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Solving voltage sags

Reactive power compensation rids theme park of complaints and safety concerns

By Rudy Wodrich

Paramount King's Island amusement park near Cincinnati, OH was one of the first parks in the world to install a roller coaster that uses a linear induction motor (LIM) for electro-magnetic acceleration. The Flight of Fear indoor ride's LIM is used to launch a vehicle with 24 riders from zero to 54 mph in under four seconds, sending riders through four inversions and more than 50 horizontal and vertical curves in complete darkness.

The linear induction motor used to launch this roller coaster at Paramount King's Island amusement park used to cause voltage sags that disrupted power to neighbouring utility customers.

The LIM launch replaces the traditional lift-hill and its relative quietness is ideal for an indoor roller coaster. The only problem with it is that the massive inrush current associated with starting a large inductive load like this typically causes a momentary voltage sag. The magnitude of the sag depends on the available fault current and the impedance of the network. In many cases, voltage sags created by an inductive load starting within one customer's facility may be disruptive to other nearby utility customers.

This is exactly what happened with Flight of Fear. The voltage sags created on the 12.47-kV feeder line by the inrush current during vehicle acceleration were severe enough to generate complaints to the utility by customers neighbouring the park. Furthermore, the sags also caused problems for other loads within the park grounds.

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

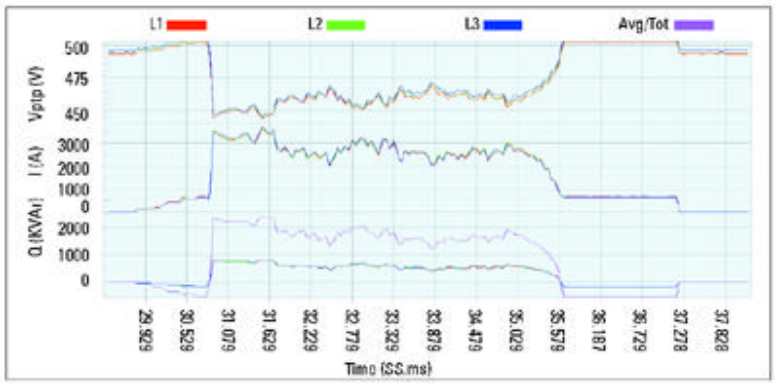
In addition to neighbour complaints, voltage sags created by LIM launches can cause safety concerns on the ride itself. There have been several widely publicized cases where a LIM-type ride failed to accelerate to sufficient speed due to the electrical grid's inability to support such a large and cyclical 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.

To correct this problem, the installation of a high-speed reactive power compensation system is required to offload the utility. 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 to 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.

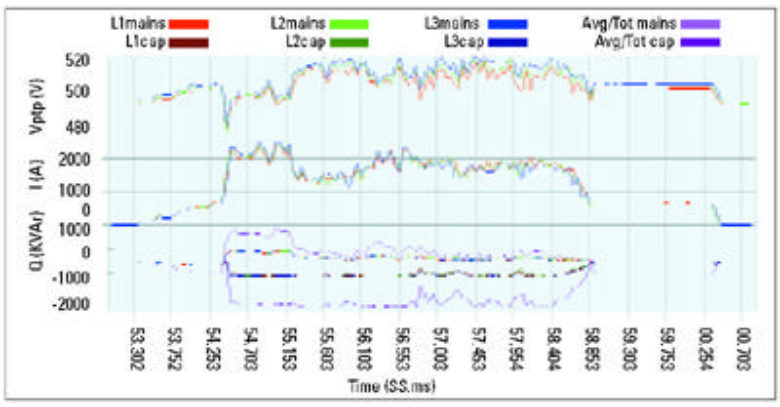
Two controllers operate 21 stages of 150 kVAR as required by load conditions. This allows for redundancy and good compensation resolution. Each step consists of SCR-controlled delta-connected capacitors with series-connected reactors to prevent resonance and reduce harmonics on the network. The system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

The King's Island system was installed and commissioned in April 2001.

Rudy Wodrich is manager of the power quality correction group at Schneider Electric.



LIM launch of unloaded vehicle without AV9000 installed.



LIM launch of unloaded vehicle with AV9000 compensation.