Square D solves a Roller Coaster's Voltage Sag Problem

USA

Paramount King's Island
Cincinnati, Ohio

Linear Induction Motor (LIM) in Amusement Ride Application

Square D ReactiVar™ AV9000 Real-Time Reactive Compensation System

Federal Pioneer
Merlin Gerin
Modicon
Square D
Telemecanique

The massive inrush current associated with starting a large inductive load typically causes a momentary voltage sag. The magnitude of this sag depends on the available fault current and the impedance of the network. In many cases, voltage sags created by inductive load starting within one customer's facility may be disruptive to other nearby utility customers. To effectively solve this problem, the installation of a solid-state (thyristor) switched capacitor bank is required to offload the utility. Schneider Electric / Square D manufactures the AV9000 Real-Time Reactive Compensation (RTRC) featuring solid-state switched capacitor stages to supply instantaneous reactive power. This application note describes an AV9000 installation that corrected the voltage sag experienced by neighbors of a theme park due to a linear induction motor used in a roller coaster.

Paramount King's Island amusement park near Cincinnati, Ohio was one of the first parks in the world to install a roller coaster which uses a linear induction motor (LIM) to electro-magnetically accelerate its vehicles. The Flight of Fear indoor ride's LIM is used to launch a vehicle with 24 riders from 0 to 54 mph in under four seconds. The LIM launch replaces the traditional lift-hill and its relative quietness is ideal for indoor use. Riders are sent through four inversions and more than 50 horizontal and vertical curves in complete darkness. The ride launches a vehicle every other minute creating a voltage sag.

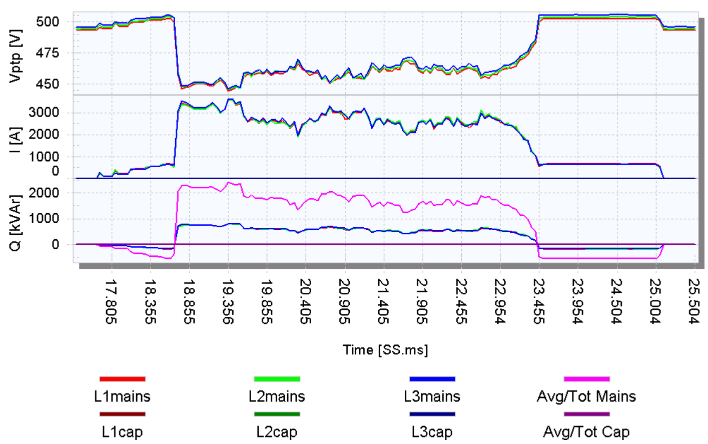
Schneider Electric

Problem:

The voltage sags created with each launch on the 12.47 kV feeder line by the inrush current during vehicle acceleration were severe enough to generate complaints to the utility, Cinergy, by customers neighboring the park. Furthermore, the sags also caused problems for other loads within the park grounds. The Square D Power Quality Correction Group was called in to investigate.

The ride is fed from a dedicated 12.47kV to 480V transformer rated 2.5 MVA. Measurements taken on the ride show a balanced three phase load with a peak of 4200 – 4500 Amps depending on vehicle loading. The load profile reaches full peak in less than 3 cycles. After one second the load settles to 3000 – 3500 Amps for three seconds and then drops to 500A for approximately 3 seconds before dropping off to zero. Nominal voltage on the transformer secondary was 519.6V (line-to-line) but sagged to 458.0 Volts at peak load. The total voltage drop was 61.6 Volts or 11.86%.

LIM Launch of Unloaded Vehicle without AV9000 Compensation

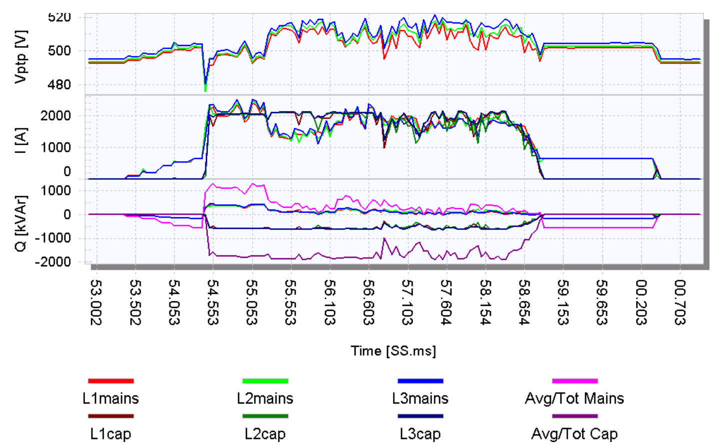


In addition to neighbor complaints, voltage sags created by LIM launches can have safety concerns on the ride itself: there have been several widely publicized cases where a LIM type ride failed to accelerate to sufficient speed due to the electrical grid's inability to support such a large and cyclical load. In at least two cases, a LIM ride's train got stuck in an inversion (upside down) and riders had to be rescued by local emergency response personnel.

Solution:

Schneider Electric / Square D proposed and built a 3150 kVAR AV9000 Real-Time Reactive Compensation system to provide the LIM's reactive starting current and eliminate the voltage drop problem. The unit was built in an outdoor enclosure with two main breakers. The AV9000 monitors the main bus via three current transformers to determine the amount of compensation required. The system was installed and commissioned in April, 2001.

LIM Launch of Unloaded Vehicle with AV9000 System Installed



Two controllers operate 21 stages of 150 kVAR as required by load conditions. This allows for redundancy and good compensation resolution. Each step consists of SCR controlled delta-connected capacitors with series connected reactors to prevent resonance and reduce harmonics on the network. The system can respond in less than one cycle (16.7ms), energizing as many of the stages as necessary to support the ride's launch without creating voltage transients.

Before and After Results with Fully Loaded Vehicle

	No Compensation	3150 KVAR Real Time
Peak Load Current	4200 – 4500 A	2295 A Peak
Real Power	~1600 kW	~1980 kW
Apparent Power	~3310 kVA	~1980 kVA
Reactive Power	~2900 kVAR	Zero +/- 150 kVAR
Power Factor	48.3%	Unity
Nominal Voltage (L-L)	519.6 Volts	493 Volts (after tap change)
Voltage Drop	- 61.6 Volts	+ 26 Volts
Voltage Drop %	11.86% drop	5.30% rise

