and power. The goal of this test was to verify that the dynamic response of the vehicle to switch between blocks had no negative effect on vehicle control or vehicle ride quality.

The 1st block is made of 4 track modules (60m) and the 2nd block is made of 3 modules (45m). The vehicle starts a test run from the energized block with a specified speed profile. When the center of the vehicle passes the proximity sensor on the track, power is handed off to the new block. No failure occurred during 200 test runs. In this scheme, only one half of the vehicle is powered at the time of switching. This causes the LSM thrust and vehicle speed to drop momentarily as the controller compensate for the loss of speed with an increase in current. The effect of the reduced thrust was assessed by evaluating:

- The ability of the vehicle to start from rest with only half the vehicle covered by powered LSM,
- The effect on the ride quality as the vehicle passes through the switch area.

The time through the switching area and the duration of the reduced thrust varies with vehicle speed. For a low speed run, the time through the switching area is longer and speed reduction and the command current changes are expected to be greater. For a higher speed run, the time through the switching area is shorter with speed reduction and current changes smaller. The following section discusses the testing performed to validate these issues.

3.2.1 Vehicle starts from rest with partial LSM coverage

Test runs were made to assess the vehicle starting from rest with less than 50% of motor powered. This situation arises when the vehicle stops between the two LSM blocks. Starting from 50%, the powered armature section was reduced until the vehicle was not able to move under LSM power. The smallest motor section generating enough thrust was found to be about 35%. In all cases of the test runs, the vehicle started with acceptable currents in the range of 2000 to 2500amps.

3.2.2 Effect of Switching on the Vehicle Speed and Current

Effect of switching on the vehicle speed and current is shown in Figures 3.3 and 3.4. These figures show speed decreasing during the switching due to the reduced thrust. The speed reduction, however, is relatively small since the LSM control quickly increases the current to make up for the reduced speed.

The effect of switching on the speed is higher when speed is low, and lower as the vehicle speed increases.

At 6m/s, the speed reduction is less than 2% and at 3m/s, the speed reduction is around 10%. However, the speed reduction was not noticeable to the passenger.

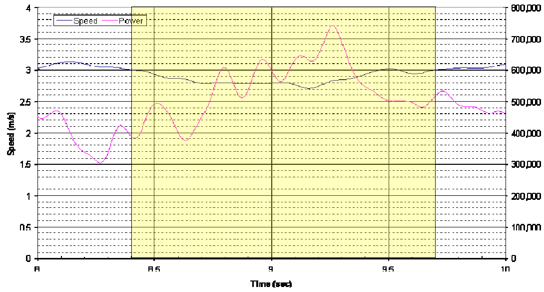

Figure 3.3 Effect of Switching on the Speed and Current (3m/s)

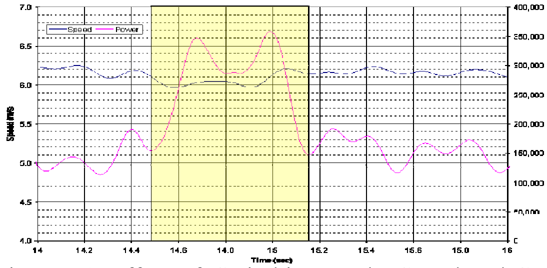

Figure3.4 Effect of Switching on the Speed and Current (6m/s)

3.2.3 Effect of Block Switching on LSM Control

Figure s 3.3 and 3.4 confirm that the control system is stable and well within its operational parameters to handle the disturbances created during the block switching. Some of the operational parameters or limits set by the control are the maximum current output and maximum current change rate. These values were set to protect the component of the inverter. Presently, the inverter operates with limit settings of a maximum current of 4000A and a maximum current change rate of 5,000A/s. No adverse effects of block switching on the LSM control were detected during this test program.

3.2.4. Effects of Switching on the Ride Quality

Ride quality is normally evaluated by measuring acceleration over a period of 10 to 15 sec during a constant speed (cruise). However, the block switching time for a 7m/s run is only 0.6 seconds. The disturbance contributed by the switching is of such a short duration that it was not detectable during normal ride quality evaluation. Figures 3.5 and 3.6 compare two ride quality plots, without and with block switching, respectively. Both ride quality plots, provide very similar results and the exposure limits for 2.5-hour reduced ride comfort. Any noticeable effects on ride quality were not detected.

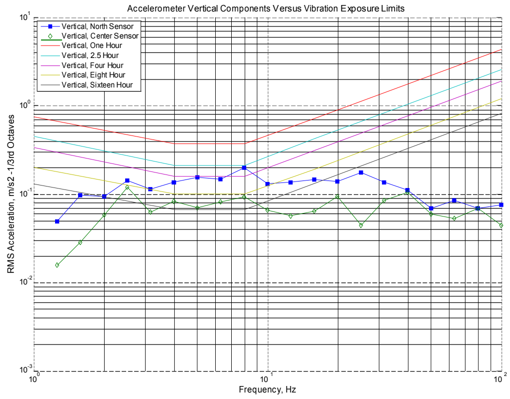

Figure 3.5 Ride Quality w/o Block Switches

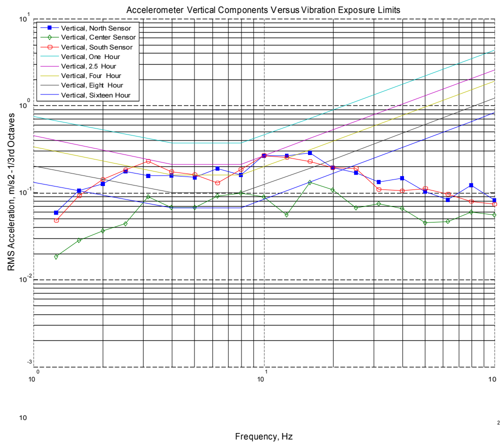

Figure 3.6 Ride Quality w/ Block Switches

3.2.5 Effect of Block Length on the LSM Power

The primary goal of the block switch in the Linear Synchronous Motor system is to improve the motor efficiency. Power in the uncovered sections provides no mechanical work and is dissipated as I^2R heating, which increases with the powered block length. Originally, our test track was powered as a single block of 7 guideway modules (105m). The re-configured track is made of two LSM blocks, one with 4 guideway modules (60m) and the other with 3 modules (45m).

It is expected that when the vehicle is on the 4-module block, the power consumption will be higher than when the vehicle is on the 3-module block. The test runs were made such that the switching took place during a cruise run. Figure 3.7 shows the power level variation during switching from the 4-module block to 3-module block. The power level decreased from about 64kW to 39kW which was close to what would be expected.

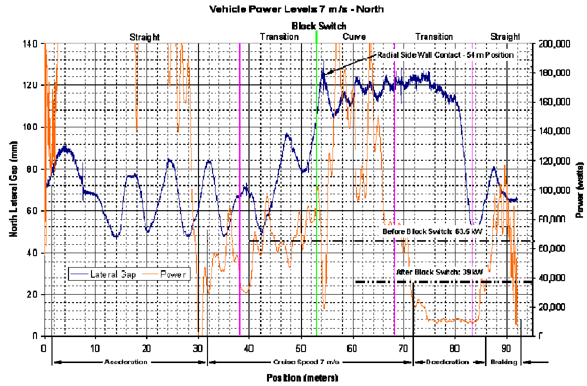

Figure 3.7 Power Level Variation between 4-Block Section and 3-Block Section

4.0 Conclusion

The block switch test confirmed that the selected block switch hardware and architecture is acceptable for a deployed urban system. The following conclusions may be made:

- The sequential block switching approach is successfully applied to the low speed urban maglev LSM system.
- The full power hand-off up to 2000A seems reliable and safe.
- The max SCR temperature was well below 120C of the maximum allowed.
- The disturbance during the switching does not cause a noticeable effect on the ride quality.
- The block switch has no ill effect on the LSM control.