Protection Up the Arc — Protecting Electric Arc Furnace Transformers and Open-Air Bus




Protecting the power system for electric arc furnace steel production presents unique challenges. Dynamic secondary load currents, ultrafine dust, intermittent loading and frequent breaker operations contribute to higher failure risks. Overcurrent-based protection alone is insufficient to address these issues. A modern, multilayer protection scheme was developed using ruggedized arc flash sensors, communications-based differential protection and voltage-based breaker failure protection. This approach effectively overcomes these challenges to significantly improve safety and reliability while protecting the most critical asset in the steelmaking operation.

Authors

Connor Moore (top left), Power Systems Engineer, Nucor Steel–Indiana, Crawfordsville, Ind., USA
connor.moore@nucor.com

Mudit Kumar (top right), Engineering Manager, SEL Engineering Services Inc., Plymouth, Mich., USA
mudit_kumar@selinc.com

Haley Newton (bottom left), Detroit Branch | Senior Engineering Manager, SEL Engineering Services Inc., Plymouth, Mich., USA
haley_newton@selinc.com

Nate Boos (bottom right), Director — Central Region USA & Canada, SEL Engineering Services Inc., Plymouth, Mich., USA
nate_boos@selinc.com

This paper is the recipient of the 2026 AIST James Farrington Award. For more information about AIST awards, visit AIST.org.

Introduction

Electric arc furnaces (EAFs) play a critical role in modern steel production by enabling efficient recycling of scrap metal and precise control over the melting process. Unlike traditional blast furnaces, EAFs utilize high-current electric arcs to generate the extreme temperatures required for melting steel, often exceeding 3,000°F (1,650°C). While efficient, this process introduces significant electrical and environmental challenges that complicate power system protection.

Protecting the power infrastructure of an EAF-based steel production facility requires addressing unique stress factors that conventional protection schemes struggle to mitigate. Dynamic secondary load currents frequently exceed the capabilities of standard transformer differential protection. The steelmaking process also generates ultrafine dust, which accumulates on electrical components despite rigorous containment efforts. This conductive dust can lead to high-impedance faults and flashovers if left unchecked. Maintenance procedures such as routine compressed air cleaning introduce further risks by subjecting sensitive components — especially fiber-optic sensors — to abrasive conditions akin to sandblasting.

Breaker failure detection presents another major challenge. EAF power systems rely on specialized breakers designed for high-frequency operation, often featuring independent pole mechanisms instead of traditional, mechanically interlinked designs. This increases the likelihood of pole disagreements. Furthermore, the load characteristics of these circuits — typically oscillating between full load and near zero — make traditional breaker failure protection methods unreliable. If undetected, a failed breaker can lead to improper operation of motor-operated knife switches and grounding switches, introducing additional failure risks.

To address these challenges, a multilayered protection scheme was implemented at Nucor Steel–Indiana. The system safeguards a 34.5 kV servomotor-style breaker, motor-operated switches, air-insulated bus sections, instrument transformers and an EAF transformer housed in two indoor vaults. The facility previously relied on overcurrent protection but now utilizes ruggedized arc flash sensors, communications-based differential protection and voltage-based breaker failure detection. This modernization enhances safety, reliability and asset protection in the demanding EAF steelmaking industry.