May 7, 1935. J. P. BALLANTINE 2,000,736

MULTIPLE RATE POWER METERING

Filed Nov. 19, 1932

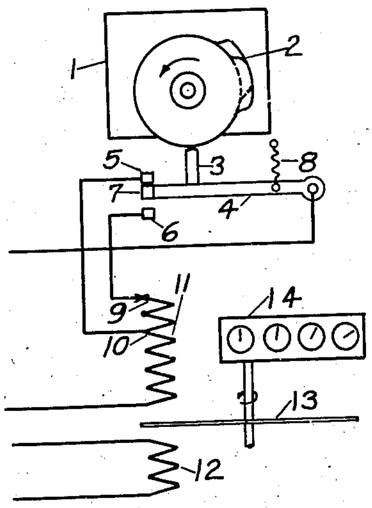

FIG. I

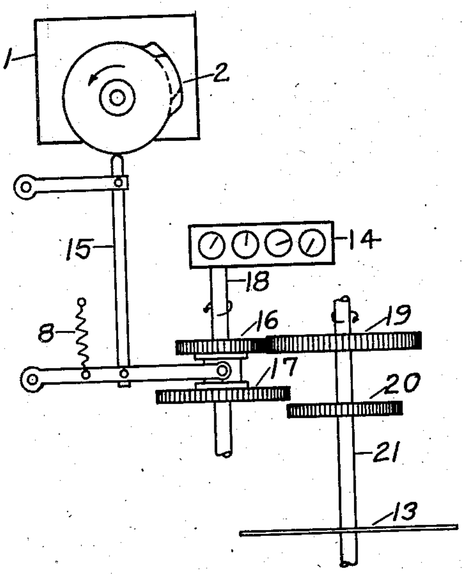

FIG. II

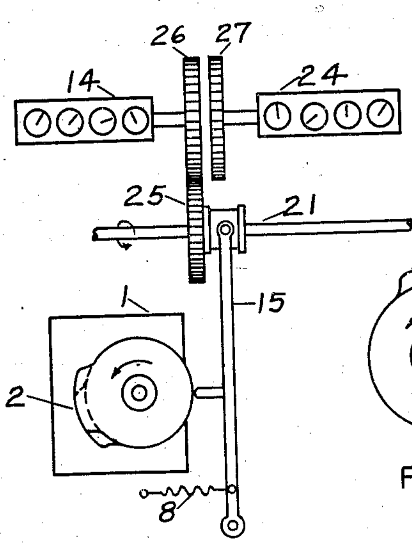

FIG. III

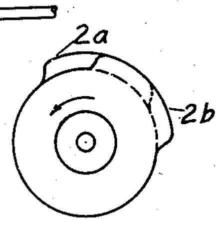

FIG. IV

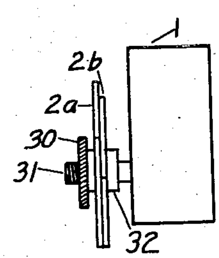

FIG. V

Inventor

John Perry Ballantine

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MULTIPLE-RATE POWER METERING

John Perry Ballantine, Seattle, Wash.

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7 Claims. (Cl. 171—268)

This invention relates to integrating and registering electric power meters. In many power generating and distributing systems, there are periods of the day, varying of course from one season of the year to another, during which the demand for power declines to less than the desirable minimum the system should be carrying. Under these conditions in water power systems it is not uncommon to find it necessary to let water go to waste which could be used profitably if the "off-peak" demand for power could be increased. While the situation in systems operating on combustible fuel is not so clearly unfavorable relative to off-peak power periods, it is found that even in those systems the large fixed charges make it desirable to increase the use of power during off-peak periods as much as possible. Perhaps one of the most important factors at present tending to discourage the use of off-peak power is that involved in metering, for the customer generally pays the same price per kilowatt-hour of energy used whether it is used at the peak of the day's demand or at its lowest depression. Under these circumstances it is inevitable that the consumer will make no effort to use power at the less convenient periods of the day. There has been suggested in the literature relating to the power industry the possibility of selling off-peak power at a lower rate than during the rest of the day, and it is said that a few power companies have made installations of meters for the specific purpose of metering off-peak power consumed at the customer's premises. This practice is one that can be applied to relatively few customers and one in which there is naturally considerable sales inertia to overcome. What is needed in this regard is a meter that can be installed for the metering of both ordinary and off-peak power sold to the consumer. My invention provides a method of metering off-peak power which is relatively simple and inexpensive to put into operation, and means which will meter both ordinary and off-peak power, automatically taking into account the ordinary and off-peak hours of the day.

What constitutes my invention is set forth in the specification following, and is succinctly defined in the appended claims.

My invention is shown in diagrammatic form in Figures I, II, III, IV, and V.

Figure I shows my invention in a preferred embodiment in which electrical features are incorporated.

Figure II shows an alternative form.

Figure III shows a third form with features differing from Figures I and II.

Figures IV and V show a detail of construction of part of Figure I.

In the metering of ordinary and off-peak power, the object to be attained is that of registering the ordinary energy used, which is to be charged for at the ordinary rate, and of registering the off-peak energy separately, so it can be charged for at a lower off-peak rate, or of registering less than the actual amount of off-peak energy so that the off-peak rate will be automatically lowered below the ordinary rate when the actual meter reading is billed at the ordinary rate. The latter method is the simpler of the two to put into effect.

One way of accomplishing this is shown in Figure I, another in Figure II. In Figure I, a clock 1, preferably electrically driven, drives a cam 2. The cam 2 is driven by the clock so as to complete one revolution in twenty-four hours. Usually there is a single period of about six hours or less during the day when off-peak power is available. On cam 2 the arc corresponding to this period is made to a greater radius than the rest of the cam. Cam 2 is made of two similar parts 2*a* and 2*b*, Figure IV, each part with a portion of its arc at the larger radius. The two parts 2*a* and 2*b* are mounted against each other on the shaft which drives them, and upon which they are held against a suitable shoulder by a thumb screw 30, Figure V.

During the ordinary load hours of the day the cam 2 has the position relative to the rest of the meter indicated in Figure I, that is, the lesser radius of the cam 2 is in control. The rotation of the cam 2 is made effective in controlling the dialing rate by means of a set of contacts 5, 6, and 7, which are opened and closed by movement of an arm 4 carrying contact 7 and a cam contact piece 3. Arm 4 is held against the cam 2 by a spring 8. Contacts 5, 6, and 7 are connected to the voltage coil 11 of the meter mechanism through connections 9 and 10. The current coil 12, driving disc 13, and register 14 are also shown in Figure I. Inasmuch as most power is sold and metered through single phase alternating current meters, this type of meter is implied in the connections shown in Figure I. The arrangement could be extended easily to three-phase meters without any change in the principle illustrated. Ordinarily, the dial 14 will indicate actual kilowatt-hours of energy passing through the meter. This will be true as long as the contact 5 is against contact 7. When the cam 2 turns around to the hour when the off-peak period begins, it forces arm 4 down so that contact 6 is against contact 7. Under this condition connection 9 on coil 11 is effective, whereas ordinarily connection 10 is effective. This causes coil 11 to produce a weaker field than ordinarily, and consequently a slowing up of disc 13. The way in which the strength of the magnetic field produced by coil 11 is varied by changing the number of turns in coil 11 can be best explained with reference to the voltage coil arrangement of ordinary alternating watt hour meters. In these meters, the voltage coil is mounted on a magnetic structure with airgaps arranged so that in the normal operation the magnetic material is not saturated magnetically. Under this condition the magnetic flux density existing in the iron is on the "straight part" of the magnetization characteristic of the material, and the flux is substantially proportional to the total ampere turns in the circuit. When an alternating voltage is applied to such a circuit the flux is built up in the magnetic material so that the voltage is represented by the equation:

$$E=4.44fn\phi10^{-8} \quad (1)$$

approximately. In this equation E is effective voltage, f is frequency, n is number of turns, and ϕ is maximum instantaneous flux. The equation

$$\phi=\frac{4\pi nI\mu A}{10l} \quad (2)$$

where ϕ is flux, n is number of turns, I is current, μ is permeability, A is airgap area, and l is airgap length gives the relationship between flux and current.

The flux in the magnetic circuit can be computed from either of the above equations. In the first one it is seen that ϕ can be computed independently of the knowledge of I, so for the purpose of explanation of this invention I need not be considered.

In the first equation, ϕ can be expressed in terms of n as follows:

$$\phi=\frac{10^8E}{4.44fn} \quad (3)$$

For a given operating condition E and f are constants so it is clear that ϕ will be decreased in inverse proportion to the increase of n.

Inasmuch as the torque in an induction meter is an increasing function of ϕ an increase in n, the number of turns in the circuit, will cause the meter to have a lower torque and to register at a lower rate. By weakening the field of the voltage coil the right amount, any amount of slowing down can be accomplished. Usually the rate for off-peak power is about one-half that for the ordinary period, so what is done in such an instance is to make the meter run only half as fast for a given amount of energy passing through it during the off-peak period as during the ordinary period. This causes register 14 to indicate only half as many kilowatt-hours of energy as actually pass through the meter during the off-peak period. The result is that the total reading of the meter when paid for at the ordinary rate will automatically admit half the off-peak period energy free of charge, or stating it another way, will charge only half-price for each off-peak kilowatt-hour. Adjustment of tap 9 on coil 11 makes it feasible to change the ratio of off-peak energy to ordinary energy at will. If the meter were adjusted to register only one-third of the number of kilowatt-hours passing through it during off-peak periods, the effect would, of course, be to admit two-thirds of the off-peak energy free, or, in effect, to charge only one-third the ordinary rate for energy used in the off-peak period.

The lowering of the rate of registration for off-peak energy can also be effected as shown in Figure II, by changing the ratio in the gearing driving register 14. The clock 1 and cam 2 operate as in Figure I, but instead of altering electrical connections, linkage 15 operated by cam 2 moves a set of gears 16 and 17 on a register drive shaft 18. Either gear 16 engages a driving gear 19 or gear 17 engages another driving gear 20, depending upon the angular position of cam 2. These two gears are driven by a shaft 21 which in turn is driven by the driving disc 13 of the meter. During ordinary periods, the angular position of cam 2 is such that the gears 16 and 19 are engaged, as shown in Figure II. During off-peak periods, the cam 2 forces gears 16 and 17 over, disengaging gears 16 and 19 and engaging gears 17 and 20. The ratio of the diameter of gear 20 to that of gear 17 is less than that of gear 19 to gear 16, so the dial is driven at a lower speed for a given speed of the driving disc when gears 17 and 20 are engaged than when gears 16 and 19 are engaged. Accordingly, the off-peak energy is only partly registered as explained for Figure I.

In some instances it is desirable to indicate the ordinary and off-peak energy separately by two registers in the same meter. Figure III provides a mechanism for accomplishing this. The cam 2 and linkage 15 coact as described for Figure II in shifting a gear 25 on a drive shaft 21 which is connected with the driving disc 13. Two registers 14 and 24 are provided to meter the ordinary and off-peak power individually. During ordinary periods cam 2 is in such position that gear 25 engages and drives gear 26 causing register 14 to indicate the kilowatt-hours of energy passing through the meter. During off-peak hours, gear 25 is caused by cam 2 to engage and drive gear 27 so that register 24 indicates the kilowatt-hours of energy passing through the meter. The result is that register 14 indicates all energy used in ordinary periods and register 24 all energy in off-peak periods. The two readings can then be charged for separately at their respective rates.

Figures IV and V show certain details of cam 2. Cam 2 is composed of two parts 2a and 2b which are similar in shape and size. They are placed against each other on shaft 31 on which they are held against a shoulder 32 by a thumb screw 30. The two cam parts 2a and 2b have portions of their circumference at a greater radius than the rest of it, for the purpose of imparting motion to other parts of the meter such as the arm 4 in Figure I, or linkage 15 in Figure II. The length of arc at the greater radius is such as to correspond to the minimum length of the off-peak period with which the meter is likely to be concerned. This is not the same in all situations but in most installations is from three to four hours out of twenty-four. The entire circumference of the cam represents twenty-four hours, so from one-eighth to one-quarter of its circumference is at the greater radius. When the two parts 2a and 2b are brought into coincidence the part of the total circumference at the greater radius is the minimum period, for example, four hours. If now one of the parts 2a or 2b is rotated slightly relative to the other, the resultant part of the circumference of the combined parts at the greater circumference is greater than the minimum amount. By rotating the part still further, the amount of circumference of the greater radius may be increased to nearly twice the minimum, in this example, eight hours. By holding both cam parts 2a and 2b to prevent their rotating relative to each other and turning them together, the off-peak registering period can be placed at any position desired in the twenty-four hours, corresponding to a complete revolution. In most instances, the off-peak period in a day is from four to six hours long, so two cam parts each three or three and one-half hours long would accommodate most practical requirements. For other conditions of either shorter or longer periods, cam parts of different peak periods can be used, or an exactly similar one can be placed with the initial two, giving a range of nearly three to one in the choice of duration of the off-peak period metering. By separating the two minimum off-peak parts of the circumferences of the two parts 2a and 2b, two off-peak periods at different parts of the day can be accommodated. This is not usually required.

Dial or register indications may be in any units, not necessarily those usually used in power practice. If desired, any arbitrary system of numbers can be used during the ordinary and off-peak periods. For example, actual energy units may be indicated in off-peak periods and some multiple of the energy units used indicated in ordinary periods. Also, the dials could be calibrated to read in monetary units directly if the rate per energy unit were a fixed quantity. If the occurrence of an off-peak period is weekly instead of daily, the cams and clock must be changed for slower rotation.

In the figures, which are diagrammatic, many mechanical and electrical details of meters and registering mechanism have for convenience been omitted. These are known in the art, and the exact form in which they are used in my invention is not subject to limitations other than those imposed by the requirements of good design in metering equipment.

What I claim is:

1. In a multiple rate metering system the combination of metering means including a voltage coil with taps, and means for changing said taps for changing the rate of metering.

2. In a multiple rate metering system the combination of metering means including a voltage coil in which the number of turns in service is changed for changing the rate of metering.

3. In a multiple rate metering system the combination of metering means including a voltage coil and the accompanying magnetic circuit, including means for increasing the number of turns in the coil for decreasing the intensity of flux in the magnetic circuit and thereby decreasing the rate of metering.

4. In a multiple rate metering system the combination of a tapped voltage coil and contact making means for changing said taps.

5. In a multiple rate metering system the combination of a tapped voltage coil, contact making means for changing said taps and timing means for controlling the changing of the taps of said coil.

6. In a multiple rate metering system the combination of a tapped voltage coil and clock operated means for changing the taps of said coil.

7. In a multiple rate metering system, the combination of an alternating current watthour meter of the induction type including the usual parts and a tapped voltage coil, and means for changing said taps.

JOHN PERRY BALLANTINE.