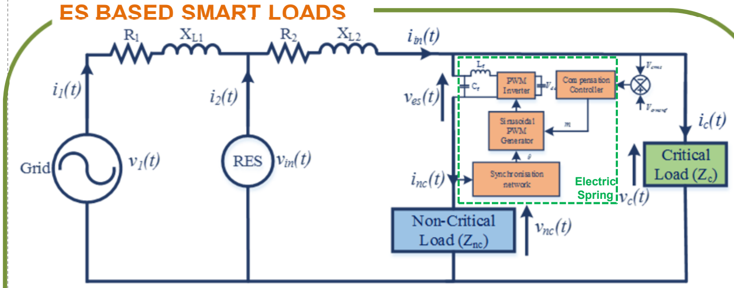
Analysis of Electric Spring Control for Voltage Regulation in a Grid connected Microgrid

Binita Sen, Kanakesh V.K., Jayantika Soni, and A/P S.K. Panda

INTRODUCTION

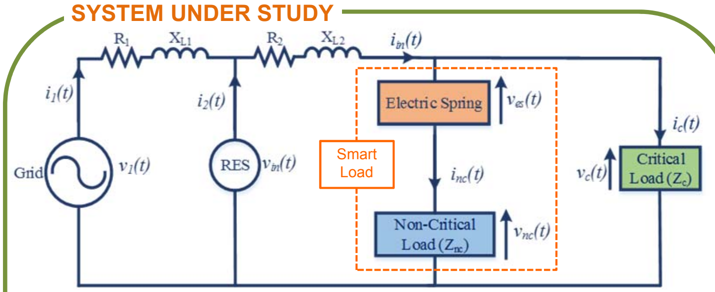
- Future grid will be ~~an~~ interconnection of many small autonomous regions of power system called microgrid
- A microgrid can enable users to involve in generation, storage and consumption, thereby making islanded operation realistic
- Lack of inertia and decentralized structure makes an islanded microgrid vulnerable to voltage and frequency fluctuations
- The Electric Spring (ES) based smart loads can mitigate voltage fluctuations in a grid connected microgrid by reactive power compensation
- Existing work in the ES based smart loads is in system with low *R/X* ratio whereas microgrids have high *R/X* ratio
- This study analyses the ES control for voltage regulation in grid connected microgrid with reactive power compensation while taking into consideration the R/X ratio of the distribution system

ES BASED SMART LOADS



- The ES with reactive power compensation for voltage regulation only
- $\vec{V_c} = \vec{V_{es}} + \vec{V_{nc}}$
- $V_{es} = m\sin(\omega t + \theta)$
- Compensation controller provides the modulation index, m, which determines the magnitude of V_{es}
- Synchronization network provides the phase of V_{es}, θ
- For reactive power compensation, $V_{es} \perp I_{nc}$ (lead or lag ?)
- The ES changes the magnitude and phase of I_{nc} which changes the line impedance drop to regulate voltage

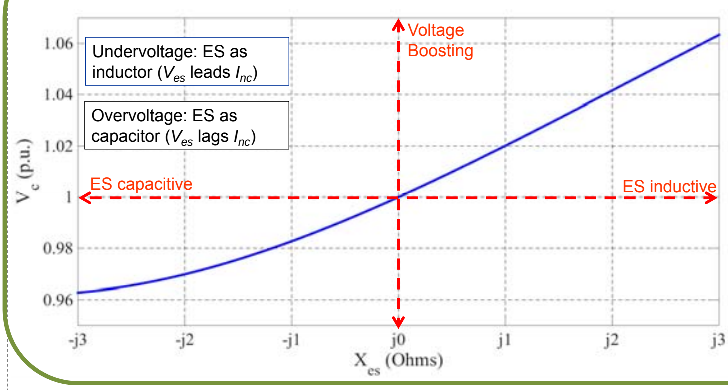
SYSTEM UNDER STUDY



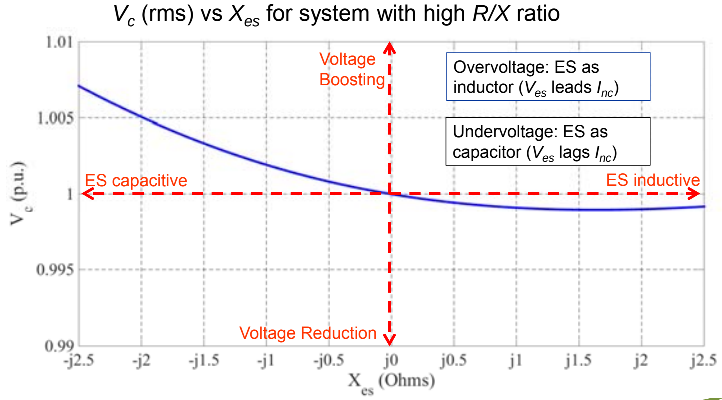
- The ES for voltage regulation of grid connected microgrid: constant frequency
- Overvoltage → reduce critical load voltage (V_c)
- Undervoltage → boost critical load voltage (V_c)
- The ES only offers reactive power consumption: $V_{es} \perp I_{nc}$ - lead or lag?
- The ES can behave as an inductor or capacitor for overvoltage/undervoltage: can be modelled as a reactance (X_{es}) in steady state operation

$$V_c = \frac{V_1\left((Z_{nc} + jX_{es}) \parallel Z_c\right)}{\left((Z_{nc} + jX_{es}) \parallel Z_c\right) + Z_1 + Z_2} + \frac{I_2 Z_1\left((Z_{nc} + jX_{es}) \parallel Z_c\right)}{\left((Z_{nc} + jX_{es}) \parallel Z_c\right) + Z_1 + Z_2}$$

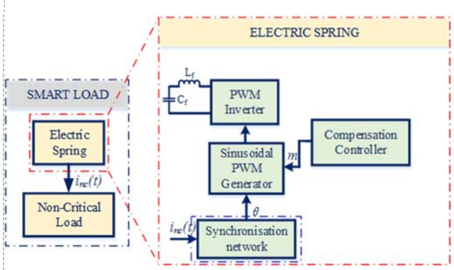
THEORETICAL ANALYSIS OF ES CONTROL

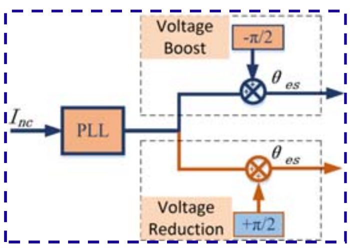


V_c (rms) vs X_{es} for system with high *R/X* ratio

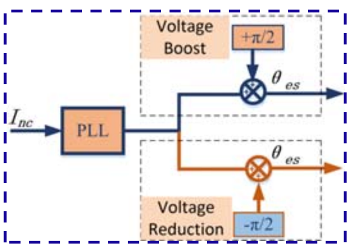


PROPOSED ES CONTROL





ES synchronisation network for system with low *R/X* ratio



ES synchronisation network for system with high *R/X* ratio

CONCLUSION

- ES control changes with system line impedance
- The control structure of ES should be varied according to characteristics of line parameters

	Undervoltage	Overvoltage
High *R/X* ratio	Inductor	Capacitor
Low *R/X* ratio	Capacitor	Inductor

"This research project is funded by the National Research Foundation Singapore under its Campus for Research Excellence and Technological Enterprise (CREATE) programme."