THE 200-MEV ELECTRON-POSITRON STORAGE RING MAGNET POWER SUPPLY*

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Summary

Two 250 V-100 kW amplidynes are controlled to give a precise output current. The load consists of the series connected bending and quadrupole magnets for the 200-MeV storage ring. This load has an inductance of 0.46 H and a dc resistance of 0.8 Ω. The magnet current is composed of dc and a triangular-shaped component at a frequency of 3 Hz. This frequency is an order of magnitude higher than the break frequency of the magnet load. The control elements act as an integrator, a summing amplifier, and a differentiator on the error signal and as a differentiator on the reference input. A gain change takes place during the cycle to compensate for saturation of the amplidyne. An electrical analog was used to determine the best range of values for the various control elements. The amplidyne drive is a high slip induction motor that also serves the purpose of smoothing out the electrical load on the power line.

System Description

Figure 1 shows in detail how the amplidynes and their magnet load is connected. This distributed type of layout is used in order that the voltage to ground of the magnet coils be minimized. The magnets and the four terminal metering shunts are located 100 feet from the rest of the power supply equipment. Also shown are the amplifiers used to develop a voltage VI that is directly proportional to the magnet current. When 400 A is flowing, the output voltage is 80 V which is well above the background noise. Two sets of twin shielded cables are used to transmit the signal from the metering shunts.

Figure 2 shows the relationship of load voltage, current, and power under the idealized condition that the output voltage of the amplidyne may be discontinuous. The drive motor speed is also shown under the idealized condition that the amplidyne is 100 per cent efficient. Each amplidyne has a Wk^2 of 116.5 $lb \cdot ft^2$ and the motor has a Wk^2 of 73 $lb \cdot ft^2$. The drive motor is rated at 150 hp - 1670 r/min when it is delta connected to the line. It has the torque characteristics of a 50 hp motor when it is wye connected to the line. When wye connected and under the idealized conditions previously mentioned, the motor load varies from 3.5 kW to 17.5 kW and the rest of the load is absorbed by the flywheel effect.

The saturation characteristics and technical data for a model 5AM669F205 amplidyne with G9 fields is available in General Electric Manual GET-1985C.

When it is desired to operate the magnets with dc as high as 400 A, the motor is switched to the delta or 150 hp connection. It is expected, using the motor service factor of 1.15, a 30°C ambient rather than a 40°C standard ambient, and our 5 per cent higher line voltage, that it will be possible to deliver 400 A continuously to the load without overheating the motor.

Figure 3 relates the control signal VC and the field current. The plate resistance of the tubes is used to make the effective time constant of the fields short. Since the quadrature time constant of the amplidyne is also short, the output current is limited by the load and the output voltage available from the amplidynes.

An internal feedback loop is used on each tube to insure stable operation. The low pass filter on the tube grid is used to prevent the tube from cutting off so quickly that high voltages would be developed across the amplidyne field coils. Under maximum grid drive conditions, the field current does not exceed its allowable maximum value. The gains for both positive and negative slopes of magnet current are individually adjustable in order to reduce the effects of saturation that occurs on the positive slope side for a positive dc offset of the magnet current.

Generation of the error signal VE, due to the difference between the reference command signal VR and the output current signal VI, is shown in Fig. 4. Two modes of operation are possible. One is the setup mode where various adjustments are made while in a low gain

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condition. The other is the run mode where VE is operated on by the augmented control amplifier. The augmented control amplifier gives an output which is the sum of VE differentiated, VE integrated, and VE amplified or attenuated depending upon the various resistor settings. This output forms a part of VC and the rest is obtained from differentiating VR. The best settings for the variable resistors in this section are found by watching VE as they are optimized. A minimum average value for VE is not the desired way to operate since the output then has some oscillations in it.

The more desired mode is with the output delayed by a constant amount from VR. 10 ms of delay gives a magnet current with very little oscillation tendencies while operating at 3 Hz. This can be seen in Fig. 5 which shows VR and VI. As the complete system of bending magnets BM and quadrupole magnets QM have not been installed yet, Fig. 5 is taken from the electrical analog of the system. Saturation of the amplidyne and nonlinearities of the power tube were included in the electrical analog.

The control was deliberately adjusted in order that both currents would be visible in Fig. 6. It was found that the system would perform at 10 Hz nearly as well as at 3 Hz for the 2 Ω load.

After the complete magnet load is assembled and tested, most of the variable resistors shown in Figs. 3 and 4 will be replaced by fixed values.

Acknowledgment

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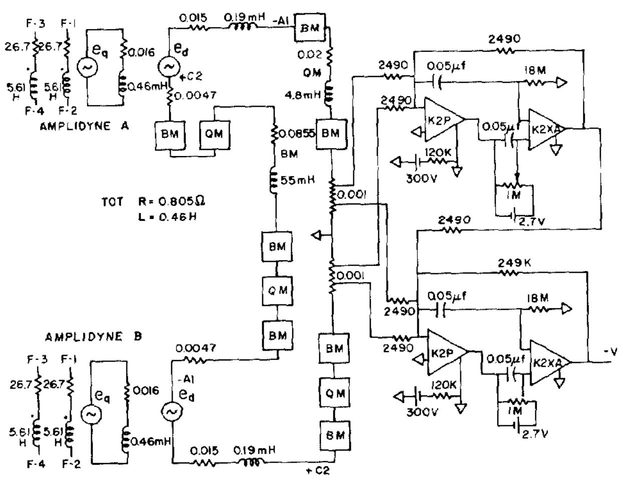

Fig. 1. Amplidynes, bending BM and quadrupole QM magnets, and output current signal VI generation circuit.

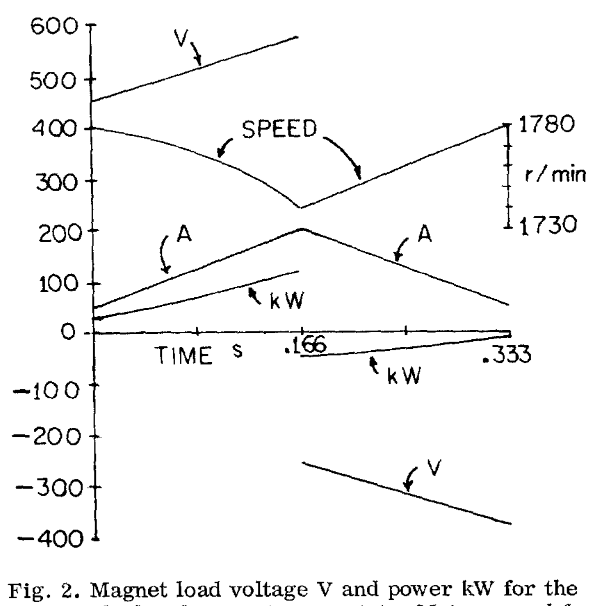

Fig. 2. Magnet load voltage V and power kW for the idealized magnet current A. Motor speed for the same conditions and 100 per cent efficient amplidynes.

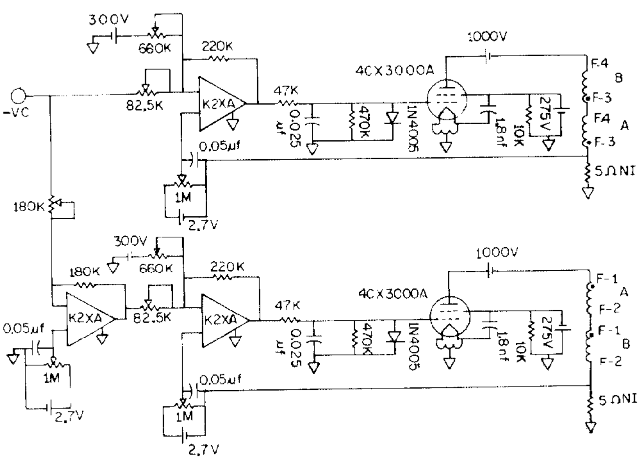

Fig. 3. Grid drive amplifiers, power amplifiers, and the amplidyne field loads.

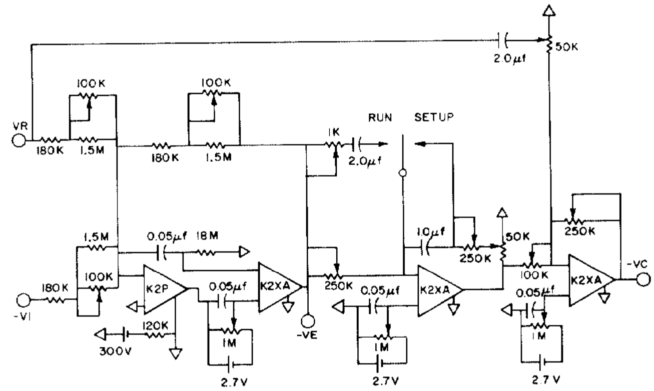

Fig. 4. Error VE formation, differentiated reference VR, the augmented control amplifier that operates on VE, and the formation of the control voltage VC.

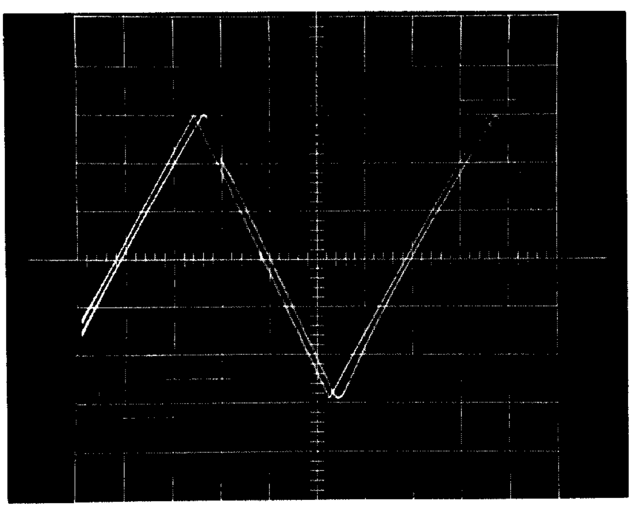

Fig. 5. Analog reference VR and output VI (delayed trace) shown varying between 50 and 200 A at a frequency of 3 Hz.

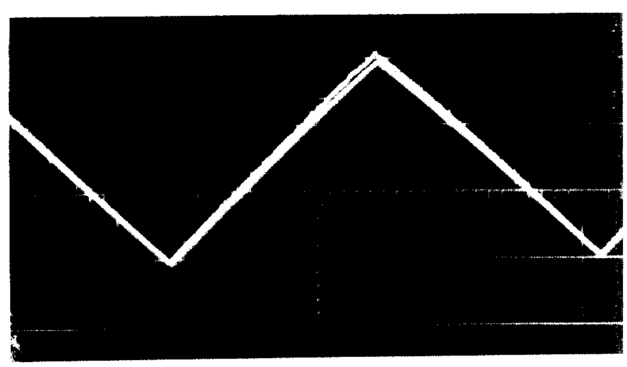

Fig. 6. Actual system reference VR (bottom trace) and output VI (top trace) shown varying between 50 and 200 A at a frequency of 3 Hz with a 2-ohm load in place of the storage ring magnets.