

Natural convection airflow inside a kiosk, resulting from transformer heating; the transformer surface is colored by temperature, with red the maximum; pathlines from the right lower are in blue and those from left are in red; flows are homogeneously mixed through the kiosk as shown by traces leaving the top

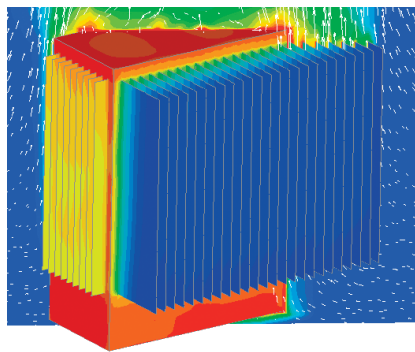
Schneider Electric, a world leader in electrical distribution and industrial automation, develops products that are compact, yet have a high level of electrical performance. Their products must meet strict international standards and satisfy customer requirements such as reliability, safety, low cost maintenance, and dependability.

Electrical transformers are a good example of products that pose such challenges to produce. To last an expected lifetime of 30 years, transformers need to be protected from high temperature peaks, which are a major contributor to material ageing. One test applied to transformers under development involves a comparison of a transformer operating inside a kiosk (a concrete or sheet metal enclosure) to the same transformer operating as a free-standing unit. In both cases, the transformers are assumed to be loaded at the same nominal electrical power. The hottest surface temperatures are measured and compared, and the difference must not exceed 10°C.

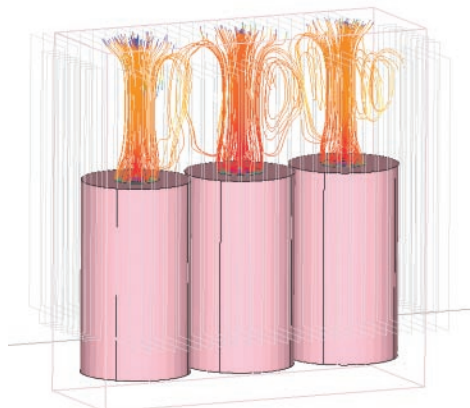
If the temperatures in the kiosk are too high for the contained transformer case, the kiosk design must be modified. Since fan cooling adds an additional maintenance cost and reliability issues, only natural con-

Optimizing Transformer Designs

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Surface temperature on the transformer and the flow circulation on a vertical plane slicing diagonally through the transformer



Inside the transformer, oil is released through gaps between the coils and magnetic circuits; the flow of oil is shown using pathlines, colored by temperature; the oil jets generate toroidal structures on top of the coils

vection is considered for kiosk cooling schemes. To model the air flow around the transformer and test different kiosk architectures, CFD simulations using Icepak have been performed. Results show that the size and location of louvers on the sides of the kiosk can be optimized to satisfy the international standards and minimize manufacturing costs at the same time.

The transformer itself is made of steel sheets and coils immersed in an oil-filled tank. The oil is heated by the transformer losses, and the heat is dispersed throughout the oil by natural convection currents. The tank dissipates the heat to the outside by natural convection in the surrounding air and by radiation. Conduction through the solid structures is negligible by comparison. In Icepak simulations of the transformer, natural convection was included in both the air and the oil. The thermal inertia of the two fluids was accounted for through temperature-dependent properties for each of the two fluids. The surface power densities of the heat-producing elements (the coils and magnetic circuit) was specified as well.

A fine mesh in the vicinity of the transformer was used. To minimize the global size of the mesh, a non-conformal interface was positioned around the transformer, so that a coarser mesh could be used in the outer regions of the model. The coils and magnetic circuit were defined as hollow blocks, and the resulting mesh consisted of 865,000 hexahedral cells. Without the meshing tools available in Icepak, the mesh would have been roughly twice as big.

Transformer simulations were performed to study the temperatures on the transformer surface and the flow of oil on the inside. Among the many interesting flow features indicated in the results were toroidal shaped structures generated by the jets of oil above the coils. Studies such as these make the internal transformer flows and cooling behavior easier to understand. At Schneider Electric, they contribute to the efficient development of products in which the number of prototypes is reduced, and the development costs are kept under budget. ■