Oct. 24, 1933. L. G. ABRAHAM 1,931,598

PILOT WIRE REGULATOR SYSTEM

Filed Jan. 23, 1932

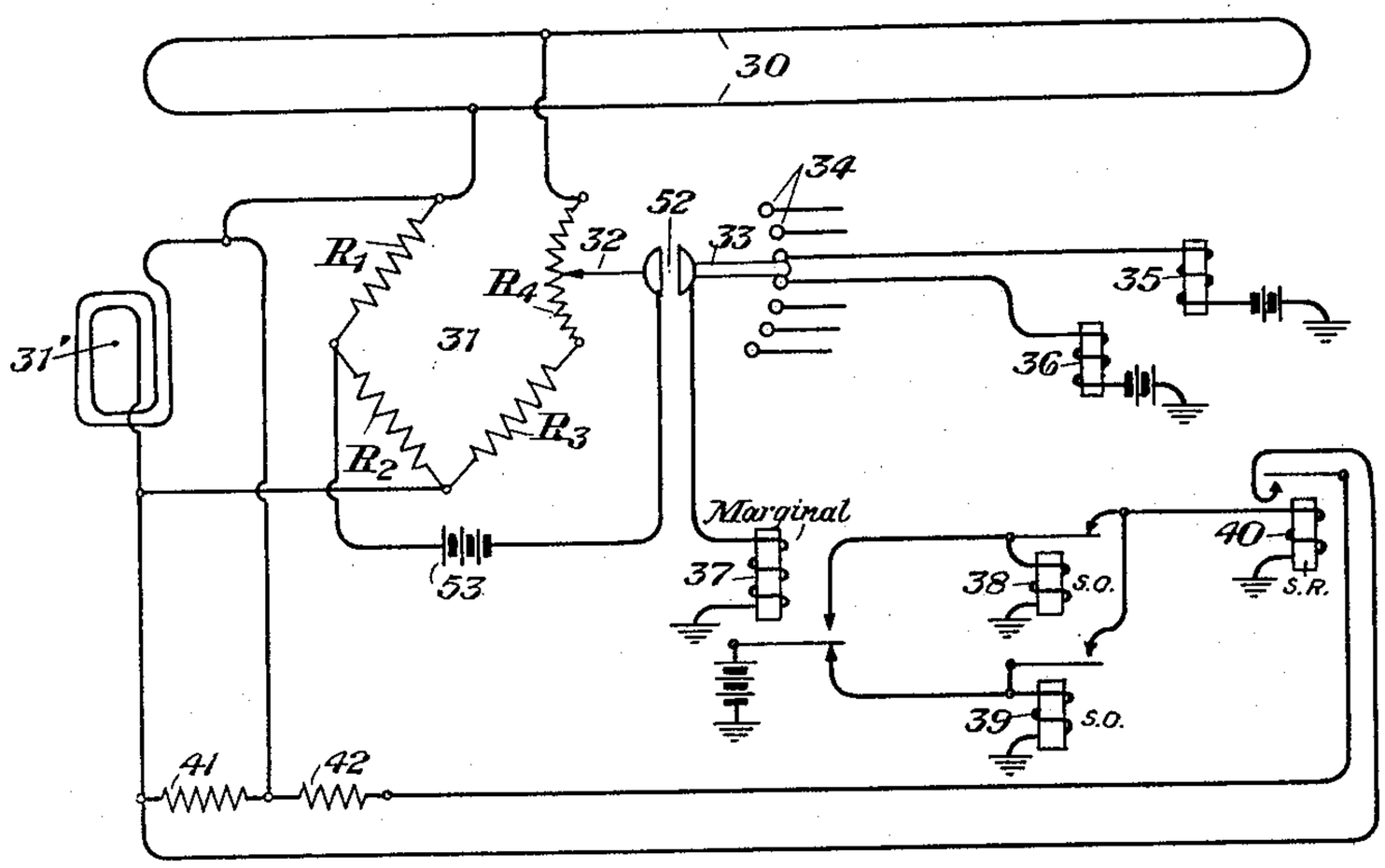
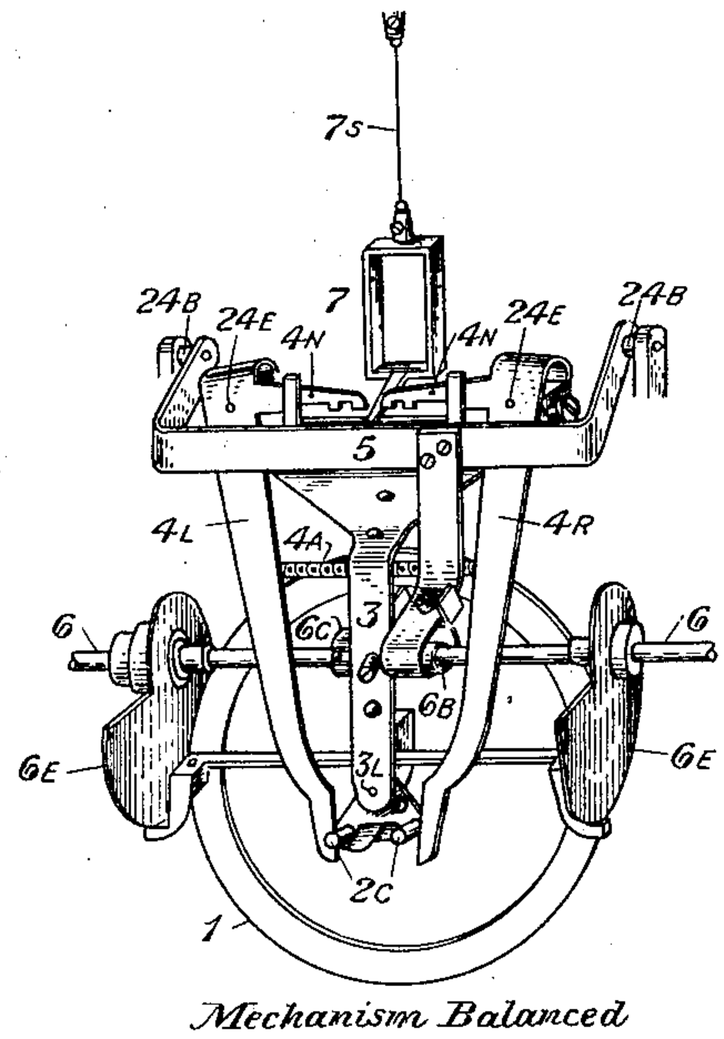
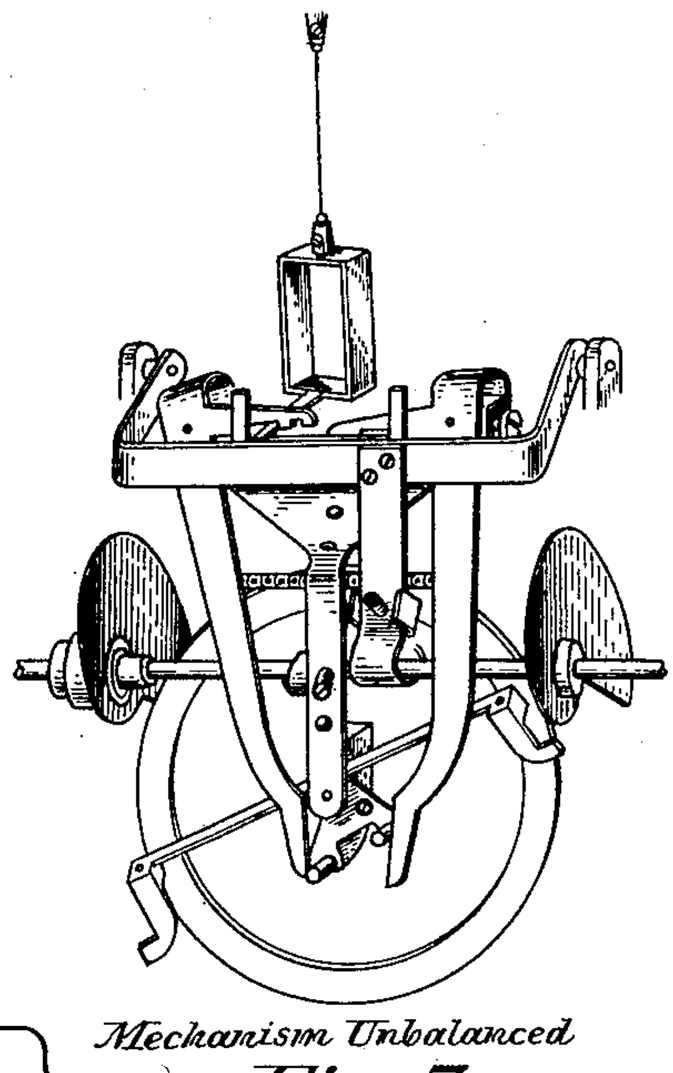


Fig. 1



Mechanism Balanced

Fig. 2



Mechanism Unbalanced

Fig. 3

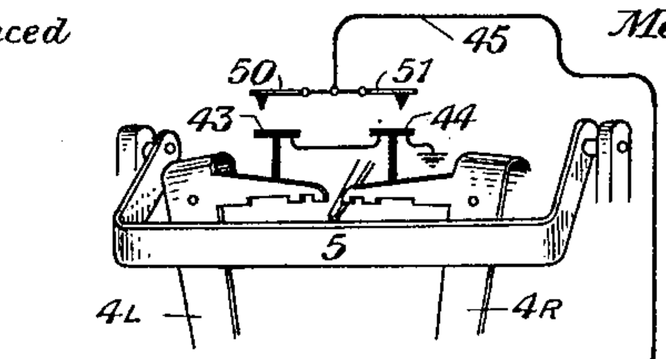
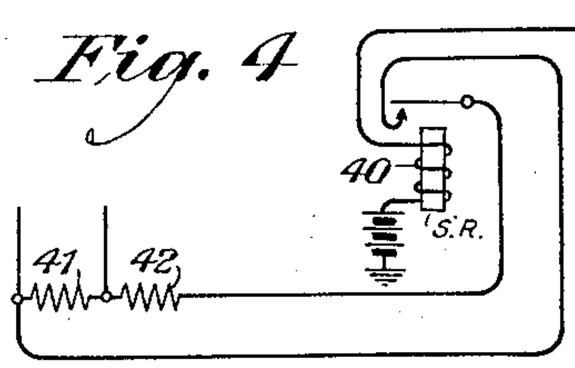


Fig. 4



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Patented Oct. 24, 1933 1,931,598

UNITED STATES PATENT OFFICE

1,931,598

PILOT WIRE REGULATOR SYSTEM

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Application January 23, 1932. Serial No. 588,475

5 Claims. (Cl. 178—44)

This invention relates to transmission systems and more particularly to improvements in pilot wire regulator arrangements associated with such systems.

It is often the practice to associate with a group of transmission lines a pilot wire circuit which is subjected to the same variations in temperature as the lines. This pilot wire would be included in one arm of a Wheatstone bridge, across one diagonal of which would be connected a galvanometer. The effect of temperature variations on the pilot wire would tend to unbalance the bridge and operate the galvanometers. The galvanometer would control a slide wire arrangement to restore the balance of the bridge. The operation of the slide wire mechanism would operate progressive mechanism to control the transmission equivalent of the group of transmission lines.

In such a device, the bridge must be unbalanced by a certain amount before an adjustment of the slide wire occurs, and this amount is called the galvanometer sensitivity (S). The amount of the adjustment which takes place will be called "A".

If the resistance of the pilot wire is changing steadily, an adjustment will take place when the bridge is unbalanced by an amount S. If A is less than S, the bridge will still be unbalanced after the adjustment by an amount S—A, which is in the same direction as before. In other words, the adjustment behind the desired value will lag by an amount varying between S and S—A, the first value being approached just before an adjustment is made and the second value being reached just after an adjustment is made.

Whatever the relative values of S and A may be, the average lag in adjustment is

$$S-\frac{A}{2}$$

and this lag varies by

$$\pm\frac{A}{2}.$$

In a circuit consisting of N regulator sections, all varying in the same direction (for example, when the sun is rising), the average lag will add up directly in all regulator sections and will be N

$$\left(S-\frac{A}{2}\right).$$

The random lag will add according to the usual probability function and its total effect may be taken as

$$\pm\sqrt{N}\frac{A}{2}.$$

It is evident from the above that the average lag will be zero and the total lag will be as small as possible if

$$S=\frac{A}{A}.$$

In this case, however, the bridge unbalance will be changed by the adjustment from

$$+\frac{A}{2}$$

to

$$-\frac{A}{2},$$

so that the bridge will tend to operate in the opposite direction or to hunt. Hunting is very undesirable in a pilot wire regulator device of this type, due to the frequent changes which would result in the net loss of the circuit; for example, transmission frequency measurements with the present methods would be almost impossible in a long circuit. Furthermore, there would be excessive wear and tear on the apparatus if hunting was permitted.

Accordingly, it is one of the primary objects of the invention to provide arrangements for eliminating or materially reducing hunting in a pilot wire regulator which is so adjusted that the sensitivity of the galvanometer is approximately one-half the amount of change in the slide wire per adjustment of the bridge. Other objects and features of the invention will appear more fully from the detailed description thereof hereinafter given.

The invention may be more fully understood from the following description, together with the accompanying drawing, in the Figures 1, 2, 3 and 4 of which the invention is illustrated. Figure 1 is a circuit diagram illustrating a preferred embodiment of the invention; Figs. 2 and 3 are illustrations of details of the regulator mechanism; Fig. 4 shows a modification of the arrangements shown in the other figures. Similar reference characters have been used to denote like parts in all of the figures.

In Fig. 1 are shown the pilot wire regulator arrangements of the invention. These comprise the pilot-wire circuit 30, which is included in one of the arms of a Wheatstone bridge 31. The other arms of the bridge are shown as the resist-

ance R_1, R_2 and R_3. Bridged across points of the bridge would be the battery 53. Bridged across the opposite points of the bridge would be a galvanometer 31'. When the resistance of the pilot-wire circuit 30 changes, due to temperature variations or other causes, the bridge would become unbalanced and the galvanometer 31' would operate. The galvanometer would control a regulator 52 which is shown in detail in Figs. 2 and 3. Regulator 52 is shown schematically in Fig. 1 and comprises a switch arm 32 cooperating with the resistance R_4 to compensate for resistance changes in the pilot-wire circuit and to restore the balance of the bridge. Regulator 52 would also comprise a switch arm 33, which would cooperate with a plurality of contacts such as 34. By means of these contacts it would close circuits for a number of relays such as the relays 35 and 36, which relays would in turn adjust the transmission equivalent of the group of transmission circuits to be regulated. With such an arrangement, when the resistance of the pilot-wire 30 changed, the device would operate to make compensating adjustments in the transmission circuits. The above arrangements are well known in the art.

It is pointed out that the switch arm 33 will be on a single contact part of the time and will rest on two adjacent contacts part of the time. When the switch arm rests on two adjacent contacts, the current from individual batteries connected to the relays, such as 35 and 36, will flow through the marginal relay 37 and cause it to operate. When the switch arm 33 moves further along and rests only on one contact, the marginal relay 37 will be released. Accordingly, whenever the device makes an adjustment which causes a change in the contacts on which the switch arm rests, the marginal relay 37 will operate or release and this will cause a circuit to be completed for the slow release relay 40. It will also close a circuit for either of the slow operate relays 38 and 39. The operation of relay 40 will close a shunt path, including the resistance 42, about the windings of the galvanometer 31 and reduce its sensitivity. When either of the slow operate relays such as 38 or 39 finally operates, it causes the slow release relay 40 to start to release. When the slow release relay 40 has released, the shunt about the galvanometer is removed and its sensitivity is restored to its higher value.

The general effect of such arrangements is as follows: The galvanometer 31 is normally quite sensitive. When the regulator operates so that a change is made in the settings of the primary relays such as 35 and 36, the slow operate and slow release relay arrangements will function so that the galvanometer is made insensitive for a period of time determined by the operate and release time of these relays. This interval, for example, might be three minutes. The pilot-wire regulator arrangements will then not tend to hunt except at three-minute intervals, and in the usual case this interval will be great enough that substantially no hunting of any kind will occur, since the resistance of the pilot-wire will usually have changed sufficiently to prevent hunting.

The regulator mechanism 52 is shown in more detail in Figs. 2 and 3. The movements of the galvanometer system 7 are controlled by the condition of balance of the Wheatstone bridge circuit, one arm of which includes the pilot-wire. When the bridge is balanced, the galvanometer pointer lies directly under the space between the ends of the two right-angle levers 4L and 4R which are pivoted at 24E and 24E. When the bridge is unbalanced the pointer may deflect until it lies at any position between the stops on the top of the rocker arm 5, its exact position being determined by the amount of the unbalance.

Shaft 6 is driven continuously by a small motor operating on the 24-volt central office battery, and carries a cam 6B by means of which the rocker arm 5, which is pivoted at 24B, is periodically raised. If, at the instant arm 5 is raised, the Wheatstone bridge circuit is balanced, the galvanometer pointer is raised into the space between the horizontal portions of levers 4L and 4R. If, however, the bridge circuit is not balanced, the pointer is deflected so that it lies under one or the other of the levers 4L or 4R. Then, as the pointer is raised by the upward movement of the arm 5, it carries up with it the horizontal arm of one of the levers 4L or 4R.

The arm 2 is one member of a clutch whose other member is disc 1, the two being held together by means of the vertical arm 3. Just before the above movement takes place, cam 60 on the motor-driven shaft 6 pushes arm 3 forward so that the arm 2 and disc 1 are held apart. When the horizontal arm of lever 4L or 4R is raised, the vertical arm acting on the pins 2C which are connected to arm 2 causes arm 2 to be rotated about its pivot at 3L. Arm 2 is now tilted from its horizontal position shown in Fig. 2, and the resultant position of the parts of the mechanism is shown for a typical case in Fig. 3. As rocker arm 5 falls due to the disengagement of cam 6B, cam 6C also disengages arm 3 which falls back and again connects arm 2 and disc 1. Cams 6E and 6E on shaft 6 now engage the extensions of arm 2 and restore arm 2 to its original horizontal position and arm 2 being connected to disc 1, carries disc 1 with it.

If the resistance in the pilot-wire arm increases, the pointer will deflect to the left while if it decreases, the pointer will deflect to the right. It is obvious that if the pointer deflects to the left, as outlined above, the restoring rotation of the disc will be clockwise, but if it deflects to the right, the restoring rotation of the disc will be counter-clockwise. The slide-wire resistance in the Wheatstone bridge circuit is mounted on the same shaft with disc 1 and the relationships are such that when movements like the one described above take place, the direction of rotation of the slide-wire will always be such as will tend to restore a balance in the Wheatstone bridge circuit. The brush of the dial switch mentioned above is also mounted on the same shaft with disc 1 so that, as the rebalancing movements take place the gains of the regulating repeaters are varied accordingly.

It will be seen from the above description that an adjustment is made, tending to rebalance the bridge once for each revolution of the motor-driven shaft 6 so that the variations in the resistance of the pilot-wire can be followed very quickly and accurately.

In Fig. 4 is shown an arrangement whereby hunting might be reduced at all times rather than only at a time when a change is made in the setting of the primary relays such as 35 and 36. Such arrangements would reduce wear and tear on the regulator itself. Such arrangements would be similar to those shown heretofore except that the marginal action of relay 37 could not be used. It would be necessary to provide some method of starting the relay 40 into op-

eration whenever an adjustment of the slide wire was made. This can be accomplished by providing on the members 4N of Fig. 2 the contacts 43 and 44, which would cooperate with the contacts 50 and 51, respectively. These would close a circuit 45 directly through the slow release relay 40 and cause it to operate to shunt the galvanometer and reduce its sensitivity in a manner similar to that heretofore described.

While the arrangements of the invention have been disclosed as embodied in certain specific arrangements which are deemed desirable, it is understood that they are capable of embodiment in many and other widely varied forms without departing from the spirit of the invention as defined by the appended claims.

What is claimed is:

1. In a transmission system a pilot wire, a Wheatstone bridge having said pilot wire included in one of the arms thereof, a galvanometer connected to said bridge, regulator mechanism controlled by said galvanometer for adjusting the balance of said bridge, separate regulator mechanism controlled by said galvanometer for adjusting the transmission equivalent of said transmission system, and mechanism controlled by the operation of said second mentioned regulator mechanism for varying the sensitivity of said galvanometer.

2. In a transmission system a pilot wire, a Wheatstone bridge having said pilot wire included in one of the arms thereof, a galvanometer connected to said bridge, regulator mechanism controlled by said galvanometer for adjusting the balance of said bridge, separate regulator mechanism controlled by said galvanometer for adjusting the transmission equivalent of said transmission system, slow release means operated by the functioning of said second mentioned regulator mechanism, and means controlled by the operation of said slow release relay means for varying the sensitivity of said galvanometer.

3. In a transmission system, a pilot wire, a Wheatstone bridge having said pilot wire included in one of the arms thereof, a galvanometer connected to said bridge, regulator mechanism controlled by said galvanometer for adjusting the balance of said bridge, separate regulator mechanism controlled by said galvanometer for adjusting the transmission equivalent of said transmission system, slow release relay means operated by the functioning of said second mentioned regulator mechanism, and a low resistance shunt about the windings of said galvanometer adapted to be closed by said slow release relay means.

4. In a transmission system a pilot wire, a Wheatstone bridge having said pilot wire included in one of the arms thereof, a galvanometer connected to said bridge, regulator mechanism controlled by said galvanometer for adjusting the balance of said bridge, separate regulator mechanism controlled by said galvanometer for adjusting the transmission equivalent of said transmission system, a chain of slow operate and slow release relays controlled by the functioning of said second mentioned regulator mechanism, and means controlled by said relay chain for temporarily varying the sensitivity of said galvanometer.

5. In a transmission system a pilot wire, a Wheatstone bridge having said pilot wire included in one of the arms thereof, a galvanometer connected to said bridge, regulator mechanism controlled by said galvanometer for adjusting the balance of said bridge, separate regulator mechanism controlled by said galvanometer for adjusting the transmission equivalent of said transmission system, a marginal relay operated whenever the setting of said second mentioned regulator mechanism is changed, and relay means controlled by said marginal relay for temporarily varying the sensitivity of said galvanometer.

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