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VFT Response to a Breaker Trip and Runback Event

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SUMMARY

An inadvertent circuit breaker trip caused Linden Cogen's supply of power to New York City to go from 530MW to 0. The three Linden VFT's were on line at the time but were not sending power into New York City before the event. While the generator runback system tripped all the steam turbines and all but one of the gas turbines, the VFT's stayed on line and prevented Linden Cogen from being islanded. The remaining gas turbine was producing 90MW of power, of which, 7MW was needed for house load. The VFT's moved the remaining 83 MW into the PJM grid in New Jersey. This was not an operator action but the function of the VFT governor controls. The response of the VFT's was stable and helpful and resulted in simpler and faster restoration. This paper describes the event in detail with a focus on the VFT response.

KEYWORDS

VFT, Reverse Power, Runback.

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INTRODUCTION

Linden Cogen supplies electrical power to New York City and steam to the Bayway refinery. Although it sits in Linden, NJ, the five gas turbines and three steam turbines supply electricity into the city through an underground 345kV cable under the Arthur Kills waterway. The generators are connected to a 345kV ring bus with the underground cable to New York City at one end of the ring bus. In 2009 three Variable Frequency Transformers (VFT's) were added to the other end of the ring bus. The VFT's connect the PJM grid to Linden Cogen, which is part of NYISO's system. VFT's are rated a nominal 100MW each. At Linden there are three units in parallel. Figure 1 shows a simplified one line diagram of the arrangement.[1] At the bottom of the figure are circuit breakers 52-3 and 52-4. These are the circuit breakers involved in this particular event. Normally, all circuit breakers are closed. In this case, circuit breaker 52-3 was open for maintenance, when 52-4 inadvertently opened, isolating Linden Cogen from the NYISO grid.

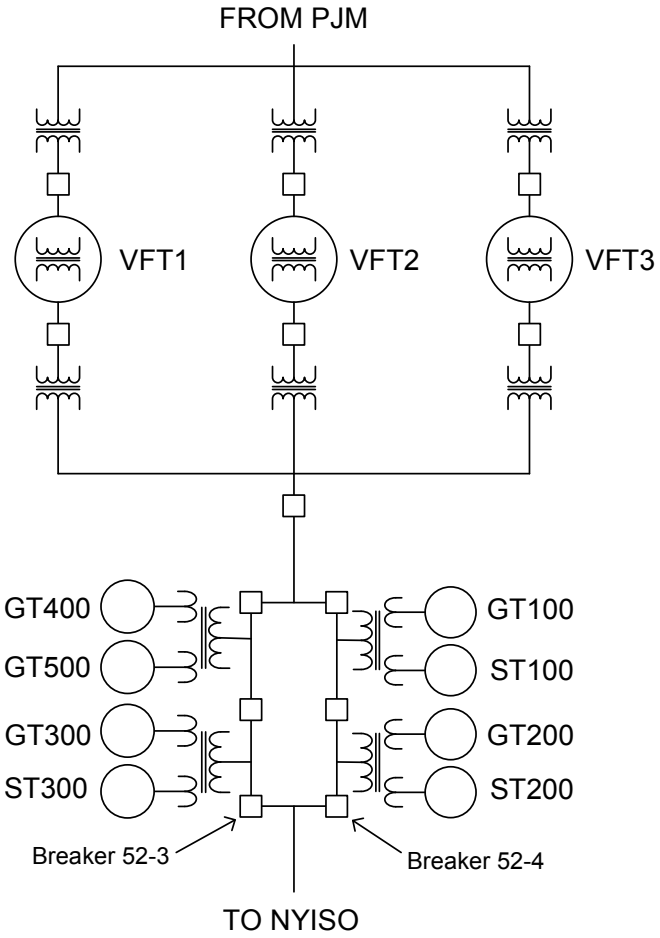

Figure 1
One-line diagram of ring bus at Linden Cogen and Linden VFT.

This paper examines the details surrounding this event and in particular the response of the Linden VFT. The VFT response was logical and helpful and resulted in faster restoration to normal conditions.

VFT TECHNOLOGY

The VFT can be considered a one to one transformer where the phase angle of one three-phase winding can be varied with respect to the other three-phase winding. It's function can be compared to a continuously variable phase angle regulator. The control system varies the angle to cause power to flow per operator dispatch. Equation 1 below shows the relationship between the phase angle and the flow of power in an AC system, V is the system voltage, X is the impedance between the points involved and δ and σ are the phase angles at the two points. In this case the two points are each side of the VFT. It is clear that by controlling the phase angle across the VFT, full control of power flow can be achieved.

$$P = \frac{V^2}{X}\sin(\delta - \sigma) \qquad (1)$$

From a physical standpoint, a VFT is not unlike a wound rotor induction motor with fully rated slip rings, called a collector. A torque motor controls the angle between the two windings and thereby controls the power flow. Figure 2 depicts the physical arrangement of a single machine. [2]

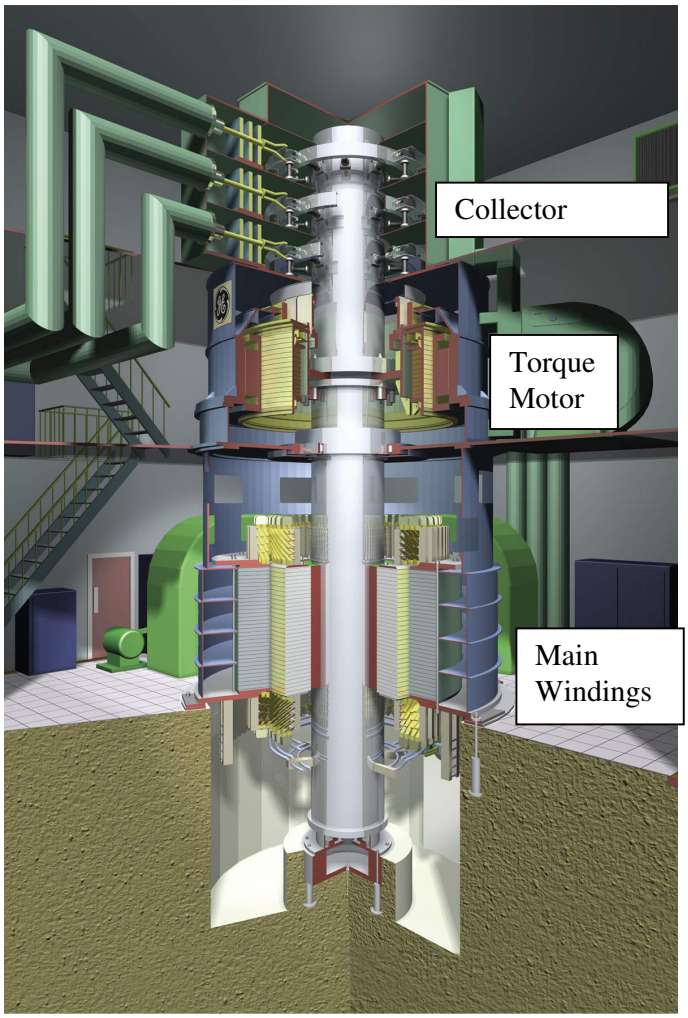

Figure 2
Arrangement of a VFT.

EVENT DESCRIPTION

At 11:55 on February 8, 2011, circuit breaker 52-4 (refer to Figure 1) inadvertently opened while circuit breaker 52-3 was already opened for maintenance. This isolated Linden Cogen from Con-Ed. At the time, Linden Cogen's net output to Con-Ed was 530MW. When circuit breaker 52-4 opened, the connected load dropped from 530 MW to 0 MW. The runback system initiated a trip on all running machines except GT-300, as it was programmed to do. GT-300 stayed on line generating 90 MW. There was a total house load of 7 MW connected, leaving an additional 83 MW.

In any AC power system, the amount of power produced, at any moment in time, must match exactly the amount of power consumed. If more power is produced than is consumed, the frequency will increase. If less power is produced than is needed, frequency will decrease. The VFT controls take this into account and include a governor function. The additional 83MW being produced by Linden Cogen resulted in a frequency increase. When the VFT controls observed a frequency error the controls overrode the power order. The VFT began exporting the 83MW of excess power into the PJM grid and stayed connected to Linden Cogen.

In this particular case, the governor function did not operate but instead it was the speed regulator of the rotor controls. Because both sides of the VFT are connected to the same Eastern US grid, the same frequency should always be observed on both sides. Normally the rotors of the Linden VFTs do not turn and only move upon changes in power order. In this case the faster speed regulator sensed the event before the actual governor function, and provided essentially the same response of changing the power order.

Plant restoration immediately began with the start-up on steam turbines 100 and 200. Gas turbine 400 was started and synchronized at 12:50. A back-up air compressor and diesel generator were placed in service.

At 13:05, Linden Cogen was informed by NYISO through ConEd not to exceed 100 MW into the PJM Grid. At 13:15, Linden Cogen was informed Goethals breaker 6 and 8 were closed, however Linden Cogen was unable to synchronize while connected to VFT. All running generators were removed from the grid with the exception of GT-400. Gas turbine 400 output was reduced to house load and VFT was isolated from Linden Cogen. At 13:55, 345 kV breaker 52-4 was closed and Linden Cogen proceeded to restore load to scheduled dispatch requirements. By 13:56 Linden Cogen resumed normal operation.

SUMMARY

The controls of the VFTs displayed a response that was helpful overall. It is generally accepted that Linden Cogen was able to restore the situation to normal in a timelier manner because of the response of the VFTs. Instead of simply following the given power order, in this case 0MW, the controls sensed an extreme condition and did what they were able to, to alleviate the condition. The transmission grid has become far more complex and complicated than ever before. Transmission devices must focus not only on their own functions and purposes but can also be programmed to provide support during extreme grid events. In this case the VFT controls sensed an abnormal condition at Linden Cogen and acted without waiting for operator input. A similar event is documented in [3]. These experiences verify that the VFT continues to be a helpful technology for the transmission grid in North America.

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