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.

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**

- **Gradient based Method**

\[

\frac{\partial f}{\partial Q_{inj}} = \frac{\partial f}{\partial x} \frac{\partial x}{\partial Q_{inj}}
\]

where

\[

\frac{\partial x}{\partial Q_{inj}} = \begin{bmatrix} \Delta x \end{bmatrix} \text{ and } \begin{bmatrix} \Delta x \end{bmatrix} = \begin{bmatrix} \frac{\partial x}{\partial Q_{inj}} \end{bmatrix} \begin{bmatrix} \Delta Q_{inj} \end{bmatrix}
\]

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

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

### 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.

- **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.