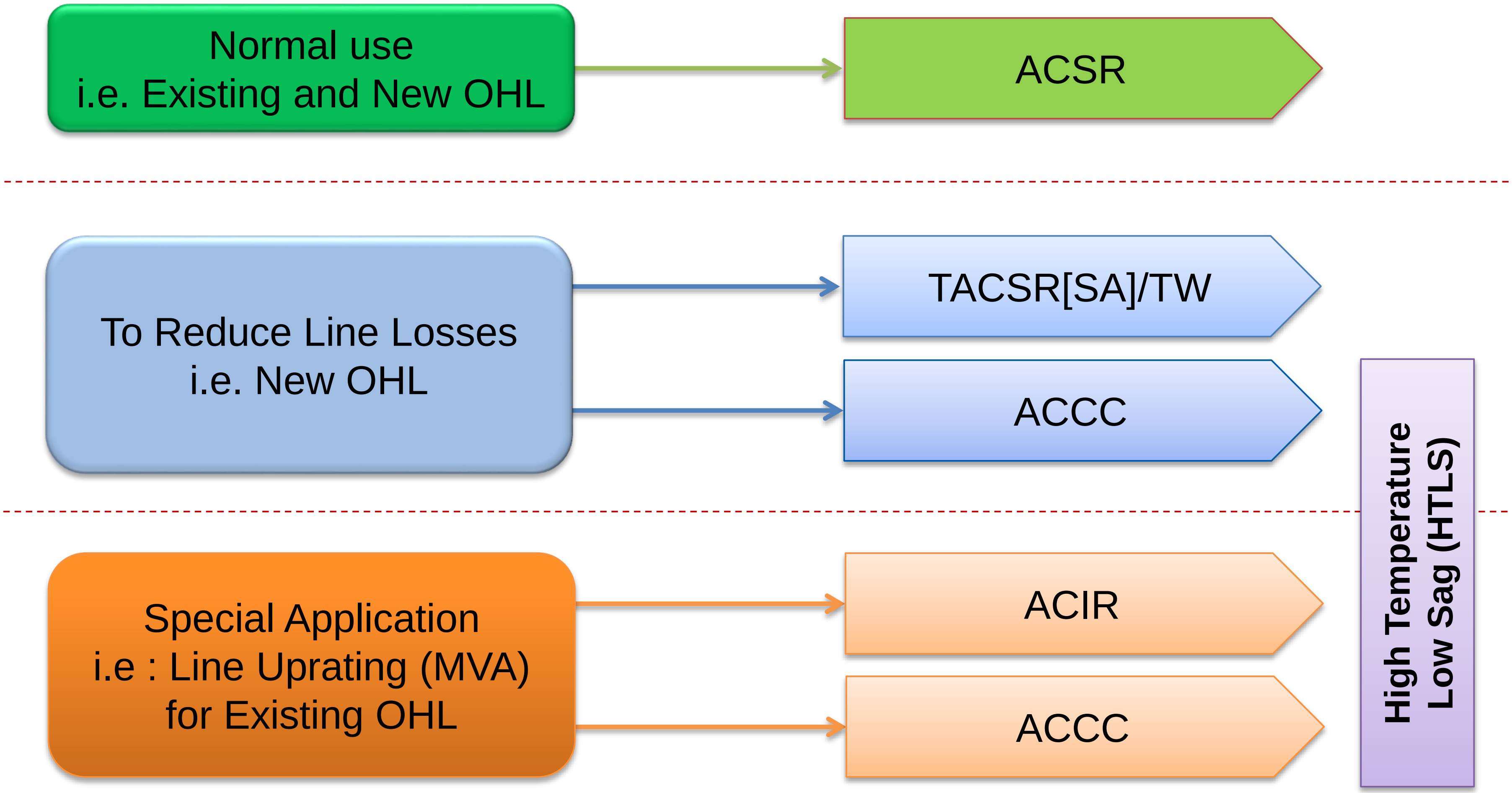
ACSR has been the traditional choice for overhead line conductor due to its simple stranding and strength of its steel core. With the advancement of technology in material and stranding technique, new conductors with low transmission losses, higher temperature (capacity) and low sag can be deployed for future OHL as well as uprating the existing OHL.

…FY2013 | **…FY2015** | **…FY2020**

ACSR (round-shaped, greased)	Low Sag High Capacity (ACIR)	Low Loss High Capacity (TACSR/TW)	Low Loss High Capacity Low Sag (ACCC/TW, ACCR/TW etc)
The traditional choice of Conductor for installation.	*Uprating OHL without dismantling of towers. High losses.*	*Reduction of losses with option for higher capacity.*	*Reduction of losses, option for higher capacity, low sag.*
Extensively used. Local conductor manufacturers ability to produce.	Selected OHL projects in Central Area, and uprating 132kV for double of existing capacity.	Major (trunk) 275kV and 500kV new OHL linking power generating plants and major substations.	Adoption for OHL across flat terrain and wide river crossing. Feasible use for uprating existing overhead lines.

- Enhancing local production capability.
- Monitoring of transmission losses.
- Continue assessment for the optimised choice of Conductor.

Conductors Used/On-Going Projects in TNB System

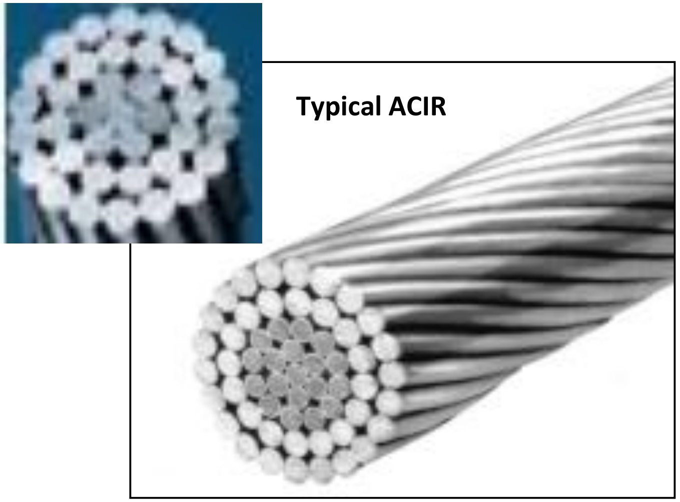


The Low Sag, High Capacity Conductor – Aluminium Conductor Invar Reinforced (ACIR)

1. In 2001, the High Temperature Low Sag (HTLS) conductor type Aluminium Conductor INVAR Reinforced (ACIR) was proposed to be used in TNB system as an alternative to ACSR conductor.

2. ACIR conductor are used in projects where uprating of existing OHL to double its capacity is required. This is especially so when acquisition of right-of-way for new OHL projects is getting more difficult.

3. The first projects using this conductor is the uprating of 275kV Port Klang – Kapar P/Stn in 2001, the new 275kV at DUKE Highway in 2005 and the uprating of 132kV Proton – Hicom in 2010.



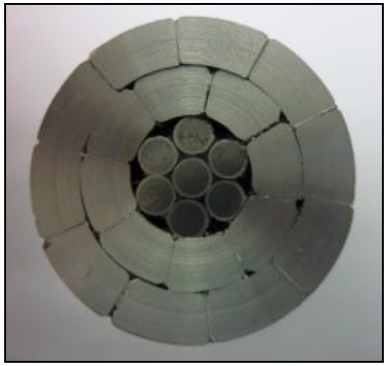
The Low Loss, High Capacity Conductor (TACSR(SA)/TW)

1. In 2010, the Low Loss Conductors (TACSR[SA]/TW) are introduced for the **new** 500kV and 275kV transmission lines installed in TNB system to reduce transmission losses.

2. The conductor provides approx. 20% reduction to transmission losses as compared to the conventional conductor (ACSR) of similar size.

3. The first project using this conductor is the new 275kV Ulu Jelai Hydro P/Stn to Tapah in 2010.

4. However, due to Sag limitations, the TACSR[SA]/TW cannot be used to uprate the existing OHL to double its capacity.

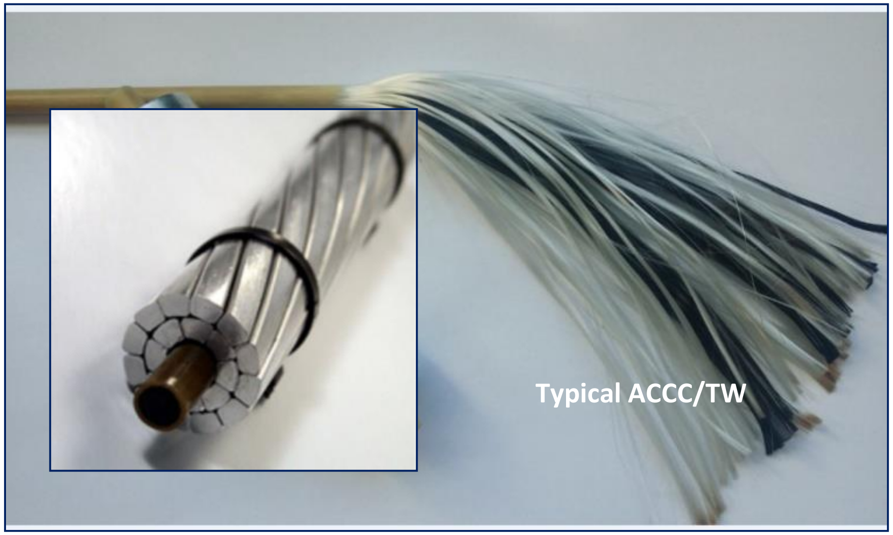


The Low Loss, High Capacity and Low Sag Conductor - Aluminium Conductor Composite-Carbon Core (ACCC)

1. In the search to find an optimum alternative to the ACSR which has limited conductor capacity and its considerable transmission losses, and the increased objections to acquire new OHL rentice, the High Capacity Low Loss and Low Sag conductors are sought.

2. The conductor required capacity vis-à-vis the sag and losses properties need to be leveraged. A complete life-cycle cost which include construction and material costs and the transmission losses need to be considered.

3. In 2014, a comprehensive study on the ACCC/TW conductor was undertaken. It was found to be suitable for uprating existing lines. It is also suitable for new lines in urban areas and flat terrain.



The ACCC (Aluminium Conductor Composite-Carbon Core)

1. The ACCC/TW comprise of annealed aluminium strands of trapezoidal shaped at the outer layers and a fibreglass coated carbon core. It also provides approx.20% reduction to transmission losses as compared to the conventional conductor (ACSR) of similar size and at similar temperature.

Manufacturing of ACCC/TW Dublin at Tenaga Cable Industry (TCI) in Malaysia (Carbon composite core from USA)

The ACCC for the 275kV Pengerang Overhead Line Project

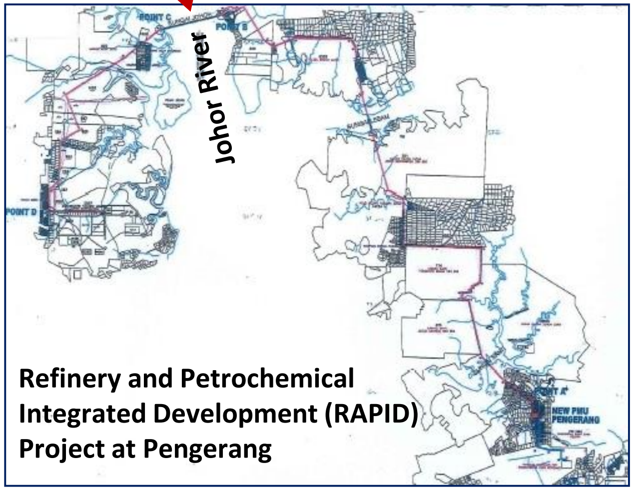
1. The ACCC/TW has been adopted for the 275kV transmission line project linking the main grid to the Pengerang petrochemical development.

2. The 45 km double-circuit overhead line traverses a generally flat terrain and crosses a wide river mouth (Johor River) in the south of Peninsular Malaysia.

3. ACCC/TW Dublin which equals ACSR Zebra in size is adopted for the project, providing the efficiency in conductor weight hence optimising the poles / tower and its associated foundations.

4. The transmission losses will be significantly reduced over the project life cycle, a value-add to the efficiency of the grid.

2 km Johor River Crossing

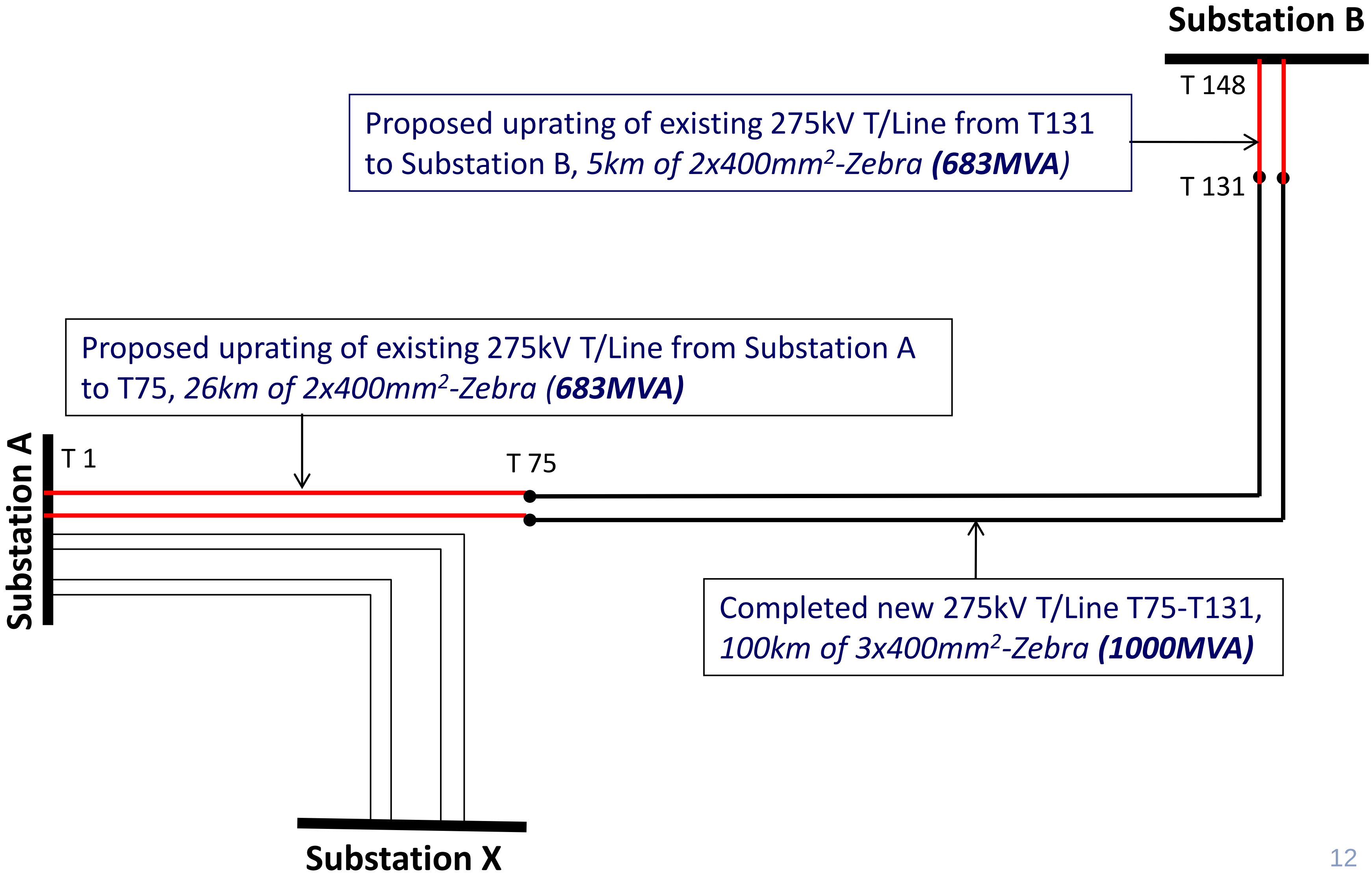


Typical Poles located in a River Crossing

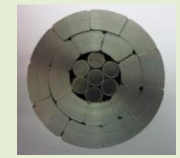
Case Study

Choosing a Conductor to Uprate an Existing 275kV 2xACSR Zebra (683MVA) to a 1000MVA Capacity

Case Study : Proposed Uprating of an Existing 275kV 2xACSR Zebra (683MVA) Transmission Line

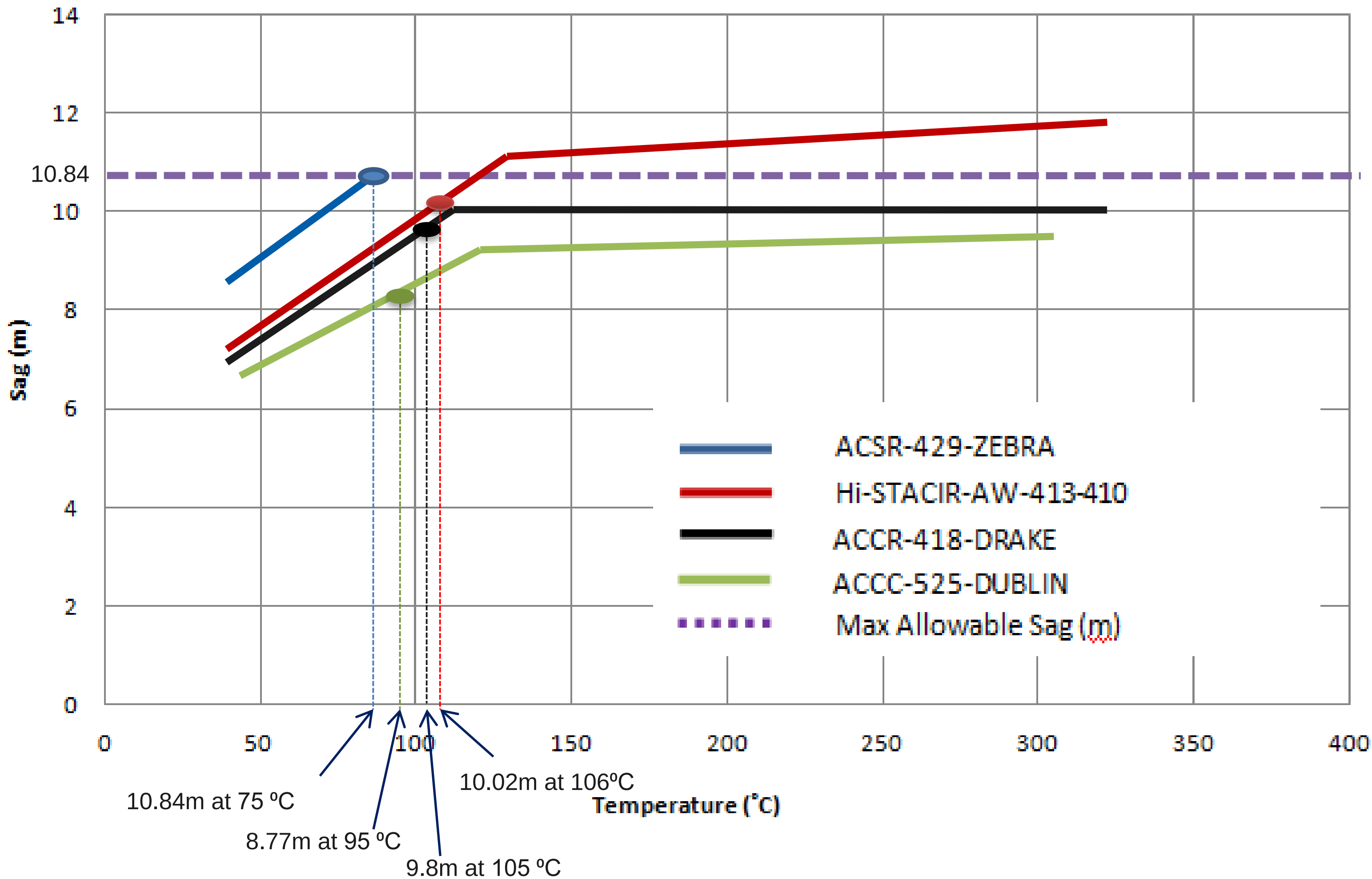


Choice of Conductors

DESCRIPTION	ACSR Zebra	Hi-STACIR	ACCC/TW Dublin	ACCR Drake	TACSR(SA)/TW
CONDUCTOR					
CONDUCTOR BUNDLING	**3** X ACSR Zebra	**2** x Hi-STACIR	**2** x ACCC/TW Dublin	**2** x ACCR Drake	**2** x TACSR(SA)/ TW
DIAMETER (mm)	28.62	28.5	28.14	28.65	28.62
WEIGHT (kg/m)	1,621	1,625	1,583	1,383	1,814
NAME	Aluminium Conductor Steel Reinforced	Aluminium Conductor Invar Reinforced	Aluminium Conductor Composite Core	Aluminium Conductor Composite Reinforced	Low Loss - Aluminium Conductor Steel Reinforced
CORE WIRE	Galvanised Steel	Al-Clad Invar	Carbon Fiber	Aluminium Fiber	Al-Clad Steel
OUTER WIRE	99.5% Aluminium	Super-thermal Al wires (STAL)	Annealed 1350 Aluminium Alloy	Al-Zirconioum (Z-tal)	Thermal Resistant Aluminum Alloy
OPERATING TEMPERATURE	75^{o}C Continuous 100^{o}C Emergency	210^{o}C Continuous 240^{o}C Emergency	180^{o}C Continuous 200^{o}C Emergency	210^{o}C Continuous 240^{o}C Emergency	150^{o}C Continuous 180^{o}C Emergency
SAG AT PEAK OPERATING AMPS (to achieve 1000MVA)	10.84m at **75 ^{o}C**	10.02m at **106^{o}C**	8.77m at **95 ^{o}C**	9.80m at **105 ^{o}C**	12.73m at **97^{o}C** (hence, not feasible)

Comparison of Sags (at 365m Span)

Ruling condition :
Rated tensile strength (RTS) is 22.2% of ultimate.
(i.e FOS = 4.5) at 32 degC everyday temperature. No wind.



Comparison of Construction Costs

Item	Line length		Rentice chain	Land acquisition cost	Conductor prices (+ 5% sag)	Fittings for reconductoring	Cost for new OHL/ Reconductoring	Cost	Total Cost
Construct New OHL (3 x ACSR Zebra)	5	km	2	* 25,800,000	1,512,000	0	11,500,000	38,812,000	145,604,400
	26	km	1	** 39,130,000	7,862,400	0	59,800,000	106,792,400	
Reconductoring (2 x Hi-STACIR)	5	km	2	0	5,378,562	1,345,485	350,000	7,074,047	43,859,091
	26	km	1	0	27,968,522	6,996,522	1,820,000	36,785,044	
Reconductoring (2 x ACCC Dublin)	5	km	2	0	2,835,000	1,345,485	350,000	4,180,485	28,089,007
	26	km	1	0	14,742,000	6,996,522	1,820,000	21,738,522	
Reconductoring (2 x ACCR Drake)	5	km	2	0	24,570,000	1,345,485	350,000	25,915,485	162,846,007
	26	km	1	0	127,764,000	6,996,522	1,820,000	134,760,522	

Notes :

* Additional 2 chains rentice required . Existing paddy field (4km) and Arowana fish breeding farm (1km).

** Additional 1 chain rentice required . Existing palm oil estate (19km) and forest trees (7km).

Estimated Conductor prices :

ACSR Zebra ~RM16,000/km (denoted as A), Hi-STACIR ~5.33 x A, ACCC ~2.81 x A, ACCR ~24.37 x A.

Cost analysis (at full load)

Options		Option 1	Option 2	Option 3	Option 4
		Construct New OHL	Reconductoring	Reconductoring	Reconductoring
		(3 x **ACSR** Zebra)	(2 x **Hi-STACIR**)	(2 x **ACCC** Dublin)	(2 x **ACCR** Drake)
Temperature (for 1000MVA)		**75 ºC**	**106ºC**	**95 ºC**	**105 ºC**
Line length	km	31	31	31	31
# **Estimated construction cost**	RM	**## 145,604,400**	43,859,091	28,089,007	162,846,007
Life Cycle Cost at **1,000MVA** per circuit (100% capacity) x 2 circuits					
Annual I^2r Losses	MWh		215,444	167,487	211,830
Cost of annual Losses	RM		44,597,004	34,669,747	43,848,776
30 Year cost of Losses	RM		1,337,910,114	1,040,092,406	1,315,463,270
Construction cost + 30 years cost of Losses	RM		1,381,769,205	1,068,181,413	1,478,309,277

Construction cost may vary with the prices of conductors at the time of procurement.

Construction cost for New OHL in this case study does not include any prolongation costs and/or loss of revenue due to project delays.

Cost analysis (at N-1 load)

Options		Option 1	Option 2	Option 3	Option 4
		Construct New OHL	Reconductoring	Reconductoring	Reconductoring
		(3 x **ACSR** Zebra)	(2 x **Hi-STACIR**)	(2 x **ACCC** Dublin)	(2 x **ACCR** Drake)
Temperature (for 500MVA)		**56 ºC**	**64 ºC**	**61 ºC**	**63 ºC**
Line length	km	31	31	31	31
# **Estimated construction cost**	RM	**## 145,604,400**	43,859,091	28,089,007	162,846,007
Life Cycle Cost at **500MVA** per circuit (50% capacity i.e. **N-1**) x 2 circuits					
Annual I^2r losses	MWh	30,424	47,719	37,565	46,264
Cost of annual losses	RM	6,297,751	9,877,875	7,775,904	9,576,747
30 Year cost of losses	RM	188,932,541	296,336,264	233,277,106	287,302,417
Construction cost + 30 years cost of losses	RM	334,536,941	340,195,355	261,366,113	450,148,424

Note : Loss factor = 0.664 and RM 207 per MWh (20.7 sen per unit) are used in the above calculations.

Summary of Case Study

1. Construction of a new Overhead Line would entail higher capital cost and time consuming land acquisitions especially at high profile areas, farms and forest reserves.

2. Uprating of an existing 275kV 683MVA (2xACSR Zebra) overhead lines to 1000MVA by reconductoring the line using the high temperature low sag (HTLS) conductors with low loss characteristics, without dismantling of the existing towers is a feasible option. Existing ground clearances are also not violated.

3. The option of **reconductoring** the existing overhead line using **2xACCC Dublin** conductors at **95 degC** would provide the required 1000MVA with competitive installation cost and comparatively low transmission losses throughout the conductor life cycle.

Thank you for your attention

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