



VFT Response to a Breaker Trip and Runback Event

CIGRE USNC 2014 Grid of the Future
Symposium

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Imagination at work.

What the heck is a VFT?



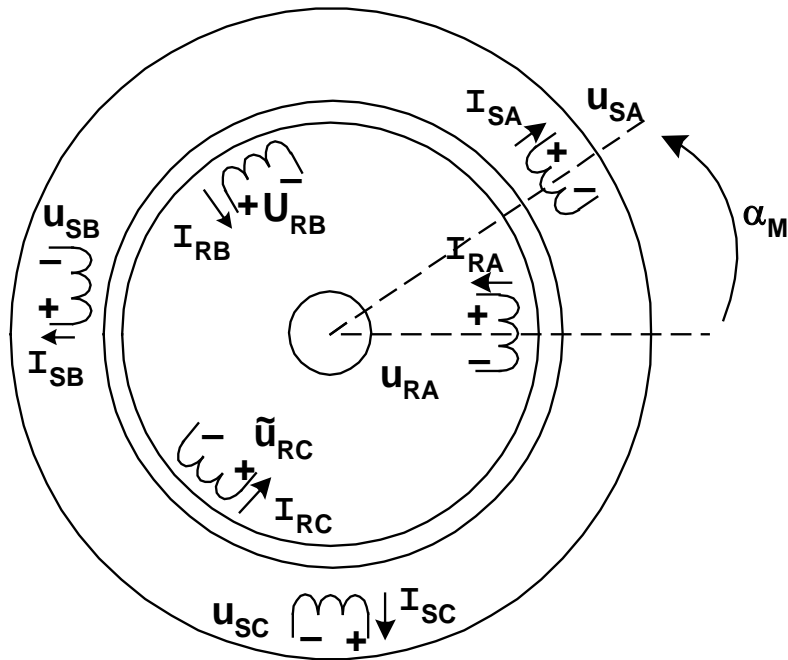
Variable Frequency Transformer

Controlled AC Power Flow

Stator construction identical to Hydro Generator - 3ph, 4 pole windings

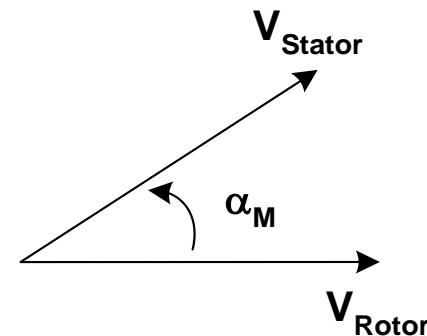
Rotor construction same as stator – Convex instead of Concave winding face

One grid is connected to Stator. Other grid is connected to Rotor



Power flow is controlled by introducing a phase-shift

Same principle as a phase shifter; instead of steps, it is continuous



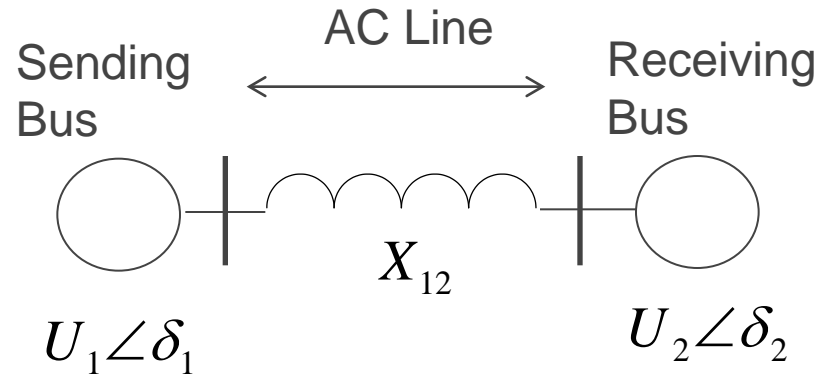
Power flow is proportional to torque applied to the shaft.



AC Transmission

- AC Power flow is proportional to angle between voltage phase angles

$$P = \frac{U_1 U_2}{X_{12}} \sin(\delta_1 - \delta_2)$$

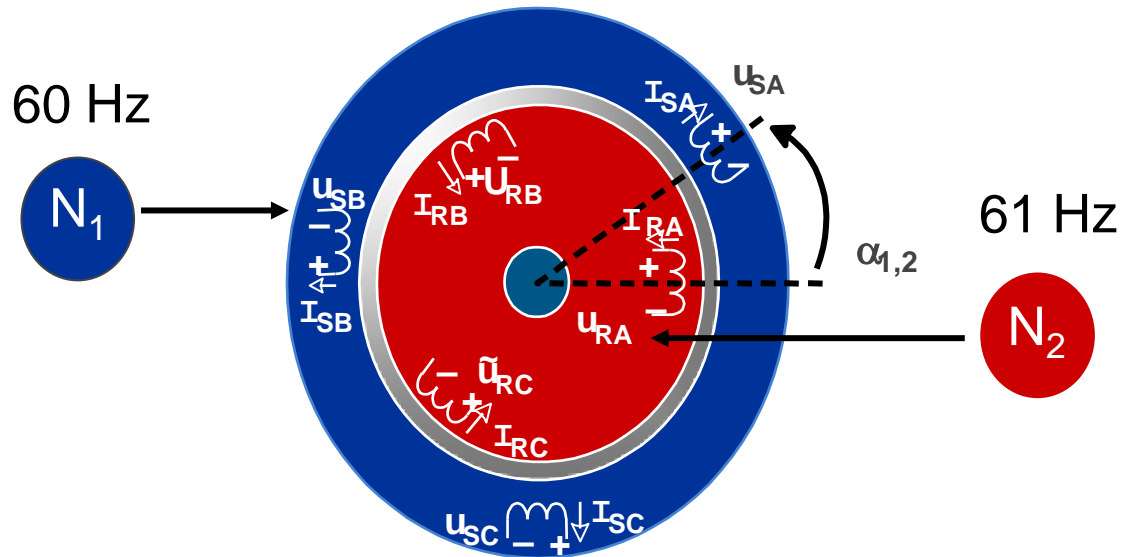


- Direct power flow control requires a device that can control angle (**VFT**, PAR, UPFC)
- Limit reached when angle difference ~ 90 degrees



Synchronous or Asynchronous

Grids need not be synchronized!



Any frequency difference is accommodated by rotation of the rotor

4 pole machine \Rightarrow 1Hz = 30 rpm

Up to 3 Hz difference

Provides a simple way to connect two grids



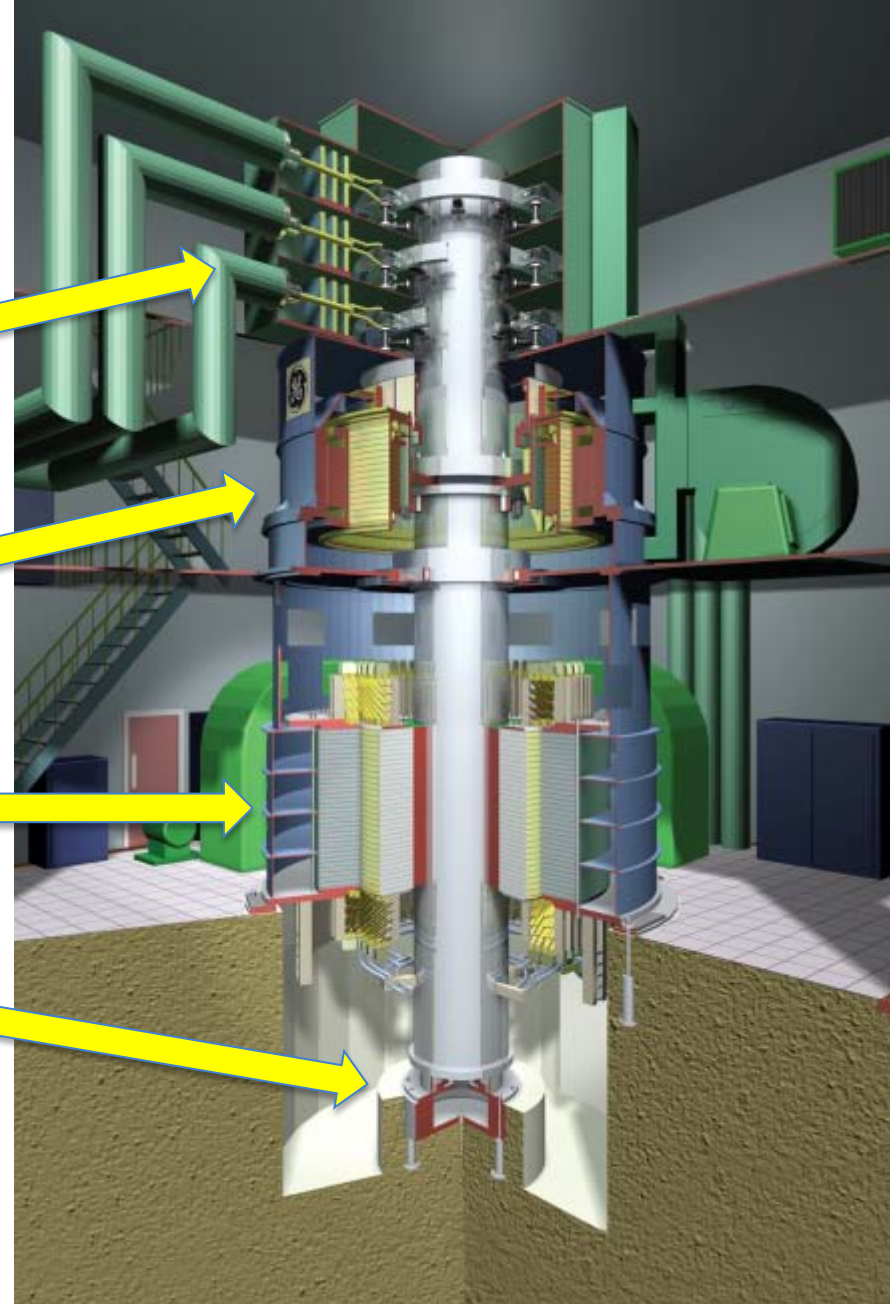
VFT Components

Collector – Power Connection
to Rotor Windings

DC Drive & Motor Control the
Angle

Machine Windings

Thrust Bearing Allows Full
Rotation



Variable Frequency Transformers

- 5 Units in commercial operation
- 32 machine-years operation

- ★ VFT Installation Site
- Asynchronous Boundary
- ▤ Back-to-Back DC Tie

AEP – Laredo, TX
100 MW

Linden - 300 MW

HQ – Langlois
100 MW



Linden VFT Site



Linden VFT Project



Phase Angle
Regulator operation to
control power flow.

Project Opportunity

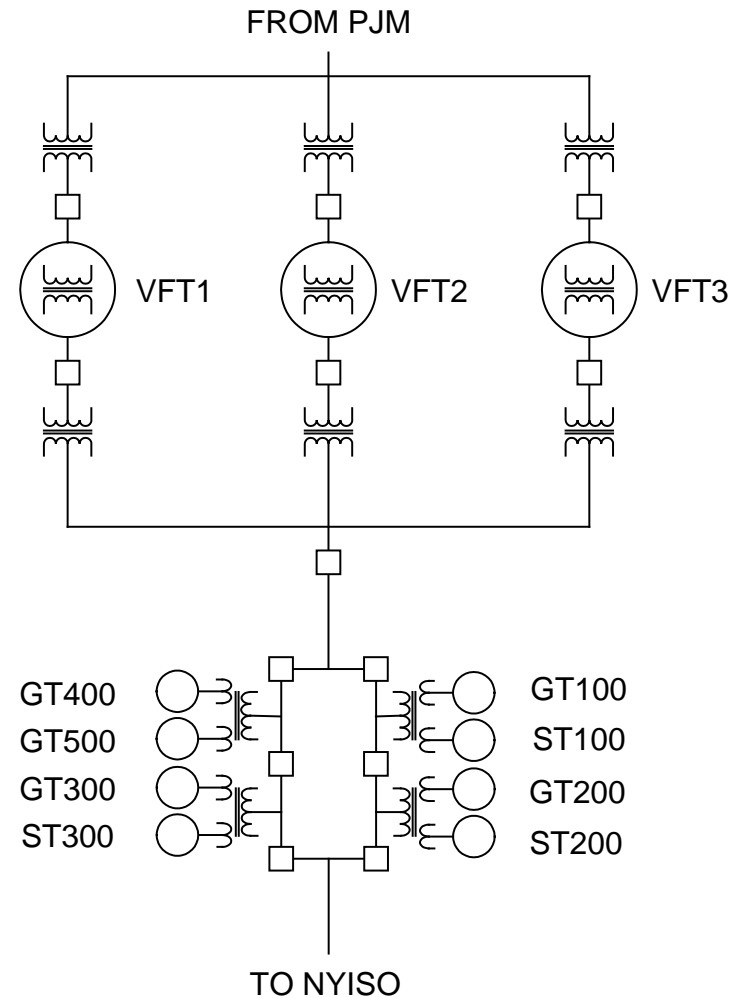
- Electricity price delta between New Jersey and New York City USA
- Ability to transfer power from Linden NJ to NYC, using the existing 300 MW capacity in cables



Linden VFT

300 MW tie between PJM and NYISO

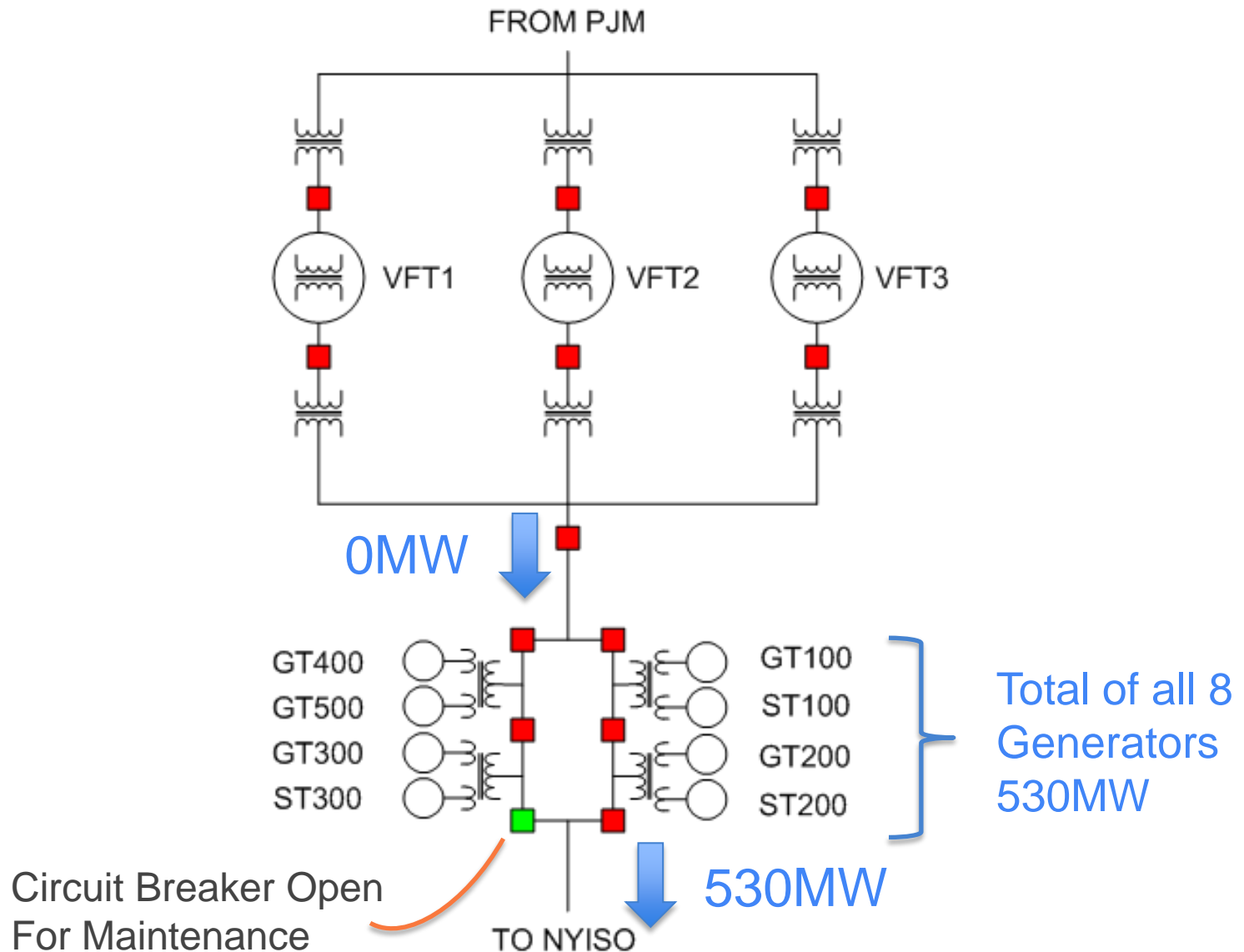
- Three Units in Parallel
- Connection between two strong systems
- Multiple generators nearby
- Works in parallel with PST's
- 3 Units on less than 1 acre
- Merchant Transmission Project
- Precise power flow control required



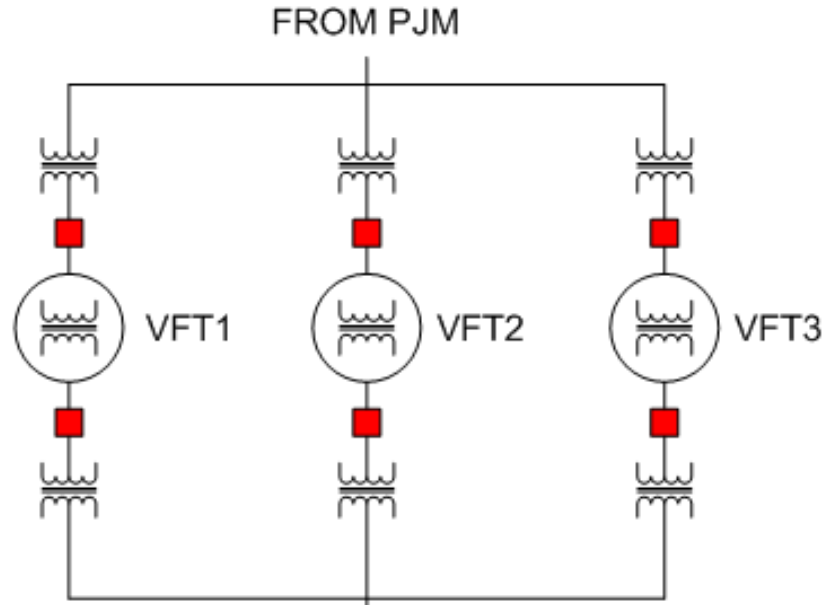
Incident Details



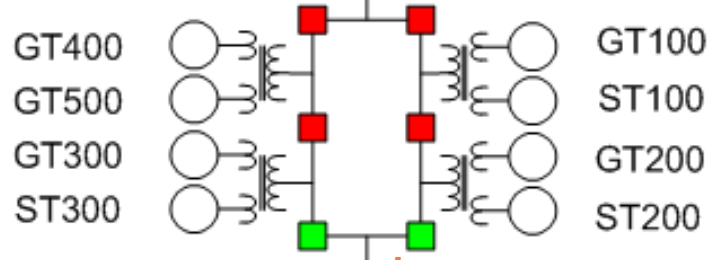
Linden Pre-Incident



Linden Incident - Oops



0MW



Runback
Reduces
Total of all 8
Generators to
90MW

@#*!



Another Circuit Breaker
Opens Accidentally

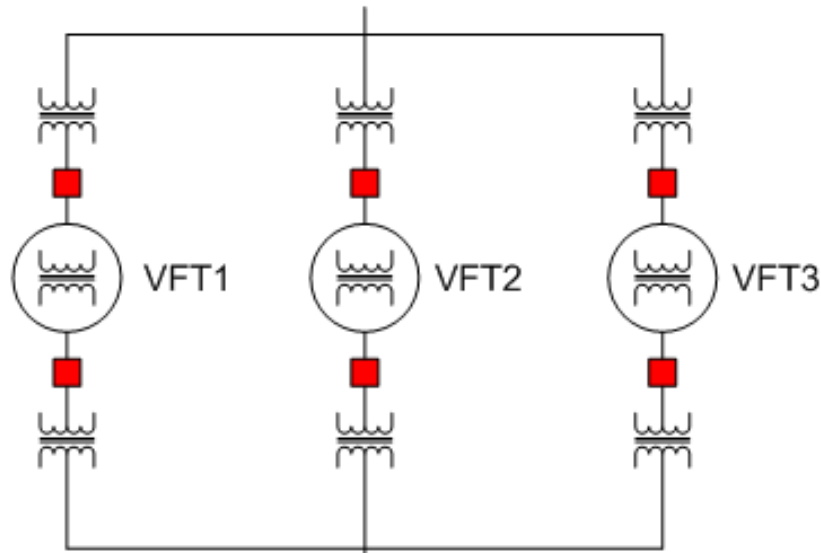
TO NYISO

0MW



Linden Incident – Excess Power

FROM PJM

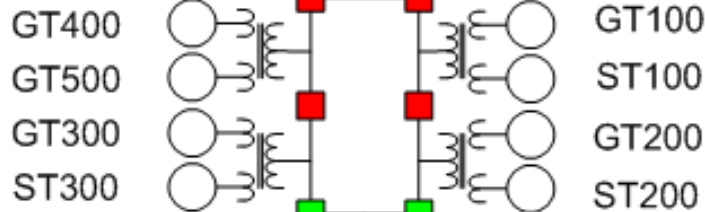


VFT Controls
are holding
0MW

→ 0MW



90MW Produced
-7MW House Load
83MW Excess



Runback
Reduces
Total of all 8
Generators to
90MW

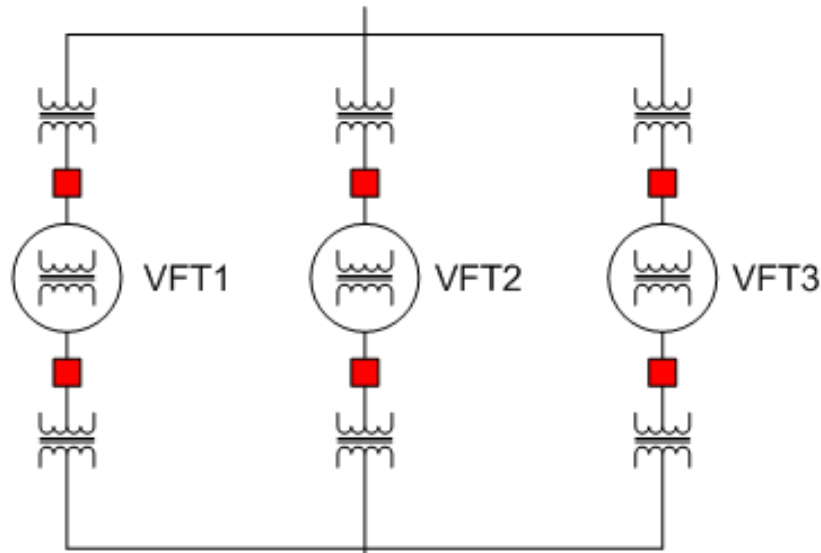
TO NYISO

0MW



Linden Incident – Excess Power

FROM PJM

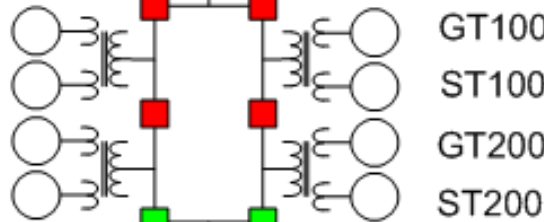


VFT Controls
are holding
0MW

0MW

90MW Produced
-7MW House Load
83MW Excess

GT400
GT500
GT300
ST300



GT100
ST100
GT200
ST200

Runback
Reduces
Total of all 8
Generators to
90MW

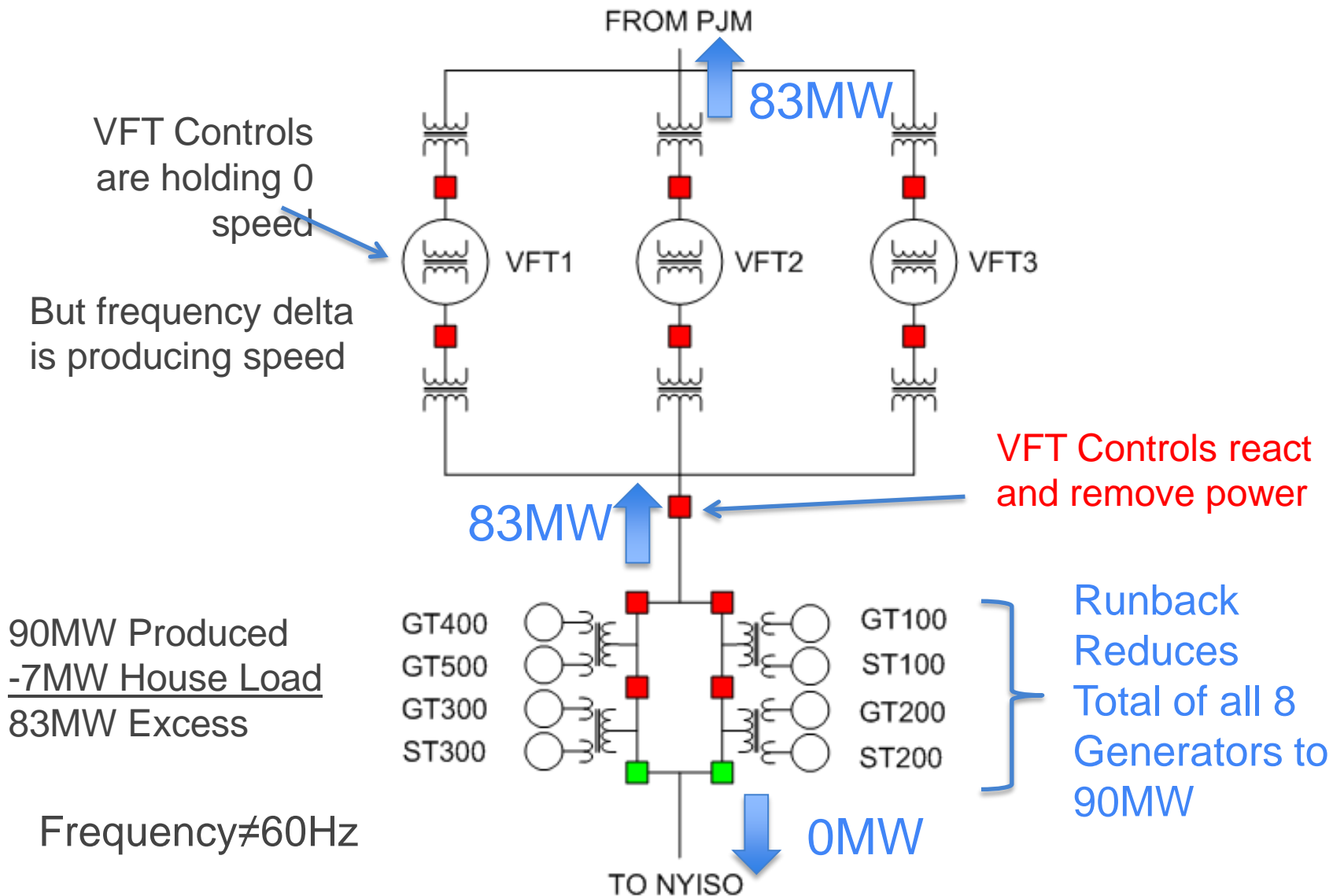
Frequency ≠ 60Hz

TO NYISO

0MW



Linden Incident – Good Controls



Conclusion



VFTs' controls exhibited a response to a system disturbance that was helpful overall.

The controls could have been programmed to simply follow power order.

System restoration was accelerated by the VFT control actions.

Lesson: **Think about the big picture!**



