Infosys | CONSULTING

Grid losses and state-of-the-art solutions for effective mitigation

An Infosys Consulting Perspective

By Ralph Trapp, Zain Asif, and Kashif Shahzad

Consulting@Infosys.com | InfosysConsultingInsights.com

Introduction

Every year, transmission system operators (TSOs) and distribution system operators (DSOs) have to collectively spend hundreds of millions of euros to compensate for energy losses in the power grid. The total cost of covering energy losses in the German grid, for example, was €450.5 million in 2020 and €458.4 million in 2021.

Due to the electrical, thermal, and mechanical properties of grid components, losses in electricity transmission and distribution grids are unavoidable. However, using advanced digital solutions and leveraging state-of-the-art technologies can help grid companies mitigate and optimize these losses. The technologies include (but are not limited to):

- Smart metering
- Internet of Things (IoT)
- Intelligent electronic devices (IEDs)
- Field sensors
- Digital integrated network models
- Advanced distribution management system (ADMS)
- Geographic information system (GIS)

This may result in considerable CAPEX and OPEX savings for businesses and increase overall grid efficiency, reliability, resiliency, and safety – all of which are crucial aspects to tackle the challenges which the global electricity industry must face in this rapidly changing landscape.

Why do losses occur, and why should they be mitigated?

Electrical power grids are the critical infrastructure which carry electricity from the points of generation to the points of consumption.

Modern day power grids are quite complex, consisting of hundreds of thousands of electrical, mechanical, and structural components, as well as electricity conductors, cables, control software, hardware, and so on. A strong power grid is one which is well-interconnected, resilient, secure, and reliable. As power grids carry electricity from one point to another, some of electricity is lost due to the various material properties of the grid components. Hence, grid losses are unavoidable, but these can be mitigated and reduced via intelligent software and/or hardware solutions.

Grid losses can constitute more than 90% of the carbon footprint of transmission and distribution grids. Intelligently deployed loss mitigation measures can eventually save energy in transmission and distribution grids. This can potentially render one or more carbon intensive power plants redundant. Hence, this topic is becoming increasingly important in the context of energy transition and net-zero targets in the energy industry globally.

Energy losses become even more significant in distribution grids. Due to lower voltage levels than transmission and sub-transmission grids, **total technical losses** may constitute up to **3-6% of the total electricity** fed into these grids – depending on the degree of sophistication and age of grid infrastructure. For instance, according to Germany's Federal Network Agency's Energy Monitoring Report 2022, DSO losses, in 2021, amounted to **17.8 TWh** – approximately **3.2%** of the total net electricity generated in Germany. On the other hand, the TSO losses amounted to **9.9 TWh**, around **1.8%** of the total net electricity generation in Germany that year. The total costs to cover the loss energy in the German grid were **€450.5 million** in 2020 and **€458.4 million** in 2021.

Furthermore, the large number of nodes in distribution grids, as well as the huge number of industrial and residential consumers, have traditionally made these grids more complex to manage and control. This in turn, has made it increasingly difficult to manage losses in these grids.

But now, due to the rapidly changing energy landscape with more and more distributed energy resources (DERs) penetrating the distribution grid and with consumers turning into prosumers, the public is increasingly focusing their attention on these grids. Therefore, it becomes strategically crucial to consider the advanced loss mitigation measures in distribution grids which, in their topology and configuration, are far more complex than transmission grids.

Broad categories of power grid losses

The losses in electrical power grids can be broadly classified into technical and non-technical losses:

Non-technical losses

Non-technical losses are sometimes also referred to as commercial losses. The non-technical reasons of losses can be, for instance:

- Manipulation of a meter reading
- By-passing meter measurement by illegal direct connection to secondary feeders
- Non-uniform testing and calibration of meters
- Use of external mechanical force on meters
- Errors in billing
- Errors in meter reading

Technical losses

Technical losses in power grids can further be classified into fixed losses and variable losses.

Fixed losses are those which aren't load-dependent i.e., they don't change irrespective of the variation in electrical load or power consumption. These losses occur even when the components are in stand-by mode and aren't actively carrying electrical current. Improvements in fixed losses can be achieved by improving the physical and mechanical design of grid components, which can be done by influencing their electromagnetic, thermal, and mechanical characteristics.

Variable losses, on the other hand, are load dependent i.e., they vary, as the electrical load or power consumption in the grid increases or decreases. Hence, during peak-hours of electricity demand, grid losses are higher as compared to the off-peak periods when electricity demand is low.

The **biggest source of technical losses** in power grids are the transformers which are responsible for almost half of total technical losses. **Transformer losses** typically consist of the following:

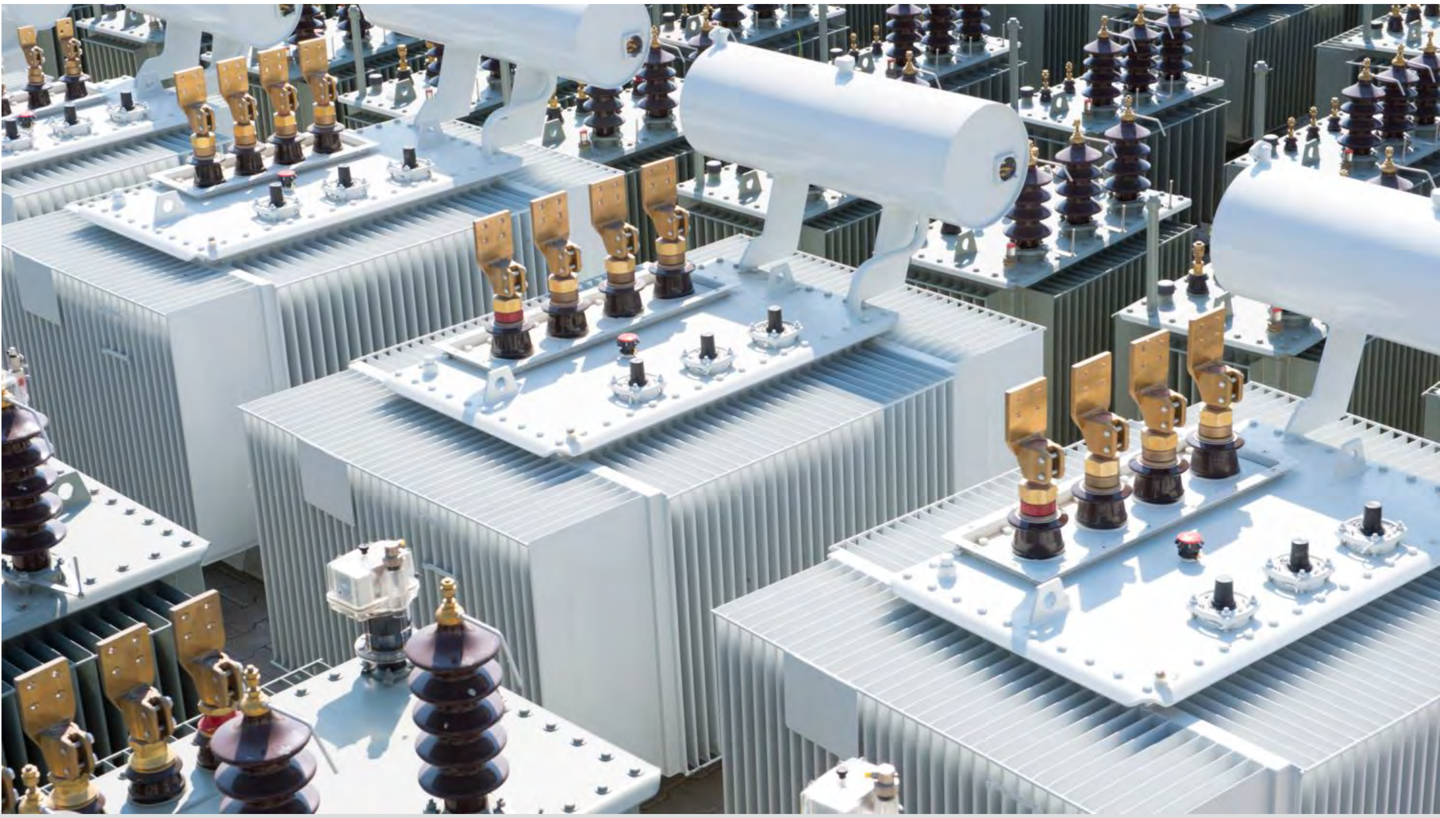
- Copper (ohmic)
- Magnetization
- Eddy current
- Stray

When transformers aren't centrally located with respect to consumption points, it leads to unwanted voltage drops due to increased feeder path resistance. Similarly, excessive overloading of transformers also leads to over-heating and so results in higher losses. Irregular or non-optimized maintenance schedules, as well as ageing of transformer windings and insulation are also major contributors to increasing losses in transformers.

Apart from transformers, non-optimized feeder configuration also leads to increased losses in distribution grids. For example, if the transmission distance of electric power to the consumption points is larger, then the increased electrical resistance in the path leads to more losses in distribution feeders.

Similarly, an imbalance in the feeder phase (phase asymmetry) due to imbalanced (asymmetrical) loads also contributes to higher feeder losses. Furthermore, an increased inductive load, such as the operation of large motors, leads to a reduced power factor in distribution grids, which, in turn, causes more losses.

Overloading feeders due to seasonal and time-of-day factors, non-optimized network topology, and unforeseen events, all lead to the creation of bottlenecks and grid congestion both locally and in neighboring regions. This results in increased losses in the wider grid.



Loss mitigation strategies

Any network loss mitigation strategy should target all three pillars of loss reduction: Organizational strategy, technical choices, and data management:

Organizational strategy

Organizational strategy for mitigating power grid losses typically involves **implementing effective processes** aimed at reducing losses.

This may include, for example:

- The implementation of operational efficiencies measures
- Offering incentives or imposing penalties on industrial and commercial consumers for power factor correction
- Upgrading, expanding, or refurbishing existing infrastructure
- Improving energy management practices
- Preventing energy theft
- Deploying advanced metering infrastructure including smart metering
- Enhancing maintenance and repair of grid infrastructure using a modern asset lifecycle management approach

Technical choices

Technical choices focus on the selection of:

- State-of-the-art efficient, low-loss components and solutions in transmission and distribution networks
- Implementing the latest smart grid technology

Data management

Data management concentrates on formulating effective data collection, migration, and management policies, leveraging cloud native applications. These aim to develop a common database environment for universal mapping of data from various external and internal sources.

This common database environment further enables the integration of various business critical applications. It also allows stakeholders to extract and disseminate data-driven insights using advanced data analytics, artificial intelligence and machine learning techniques.

Such advanced data management enables, among other benefits:

- A **better understanding and tracking** of actual energy consumption
- **Identifying** consumption patterns and load profiles
- **Predicting** accurate load and price forecasts
- **Predicting and mitigating** grid congestion

What are the business drivers to reduce energy losses?

Reducing losses in a power grid can have several positive outcomes. Key business drivers for utilities and grid operators to reduce the losses in their grids include:

Energy costs

Reducing losses means that more of the electricity generated is being used for its intended purpose, rather than being wasted. This can lead to a more efficient use of resources and lower costs for electricity generation, transmission, and distribution to compensate for energy losses.

Saving energy has become more crucial in the context of prevailing high energy prices today, amidst increasing energy demand. Consequently, reducing losses, will eventually enable TSOs and DSOs to save hundreds of millions of euros every year, as well as create a trickle-down effect which will help commercial and residential customers to save on their energy bills.

Energy reliability

By reducing losses, power grids become more resilient, as there's less risk of power outages due to problems with grid bottlenecks and congestion. This can improve the reliability of grid operations and lead to better end-consumer satisfaction.

Sustainability goals

Many developed and developing countries around the globe are committed to sustainability goals, reducing the greenhouse gas emissions, and transitioning to a carbon-neutral or, ideally, carbon-negative economy. So, reducing power system losses can not only help grid businesses contribute to local, regional, and global climate change goals but also avoid imposition of regulatory penalties.

Grid capacity

If losses in the electricity grid are reduced, it increases the capacity of existing transmission and distribution infrastructure to carry more load. This, then, enables TSOs and DSOs to meet the demand for electricity even during peak-hours.

This could be especially important in areas where demand for electricity is increasing rapidly such as urban centers and big metropolitan cities.

Competitive advantage

Grid businesses that adopt energy-efficient practices and invest in reducing energy losses can differentiate themselves from their competitors and attract more environmentally-conscious customers or investors.

Overall, reducing losses in an electricity grid can lead to a more efficient, profitable, reliable, and sustainable electricity system.

A few state-of-the-art solutions to mitigate grid losses

Hardware improvements such as…

- Power factor correction measures using capacitive shunt devices
- Expansion of grid generation and transmission capacity
- Grid reinforcements and refurbishments
- Re-configuration of transformers and feeders

…require intensive capital investments. But by using advanced digital techniques which are software focused, losses can be mitigated with much less capital expenditure, realizing both CAPEX and OPEX savings for TSOs, DSOs, and utilities.

One of the state-of-the-art techniques that DSOs and utilities may implement is the **advanced system planning and analysis solution** which can simulate optimal power flow – e.g., via Volt-Var Optimization (VVO) – and calculate elements related to the cost of transmission, losses, and congestion. This can be used in tandem with other applications to provide optimized price forecasting. It also delivers the value of optimal load flow in the grid, reducing bottlenecks and operational losses.

Another cutting-edge technique for distribution grids is the implementation of an **ADMS** that provides features such as:

- Distribution system network modelling
- Real-time distribution power flow
- Advanced distribution operations
- Advanced network analysis
- Distribution grid load forecasting
- Distribution system improvement planning

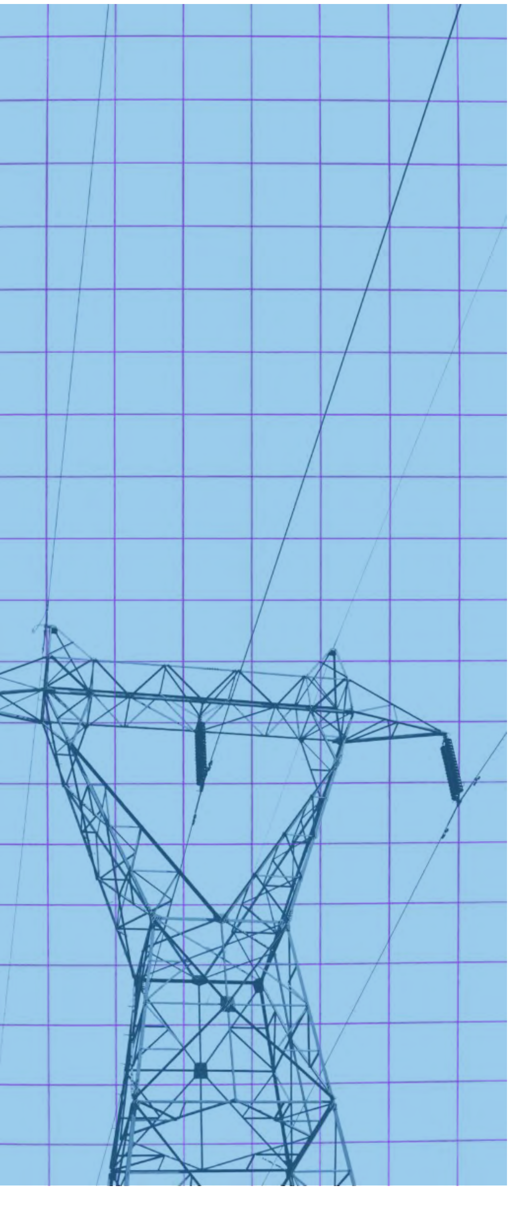
The potential value proposition of such a solution is the optimized distribution network planning and operation, resulting in reduced operational losses.

Since transformers comprise major chunks of technical losses in the grid, a sophisticated solution to this is the deployment of **Dissolved Gas Analysis and Condition Based Maintenance** methods for transformer health monitoring. In principle, this solution provides IoT based failure prediction of transformers using the **Dissolved Gas Analysis (DGA)** technique. It's used to visualize, monitor, and analyze the health of a transformer throughout its operational lifecycle. It helps to:

- Extend transformer service life
- Predict and avoid failures
- Reduce ongoing maintenance costs
- Increase overall system reliability

Hence, this ensures that the transformers are in optimum condition throughout their operation life and thus have reduced losses.

Our recommendation and experience



Losses in electricity transmission and distribution grids are unavoidable, but by deploying software-focused state-of-the-art solutions, these can be mitigated and reduced, rendering power grids more efficient and sustainable.

Modern grid businesses, irrespective of whether they operate at transmission, sub-transmission, distribution, or retail (supply) level, should look to **adopt the digital approach**. This isn't to imply that the more capital-intensive hardware-focused solutions won't be required at all. But the potential value release for grid owners and operators lies in the fact that given the rapid pace at which the grid industry is evolving, the physical assets aren't going to be the most valuable assets that they own. Rather, it would be the right exploitation of the copious amounts of data to which they have ready access to. This will enable them to secure a competitive advantage in this swiftly evolving, critical-infrastructure industry with ambitious net-zero targets.

We have helped many DSOs and utilities worldwide, both in green and brownfield settings, to modernize and efficiently manage their grids by deploying **highly specialized advanced digital solutions** and leveraging state-of-the-art technologies.

Deploying such advanced digital solutions can help DSOs and utilities become **fully digitally-enabled grid businesses**. It also equips them with powerful resources to overcome the complex challenges the grid industry is facing today, such as increasing grid complexity and relentless pressure to become carbon-neutral amidst rising energy demand and decreasing grid resilience.

MEET THE EXPERTS

RALPH TRAPP

Partner, SURE

Ralph.Trapp@infosys.com

Ralph has been working in the energy, utilities, chemicals and resources industry for over 28 years. He's been responsible for the European SURE Practice at Infosys Consulting since 2017 and is the Global Industry Lead for the Utilities sub-practice. He specializes in operational excellence and M&A, as well as the energy transition and how the future energy supply can be set up safely, efficiently and sustainably through digitalization and innovation.

ZAIN ASIF

Principal, SURE

Zain.Asif@infosys.com

For nearly 10 years, Zain has served several clients globally in the transmission and distribution industry. Zain brings a rich project management experience and domain expertise in the areas of grid modernization, grid management, asset management, system planning, design, operation and control. He is well-versed in tendering and delivery of large capital projects in the power grid industry.

KASHIF SHAHZAD

Senior Consultant, SURE

Kashif.Shahzad@infosys.com

Kashif is a results-driven professional with broad experience in utilities, energy, power systems and automation. He has domain expertise on advising utilities in the energy transition, ERP-enabled digital transformation, data migration, intelligent automation and project management.

consulting@Infosys.com
InfosysConsultingInsights.com

LinkedIn: /company/infosysconsulting
Twitter: @infosysconsltng

About Infosys Consulting

Infosys Consulting is a global management consulting firm helping some of the world's most recognizable brands transform and innovate. Our consultants are industry experts that lead complex change agendas driven by disruptive technology. With offices in 20 countries and backed by the power of the global Infosys brand, our teams help the C-suite navigate today's digital landscape to win market share and create shareholder value for lasting competitive advantage. To see our ideas in action, or to join a new type of consulting firm, visit us at www.InfosysConsultingInsights.com.

For more information, contact consulting@infosys.com