Energy Efficiency Initiatives towards Sustainability on University Campuses in Saudi Arabia

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Overview

A significant share of electricity from renewable resources has been mandatory to reduce greenhouse gas emissions released from burning fossil fuels, and to de-carbonize the electricity sector. With the evolution of smart grids and microgrids, effective and efficient penetration of renewable generation such as wind and solar can possibly be attained. The concept of Microgrids has been introduced in the distribution network to obtain a reliable and stable use of distributed energy resources (DERs), and distinguish between a large power network and a group of DERs located next to each other, which can be seen as a single generator or loads. A microgrid can be defined as a self-sufficient energy system that includes one or more kinds of DERs (solar panels, wind turbines, combined heat & power, generators) to produce power and serves a discrete geographic footprint, such as a university campus.

The Kingdom of Saudi Arabia recognizes the importance of diversified energy mix to its long-term economic prosperity. The Ministry of Energy, through the National Renewable Energy Program, has therefore pledged a commitment to the deployment of renewable energy to meet electricity demand growth. On the other hand, the electricity sector in the Kingdom of Saudi Arabia is one of the largest in the Arab Gulf region, and its peak demand increased from 35 GW in 2007 to 61.7 GW in 2018, with an average 5.31% annual increase in demand between 2007-2018. In order to advance and improve energy efficiency services in the Kingdom and to tackle rising energy consumptions in existing buildings and facilities, the National Energy Services Company (Tarshid) was recently established by the Public Investment Fund. It is a result of a collaborative effort between the Ministry of Energy, Ministry of Finance and the Saudi Energy Efficiency Centre, for creating robust energy efficiency solutions in the Kingdom. Tarshid has set ambitious targets for implementing energy efficiency projects in buildings and facilities across the Kingdom. For instance, it has launched a retrofit project to increase the energy efficiency and reduce the consumption in the buildings of Imam Mohammad ibn Saud Islamic University (IMSIU) in Riyadh, with an estimated annual reduction of 43% in a targeted annual energy consumption of 229 GWh.

The IMSIU main campus consists of 255 buildings in Riyadh, and that consumes an annual energy of 414 GWh. Such energy consumptions annually account to about 270 thousand tons of greenhouse gas emissions released from burning fossil fuels. Indeed, there is a need to create a sustainable and energy efficient campus buildings by relying on renewable energy systems as a main source of power, such as a hybrid solar energy system (HSES), in supplying the campus' electricity needs. This will make the university campus more in line with Saudi Vision 2030 in energy and sustainability by having energy conservations and increasing the contribution of renewable energy to the overall energy. Nevertheless, an annual demand of the campus is about 48 MW, and that requires an installation of a very large capacity of the HSES, leading to a high financial burden and large installation area. It is therefore essential to reduce the energy consumption of the campus buildings through improvement of the buildings energy efficiency, by retrofitting the building components, which is identified as the most promising in synergy with hybrid solar energy systems. This is because building renovation allows reducing both the required installed solar energy system and storage capacity used in supplying campus loads. This paper presents the development of an energy management model which considers the features of campus microgrid for the IMSIU, including interrelationships between various entities such as a rooftop photovoltaic (PV) generation, battery energy storage system (BESS), demand response and the utility. The model also considers the retrofit project implemented by Tarshid at IMSIU, for increasing energy efficiency and reducing the energy consumptions in the IMSIU buildings. The primary objective of this paper is to investigate to what extent the building retrofit can maximize building energy efficiency while reducing the installed capacity of a HSES and the total cost of a campus microgrid for the IMSIU.

Methods

A mathematical optimization model is developed for optimal design and planning of a campus microgrid for the IMSIU. The developed model that includes a rooftop photovoltaic (PV) generation, battery energy storage system, and demand response capabilities can be used to analyze the effects of buildings retrofit on the campus loads as well as the installed capacity of the HSES for a campus microgrid. Moreover, this model investigates the impact of increasing energy efficiency on the level of penetration of renewable generation in campus microgrid.

The objective function is to minimize the total cost (TC) of the campus microgrid using its local generation resources and importing /exporting power from /to the distribution grid.

$$TC = CC^{E}\ Esize^{bess} + CC^{P}\ Psize^{bess} + CC^{PV}\ Psize^{PV} + \sum_{h\in H}\left(P_h^{Im} \times C_h^{grid}\right) - \sum_{h\in H}\left(P_h^{Ex} \times C_h^{grid}\right) \qquad (1)$$

The first three terms of (1) are associated with the capital cost of installed capacity of the HSES, while the last two terms of (1) are the cost for importing and exporting power from/to the distribution grid, respectively.

Energy Management Equation of Campus Microgrid: This constraint ensures that the total generation meets the forecasted campus load of period *h*, and includes PV generation, BESS, power import and export from/ to the distribution grid.

$$Psize^{Pv}\ \beta_h^{PV} + P_h^{Disc} + P_h^{Im} = Pd_h + P_h^{ch} + P_h^{Ex} \qquad (2)$$

In order not to receive and send power from/to the main grid at the same hour h, the following constraint is included into the model.

$$P_h^{Im}.\ P_h^{Ex} = 0 \qquad (3)$$

HSES Equations: The HSES should satisfy the following constraints:

Discharge/ charging power limits: $P_h^{disc} \leq Psize^{bess}$; $P_h^{ch} \leq Psize^{bess}$ (4)

State of charge equation: $C(h+1) = C(h) - d_h \cdot P_h^{disc}/\eta_d + d_h \cdot P_h^{ch}\eta_c$ (5)

Initial/Ending limits: $C(0) = 0.5\ Esize^{bess}$; $C(H) = 0.5\ Esize^{bess}$ (6)

Stored Energy limits: $C_{min} \leq C(h) \leq Esize^{bess}$ (7)

Coordination of Charging/discharging power: $P_h^{disc}\ .\ P_h^{ch} = 0$ (8)

The above proposed mathematical optimization model is a nonlinear programming problem, and solved using the MINOS solver in General Algebraic Modeling System environment.

Expected Results

Business models for microgrids rely on many factors, such as energy cost savings, improved reliability, and the amenity value of self-supply. The focus of our work on economic costs and benefits of self-supply which are the core of any commercial proposition. In this paper, we will model the business case for local energy provision, in which a Saudi university adopts a microgrid to self-generate electricity partially or fully to supply its own load and possibly provide energy to the main grid. This business case also seeks to address whether there is a need for incentives to motivate the university in transforming its campus to the microgrid that includes renewable energy, demand response capabilities, energy storage systems, and/or electric vehicles smart charging, so that the energy sector will be in line with the general objective of Saudi Vision 2030, which aims to diversify the Saudi economy away from oil. The expected results of the proposed research are summarized as follows: 1) Prior to the implementation of a campus microgrid for a Saudi university, several studies and analysis will be carried out to estimate and forecast the load profiles, identify a suitable network configuration, and selecting proper generation and storage units for a campus microgrid. 2) an investment support tool will be built for assessing business models in determining whether it is beneficial for the Saudi university to transform its campus to a microgrid.

Conclusions

Energy efficiency initiatives implemented by Tarshid in the KSA is a key factor in transforming a university campus to a microgrid, that offers a Saudi university a way to keep critical electricity flowing during power outages, increase use of renewable energy, and better optimize energy supplies and campus loads. It can also be used as an educational and sustainability awareness tool, connecting technology to students and community. On the other hand, pairing energy storage, renewable energy, and advanced controls, in the context of a smart building, creates possibilities to better manage building energy use, save money and generate income while supporting the grid. The expected research outcomes are in the line with the National Industrial Development and Logistics Program that aims at increasing the share of the renewable energy sector in local consumptions, improving the competitiveness of the electricity sector through restructuring and exploring power exportation opportunities, and enhancing power supplies and prices. The university campus microgrid includes self-sustaining electricity infrastructure, an intelligent distribution system and system controllers, onsite electricity production, demand-response capability, and sustainable energy systems. The adoption of campus microgrids will make the energy sector in line with the general objective of Saudi Vision 2030, that aims to diversify the Saudi economy away from oil.