# The new generation of traction transformers pave the way for sustainable mobility while reducing operating cost

## The advantages of dry RESIBLOC® Rail 15 kV compared to traditional transformers

In recent years, Hitachi Energy has been conducting significant research and development (R&D) efforts to evolve a new generation of onboard traction transformers.

Experts from several disciplines and nationalities were confronted with the question of how Hitachi Energy's transformers could help train manufacturers in offering better transformers.

Hitachi Energy team chose to focus mainly on the below four areas of improvement and development for their range of traction products and services:

1. weight reduction,
2. gain in efficiency (reduction of losses and consequently of $CO_2$ emissions),
3. reduction of the total cost of ownership (TCO), in particular operating costs,
4. increased safety.

A substantial R&D effort coupled with Hitachi Energy's long experience with traction transformers resulted in the launch of a few consecutive new generation traction transformers.

**In 2016, Effilight® traction transformer** was launched; these next-generation transformers are up to 20 percent lighter and can incur reduced losses by up to 50 percent.

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Effilight® and its variants were developed and marketed since 2016

RESIBLOC® Rail 15 kV

**In 2018, RESIBLOC® Rail 15 kV transformer** was officially launched at Innotrans as the world's first dry modern traction transformer (liquid-free), which allows savings in electrical losses of up to 50 percent. With the elimination of the dielectric and cooling liquids (oil, ester) this dry transformer almost eliminates the risk of fire load that is associated with the presence of these liquids.

**In 2021** Hitachi Energy launched two new traction products: RESIBLOC® Rail 25 kV transformer and Natural Cooling Effilight®.

RESIBLOC® Rail takes voltage levels up to 25 kV, allowing its use in the most commonly used rail AC network system in the world.

The Natural Cooling Effilight® transformer allows for natural or passive cooling of the transformer, thus eliminating the necessity of air-forced cooling hardware such as fans and relying on the natural air flow coming from the train in motion.

## September 2022

Hitachi Energy continues to up the game and further expand its RESIBLOC® Rail product portfolio by launching the first 25 kV dry transformer with an integrated plug-and-play cooling system this year.

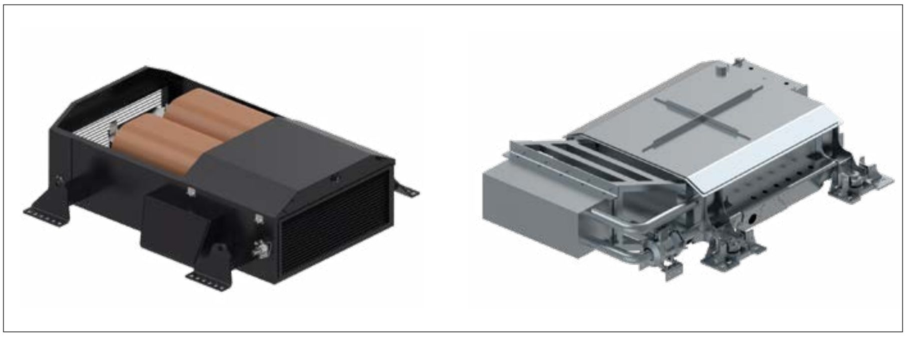
The world premiere launch of this product happened at Innotrans 2022. It is a technological feat that combines the existing advantages of the RESIBLOC® Rail transformer with the benefit of easy installation and operation. The new 25 kV dry transformer RESIBLOC® Rail transformer provides a single-point, all-encompassing transformer solution.

All these new and improved products are the result of the significant innovation effort invested by Hitachi Energy and are synchronized perfectly with the R&D goals identified by the company.

## Case study

To emphasize and highlight the path of technological advancement, a case study comparing the traditional transformer to a dry RESIBLOC® (RB) Rail 15 kV transformer is conducted. This will illustrate the advantages and benefits offered by these new generation products.

Data are collated from different generation transformers mounted on the same train, which provides an effective comparison. Simple assumptions are made to illustrate the potential gains in TCO, and an attempt is made to quantify them in a simple way. The case study will also cover other more difficult-to-quantify benefits that accrue to train manufacturers and operators.



RESIBLOC® Rail 25 kV and Effilight® Natural Cooling

**RESIBLOC® Rail 25 kV transformer takes voltage levels up to 25 kV, allowing its use in the most commonly used rail AC network system in the world**

The case study base relies on a comparison between:
Transformer 1: Classic or traditional
Transformer 2: RB Rail TT (dry)
The basic parameters and assumptions that are being used for the comparison are:

- EMU Traction Transformer
- 15 kV, 16 2/3 Hz
- 1 MVA
- 1 air-forced cooling (1 motor fan)
- 1 pump
- TCO calculated over 30 years cycle time
- $100/MWh
- 2,200 h at 80 percent rated power
- 3,800 h at standstill
- Labor costs in use in Europe

These parameters and assumptions allow a simple comparison of the two transformers, but they do not aim to represent all the nuances in the management of a complex system of a train. However, they help for an easy understanding of the differences and advantages of the RB Rail technologies under the defined parameters and assumptions.

## Description of the simplified model for the estimation of TCO

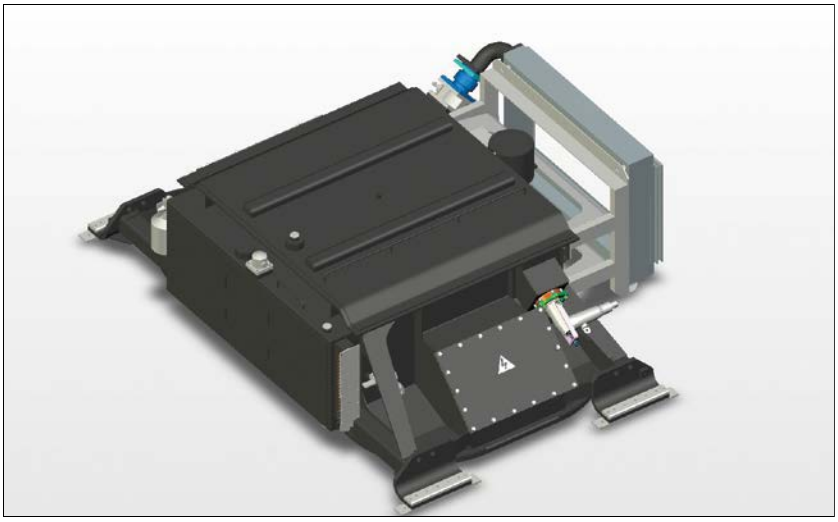
The chosen model focuses on the main factors that contribute to the TCO of a traction transformer:

1. The purchase price of the traction transformer
2. Energy costs related to traction transformer losses (mainly related to copper losses)
3. Energy costs to supply cooling systems fan(s)
4. Energy costs to supply the pump(s) (for liquid transformers)
5. Maintenance costs according to a common maintenance plan used for European Hitachi Energy projects
6. The costs related to the expected defect rate in relation to the Failure In Time (FIT) data of traction transformer (TT) component.

These are explained and compared below. The positive effects of a new generation transformer like the RB Rail in comparison to a classic or traditional solution are made apparent.

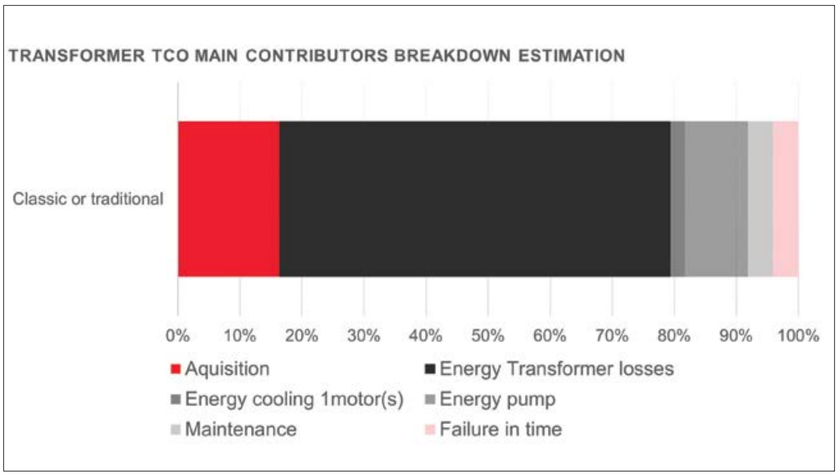
Graph 1 is a representation of the main contributors and their weights compared

**To emphasize and highlight the path of technological advancement, a case study comparing the traditional transformer to a dry RESIBLOC® (RB) Rail 15 kV transformer is conducted**



Classic or traditional traction transformer

RB Rail Dry traction transformer




Graph 1. Transformer TCO main contributors' breakdown estimation

**The initial disadvantage of a higher purchase cost is quickly compensated for, with all the attendant benefits that accrue over the life of the asset**

to the total value at 100 percent of these contributors for a classic or traditional transformer in a simplified model.

### 1. Buying price

The price of the RB Rail (dry) traction transformer generally is higher than the classic or traditional transformer. This is mainly linked to the cutting-edge technology of the RB Rail dry transformer and its unique insulation system (RESIBLOC®), which are incredibly robust and have been successfully used in different applications under extremely restrictive and difficult conditions, like nuclear, maritime, and mining industries. However, as demonstrated below, the initial disadvantage of a higher purchase cost is quickly compensated for, with all the attendant benefits that accrue over the life of the asset.

### 2. Energy consumed by transformer losses

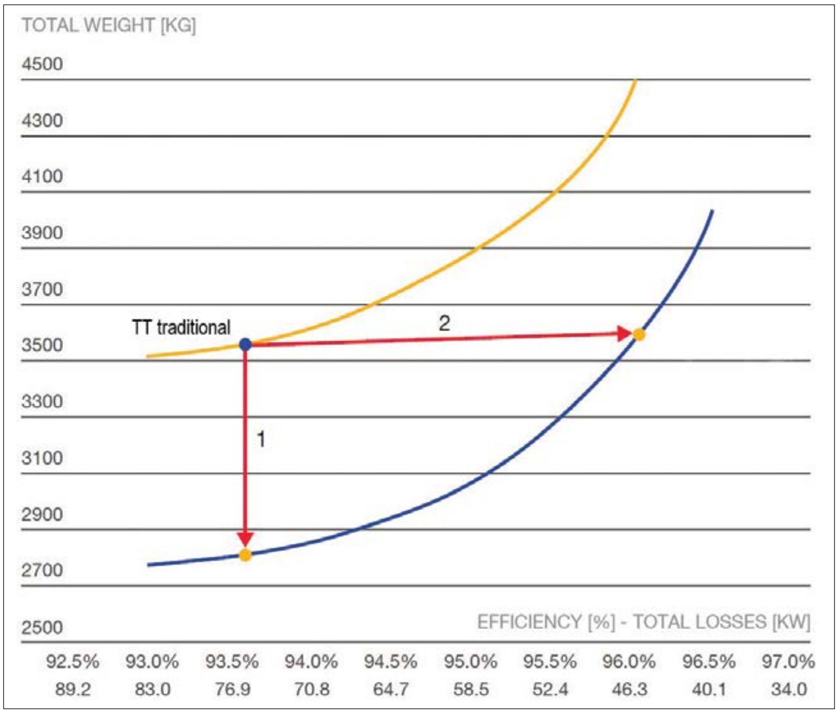
In the case of a traditional or classic transformer, the only way to reduce losses is to increase its mass by adding copper, magnetic sheet metal, and other associated materials. The reduction of losses translates into an increase in efficiency. The yellow curve in Graph 2 illustrates an inverse correlation. The more the requirement of loss reduction, the heavier the transformer must become, bringing its own implications.

By its technology, the RB Rail is a dry transformer which does not contain any dielectric coolant liquid like oil or ester that liquid transformers have. Consequently, substantial weight savings is achieved from this technology, as illustrated by red arrow 1 in Graph 2.

It then becomes possible to reinvest in more material (copper, sheets, insulation and other associated materials) in order to reduce losses considerably or, in other words, increase the efficiency of the transformer and have the right insulation system for air.

These material additions then allow the move on the blue curve from arrow 1 to arrow 2 with significant savings in transformer losses and energy costs over the life of the transformer; these can go up to 50 percent.

Energy costs are one of the main contributors to the TCO associated with transformers.




Graph 2. Example of curves illustrating the principle of weight gain or efficiency (less losses) associated with new technologies such as RB Rail

### 3. The energy consumed by the cooling system

In this area, there are no significant differences between the two technologies; both require a cooling system and therefore do not generate any advantages in terms of TCO.

### 4. The energy consumed by the pump

The pump used for cooling the oil or ester is not used in the RB Rail transformer, which is a dry traction transformer that contains no liquid.

There is no consumption and, therefore, no costs arising from the consumption of energy for the pump; this allows substantial savings of energy and, consequently, TCO during the life of the RB Rail transformer.

### 5. Maintenance during the life of the transformer and the associated costs

The RB Rail transformer has an undeniable advantage in terms of preventive and corrective maintenance compared to oil or ester transformers due to the fact that it is a dry transformer that does not contain components or parts pertaining to oil or ester.

Hence, there is **no need for preventive or corrective maintenance** throughout the life of the transformer. Hereunder is presented a non-exhaustive list of activities removed with the RB Rail transformer.

1. oil analysis,
2. checking the level of oil or ester / adding oil or ester for leveling,
3. checking, regenerating, changing the silica gel of the oil or ester dryer,
4. conducting preventive or corrective maintenance operations on the pump, such as changing the ball bearings,
5. changing the seals during dismantling – reassembly of a part providing sealing with oil or ester,

## The RB Rail transformer has an advantage in preventive and corrective maintenance compared to oil or ester transformers because it is a dry transformer that does not contain components or parts pertaining to oil or ester

6. leak control,
7. reduced need for cleaning,
8. maintenance on the exchanger,
9. corrective and preventive maintenance on the various oil or ester valves, compensators, pressure relief valves, oil levels, oil detector, oil or ester flow detector and the connectors and cables of the components
10. no oil or ester change or regeneration due to the aging phenomenon.

All this maintenance is not needed in the RB Rail transformer, which helps to significantly reduce the maintenance costs of RB Rail transformers compared to oil or ester solutions.

These benefits are quantified through Hitachi Energy's maintenance cost calculation model, as illustrated in the comparative graphs 3 and 3a.

These graphs show a substantial change in amplitude and the absence of the need for maintenance for many items for the RB Rail (dry). This translates into a **reduction of maintenance costs up to a factor of three,** as illustrated by the Hitachi Energy model.

### 6. Failure in Time (FIT) and associated costs

The RB Rail transformer has an undeniable advantage in terms of fault rate compared to oil or ester transformers, again for the simple reason that components which do not exist cannot fail in this type of dry transformer.

There will therefore be no faults on the following components according to the non-exhaustive list below:

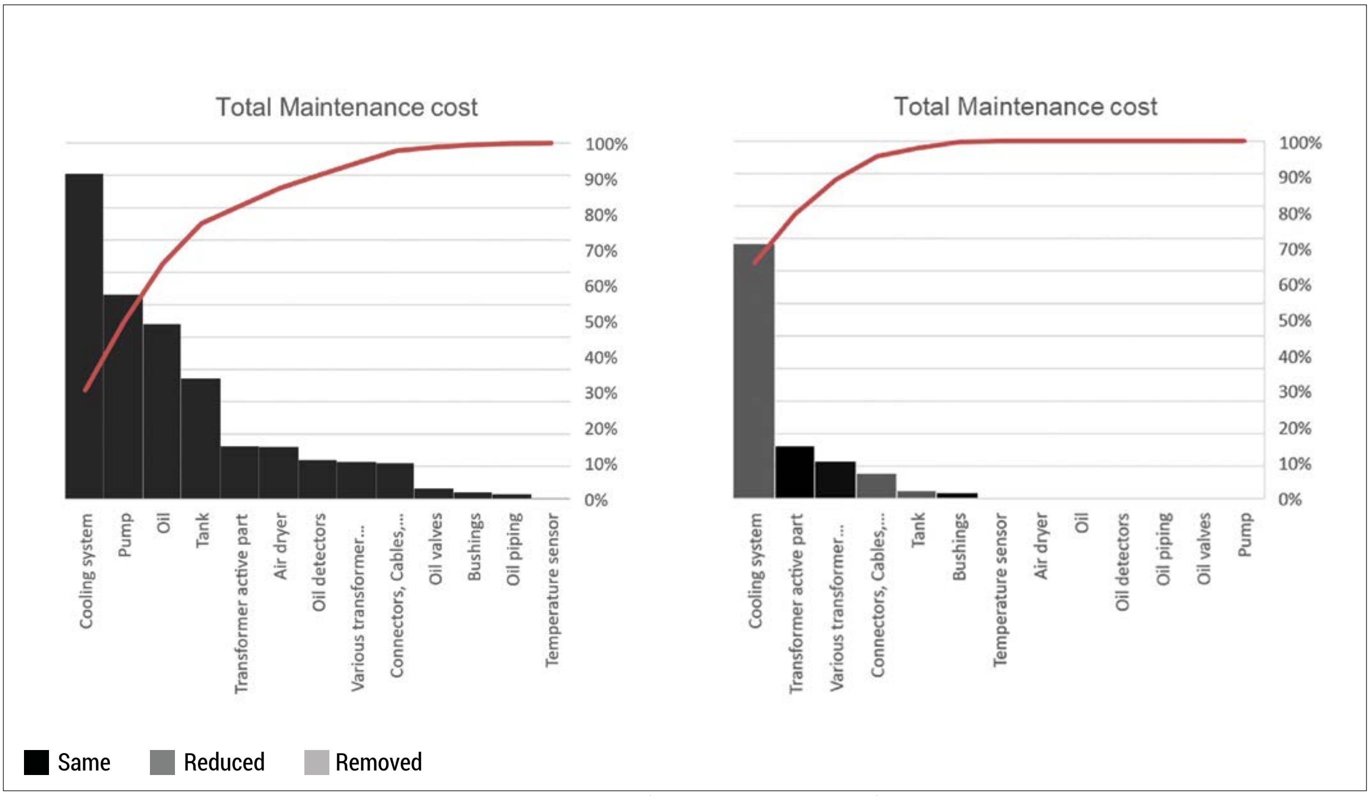
1. oil or ester,
2. sealing system, seals, others,
3. sensors (oil level, oil flow),
4. pressure relief valve,
5. piping, valves, compensators,
6. desiccator, silica gel, over pressure valve, pump,
7. connectors and wiring.

These eliminated potential defects also contribute to a significant reduction of the costs arising from defect rates associated with the absence of those components in RB Rail transformers, compared to traditional liquid-filled transformers.

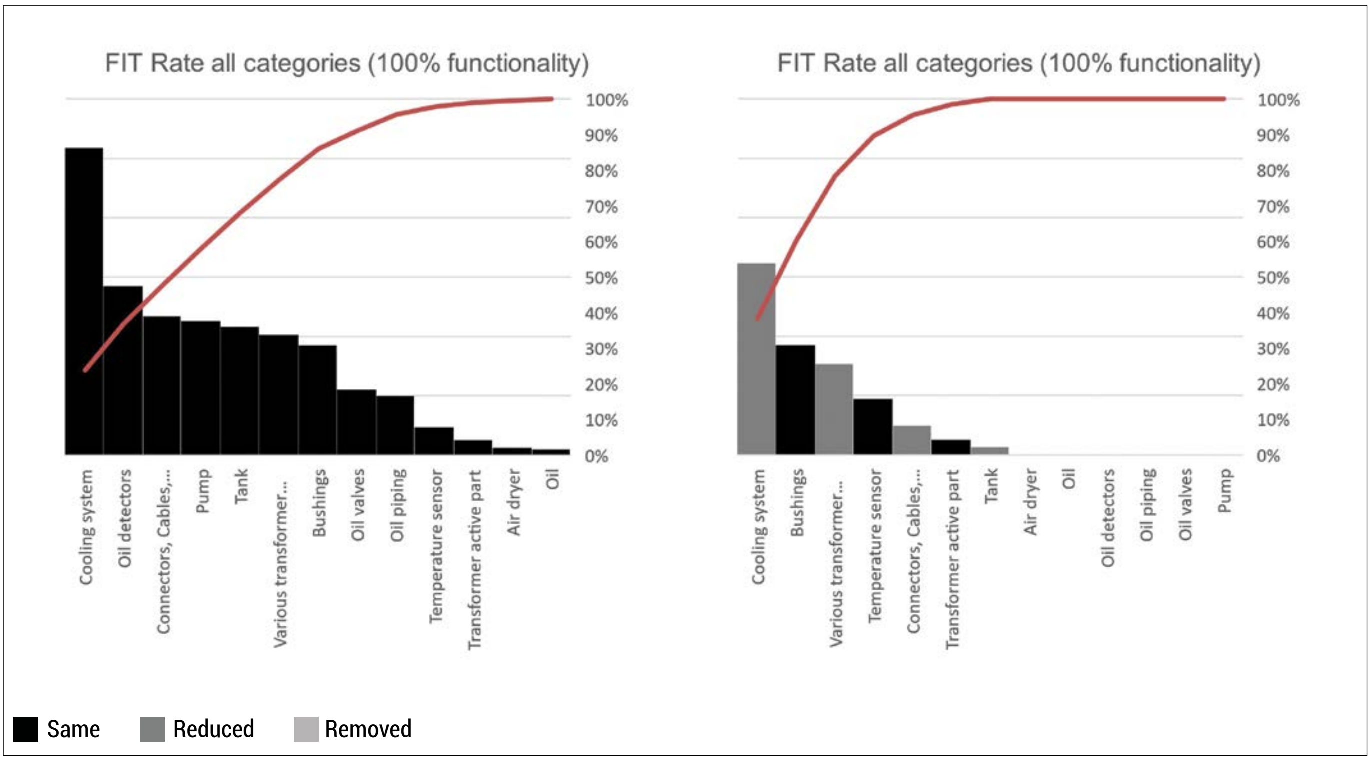
The benefits are quantified through Hitachi Energy's calculation model of the costs associated with the FIT of various transformer components.

Both graphs 4 and 4a show a substantial change in amplitude, and by removal of the items and their potential failure risk, for the RB Rail (dry) TT.

This translates into a **reduction of FIT costs up to a factor of 2.5,** according to the Hitachi Energy model used.




Graphs 3 and 3a. Maintenance – traditional transformer and RB Rail (dry traction transformer)




Graphs 4 and 4a. FIT traditional transformer and FIT RB Rail dry traction transformer

## The RB Rail robust transformer design translates into significantly lower maintenance as well as failure in time and associated costs

### TCO benchmark consolidation between the classic or traditional traction transformer

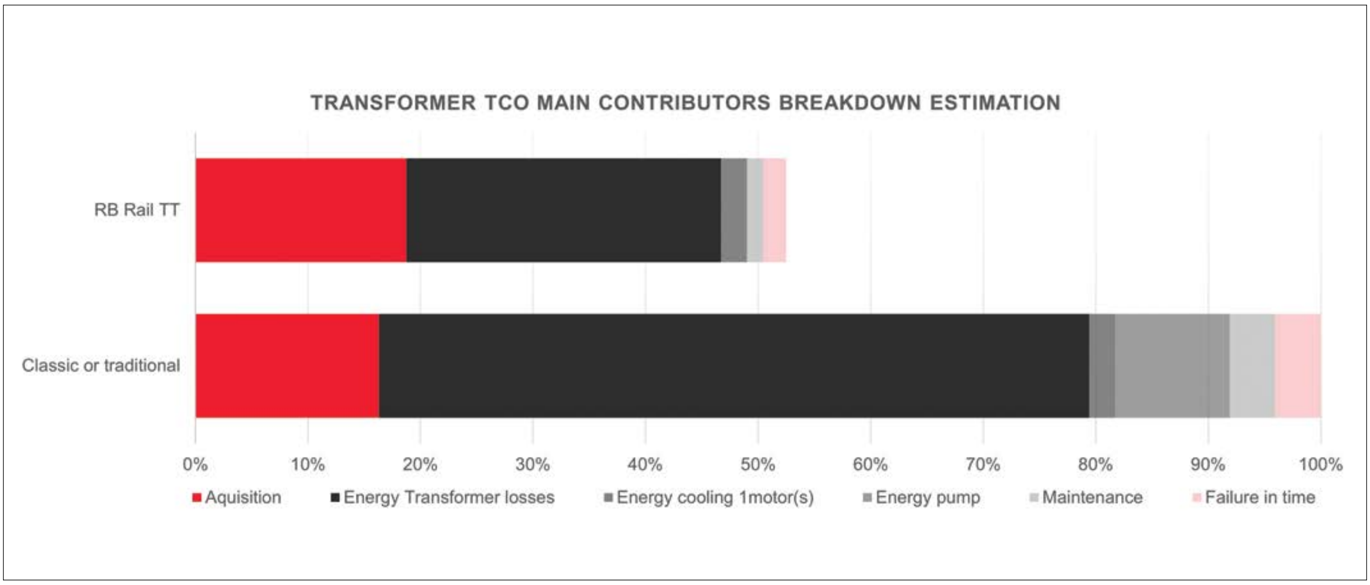
The TCO benchmark chart (Graph 5) graphically shows each contributor to the TCO of a traction transformer and illustrates the differences between a traditional transformer and a new generation one like the RB Rail TT.

This chart is the result of a simplified model developed by Hitachi Energy which gives a good representation of the differences between the two technologies and highlights the advantage of the RB Rail TT.

An overview and comment on their differences is presented below.

#### Acquisition

- The RB Rail TT comes at a higher price than a classic or traditional transformer, but the savings over the lifetime of the new product quickly compensate for the initial increased outlay disadvantage.




Graph 5. Transformer TCO main contributors' breakdown estimation

| Specific features | Value level 1 | Value level 2 | EOM | Operator | R&A (reliability & availability) | M C&P Maintenance corrective & preventi | Stock parts & space | Eco & safety |
|---|---|---|---|---|---|---|---|---|
| **No oil/ester** | **No oil/ester to handle** | No oil/ester in stock - Space saving in warehouse | (x) | x | | | x | x |
| | | No oil/ester handling when changing parts for preventive, corrective or repair | (x) | x | | x | | x |
| | | No need to check and/or adjust levels | (x) | x | | x | | |
| | | No risk of failure, no need to maintain oil/ester | (x) | x | x | x | | x |
| | **No leak** | Better availability, Reliability & no need of corrective maintenance | (x) | x | x | x | | |
| | | No risk of polution. No need to clean product, train, environement,… | (x) | x | | x | | x |
| | **No oil/ester aging** | No test oil/ester needed | (x) | x | | x | | |
| | | No replacement needed | (x) | x | | x | x | x |
| | | No need to check, regenerate air dryer | (x) | x | x | x | | |
| | **No parts required by oil/ester use** | No Air dryer, heat exchanger | (x) | x | x | x | x | x |
| | | No gasket, liquid valves in all kind, oil level indicator | (x) | x | x | x | x | x |
| | | No oil pump, oil flow sensor, | x | x | x | x | x | x |
| | | No wiring, protection, supervision | x | x | x | x | x | x |
| | | Less complexity | x | x | x | x | | |
| | **Easy to recycling** | Parts not "contaminated" with oil/Ester | (x) | x | | x | | x |
| | **Easy accessibility for quick inspection** | No oil to handle just open the enclosure for a quick diagnose | x | x | | x | | |
| | **Could start at - 60°C** | No need for pre-heating | x | x | | | | |
| | **Safety** | No risk of explosion, self estinguish insulation system, much lower fire load | x | x | | | | x |
| **High efficiency** | **In the RB Rail TT DNA** | Lower losses less enegy cost | x | x | | | | x |
| | | Lower carbon emission | x | x | | | | x |
| | | Less to dissipate - reduced cooling | x | x | x | x | (x) | x |
| | | Less cleaning cooling filter (no heat exchanger) | x | x | x | x | | |
| **RESIBLOC insulation system using fiberglass rovings** | **Robust** | Incredible mechanical withstand/strenght | x | x | | | | |
| | | Coil shaping possibility feature for better integration in train | x | | | | | |

x Direct benefit
(x) Indirect benefit

## The RB Rail TT offers many other advantages – even though they also offer operating cost savings, these are difficult to quantify for a transformer manufacturer

**Energy - transformer losses**

- The greatest contribution of the RB Rail TT is its high level of efficiency; this is linked to the possibility of reinvesting the weight saved by the absence of oil or ester in adding more material to reduce energy losses. The loss-reduction can go up to a factor of two and has an impact of the same order of magnitude on the reduction of energy costs and $CO_2$ emissions.

**Energy for cooling one motor**

- The cooling system does not present any notable differences between the two types of transformers in terms of TCO.

**Energy for a pump**

- The oil pump is not required for a TT RB Rail (dry); therefore, the power supply and associated costs are simply eliminated.

**Maintenance and failure in time**

- The RB Rail TT has a definite advantage in terms of maintenance. This advantage comes mainly from the absence of oil or ester and of all the associated components which are otherwise subject to maintenance and failures. The saving on maintenance costs can reach up to a factor of three (three times lower for the RB Rail TT) and a FIT reduction of up to 2.5 times.

The RB Rail TT offers many other advantages – even though they also offer operating cost savings, these are difficult to quantify for a transformer manufacturer. The non-exhaustive list below gives a good overview of the advantages for train manufacturers and operators (see the list on page 89).

## Conclusion

The above analysis provides a general overview of the developments engineered by Hitachi Energy in the field of traction transformers, particularly on the new generation of transformers developed in recent years.

These developments address four main axles of transformer improvement (weight, efficiency, operating costs and safety) and should allow train manufacturers to manufacture better trains and afford train operators the opportunity to respond more effectively to some of the challenges they face.

The case study illustrates and quantifies the advantages of an RB Rail traction transformer compared to a traditional one in terms of energy saving, maintenance, and fault rates.

**Energy savings of up to 50 percent, maintenance savings of up to a factor three, and a reduction in fault rates become possible with this technology compared to conventional or traditional transformers. This assertion is based on the simple principle that a component which does not exist has no need for maintenance nor, therefore, cannot break down.**

### Definitions:

EMU: Electrical Multiple Unit

AC metro: metro powered by alternating current

RB Rail TT: RESIBLOC® Rail Traction Transformer (dry or liquid-free)

Traditional or classic transformers are transformers whose technological base has not benefited from the R&D work mentioned above, in particular on the Effilight family (liquid) and the RB Rail family (dry).

## RB Rail transformer allows energy savings of up to 50 percent, maintenance savings of up to a threefold factor, and a reduction in fault rates

### Author

**Valter Porcellato** is currently acting as Global Product Traction Transformers (onboard) for Railways with the mission of developing and executing the product strategy worldwide.

Engineering and manufacturing footprint and product innovation roadmap definition and execution are two examples of his responsibilities. He has over 25 years of experience in having held various positions as technical manager, profit center manager and having been deeply involved in a JV creation in China. He holds a master's in electrical engineering from l'Ecole Polytechnique de Lausanne, Switzerland, and is currently based in Geneva, Switzerland.