Rensselaer Polytechnic Institute
Electrical, Computer, and Systems Engineering

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Development of a Multi-Functional FACTS Controller Operator Training Simulator

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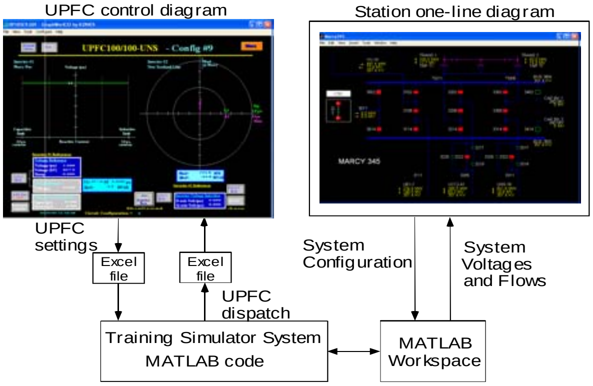
Objective

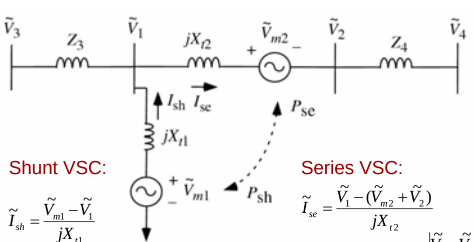
Develop an off-line general purpose multi-functional FACTS Controller Operator Training Simulator, capable of "seeing" the impact of dispatching one or more FACTS Controllers on the power system.

Design

- Platform: PC with Windows XP operating system and dual display monitors
- Human-machine interface (HMI): commercial SCADA package (such as GENESIS) to display FACTS control screens from equipment supplier and MATLAB to display station one-line diagrams
- Computation: MATLAB-based MatNetFlow program with multiple FACTS dispatch modes; communicate with HMI via Microsoft Excel files
- System data: any detailed or reduced IEEE or PSS/E data set compatible with FACTS Controllers and station diagrams



Injected Votage-Sourced Model



Shunt VSC:

$$\tilde{I}_{sh} = \frac{\tilde{V}_{m1} - \tilde{V}_1}{jX_{t1}}$$

$$S_{sh} = \tilde{V}_1 \tilde{I}_{sh}^* = \frac{\tilde{V}_1 \tilde{V}_{m1}^* - V_1^2}{-jX_{t1}}$$

Series VSC:

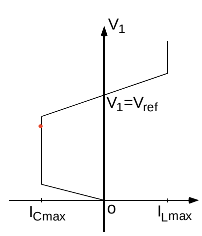
$$\tilde{I}_{se} = \frac{\tilde{V}_1 - (\tilde{V}_{m2} + \tilde{V}_2)}{jX_{t2}}$$

$$S_{se} = (\tilde{V}_1 - \tilde{V}_2)\tilde{I}_{se}^* = \frac{|\tilde{V}_1 - \tilde{V}_2|^2 - (\tilde{V}_1 - \tilde{V}_2)\tilde{V}_{m2}^*}{-jX_{t2}}$$

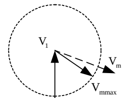
$$S_2 = \tilde{V}_2 \tilde{I}_{se}^* = \frac{\tilde{V}_2(\tilde{V}_1^* - \tilde{V}_{m2}^*) - V_2^2}{-jX_{t2}}$$

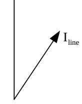
FACTS Controller Operating Modes

- Shunt VSC
  1. Var reserve mode – voltage control mode with droop and var reserve
  2. Voltage control mode with or without droop
     If $Q_{sh} > Q_{max}$, switch to control mode 3 and $Q_{ref} = Q_{max}$;
     If $Q_{sh} < Q_{min}$, switch to control mode 3 and $Q_{ref} = Q_{min}$;
     Q_{sh} is the reactive power output required to achieve voltage setpoint.
  3. Var reference control
     If $Q_{ref} > Q_{max}$, $Q_{ref} = Q_{max}$;
     If $Q_{ref} < Q_{min}$, $Q_{ref} = Q_{min}$;



- Series VSC
  – Standalone
  1. Fixed line P flow setpoint
     If $V_m > V_{mmax}$, switch to control mode 2 and $V_{mref} = V_{mmax}$;
  2. Fixed series voltage injection magnitude
     If $V_{mref} > V_{mmax}$, $V_{mref} = V_{mmax}$;
     V_m is the VSC voltage insertion to achieve actvie power setpoint.





Coupled

i. Fixed line P,Q flow setpoints

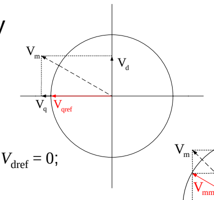
If $\sqrt{V_d^2 + V_q^2} > V_{mmax}$ and $V_q \geq V_{mmax}$,

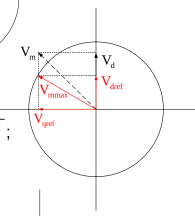
switch to V_d, V_q control mode and let $V_{qref} = V_{mmax}$, $V_{dref} = 0$;

If $\sqrt{V_d^2 + V_q^2} > V_{mmax}$ and $V_q < V_{mmax}$,

switch to V_d, V_q control mode and let $V_{qref} = V_q$ and $V_{dref} = \sqrt{V_{mmax}^2 - V_q^2}$;

V_d, V_q are the direct and orthogonal components of the voltage insertion.

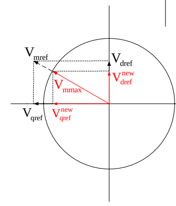




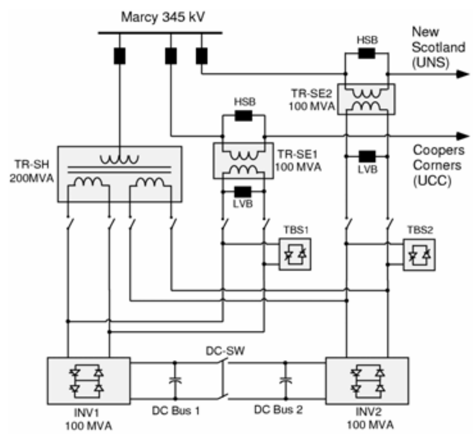
ii. Fixed series voltage injection (Vd,Vq)

If $\sqrt{V_{dref}^2 + V_{qref}^2} > V_m$,

let $V_{dref}^{new} = \frac{V_m}{\sqrt{V_{dref}^2 + V_{qref}^2}} V_{dref}$ $V_{qref}^{new} = \frac{V_m}{\sqrt{V_{dref}^2 + V_{qref}^2}} V_{qref}$

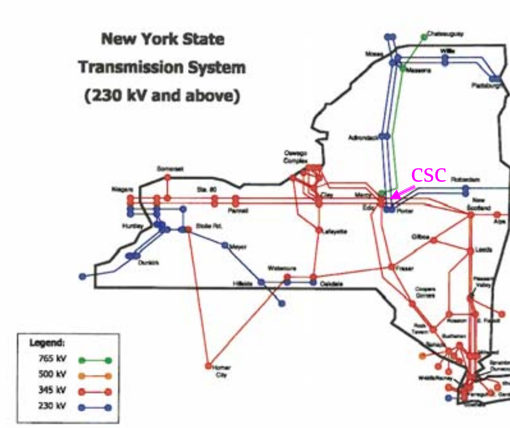


Customization to NYPA CSC



Configuration	Number of modes
1. STATCOM100-1	3
2. STATCOM100-2	3
3. STATCOM200	3
4. SSSC100-UCC	2
5. SSSC100-UNS	2
6. SSSC100-UCC SSSC100-UNS	4
7. STATCOM100-1 SSSC100-UNS	6
8. SSSC100-UCC STATCOM100-2	6
9. UPFC100/100-UNS	6
10. UPFC100/100-UCC	6
11. IPFC100-UCC/100-UNS	4 4
Total number of modes	49

New York State Transmission System



A Training Scenerio

	References		Marcy Voltage (pu)	Shunt output		Series VSC		Line UNS	
	Shunt	Series		P (MW)	Q (MVar)	Vmd (pu)	Vmq (pu)	P (MW)	Q (MVar)
Base case	-	-	1.0327	0	0	0	0	554.8	3.5
UPFC P,Q mode	Vset: 1.04 Droop: 0.03	P: 600 Q: 50	1.0323	-11.0	25.7	0.372	0.313	600.0	50
UPFC Vd, Vq mode	Vset: 1.04 Droop: 0.03	Vmd: 0.37 Vmq: 0.31	1.0323	-11.0	25.7	0.372	0.313	600.0	50
UPFC Trip ENS	Vset: 1.04 Droop: 0.03	Vmd: 0.37 Vmq: 0.31	1.0279	-14.3	40.4	-0.372	-0.313	791.0	83.0
UPFC P,Q mode	Qset: -1.00	P: 660 Q: 100	1.0337	-15.3	98.8	0.52	0.86	659.7	82.7
UPFC Vd, Vq mode	Vset: 1.07 Droop: 0.03	Vd: 0.5 Vq: 1.2	1.0343	-11.5	99.5	0.38	-0.92	662.9	70.3