Spectrally Selective Coatings for Overhead Powerlines to Increase Ampacity and Reduce Power Losses[1]

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Formulating Functional Films and Coatings IV, 8th Dec 2021

1. Introduction

- Overhead power lines (conductors) reach elevated temperatures during operation, both from the current they are carrying, as well as from incident solar radiation, leading to increased electrical resistance and power losses.
- Transmission and Distribution (T+D) capacity needs to be increased in cost efficient ways.
- Spectrally Selective Coatings (SSC) work via Passive Radiative Cooling
- This minimises solar absorption (solar reflectance >0.8) and maximises thermal emissivity (>0.9), through selective interaction with different wavelengths of light (Figure 1).
- SSCs can therefore reflect external heat sources, whilst effectively dissipating internal heat; in conventional systems, only one of these strategies is possible.
- SSCs therefore:
  - Lower conductor temperatures
  - Increase ampacity
  - Reduce power losses
  - Reduce carbon emissions

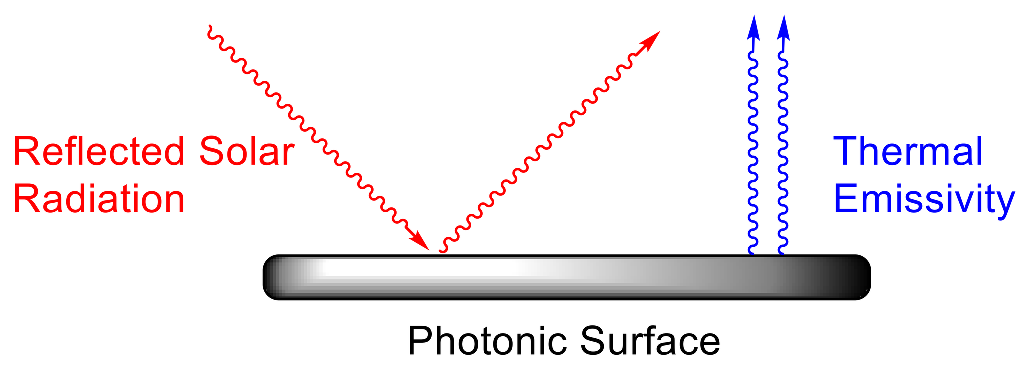


Figure 1: Interaction of light with photonic surface/SSC

2. AssetCool Spectrally Selective Coating

- AssetCool's spectrally selective coating has been formulated to show strong radiative cooling through inclusion of optically active pigmentation.
- The coating has to operate in a harsh environment for decades and therefore must be stable/resistant to:
  - High temperatures
  - High UV intensity
  - High voltages
  - Corrosive environments

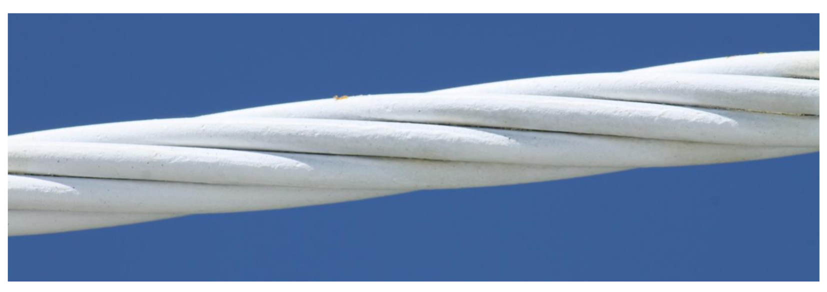
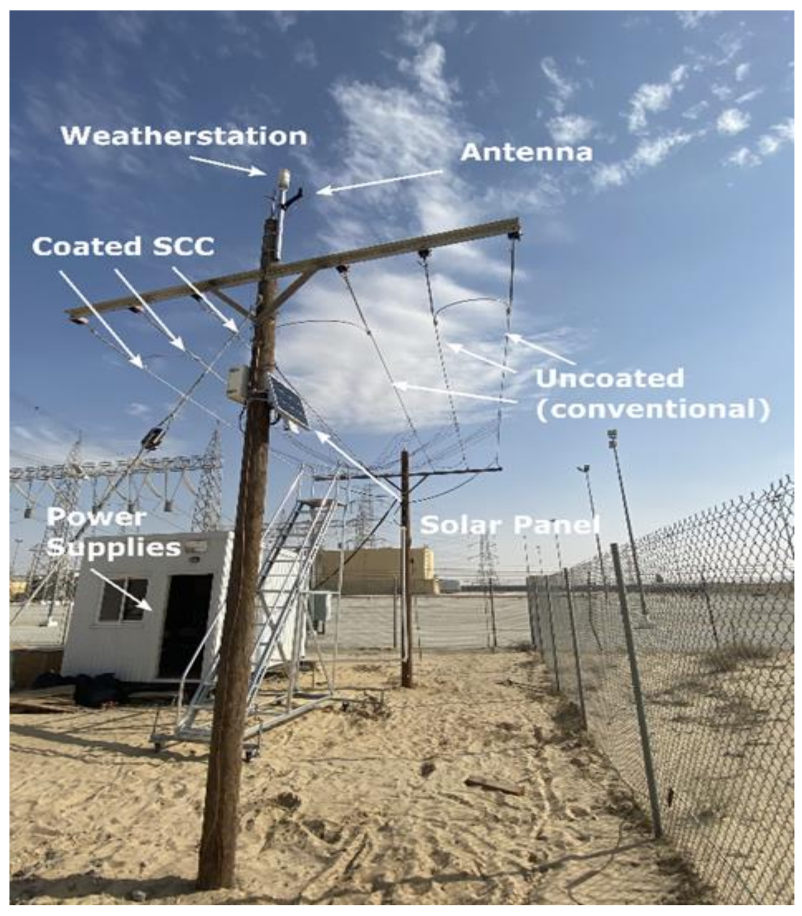


Figure 2: AssetCool SSC on ACSR conductor

- These conditions preclude the use of many raw materials and additives, specifically many organic raw materials.
- Accordingly, AssetCool's SSC is formulated around an inorganic scaffold (Figure 2).

3. Experimental

- The SSC was applied to ACSR Conductor, and subjected to a field trial in Al Fadhili, Saudi Arabia (KSA) (Figure 3).
- The chosen site provides a wide range of weather conditions in which to test the coating:
  - Ambient temperature variations of 14.3 – 49.7 °C
  - Monthly average wind speeds of 5.7 m s^{-1}, and peak speeds up to 19.9 m s^{-1}
  - Relative humidity of 4.7 – 100%
  - Solar radiation consistently approaching 1000 W m^{-2}



- 3 coated conductors were tested and compared to three uncoated, traditional conductors.
- Temperatures were measured using thermocouples inserted into the conductor core.
- A weather station was installed on the rig to capture high resolution weather data.

Figure 3: Experimental Field Trail Rig (left)

4. Mechanical Stability

- As well as consistent cooling performance, the coating must be mechanically robust and durable.
- Accredited testing has shown that the coating is unaffected by a wide range of environmental factors (Table 1) and is suitable for long-term use in challenging environments.

Table 1: Environmental Testing and Results

Test	Standard	Result
UV Stability	ASTM G155	5 (no change in colour according to ISO105-A02). No indentations, chipping, flaking.
Corrosion Stability	ASTM B117	5 (no change in colour according to ISO105-A02). No indentations, chipping, flaking, or discolouration.
Temperature Stability	Internal	Pass - No indentations, chipping, flaking, or discolouration.
Chemical stability	EN 598	Pass - No cracking, no foaming, no peeling
Moisture Stability	ASTM D870	Pass - No cracking, no foaming, no peeling
Humidity Stability	ASTM D2247	Pass - No colour change, no blisters
SO_2 Resistance	ASTM G87	No pits, no cracks, no blisters

5. Cooling Results

- The coating shows significant cooling compared to the uncoated standard (Figure 4; Table 2)
- Peak cooling of up to 33.6%
- Average monthly cooling of up to 8.23%
- Calculations (CIGRE 601[2]) indicate a 28.3% increase in current carrying capacity is available from SSC.

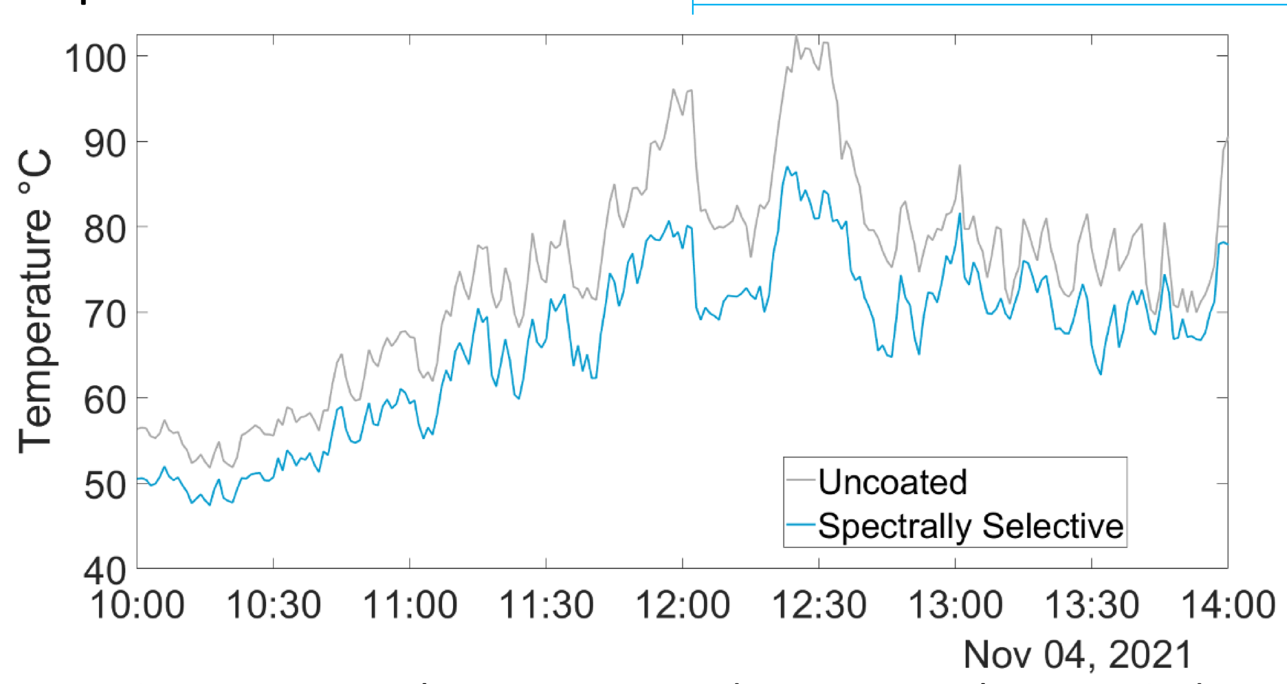


Figure 4: Example temperature data over a 4 hour period

Table 2: Average and Peak Monthly Cooling

	Average Monthly Cooling						Peak Cooling per Month			
	Uncoated	SSC	Cooling (%)	AT (°C)	WS (m s^{-1})	SR (W m^{-2})		Uncoated	SSC	Cooling (%)
April	64.9	59.6	8.3	28.0	4.0	207.7	**28 April**	103.5	78.9	23.7
May	65.1	60.5	7.1	34.0	3.2	234.5	**4 May**	105.3	76.5	27.4
June	57.6	56.1	2.5	36.4	5.7	203.7	**9 June**	100.1	78.9	21.2
July	67.4	64.1	4.8	38.0	3.3	220.9	**30 July**	88.0	71.2	19.1
Aug	67.7	64.0	5.4	37.1	3.0	198.9	**31 Aug**	100.8	67.2	33.6
Sept	61.3	57.9	5.6	33.8	3.8	175	**2 Sept**	79.6	57.3	28.0

AT is ambient temperature; WS is wind speed; SR is solar reflectance

6. Conclusions

- Robust, mechanically and environmentally stable Spectrally Selective Coating formulated and developed
- Tested under field trail conditions in Saudi Arabia
- Peak cooling of up to 33.6% demonstrated with average cooling on a monthly basis up to 8.27%.
- 28.3% increase in ampacity

References

1. Higbee et al., (2021) A Field Analysis of New Overhead Line Conductor Coatings to Increase Ampacity/Reduce Power Losses in Desert Environment: Performance and Durability Assessments, CIGRE GCC Power 2021
2. CIGRE, Working Group B2.43 (2014) Guide for thermal rating calculation of overhead lines, Technical Brochure 601