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(54) Title: ELECTRICAL POWER METERING SYSTEM

(57) Abstract

A stand–alone electrical power metering system for sub–metering applications. The non–invasive system has current transformers (44, 45) placed around the electrical service legs (33, 34) of the electrical supply to a customer's service panel (13), and with associated voltage taps which are then routed to an interface panel which interfaces the sensed readings from the voltage taps and the current transformers, processes the values within circuity associated with the interface panel (28) and then supplies the resulting values to an electronic metering circuit board (24) which processes the values to electrical power consumption readings to provide electrical comsumption readings for visual display and/or communication to external equipment, e.g., via an optical port, for reading and billing.

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ELECTRICAL POWER METERING SYSTEM

Background of the Invention

I. Field of the Invention.

The present invention relates generally to the field of metering electrical power consumption, and, more particularly, relates to stand-alone power meters for sub-metering applications. Typical sub-metering applications include locations where the electrical service drop may be fed to one centralized electrical service panel and then broken out into several electrical service sub-panels for the purpose of servicing various tenants in a large building. In sub-metering applications, several meters are linked together by a communications cable and linked to a central computer system allowing computerized reading and billing of individual units within large complexes involving many tenants.

The typical type of watthour power meter installation utilized today may measure power consumption with a watthour meter that is placed into a meter pan supplied by the power company and mounted at the desired location. Typically, this type of installation is known as an "invasive" installation, because the electrical service drop to the installation is split in the meter pan, and the electrical watthour meter plugs into a socket arrangement to complete the power circuit and to be able to read the power consumption used by the circuit.

Typically, the watthour meters utilized in these invasive installations may be either an electromechanical meter which has the familiar spinning disk mounted therein, or it may be an electronic device which will measure the power consumption and which has no moving parts. The electronic watthour meter utilizes one or more printed circuit boards with internally mounted current sensors, and, like the electromechanical watthour meter, the electronic watthour meter requires the voltage and current to pass through the meter in order to monitor the power. This type of watthour meter plugs into a meter pan supplied by the power company. When the electronic meter is plugged in and locked in position, the power then flows through the meter and is sensed and recorded accordingly. While this type of electronic watthour meter is used extensively in residential and some commercial applications, it is impractical for other commercial and industrial applications.

Examples of the electromechanical type of power meters which typically have a spinning disk to register power usage are shown in the patents to William C. Beverly, II, (Patent No. 4,922,187) and Francois Tanguay et al (Patent No. 5,089,771). Electronic type power meters typically are such as those shown in the David E. Burrows et al Patent (No. 4,881,070) and in the Walter L. Schutrum et al Patent (No. 4,803,484). However, none of these patents disclose a device which can record power usage in a sub-metering environment wherein an electronic circuit board, designed for the typical type electronic recording watthour meter, is utilized with an interface card and connected to the electrical sub-panel to thereby measure power usage in that particular sub-panel without the use of a conventional meter pan.

In situations involving commercial buildings, it is quite common for the electric power company to provide the building with one large electrical service drop to a large centralized electrical panel. However, in multi-tenant buildings, such as apartment complexes, or a shopping mall, it is necessary to individually meter each location in order to achieve a separate equitable billing statement for each tenant. However, the electrical power company will only supply the main power meter for the centralized location, and it does not normally sub-meter various sub-panels for the various tenants.

SUMMARY OF THE INVENTION

In accordance with the present invention, and considering the problems that have existed and continue to exist in this field, one objective of the invention is to provide a relatively simple and transportable electrical power usage recording device which may be attached to an electrical sub-panel of an electrical system to record the power usage of that particular sub-panel.

Yet another object of the invention is to provide an electrical power recording meter in an electrical system which is non-invasive and may be easily attached to an electrical sub-panel for reading power consumption of the electrical power sub-panel and for measuring current and voltage therein.

Another object of the invention is to provide a universal interface to mate a metering circuit board of the electronic power recording type with an interface board mounted in a convenient, easy to use enclosure , and to utilize the resulting device as a stand-alone meter for sub-metering applications in a non-invasive environment.

The invention accomplishes the above objectives and other objectives by taking a metering circuit board from an electronic type electrical watthour meter and connecting it to an interface board within a suitable enclosure. Within the enclosure, electrical connecting devices are provided to connect a wiring harness to an adjacent electrical sub-panel for the purposes of measuring power consumption, current flow, and voltage within the sub-panel. It is anticipated that the non-invasive characteristics of the present invention will utilize standard current transformers placed around the service leg wires of the electrical service drop in the sub-panel and will utilize voltage taps on the particular service legs. Power readings calculated by the electronic metering circuit board will be made available to the liquid crystal display (LCD) on the metering circuit board for visual display. The interface board is the most critical part of the design, and can be used to adapt any of the available electronic metering boards from socket based meters. The interface board is designed with connectors for easy attachment of the voltage sensing lines and the current transformer lines from the sub-panel. Isolation resistors are placed in close proximity to the voltage connectors to limit the power available and to provide surge protection for the electronic metering board. The surge protection is provided by using wire wound resistors having an inductance adequate to prevent line surges due to electrical transients. Three networks mounted near the transformer connector are designed to match the external current transformers to the metering board.

Other objects, advantages and capabilities of the invention will become apparent from the following description taken in conjunction with the accompanying drawings showing a preferred embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a front elevation view of the stand-alone meter of the present invention connected to a typical electrical sub-panel;

Figure 2 is a perspective view of the stand-alone or system meter of the present invention;

Figure 3 is a front elevation perspective view of the stand-alone or system meter of the present invention with the front cover opened showing the internal characteristics of the meter, which is connected to an electrical sub-panel which is shown with the front cover of the panel removed;

Figure 4 is a front exploded, perspective view of the stand-alone or system meter;

Figure 5 is a diagram of a generic socket based electronic meter corresponding to the prior art;

Figure 6 is a diagram of the invention with the interface adapter board and the related adapter network; and

Figure 7 is a diagram of the compensation network and the metering network.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Theory of Operation:

For a given current (I_p), in the power line, a socket based electronic meter's internal current transformers (CT's) generate a current proportional to the turns ratio N, of the CT's.

This lower value of current I_p/N_i, along with the power line voltage is provided to internal networks on the metering board which interface with the microprocessor. The voltage and current signals are supplied to the microprocessor which can then compute Power, Power Factor, Reactive Power and other billing related parameters. Figure 5 shows a diagram of a generic socket based electronic meter.

Figure 6 shows a diagram of the invention with its interface adapter board and related compensation network. The adapter network Z_c is used to transform the current I_1 from an external current transformer of turns ratio N_x into the current K_1I_i at the metering board interface. Likewise the power line voltage V_p goes into adapter network Z_v, for transient suppression and scaling, where care is taken to insure the output to the metering board is equal to K_2V_p. The metering circuit will then have K_1I_i and K_2V_p as inputs from which to calculate Power, Power Factor, Reactive Power and other billing parameters as before. The obvious problem is that K_1xK_2 must be equal to unity if a pre-calibrated metering board is to be used. Another solution is to recalibrate the meter as a whole, knowing the constants K_1 & K_2 and compensating for the differences in the software. The calibration process adjusts the constants within the microprocessor on the metering card to compensate for current and voltage losses K_1 & K_2. The input voltage and current V_p and I_p, are routed to a calibrated standard and used as a reference. The microprocessor constants are adjusted until the power meter output matches the standard.

The component values for the compensation of each of the phase networks Zc may be computed that will produce the desired values of current and voltage at the input to the metering circuit board. Figure 7 is a diagram of the networks involved.

The following general equations apply:

Equation 1 $V_1 = I_1Z_{11} - I_2Z_{12}$

Equation 2 $V_2 = I_1Z_{21} - I_2Z_{22}$

where:

I_1=input current from the phase current transformers

I_i=current input of a socket based meter

I_2=current output of the compensation network to the metering board

I_p=input current to the phase current transformers

K_1=meter current constant

K_2=meter voltage constant

N_i=turns ratio of the current transformers in a socket based meter

N_x=turns ratio in the external current transformers of the stand-alone meter

M_p=microprocessor which calibrates all outputs of the metering board

V_p=power line voltage

Z_c=compensation network impedance

Z_m=metering board network impedance

Z_{11}=input impedance with open circuit output

Z_{12}=backward transfer impedance with open loop input

Z_{21}=forward transfer impedance with open circuit output

Z_{22}=output impedance with open circuit input

In the case of the invention, equations 1 and 2 may be simplified and used to compute Z_c as follows:

$$V_1 = V_2 = I_1 Z_c - I_2 Z_c$$

$$V_2 = I_i Z_m$$

$$I_i - (I_p/N_x)$$

$$I_2 = I_1$$

$I_2 - (I_p/N_i)$

$Z_{21}=Z_{22}=Z_c$

Substituting, Equation 2 can be rewritten as follows:

$(I_p/N_x)Z_c = (I_p/N_i)Z_c = (I_p/N_i)Z_m$

$Z_c((1/N_x)-(1/N_i))=Z_m/N_i$

$Z_c = Z_mN_x/(N_i - N_x)$

Referring to the drawings wherein like reference numerals designate corresponding parts throughout the several figures, reference is first made to Figures 1 and 3 showing the stand-alone or system meter 11 of the present invention connected by suitable conduit 12 to a customer's electrical panel 13. Within the service panel are located current transformers 44 and 45, and voltage taps 39 and 41. The meter 11 is composed of an enclosure 14, an electronic metering board 24 and an interface adapter board 28.

Generally, in order to measure power consumption, one must know the voltage and current in each phase and/or leg of the power service being measured. In order to measure voltage and current to supply the meter 11 and its components, the wiring harness from the meter 11 will be attached to the electrical service drop in the following manner. To obtain voltage for each phase and/or leg, fused leads are tapped onto each leg of the power lines. The current in each phase is determined using current transformers. The resulting leads are then routed through the conduit 12 to the meter 11. In Figure 3, it is shown that voltage leads 37 and 38 are tapped to the respective service legs 33 and 34 at points 39 and 41. In standard electrical configuration, the voltage leads 37 and 38 are fused in-line by suitable size fuses 42 and 43 to limit the risk of a meter failure affecting the service. Current transformer leads 46 and 47 are connected to points 31. A ground lead 48 is also led from the customer's service panel 13 to the interface circuit board 28.

In the normal installation, the panel 13 will have an electrical service drop 32 which will typically run from the power company's interface junction box to the electrical panel. In the embodiment shown herein the service drop is depicted as a single phase electrical service comprising two service legs 33 and 34 and ground.

For purposes herein, leg 33 will be considered Phase A and leg 34 will be considered Phase B. Both legs 33 and 34 will be suitably connected to the panel breakers 36 while the neutral leg 35 is grounded to the panel. The panel breakers 36 are ultimately connected to various electrical loads placed thereon by the customer.

Current sensing devices are similarly hooked up to the service legs 33 and 34 in an orientation such that the polarity indicator dot of the CT is facing the incoming service. To sense the current flowing in each leg of the service, current transformers 44 and 45 are used. Typical current transformers comprise multiple turns of wire in a tight configuration looking much like a doughnut.

The current transformers are then placed around the respective service legs which are to be measured. In actuality, the current transformers may be solid and placed around the service legs when such are installed or, for ease of retrofit installation, the current transformers may be of split construction and placed around the service legs without disconnecting the service. In any event, the current transformers are placed totally around the service legs to be measured. Typically, the current transformers are chosen to limit the current into the metering circuit board 24 to approximately 100 milliamps, which is a value that can be safely handled by an electronic meter of the present invention. To achieve such a value, the current transformers 44 and 45 will be manufactured by selecting a proper turns ratio for the situation to be monitored. For instance, if the electrical service drop is sized at 300 amps, then a 4,000 to 1 transformer will be selected to reduce that value down to 75 milliamps into the metering circuit board 24. In the configuration shown in Figure 3, pairs of sensing connecting leads 46 and 47 are led from respective current transformers through conduit 12 to the current terminal block 31.

The meter 11 is composed of a plastic enclosure, an electronic metering board and a specially designed interface adapter board. Typically, at the upper portion of the meter, there is a face plate 16 which has an opening 17 therein to allow authorized personnel to observe the information readout panel 18 located behind the face plate. On the lower portion of the cover 15 are systems to allow additional information to be gathered, namely, a switching mechanism 19 to allow the power company, or other authorized personnel, to reset the demand consumption parameter of the meter. Also, on the lower portion of the cover 15 is an aperture 21 that will normally allow authorized personnel to have access to an infrared optical communications port 22. The port 22 is designed to transmit and receive meter operating data and to give additional operating information to the personnel.

The enclosure 14 of the meter 11 typically will have one or more mounting fixtures 23 to enable installation personnel to install a meter at desired locations. The enclosure 14 has a separate cover 15 which allows access to the meter by authorized personnel. The cover may be locked to the enclosure base member by means of two captive stainless steel screws in conjunction with a tamper resistant meter seal.

Referring now specifically to Figure 3, the stand-alone meter 11 is shown with the cover 15 opened to show generally the internal construction of the metering apparatus. A typical meter circuit board 24 is mounted within the enclosure 14 and secured to the enclosure by suitable mounting posts 25 (see Figure 4). The meter circuit board may be of any suitable type known in the industry and which are used in electronic power metering devices, such as ones produced by Schlumberger Industries, ABB Power T&D, General Electric, or Landis and Gyr. These particular manufacturers are indicated as possible choices, but other choices may well be available to those skilled in the art of developing metering products. The metering circuit board 24 will have all of the circuitry necessary for metering and displaying the desired correct information upon the integral readout panel 18. Typically, these types of circuit boards will have reset switches 26 which will cooperate with the demand factor reset mechanism 19 in order to allow authorized personnel to reset the demand consumption parameter of the meter in the standard procedure. Also, the board will have integral therewith, in certain instances, an infrared optical communications port 22 which will be used to indicate various operating parameters of the system to authorized personnel.

Operating information is supplied to the meter circuit board 24 through input wiring harnesses 27 which extend from the interface circuit board 28. The interface circuit board contains a series of components that provide the interface between the customers service to be monitored and the metering circuitry on the metering circuit board 24. Typically, the interface circuit board will have several terminals, and in this case, two terminals 29 and 31 to which the voltage and current transformer wiring harness from the customer's electrical panel may be connected. Inasmuch as it is required to monitor both voltage and current in the customer's electrical panel 13, terminal 29 is the voltage terminal to which the voltage sensing wires are connected, and terminal 31 is the current terminal to which the current sensing wires are connected. The various sensing wires from the customer's electrical panel 13, to terminals 29 and 31 are typically fed through a conduit 12.

As previously noted, inside the meter 11, the voltage sensing connecting leads 37 and 38 are connected to the voltage terminal 29, and are then routed through suitable wire wound resistors 48 (as described above) which have been chosen to provide transient protection by virtue of the inductance of their windings and to provide isolation to the metering circuitry. Such is accomplished by selecting a relatively high value of resistance for the resistors, however, the resistance is still small in comparison to the metering circuit impedance. Therefore, this arrangement allows the voltage to be sensed, but limits the risk of injury or damage due to the presence of voltages which may be up to 600 volts in the normal situation.

The current transformer leads 46 and 47 are also led to the meter 11 through conduit 12 and terminate at current terminal 31. The sensed current then passes through precision interface network 49 to thereby generate a voltage proportional to current with respect to each leg of the customer's service. The resulting voltages herein are then routed to the meter circuit board 24 to supply the microprocessor therein with signals that are proportional to the current being used by each phase.

The resulting voltage and current signals which have been processed by the interface circuit board 28 and fed to the meter circuit board 24 for each leg and/or phase of the customer's service, are utilized by the built-in circuitry of the meter circuit 24 to compute the total power consumption within the electrical panel which is being monitored. The resulting power consumption can be then read on readout panel 18.

Various modifications may be made of the invention without departing from the scope thereof and it is desired, therefore, that only such limitations shall be placed thereon as are imposed by the prior art and which are set forth in the appended claims.

WHAT IS CLAIMED IS:

1. A system capable of monitoring power usage by an electrical load comprising:

(a) an enclosure;

(b) an electronic metering circuit mounted within said enclosure, said electronic metering circuit having inputs for receiving a voltage input signal and a current input signal, said electronic metering circuit being capable of calculating and recording electricity used by a load based upon said input signals;

(c) sensing means for connecting to a source of electric energy, said sensing means being able to detect voltage across said sensing means and current flow through said sensing means, said sensing means being mounted external to said enclosure, said sensing means having a current output which is proportional to the current flow through said sensing means and a voltage output which is proportional to the voltage across said sensing means;

(d) an interface adapter mounted within said enclosure, said interface adapter including input means for connecting said interface adapter to said current output and to said voltage output of said sensing means, said interface adapter further including output means for providing current and voltage signals to said inputs of said electronic metering circuit,

whereby said electronic metering circuit can calculate and record the use of electric power by a load connected to a source of electric energy which is monitored by said sensing means.

2. The system of Claim 1 wherein said interface adapter includes matching means for matching the outputs of said sensing means to the inputs of said electronic metering circuit.

3. The system of Claim 2 wherein said matching means includes calculating means for matching the outputs of said sensing means to the inputs of said electronic metering circuit

4. The system of Claim 3 wherein said calculating means includes a programmed microprocessor.

5. The system of Claim 1 wherein said sensing means includes a current transformer.

6. The system of Claim 1 wherein said sensing means includes a voltage transformer.

7. The system of Claim 1 wherein said interface adapter includes protection means for protecting said interface adapter and said electronic metering circuit from transients.

8. The system of Claim 7 wherein said protection means includes at least one

inductive element.

9. The system of Claim 8 wherein each said inductive element is comprised of a wire wound resistor.

10. The system of Claim 1 further comprising an optical port mounted on said enclosure, said optical port being connected to said electronic metering circuit mounted within said enclosure, whereby said optical port is adapted to permit communications with said electronic metering circuit by external devices.

11. The system of Claim 10 whereby said communications with external devices, through said optical port, include meter reading data from said electronic metering circuit, said meter reading data being based upon data provided to said electronic metering circuit by said interface adapter from said sensing means.

12. A system for providing sub-metering, comprising:

(a) at least two of the metering systems of Claim 1, each of said systems including meter communication means;

(b) a central computer, said central computer having computer communication means, said meter communication means being capable of communication with both other meter communication means and with computer communication means,

whereby said computer communication means of said central computer is able to receive data from said meter communication means of said metering systems, and said central computer is able to calculate sub-metering data from the data communicated from said metering systems.

13. The system of Claim 12 wherein said interface adapter includes matching means for matching the outputs of said sensing means to the inputs of said electronic metering circuit.

14. The system of Claim 13 wherein said matching means includes calculating means for matching the outputs of said sensing means to the inputs of said electronic metering circuit.

15. The system of Claim 14 wherein said calculating means includes a programmed microprocessor.

16. The system of Claim 12 wherein said sensing means includes a current transformer.

17. The system of Claim 12 wherein said sensing means includes a voltage transformer.

18. The system of Claim 12 wherein said interface adapter includes protection means for protecting said interface adapter and said electronic metering circuit from

transients.

19. The system of Claim 18 wherein said protection means includes at least one inductive element.

20. The system of Claim 19 wherein each said inductive element is comprised of a wire wound resistor.

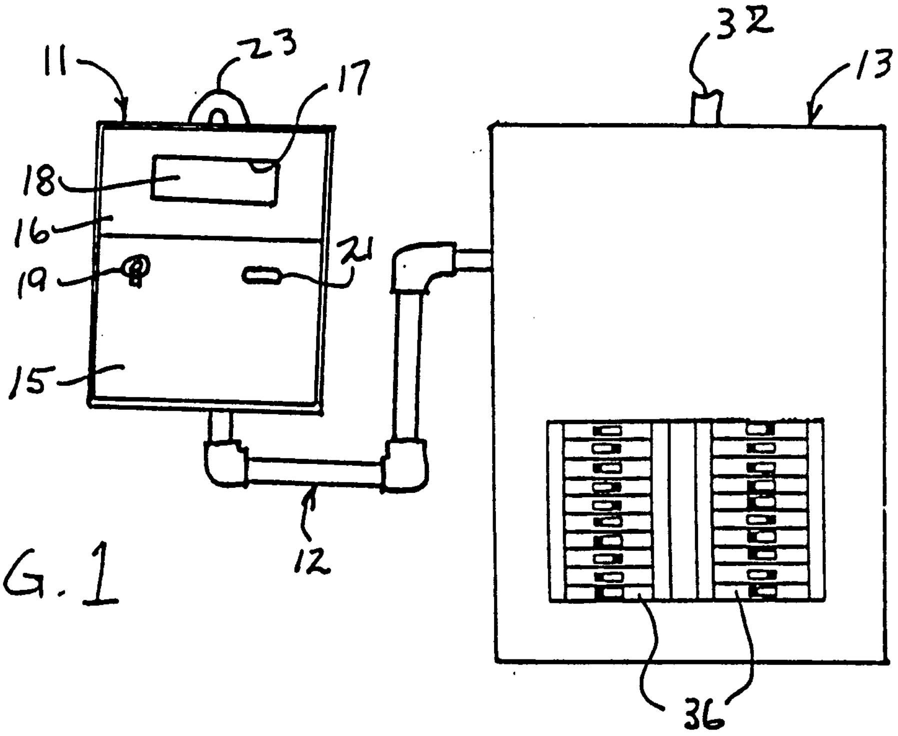
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FIG. 1

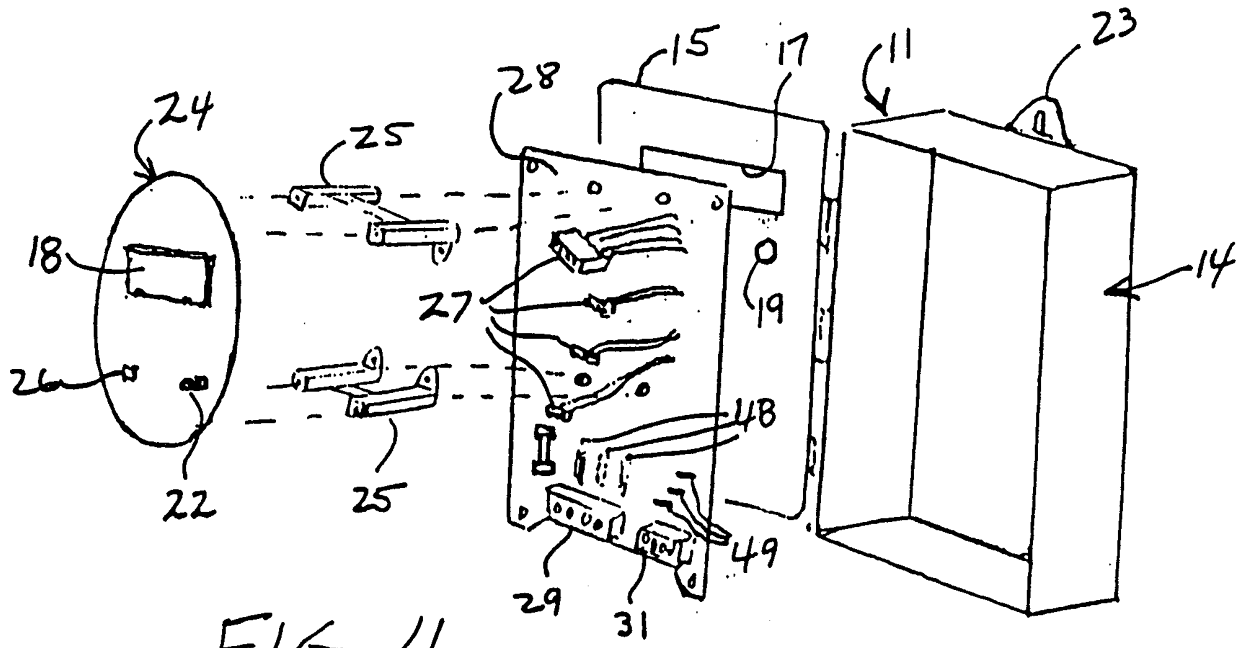
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FIG. 4

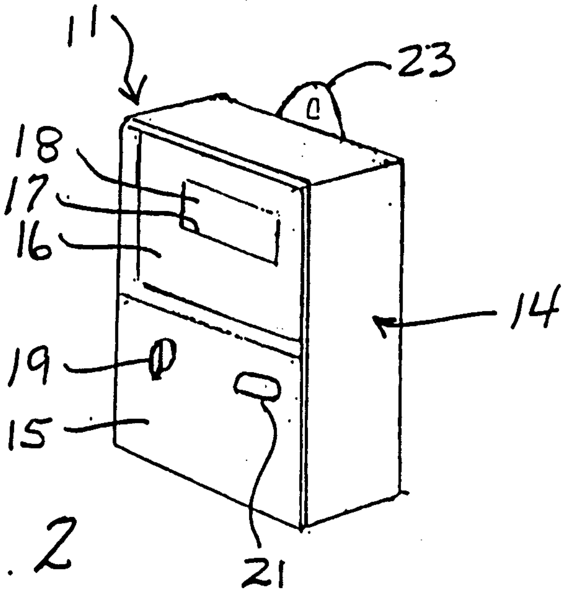
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FIG. 2

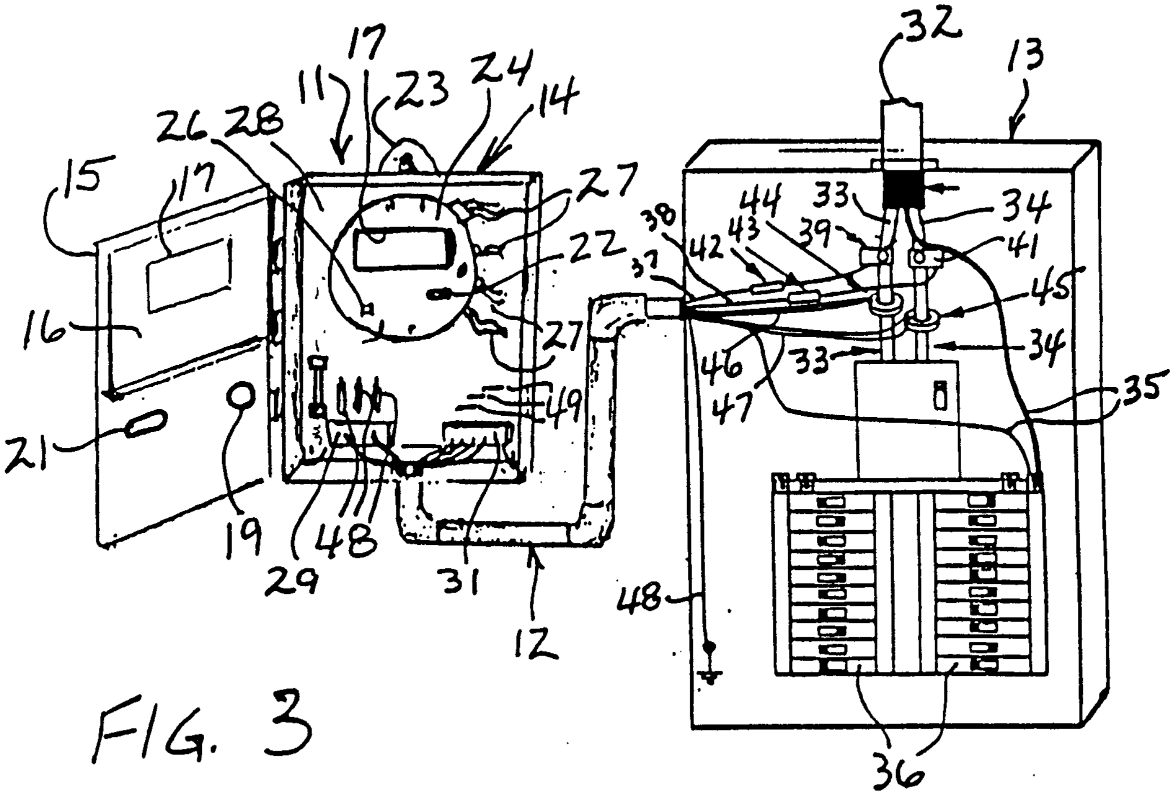
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FIG. 3

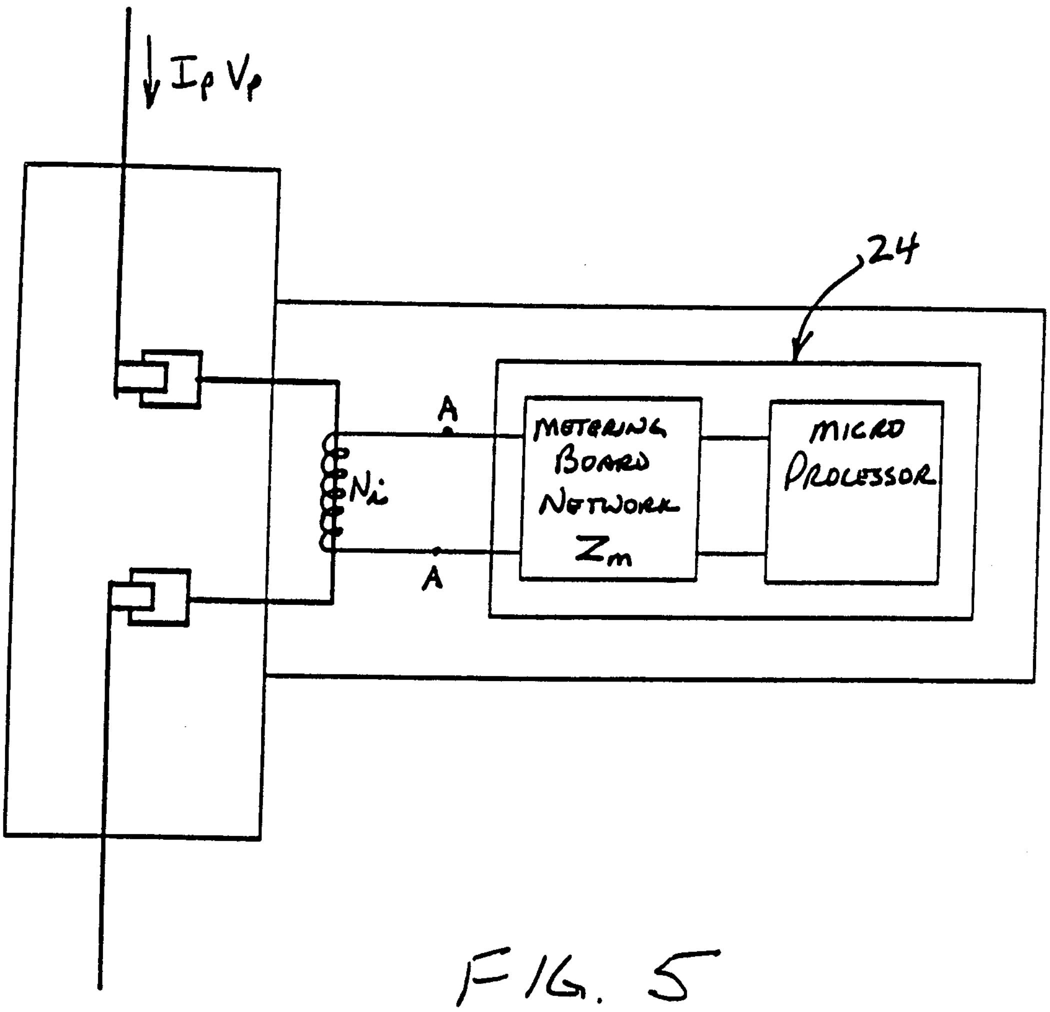
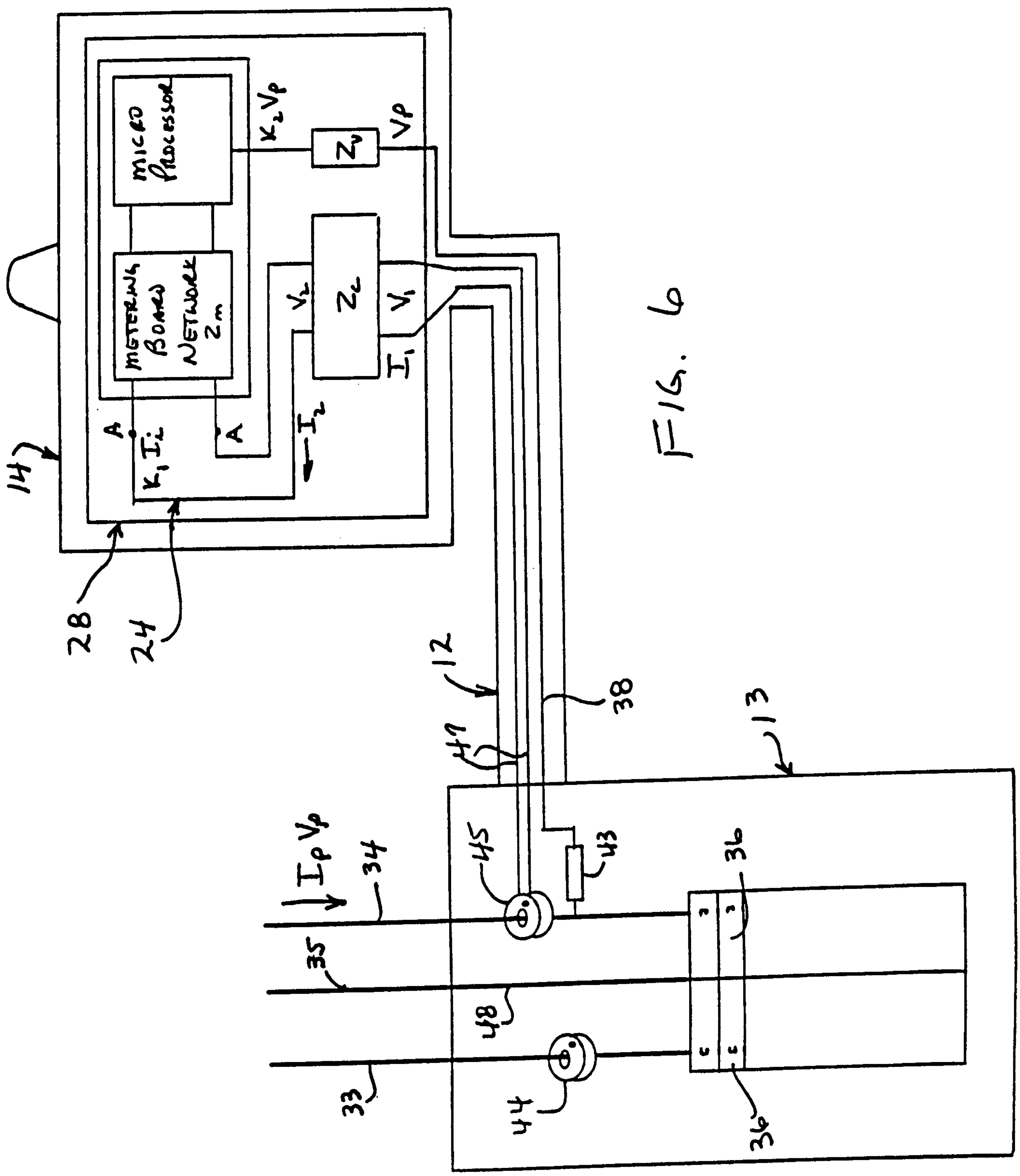


FIG. 5
(PRIOR ART)


MICRO PROCESSOR
METERING BOARD NETWORK Zm
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Z_V
V_P
V_2
Z_C
V_1
I_1
I_2
A
A
$K_1 I_2$
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28
24
12
38
47
13
45
43
36
$I_P V_P$
34
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44
36

FIG. 6

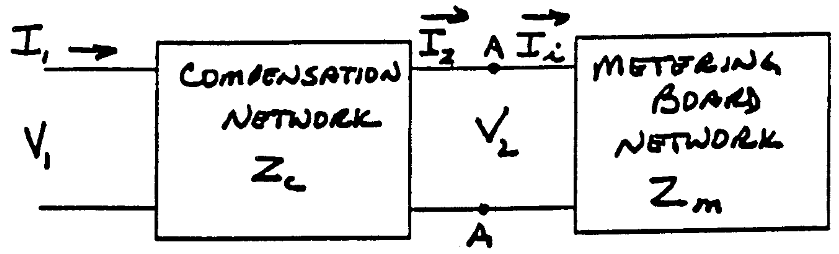
I_1
V_1
COMPENSATION NETWORK
Z_c
I_2
A
I_i
V_2
A
METERING BOARD NETWORK
Z_m

FIG. 7