White paper

Wet blasting overhead power cable to maximise electrical power transmission efficiency and reduce costs

Overhead power cables are essential for transmitting electrical power over long distances and power needs to be transmitted as efficiently as possible to help reduce losses, and generation costs.

Global transmission networks are under strain due to increased demand for electricity and an increasing amount of electricity is mandated to be generated by renewable methods. Running power cables at a lower temperature can help increase the amount of electricity transmitted and the environmental impact.

Power cables that operate at lower temperatures transmit power more efficiently because when a power cable is cooler, its resistance is lower, leading to reduced power losses.

Two factors play a major role in reducing operating temperature: **emissivity** and **absorptivity**.

Emissivity

Emissivity is a measure of an object's ability to emit thermal radiation compared to that of an ideal blackbody at the same temperature. It is a dimensionless quantity that ranges from 0 to 1.

0 indicates that the object does not emit any thermal radiation.

1 indicates that the object emits the maximum amount of thermal radiation possible at its temperature, similar to a perfect blackbody.

Mathematically, emissivity (**ϵ**) is defined as[1]

$$\epsilon = E_{object} / E_{blackbody}$$

where:

E_{object} is the thermal radiation emitted by the object and $E_{blackbody}$ is the thermal radiation emitted by a blackbody at the same temperature.

For overhead power cables, the optimal emissivity is around 0.8.

Absorptivity

Absorptivity is a measure of how effectively a material absorbs incident radiation, primarily from solar radiation*. It is the fraction of the incident electromagnetic radiation that is absorbed by a material, rather than being reflected or transmitted. Absorptivity can vary between 0 and 1.

0 indicates that the material does not absorb any incident radiation, all radiation is either reflected or transmitted.

1 indicates that the material absorbs all the incident radiation, none is reflected or transmitted.

Absorptivity (**α**) and can be mathematically defined as[2]

$$\alpha = P_{absorbed} / P_{incident}$$

where:

$P_{absorbed}$ is the power, or energy, of the radiation absorbed by the material.

$P_{incident}$ is the power (or energy) of the incident radiation on the material.

The ideal absorptivity for overhead power cables is around 0.4.

* Incident radiation refers to electromagnetic radiation that strikes or falls onto a surface from an external source. This radiation can come in various forms, including visible light, ultraviolet light, infrared radiation, and other wavelengths in the electromagnetic spectrum. In the case of power cables, we are referring to solar radiation.

The benefits of increasing emissivity and reducing absorptivity for increased efficiency

Increasing emissivity[3] and reducing absorptivity of overhead power cables is important for reducing running costs due to their combined effect on thermal management and energy efficiency. They contribute by:

Thermal management:

Higher emissivity means the conductor can more effectively radiate heat away into the environment. This reduces the operating temperature of the cable by enhancing heat dissipation.

Lower absorptivity means the cable absorbs less heat from external sources, such as sunlight. This further helps in keeping the cable temperature lower.

Lower operating temperatures due to better thermal management:

When a cable both emits heat more efficiently via convection and thermal radiation, and absorbs less external heat, it operates at a significantly lower temperature. This reduces thermal stress on cable materials, enhancing their longevity and reliability.

Lower temperatures minimise thermal expansion and contraction, reducing mechanical stress and the risk of damage over time. It also reduces maintenance costs.

Enhanced current-carrying capacity:

Cooler cables have lower electrical resistance. This improves the efficiency of power transmission by reducing resistive (I^2R) losses.

With better thermal management, cables can safely carry higher currents without overheating, thus increasing their capacity.

Improved energy savings:

Improved heat dissipation and reduced heat absorption lead to lower power losses, directly saving energy and reducing operational costs.

The reduction in resistive losses translates to more efficient power transmission, ensuring that more energy reaches end users.

Maintenance and Longevity:

By operating at lower temperatures, the lifespan of the cables is extended, reducing the frequency of maintenance and replacements.

Fewer temperature-related failures and reduced thermal stress result in lower maintenance costs and less downtime.

Environmental Benefits:

Lower cable temperatures might reduce the need for additional cooling mechanisms, which can be energy-intensive and costly.

Enhanced efficiency and lower energy losses contribute to a reduced carbon footprint, especially if the power source includes fossil fuels.

System Reliability and Safety:

Better thermal management reduces the risk of overheating, which can lead to system failures or power outages.

Lower operating temperatures decrease the risk of heat-related hazards, such as fires, improving overall system safety.

Increasing emissivity and reducing absorptivity of overhead power cables works together to improve heat management, enhance efficiency, reduce energy losses, extend the lifespan of the cables, increase ampacity and lower overall running costs compared with cables operating at higher temperatures. This combination results in a more reliable, efficient, and cost-effective power transmission system.

Factors affecting emissivity and absorptivity include:

Different materials have different levels of emissivity and absorptivity. For example, polished metals tend to have low emissivity and absorptivity, dark and matte materials tend to have higher emissivity and absorptivity.

In a similar way, a surface's texture and finish can significantly affect emissivity and absorptivity too. Smooth and shiny finishes equal lower emissivity, and rough and matte finishes equal higher emissivity.

Emissivity and absorptivity can vary with electromagnetic wavelength, meaning both can change depending on the specific part of the electromagnetic spectrum being considered. For example, a material might absorb visible light but not infrared radiation, or vice versa.

For some materials, emissivity and absorptivity can change with atmospheric temperature, though this effect is often less significant compared to other factors.

Wet blasting affects the surface finish and as you will discover later in this whitepaper, the key is to finish the cable so it emits as much heat radiation as possible at the relevant wavelengths for emissivity while absorbing as little solar radiation as possible at the relevant wavelengths for absorptivity.

Non-specular finish for increased emissivity

We have established that increasing emissivity increases power transmission efficiency. The way to achieve this is by creating a non-specular finish to the standard specification. The standard specification code for a non-specular finish on power cables is ASTM B979 – 12 in North America[4]. Similar specifications exist like AS 2536-1982, IEEE 738-2012 and IEC 61597.

Overhead power cable with a non-specular finish created by wet blasting

A non-specular finish is a type of surface finish that diffuses light, scattering it in many directions rather than reflecting it in a concentrated, mirror-like manner. This results in a matte or dull appearance without sharp reflections. Non-specular finishes also reduce glare and reflections, providing a softer, more uniform look.

A non-specular finish increases emissivity by...

Achieving a typically rougher or more textured than specular, mirror-like, finish. This increased surface roughness enhances the power cable's ability to emit thermal radiation by providing more surface area from which radiation can be emitted.

Emitting thermal radiation more diffusely, meaning the radiation is spread out over a wider range of angles. This diffuse emission enhances the overall emissivity of the material because it reduces the amount of energy reflected back.

Trapping and re-radiating energy more efficiently thanks to the microscopic structure. This microstructure effect can lead to higher overall emissivity compared to smoother, specular surfaces.

Higher emissivity leads to more heat being emitted at the same air temperature. So, a cable with higher emissivity, in the same environmental conditions, with the same structure and current range, operates at lower temperatures as it can more easily emit excess heat.

Typically, we have found that an increase in current carrying capacity of around 5% can be achieved due to an increase in surface emissivity.

Controlling emissivity by controlling reflectivity

The standard specification code for a non-specular finish on power cables, ASTM B979 – 12, specifies a reflectivity of less than 32%, because reduced reflectivity equates to increased emissivity. We have achieved as low as 26% in our Profelis automatic wet blasting machine, as measured by our Photovolt measuring instrument.

Producing the ideal surface finish by wet blasting for a current carrying capacity improvement of circa. 5%

Wet blasting** power cable can produce a surface finish to a specific Ra surface roughness range, which is dependent on the type of power cable, that optimises thermal management and subsequent efficiency. Here's how this process can be tailored for the best results:

Wet blasting thoroughly cleans power cable removing all contaminants from the surface, which can influence both emissivity and absorptivity. A clean surface ensures that the precise surface finish can be applied.

Wet blasting creates a controlled surface texture that enhances emissivity by increasing surface roughness, which aids in radiating heat. However, the texture should not be too rough to avoid excessive absorption of solar radiation.

Choosing the right abrasive media is crucial. Aluminium oxide produces a rough enough texture to increase emissivity without creating a surface with excessive absorptivity.

Adjusting the pressure, angle, and duration of the wet blasting process allows precise control over the surface finish. Lower pressures and controlled angles can prevent over-roughening the surface, achieving a balance between roughness for emissivity and smoothness for low absorptivity.

The production of a non-specular finish by wet blasting gives the cable higher emissivity (approx. 0.8) compared to the specular finish of an untreated cable (approx. 0.5), while keeping absorptivity to a minimum.

The unique Vapormatt Profelis automatic wet blasting machine

One machine in our range is specifically designed for the processing of overhead power cable, the Profelis automatic wet blasting machine. Capable of producing the ideal surface finish on power cables up to 54mm in diameter as described above, the machine sits in-line with existing production and features 360 degree wet blasting. Learn more about the Profelis by visiting our dedicated wire and cable page and downloading the system specifications:

vapormatt.com/industries/wire-and-cable

**Visit our 'what is wet blasting?' page to learn about the wet blasting process:

vapormatt.com/our-technology/what-wet-blasting

Additional benefits for overhead power cable manufacturers

The benefit of wet blasting over coating

An alternative to wet blasting power cables is to coat them to increase emissivity. However, high-quality coatings can be expensive, both in terms of materials and application when compared with wet blasting. Over time, coatings may degrade and require reapplication, adding to maintenance costs.

Preparing cables for coating

If coating is the preferred method for increasing emissivity and reducing absorptivity, then wet blasting can still play an important role by thoroughly cleaning and activating the surface of the cable for the optimum adhesion of the coating.

Non-specular finish for power transmission over US federal land

Wet blasting produces a surface finish that is dull and non-reflective. This non-reflective or 'de-glared' surface finish allows the conductor to become less visible when observed from a distance and enables the transmission line to blend in with the skyline or landscape background. It produces a non-specular finish to ASTM B979 - 12 specification, which is the standard specification for Non-Specular (NS) surface finish on overhead aluminium electrical conductors. This standard is specified for power cables traversing US federal land.

In conclusion,

By carefully controlling the wet blasting process, power cables can be optimised to achieve high emissivity for effective heat dissipation while maintaining low absorptivity to minimise external heat absorption. This balance ensures the cables operate efficiently and reliably, with reduced risk of overheating.

References

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