A PROPOSAL TO PULSE THE BEVATRON/BEVALAC MAIN GUIDE FIELD MAGNET WITH SCR POWER SUPPLIES*

B. Frias, J. Alonso, R. Dwinell, F. Lothrop
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

Abstract

The Bevatron/Bevalac Main Guide Field Power Supply was originally designed to provide a 15,250 Volt DC. @ 8400 Ampere peak magnet pulse. Protons were accelerated to 6.2 Gev. The 128 Megawatt (MW) pulse required two large motor-generator (MG) sets with 67 ton flywheels to store 680 Megajoules of energy. Ignitron rectifiers are used to rectify the generator outputs. Acceleration of heavy ions results in an operating schedule with a broad range of peak fields. The maximum field of 12.5 kilogauss requires a peak pulse of 80 MW. Acceleration of ions to 1.0 kilogauss requires an 8 MW peak pulse. One MG set can provide pulses below 45 MW. Peak pulses of less than 15 MW are now a large block of the operating schedule. A proposal has been made to replace the existing MG system with eight SCR power supplies for low field operation. The SCR supplies will be powered directly from the Lawrence Berkeley Laboratory's 12.3 KV. power distribution system. This paper describes the many advantages of the plan.

Brief History of Bevatron/Bevalac Operation

1954: The original operation required a 128 MW peak pulse. Two large motor-generators are required.

1974: Heavy Ion operation requires a lower magnet field.

1980: Power losses are reduced by operating at low fields with only 1 MG Set.

1988: Increased scheduling of low field operations due to...

- An increased low field therapy program.
- Fast switching between therapy and nuclear science is normal operation.[1]

Introduction

The existing Bevatron/Bevalac Power Supply was designed in 1948 to provide a 128 Megawatt Peak Pulse for Bevatron operation. Innovations at LBL have led to the operation of the Particle Accelerator at very low fields. Where originally two Motor-Generators were required for normal operation, now many Biology, Biomedical and Nuclear Science experiments are carried out by using only one MG Set at peak pulse loads of less than 30 MVA. Figure 1. is a one line diagram of the 1 MG Set circuit configuration.

In addition to the inefficient peak power mis-match, high Power Supply ripple components, excessive Ignitron warm-up time and the inability to easily synchronize to the Hilac injection line, are three other reasons that direct line pulsing with SCR Power Supplies would be a cost effective improvement at the Bevatron.

*This work was supported by the Director, Office of Energy Research, Division of Nuclear Physics, Office of High Energy & Nuclear Physics, Nuclear Science Division, U.S. DOE under Contract No. DE-AC03-SF00098.

The proposal calls for eight SCR power supplies to be built to meet the following goals, and to provide the Bevatron Magnet with the voltage and current waveforms that are shown in Figure 2.

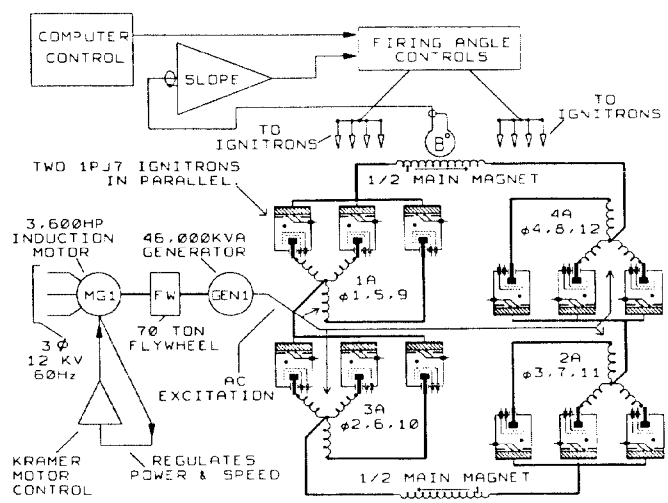

Fig 1. Existing Bevatron One MG Set Circuit Configuration.

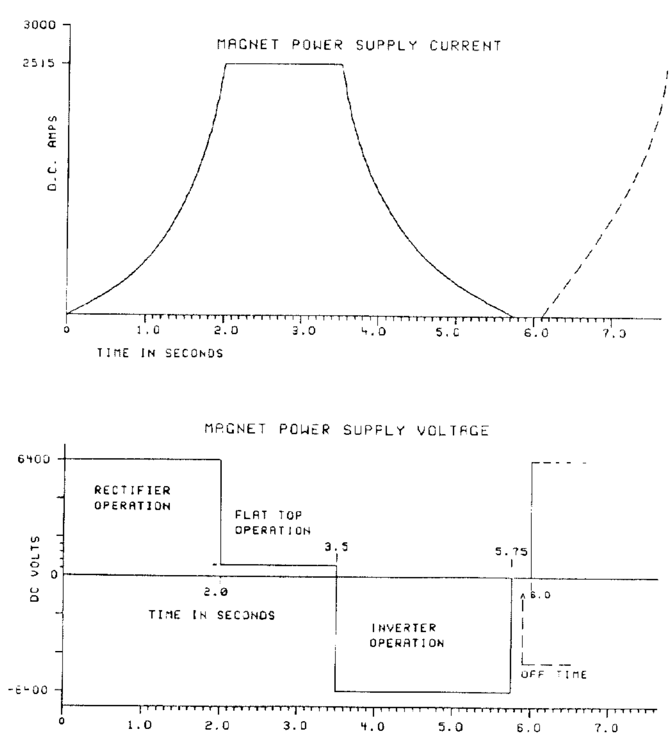

Fig 2. Bevatron Magnet Voltage and Current Waveforms with the Proposed Power Supply.

Goals:

- Eliminate the need for Ignitron warm-up periods, thereby increasing the users beam time. At present these periods are as long as eight hours.
- Provide a more efficient excitation mode for low field operation. The MG Set no load loss is 650 Kilowatts.
- Effect a cost reduction in operations by not using an MG Set for low field operation. An MG Room operating staff would not be required when the MG Sets were not used.
- Reduce the time necessary for fast switching of field levels. In the MG Set mode the control systems must stabilize the speed of the shafts to reproduce the same speed range on every pulse. This is a transient period of as much as one minute that must be controlled and allowed when field changes are requested.
- Design the system flexibly enough to allow configurations to drive future loads.
- Provide circuitry to minimize the amplitude of magnet ripple voltages.

Proposed Low Field Bevatron Magnet Power Supply

The configuration of the proposed power supply is shown in Figure 3.

Four Basic 1600 Volt @ 1275 Ampere Rectifier/Inverter units are added to four Combination power supplies. Each Combination supply has a 1225 Volt @ 1275 Ampere Rectifier/Inverter as well as a 350 Volt 1275 Amp Rectifier/Inverter with transistor actuators for precision control and regulation. These power supplies have been developed and sold commercially.[2]

A Basic and Combination module are connected in series to provide a 12 pulse rectified output. A passive filter will attenuate the 720 Hz ripple component during the beam acceleration period.

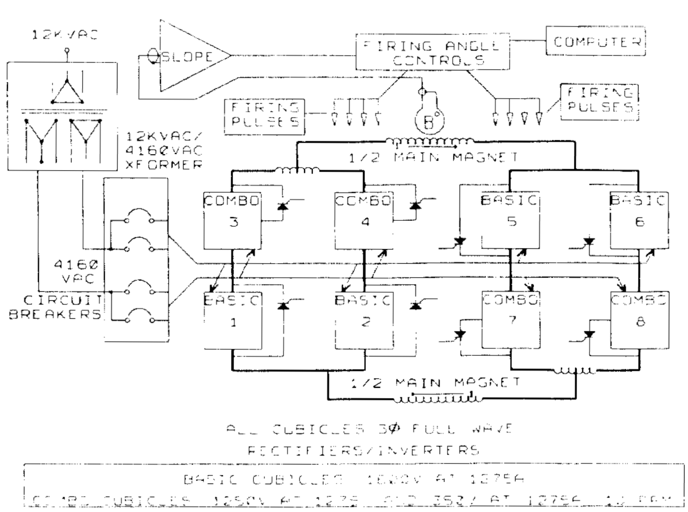

Fig 3. Proposed Bevatron/Bevalac Main Magnet Power Supply Configuration.

Each of the eight modular power supplies includes a three phase power transformer having a primary voltage of 4160 VAC.

Table 1. - Summary of Modular Units.

UNIT	QUANTITY
BASIC UNITS: 1600 Volt @ 1275 Amps Rectifier/Inverter SCR Power Supply - With shunting (BYPASS) SCR and Passive Filtering.	4
COMBINATION UNITS: 1250 Volt @ 1275 Amps Rectifier/Inverter SCR Power Supply - With shunting (Bypass) SCR and Passive Filtering.	4
350 Volt @ 1275 AMPS - 10 PPM Regulated Power Supply with full Rectification/Inversion capabilities.	

Description of Operation

The proposed operation of the Bevatron/Bevalac would call for the following operational cycle:

Acceleration:
To accelerate the Ions the Rectifiers are programmed into full rectification. Acceleration voltage is maintained until the maximum field of 7650 Gauss is reached. With the proposed 6400 volts this time of rectification is approximately 2 seconds.

Flattop:
When the peak magnet field is reached, and in order to provide a longer period for spilling the particle beam, the power supply can provide an extended period of peak field. This period is called Flattop and is developed by bypassing all the rectifiers units with exception of the four sections of the combination power supplies that are rated at 350 Volts DC.[3]

These rectifier groups are then programmed so there is enough driving voltage, in the magnet ring, to just equal the resistive voltage drop. The magnet current and field can then be maintained at the required constant value for a time determined by the RMS value of the pulse. A typical Bevatron 7,650 Gauss field flattop is 1.5 seconds, with a 10 pulse per minute repetition rate .

Full Inversion:
At the end of the flattop period all rectifiers are programmed as inverters. This returns most of the energy stored in the magnet to the power grid. The Table 2. shows some of the electrical parameters of the Bevatron Pulse while the magnet field builds to the flattop level.

Table 2. Where "Time" is time into the magnet pulse. The table is derived for the proposed power supply.

Time sec.	I amps	Mag E. kv	Field gauss	L hy	Power mva	Ut mj
0	0	6.4	0	5.65	0	0
0.633	710	6.4	2,150	5.65	4.5	1.4
1.260	1440	6.4	4,398	5.55	9.2	5.8
1.870	2200	6.4	6,717	5.26	14.1	13.3
2.065	2515	6.4	7,650	4.77	16.1	17.3

Table 3. Summary of Maximum Values for the Existing and Proposed Bevatron/Bevalac Magnet Power Supply.

	1988 BEVALAC OPERATION	PROPOSED POWER SUPPLY
Magnet Circuit	Bevatron	Bevatron
Magnet Field (Gauss)	12,575	7650
Inductance (H)		
Bevatron Magnet (Zero I.)	5.65	5.65
Bevatron Magnet @ Max I.	2.15	4.77
Resistance (Ohms)	0.250	0.250
Time Constant, L/R (S)	20	20.
Voltage, DC (KV) (L(di/dt) + IR)	15,000	6,400
Current, DC (KAMPS)	5.2	2.515
Peak Power, DC (MW)	6.760	1.581
Inductive Power (MW)	78.5	16.1
Total Peak Power (MW)	85.26	17.68
Freq (Pulses per Minute)	10.00	10.00
Rise Time (S)	1.75	2.17
Stability (PPM) $\Delta I/I_{max}$	79	10
Type of Regulated Power Supply	Ignitron 3 Phase 1/2 Wave Rectifier	SCR 3 Phase Full Wave Rectifier *

* Includes active transistor regulator.

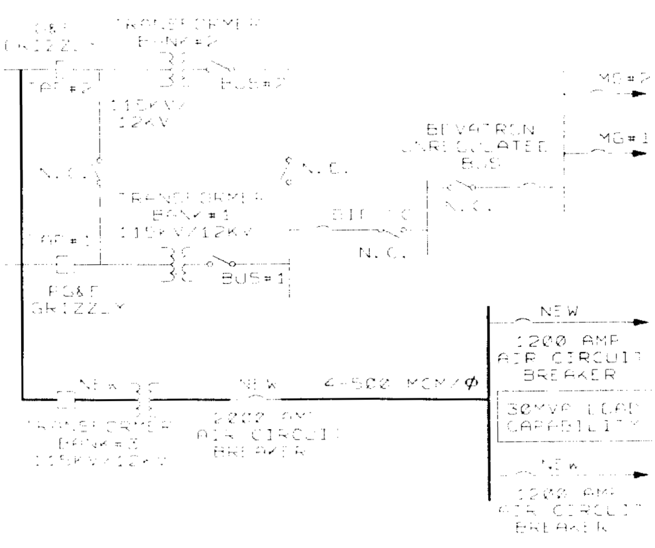

Fig. 4. Proposed Bevatron/Bevalac Main Magnet Power Supply 12 KV. Power Feeder.

AC System Changes

This proposal includes the addition of a new 30 MVA. transformer bank to insure that the pulse load does not cause voltage variations that might be objectionable to other LBL power users. This new transformer will be located at the Grizzly Substation and supplied by the PG&E 115 KV line. Two new 1200 ampere @ 12,000 VAC circuit breakers, with 500 MVA interrupting capacities, will distribute the 12,000 volts to the SCR power supply busses at the Bevatron Building. Analysis of the power system with the proposed pulse load has a calculated value of 0.5% flicker at the PG&E grid. Figure 4 illustrates the proposed power distribution system.

Cost Estimates

A cost estimate for this proposal has been made by summing the costs of the power supplies and the power distribution system.[4] The cost of the power supplies, installation, switching and interlocking necessary to switch back to the MG Sets, is estimated at $1.5 Million. The power distribution system that is shown in Figure 4 has been estimated at $3.4 Million which includes a 25% contingency. Total cost in 1988 dollars is $4.9 Million.

Conclusion

The implementation of this proposal will benefit Bevatron/Bevalac operations by reducing operating costs and improving beam quality. The ability to achieve a requested field without extensive Ignitron warm-up would, by itself, be justification for the concept. A brief restatement of the goals of the project can also be reviewed as a list of operational benefits...

1. Increased Research Time - No Ignitron warm-up time.
2. Pulsing Flexibility - Pulse to Pulse Fast Switching.
3. Improved Beam Quality - Reduction of the Magnet Voltage Ripple.
4. Operational Cost Streamlining:
   - Reduced Power costs.
   - Reduced Operator Costs.

References

[1] F. Lothrop, et al, "Mixing and Matching Bevalac Programs: A Progress Report on Rapid Switching of Ions and Other Operational Highlights." Presented at the 1987 Particle Accelerator Conference, Washington, DC, March 16-19, 1987.

[2] L. Farkas, J. McCarthy, D. Wolff, "Very High Precision Current Regulated Power Supplies." Presented at the 1985 Particle Accelerator Conference, Vancouver, B.C., CANADA May 13, 1985.

[3] D. Wolff, Bob Flora "Energy Saver Power Supplies - Shunt SCR Control During Flattop". Internal Report - Fermi National Accelerator Laboratory.

[4] J.R. Alonso, et al, "The Bevalac Upgrade Project." Presented at the 1987 Particle Accelerator Conference, Washington, DC, March 16-19, 1987.