Electron tubes in industrial service

By W. R. G. BAKER [1] A. S. FITZGERALD [2] and C. F. WHITNEY [3]

SOME insight into what the Thyratron tube can do was discussed in January *Electronics;* the following descriptions are illustrative of further Thyratron, and other electron tube applications:

The parallel inverter, shown in Fig. 1, is a device for obtaining a.c. output from a d.c. input, which is definitely related in frequency and phase to the a.c. grid excitation. The grids, normally biased negatively, are excited so that one is positive when the other is negative. During the positive half-cycle of grid excitation, tube *A* will conduct while the anode of tube *B* is at line potential. During the negative half-cycle tube *B* will conduct, thus lowering its anode voltage to the tube drop. Since the tubes are tied together by the capacitor *C*, the anode voltage of *A* will go negative because the capacitor cannot discharge immediately. If the circuit constants are such that the existing ions can diffuse before the anode voltage becomes positive, the grid of tube *A* will resume control. Similarly if the grid of tube *B* is made positive and that of tube *A* negative, the current will again shift tubes. The circuit is started and stopped by switching the d.c. source. The wave form of this type of inverter tends to be rectangular but may approximate a sine wave with suitable circuit constants.

The circuit in Fig. 2 shows the parallel inverter arranged for self-excitation instead of being driven. The circuit will invert at the frequency determined by the constants of the circuit when the line switch is closed. The circuit is stopped by switching the d.c. supply.

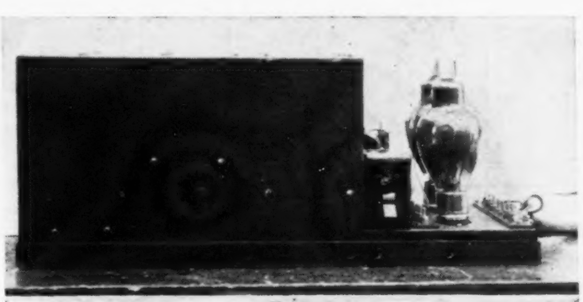

Fig. 3—This inverter supplies 150 watts, 60 cycles from a 115-volt d.c source for refrigerators, radios, etc.

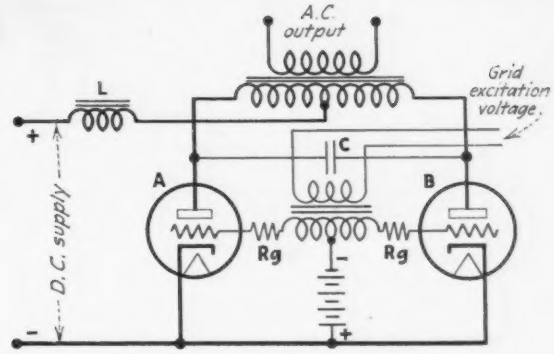

Fig. 1—An inverter circuit for supplying a.c. from a d.c. source

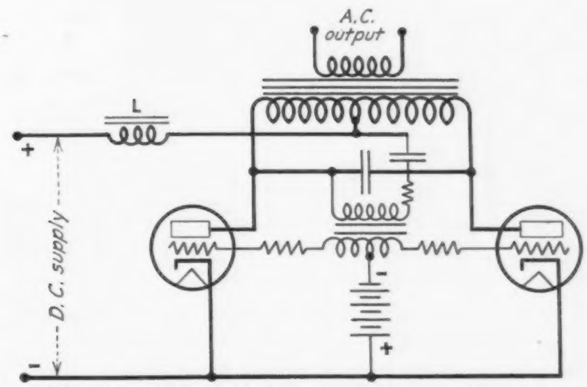

Fig. 2—Self-excited inverter. Output frequency determined by the circuit constants

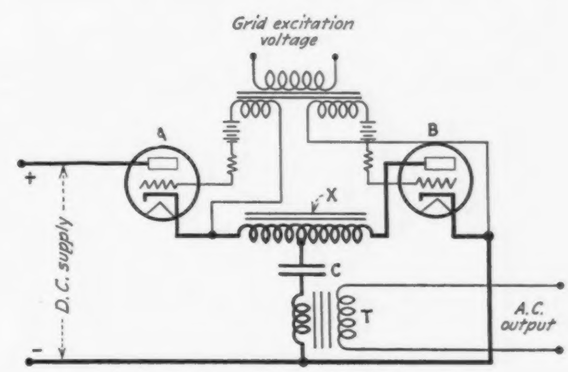

Fig. 4—Separately excited series type inverter circuit

These circuits may be used to supply a.c. power from a d.c. source or to supply frequencies higher than 60 cycles as frequently desired for special purposes.

Fig. 4 shows a circuit for a separately excited series type inverter which may be used as a source of a.c. from d.c. supply, or as a high output amplifier to reproduce phase and frequency. The grids of the tubes are excited so that one is positive when the other is negative. Bias batteries keep the grids normally negative. If a d.c. voltage is applied to the plate of tube *A*, when its grid is positive current will flow through the tube, half of the reactor *X*, capacitor *C*, and the primary of the load transformer *T*. When *C* becomes charged the current stops. In the next half-cycle of excitation the capacitor discharges through the other half of the reactor *X*, tube *B*, and the load transformer *T*, thus furnishing the load with an alternating current.

[1]Vice-president in charge of manufacturing, RCA Victor Company.
[2]Engineering department, RCA Victor Company.
[3]Radio department, General Electric Company.

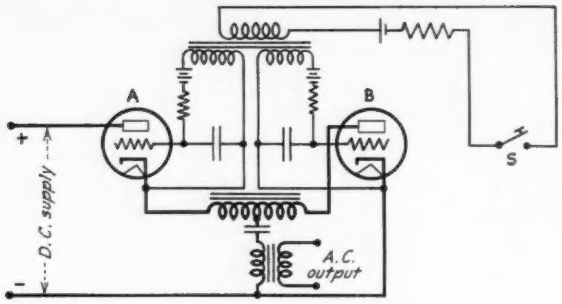

Fig. 5—Self-excited inverter for working into loads of low resistance

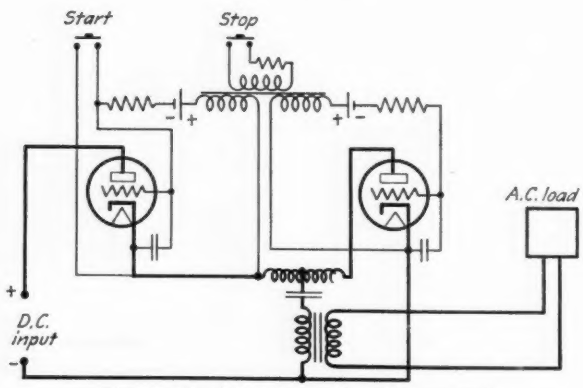

Fig. 6—Rush-button or impulse control of inverter

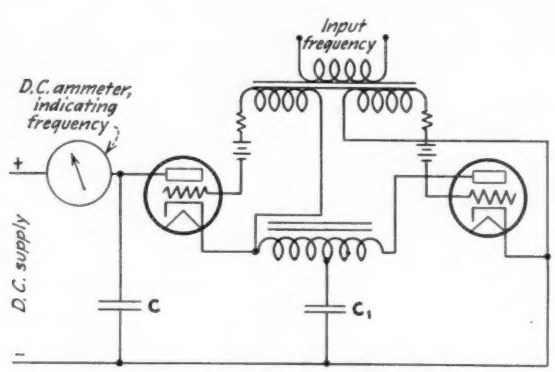

Fig. 7—Thyratrons for use as a frequency indicator

In Fig. 5 is shown a self-excited inverter circuit having a special control feature. In this circuit the grid excitation is obtained by means of the mutual inductance between the two windings of the grid transformer. This permits the inverter to operate into loads of low resistance. The operation of the inverter may be stopped and started by removing or restoring the grid transformer coupling. This can be done by means of the switch *S*, shown in the diagram, without switching the d.c. supply.

The circuit shown in Fig. 6 is similar to the one in Fig. 5 but is arranged for impulse or push-button control. When the "start" button is pressed the inverter will commence oscillation and the load will be energized. It will continue to operate until the "stop" button is pressed, which causes the inverter to stop oscillating, and no further action will occur until the "start" button is again pressed. No switching means in the d.c. power supply circuit are necessary.

The circuit shown in Fig. 7 employing two Thyratrons, may be used as a frequency indicator. It furnishes a direct current which is proportional to the *frequency* of the voltage applied to the grids of the tubes and within limits independent of the grid *voltage*. The device operates on the series type inverter principle.

A time-delay relay

The circuit shown in Fig. 8 was designed to give a definite time delay device to operate over a time range of 30 minutes. To obtain the desired characteristic, the four-element vacuum tube was brought into use. The plate current of a screen-grid tube is practically independent of plate voltage; it is determined by the voltages on the control and screen-grids as long as the plate voltage is above the screen voltage. As the plate voltage is reduced below the screen voltage, the plate current falls off rapidly.

The circuit in Fig. 8 utilizes this characteristic. The a.c. supply is rectified and divided by the potentiometer to give the proper voltages on the two grids, and the remainder is applied to the capacitor *C*. When switch *S* is opened, the capacitor *C* discharges at a constant rate through resistor *R* and the plate filament circuit of the Pliotron. The discharge current gives a drop across *R* which controls the Thyratron. The time is directly proportional to the voltage to which the capacitor is charged and the value of the capacity.

The time delay between the opening of the switch *S* and the operation of the Thyratron is directly proportional to the charging voltage applied to the capacitor. The obvious way to control the timing is by means of a potentiometer controlling this voltage. The potentiometer may then be calibrated directly in time. The time error with voltage change is very small over a given range.

Electron tube telemetering system

For transmitting instrument readings over long distances, the varying frequency principle has a distinct advantage because a frequency indication is substantially independent, so far as accuracy is concerned, of variations in the resistance or transmitting quality of the line over which the signal is sent.

To carry this system into effect it is necessary to

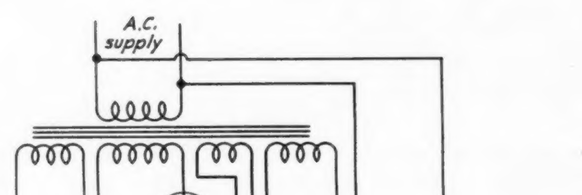

Fig. 8—Time-delay relay using screen-grid tube and Thyratron

generate a frequency definitely related to the reading of the instrument which is to be telemetered. This frequency is transmitted to the instrument which is to be telemetered. This frequency is transmitted to the dispatcher's office or remote station, where a device, operated by frequency will give a deflection proportional to the reading of the transmitting instrument. In such systems the totalizing of loads at two or more different stations is almost invariably required and any frequency telemetering system should be capable of accomplishing this.

The electro-mechanical system shown on the left of Fig. 9 has a contact mounted upon the pointer of the transmitting meter which cooperates with two contacts fixed on a co-axial follower element driven by a motor. The follower controls a variable resistance and automatically adjusts itself to the position of the pointer. The resistance controls the speed of a motor-alternator. Thus the frequency generated depends upon the instrument reading.

This frequency is transmitted over a special pilot wire to the remote station where it is arranged to drive a small synchronous motor. This synchronous motor drives a d.c. generator. The voltage of this generator, if the field be kept constant, will clearly be proportional to the frequency. Thus it will be definitely related to the pointer position of the transmitting instrument. A d.c. voltmeter may therefore be connected to this generator and its deflection will be a function of the reading of the transmitting meter.

Transmitting meters at two different remote stations are shown, the readings being telemetered to a third location. The load at each station is indicated by the voltmeter reading, the voltage of the respective d.c. generator and the total load is shown by a third voltmeter reading the sum of the two d.c. voltages.

The operation of the electron tube system is as follows: A small condenser is mounted on the movement of the meter of which the reading is to be transmitted. This condenser controls the frequency of a beat oscillator. The beat frequency is proportional to the deflection of the meter. The condenser is light and of small dimensions and may be mounted on the movement of any type of meter ordinarily employed in power distribution systems without interfering with its accuracy.

The frequency might be transmitted by pilot wires if desired. In the diagram it is shown transmitted by means of carrier current. The beat frequency modulates a carrier wave, the usual master oscillator power amplifier and modulator connections being shown.

At the receiving station the carrier is detected and the de-modulated beat frequency is amplified and connected to a Thyratron frequency indicating circuit shown in Fig. 7. This furnishes a direct current exactly proportional to the beat frequency and thus also proportional to the deflection of the meter. Thus a simple d.c. current measuring instrument connected to the circuit such as shown in Fig. 7 gives an indication of the reading of the remote meter. Any number of readings may readily be totalized by adding together by means of an additional d.c. instrument the sum of the d.c. current furnished by the several circuits of Fig. 7.

It will be noted that the electron tube scheme eliminates all moving parts other than the meter movements at the two ends. It also avoids the use of rotating machines which have to be kept in synchronism. This feature of the electro-mechanical system is not without certain practical difficulties.

By the use of electron tubes another feature of interest is obtained. In the left-hand diagram it will be noted that a special pilot wire must be used to transmit the frequency signal. This is avoided in the tube system by transmitting the beat frequency over the high-voltage power circuit by means of carrier current. Electron tubes are further employed for the generation and reception of carrier current.

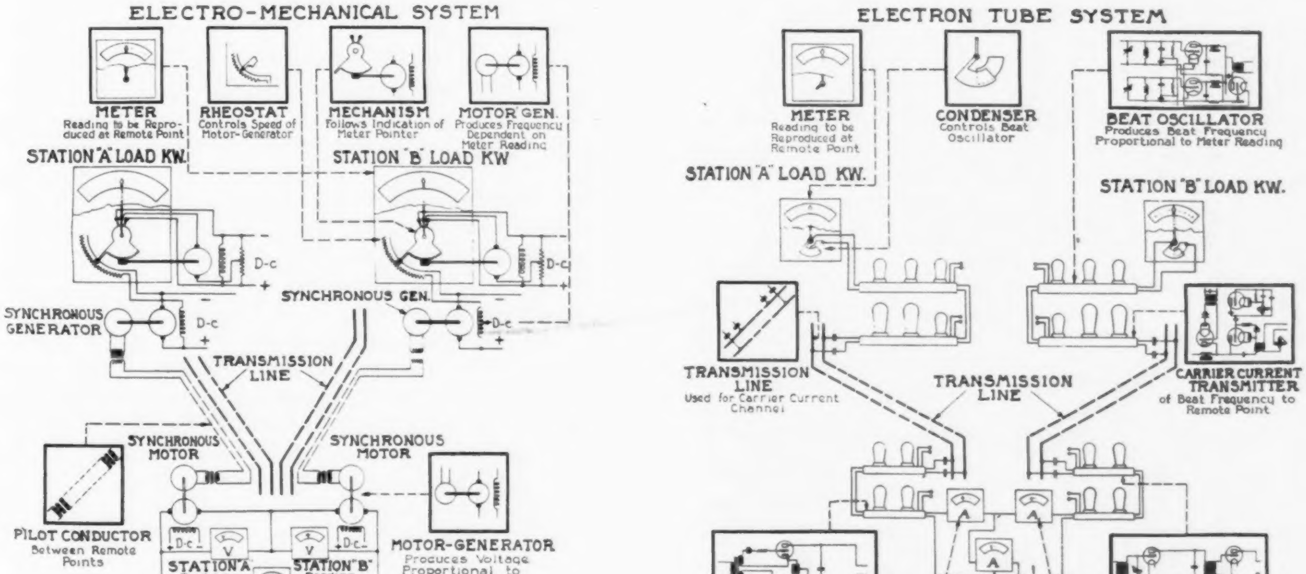

Fig. 9—Electron tube telemetering and totalizing system, variable frequency method