Motor Run-Up and Control Unit

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A motor generator set is used to convert 60-Hz line voltage to 400-Hz voltage for use in the high-power transmitter. The motors used in the motor generator sets are either 1750- or 3500-hp synchronous motors. They must be brought up to speed before line voltage can be applied to avoid severe power-line transients. The present unit being used to bring the motor up to speed is an open-loop analog device and cannot compensate for drift, temperature changes, or line frequency changes. The design of the new unit will compensate for all variations and is simple to set up and maintain.

I. Introduction

A motor generator (MG) set is used to convert 60-Hz line voltage to 400 Hz for high-voltage use on the high-power transmitters. The motors used in the MG sets are either 1750- or 3500-hp synchronous motors. They must be brought up to speed before line voltage can be applied (Fig. 1) to avoid severe power-line transients. The present unit being used to bring the motor up to speed is an open-loop analog device. It does not compensate for such things as drift, temperature changes in the motors or magnetic clutch, or changes in the line frequency. The new unit has been designed using digital circuits to compare the motor speed to the line and compensate for speed variations without any adjustment. The motor run-up and control unit serves three functions: speed control, voltage control, and power factor control.

II. Speed Control

The synchronous motor is brought up to speed by varying the magnetic coupling of an eddy-current clutch, which connects it to an induction starter motor. To prevent the magnetic coupling from becoming excessive and overloading the starter motor, the current of the starter motor is monitored. This signal is used as a feedback to limit the coupling when the current approaches the maximum rating.

The speed of the synchronous motor is monitored by use of a tachometer that produces a frequency and voltage proportional to its speed. As this frequency approaches 55 Hz, the motor field voltage is applied. The motor acts as a generator producing a voltage having a frequency proportional to its speed. This frequency is then used for speed control to synchronize the motor frequency with the line frequency.

III. Voltage Control

While the motor is acting as a generator, the voltage it produces must be matched to the line voltage. This is done by comparing voltages and producing an error voltage that will vary the field current to match the motor voltage to the line voltage.

IV. Power Factor Control

After the motor has been matched to the line in frequency, phase, and voltage, the motor contactor is closed and the motor is "on line." The power factor of the motor must then be maintained near unity. This is done by comparing the input voltage phase to the current phase and varying the motor field voltage to keep the voltage and current in phase.

V. Design

In order to compare the frequency of the 60-Hz line to that of the motor, an up/down counter (C1) was utilized (Fig. 2). This counter is counted up or down depending on the speed of the motor. After one complete cycle of both the line and motor, the value of the up/down counter is transferred to a latch (L1) and the up/down counter is again preset. This allows a comparison to be made up to 30 times a second. The output of L1 goes to a digital-to-analog (D-A) converter (D-A1), whose output is held high until a frequency of 55 Hz is obtained. As the motor speed increases beyond 55 Hz, the output of D-A1 will decrease, causing the acceleration rate to slow until approximately 58 Hz is obtained. At this time the output of D-A1 has decreased to the point where acceleration stops. The output of L1 also goes to another latch (L2) and two comparators (CM1 and CM2). L1 and CM1 are used to determine if motor speed is increasing or decreasing. This is done by comparing the latest value of C1 with a value taken one second earlier.

CM2 compares the latest value of the up/down counter to its preset value. This comparison will show the frequency of the motor to be low, high, or equal to the line. If the frequency of the motor is low and the speed of the motor is not increasing, another up/down counter (C2), which has been held preset until 55 Hz, will be counted up. The output of this counter goes to a second D-A converter (D-A2) whose output is in parallel with D-A1. Since the outputs of the D-A converters are paralleled, the output to the clutch will be increased, increasing the speed of the motor.

If the speed of the motor is found to be fast and not decreasing, C2 will be counted down. A safety overspeed sensor (not illustrated) will remove all drive to the clutch if the motor frequency exceeds the line frequency by more than 0.8 Hz. Drive is restored when the motor frequency drops below 0.8 Hz above the line.

Voltage control of the motor takes place after the motor reaches a speed of 55 Hz. The motor field contactor is closed and the motor acts as a generator. The voltage it produces is compared to the line voltage with a resistor divider network (Fig. 3). The error voltage from this comparison is amplified and sent to the field power supply. If the motor voltage goes low, the error voltage will go high, causing the field power supply to increase the field current. As the field current increases, the motor voltage increases. If the motor voltage goes high, the error voltage will go low, causing the field current to decrease, lowering the motor voltage. In this manner the motor voltage and line voltage will be matched when the motor is placed "on line."

When the motor is placed "on line," a relay is activated which switches the motor field power supply input from the voltage comparator to a phase comparator. This comparator compares the phase of the voltage to the motor with the phase of the current of the motor. An error voltage goes to the field power supply and will vary the field current to keep the motor current in phase with the voltage. In this way a power factor of near unity is maintained under varying loads.

VI. Conclusion

Tests made using this new control unit show a marked improvement in speed control. A complete unit is now being built which will be installed at DSS 14.

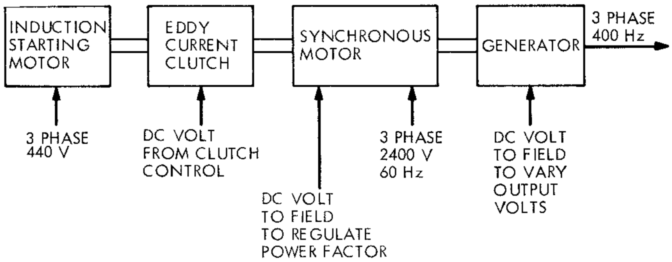

Fig. 1. Motor generator set

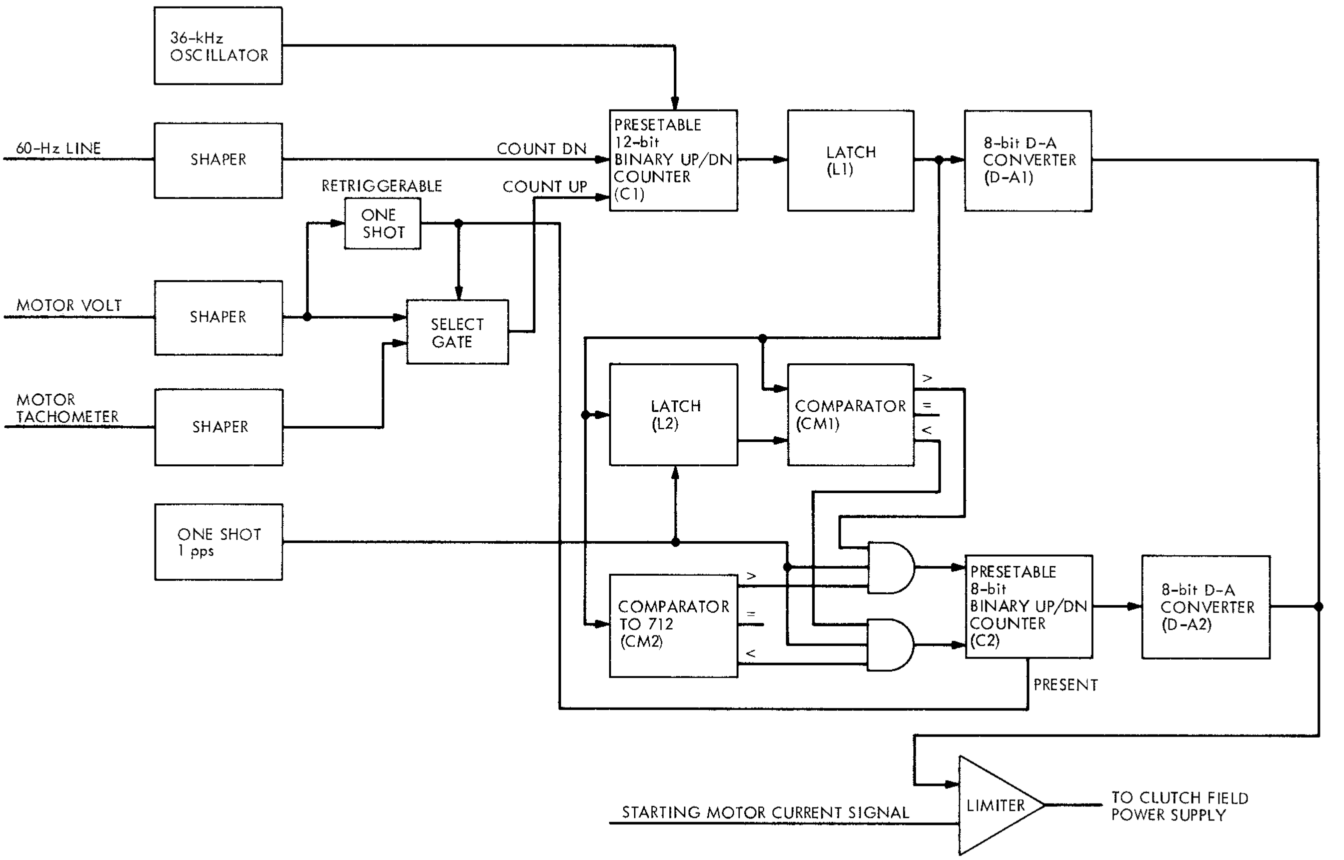

Fig. 2. Speed control

Fig. 3. Voltage and power factor comparators