Weight loss program

ABB's Effilight® traction transformer delivers less weight and losses and needs up to 70 percent less oil

TOUFANN CHAUDHURI, MARIE-AZELINE FAEDY, STEPHANE ISLER, MICHELLE KIENER – **Traveling across Europe by train is already faster than by plane right now [1], and just last year a Japanese train reached 601 kph (374 mph) on a test track, covering 1.77 km in 10.8 seconds and setting a new world record. While speed records make great headlines and public reading, for designers and innovators, the weight of the train is just as important. ABB's new Effilight traction transformer is up to 20 percent lighter than a classic traction transformer. It is also up to 50 percent more efficient when the saved weight is reinvested in additional core and winding material, therefore significantly reducing energy costs for the operator. ABB's new Effilight traction transformer is up to 20 percent lighter than a classic traction transformer. When a celebrity loses weight, the news travels faster than a new train speed record. The remaining challenge for Effilight is for the traction transformer weight loss news to be as widely known.**

Title picture
Effilight was launched to the market at InnoTrans, in Germany, in September 2016.

Traction transformers take up valuable train space and add weight to the train, so the motivation to reduce their size and weight is strong. However, the constraints applied by the law of physics are also strong. The transformer core must have certain dimensions in order to accommodate the magnetic field. In addition, weight constraints make traction transformers less efficient because the amount of copper and iron must be limited. On traditional trains pulled by locomotives, the heavy transformer is not necessarily a disadvantage as it contributes to adhesion: the maximum force that the locomotive can apply to pull a train without losing adhesion on the rails is limited by the weight of the locomotive. In modern passenger trains, however, there is a tendency toward multiple unit trains where the traction equipment is not concentrated in the locomotive but distributed along the length of the train in the same vehicles which passengers travel [2]. This brings considerable benefits in terms of adhesion and acceleration, but also requires that the size and location of the installed transformers is carefully considered. Space in the passenger vehicle must be maximized and noise must be at a minimum.

Proven technology improved

Effilight was introduced to the market at the beginning of 2016 → 1 and the public launch was in September 2016 at InnoTrans → Title picture. The key technological differentiator between Effilight and a classic traction transformer is that in a classic transformer the active part is fully immersed in oil. This means oil volume is far from ideal and the whole assembly is penalized by the large oil tank and the resulting constraints. However, for Effilight, ABB developed a hybrid transformer concept where there is a small oil tank around the winding, while the core remains in the air.

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1 ABB's Effilight hybrid concept traction transformer: roof-mounting version

Weighty matters

Weight is a pivotal concept for traction transformers. The maximum admissible weight is imposed by the train manufacturer, who in turn must reach the axle load constraint imposed by the railway infrastructure operators. If the weight is exceeded, the train simply cannot be homologated and therefore cannot run.

It was the initial desire to reduce the weight of the equipment which drove the development of what was to become Effilight. ABB oil insulation traction transformers have a proven lifetime record with more than 40,000 units in operations. Building on this experience ABB researchers started brainstorming how their weight could be reduced. During continued discussions and research, an idea started to emerge: what if only the parts that actually need to be immersed in oil, were immersed? A concept for a radical redesign began to develop. Work started on how to realize the idea of separating the active part of the transformer, from the core.

Over a period of about three years the concept was developed from the idea to the physical testing stage. Small prototypes were built at first and as refinements took place were scaled up to building and testing large prototypes. The biggest challenges that were overcome were mainly to do with mechanical integration, dielectric constraints and magnetic field issues.

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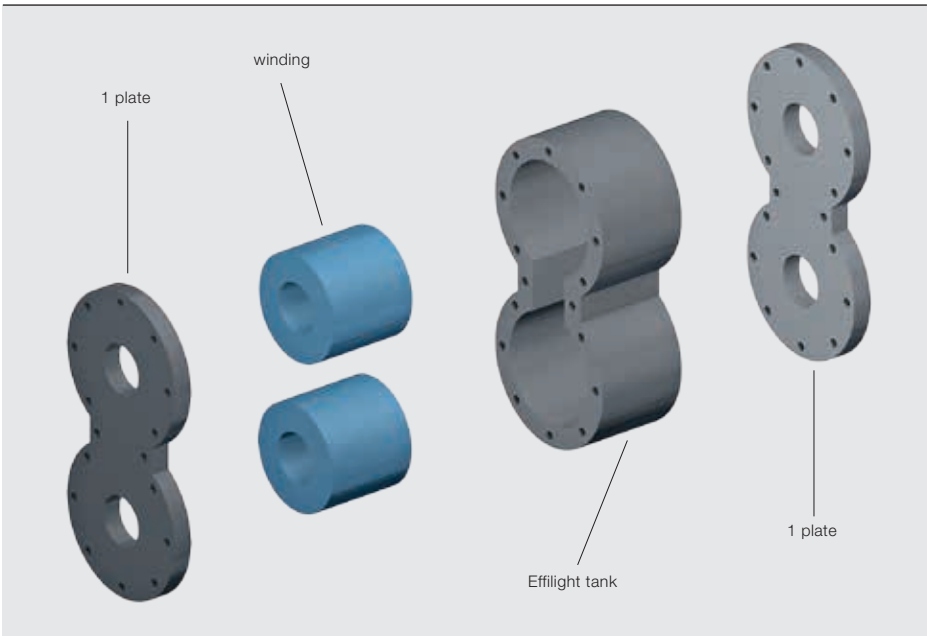
Full type testing, including two shock and vibration tests, were performed, followed by environmental testing that was carried out over a number of months. The prototype transformer was subjected to frequent daily fast switch-ons and warm-ups and performed extremely well. Thanks to the weight saving, the efficiency of the transformer can also be increased because more copper can be added to reduce the winding resistance. The losses of the transformer can be halved while keeping the weight unchanged.

Oil tight

Effilight is a typical example of a solution or product where once it exists, it suddenly strikes people as an incredibly obvious solution. A classic moment of

2 Expanded product view of how the cell is fully sealed and protected from leaks



3 Effilight study prototype – parameters and savings

Parameters	Prototype 1.1 MVA – 15 kV	Base transformer 1.1 MVA – 15 kV	Savings
Total weight	3150 kg	3450 kg	- 9 %
Losses (75°C)	57.2 kW	84.5 kW	- 33 %
Oil weight	200 kg	573 kg	- 65 %
Length	1944 m	1995 m	–
Width	2500 m	2524 m	–
Height	851 mm	834 mm	–

Now that only the windings are immersed in oil, for cooling and dielectric purposes, the oil volume can be reduced by up to 70 percent when compared to a classic transformer.

“of course, how obvious, why did no one think of that before?”. The answer is that, as can often be the case, the technology needed to catch up with the ideas. Once the idea of removing the core from the oil had been conceived, the challenge was how to achieve that in reality. A key solution to develop was, how is it possible to ensure that the “cell” (enclosure of the active part) is fully sealed and immune from leaks, when the core is now external? The answer was a form of “tank in tank” concept, where the cell is sealed separately within another enclosure → 2. O-ring gaskets ensure tightness using a time proven solution.

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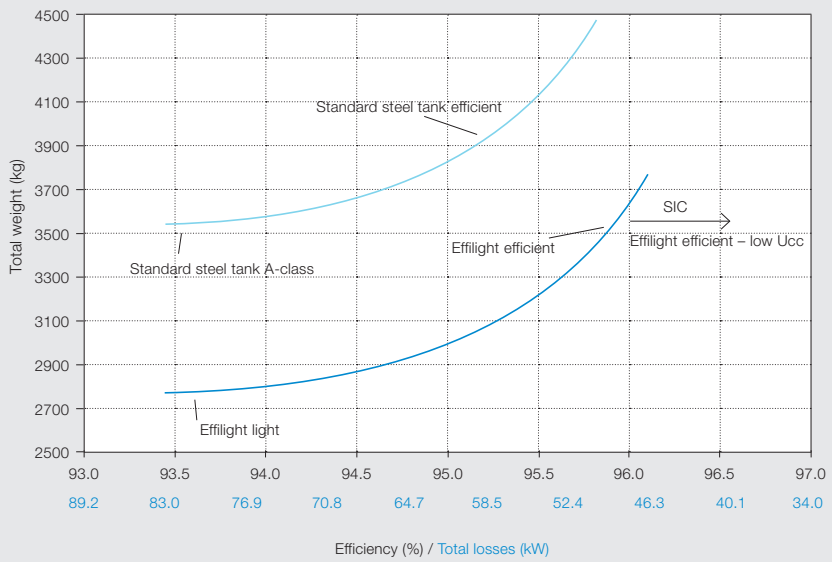
4 Weight and efficiency trade-off



5 Effilight's benefits

Power	15 kV / 16.7 Hz	25 kV / 50 Hz
1.0 MVA	Up to - 20 %	–
2.0 MVA	- 10 to - 15 %	- 20 %
3.0 MVA	Up to - 10 %	- 15 %
4.0 MVA	–	Up to - 10 %

5a Average weight benefit

Power	15 kV / 16.7 Hz	25 kV / 50 Hz
1.0 MVA	Up to + 50 %	–
2.0 MVA	+ 20 to + 30 %	Up to + 50 %
3.0 MVA	Up to + 20 %	+ 20 to + 40 %
4.0 MVA	–	Up to + 20 %

5b Average efficiency benefit

The "active part" windings and the enclosure require no redesign to adapt them for different mounting positions, be that roof-mounted, underframe or in a machine room.

Now that only the windings are immersed in oil, for cooling and dielectric purposes, the oil volume can be reduced by up to 70 percent when compared to a classic transformer. The new approach also brings a reduction of up to 20 percent in weight. The weight saving can then be reinvested in heavier windings using thicker copper wiring that improve the energy efficiency of the transformer by 50 percent, cutting electrical losses in half ➔ 3.

A place for everything ...

For high-power transformers, the amount of oil is not as significant as the amount of copper or steel used, which means there are high-power cases where Effilight does not provide a significant weight reduction advantage. The full benefit of Effilight is achieved in the lower power ratings. The reason for this is the filling factor (the ratio between the weight of copper and steel versus the total transformer weight) tends to decrease when power decreases ➔ 4–5.

... and everything in its place

The prototype has been built and tested for roof-mounting, however the Effilight traction transformer has been designed to be modular. This means that the "active part" windings and the enclosure require no redesign to adapt them for different mounting positions, be that roof mounted, underframe or in a machine room ➔ 6–7. Naturally this brings economies of scale and repetition advantages for train manufacturers and easier maintenance for operators. It means that a variety of different equipment can be fitted with the same transformer, resulting in reduced training costs by using the same transformer across their fleet.

Maintenance and protection functions are the same for Effilight and classic transformers, which means an existing transformer can be replaced by an Effilight without affecting existing maintenance and protection systems or processes.

Future on track

Today, more than half the world's trains are powered by ABB traction transformers, and most of the world's train manufacturers and rail operators rely on them. Effilight is the latest member of this illustrious family. That Effilight's design still

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6 Effilight is suitable for all the different assembly positions

7 Efficient traction transformers – comparing technology and application

Parameters	Classic	Effilight®
Lightweight variant		✓
25 kV option	✓	✓
Wind speed cooling possible		✓
Roof mounted	✓	✓
Machine room mounted	✓	✓
Underfloor mounted	✓	✓
Lifetime	40 years	40 years

includes oil insulation, continues the guarantee expected from an ABB transformer of a 40 year lifetime. Achieving substantial weight reduction through the Effilight technology allows ABB to deliver to its customers a new degree of freedom which was not previously existing: a choice of weight reduction and energy efficiency increases. It is possible to tailor the solution to specific needs for specific train platforms, allowing for instance the weight to be reduced by 10 percent while still increasing the efficiency by 20 to 30 percent. Effilight may currently be a young upstart, but its future looks sparkling. Light it may be, but in terms of lifetime, efficiency and delivery, a lightweight performer it is not.

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