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Study Committee B3

Substations and Electrical Installations

Paper B3_10671_2022

An incremental approach to sustainable data center power supply

A. Oudalov, K. Lainez Amaya, S. Trolle, M. Giese, S. Porras Aparicio

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Motivation

- Digitalization of society is leading to a constant growth of the data center segment. Some predict that data centers and data networks could account for over **8% of the global energy demand in 2030**.
- Data center operators generally have ambitious sustainability commitments and targets. This paper explores how data centers can **reduce the carbon footprint of their power infrastructure and power supply** through a combination of short-term and long-term solutions, from compacting high-voltage substations and utilizing eco-designed switchgear and transformers to implementing sustainable options for on-site back-up power.

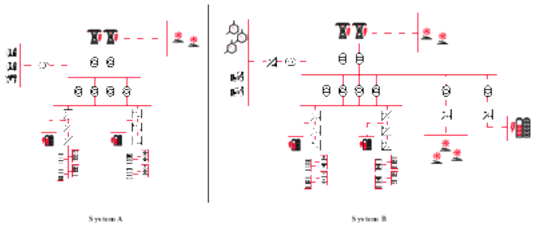
System modelling

Two alternative systems – System A and System B – were defined for a **data center with 50 MW nominal power demand**, assumed to be located in southern Germany.

In both System A and System B, the data centers were assumed to be connected to a 132 kV grid with two 50 MVA 132/20 kV main transformers.

Characteristics	System A	System B
Substation type	Site-built GIS substation	Compact prefabricated GIS substation
Transformers	Conventional transformer (mineral oil)	Eco-designed transformer (ester oil)
Transformer losses (MWh)*	45,000	35,800
Switchgear	GIS (SF6)	Eco-designed GIS (alternative gas)
Gas leakage	0.1% per year, 1% initial filling and dismantling	0.1% per year, 1% initial filling and dismantling
Building	Concrete and steel building	Prefabricated enclosures

The **first** part of the study, consist of an evaluation focused on **optimizing high-voltage substation designs and components** from a sustainability point of view. This evaluation was performed through a **Life Cycle Assessment (LCA), considering the whole life cycle of the products, from raw material extraction until end of life.**



The **second** part, is an evaluation that addressed the potential impact on data center sustainability from using a combination of **energy storage technologies and renewables to replace diesel generators for back-up power.**

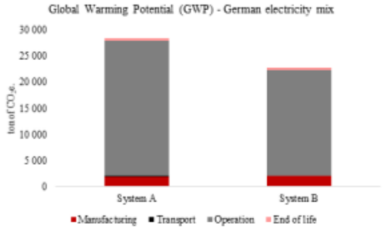
In System A, diesel generators with a total power of 62,5 MVA were assumed to be connected the data center internal 20 kV grid.

In System B, the diesel generators were replaced with a combination of hydrogen fuel cells, BESS and photovoltaic (PV) solar panels. The replacement was assumed to be incremental, and an increasing share of diesel generator power was replaced for each year of operation.

System	Power source	Parameter	Value
A	Diesel generators	Diesel price	1.6 €/L
		Efficiency	30%
		Carbon intensity	850 g CO2/kWh
	Power from grid	Electricity price	0.13 €/kWh (average from EU non-household consumers)
		Carbon intensity	400 g CO2/kWh
B	BESS	Power Capex	120 €/kW
		Energy Capex	150 €/kWh
		Fixed Opex	0.45% from Capex
		Variable Opex	5.82 €/MWh
		Efficiency	81% round trip
	Hydrogen fuel cells	Capex	2,200 €/kW
		Opex	5% from Capex
		H2 price	5 €/kg
		Efficiency	60%
	Solar PV	Capex	750 €/kW
		Opex	5% from Capex
		Available area	2,400 m²
		Power density	2.5 kW/m²
	Power from grid	Electricity price	0.13 €/kWh (average from EU non-household consumers)
		Carbon intensity	400CO2/kWh

Results

The life cycle assessment of the two substations in System A and System B show that system operation – here based on transformer losses and gas leakage from the high-voltage GIS – would be a key factor to reduce environmental impact, **accounting for around 89%-91%** of the total environmental impact in terms of GWP as shown.



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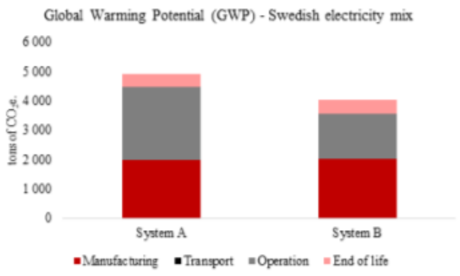
Results

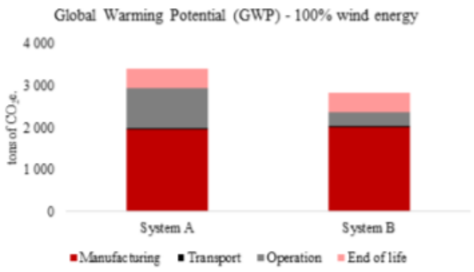
For the **manufacturing phase**, the impact of the prefabrication in System B represented a **reduction of environmental impact by 43% (100 tons CO_2e.)** when compared with the site-built building.

In the **operational phase**, the **transformer** losses presented a **GWP reduction of 22% (5,200 tons CO_2e.)** between System A and System B, due to the improvement of the load and no-load losses of the eco-designed transformer. The change of **GIS** insulating gas from SF_6 to a fluoronitrile-based gas **reduced GWP impact from gas leakages over lifetime by 98% (560 tons CO_2e.).**

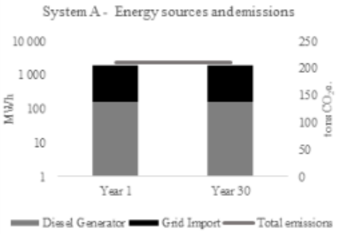
Overall, a 20% (5,715 tons CO_2e.) reduction in GWP was achieved through replacing traditional high-voltage switchgear and transformers with eco-designed alternatives as described in this section.

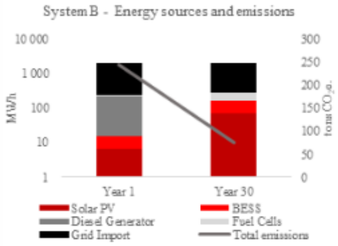
Additionally, a sensitivity analysis was conducted where the German electricity mix was substituted with the Swedish electricity mix (43g CO_2e/kWh) and a 100% wind electricity mix (8.94g CO_2e/kWh), to evaluate the impact of the carbon intensity of the local electricity mix on the lifecycle carbon footprint of the system





For the modelling of sustainable back-up power, **two outages of 2 hours per day** were assumed to happen during each year of the simulations. **One representative winter and summer day were analyzed.**
System B showed an incremental deployment of renewable and carbon-free installed capacity (solar, storage and back-up).





Conclusions

There is an opportunity to significantly reduce the environmental impact of equipment, products and systems through setting specific requirements on **environmental performance on the supply chain**. These may include meeting emission targets under a given benchmark and a commitment to **use secondary material and renewable energy resources during production processes.**

Additionally, for **back-up power operation** where diesel generation sets are commonly used today, there are many alternatives under evaluation, from using more **sustainable fuels such as hydrogenated vegetable oil to using microgrid-type systems** as described in this paper. While some emerging technologies have high investment costs at present, increased technology deployment will likely lead to lower costs in the future, supporting the transition toward sustainable power systems for data center operators and others.