# Extended Abstract: Energy Management of a Microgrid using Virtual Inertia and Energy Storage

Ahmed Saad Karsani, Saleh Dinkhah, Sofia Brumbaugh, Nathan Kehl
Advisor: Dr. Maryam Khanbaghi
Santa Clara University – Latimer Lab – Solar Saviors Broncos

***Abstract* — The power grid is undergoing structural transformation with the integration of renewable energy (RE) sources as well as increasing resiliency challenges in the form of extreme weather events. RE sources differ in operation principle than conventional power sources that make up the grid, therefore measures need to be taken in order to implement them to the grid. In this work, a microgrid is modeled in Simscape Electrical to propose an Energy Management Strategy (EMS) and implement virtual inertia for the inverter control scheme, following the addition of energy storage to the microgrid along with commercial loads, consisting of a synchronous machine (SM), a fuel cell and a photovoltaic system. Results obtained illustrate the effectiveness of the proposed contributions.**

***Keywords—Energy Storage, Virtual Inertia, Microgrid***

## I. Introduction

The electric power grid is facing bigger reliability and resiliency challenges than ever due to climate change and its consequent extreme weather events. This issue is compounded when the need to integrate renewable energy (RE) sources is considered. However, RE sources at the demand side could provide a platform for essential power delivery to loads during power grid outages.

With the present day set up of the power grid, there are some complexities faced with implementing renewable energy sources as they operate in a different manner than conventional generation. A possible solution to this issue would be to design microgrids (MGs) with control schemes which can reliably, efficiently and easily integrate renewable energy sources. This project proposes an Energy Management Strategy (EMS) for Santa Clara University (SCU) campus' school of engineering building Sobrato Campus for Discovery & Innovation (SCDI) - modeled as a MG - in an emergency scenario with regards to energy storage integration as well as the addition of virtual inertia for frequency damping.

## II. System Model

Fig. 1 illustrates the on-campus SCDI building, modeled as a MG with integrated energy storage. There is a synchronous machine (SM), photovoltaic (PV) and fuel cells as generation units along with a battery (energy storage). In the simulation, an islanding detection scheme was implemented, where the MG transitions from grid-connected to islanded mode when the grid frequency leaps from 60 Hz to 60.5 Hz. The reactive power is set to be zero throughout. The proposed work focuses on energy storage integration, i.e. tertiary-level control in terms of constrained optimization and primary-level control for frequency regulation in terms of virtual inertia via a unified droop and damping scheme [1]:

$$\frac{2H}{\omega_s}\dot{\omega} = \frac{P^* - P}{\omega} - D_\omega(\omega - \omega_s) - K_d(\omega - \omega_g) \quad (1)$$

where $P^*$ and $P$ are the reference and actual active power, $\omega_s$, $\omega_g$ and $\omega$ are the base, grid and calculated angular frequency, $H$ is the inertia constant and $D_\omega$ and $K_d$ are the droop and damping gain coefficients.

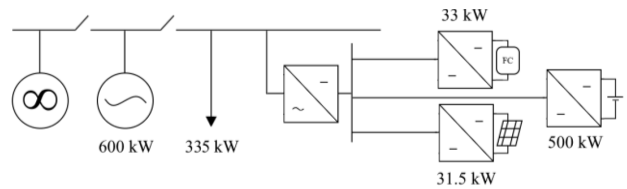



Fig. 1: SCDI Building MG

## III. Simulation & Results

### A. *Virtual Inertia Synthesis (Primary-level Control)*

The proposed scheme has been implemented for the inverter and compared with the conventional droop control scheme. It mimics the SM dynamics and provides virtual inertia, i.e. more stable frequency in terms of oscillations and rate of change following a disturbance in the grid. Fig. 2 shows the MG frequency with an operating SM. The MG goes from islanded to grid-connected mode at 110 secs. After 127 secs, the islanding detection scheme picks up an increase in grid frequency to 60.5 Hz which results in the MG going back to islanded mode. At 150, 160 and 170 seconds, the load changes by factors of 50%, 25% and 33% respectively. However, both the conventional and proposed scheme produce similar frequency oscillations. In Fig. 3, without the SM, a phase-locked loop (PLL) is used to measure the MG frequency. No feasible results were unobtainable using the PLL for the conventional control scheme.

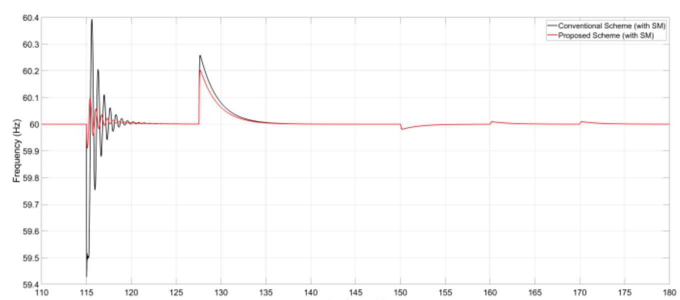



Fig. 2: MG Frequency with SM using conventional droop control (black) and proposed control (red)

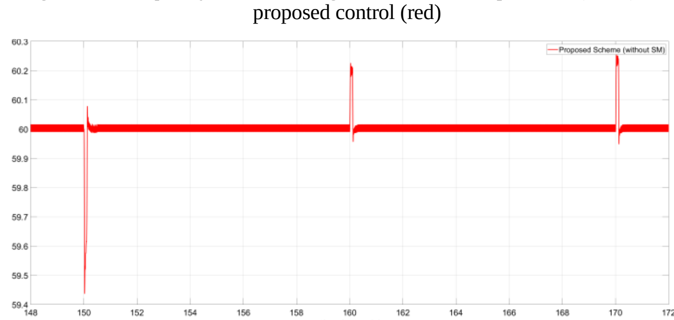


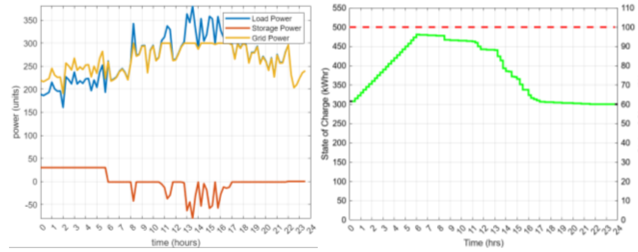

Fig. 3: MG Frequency without SM using proposed control (red)

### B. *Energy Management Strategy (Tertiary-level Control)*

In terms of EMS, constrained optimization has been performed on MATLAB following the addition of energy storage into SCDI, considering peak lopping, grid cost and State-Of-Charge (SOC) limits. Fig. 4 shows the optimized charging profile for peak lopping and storage unit SOC. The grid supply peak is 300 kW, and the power utility company Silicon Valley Power's (SVP) Time-Of-Use (TOU) peak hours are between 6 AM and 10 PM. Therefore, the storage SOC is 100% at off-peak hours (0.104 \$/kWh) and discharges during peak hours (0.136 \$/kWh), resulting in a 0.71% reduction in energy cost. It is also assumed there is an SOC lower limit of 50% as 'operating reserve' in case of emergencies.

## IV. Conclusion

In this work, an SCU-based MG is modeled with added energy storage, and tertiary-level Energy Management Strategy (EMS) along with a primary-level virtual inertia schemes have been successfully implemented as demonstrated by simulation results on MATLAB/Simscape.




(a) (b)

Fig. 4: Energy Management Strategy Analysis (a) Optimized Charging Profile for Peak Lopping and (b) Storage Unit State-Of-Charge (SOC)


## V. Acknowledgement

This work was a submission to Mathworks/IEEE Power and Energy Society Ideathon '22 competition. The work has not been published.


## VI. References


[1] S. Dinkhah, C. A. Negri, M. He and S. B. Bayne, "V2G for Reliable Microgrid Operations: Voltage/Frequency Regulation with Virtual Inertia Emulation," 2019 IEEE Transportation Electrification Conference and Expo (ITEC), 2019, pp. 1-6.