The principle of operation of the closed-loop servosystem is as follows:

At the static position (electrical zero) the output voltage of the INPUT CONTROLLER will be zero, and the output voltage of the FOLLOWUP TRANSFORMER will also be zero. Thus, no error signal is sent to the amplifier, and the voltage to the control field of the servomotor is zero.

When the input controller's shaft is rotated (either left or right) a voltage is induced into the rotor of the control transformer. This voltage is connected through the followup resistor to the amplifier, where it is sent through the necessary stages of amplification, and drives the servomotor. The direction of rotation of the servomotor shaft is determined by the direction of the TX rotor displacement, which controls the phase relationship between the motor's two fields. The variable control field will always lead or lag the fixed control field by 90°. As the servomotor shaft turns, it drives the load in the direction commanded. It also drives the gear train of the followup control transformer rotor. Driving the followup CT rotor from its electrical zero position causes a voltage to be induced into the rotor by the excited stator. This voltage will always be 180° OUT OF PHASE with the voltage generated by the INPUT CONTROLLER. (This is done by the gear arrangement which drives the followup CT rotor). The followup voltage is developed across the same followup voltage resistor through which command signals are sent to the amplifier. As the servomotor rotates, the followup voltage increases. When the followup voltage becomes equal to the command voltage, being opposite, the error voltage sensed by the amplifier will be zero. The servomotor stops rotating. Note that it is unnecessary to reposition the transmitter's rotor (input controller) to electrical zero in order to stop rotation of the servomotor. The servomotor will rotate to move the load to whatever position is commanded by the control transmitter.

WARD-LEONARD SYSTEM

As previously stated, one of the basic requirements of a servomechanism is that the drive motor has variable speed and reversible rotation capabilities. Since the ordinary single-phase or 3-phase a-c motor is inherently a constant-speed device, the direct current motor is commonly used for controlled drives. The direction of rotation can be changed readily by reversing either the armature current or the field current.

The speed can be controlled by the voltage on the armature.

The circuit shown in figure 21-34, commonly known as the Ward-Leonard system, accomplishes this result. The d-c motor is this circuit is fed directly from a d-c generator which is operated at a constant speed. The d-c field supply to the generator is variable in both magnitude and polarity by means of a rheostat and reversing switch as shown. Therefore, the motor armature is supplied by a generator having smoothly varying voltage output from zero to full-load value. The motor field is supplied with a constant voltage from the same source as that supplying the generator fields. The generator drive power could be from a single-phase or the 3-phase a-c motor, from an engine, or from any other constant speed source. In the same way the d-c field supply can be supplied from a rectifier, from an exciter on the end of the generator shaft, or from any other suitable d-c source.

The advantage of the Ward-Leonard system is that by means of the variation of a small field current, a smooth, flexible, yet stable control can be maintained over the speed and direction of rotation of a d-c motor. Such systems are applicable to ship propulsion, hoists, and elevators, diesel electric equipment and to the rotation of gun turrets, radar antennas, and similar heavy equipment. The action of the system is very much like that of an amplifier since a very small amount of power is used to control greatly increased power.

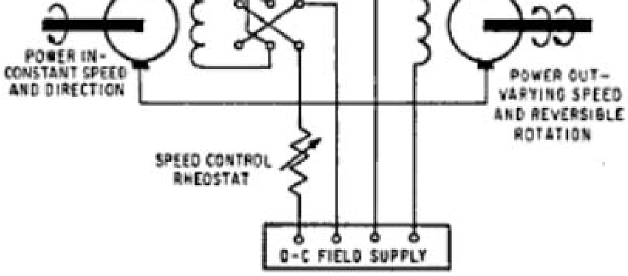

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Figure 21-34.—Ward-Leonard drive.

A simple Ward-Leonard drive for a radar antenna is shown in figure 21-35. The d-c generator in this system is driven by a 230-volt single-phase a-c motor. The same a-c line supplies a rectifier which furnishes field supply for both the d-c generator and the d-c motor fields. However, the generator field is connected to a potentiometer in such a way that the magnitude and polarity of the applied voltage can be varied. By varying the setting of the potentiometer control knob, the antenna can be rotated in either direction and at any speed from zero to full rate.

The system shown is an open-loop type and is applicable to a search type radar where the speed and direction of the antenna rotation is under direct control of the operator. This system could be modified for use as a closed-loop system by providing feedback from the antenna drive mechanism to the speed and direction control potentiometer so that the voltage supplied to the field of the d-c generator would be reduced to zero when the antenna position was in correspondence with the input order. One method of providing feedback for the system shown in figure 21-35 is by use of a simple transmitter-receiver system and a mechanical differential, illustrated in figure 21-36.

AMPLIDYNES

As has been stated earlier in this chapter, SYNCHROS are used for the transmission of angular motion without developing a large amount of torque.

DIFFERENTIAL SYNCHROS are used for combining, in the desired manner angular motion from two different sources, again without developing a large amount of torque.

SYNCHRO CONTROL TRANSFORMERS are used to produce an output voltage that is proportional to the angular difference between the input and output shafts of a servomechanism.

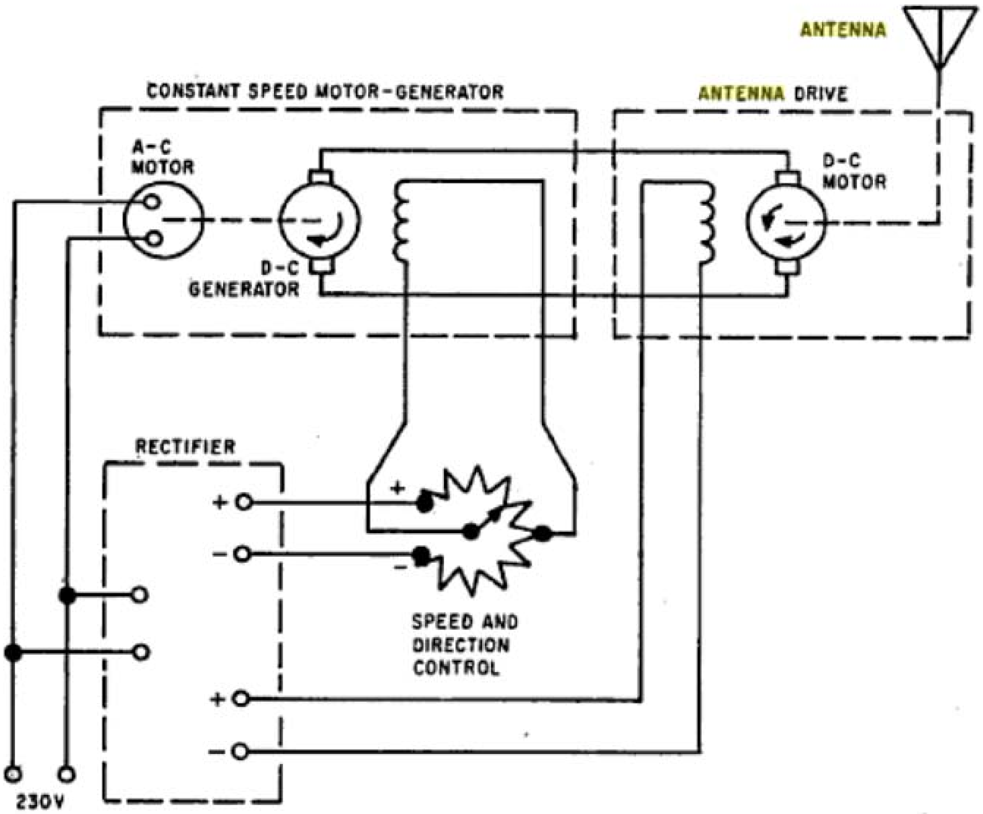

Figure 21-35.—Simple radar antenna drive.

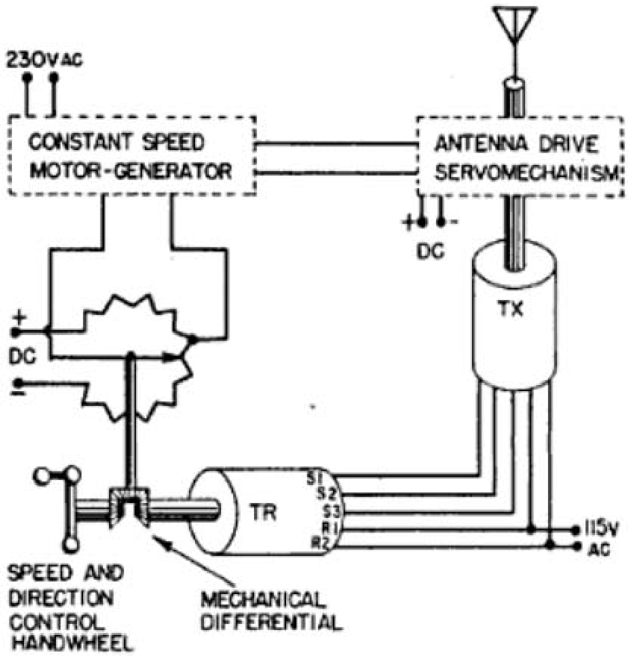

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Figure 21-36.—A feedback system for Ward-Leonard type servo control.

discussed later in the text. The amplidyne drive motor is ordinarily a 3-phase a-c induction motor.