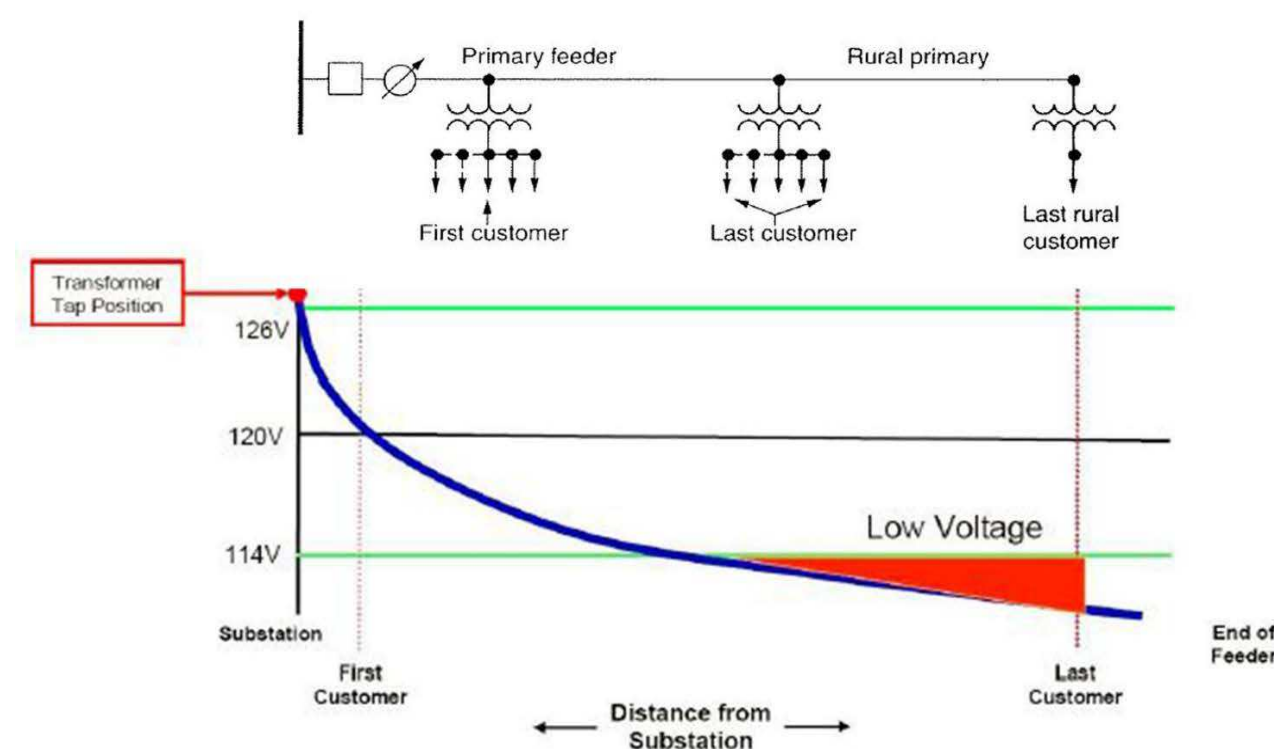


Background

In FREEDM system, voltage violation may occur as the load and PV generation changes. Volt/Var optimal (VVO) is a process of optimally managing voltage levels and reactive power to achieve more efficient grid operation. Solid State Transformer (SST) can provide reactive power support for the purpose of VVO, and therefore adjust the voltages to an acceptable range.



Under-voltage violation example

VVO Problem Statement

VVO aims at minimizing power loss while keeping voltages within limits on the FREEDM Systems:

$$\min f(x) = P_{loss}(x)$$

$$s.t. g(x, u) = 0$$

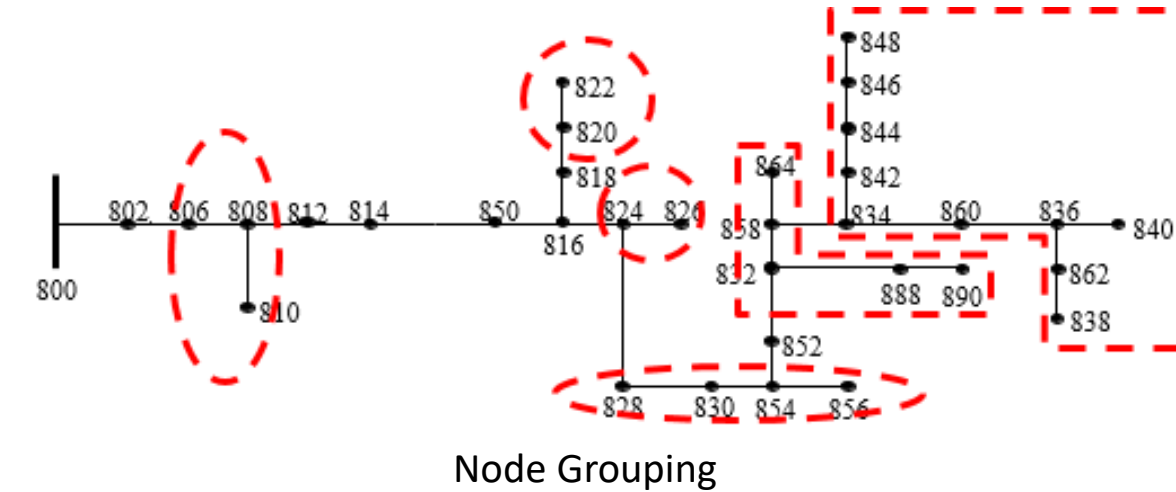
$$V^{min} \leq V \leq V^{max}$$

$$Q^{min} \leq Q_{inj} \leq Q^{max}$$

$f(x)$ is the power loss function
 $G(x, u)$ is the power flow equation
 u contains the control variable Q_{inj} , which is the reactive power at SST

Method

- Grouping the nodes based on sensitivity analysis



Node Grouping

- Gradient based Method

$$\nabla f = \frac{\partial P_{loss}}{\partial Q_{inj}} = - \left[\frac{\partial g}{\partial Q_{inj}} \right]^T \lambda$$

where $\frac{\partial g}{\partial Q_{SST}} = \begin{bmatrix} \frac{\partial \Delta P}{\partial Q_{SST}} \\ \frac{\partial \Delta Q}{\partial Q_{SST}} \\ \frac{\partial \theta}{\partial Q_{SST}} \end{bmatrix} = \begin{bmatrix} 0 \\ I \end{bmatrix}$ and $\lambda = - \left(\begin{bmatrix} \frac{\partial \Delta P}{\partial \theta} & \frac{\partial \Delta P}{\partial V} \\ \frac{\partial \Delta Q}{\partial \theta} & \frac{\partial \Delta Q}{\partial V} \end{bmatrix} \right)^{-1} \begin{bmatrix} \frac{\partial P_{loss}}{\partial \theta} \\ \frac{\partial P_{loss}}{\partial V} \end{bmatrix}$

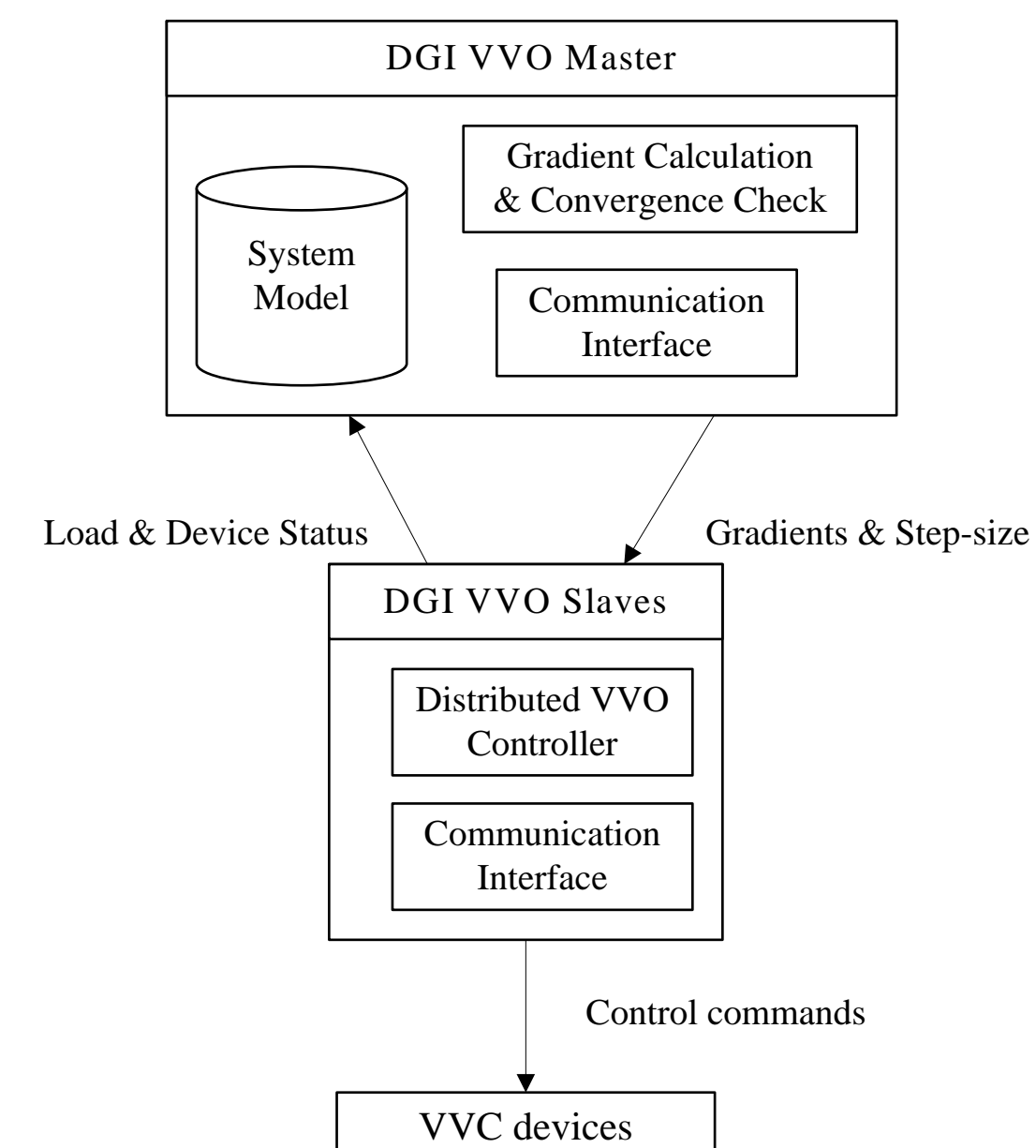
$$Q_{inj}(k+1) = Q_{inj}(k) - \nabla f \cdot \beta$$

- A master-slave based decentralized VVO scheme has been developed based on gradient.

Master :
 Calculates gradients and determine the optimal step-size
 Sends the new updates to all slaves

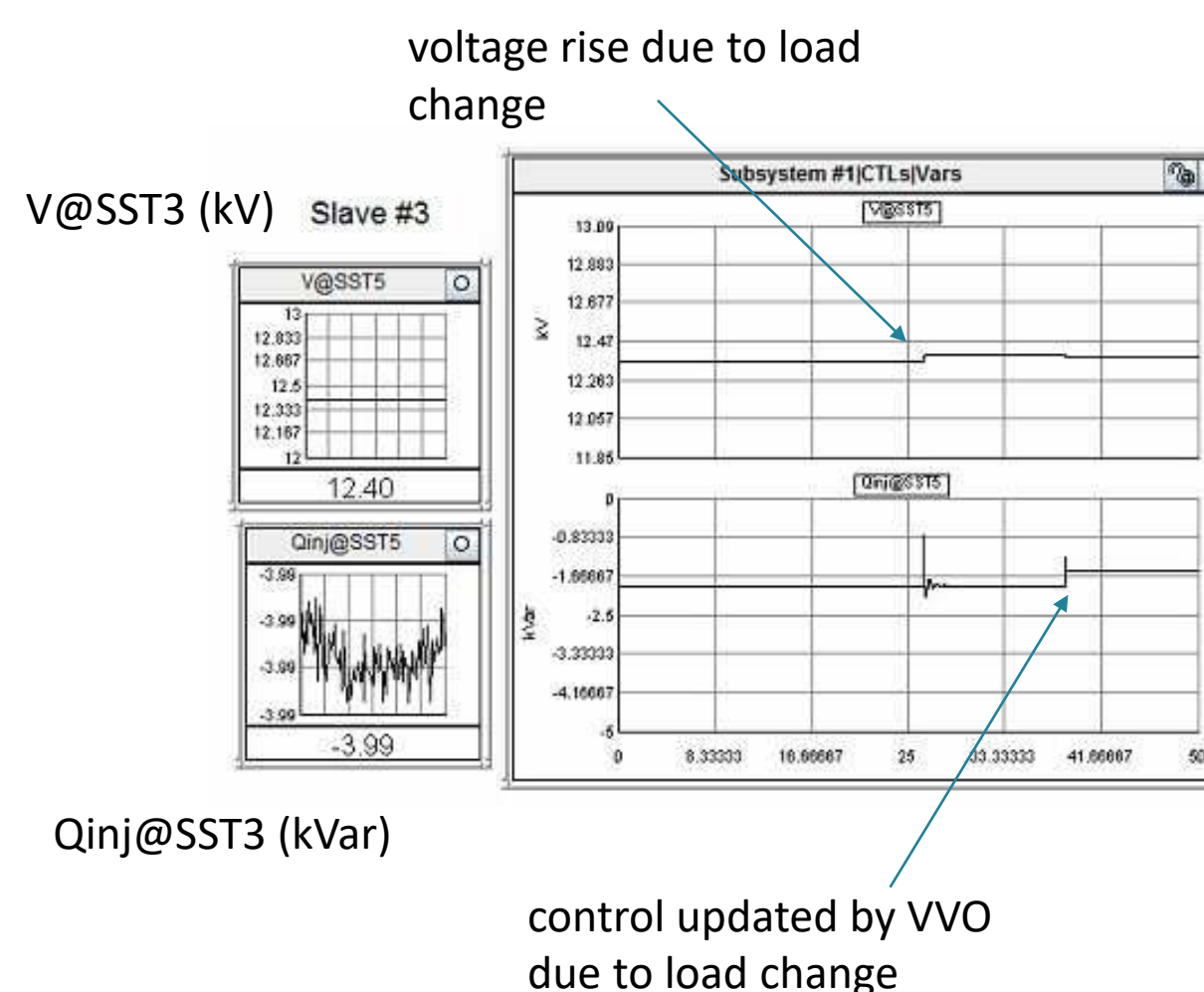
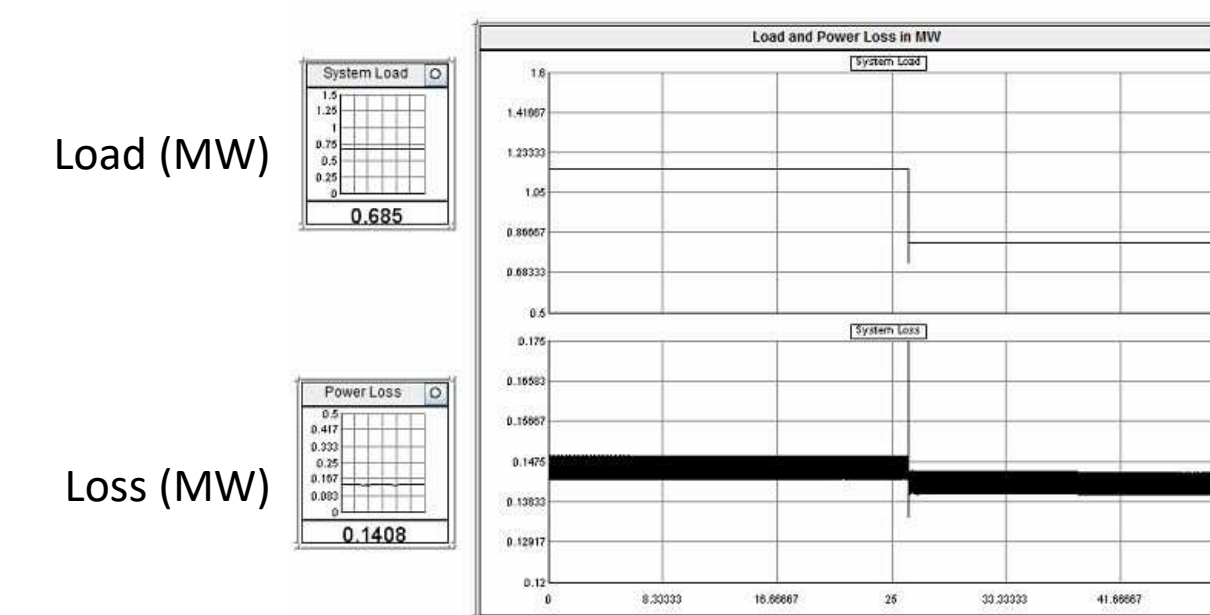
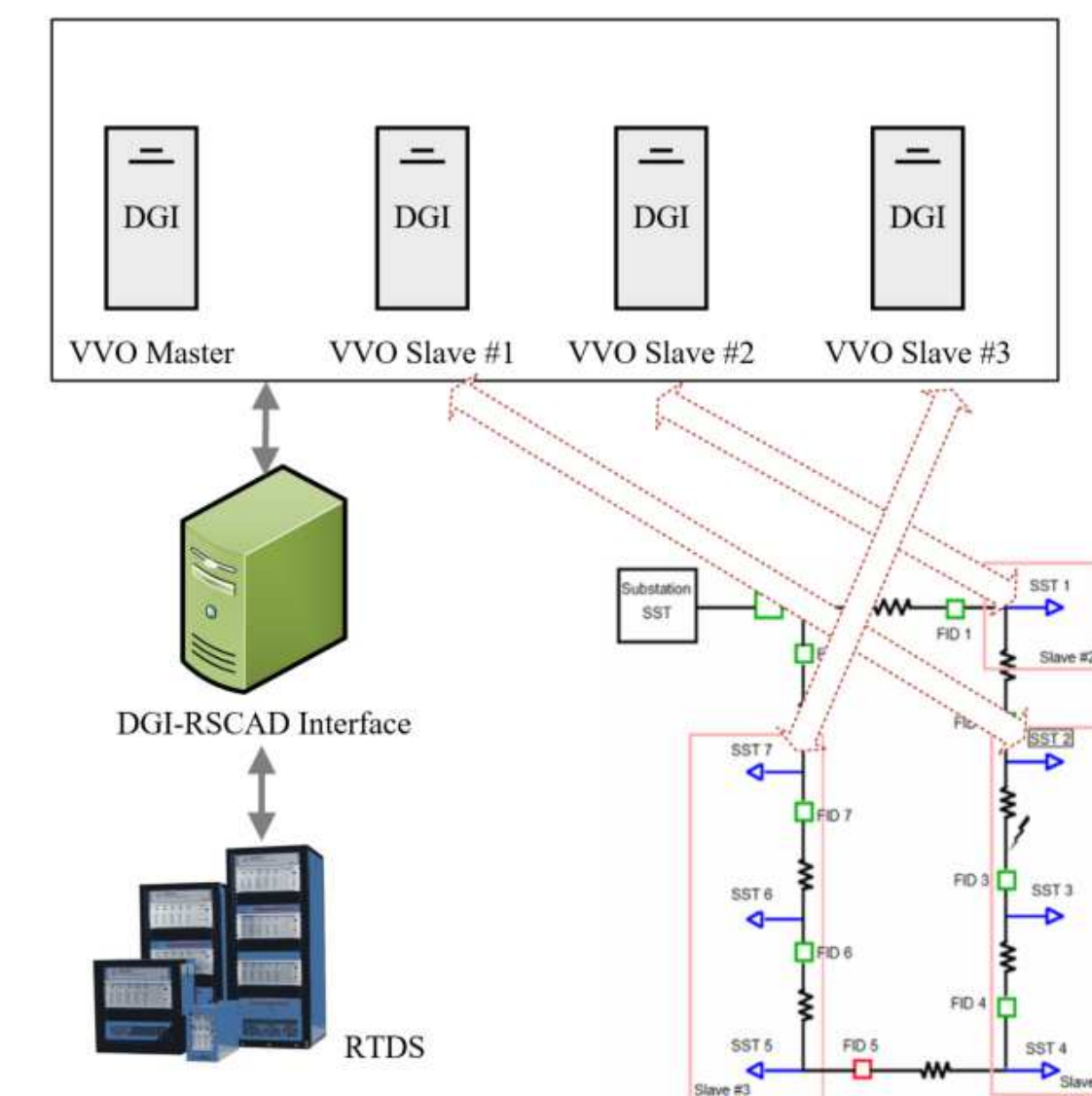
Slave:
 Allocate Q_{inj} for each SST

- Implementation of VVO on DGI



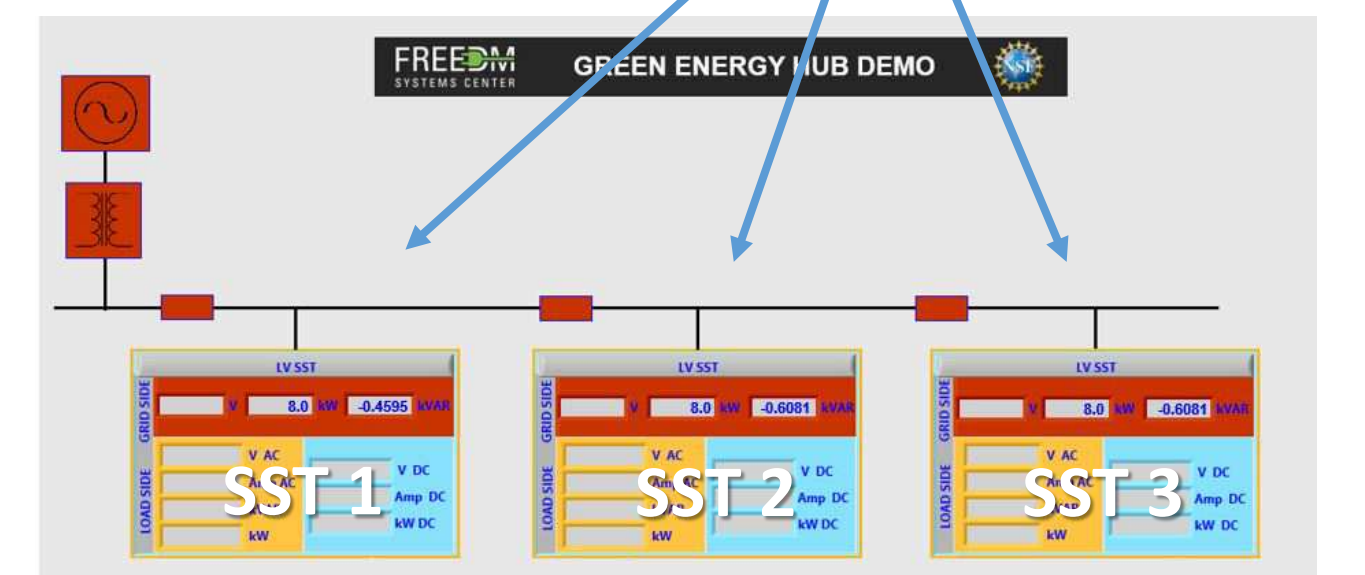
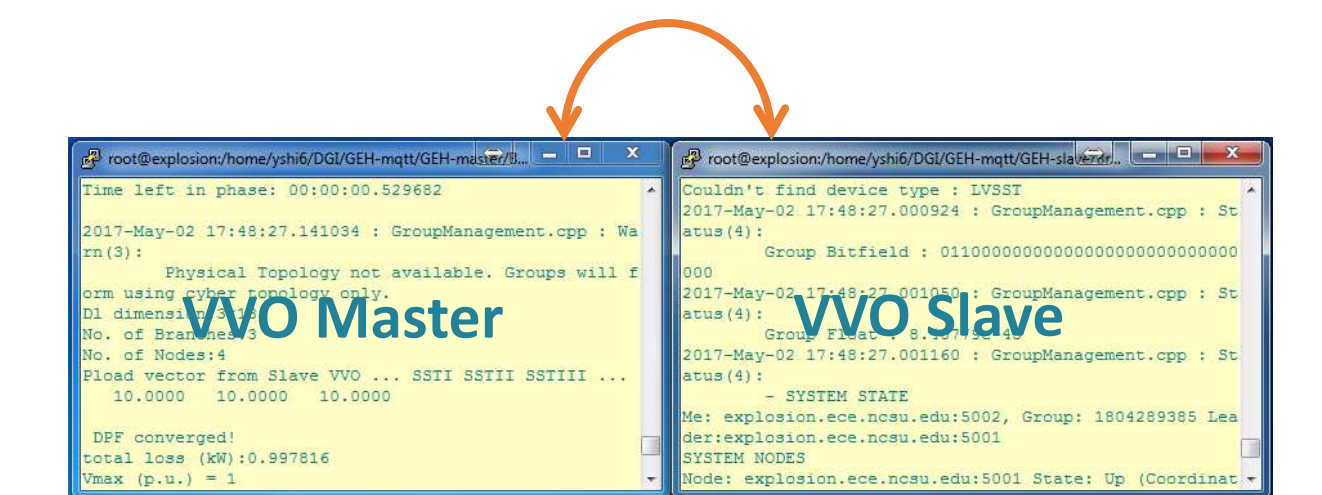
Results

- Implementation on HIL System**
 The Volt/Var optimization module has been created on DGI 2.0 and tested on HIL System in RSCAD
 VVO is able to adjust the reactive power of SSTs as load changes to minimize the system power loss



Results

- Implementation on GEH System**
 The effectiveness of the proposed VVO has been verified by MATLAB simulation
 MQTT library has been merged with VVO-DGI
 VVO is able to adjust the reactive power of SSTs as the load signal from MQTT client changes



Partners

