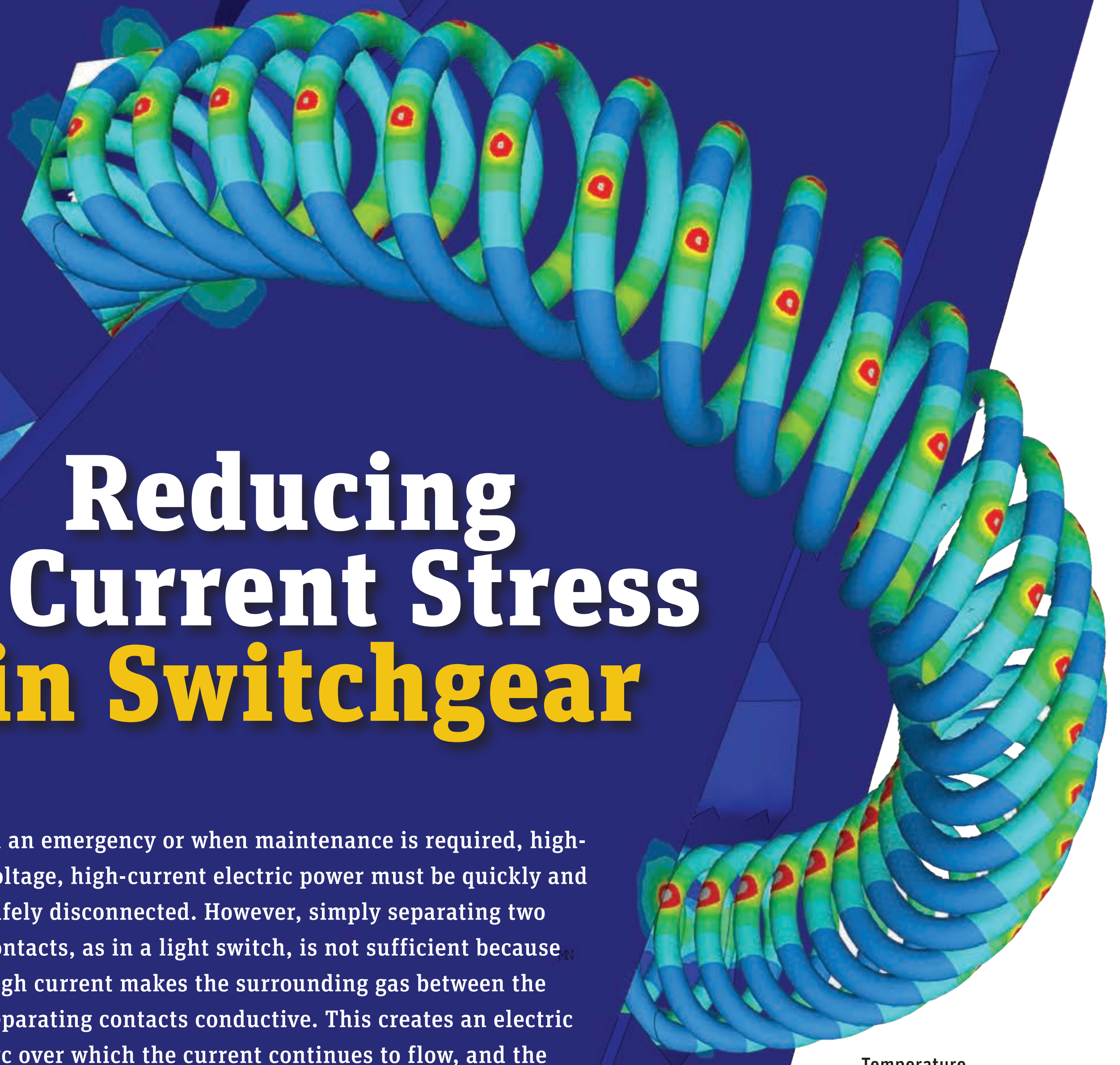
Reducing Current Stress in Switchgear



Temperature distribution plotted on a spring contact during a short circuit

In an emergency or when maintenance is required, high-voltage, high-current electric power must be quickly and safely disconnected. However, simply separating two contacts, as in a light switch, is not sufficient because high current makes the surrounding gas between the separating contacts conductive. This creates an electric arc over which the current continues to flow, and the current causes additional stresses on the associated busbar. Lucy Electric engineers estimated the electrodynamic forces and applied ANSYS Mechanical to optimize the shape, placement and durability of special splitter plates. Using simulation, the company increased the performance of switchgear designs quickly and economically and delivered superior, reliable energy products to market.

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Thermal Analysis
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“Engineers use *ANSYS Mechanical* to precisely determine the electrical, mechanical stresses and temperature rise inside their equipment.”

Turning off a light at home simply involves separating two contacts in a switch. Turning off much higher currents at higher voltages in power distribution systems also requires extinguishing the arc that forms between the contacts after separation. The switchgear that performs this task sometimes bathes the arc in insulating SF_6 gas and splits it with a series of metal plates. Busbars — metal bars that distribute current to the various switching devices — together with the switches and their controlling equipment make up the switchgear. Lucy Electric builds a wide range of medium voltage switchgear for specific applications, each of which is designed to provide a safe and reliable performance in a compact package and at a competitive price. To meet these requirements, Lucy Electric engineers must precisely evaluate the stresses inside the equipment under both steady-state and transient conditions. Engineers use the ANSYS Parametric Design Language (APDL) with ANSYS Mechanical to precisely determine the electrical and mechanical stresses and the temperature rise inside their equipment under both conditions.

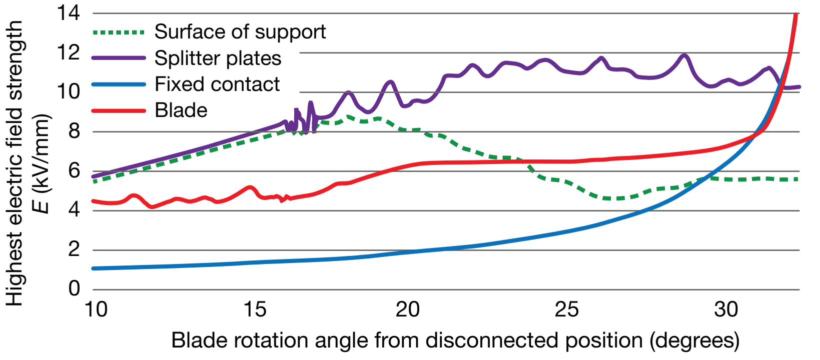
SWITCHGEAR DESIGN REQUIREMENTS

Lucy Electric is a leader in secondary power distribution solutions for utility, industrial and commercial applications. Switchgear must be designed for safe operation not only under normal conditions but also in extreme cases such as short circuits or lightning strikes. Switchgear designers must also meet market needs for compact solutions that can fit within often-crowded equipment rooms. But compressing switchgear size moves the conductors closer to each other, resulting in higher electrical field strengths, in stronger electromagnetic skin effect, and in higher electrodynamic forces that produce higher mechanical stresses. The design parameters of the switchgear need to be finely tuned to withstand the rated voltages and over-voltages, the rated currents and over-currents, and the resulting dynamic forces, while not exceeding specified maximum temperature values.

Lucy Electric engineers use APDL scripts with ANSYS Mechanical to evaluate the performance of concept designs. In a recent project, engineers prepared the geometry using computer aided design (CAD) software and imported it into ANSYS DesignModeler. They put the finishing touches on the model in DesignModeler by creating the surrounding gas volume with the Enclosure command, merging the volumes and defining the boundaries as named selections.

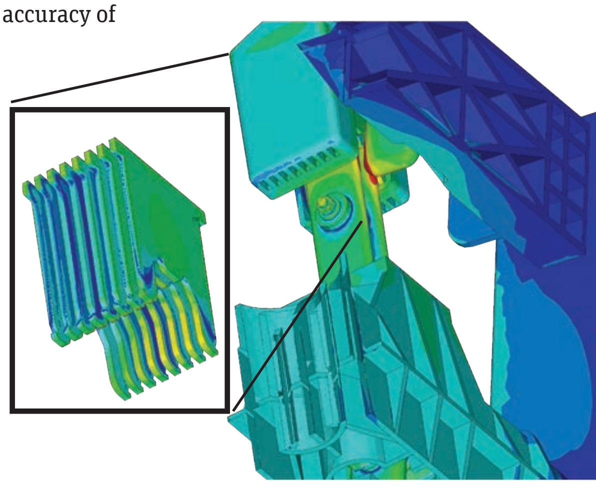
ARC MOTION BETWEEN THE PLATES AND OPTIMIZING SPLITTER PLATE GEOMETRY

The temperature of the hot ionized gas that composes the electric arc is maintained by the electric current flowing through the arc. To extinguish the arc and interrupt the current requires reducing the arc’s conductance. In the case of alternating-current switchgear, the current reduces to zero and ramps up again on each time cycle. One type of switching device in a medium voltage Lucy Electric switchgear uses splitter plates to block the restriking of the arc. The arc is constrained into small notches at the edge of the plates to increase the efficiency of the arc chute. Other methods are used in different switchgear.



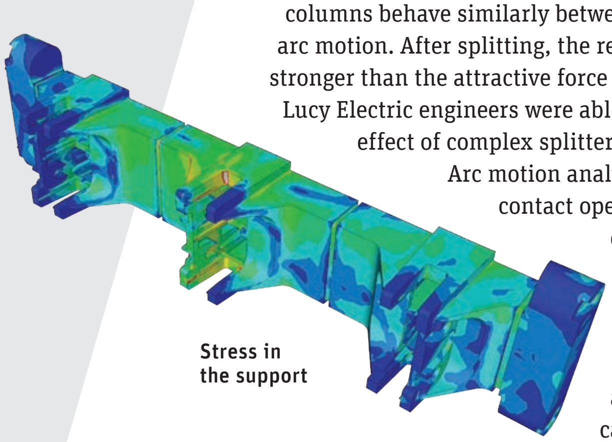
Maximum field strength of different components as a function of blade rotation angle

The first analyses of the splitter stack focused on the forces acting on the arc before it reaches the plates during contact opening. Several 2D and simple 3D models were used to determine which splitter plate geometry could more effectively pull the arc into the notches. These models could be solved quickly so that engineers could compare several plate geometries in a single day. Lab tests demonstrated the accuracy of these simulations.



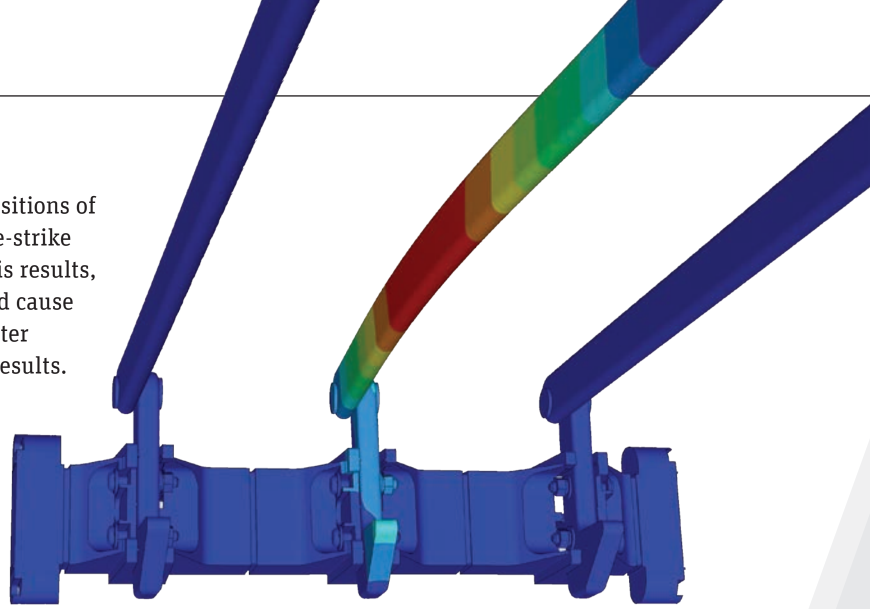
Electric field strength distribution over conductor and insulator surfaces in the insulating gas of a switchgear

Lastly, engineers modeled the electric arc as a small cylinder moving in the insulating gas. They used an APDL script to solve the equations of motion of the arc columns, including an electromagnetic acceleration and a braking term caused by drag. The 3D model is simple but takes all the major forces acting on the arc column into account. Engineers assumed that the arc had reached the splitter plates and had been split between them. Only two adjacent arc columns were modeled based on the assumption that the arc columns behave similarly between all plates. The results showed the complexity of the arc motion. After splitting, the repelling forces between two adjacent arc columns were stronger than the attractive force from the ferromagnetic plates. This is the first time Lucy Electric engineers were able to calculate the motion of the arc and determine the effect of complex splitter geometries.



Stress in the support

Arc motion analyses showed the performance of the switch during contact opening. To verify the behavior during contact closing, engineers used ANSYS Mechanical's static dielectric analysis to calculate the electric field strength distribution. If the field strength is too high, it causes a breakdown in the gas between the two contacts, resulting in a pre-strike arc. A pre-strike arc that occurs too early in the closing cycle may cause the contacts to deteriorate over time. Engineers calculated the field strength at different positions of the moving contact to see if and when a pre-strike arc could be expected. Based on the analysis results, they identified high-stress points that could cause breakdowns between the contacts and splitter plates. Additional lab test validated these results. Engineers modified the geometry to reduce the stress at the edges of the splitter plates to prevent a possible pre-strike arc between the plates and the moving contact.



Deformation of conductors and support during a short circuit.

CALCULATING JOULE HEATING AND TEMPERATURE RISE

Electric current flows through the switchgear conductors and contacts over most of their life, causing Joule heating, which generates thermal loads. Lucy Electric engineers coupled transient magnetic and thermal finite element analysis to calculate the temperature rise of the conductors and canted spring contacts during a short circuit to see if it exceeded the material limits. The simulations showed the influence of the relatively high contact resistances on the current-density distribution and were confirmed by test results.

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CALCULATING MECHANICAL STRESSES

The high electric current also generates electrodynamic forces in the conductors. Lucy engineers coupled transient electromagnetic and structural models to calculate the displacement and stresses in the conductors and their supports in a medium voltage switchgear during a short circuit. The analysis showed that the high displacement and stress was caused by a resonance that could not be resolved by strengthening the existing supports. Lucy engineers added an additional busbar support to eliminate the resonance.

Lucy Electric engineers use ANSYS Mechanical to simulate concept designs faster and more cost efficiently than required by physical testing. Starting from a CAD model, Lucy Electric engineers can perform any of the simulations mentioned in this article in about a week. They often obtain results that would be difficult or impossible to measure during physical tests. If modifications are required, they can change the model and re-run the simulation in a few minutes or within a day, depending on the extent of the changes and on the type of the simulation. A complete analysis of a whole unit from scratch starting with a CAD model takes several weeks. As a result, engineers can evaluate more design iterations than in the past and create higher performing designs in less time while reducing the number of prototypes and test rounds during the development process.

Position of two adjacent arc columns after splitting