

MI PS RAMP RATES

- * Present Power Supply Capability
- * Improvements Needed for
1.0 Second Cycle Time Operation
- * Improvements Needed for
1.34 Second Cycle Time Operation

Present Power Supply Capability

- Bend Bus: Regulated: +11.8kV/-10.8kV
- Quad Bus Regulated: +2.8kV/-2.5kV
- Min. Cycle Time Type 23 (NuMI):
1.75 Seconds (0.5 sec injection)

Present (3/05) 23 Ramp

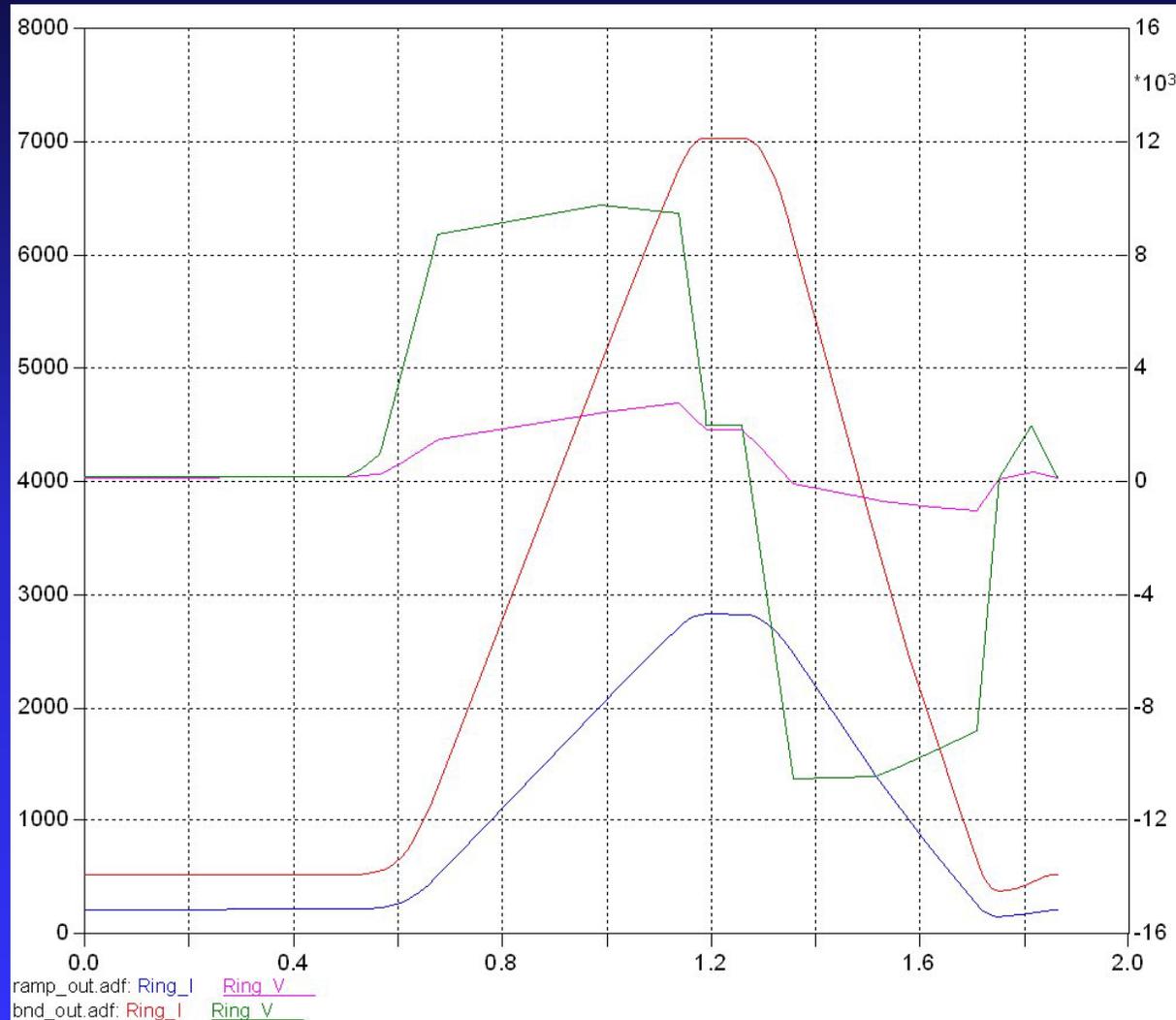
Delta t	Time	Momentum	Pdot
0.50000	0.50000	8.884	0.00
0.02533	0.52533	8.96	6.00
0.04154	0.56687	9.5	20.00
0.11111	0.67798	22	205.00
0.30732	0.98530	85	205.00
0.15385	1.13915	115	185.00
0.05081	1.18996	119.7	0.00
0.07000	1.25996	119.7	0.00
0.09800	1.35796	105	-300.00
0.15517	1.51313	60	-280.00
0.19600	1.70913	11	-220.00
0.04182	1.75095	6.4	0.00
0.06198	1.81293	7.7945	45.00
0.04842	1.86135	8.884	0.00
0.00500	1.86635	8.884	0.00

Minimum Cycle Time Ramp

Delta t	Time	Momentum	Pdot
0.50000	0.50000	8.884	0.00
0.02533	0.52533	8.96	6.00
0.04154	0.56687	9.5	20.00
0.08333	0.65021	22	280.00
0.23774	0.88794	85	250.00
0.13636	1.02430	115	190.00
0.04947	1.07378	119.7	0.00
0.07000	1.14378	119.7	0.00
0.09639	1.24017	105	-305.00
0.15385	1.39402	60	-280.00
0.19600	1.59002	11	-220.00
0.04182	1.63184	6.4	0.00
0.06198	1.69381	7.7945	45.00
0.04842	1.74224	8.884	0.00
0.00500	1.74724	8.884	0.00

Present Bend and Quad Ramps

Ring voltage and current



Improvements Needed for 1.0 Second Cycle Time

but... unknown PS regulation – will beam make it?

■ Ramp Description

Time	Momentum	Pdot	Pddot
<u>0.34000</u>	8.889	0.00	0.00
<u>0.41037</u>	30	600.00	8526.36
<u>0.52901</u>	100	580.00	-168.57
<u>0.59695</u>	119.7	0.00	-8538.07
<u>0.61695</u>	119.7	0.00	0.00
<u>0.66763</u>	105	-580.00	-11442.18
<u>0.82693</u>	15	-550.00	188.33
<u>0.85711</u>	6.7	0.00	18222.89
<u>0.90575</u>	7.7945	45.00	925.08
<u>0.95440</u>	8.889	0.00	-925.08
<u>0.95540</u>	8.889	0.00	0.00

Changes:

Injection parabola 70 ms

Flattop parabola 70 ms

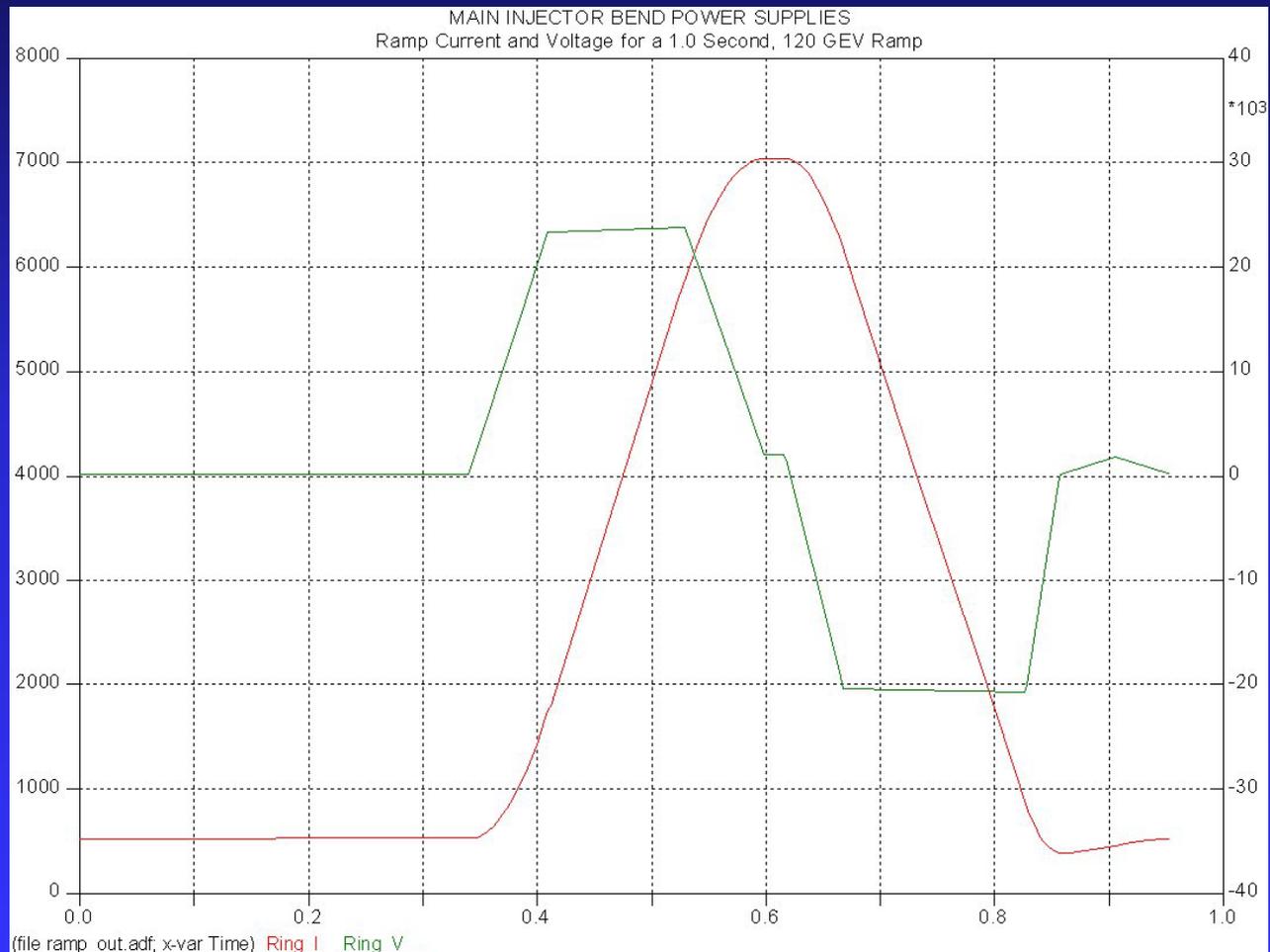
Invert parabola 50 ms

(Limited by max. PS slew rate while maintaining reasonable voltage regulation)

Ramp undershoot kept the same

Improvements Needed for 1.0 Second Cycle Time Operation

■ Ramp Waveform



Improvements Needed for 1.0 Second Cycle Time Operation

■ Power Numbers

Bend Bus

INPUT DATA :

Ring current/energy ratio (amps/GEV) = 58.759
Total ring inductance (Henry) = .65000
Total ring resistance (ohms) = .28600
Desired Max. Operating Voltage for Holding PS = 0.201E+04
Desired Max. Operating Voltage for Ramping PSs = 0.201E+04
Number of power supplies = 12
Maximum Voltage Available from Holding PS = 2200.0
Maximum Voltage Available from Ramping PS = 2200.0
The Power Supply Turn-on order:
1 3 6 9 12

RAMP CALCULATIONS :

Peak ramp current (amps) = 7033.4
Total RMS ramp current (amps) = 3348.2
Min. and max. ramp voltage (volts) = -20754. 23833.
Maximum number of power supplies = 12
Ramp power (watts) = 0.32062E+07

FEEDER CALCULATIONS :

Peak feeder current (amps) = 6533.9
RMS feeder current (amps) = 2762.5
RMS feeder volt-amps (v-a) = 0.66030E+08

REAL/REACTIVE POWER CALCULATIONS :

Peak real power (watts) = 0.14004E+09
Peak reactive power (vars) = 0.93873E+08
Average real power (watts) = 0.32400E+07
Average reactive power (vars) = 0.23221E+08
Peak volt-amps = 0.15617E+09
Average volt-amps = 0.41907E+08

Quad Bus

INPUT DATA :

Ring current/energy ratio (amps/GEV) = 23.640
Total ring inductance (Henry) = .23600
Total ring resistance (ohms) = .64000
Desired Max. Operating Voltage for Holding PS = 880.
Desired Max. Operating Voltage for Ramping PSs = 0.110E+04
Number of power supplies = 6
Maximum Voltage Available from Holding PS = 1300.0
Maximum Voltage Available from Ramping PS = 940.00
The Power Supply Turn-on order:
1 2 3 4 5 6

RAMP CALCULATIONS :

Peak ramp current (amps) = 2829.7
Total RMS ramp current (amps) = 1347.1
Min. and max. ramp voltage (volts) = -2841.5 4748.8
Maximum number of power supplies = 6
Ramp power (watts) = 0.11613E+07

FEEDER CALCULATIONS :

Peak feeder current (amps) = 552.83
RMS feeder current (amps) = 192.66
RMS feeder volt-amps (v-a) = 0.46050E+07

REAL/REACTIVE POWER CALCULATIONS :

Peak real power (watts) = 0.11226E+08
Peak reactive power (vars) = 0.71034E+07
Average real power (watts) = 0.11633E+07
Average reactive power (vars) = 0.17025E+07
Peak volt-amps = 0.13214E+08
Average volt-amps = 0.29162E+07

Improvements Needed for 1.0 Second Cycle Time Operation

■ Power Supply Requirements

Basically, need to double the maximum available power supply voltage

Plan: Add 2 Bend power Supplies and 1 Quad power to every MI Service Building

Voltage to Ground Effects:

Bend Bus 500 v to 1kV

Quad Bus unchanged

Improvements Needed for 1.0 Second Cycle Time Operation

■ Modifications Needed

MI Service Buildings

- Need to be Enlarged

 - Preferably, straight out from PS room

Transformer pads

- Additional pads and feeder work needed

Power Supplies

- 2 Additional Bends and 1 additional Quad

- Tunnel Bus Extended to pick up added PS's

- Additional Water cooling for PS's

- Additional PS Controls

Improvements Needed for 1.0 Second Cycle Time Operation

■ Modifications Needed – Continued

MI PS Feeders:

Might Need to double the number – more study needed
Duct Bank probably OK except for MI 60

Kautz Road Substation

2 Additional 345kV transformers needed
Substation building expanded
2 Additional Harmonic Filters Needed

Improvements Needed for 1.34 Second Cycle Time

but... unknown PS regulation – will beam make it?

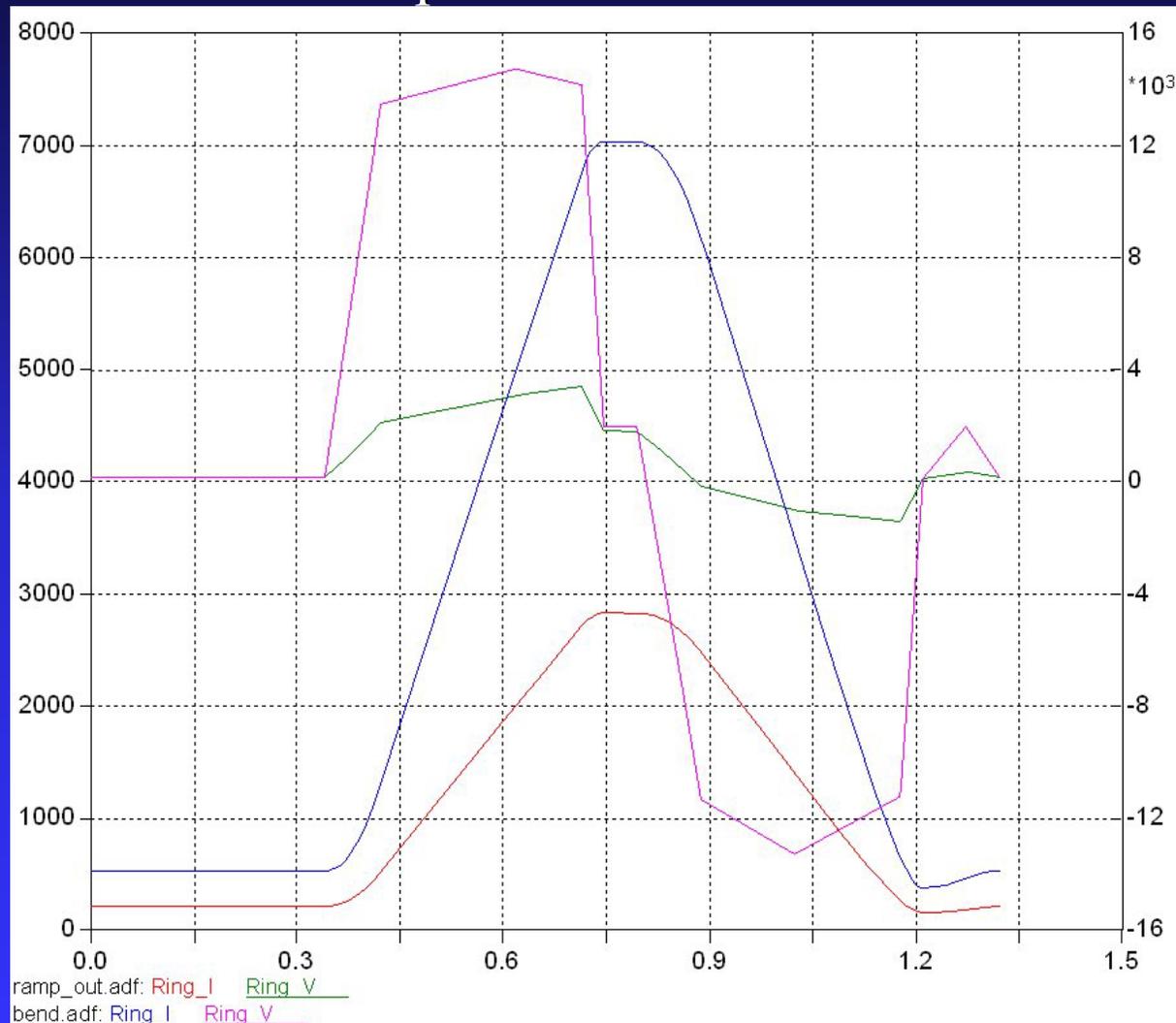
■ Ramp Description

Ramp undershoot kept the same

Delta t	Time	Momentum	Pdot	Pddot	PS Volt
0.34000	<u>0.34000</u>	8.884	<u>0.00</u>	<u>0.00</u>	147.22
<u>0.08198</u>	<u>0.42198</u>	22	320.00	<u>3903.63</u>	13452.01
<u>0.19535</u>	<u>0.61732</u>	85	325.00	<u>25.60</u>	14700.46
<u>0.09600</u>	<u>0.71332</u>	115	300.00	<u>-260.42</u>	14175.13
<u>0.03133</u>	<u>0.74466</u>	119.7	0.00	<u>-9574.47</u>	1983.53
0.05000	<u>0.79466</u>	<u>119.7</u>	<u>0.00</u>	<u>0.00</u>	1983.53
<u>0.09188</u>	<u>0.88653</u>	105	-320.00	<u>-3482.99</u>	-11347.51
<u>0.13433</u>	<u>1.02086</u>	60	-350.00	<u>-223.33</u>	-13320.15
<u>0.15556</u>	<u>1.17642</u>	11	-280.00	<u>450.00</u>	-11269.24
<u>0.03286</u>	<u>1.20927</u>	6.4	0.00	<u>8521.74</u>	106.05
<u>0.06198</u>	<u>1.27125</u>	7.7945	45.00	<u>726.07</u>	1969.58
<u>0.04842</u>	<u>1.31967</u>	8.884	0.00	<u>-929.33</u>	147.22
0.00500	<u>1.32467</u>	<u>8.884</u>	<u>0.00</u>	<u>0.00</u>	147.22

Improvements Needed for 1.34 Second Cycle Time Operation

■ Ramp Waveforms



Improvements Needed for 1.34 Second Cycle Time Operation

■ COSTS WAGs!!! As of 3/01/05

Service Building Civil	\$?.0M
Power Supplies	\$2.1M
Quads: 4x 150k (mod. To 1200Vdc)	
Bends: 3x 500k	
Feeders	\$0.7M
Kautz Road Substation	
1, 345 kV Transformers	\$1.1M
Construction and Installation	\$0.9M
Building Changes	\$0.5M
Harmonic Filters	\$0.25M