Renewable Integration and Balancing Challenges in Saudi Arabia's Evolving Power System

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Overview

Saudi Arabia has committed to reducing carbon dioxide emissions from its power sector: by 2030. To do so, the share of renewables in 2030 is planned to reach 50% of the total installed capacity while displacing oil (Vision 2030) and net-zero emissions should be achieved by 2060 (SMEGI 2022; Al-Sinan et al. 2023). In parallel, Saudi Arabia has started modernizing its power sector and has successfully completed the nationwide roll-out of smart-meters (Arab News 2021). Further, electricity demand is expected to grow, driven by economic growth and industries' electrification. At the same time, the increasing penetration of renewables could pose future challenges for the short-term operations of the Saudi power system. Given the social value of electricity due to the critical role it plays in many sectors, ensuring the reliability of the power system and the security of supply is paramount for all stakeholders of the power sector, being the system operator, the single buyer, the ministry of energy, the regulator and end-users. In this context, can digitalization and advanced forecasting techniques be leveraged to optimize the short-term operations of the Saudi power system? This paper investigates this question using a quantitative approach tailored to the specific case of Saudi Arabia and provides key recommendations for policymakers.

Methods

We utilize an hourly dispatch model of Saudi Arabia, comprising six regions, each with distinct hourly demand profiles and renewable energy potentials while accounting for transmission constraints between regions. This model simulates the short-term operations of the Saudi power system, including the management of the operating reserves (sizing, reservation, and activation). To achieve this, the model incorporates forecast and actual datasets for hourly electricity demand as well as wind and solar generation profiles specific to each region. Additionally, the model simulates the regional redispatching that occurs due to transmission congestions between the six regions.

First, we build our datasets based on publicly available data for Saudi Arabia. The forecast and actual datasets (electricity demand and renewable generation) are generated through simulation techniques, representing different forecasting methods – ranging from traditional ones to the more advanced methods that incorporate AI-driven forecasting in a digitalized power system. We consider reserves' characteristics and volumes according to the known practices in Saudi Arabia.

Second, we simulate the short-tem operations of the Saudi power system for several scenarios with time horizons set for 2030 and 2040. These scenarios vary in terms of (i) the level of renewable energy penetration, (ii) the forecast accuracy of hourly demand and generation from renewables, and (iii) the strategies used for real-time system balancing (conventional technologies, renewables, storage assets, and demand participation).

Finally, we assess the economic performance of the Saudi power system across these scenarios using a multi-criteria analysis. We isolate and quantify the costs associated with forecast errors in each scenario, i.e., the balancing costs. By comparing the scenarios, we also identify the benefits of power system digitalization and advanced forecasting methods, and pinpoint the key drivers of cost improvements (e.g., effect on reserve sizing, reserve activation and/or redispatching to mitigate network congestions).

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Results

Our simulations across different scenarios highlight that short-term operational costs can significantly vary within a power system – Saudi Arabia in this case. Notably, the results demonstrate that these costs can be reduced by minimizing forecast errors, expanding the range of assets (including demand-side participation) used for system balancing, and adapting short-term operational practices to the specific features of the power system (e.g., adjusting reserve sizing based on renewable energy penetration).

The quantitative results enable us to make several recommendations. First, studies and analyses of short-term operations should be regularly conducted for a given power system, incorporating updated forecasting techniques and balancing strategies to better inform policymakers about potential future developments. This requires that the system operator has access to sufficient human, technical, and financial resources to carry out such studies.

Second, policymakers should implement effective incentives to minimize the costs of power system balancing while maintaining a socially-acceptable level of reliability. The approach to achieving this will vary depending on the specific context of each power system. For instance, it may involve incentivizing a broader range of assets to participate in balancing efforts, such as demand-side management, storage assets, and renewable energy projects under power purchase agreements. Additionally, enhanced planning for network development and the strategic localization of generation and storage assets can help alleviate local network congestions.

Conclusions

This paper quantifies the economic benefits that improved forecact accuracy, driven by digitalization and advanced forecasting techniques, can bring to the the Saudi power sector. It demonstrates that significant savings in short-term operations of the Saudi power system are achievable, provided that accurate and reliable data are available.

Additionally, the paper lays the groundwork for future research on power systems of the Gulf Cooperation Council (GCC) and Middle East and North Africa (MENA) regions. With the recent developments of interconnections between countries in these regions, optimizing the short-term operations of power systems is becoming increasingly critical on a regional scale. The approach and strategies to reduce balancing costs identified in this study could be further expanded and applied in the context of interconnected power systems across the GCC and the wider MENA region.

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