DEVELOPMENT OF MAGNET POWER SUPPLY SYSTEM FOR FAST PATTERN EXCITATION

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Abstract

A power supply system for a fast pattern excitation has been required for bump magnets for the injection into a synchrotron, scanning magnets for the particle therapy and industrial use and etc. It is necessary that the excitation time to the target current value is short and the current fluctuation is low enough. We developed a new power supply system in order to make the pattern excitation faster and to make a deviation from the target current value smaller. The power supply is composed of two circuits; one is a forcing circuit and the other is a constant current circuit. Two circuits of power supply are connected in series with the magnet. IGBT (Insulated Gate Bipolar Transistor) is applied as the switching device of each circuit. The forcing voltage is set from -200V to 200V and the output current is set from -450A to 450A. The current is increased linearly with 1A per 0.1ms as the rate of the current excitation. The deviation of the target current is also suppressed within +/- 0.1%.

1 INTRODUCTION

It is required that a magnet power supply for a particle beam utilization, such as scanning magnets for medical and industrial use and a bump magnet of synchrotron, is excited rapidly with a prescribed pattern data [1][2]. These magnets have several mH of inductance and several ten mOhm of resistance. It is necessary to excite these magnet to a given magnet strength within very short time like 0.1ms and keep magnetic strength constant.

There are two types of scanning method for industrial and medical use. One is a spot scanning method, and the other is a raster scanning method.

In spot scanning method, beam is stood at a position and a prescribed dose is irradiated. It is necessary to control dose at each point in order to irradiate target volume uniformly. After irradiation, beam is moved to next position. A pattern of magnet current is stepped. The variance of current is several amperes, corresponding to spacing of each spot. The time of current variation should be shorter than 1ms, because it is dead time for irradiation as long as beam is moved. After magnet current is target value, beam is stopped at a position precisely. Time deviation of magnet current has to be suppressed within very low value of +/-0.1%.

In raster scanning method, beam is not stood at any point. Beam is scanned in constant velocity. Scan length should be varied in strict accordance with the target shape. Magnet current should be varied constantly.

It is necessary to excite bump magnet for synchrotron with trapezoidal current pattern or a current pattern with a given function.

Magnet and power supply form a L-R circuit. Magnet currents increase exponentially with time constant of L over R when voltages of power supply steps up. L is inductance of a magnet and R is resistance. It is well known that forcing voltage step up and magnet currents increase linearly. A conventional power supply, which excite bending magnets for synchrotron, could generate precise current pattern. Time deviation of current at flat shape is less than $1x10^{-6}$. However these power supplies could not vary currents rapidly because of low forcing voltages.

2 POWER SUPPLY FOR FAST PATTERN EXCITATION

Figure 1 shows a block diagram of the power supply system for the fast pattern excitation of magnet. Maximum output current of the power supply is +/-450A and Maximum output voltage is +/-200V.

The power supply consists of two parts. One is a precise current generator and the other is a forcing voltage generator. IGBT (Insulated Gate Bipolar Transistor) is employed for switching devices of both a precise current generator and a forcing voltage generator. Switching time of IGBT is shorter than 0.1 micro seconds and limitation of applied voltages is higher than 300V. IGBT module is used as switching devices for an inverter in the precise current generator. In the forcing voltage generator, IGBT is used as switching device.

The precise current generator consists of a converter, a passive filter and an active filter using feedback system. A converter converts AC voltage to DC. A gate driver drives the IGBT module as an inverter. Output voltage becomes smooth passing through the passive filter. The feedback system observes output currents with DCCT (DC Current Transformer) and calculates a deviation of currents from given currents. A local controller controls converter voltages precisely less than 0.1%.

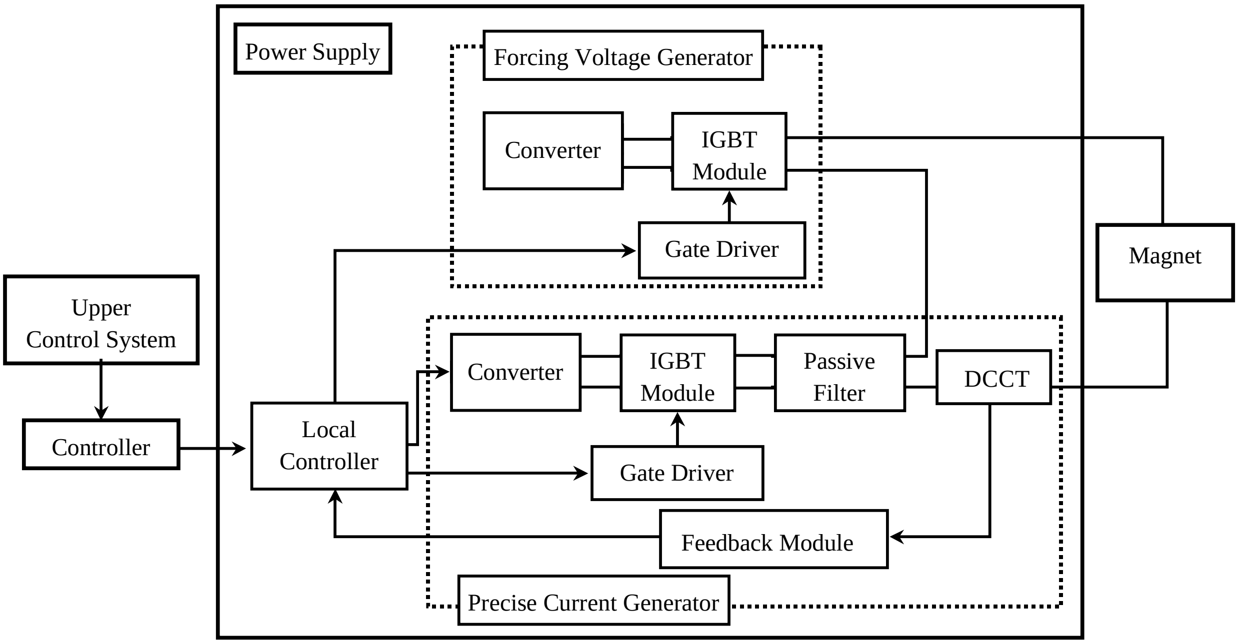

Figure 1 Schematic drawing of the Power supply system for fast pattern excitation

The circuit of the forcing voltage generator is about the same as one of the precise current generator without a feedback system. Forcing Voltage can be changed manually.

When a trigger signal is transferred to power supply, the gate driver of the forcing voltage generator turn on IGBT. Forcing voltages are generated and output current increase. Currents reach to given value and the driver turn off IGBT and forcing voltage is stopped.

3 CONTROL SYSTEM FOR THE POWER SUPPLY

Figure 2 shows a block diagram for a controller of the power supply. The controller is based on Windows NT computer and is composed of Master CPU, memory, HD, DSP board (Digital Signal Processor), Digital I/O, ADC and 32 bit counter. Master CPU receives pattern data from a upper control system with net work and save HD. It transfers pattern data to memory on DSP board. Counter counts number of pulses from pulse generator and generates a trigger signal when counts reach to given value. When trigger signal is received, DSP transfers a current data to power supply through Digital I/O.

4 RESULTS OF OPERATION TEST

A dipole magnet, of which inductance was 2.7mH and resistance was 3mOhm, was applied for a performance test of the power supply.

Figure 3 shows a current pattern excited with the power supply. In this case, current pattern is staircase and is applicable to spot scanning method.

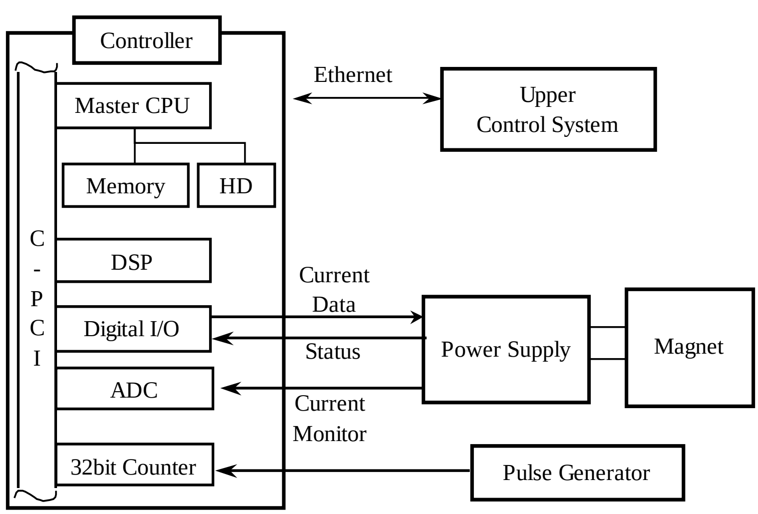

Figure 2 Control system of the power supply for fast pattern excitation

Figure 4 (a), (b), (c) is enlarged view of Figure 3. Figure 3 (a) shows target value converted DAC in power supply and output currents. In this case, current variation in each step was 5A and forcing voltages were 200V. Time of current variation was about 0.07ms. The rate of current variation was 70kA/sec.

Figure 4 (b) shows the output voltages of the power supply. Forcing voltages were +/-200V. Rise and fall time of ssforcing voltages were very fast less than 0.01ms. Figure 4 (c) shows deviation of currents after output currents reach to target value. It can be seen that current deviation was suppressed less than 0.1%.

Figure 5 shows saw-tooth or trapezoidal current pattern for raster scanning method or bump magnet of synchrotron. In this case, output currents was varied from –200A to 200A. Forcing voltage was 200V. It can be seen that output current increased or decreased linearly.

5 CONCLUSION

A new power supply has been developed. The power supply consists of a precise current generator and a forcing voltage generator. IGBT is employed for switching devices. Maximum output current is +/-450A and Maximum output voltage is +/-200V. The rate of current variation is 70kA/sec in the case that inductance and resistance of magnet is 2.7mH and 3mOhm. The power supply can be used for beam scanning method for industrial and medical application and for a power supply for bump magnets of synchrotron.

REFERENCES

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[2] Eros Pedroni, "The 200-MeV proton therapy project at the Paul Scherrer Institute: Conceptual design and practical realization" Medical Physics Vol. 22, No. 1 (1995) p. 37

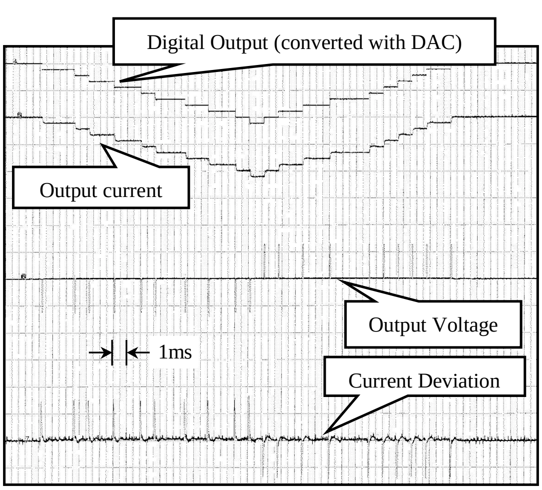
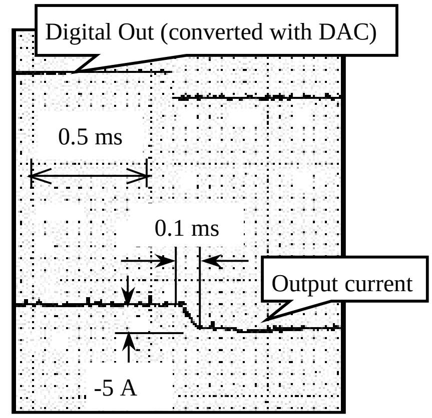
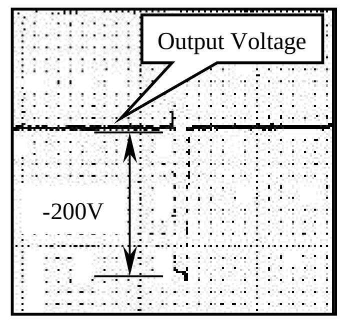


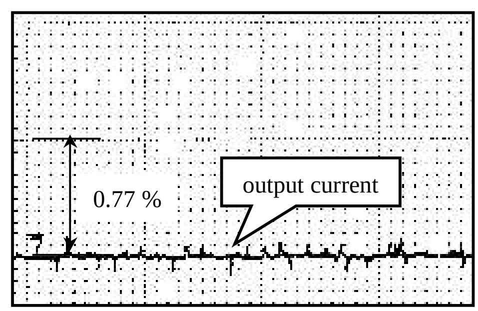
Figure 3 Result of the test for Power supply sytem



(a) Output current of the power supply



(b) Output Voltage of the power supply



(c) Deviation of output current

Figure 4 Result of the performance test

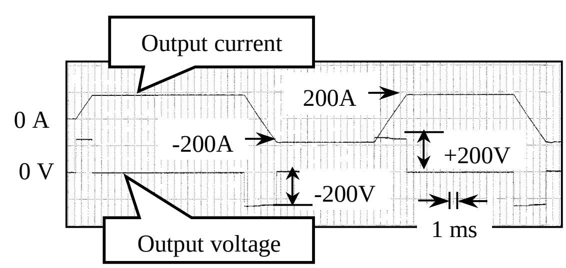


Figure 5 Current Pattern for raster scanning method