Y9.LSSS.1: Islanded Operation of LSSS and Inverter-less PV

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1. Project Goals

Islanded Operation of LSSS

The following are the project goals for year 9.

- Integration of frequency control using Master-Slave configuration. Figure 1 gives an idea of operation of LSSS in islanded mode of operation. SST at bus 890 controls the frequency and voltage of the entire feeder under islanding conditions.

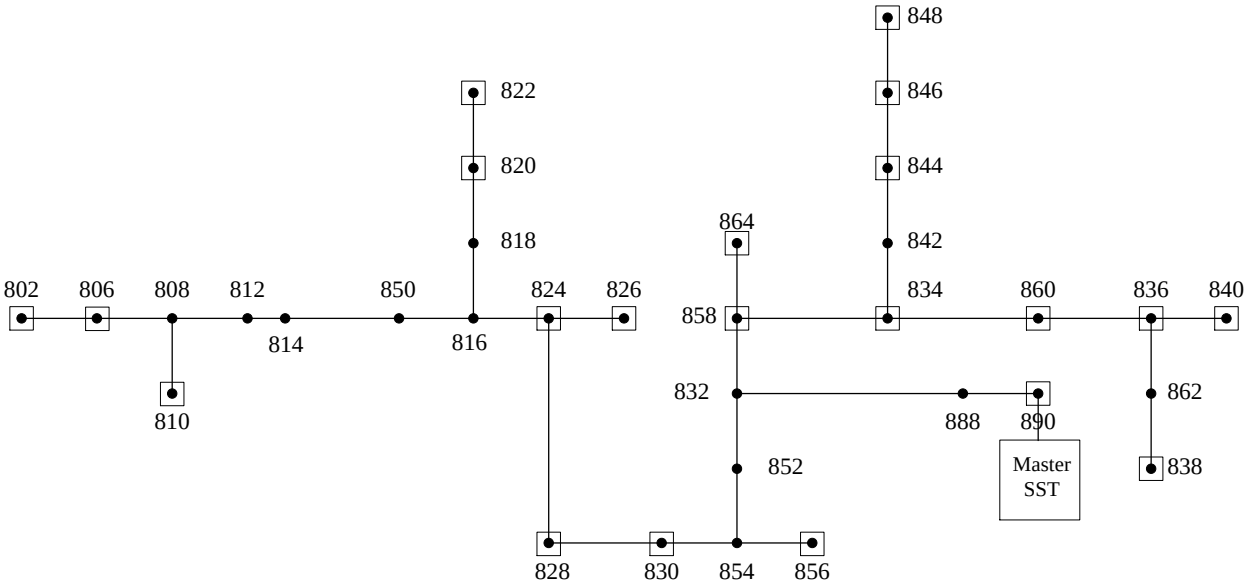

Figure 1. LSSS in Islanded mode

- Implement hierarchical frequency control
- Distributed frequency control for islanding applications
- Autonomous energy management and distributed generation

Inverter-less PV

The following are the project goals for year 9.

- Integration of high amounts (125%,150%, and so on) of PV penetration into the system
- Development of VVC approach that can be deployed by the PV inverters as opposed to VVC from the SSTs

2. Role in Support of Strategic Plan

Year 9 and beyond goal of LSSS is to validate and demonstrate the islanding application of medium scale distribution system testbed with SSTs. The project goals of year 9 will help in expanding the functionality of LSSS to islanding applications. The Inverter-less PV is an ancillary component of LSSS for the reactive power compensation in the system.

3. Fundamental Research, Technological Barriers and Methodologies

Islanded Operation of LSSS

Fundamental Research

- SST control in Islanded mode.
- Power Management of SST based AC Microgrids

Technological Barriers and Methodologies

- Improvement of SST control to support droop control and power sharing between SSTs in Islanded mode of operation
- Incorporate and implement hierarchical and distributed frequency control in LSSS testbed

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Fundamental Research

- PV inverter challenges for a conventional distribution transformer includes developing averaged model of single phase inverter that includes VVC. The averaged model must deliver variable power based on insolation profile and be capable of injecting reactive power to maintain voltage profiles. Challenge includes creating averaged model integrated as current source to the IEEE 34 bus distribution feeder

4. Achievements

Islanded Operation of LSSS

- Validation of seamless bidirectional capability of SSTs under high penetration of renewable energy resources. Figure 2 shows the power profiles of SST 822 supporting the statement.

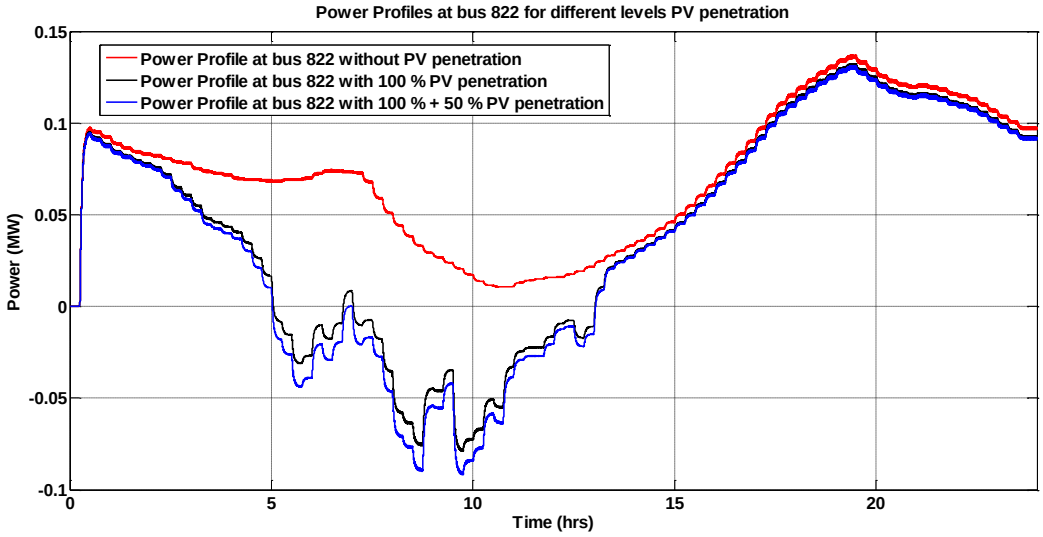

Figure 2. Power profiles of SSTs at bus 822 demonstrating seamless bidirectional capability

- Preliminary validation of Master-slave configuration and droop control in islanded LSSS

- Development of building block module of SST in islanded mode of operation. Figure 3 shows the building block module of the SST operating in islanding mode of operation

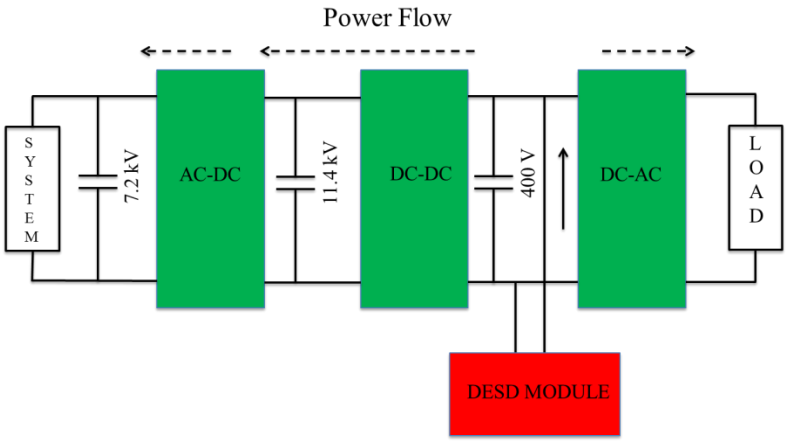

Figure 3. Building block of SST in Islanding mode of operation

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- Compared the results of voltage profiles of SST with DC integration of PV, SST with AC side integration of PV and with PV injection to a normal distribution transformer.

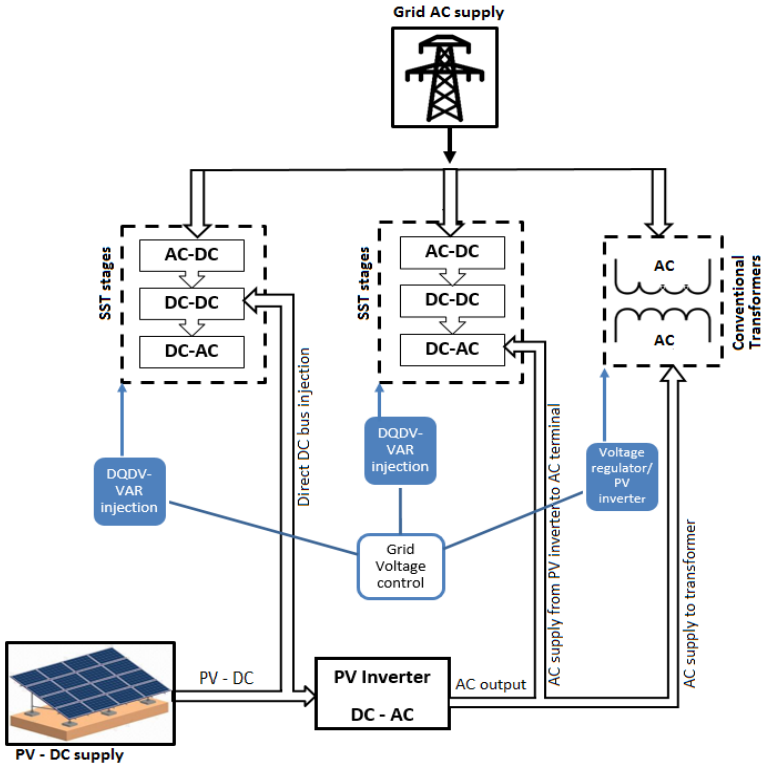

Figure 4. Comparing the SST performance in AC and DC and with conventional transformers

- Successful integration of Distributed Renewable Energy Resource (PV) on the AC side of the SST. Achieved stable system with nominal voltage profile using volt-var control

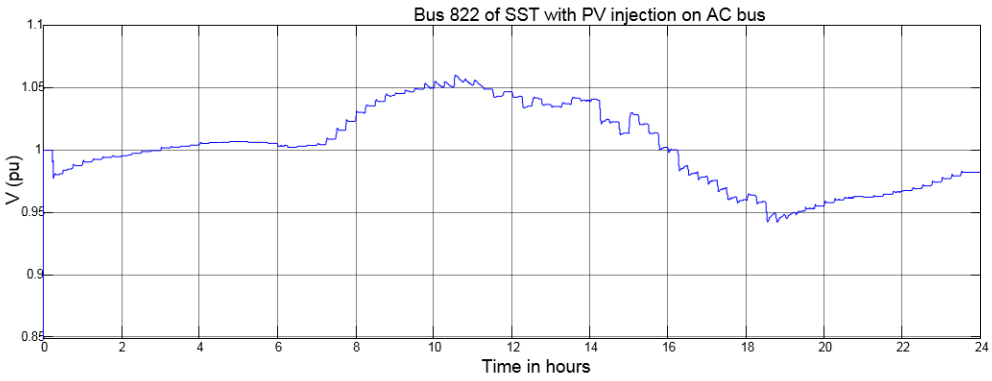

Figure 5. Voltage profile with PV injected successfully to AC bus 822 of SST with DQDV volt-var control

- Developed a scaled IEEE-34 voltage regulator in PSCAD to compare normal transformers performance with two regulators vs. SST with DQDV algorithm with no voltage regulators.
- Built the IEEE 34 bus distribution feeder with normal distribution transformers and integrated the PV with inverter to the AC load side of the distribution transformer.

5. Other Relevant Work Being Conducted Within and Outside of the ERC

- Autonomous control of FREEDM system
- Decentralized Volt/Var Optimization on HIL Testbed
- Wireless pilot differential protection operation
- System Cost benefit analysis
- Development of generation III SST

6. Milestones and Deliverables

Islanded Operation of LSSS

Milestones

- Implement hierarchical frequency control
- Distributed frequency control for islanding applications
- Distributed Volt/Var Control with 100 % PV penetration

Deliverables

- Successful plug and play with Volt/Var control and frequency control in islanded mode of operation

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Milestones

- Development of VVC approach that can be deployed by the PV inverters as opposed to VVC from the SSTs

Deliverables

- Validation of FREEDM feeder against non-FREEDM systems with 100% PV penetration and Energy Storage Systems.

7. Plans for Next Five Years

- Inclusion of ongoing research innovations in other components such as Gen III Fault isolation device, Gen III Solid State Transformer, Distributed Grid Intelligence, and Distributed Energy Storage Devices into Large Scale Simulation System (LSSS) testbed
- Development of concrete (LSSS) testbed platform for implementing future innovative technologies in renewable energy integration
- Development of Inverter-less PV for VVC applications

8. Member Company Benefits

- A comprehensive testbed is available for the industry to test out new innovative technologies in renewable energy integration
- Simulation packages are readily available to perform analysis for different real time applications

9. References

[1]. Phani Marthi, Darshit Shah, M.L.Crow, “100% Penetration of Photovoltaic Energy Resource in LSSS with SSTs”, NSF FREEDM Site Visit, 2015.

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[4]. D. Shah and M. L. Crow, "Online Volt-Var Control for Distribution Systems With Solid-State Transformers," in *IEEE Transactions on Power Delivery*, vol. 31, no. 1, pp. 343-350, Feb. 2016.

[5]. D. G. Shah and M. L. Crow, "Stability Design Criteria for Distribution Systems With Solid-State Transformers," in *IEEE Transactions on Power Delivery*, vol. 29, no. 6, pp. 0-0, Dec. 2014.