VFT Response to a Breaker Trip and Runback Event

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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

Any frequency difference is accommodated by rotation of the rotor
4 pole machine => 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

- AEP – Laredo, TX 100 MW
- HQ – Langlois 100 MW
- Linden - 300 MW

VFT Installation Site
Asynchronous Boundary
Back-to-Back DC Tie
Linden VFT Site
Linden VFT Project

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

Phase Angle
Regulator operation to control power flow.
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

Total of all 8 Generators 530MW

Circuit Breaker Open For Maintenance

0MW

530MW
Linden Incident - Oops

Another Circuit Breaker Opens Accidentally

Runback Reduces Total of all 8 Generators to 90MW
Linden Incident – Excess Power

VFT Controls are holding 0MW

90MW Produced
-7MW House Load
83MW Excess

Runback Reduces Total of all 8 Generators to 90MW

0MW
Linden Incident – Excess Power

90MW Produced
-7MW House Load
83MW Excess

0MW

Frequency ≠ 60Hz

VFT Controls are holding 0MW

Runback Reduces Total of all 8 Generators to 90MW
Linden Incident – Good Controls

VFT Controls are holding 0 speed

But frequency delta is producing speed

90MW Produced
7MW House Load
83MW Excess

Frequency ≠ 60Hz

Runback Reduces Total of all 8 Generators to 90MW

VFT Controls react and remove power

83MW

0MW

FROM PJM

VFT1

VFT2

VFT3

GT400

GT500

GT300

ST300

GT100

ST100

GT200

ST200
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!