

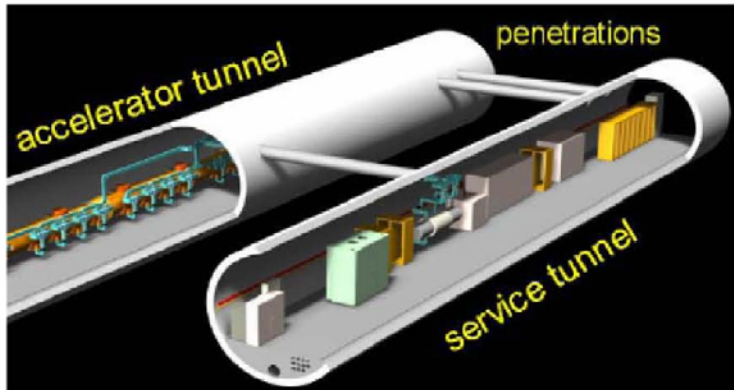
ILC Modulator Power Supply

R. Cassel

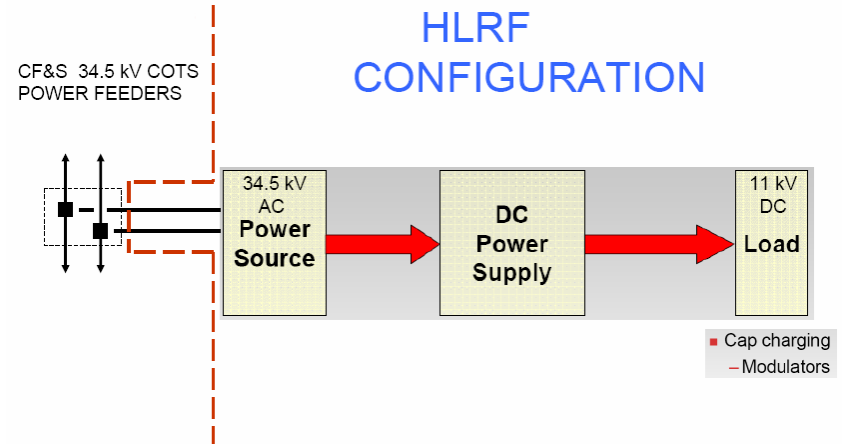
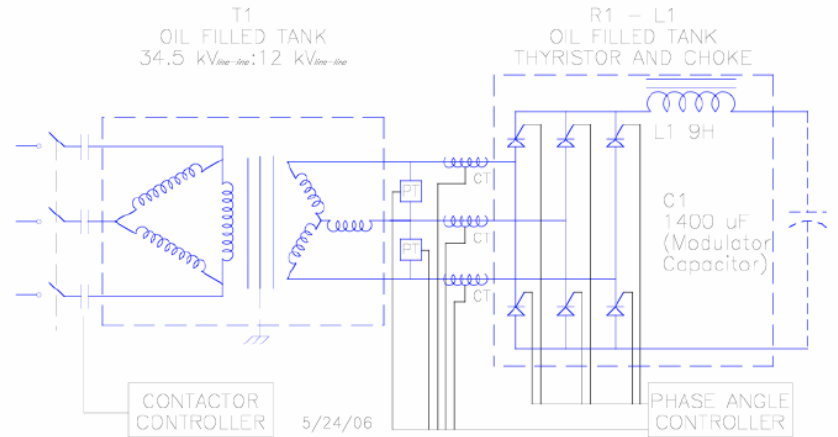
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Present ILC Modulator Supply

- Max depth 1.8 Meters
- Max High 2.0 meters
- Max Length 2.2 Meters



Charging Supply Cost Estimate Model

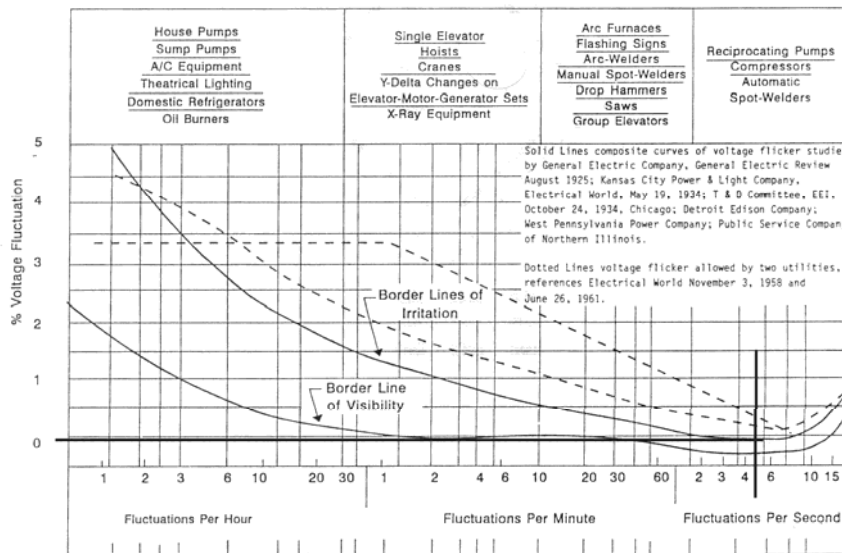


ILC Marx Modulator Supply Problems

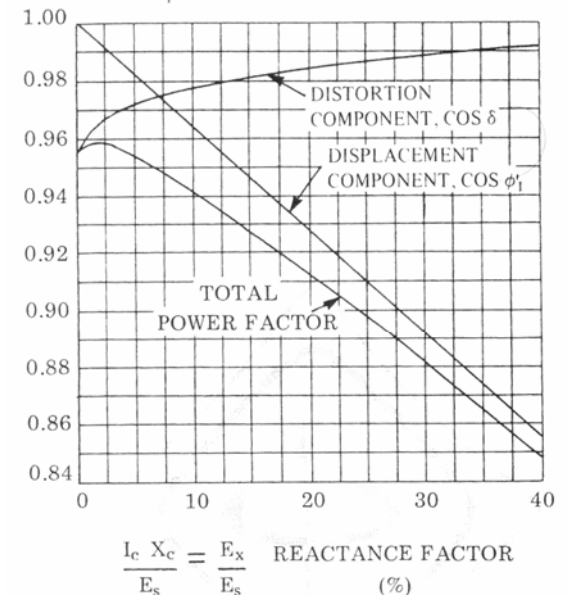
- **Use of SCR control power supply results in Power swings on the power lines**
 - Reactive power changes during pulse
- **Costs of supply is high**
 - 120 kilowatts SCR supply at 12kV is expensive
- **Control of charging voltage difficult.**
 - SCR Supplies are voltage supplies driving a large capacitor resisting in inductive filter which is difficult to control variable repetition rates

Power Line Voltage Swings

- Voltage fluctuation can be a problem at 5Hz
 - Power Changes results in voltage fluctuations
- SCR control has poor power factor when it is phase back to 70%-80% voltage
 - Reactive power changes fluctuates voltage



Maximum Permissible Voltage Fluctuations



Relationship Between Distortion, Displacement, and Total Power Factor Components

Cost of supply is high for the Power Provided

- 35kV input Voltage or 11kV output voltage the currents are Low
 - ~22 amps RMS secondary
 - Number of SCR in Series from 6 to 15
- Transformers for 120 kW at 35kV are expensive.
 - The “Costing model” use 225kVa Transformers
 - Mechanically they 225kva and 150kVA are close in size

Three-Phase Pad-mounted Compartmental Type

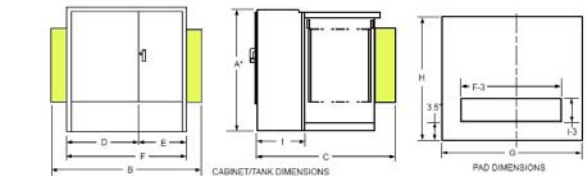
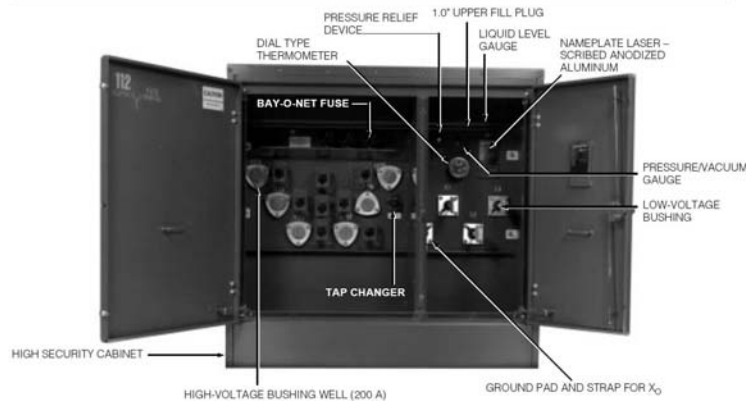


Figure 3. Transformer and Pad Dimensions.

*Add 2" for Bay-O-Net fusing.

TABLE 6 Typical Dimensions and Weights¹

kVA Rating	65°C Rise	DEAD-FRONT LOOP OR RADIAL FEED - BAY-O-NET FUSING ¹ OIL FILLED -ALUMINUM WINDINGS									Gallons Of Fluid	Approx. Total Weight (lbs.)
		OUTLINE DIMENSIONS (in.)										
		A'	B	C	D	E	F	G	H	I		
45		50	68	39	42	26	68	72	43	20	150	2600
75		50	68	39	42	26	68	72	43	20	160	2800
112.5		60	68	49	42	26	68	72	53	20	165	2900
150		60	68	49	42	26	68	72	53	20	170	3200
225		60	72	51	42	30	72	76	55	20	180	3800
300		60	72	51	42	30	72	76	55	20	190	4450
600 ²		60	99	53	42	30	72	90	57	20	240	5700
750 ²		64	99	57	42	30	72	90	61	20	300	8200
1000 ²		64	99	59	42	30	72	90	63	20	480	10,100
1500 ²		73	99	66	42	30	72	90	90	24	570	13,950
2000 ²		73	72	67	42	30	72	76	91	24	640	15,000
2500 ²		73	72	69	42	30	72	76	103	24	760	19,850
3000 ²		73	84	69	46	37	84	88	103	24	780	19,000
3750 ²		84	85	108	47	38	85	88	112	24	800	19,500
5000 ²		84	96	108	48	48	96	100	112	24	900	29,400
7500 ²		94	102	122	54	48	102	100	126	24	1580	41,900

SCR Control are Difficult

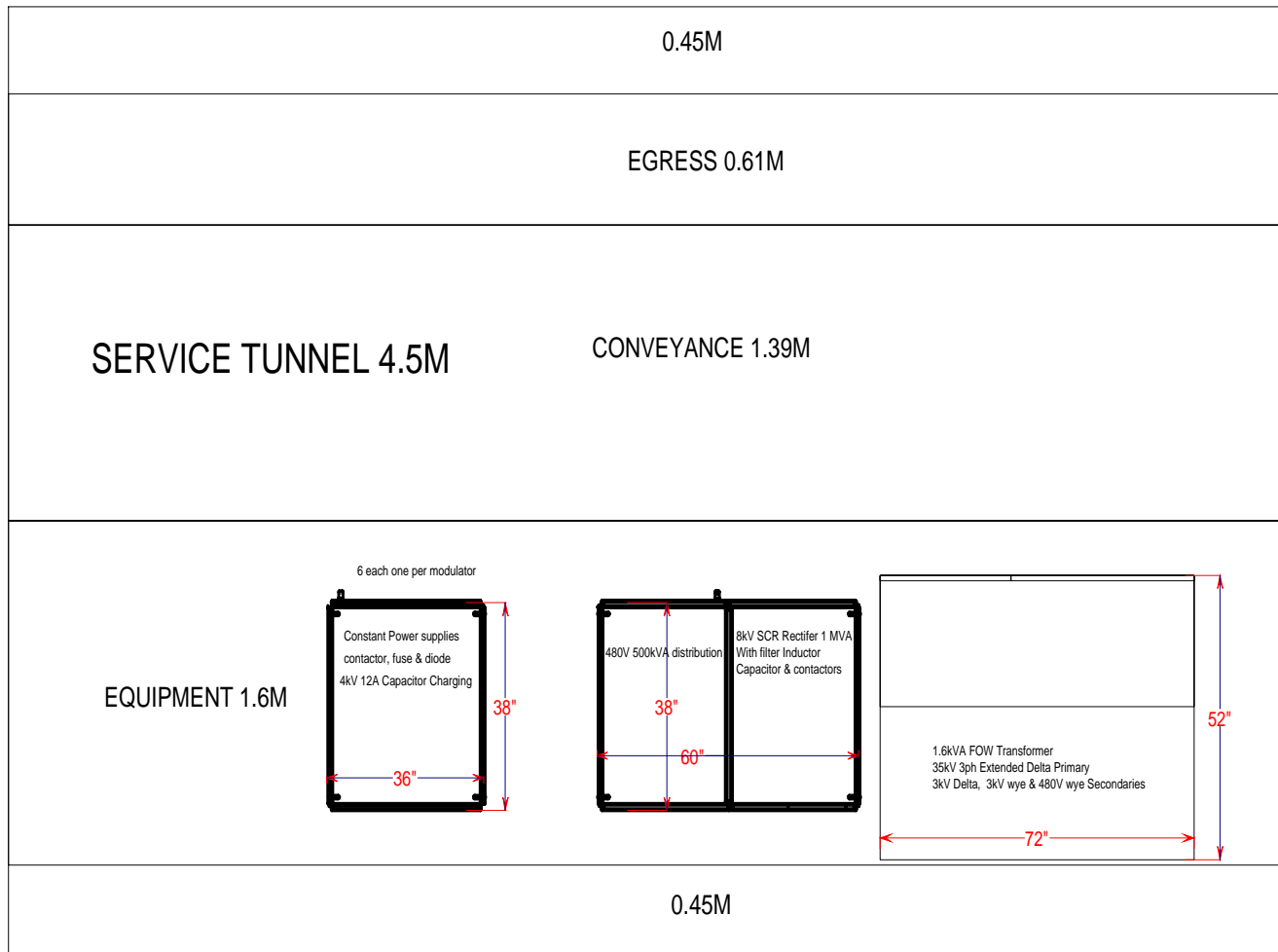
- A voltage droop of ~20% means the SCRs should be Phased back every pulse to keep from causing Real power Line fluctuations.
 - At changing repetition rate the needs to be controlled to compensate for the reduce power supplied
- A Filter inductor needs to be large enough to not only reduce harmonics on the power line but also give the supply to reduce its voltage to ~80% without excessive currents.

Proposed Alternative Charging Supply System

- Power Line fluctuations can be reduced by use of Switching type supplied.
 - They are expensive if all the power comes from charging supplies
- A transformer and rectifier better optimized for high voltage input & output voltage should be used.
 - ~1.5MVA FO water cooled would be a better size for 35kv and 12kV DC
 - Transformers should be phase shifted for 12 phase or higher operation
 - ~ 100 Amps RMS Line current
- Rectifier at ~ 8kV DC output ~150 amps 6 phase would be a more economical size.
 - Use SCRs in the rectifier for short circuited protection and start up only
- The Modulator voltage droops by 20-30% due to the 1.6 millisecond pulse
 - A ~ 8kV DC output rectifier would provide constant power to the drooping pulse.
 - A switching supply would make up the voltage, operating in a constant power mode.
- Isolation Switch would allow independent operation of the Power supplies.
- Fuses, Disconnect and Diodes could provide the equipment and personnel Safety.
- Sectionalizing switches could allow for operation if a transform rectifier failed

Proposed Alternative Charging Supply System

- Size of proposed equipment



Alternative Charging Supply System Cost

each 4kV Modulators			\$53.00			15.00%		
Using Clay Corvin Distribution Costs			Material	Labor	Total			
Qty	Item Descriptions	Hours	\$US	US\$ IL	\$US	\$US	"O&P	Total
6	.48kVAC~4kVDC EMI 303 4kV, 50kJ/sec	0 Ea.	\$41,000	\$0	\$41,000	\$246,000	\$282,900.00	\$282,900
1	kV pri, 277/480 V sec, 3 ph, 1000 kVA	50 Ea.	24450	\$2,650	\$27,100	\$27,100	\$31,165.00	\$31,165
39	THWN-THHN, in raceway	3.64 CLF	226	\$193	\$419	\$16,338	\$18,788.56	\$18,789
700	terminations, 2 els, 11 clamps per 100 LF	0.12 LF	6.4	\$7	\$13	\$9,043	\$10,399.80	\$10,400
6	Hardware	5.25 Lot	715	\$278	\$993	\$5,960	\$6,853.43	\$6,853
4	enclosed NEMA 1	4 Ea.	900	\$212	\$1,112	\$4,448	\$5,115.20	\$5,115
1	4 wire, 120/208 volt, 225 amp	13.33 Ea.	3105	\$707	\$3,812	\$3,812	\$4,383.40	\$4,383
5	neutral 35kv 1/0 in RSC	4.71 CLF	410	\$249	\$659	\$3,297	\$3,791.65	\$3,792
7	4/0	2.81 CLF	230	\$149	\$379	\$2,651	\$3,049.11	\$3,049
1	amp, enclosed NEMA 1	4 Ea.	1800	\$212	\$2,012	\$2,012	\$2,313.80	\$2,314
6	for feeder section	1.51 Ea.	246	\$80	\$326	\$1,956	\$2,249.24	\$2,249
6	insulation dia, .975 to 1.570	1.51 Ea.	183	\$80	\$263	\$1,578	\$1,814.54	\$1,815
24	Grounding clamp, bronze, 5/8 diameter	0.25 Ea.	4.2	\$13	\$17	\$419	\$481.62	\$482
3.6	THWN-THHN, in raceway	0.73 CLF	7.1	\$39	\$46	\$164	\$188.91	\$189
Subtotal						\$78,151	Modulator	\$373,494
Modulators								
Qty	Item Descriptions	Hours	\$US	US\$ IL	\$US	\$US	"O&P	Total
1	8kV 200A SCR rectifier	12 Ea.	\$890.00	\$636	\$1,526	\$1,526	\$1,754.90	\$1,755
1	controls	24 Ea.	5000	\$1,272	\$6,272	\$6,272	\$7,212.80	\$7,213
1	Enclosure	6.67 Ea.	2100	\$353	\$2,453	\$2,453	\$2,821.35	\$2,821
1	2 phase 80A 12kV vacuum contactors	16 Ea.	800	\$848	\$1,648	\$1,648	\$1,895.20	\$1,895
1	8kV capacitor bank 1kJ	18 Ea.	600	\$954	\$1,554	\$1,554	\$1,787.10	\$1,787
1	filter inductor	18 Ea.	250	\$954	\$1,204	\$1,204	\$1,384.60	\$1,385
6	36 D	6.67 Ea.	2100	\$353	\$2,453	\$14,720	\$16,928.12	\$16,928
2	80A 12kV vacuum contactors	16 Ea.	980	\$848	\$1,828	\$3,656	\$4,204.40	\$4,204
6	80A 12kV vacuum contactors	8 Ea.	530	\$424	\$954	\$5,724	\$6,582.60	\$6,583
6	diode 25kV 15A	8 Ea.	850	\$424	\$1,274	\$7,644	\$8,790.60	\$8,791
6	15A 12kVDC fuse	8 Ea.	98	\$424	\$522	\$3,132	\$3,601.80	\$3,602
5	neutral 15kv 1/0 in RSC	4.71 CLF	410	\$249	\$659	\$3,297	\$3,791.65	\$3,792
700	terminations, 2 els, 11 clamps per 100 LF	0.12 LF	6.4	\$7	\$13	\$9,043	\$10,399.80	\$10,400
24	15kv cable terminations	13.33 Ea.	150	\$707	\$857	\$20,560	\$23,643.51	\$23,644
Subtotal					159 Hr labor	Modulator		\$94,798
Total						Modulator		\$468,293
						724		\$56,507,318
						modulator		\$78,049
						\$/watt		\$0.52

Baseline Charging Supply Costs

Fermi Charger using Clay Corvin costs									
53									
15.00%									
Qty	Item Descriptions	Hours		\$US	IL	\$US	\$US	"O&P	Total
724	1 sec, 3 ph, 225 kVA	36.364	Ea.	12535	1,927.30	247	14,462	\$16,632	\$16,632
4344	6 1.570	1.509	Ea.	183	80	0	1,578	\$1,815	\$1,815
5129	7.08 raceway	1.78	CLF	76.5	94.3	0	1,210	\$1,392	\$1,392
724	1 Other: EMS, SCADA, RF X-Locks, Hardware	5.25	Lot	715	278.3	0	993	\$1,142	\$1,142
18100	25 Wireway, screw cover, 6 x 6, NEMA 1, incl fittings and supports	0.267	LF	19.1	14.2	0	831	\$956	\$956
1086	1.5 Circuit breakers, 3 pole, 480 V, to 100 amp, for feeder section	2	Ea.	475	106	0	872	\$1,002	\$1,002
1368	1.89 Ground wire, copper wire, bare stranded, 4/0	2.807	CLF	178	148.8	0	617	\$710	\$710
22806	31.5 Grounding clamp, bronze, 5/8 diameter	0.25	Ea.	4.2	13.3	0	550	\$632	\$632
1086	1.5 1.570	1.509	Ea.	183	80	0	394	\$454	\$454
363	0.5 Shielded cable copper XLP gounded neutral 35kv 1/0 in RSC	4.706	CLF	410	249.4	0	331	\$380	\$380
14500	20.03 per 100 LF	0.123	LF	6.4	6.5	0	259	\$298	\$298
							Transformer		\$25,412
							Charger cost		\$80,000
							Modulator		\$105,412
							\$/Watt		\$0.70
(SCR power supply Cost per Fermi \$80,000 each 724 units)							Total COST		\$76,318,283