Power Supply System

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POWER SUPPLY SYSTEM

BNL/NSNS TECHNICAL NOTE

NO. 014

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1.5.4 POWER SUPPLY SYSTEM

The NSNS main ring (MR) has to have good stability, flexibility and reliability. Thus, the power supplies (ps), that supply energy to the main dipoles and quadrupoles, will be designed in a conservative manner to produce the high stability and reliability. The flexibility will be provided by a number of correctors that control fractional tunes and the various stopbands that will be encountered. A preliminary list of the ps's is shown in table 1. The parameters and present designs are described in the following sections. One quarter of the MR (superperiod) is shown in figure 1. The designations of the main magnets is also shown.

1.5.4.1 - Dipole PS

The 32 main ring dipoles will be connected in series to a single, large ps. The main requirement is to provide a stable bending field. The long-term and short-term stability shall be better than 1 part in 10^4. This includes drift after an initial warm-up, and high frequency ps ripple. The latest ps design parameters are shown in table 2, while the magnet parameters are shown in the magnet section 1.5.3. The dominant parameter is the required high power. In order to handle this, the dipole ps will be an ac to dc converter utilizing multi-phase, thyristor (SCR) control. Many units with these ratings have been used successfully in proton accelerators and Light Sources for a number of years.

The basic dipole converter scheme is shown in figure 2. The main sub-systems consist of high-voltage switchgear, outdoor transformers, thyristor bridges, passive filter, free-wheeling rectifiers (FWD), and voltage and current sensors. Regulation, protection and control circuitry will be designed to protect and provide the fine control required. The fundamental output ripple will be 12-pulse or 720 Hertz. To reduce the voltage ripple further, it is planned to use a damped, passive 2nd order filter. It will be a balanced LCRC type, with the R and the capacitor ratio chosen to make the filter close to critically damped. The cutoff frequency will be selected to reduce the fundamental ripple by approximately a factor of 50. Lower sub-harmonic frequencies will be controlled by system balance and by feedback from the regulator to the SCR triggering circuits.

The heart of the dipole ps system consists current and voltage regulators. Both of these will produce analog feedback error signals to the SCR triggers. The fundamental 12-pulse ps sampling frequency enables a wider closed loop bandwidth than a 6-pulse unit. Sensing of dc output current will be by a DCCT (dc current transformer), and the voltage sensor will be a DCPT (dc potential transformer). The advantages of these type sensors is that they provide ground and galvanic isolated signals from the power circuitry and hence lower electrical noise. The reference to the feedback loop will be via a 16-bit digital-to-analog (D/A) converter that will be mounted near the main regulator. The digital communication to the D/A and to the ps monitoring via an accurate

FIGURE 1 :- NSNS

LAYOUT & NOMENCLATURE

3-97

HEBT

"A"

SUPERPERIOD

INJECTION

A/D (analog-to-digital converter), will be via fiber-optic links. The basic computer control interface is shown in figure 3. Analog signals will be also fed to a lower accuracy (12 bit) multiplexed A/D converter and memory for fault analysis after a machine beam abort. Designs of this type have been developed at BNL for use by RHIC. Further details can be found in the controls sections (Beam Abort System).

The ps will be fully protected with standard ac and dc overload relays. Over-temperature of critical water-cooled components such as the SCR's, the filter choke and FWD's will be employed. Fuse failures and filter capacitor fuses will be alarmed. A magnet ground fault detection circuit will be implemented. Errors will be monitored and conveyed to the higher level host control computers for detailed analysis. The local control and some of the protection functions will be handled by a programmable logic controller (PLC). These units are commercially available and exhibit high reliability. Both analog and digital type modules can be obtained. A high-level communication module is available that plugs into and communicates to the local front end computer in the VME chassis. This local network link is either via metallic or fiber-optic cable (see figure 3).

Table 1- List of NSNS Main Ring PS's

Main Dipole	1	
Main Quadrupole	3	
Quadrupole Trim	4	
Horiz. Dipole Correctors	24	
Vert. Dipole Correctors	24	
Skew Quadrupole	4	
Quadrupole 1/2 Integer	4	
Sextupole 1/3 Integer	4	
Skew Sextupole	4	
Octupole	4	
Inj. Dump Line Quadrupoles	2	(See HEBT Area)
Inj. Dump Line Correctors	2	(" " ")

Total   80-4=76

Table 2- Main Ring Dipole PS Design Parameters

No. Dipoles	32
Bend Angle/Magnet	11.25 deg.
No. Power Supplies	1
Type	DC-SCR
Configuration	12-Pulse
Ring Connection	Series, Folded-Bus
Ring Bus	Water-Cooled Copper
Bending Field	7.08 KG
B/I Transfer Function	1.7 KG/KA
PS Maximum Current	4.5 KA
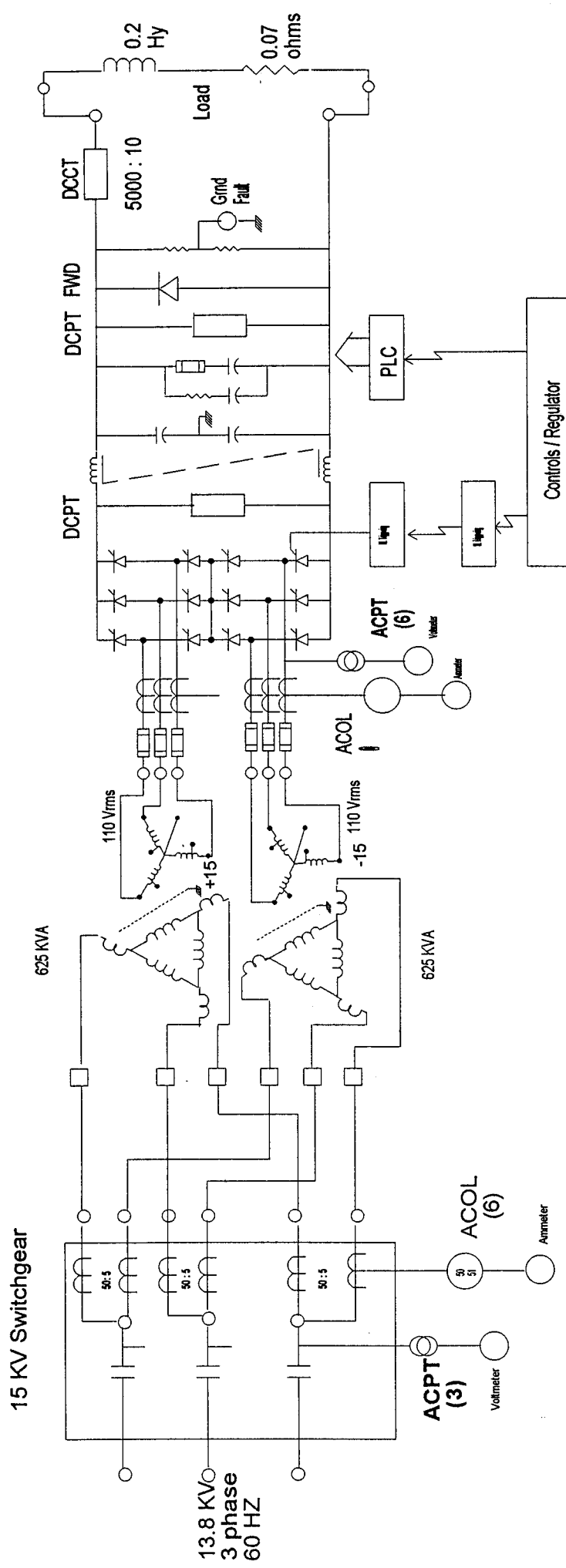
FIGURE 2: - Diagram of the NSNS Dipole
Power Supply
1.5.4.1

Power Supply Group

Power Supply Regulator

D/A

MUX

A/D

Optical Decoder

Commands (3)
Status (16)

AB PLC

Controls Group

VME Crate

AB PLC VME Module

RHC Waveform Generator Module

Fiber Optic Cable

Fiber Optic Cable

Fiber Optic Cable
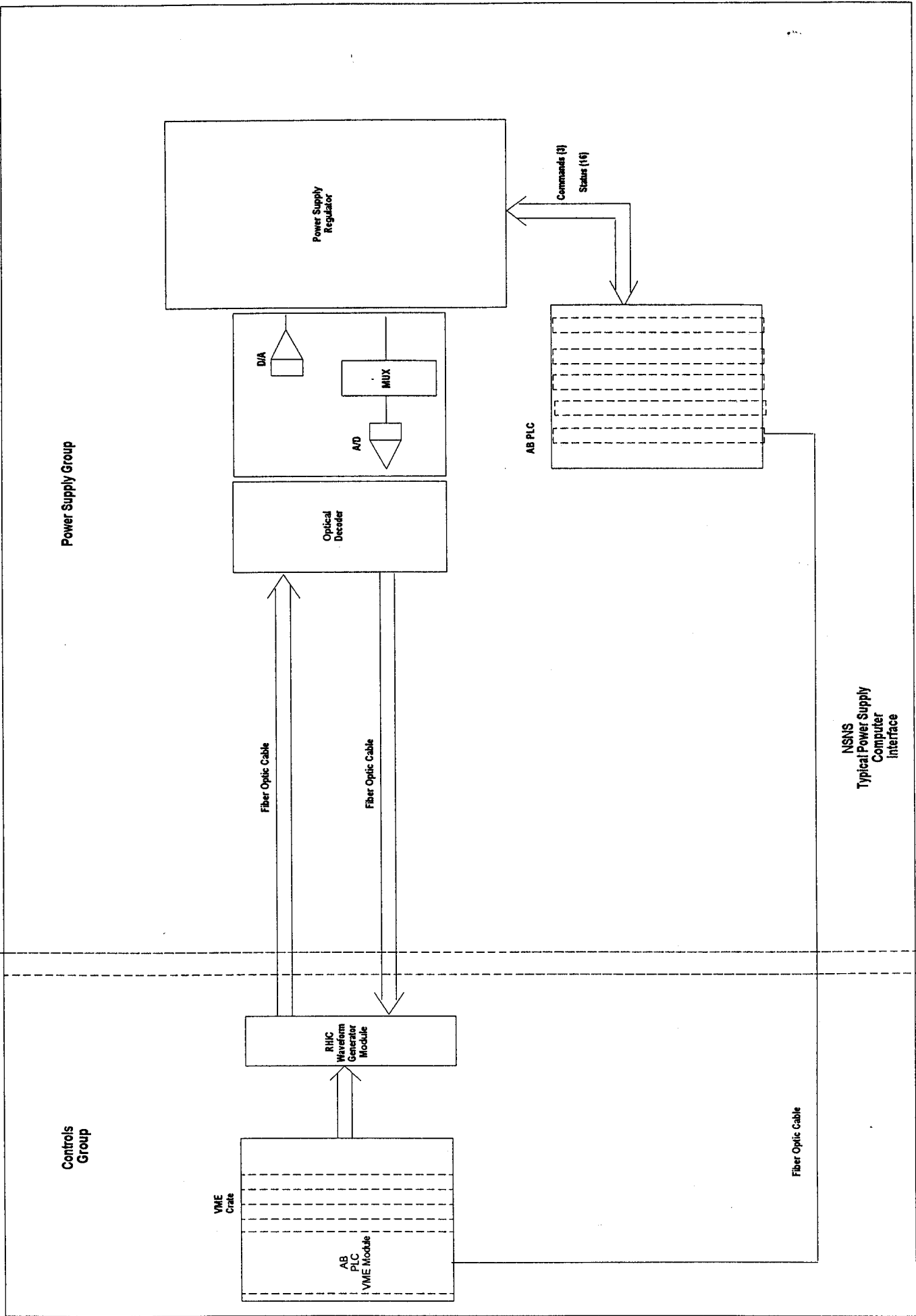
NSNS
Typical Power Supply
Computer
Interface

FIGURE 3

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Resistance/Magnet	2.0 mOhm
Ring Total Resistance	90 mOhm
Inductance/MAgnet	4.0 mHy
Ring Total Inductance	130 mHy
PS Maximum Voltage	400 Volt
PS Maximum Power	1.8 MW
Regulation; Ripple	10^{-4}
Filter	Passive LCRC

The 32 MR magnets and the dipole ps will be interconnected by a water-cooled, insulated, copper bus system. The bus will be arranged in a folded-loop scheme where a designated loop break is selected. The loop break will apply for all contiguous metallic conductors; NO MACHINE SYSTEMS should be allowed to cross this point. The main dipole bus will be designed in-house with proper insulators, supports, clamping and flexible joints. Take-offs to each magnet will be with flexible braids. It will go from the MR house to an alcove in the ring through a driven pipe or sleeve. The current density will be fairly low, say ~300 amps/cm^2.

1.5.4.2 - Quadrupole PS
The NSNS quadrupole system will have 3 independent Main quadrupole strings and 4 Trim strings. The magnet parameters are listed in the Ring Magnet sections. Three (3) ps's will enable independent horizontal and vertical tune adjustment while maintaining other ring lattice parameters such as betafunction and dispersion under control. The four (4) trim ps's will adjust the various differences of the quadrupoles and thus will enable their series connection (See NSNS TECH NOTE 026).

Main Quadrupoles:
The first of three main quadrupole strings includes the 7 quadrupoles in the center of each of the four arcs for a total of 28 magnets. These will be connected in series to one ps.

The second main string includes the first and last quadrupole in each of the four arcs and the quad at the center of each straight section for a total of 12 horizontal focussing magnets. These will be connected in series to the second ps.

The third main string includes the two defocussing or vertical quadrupoles in each straight section for a total of 8 magnets. The third ps will power these in series.

The parameters for these units are shown in table 3.

Table 3 - Quadrupole PS Design Parameters

	PS 1	PS 2	PS 3
No. Quads	28(24S,4L)	12(8S,4L)	8(8S)
No. PS	1	1	1
PS Type	SCR	SCR	SCR

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| Configuration	12-Pulse	12-Pulse	12-Pulse
Ring Connection	SERIES CONNECTIONS - FOLDED BUS (3)		
Max. Gradient	S 3.5 T/m	S 2.7 T/m	S 2.2 T/m
	L 3.1 T/m	L 2.4 T/m	
Max. PS Current	600 A	500 A	500 A
Res./Magnet	22mO,44mO	22mO,44mO	22mO
Total Str. Res.	0.734mO	0.382mO	0.215mO
Max. PS Voltage	450 V	200 V	120 V
Max. PS Power	270 kW	100 kW	60 kW
Regulation/Ripple	$2x10^-4$	$2x10^-4$	$2x10^-4$
Filter	Passive,LC	Passive,LC	Passive,LC

The three Main Ring Quadrupole ps's will be constructed identically except for the final voltage and current ratings. The basic unit design will be multi-phase SCR control. The configuration will be 12-pulse to enable wide bandwidth and low voltage ripple. In addition, a balanced passive filter will be use to reduce the raw dc voltage output ripple within acceptable requirements. A basic schematic is shown in figure 4. The scheme includes ac switchgear, step-down rectifier transformers, full-wave SCR bridges, output FWD, and dc output isolated voltage and current sensors. The regulation will be handled by analog feedback loops that trigger the SCR's to hold the voltage and current constant.

The protection, analog and digital control will be designed in an 'NSNS standard' fashion and similar to other NSNS ps's. Some of the protection will be hardwired to trip the main contactor. This includes ac and dc overloads and magnet ground fault protection. The rest of the protection and control will be handled by a programmable logic controller (PLC). The PLC will also interface the digital OFF/ON control and status monitoring to the control computers (VME chassis). A schematic diagram of the controls and interface are shown in figure 3, which are similar to the dipole ps. The analog references will be derived from waveform generators (WFG) similar to units already being used by BNL at the RHIC accelerators. These will be imbedded in the ps regulators to reduce noise and improve ps repeatability. The controls are further described in the controls section.

Trim Quadrupoles:
The trim ps's will be isolated from the main ps's by powering a small set of independent pole windings next to the main quadrupole coils. The ampere-turns in these windings will typically be 4-8 percent of the main windings. These ps's will be linear, bipolar units so that easy trim adjustments and matching can be made.

The protection and controls will be identical to the other ring corrector ps's described below (1.5.4.3). The digital control will be done via a PLC and the analog via a WFG.
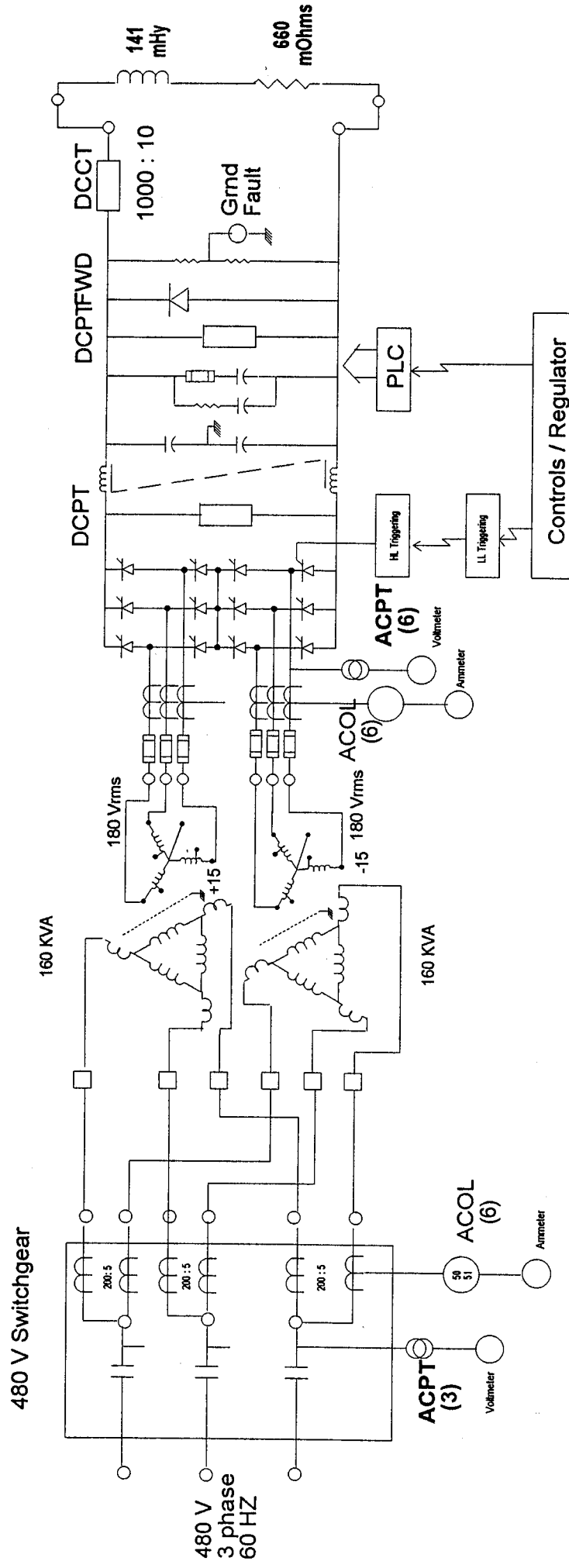
FIGURE 4: - Diagram of the NSNS Large Quadrupole
Power Supply
1.5.4.2

1.5.4.3 - Closed Orbit Corrector PS's

A set of 24 Horizontal dipole and a set of 24 Vertical dipole magnets will enable closed orbit adjustment of dipole errors for the NSNS. This correction will typically require orbit information from the strip-line pickup electrodes and a harmonic type application program to correct the orbit to within the millimeter range, typically. The dipoles for both planes are distributed around the machine to provide a smoother orbit correction scheme. The magnets will be constructed similar to those in the AGS Booster.

The ps's for the correction dipoles will be linear, transistor, bipolar types, which will be adjustable over their entire +/- current range. A typical schematic is shown in figure 5.

Banks of complimentary transistors of either bipolar technology or MOSFET technology will be employed. They can be built as either water-cooled or air-cooled, since both designs exist. The final choice will be based on size and on HVAC considerations. The units will operate in all 4 quadrants of the V,I diagram. The units will be fully protected and will be interfaced to the control computers by a WFG described for the MR dipole ps and in the controls section. The protection will consist of overcurrent, overvoltage, overtemperature, current error, cooling failure, and slew rate limiting.

1.5.4.4 - Corrector PS's

Correctors for the NSNS lattice will take the form of stop-band or resonance correction. (See BNL/NSNS TECH NOTE 026). Also, some higher order correctors in the form of octupoles will be provided. The major stop-bands of concern in the machine are: coupling (skew quadrupole); 1/2 integer (quadrupole); 1/3 integer (sextupole); and skew sextupole.

The described resonances will be corrected using strings of quadrupole and sextupole magnets in the MR lattice. Strings are used so that in the act of correcting a certain resonance line in the tune vs tune diagram, other perturbing effects are not induced. The 1/2 integer correction will be performed by using extra trim windings on the MR quadrupoles. Coupling lines will be corrected using skew quads built into the dipole corrector magnets as in the AGS Booster design. Individual sextupole and octupole magnets will be installed in some of the MR lattice cells to enable sextupole, skew sextupole and octupole corrections to take place.

The ps's for these corrector schemes will be constructed very similar, if not identical, to those described above for the closed orbit dipoles. They will operate in bipolar fashion in both voltage and current modes (i.e. 4 quadrant oper.), using bipolar waveform function generator analog computer controls. The digital ps and computer interface will be handled by PLC's and their VME communication modules.
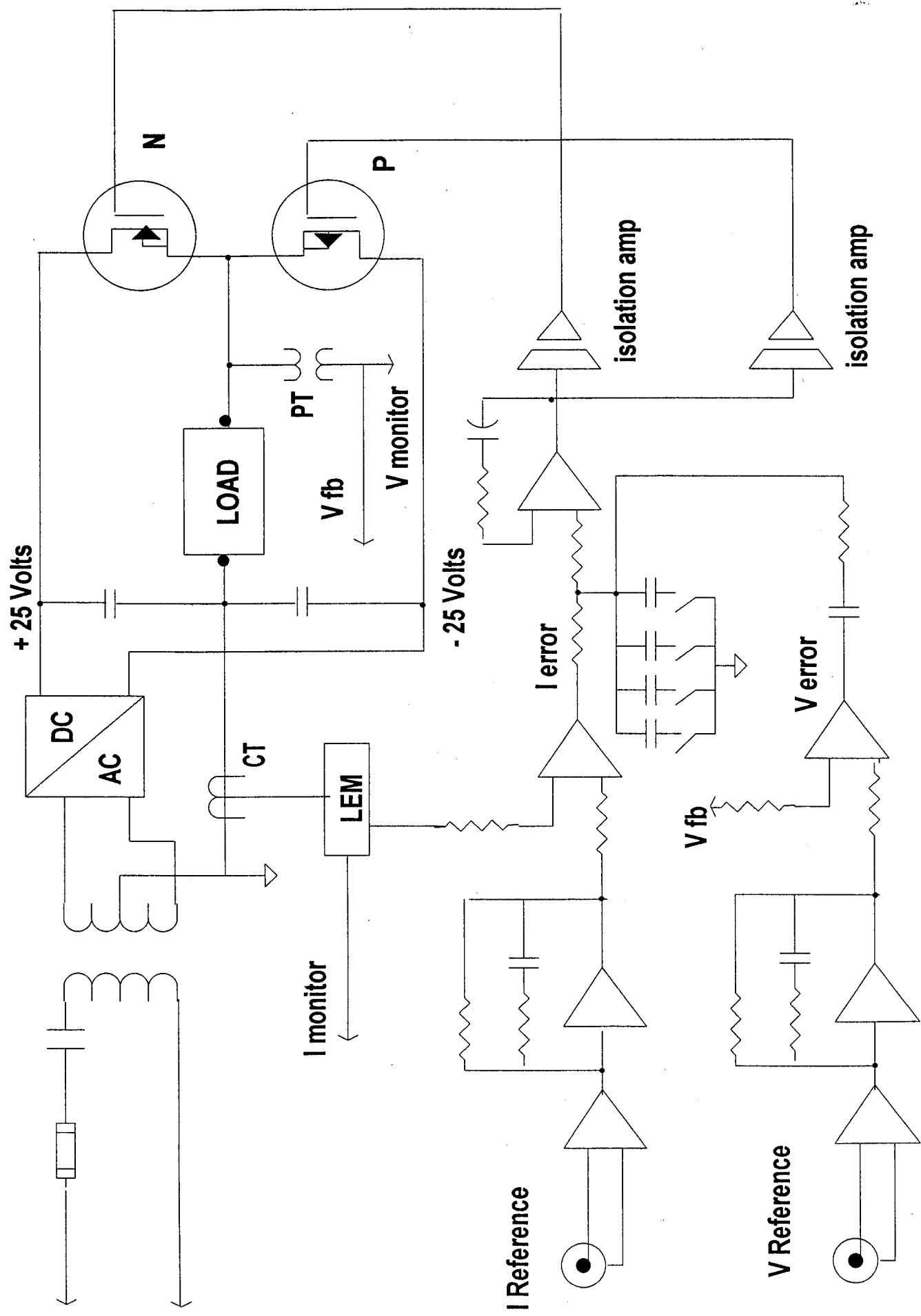
FIGURE 5: — Diagram of the NSNS Corrector Power Supply

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