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Author
Lutz, I.C.

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I.C. Lutz, C.A. Arthur, G.J. deVries, and H.M. Owren

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I.C. Lutz, C.A. Arthur, G.J. deVries and H.M. Owren
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

SUMMARY

The Lawrence Berkeley Laboratory is upgrading the neutral beam source test facility (NBSTF) into a neutral beam engineering test facility (NBETF) with increased capabilities for the development of neutral beam systems.

The NBETF will have an accel power supply capable of 170 kV, 70 A, 30 sec pulse length, 10% duty cycle; and the auxiliary power supplies required for the sources.

This paper describes the major components, their ratings and capabilities, and the flexibility designed to accomodate the needs of source development.

INTRODUCTION

The LBL NBSTF power supply system was designed in 1977 to test the neutral beam system for the Princeton Plasma Physics Laboratory TFTR and has been described in an earlier paper.[1]

The system is being upgraded for NBETF to provide the capabilities of: (a) 30 sec pulse lengths, (b) 10% duty cycle, (c) 170 kV, 65 A accel power, (d) higher power and more flexibility in the arc power supply, (e) more flexibility in the filament power supply, (f) a source magnet power supply, (g) more flexibility in the accel power supply controls, and (h) increased monitoring facilities for long pulses.

The power supply system is shown in one line diagram form in Figures 1 and 2.

ACCEL POWER SUPPLY

The accel power supply (Figure 1) was originally built for the LBL NBSTF requirements of 120 kV, 65 A, 0.5 sec pulse, 1% duty and is being modified for higher voltage, longer pulse lengths, and higher duty cycle.

The rating of the supply is determined by the rectifier transformers. The ratings of some of the other components are not entirely consistent because the supply was constructed from components on-hand or obtained surplus from other projects. The rectifier transformers are each rated 3.38 MVA, 150 kV line-to-line, 13 A rms, 6.6% impedance, and continuous duty. A 3φ FWB rectifier connected to each transformer gives an output capability of 170 kV, 16 A DC, continuous duty for each rectifier transformer. The impedance of each supply is about 15% on the 3.38 MVA base. The tap changing transformers give an output voltage range from about 38 kV to 213 kV at no load. Means are built in, but not shown in Figure 1, for connecting the tap changing transformers in series to provide output voltages down to about 12 kV DC.

The components are connected into two separate power supplies to give maximum flexibility to meet the needs of source development. When connected in parallel, as shown, an output of 170 kV DC, 70 A DC, 30 sec pulse length, and 10% duty can be obtained.

For sources operating at voltages up to 100 kV DC, 100 A, 30 sec pulses DC can be obtained at 10% duty cycle.

For higher voltage sources, the rectifier diodes of one supply can be reversed and by connecting the two supplies in series, voltages up to 340 kV (± 170 kV from ground) can be obtained.

For continuous duty sources, the power supplies, when connected in parallel, have a rating of 170 kV at 32 A DC continuous.

With a modification to the DC output switch, each of the supplies could be used for separate sources with independent operation except for the common [illegible] kV circuit breaker used for certain fault conditions.

The SCR power controllers are an addition to the NBSTF version and are of the back-to-back SCR configuration to give full phase control of the voltage to the rectifier transformers. They are rated for 762 A rms, 30 sec pulse length, 10% duty on a 7 kV, 3φ line. Each SCR assembly consists of nine 2400 V, 420 A SCR's in series. They give the added flexibility of being able to regulate the power supply output voltage during long pulse operation as well as being used for ON-OFF pulse control.

The 12 kV line vacuum contactor assembly includes a fast opening (~1 cycle) 3 phase vacuum contactor which is used only for turn-off under certain fault conditions. Two additional (~5 cycle) vacuum contactors are installed in a step-start arrangement and were used in the NBSTF for normal pulse on-off control before the SCR power controllers were installed.

All of the components shown in Figure 1 are installed outdoors on a concrete pad. The output power is run underground into building 6 via a 350 kV DC coaxial cable. Building 6 is the location of the source vacuum tank and controls used for the NBSTF which are now being modified for NBETF. Another conduit exists from the accel power supply pad to Building 16 where LBL has other neutral beam source test stands in operation.

The components shown in Figure 2 are installed in Building 6 near the neutral beam source vacuum tank in an area fenced for personnel protection.

CAPACITOR BANK

The 10 mFd capacitor bank (C_1) has been added to permit operation without the shunt regulator circuit that was used in the NBSTF. The capacitor bank is sized to provide the full accel current to the source, during the time required to build up the current in the accel power supply when the series SCR switch (SCR_1) is fired.

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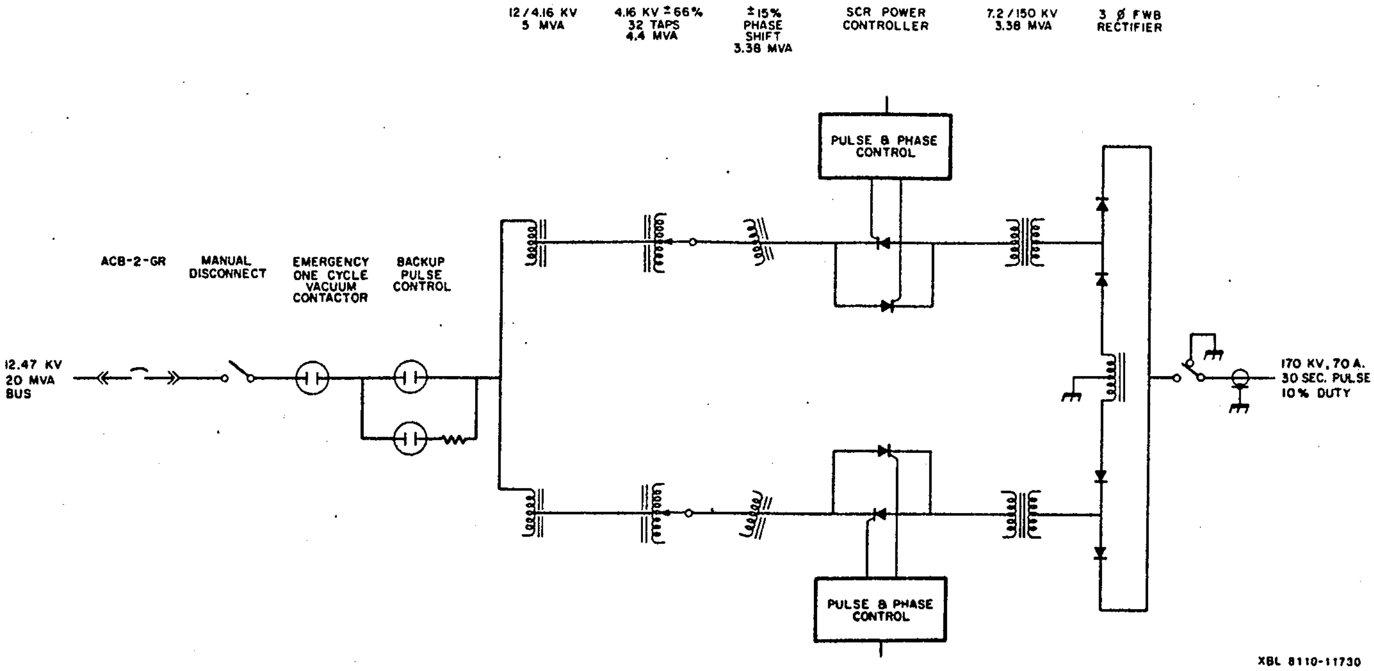

Figure 1 Accel Voltage Power Supply

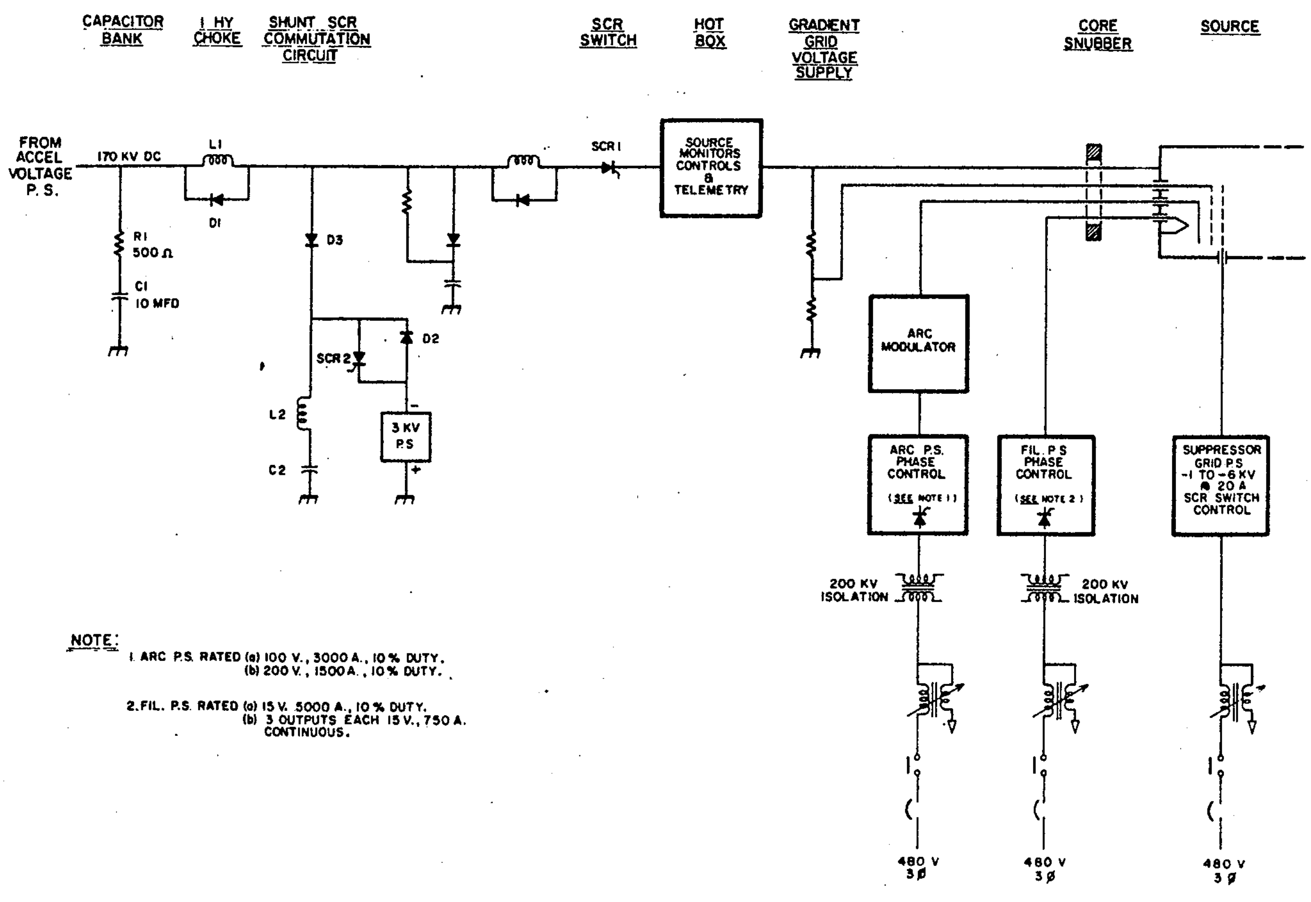

Figure 2 Accel Voltage Switch and Auxiliary Power Supplies

SERIES SCR SWITCH AND ASSOCIATED CIRCUITS

The series SCR switch (SCR_1) is the same as used in NBSTF[2] with the addition of more SCR's to increase the voltage rating to 250 kV DC.

The commutation circuit (SCR_2, L_2, C_2, D_2, D_3) differs from that used in NBSTF in that the ignitron switch has been replaced with an SCR switch (SCR_2), identical to SCR_1, and the circuit has been rearranged, but the operation is the same.[1] D_3 has been added in place of the saturable reactor to prevent C_2 from discharging except when SCR_2 is fired.

GRADIENT GRID POWER SUPPLY

At any accel voltage, the ratio of gradient grid to accel volage should ideally be maintained at a fixed value to achieve optimum focus of the extracted beam. The gradient grid current may be either positive or negative and is normally a few tens of milliamps but may be as high as several hundred milliamps.

A resistor voltage divider connected from accel voltage to ground with a tap for the gradient grid has proven to be adequate if the divider current is at least 2 A.

The voltage divider for NBETF is made up of 630, 100 W, Carborundum resistors which can absorb the 30 sec pulse length power without overheating and have forced air cooling to operate at 10% duty.

The nominal design value of the gradient grid voltage (V_g) is 83% of V_{accel}. Five relays are used to vary V_g from 79% to 90% of V_{accel} in 32 steps at the 170 kV level. Four range changing relays are used to keep the divider current between 2 and 3 A for any V_{accel} from 40 to 170 kV. These are all pneumatic actuated relays which can be remotely operated manually or by the computer.

FILAMENT POWER SUPPLY

Neutral beam sources typically have many tungsten filaments. The LBL designs connect all filaments in parallel but other designs connect the filaments in three groups and may run them at different temperatures.

For maximum flexibility, the NBETF filament power supply was designed with three independently controlled outputs for the ORNL sources, which can be connected in parallel for the LBL sources. See Figure 3.

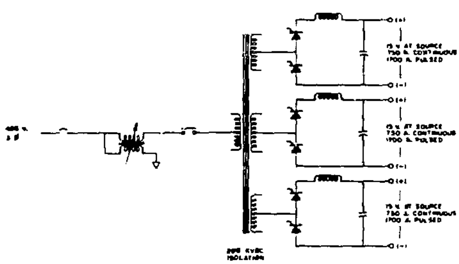

Figure 3 Filament Power Supply

SCR's with full phase control on each of the three outputs provide the independent control and the IVR provides a common control for the three outputs. The SCR's also allow voltage programming and/or regulation during the long pulses.

Each of the three outputs is designed for 15 V DC at the source terminals, 750 A continuous duty, and 1700 A, 30 sec pulse length, 10% duty. An L-C filter reduces the voltage ripple to $\leq$3% at any phase back angle.

The rectifier transformer has three sets of secondary windings isolated from the primary winding for 200 kV DC and is mounted in a fiberglass enclosure filled with SF_6. The SCR's are mounted in the "hot box' to facilitate control, monitoring, and maintenance. The supply is described in more detail in reference 4.

ARC POWER SUPPLY

The arc power supply is a 3ϕ rectifier type with 200 kV DC isolation between the transformer primary and secondary windings. There are two sets of 3ϕ secondary windings, one delta and one wye, each with an SCR type bridge rectifier and an L-C filter. See Figure 4.

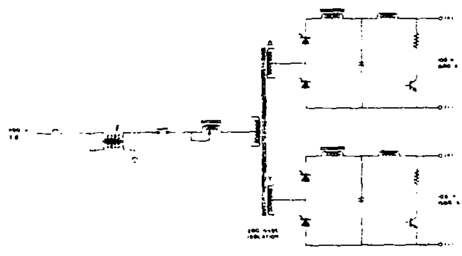

Figure 4 Arc Power Supply

The output of each bridge rectifier is connected to an "arc modulator" circuit and the outputs of the modulator circuit can be connected in parallel or series.

Each output is rated 100 V, 1.5 kA, 32 sec pulse length, 10% duty, with an open circuit voltage of less than 125 V. In parallel the capability is 100 V DC, 3 kA; and in series it is 200 V DC, 1.5 kA.

The IVR has a range from half to full rated output voltage. The SCR's in the bridge rectifiers have full phase control from 0 to 100% rated output. The supply is described in more detail in reference 5.

ARC MODULATOR

The NBETF arc modulator is a simplified version of the one in use on NBSTF.[3] The major changes are: (a) omission of the series resistors, and transistor switches, to eliminate the heat dissipation during long beam pulses; (b) use of the shunt resistors, and transistor switches, for short time "turn-on" and "divert" control only, and (c) dividing the modulator into independent units connected to each of the two power supply outputs.

At "turn-on", the modulator programs the arc power to match the rise time of the accel voltage.

In the event of a source fault, the modulator diverts the arc current until the fault is cleared.

The circuit consists basically of a series 300 μH inductor and shunt resistors, with transistor switches, connected between the arc power supply output and the source.

Arc power regulation during the long pulses can be accomplished by phase control of the SCR rectifiers.

SUPPRESSOR GRID POWER SUPPLY

The suppressor grid power supply has an output capability of -1 to -6 kV, 20 A, 30 sec pulse length and 10% duty.

The supply consists of a primary line IVR to set the desired voltage, a 3ϕ, 12 pulse rectifier, and a series SCR switch in the DC output.

A commutation circuit similar to that in the accel power supply is used to turn off the series SCR switch. See Figure 5.

Figure 5 Suppressor Grid Power Supply

MONITORING FACILITIES

The test stand operator has eight storage scopes, each capable of recording four signals, to monitor the source and power supply signals required for operations. Typically, these scopes are triggered at various critical times during the pulse, (e.g., turn-on, interrupts, and turn-off) and sweep at speeds required to diagnose a particular portion of the pulse.

For monitoring the entire 30 second pulse length, a 28 channel, 200 kHz, analog tape recorder has been added. Between pulses, selected portions of the stored data can be read into the storage scopes or into a digital scope for analysis as desired.

The tape has capacity to store about 150 30 sec pulses and provides a convenient means of comparing several successive beam pulses.

Certain signals from the source and power supply are also recorded by the computer for use in computer control of the test stand. These signals can also be read out onto video screens and a hard copy printer if desired.

The control room has been expanded to provide additional facilities to monitor the accel and auxiliary power supplies, and the cooling water systems for the beam dumps. A separate area has been added for experimenter's equipment and data acquisition.

REFERENCES

1. O.B. Hopkins, et. al., "The Lawrence Berkeley Laboratory Power Supply System for TFTR Neutral Beam Source Development", Proc. of the 7th Symp. on Engr. Prob. of Fusion Research, IEEE Pub. No. 77CH1267-4-NPS, Knoxville, TN, LBL-6377, October, 1977.

2. J.V. Franck, et. al., "An SCR Series Switch and Impulse Crowbar at the Lawrence Berkeley Laboratory for CTR Neutral Beam Source Development", Proc. of the 7th Symp. on Engr. Prob. of Fusion Research, IEEE Pub. No. 77CH1267-4-NPS, Knoxville, TN, LBL-6382, October, 1977.

3. G.J. deVries, et. al., "Arc Current Modulator for Neutral Beam Source", Proc. of the 8th Symp. on Engr. Prob. of Fusion Research, IEEE Pub. No. CH1441-5/79/0000-1277, San Francisco, CA., LBL-9390, November, 1979.

4. I.C. Lutz, "NBETF Filament Power Supply", Internal Report No. ETF-0008, May, 1981.

5. I.C. Lutz, "NBETF Arc Power Supply", Internal Report No. ETF-0014, August, 1981.