Y10.GEH1.1 Volt/Var Optimization and its Implementation

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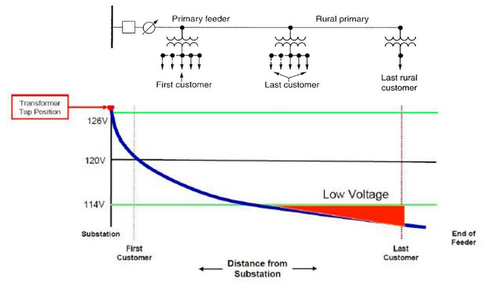
Background

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 gird 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:

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

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

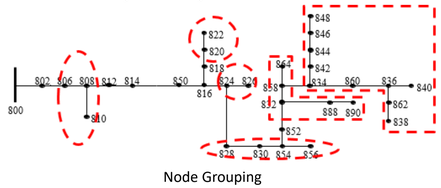
$$V^{min} \le V \le V^{max}$$

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

f(x) is the power loss function
g(x,u) is the power flow equation
u contains the control variable *Qinj*, which is the reactive power at SST

Method

- Grouping the nodes based on sensitivity analysis



Node Grouping

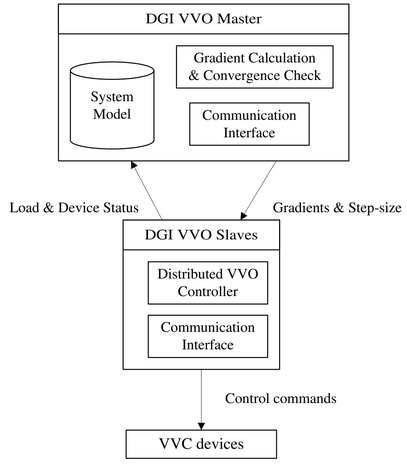
- Gradient based Method

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

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

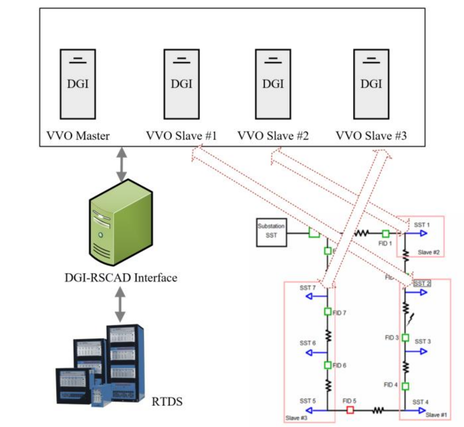
$$Q_{inj}(k+1) = Q_{inj}(k) - \nabla f \cdot \beta$$

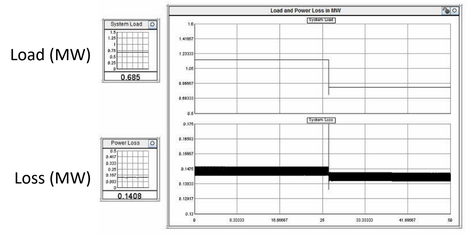
- A master-slave based decentralized VVO scheme has been developed based on gradient.
  Master :
    Calculates gradients and determine the optimal step-size
    Sends the new updates to all slaves
  Slave:
    Allocate *Qinj* for each SST
- Implementation of VVO on DGI

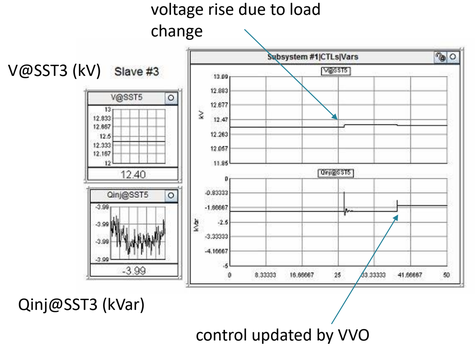


Results

- **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



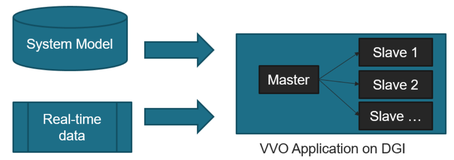


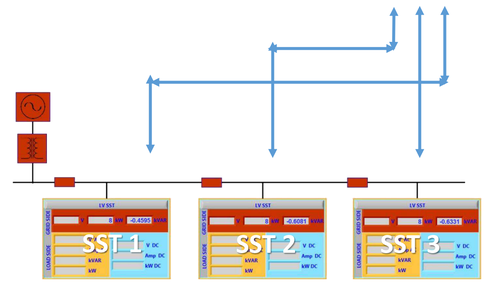


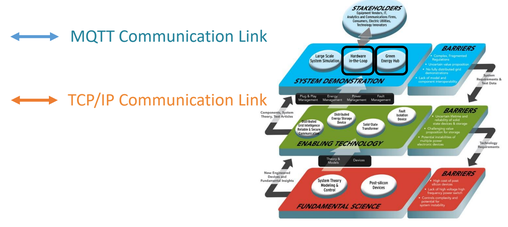
Results

- **Implementation on GEH System**
  The effectiveness of the proposed VVO has been verified by MATLAB simulation

  MQTT library has been merged with VVO-DGI and VVO is able to adjust the reactive power of SSTs as the load signal from MQTT client changes







Partners