Energy efficient
distribution transformers

A small efficiency improvement = a large energy gain

Electricity network losses vary substantially between countries worldwide. Figures range from less than 4% to more than 20%. There is obviously significant room for improvement in many — if not most — countries. **A major potential for reducing network losses lies in distribution transformers.**

Distribution transformers are used by utility companies to transform the electricity from a voltage level of 1 to 50 kV – the level at which the power is transported locally and supplied to many industrial consumers – to a voltage level ranging between 120 V and 1 kV - typically used by residential consumers and the tertiary sector.

Significant energy savings can be realized in industrial distribution transformers as well as those on the public grid.

Distribution transformers may seem to have relatively high energy efficiency compared to other electrical equipment. Efficiencies range between 90% and 99%. However, they work in continuous operation and have a long life span — typically 30 to 40 years. As a result, **a small efficiency increase can add up to significant energy savings over the lifetime of the transformer**.

- **Switching to energy efficient distribution transformers can save Europe 18.5 TWh in annual electricity consumption (EU-25). This is equivalent to the annual production of 3 nuclear power stations (1,000 MW).**
- **These losses represent an annual operating cost to industrial and residential users of €1 billion, as well as 7 million t/yr of CO_{2eq} emissions**
- **In the large majority of cases, energy efficient distribution transformers have an attractive Life Cycle Cost**

How energy losses can be minimised

Energy losses in distribution transformers

A distribution transformer consists of an iron core, with a limb for each of the phases (see illustration). Around each limb, there are two windings: one with a large number of turns connected to the higher voltage side, and one with a low number of turns connected to the low voltage.

The energy losses fall into three distinct classes:

- **No-load losses:** caused by hysteresis and eddy currents in the transformer core. It is a constant energy loss that is present from the moment the transformer is connected. In the average European distribution grid, no-load losses represent about 70% of the total loss.
- **Load losses:** caused by resistive losses in the windings and leads, and by eddy currents in the structural steelwork and windings.
- **Cooling losses:** some transformers require fan cooling — leading to extra energy consumption. The larger the intrinsic losses of the unit, the greater the need for cooling and the higher the energy consumption by the fan. Cooling losses are relatively small compared to load and no-load losses.

Several proven technical solutions exist to improve the energy efficiency of a distribution transformer:

- No-load losses can be reduced by improved design, assembling and selection of materials for the core
- Load losses are proportional to the square of the load current. They can be reduced by increasing the cross section of the windings.
- The energy consumption for cooling needs can be reduced by keeping the other types of energy losses low.

By combining those techniques, a Best Available Technology distribution transformer can be built which also has — in the large majority of cases — the lowest Life Cycle Cost (LCC).

Amorphous Core Transformers (AMT)

An amorphous core transformer (AMT) uses amorphous metal alloy strips for its magnetic circuit. This allows building transformers with very low no-load losses (up to 70% less than conventional types). Because of the flexible structure of the core, the capacity of amorphous core transformers is currently limited to 10 MVA. Amorphous core transformers are 5 to 20 % heavier than conventional transformers of the same capacity.

Harmonic currents increase losses

The energy efficiency of a transformer is also negatively influenced by 'harmonic currents'. Harmonic currents are distortions that are inherent to the electrical power of the grid, albeit grid operators try to keep them as low as possible. On the average European public grid, harmonic currents result in an extra energy loss in distribution transformers of about 10 % (source: SEEDT project). Apart from that, harmonic currents also reduce a transformer's lifespan.

Efficiency categories of transformers

The two main types of distribution transformers are oil-immersed and air-cooledThe European voluntary standard EN 50464-1 divides oil-filled transformers into several categories of losses. The resulting efficiencies range between 96% and 99%. Despite of this, the average operating efficiency of distribution transformers in the EU-27 is still only 93.38% (source: SEEDT project).

Air-cooled types (or the so-called dry transformers) are used in places with a high fire risk or specific working conditions. In general they have lower energy efficiency, but can reach higher efficiencies if they are tailor-made.

Long life cycle and continuous operation

Distribution transformers have a life cycle of 30 to 40 years and work in continuous operation mode. Consequently, a small energy efficiency difference can add up to significant savings.

In many companies and organisations however, the purchasing budget is separated from the operational budget. As a result, purchasing decisions are often based solely on the delivery price, instead of taking the TCO into account. Such decisions will result in a negative impact lasting for decades.

Total Cost of Ownership (TCO), asset management, externalities

Operating losses typically represent 30% to 70% of the TCO of distribution transformers. The pay-back periods for investing in high-efficiency transformers are relatively short, often less than two years. The Internal Rate of Return in efficient transformers is consistently above 10% and sometimes as high as 70%.

In addition to the TCO considerations, increasing the efficiency of distribution transformers also results in environmental benefits and in a reduction of externalities (reduced CO_2, NO_x and SO_x emissions).

Endesa Effitrafo Project proves profitability

In the framework of the Effitrafo Project, grid operator Endesa (Spain) exchanged transformers that merely fulfilled national standards by high efficiency transformers. The energy losses were reduced by 50 to 80%, while the pay-back period of the new transformers was only 1-2 years. For each 400 kVA transformer on their grid, this operation in resulted in an annual energy saving of 5.5 MWh, which is equivalent to 30 washing machines turning non-stop for one year.

ECI and energy efficient distribution transformers

In 2005, the European Copper Institute (ECI) published a paper on the benefits of energy efficient distribution transformers, targeting EU policy makers. This paper was the result of years of intensive intelligence gathering and analysis.

ECI also participates in SEEDT, a project within the framework of the Intelligent Energy programme of the European Union. SEEDT builds the business case for development and diffusion of energy efficient distribution transformers. For the SEEDT project, ECI works in collaboration with the NTUA (Greece), Wuppertal Institute (Germany), and ENDESA (Spain).

Since 2006, the Leonardo ENERGY programme, managed by ECI, regularly reports on the latest developments in transformer efficiency standards, regulation, and technology.

HOW TO PROMOTE ENERGY EFFICIENT TRANSFORMERS

Based on the realities of the market over the last 10 years, to ensure that all economic and environmental benefits of high efficiency transformers are harvested, ECI stresses that new regulation is required.

The following regulatory steps are recommended:

- **Set Minimum Efficiency Performance Standards (MEPS)**
  MEPS can phase out the lowest energy efficiency levels. An international benchmark can help to adequately define those levels. Strict and enforceable minimum standards will stimulate innovative manufacturers and ensure that they profit from current and past R&D investments.

- **A voluntary scheme for premium efficiency levels**
  Such a scheme is preferably established within the context of a broader voluntary programme for energy conservation.

- **Promote Life Cycle Costing (LCC)**
  Promoting LCC as a best practice for equipment purchasing will indirectly promote energy efficient distribution transformers, since the latter have, in most cases, the lowest LCC.

  Electrical grid operators are often subjected to a regulatory framework that prevents – instead of provides incentives – to invest in equipment with a low LCC but a high initial purchase price. Establishing regulatory schemes that support investments in low LCC equipment is required.

  To spread 'life cycle thinking' as a general policy in private companies, it should be included in the requirements for EMAS certification (Eco-Management and Audit Scheme). The LCC practices of the company would then be verified during the EMAS certification audit. Similarly, the future ISO 50001 for Energy Management should also include a chapter on LCC practices.

ENVIRONMENTAL, ECONOMICAL, AND GEOPOLITICAL ADVANTAGES

Fully implementing Best Available Technologies for distribution transformers could save the EU 18.5 TWh per year in electricity consumption. This corresponds to a generating capacity of 4,000 MW, equivalent to:

- 3 nuclear power stations (1,000 MW)
- 11 fossil fuel power units (350 MW)
- One third of the EU's total 2007 wind capacity (56.531 MW with an average capacity factor of 0.21%)

EU advantages are environmental, economic, and geopolitical:

- A 7 million tonne annual reduction in CO_{2eq} emissions
- Significant reductions in NO_x, SO_2 and dust emissions
- A €4.5 billion reduction in capital investments for new generating capacity
- An annual €1 billion saving in operating costs
- A reduced dependency on fossil fuel imports

If you are interested in receiving ECI's report on Energy Efficient Distribution Transformers, please contact

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