CompactCool - blending dry and liquid cooling transformer technologies

An innovative, path-breaking transformer technology that combines the best of both worlds

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The transition to clean energy sources have caused a shift in the established models of energy generation and electricity transmission and distribution. Coupled with the emergence of increased electrification, e-mobility and data centers, this shift has created the need for transformer design to evolve and meet new challenges. Additionally, the applications for transformers are now more demanding with the increase in scale, size, and power ratings. The new generation of wind turbines, solar inverters and data centers will need new solutions for transformers to meet application-specific requirements – which are different from mainstream utility distribution transformers such as electric distribution, gas utilities, or waste utilities and more.

The transformer design conundrum – liquid-immersed or dry-type?

When it comes to sustaining safe and reliable grid performance, the transformer type plays a critical role in effectively managing operational hazards and ensuring service continuation. However, choosing the right transformer type depends on the premise and application, its safety requirements, and the overall initial investment. For our discussion, we shall consider the two main transformer types – dry-type and liquid immersed.

Dry-type transformers have multiple merits that make them the preferred choice for different applications, especially indoors, like buildings, shopping malls, hotels, hospitals, airports and metro stations. The absence of liquid cooling media provides an increased level of fire safety and environmental protection compared to mineral oil-filled transformers. They also provide advantages from the maintenance perspective as they are virtually maintenance-free.

At the same time, liquid immersed transformers have higher operating efficiencies, overloading capability and a comparatively smaller footprint as compared to conventional dry-type transformers.

However, the dry-type transformer's larger size remains a major drawback when compared to liquid-immersed transformers. In addition, the innate differences between these two types of transformers pose a challenge for businesses looking to get the best of both technologies: the compact form factor and lower footprint of liquid immersed transformers, as well as the enhanced safety and low maintenance of a dry-type transformer.

This is especially valuable for renewable energy applications like operating wind and solar generation facilities and data centers where transformers must deliver safety, reliability, and availability with the lowest possible footprint and maintenance requirement.

In the wind industry, both onshore and offshore, transformer size is a challenge because they must be installed either on the ground floor or the first level of wind turbine towers, if not inside the turbine nacelle platforms. In each of these cases, the availability of space is limited. These conditions, therefore, require transformers that not only have an optimal footprint but also can withstand adverse climatic conditions.

Transformers with smaller footprints can also yield endless possibilities in the solar power and data center segments. Here, compact solutions are gaining traction due to ease of logistics, low space requirements, and lower installation costs, among other advantages.

The data center segment, for instance, is rapidly expanding and will grow significantly in the coming years. Handling this rapid growth directly translates to the need for better infrastructure to support more efficient energy management. And since the equipment used in a data center

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environments are required to operate for longer periods, it often results in excess heating and a lower overall power usage effectiveness (PUE). The electrical losses resulting from transformer also impact the PUE.

Similarly, in solar plants, photovoltaic cells produce DC current that is converted to AC current by an inverter. Thereafter, a set of transformers steps it up to higher voltage levels. The transformers at the solar sites must be capable of efficiently countering severe conditions such as extremely high temperatures within the limited availability of space. This is where cooling becomes critical. Therefore, it is evident that these sectors now need compact size transformers.

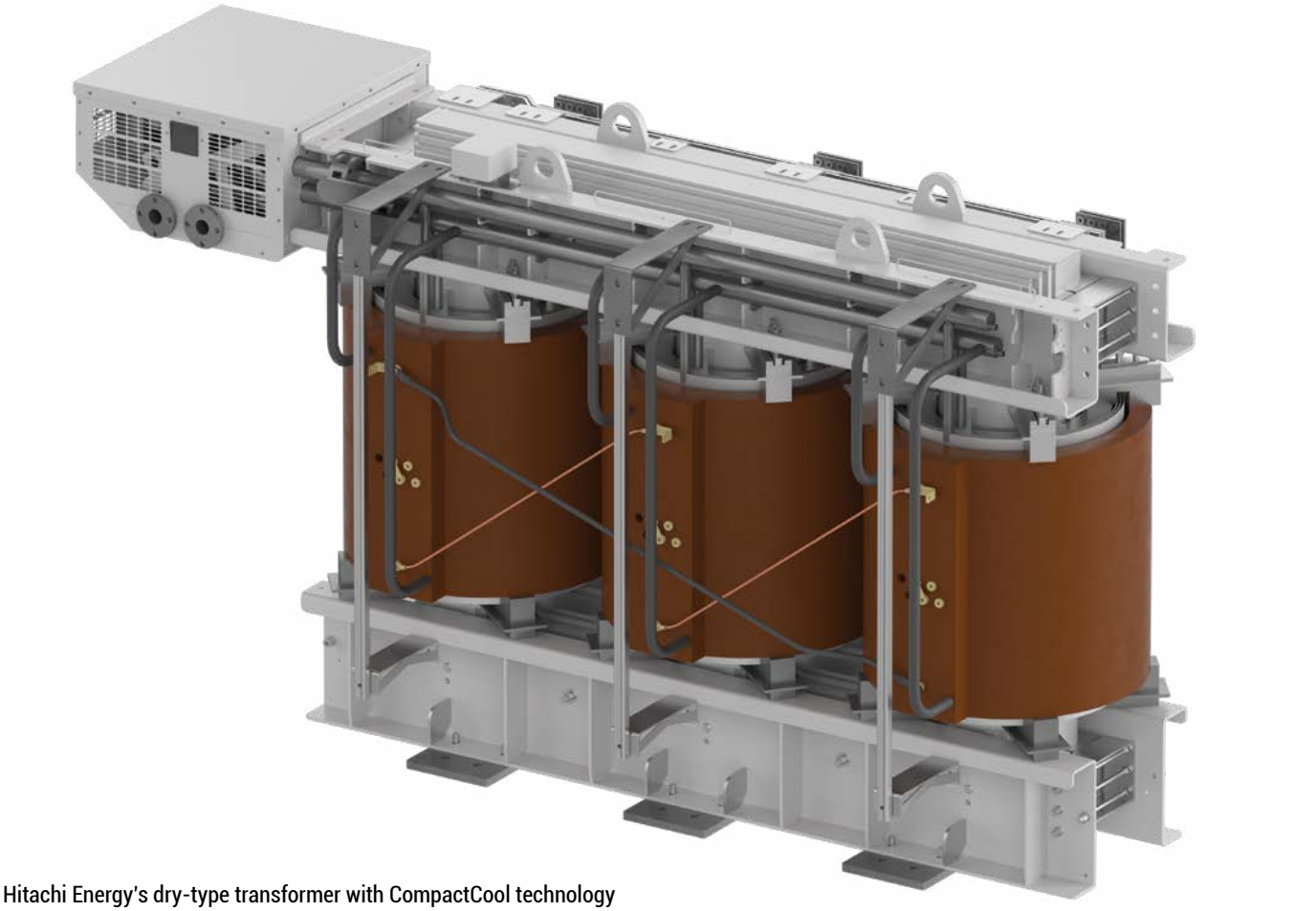
CompactCool technology for transformers – optimizing footprint with innovation

One of the major drivers of the footprint of a dry-type and a liquid-filled transformer is the cooling mechanism involved. Transformers generate heat due to energy losses and the heat has to be dissipated and controlled with a cooling system or mechanism. Then, an optimization of the cooling mechanism can directly result in the reduction of transformer footprint.

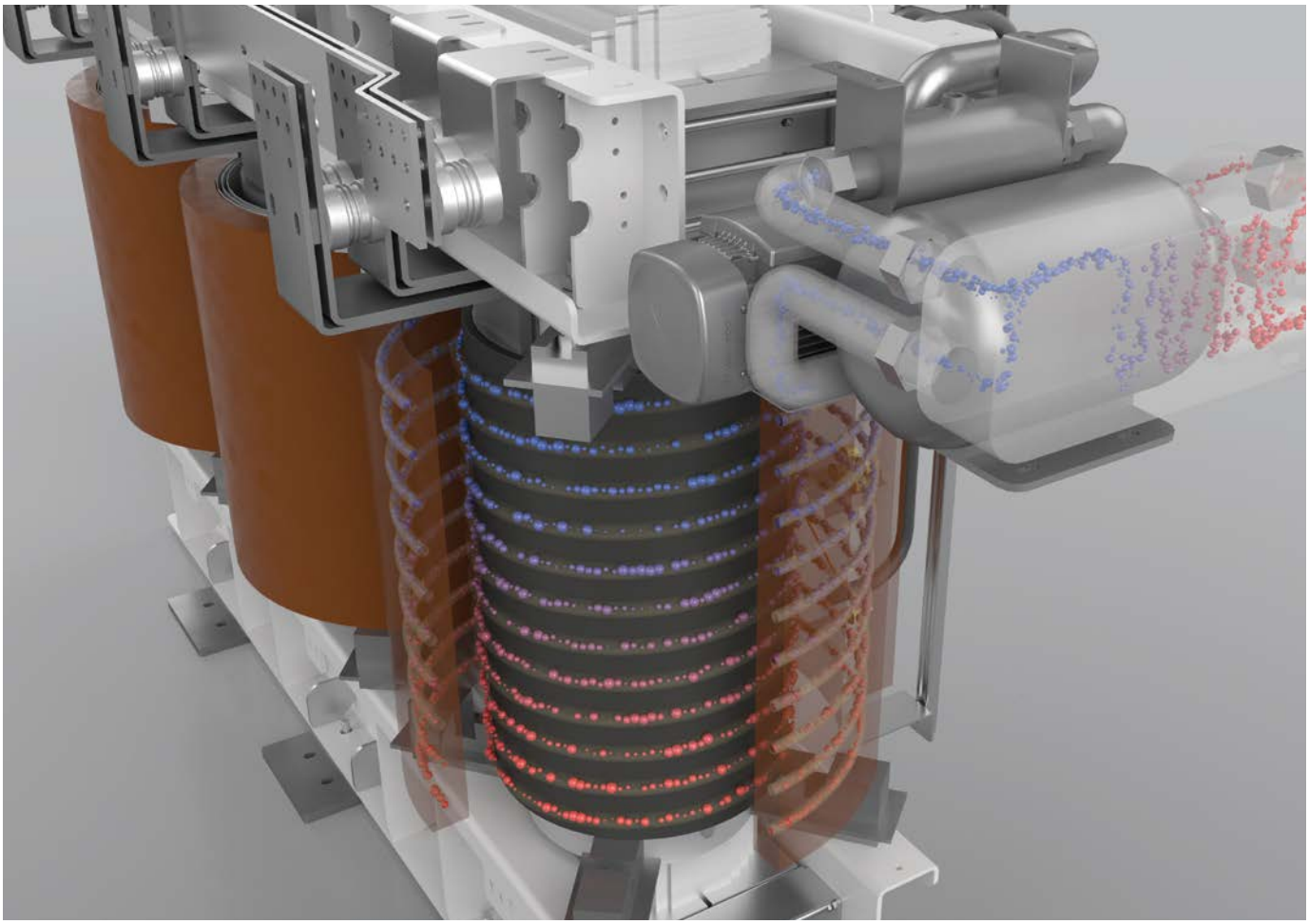
CompactCool technology introduces an advanced hybrid cooling mechanism where a liquid coolant is used inside of the coils of a dry-type transformer to extract the losses out of windings and circulate them through an external heat exchanger. In this type of transformer, the energy losses get distributed to an external ambient (to air or a water circuit supply) without the need for any enclosure or liquid containment tank.

Such an optimized cooling mechanism, termed as closed-circuit direct liquid cooling, has the potential to reduce the footprint of a conventional dry-type transformer by 15-50%, depending mainly on the rated power of the transformer. Additionally, the liquid is only used for cooling and not for dielectric purposes, which means that the insulation of the transformer maintains the structure of the air-solid-insulation resembling a conventional dry-type transformer.

This innovative hybrid solution can act as a panacea for size and safety-related issues. CompactCool allows users to reap the benefits of a dry-type transformer such as fire and environmental safety, and lower maintenance cost due to the minimal usage of cooling liquid. On the other hand, it also helps deliver a 15-50% reduction of footprint, helping companies overcome the challenge of reducing footprint dimensions.



Hitachi Energy's dry-type transformer with CompactCool technology



Working mechanism of Hitachi Energy's dry-type transformer with CompactCool technology

CompactCool technology involves the usage of an external heat exchanger which is capable of capturing 90% of the losses when the transformer is loaded 100%. And since it is possible to extract the losses directly from the transformer to the external ambient, the need to install air cooling ducts, air fans, and additional air extractors in the enclosure is eliminated. Eliminating these air extractors would let the enclosure become smaller, or alternatively, while keeping the enclosure size the same, installing larger power rated transformers would be possible.

The main features and benefits of CompactCool can be rounded up as:

- **Direct liquid cooling of coils:**
  - Optimized cooling: up to 50 % size optimization compared to conventional dry-type transformers. Can fit in space-constrained locations, including wind turbine nacelle, the first level of wind turbine tower or on the ground floor, in data centers and containerized solar applications.
  - Extraction of losses in a controlled way: Possibility to use central cooling systems of the stations. Moreover, 90% of the losses are captured when the transformer is 100% loaded.
  - Minimal liquid coolant volume: Liquid is used only for cooling and not for dielectric purposes. Compared to conventional liquid immersed transformers, the quantity of liquid is 98% lesser.
- **Dry-type air-solid insulation:**
  - Easy maintenance: Low maintenance costs benefits from a conventional dry-type transformer. Trouble-free operation ensures that total installation and maintenance costs are low.
  - Ultimate safety: No chance of the oil getting into the environment or causing fire hazards.

After finalizing the intense verification process with pilots and prototypes, Hitachi Energy is now taking orders for dry-type transformers with CompactCool technology

The specialized features of CompactCool transformers unlock the following primary business values:

- **Footprint reduction** increases applicability across specialized uses
- **Cost reduction** of HVAC equipment in stations
- **Unmatched safety,** reliability, availability, and cost-effective maintenance

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Applications apt for CompactCool

Wind power generation (installation inside wind turbines)

The challenge:

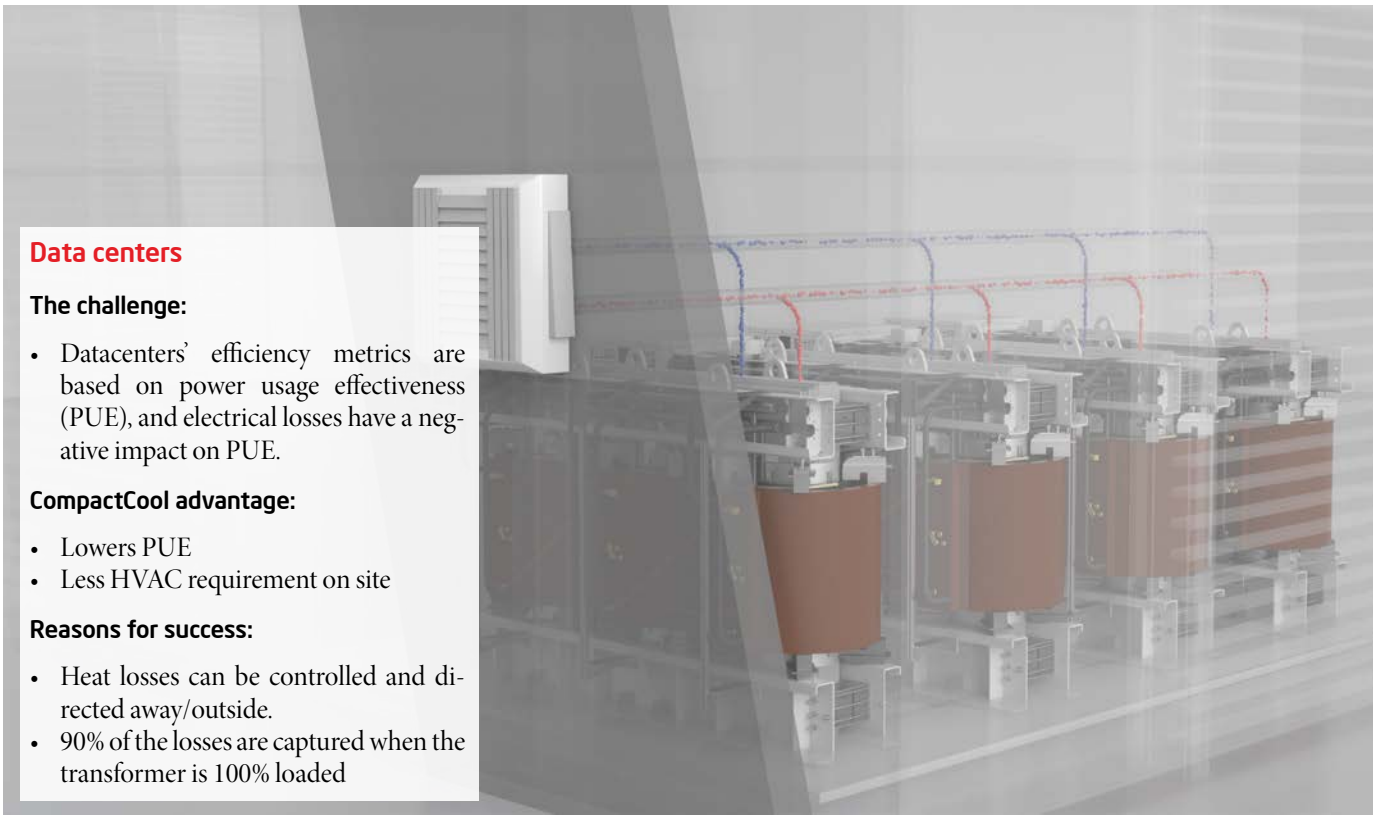
- Size limitation

CompactCool advantage:

- Reduced size
- "More watts per box"

Reasons for success:

- Compared to conventional dry-type transformers, size reduction with CompactCool is between 15–50 %.



Data centers

The challenge:

- Datacenters' efficiency metrics are based on power usage effectiveness (PUE), and electrical losses have a negative impact on PUE.

CompactCool advantage:

- Lowers PUE
- Less HVAC requirement on site

Reasons for success:

- Heat losses can be controlled and directed away/outside.
- 90% of the losses are captured when the transformer is 100% loaded

Indicative technical specifications

Recommended power rating is 5MVA and above, where the value of footprint reduction is observed more in larger sizes.

In conclusion

As we are accelerating the transition to a sustainable energy future, future-facing projects in the wind, solar and data center segments will need to leverage innovations to achieve higher levels of productivity while maintaining desired levels of efficiency.

This rapid ascent will, however, depend on the availability of efficient infrastructure, one that needs to evolve and grow in tandem to keep up with the pace of newer developments. In such a paradigm, innovative solutions like Hitachi Energy transformers with CompactCool technology are determined to pave the path forward for more businesses and industries of the future.

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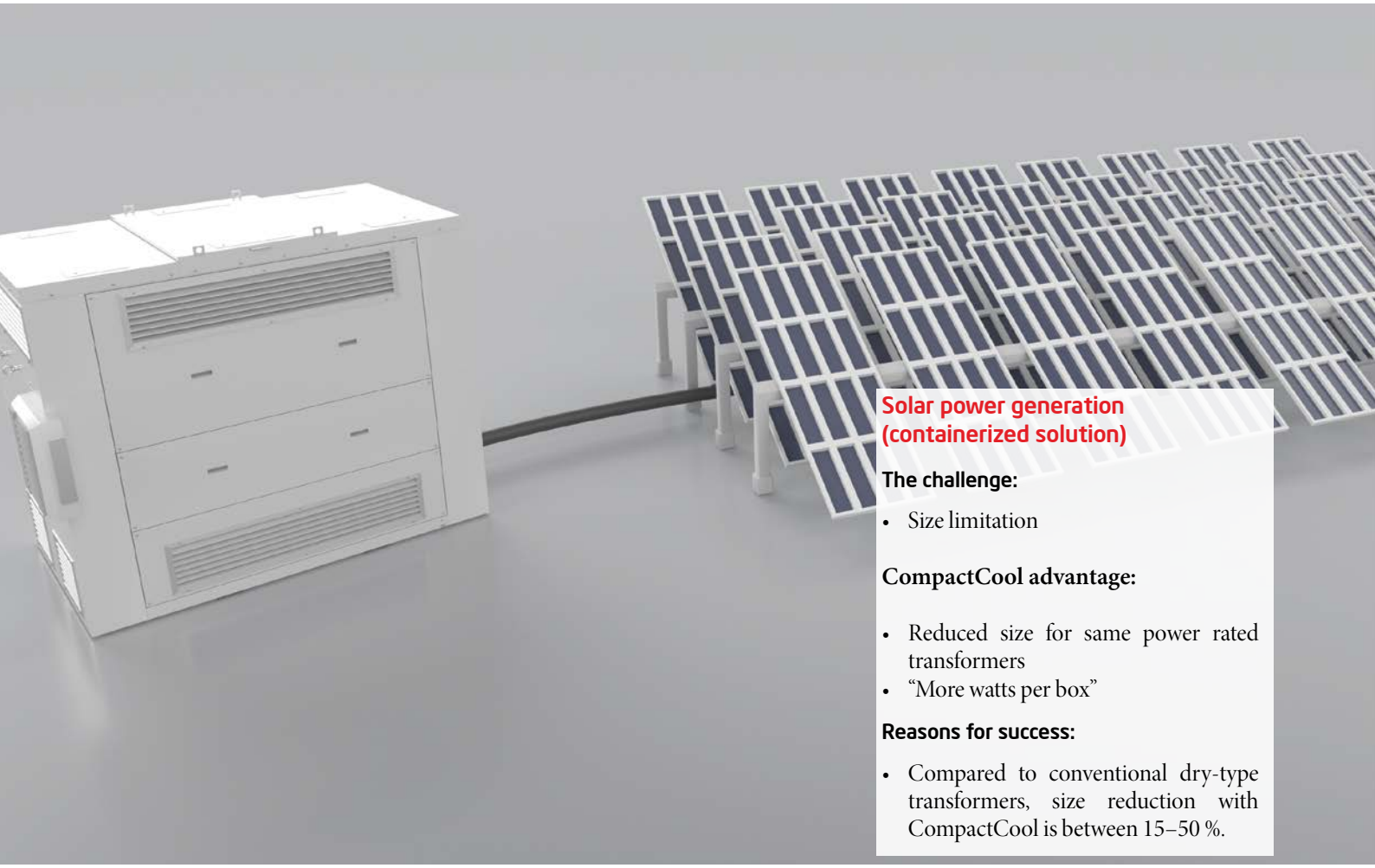

Solar power generation (containerized solution)

The challenge:

- Size limitation

CompactCool advantage:

- Reduced size for same power rated transformers
- "More watts per box"

Reasons for success:

- Compared to conventional dry-type transformers, size reduction with CompactCool is between 15–50 %.