Microgrid for a Cluster of Grid Independent Buildings Powered by Solar and Wind Energy

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The energy demands from a cluster of houses in North Texas can be supplied with a determined area of photovoltaic cells and wind turbines. The fluctuating demand can be satisfied if renewable energy is used with energy storage. Hydrogen storage, although not yet widely used, is the superior alternative for this region since it can store energy for long seasons. A parametric study of the base case of such system reveals that increased storage component efficiencies and decreased demand reduces the required area for solar arrays and volume for hydrogen storage.

Abstract

The reduction of CO_2 emissions and the avoidance of Global Climate Change necessitate the conversion of the electricity generation industry to rely on non-carbon sources. Additionally, the mitigation of the duck-curve effects in microgrids requires the development of grid-independent buildings. Computations were performed for a cluster of one thousand grid-independent buildings in the North Texas area, where air-conditioning demand is high in the summer months. The electricity demand is balanced with energy supply generated from wind turbines, photovoltaic cells, or stored energy in hydrogen tanks. The results indicate that with one wind turbine operating, each building must be fitted with 10.2 kW rating photovoltaics capacity and a tank with 5.2 m^3 of hydrogen storage capacity to satisfy the hourly demand of the buildings' community. The addition of more wind turbines significantly reduces the needed PV rating but increases the required storage. Investing in energy conservation measures in the buildings significantly reduces both the needed storage capacity and the PV cell ratings.

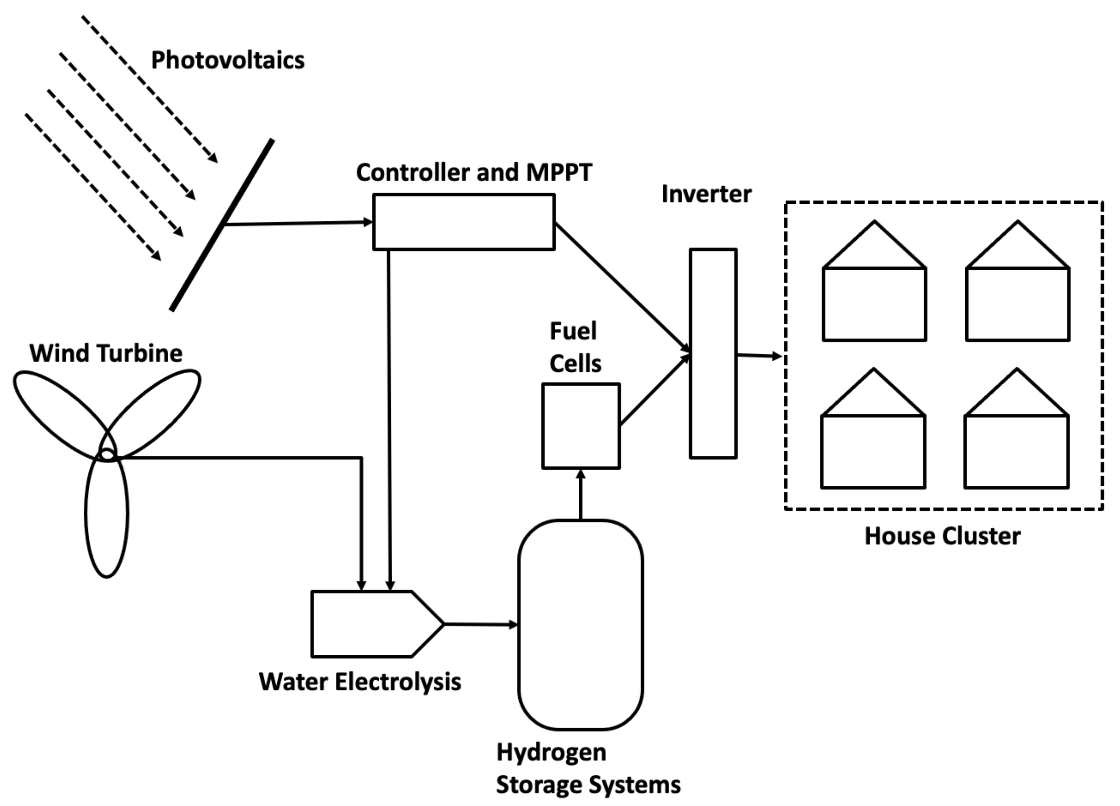

Figure 1. System diagram for grid-independent cluster of buildings with hydrogen storage.

System Description

Photovoltaic (PV) cells and wind turbines supply all the needed energy for the cluster of buildings. Controllers and maximum power point trackers (MPPT) ensure that maximum electric power is produced by the PV cells. The generated power is directed to the cluster of buildings to meet the demand. If the generated power is higher than the present demand, the excess energy is directed to electrolysis systems that feed the hydrogen storage system. When the power supply is less than the demand, the power deficit is provided by the fuel cells, which convert the stored hydrogen to electricity. If the cluster of buildings operatess with alternating current (ac), voltage inverters convert the direct current (dc) generated in the fuel cells and the PV cells to ac.

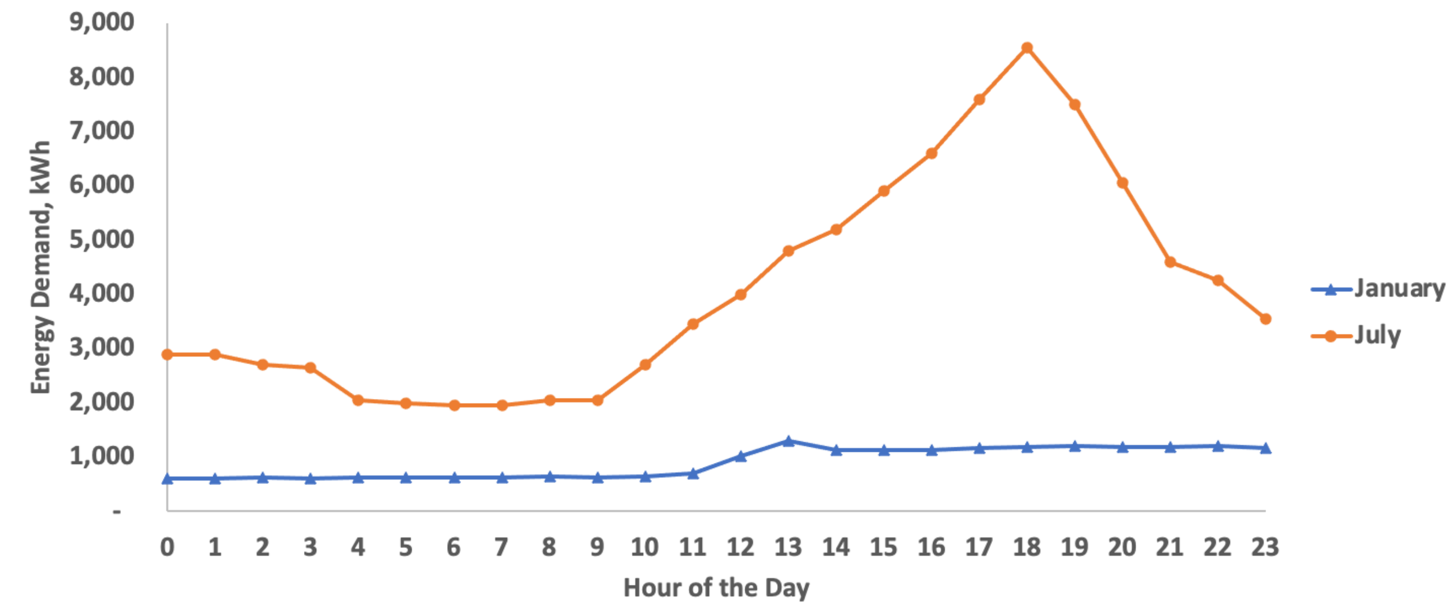

Figure 2. Hourly electric energy demand in the microgrid on two typical days in the summer and winter.

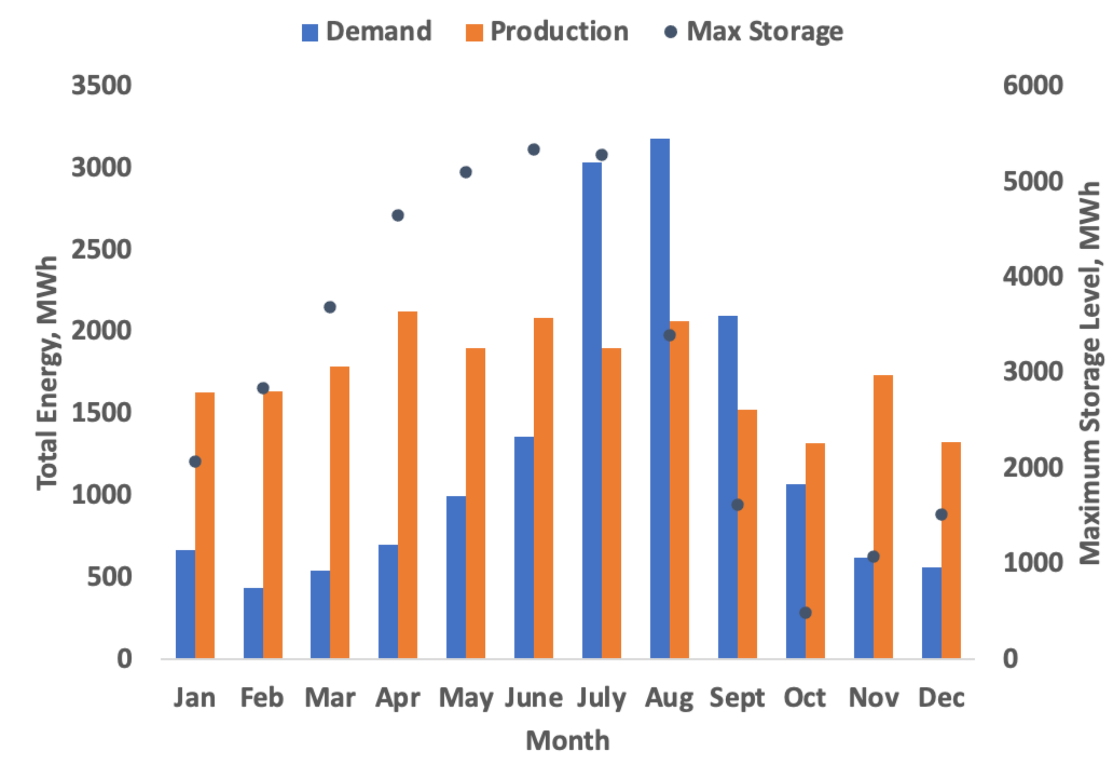

Figure 3. Total monthly energy production, consumption, and maximum storage level during each month of the year.

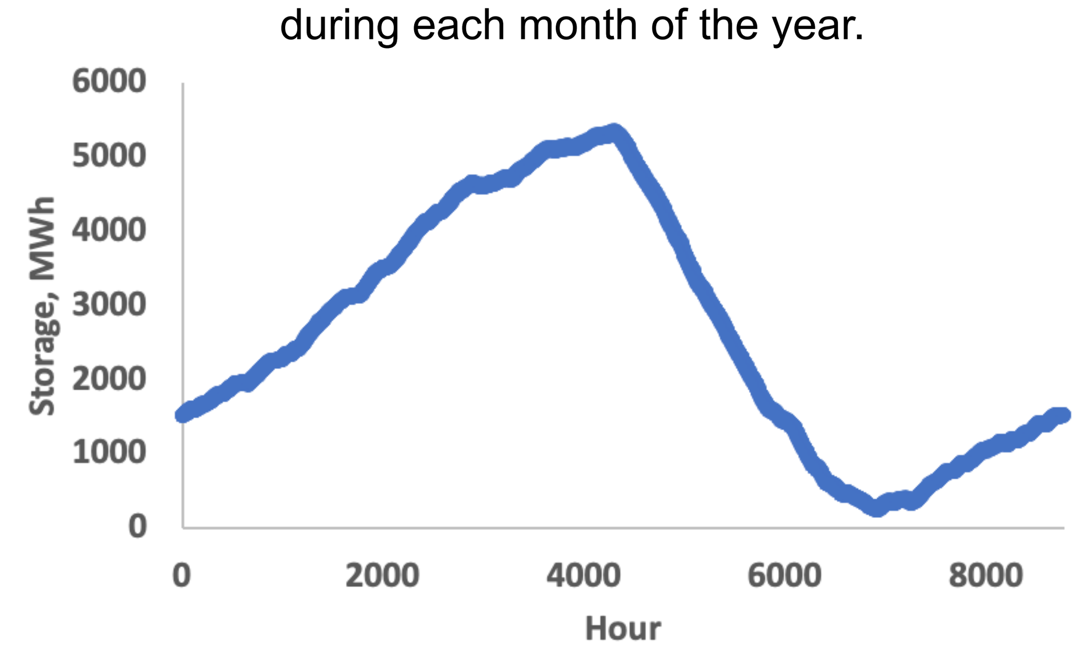

Figure 4. Hourly variation of energy storage levels throughout the year, in MWh.

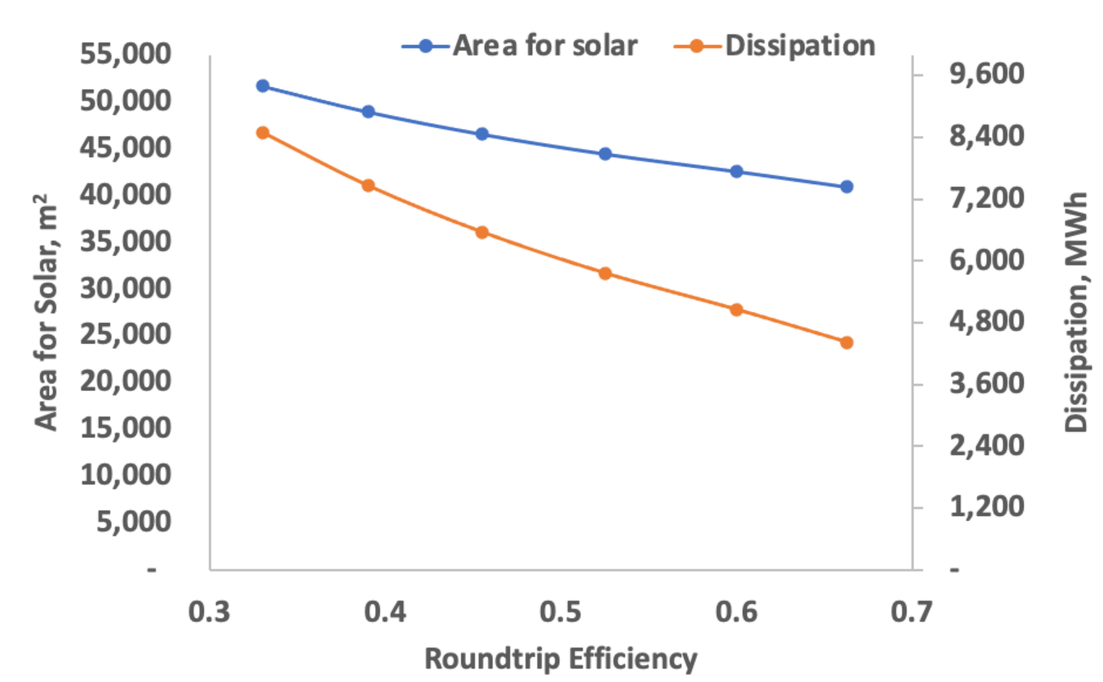

Figure 5. Effect of storage component efficiency on area needed for solar arrays, in m^2, and energy dissipated in the system, in MWh.

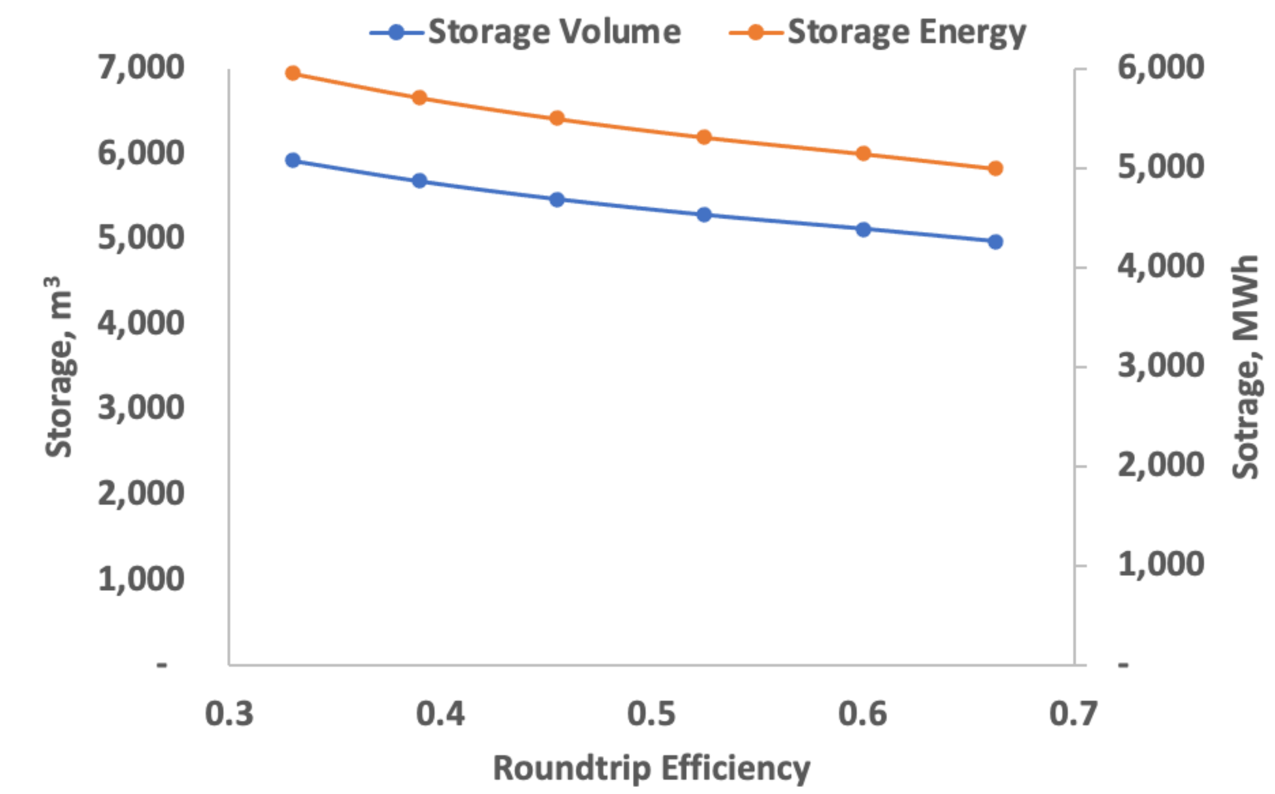

Figure 6. Effect of round-trip efficiency on the required storage capacity, in m^3 and MWh.

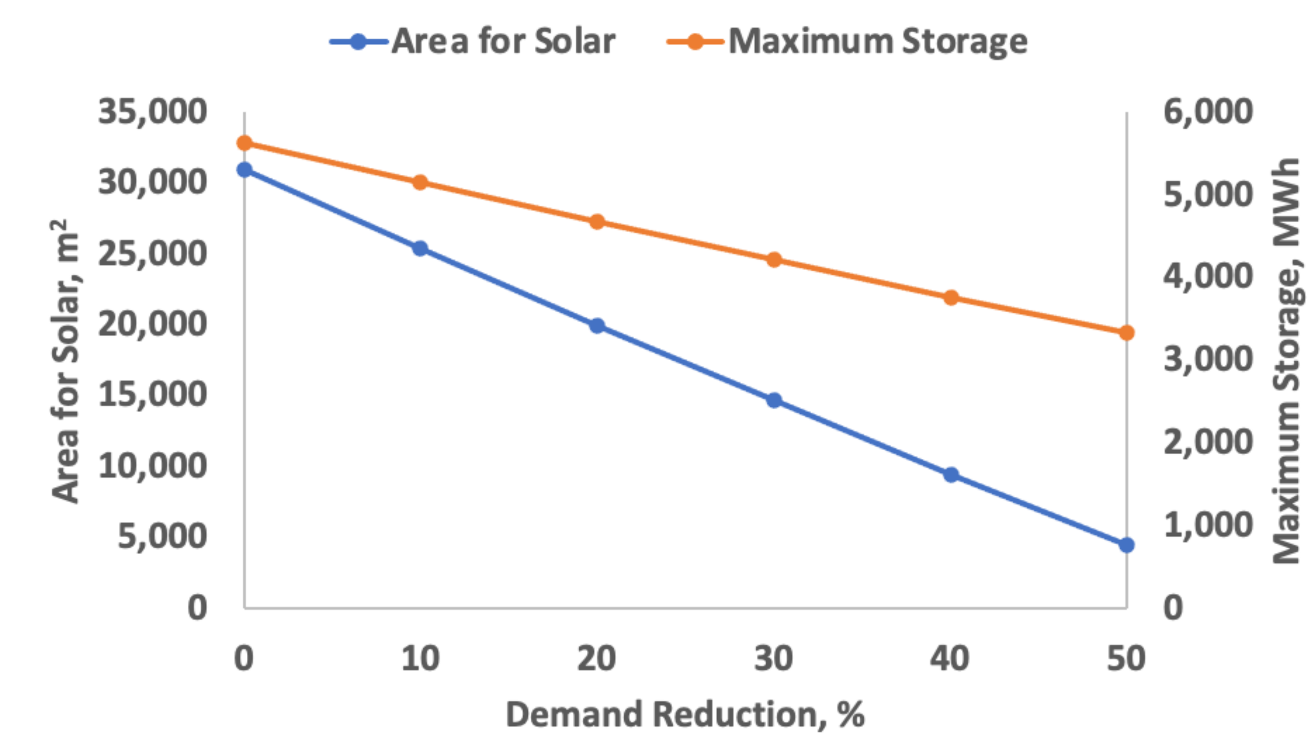

Figure 7. Effect of improved efficiency and demand reduction on the required PV cell area and storage capacity.

Conclusions

- Evident need for energy storage to satisfy fluctuating demand
- For 1000 homes in North Texas, substantial storage required make hydrogen the best storage alternative
- Microgrid with one wind turbine requires 10.kW PV rating installed and 5.2 m^3 of hydrogen storage
- Additional wind turbines reduce the needed PV rating but increase required storage
- Energy conservation measures in buildings significantly reduce the needed storage capacity and PV cell ratings

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