HBKU Flagship Research Grant Program 3rd Cycle– Project Highlight

Project Title: AI-Enhanced Resilience for Data Centers in Arid Cities: Sustainable Cooling, Predictive Control, and Climate-Aware Cost Optimization

Research Team:

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Executive Summary

As Qatar advances its digital economy, data centers are becoming essential infrastructure. However, operating them in arid environments presents unique challenges, including extreme heat, water scarcity, dust exposure, and high energy demands for cooling. This project aims to develop an AI-driven framework to design, operate, and future-proof resilient, sustainable data centers tailored for desert climates. Leveraging machine learning, edge AI, and digital twins, the platform will enable real-time thermal optimization, predictive HVAC maintenance, smart energy-water management, and adaptive control under climate stress events. A hybrid physical-virtual testbed will simulate critical scenarios such as heatwaves, grid outages, and renewable intermittency, integrating advanced cooling technologies, heat recovery, and renewable energy sources with storage systems like batteries and liquid CO_2. The project introduces novel climate-aware cost metrics—such as cost-per-joule of cooling and cost-per-MB stored—to support investment decisions and benchmarking. Key outcomes include a validated digital twin platform, demonstrable reductions in energy use and carbon emissions, enhanced resilience and uptime, and policy recommendations for scalable deployment. The project directly supports Qatar's national goals for climate resilience and digital transformation, contributing to the development of green data center standards for the region.

Expected Outcome

This project will deliver a validated AI-powered digital twin platform for sustainable data center design and operation in arid climates. It will demonstrate advanced AI algorithms for thermal prediction, workload-aware cooling, and anomaly detection, alongside optimized integration of renewable energy, energy storage, and next-gen cooling technologies. Outcomes include improved energy efficiency, reduced carbon and water footprints, and enhanced operational resilience. The project will also provide life cycle and technoeconomic benchmarks, introducing climate-aware metrics such as cost-per-joule and CO_2e/MB. Outcomes include policy and certification guidelines for Qatar, protected IP (patent filings and

licensed software), and a portfolio of high-impact journal papers and conference publications that enable commercialization and regional scale-up.

Flagship Area, keywords, tags:

This project is strongly aligned with the HBKU Flagship Research Area of “Sustainable and Resilient Arid Cities”, specifically targeting challenges related to smart and connected infrastructure, climate adaptation, and environmental health in extreme environments.

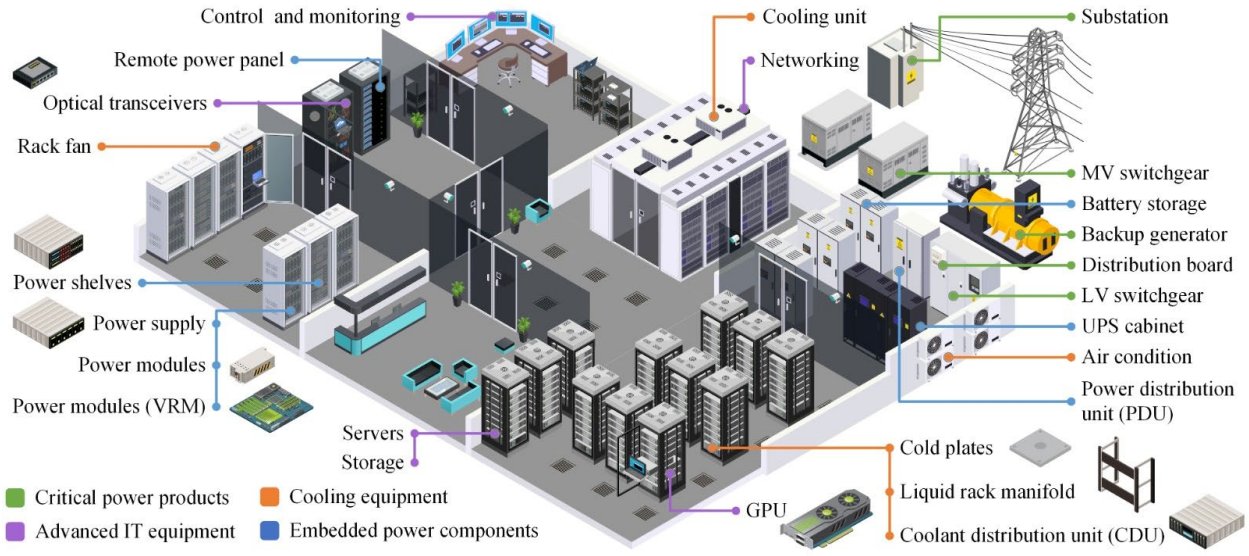

Figure 1. The general structure of data centers