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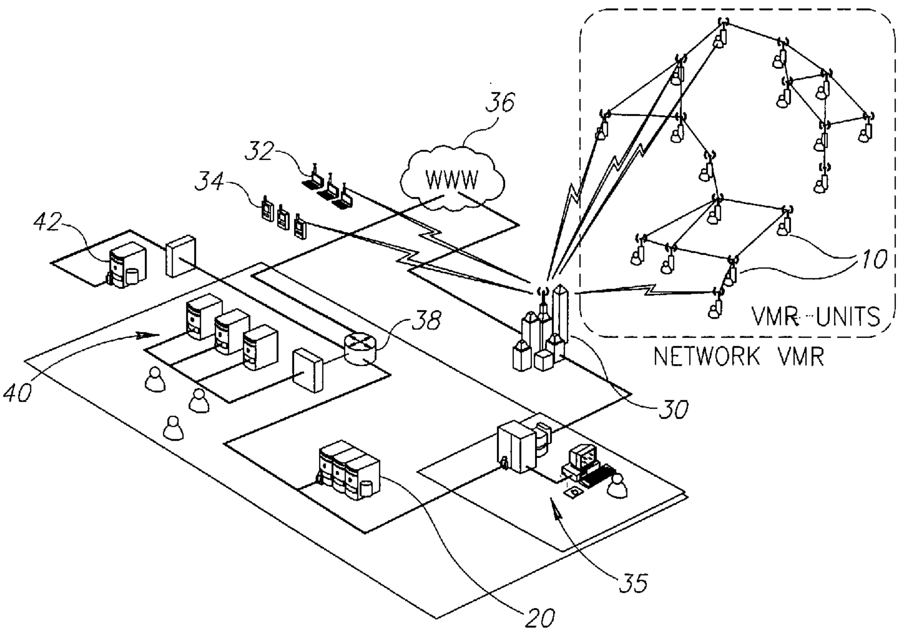
(54) **Title:** METER READOUT SYSTEM



(57) **Abstract:** A method is presented for remote meter reading that addresses upgrade needs for automatic periodical readout of meters lacking electrical output signals. The solution embodied in the invention is a self contained, fully enclosed, low energy solution with provisions for onsite visual meter inspections. It can be implemented in various applications, such as but not limited to, water meters, electricity meters, gas meters, tachometers, and other meters. Methods are incorporated that enables the user full control over the timing and rate of the data acquisition, and control over system performance and power consumption.

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METER READOUT SYSTEM

FIELD OF THE INVENTION

The present invention relates generally to the field of telemetry for reading meters, such as but not limited to, water, gas or electric meters, and particularly to an automated visual meter readout system.

BACKGROUND OF THE INVENTION

Meters lacking electrical signal output require human reading. Such meters are typically accurate over a long time period and are often found in water, gas, and electric utility systems. In such applications, the cumulative errors of even minute systematic inaccuracies may be substantial. Since these meters support the compensation distribution system for the utility company, they are strictly tested and approved by government regulatory bodies. In cases where there is a need to upgrade/convert an existing meter for telemetry, often the meter is upgraded through modifications and subsequent recalibration. This process does not alter the meter's mechanism and thus does not require recertification provided it is calibrated by the regulatory body. Typical approaches involve the addition of electromechanical interfaces to convert the meter's mechanical action to electrical signals. In many meters in the utilities industry the meter's rotary motion is converted to a PWM (pulse width modulated) signal through a rotary encoder. The ultimate meter output after further processing may be analog voltage, a serial communication protocol message, or other. This, however, requires continuous monitoring of the encoder and precludes an energy saving approach whereby the system may hibernate till the readout time which is often days apart. In addition, this solution requires dismantling the meter, modifying it in a machine-shop and refitting that can not be done quickly and certainly not on the spot.

In some cases, meters have been outfitted with cameras to record the mechanical readout's image for processing and digitization. In these cases, Optical Character Recognition (OCR) is used to ascertain the digits on the meter. This approach only works with meters with mechanical digit readout and is incapable of reading meters with dial readout as there are no numerical characters to convey the meter's readout. When implementing image acquisition solutions for mechanical meters deployed in the field there are additional constraints that must be met:

1. The upgraded system must be weather resistant.
2. The unit must enable visual inspection and readout by a human.
3. The unit must be able to perform in all ambient lighting conditions.

4. The unit must be tamper resistant.

5. The system must be readable in constant intervals and in between on demand.

6. The system must be energy self-sufficient for many years.

7. Advantage is given to low-cost solutions upgrades that can be performed on the spot without dismantling the meter.

8. Advantage is given to solutions that can perform onsite analysis of the meter readout to determine specific states of the system containing the meter. These may include capabilities such as, but not limited to determination or identification of:

a. Reverse flow on a water or gas meter

b. Jammed meter

c. Readings above or below a threshold

d. Rates and accelerations of the quantity measured by the meter

9. Advantage is given to solutions that can combine analysis capabilities with control of external devices. This may include examples, such as but not limited to, valve closure in response to identification of reverse flow or valve throttling control in response to rate of flow.

In the known prior art, there is not a single solution which addresses all requirements in one, self contained solution. As an example, OCR systems have been typically implemented in meters in lab or industrial settings where lighting is well controlled, the system is kept out of the weather and protection from tampering is provided by the building in which the system is housed, and electrical power is readily available through the AC grid. However, these systems cannot provide all the above features when installed in a real-life setting out of the laboratory.

SUMMARY OF THE INVENTION

In contrast to the prior art, the present invention, as described hereinbelow, is designed to provide a comprehensive solution to all the abovementioned criteria, and may provide added capabilities such as:

1. Ability to store large amounts of data

2. The ability to perform complex data analysis including, but not limited to identification of a jammed meter, identification of reverse flow, determination of above threshold first and second time derivatives of the quantity measured.

3. The ability to control external devices - determination of control output based on data analysis results and linear or nonlinear control laws.

4. Presenting a small footprint meter upgrade solution that can be added on the spot without shutting down the meter line.

There is thus provided in accordance with an embodiment of the invention a system for reading meters including a visual meter readout (VMR) system that includes at least one image capture device, a processor in communication with the at least one image capture device and adapted to process images received from the at least one image capture device, at least one power source, at least one light source for illuminating a meter face with intensity for capturing an image of the meter face with the at least one image capture device, and a tamper-resistant encapsulating enclosure for housing the processor and the at least one image capture device. The processor may extract meter dial angles and indicia on the meter face and translate then into digitized numerical values. A transceiver may be provided for communication of data and images between the processor and a control center. A plurality of the VMR systems may be connected by networked telecommunication. A processor may manage the VMR systems with at least one of rerouting, multi-hopping and mesh capabilities. A remotely enabled internal locking mechanism may be disposed in the VMR system that selectively locks at least one component of the VMR system.

There is also provided in accordance with an embodiment of the invention, a method for upgrading a meter, including mounting a VMR system on an existing meter at an installation site of the meter, the VMR system including at least one image capture device, a processor in communication with the at least one image capture device and adapted to process images received from the at least one image capture device, at least one power source, at least one light source for illuminating a meter face of the existing meter with intensity for capturing an image of the meter face with the at least one image capture device, and a tamper-resistant encapsulating enclosure for housing the processor and the at least one image capture device.

The method may further include managing power consumption and condition of the at least one power source, performing data analysis of measurements of the meter, performing reading of the meter automatically in programmable intervals or asynchronously on demand. The upgrading may be performed without dismantling the meter.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood and appreciated more fully from the following detailed description taken in conjunction with the drawings in which:

Fig. 1 is a simplified illustration of a power management scheme that may be used to enable maximum endurance, in accordance with an embodiment of the present invention, which may be used in both PPR and ODR operation modes;

Fig. 2 is a simplified illustration of a networked VMR infrastructure, in accordance with an embodiment of the present invention, including deployed VMR units and a control center at the client premises, wherein data may be relayed by some VMR units to a long distance communication VMR unit (e.g., cellular) for up-link to the control center;

Fig. 3 is a simplified illustration of system components that may be combined in the VMR and related power and data flow, in accordance with an embodiment of the present invention;

Fig. 4 is a simplified illustration of automated extraction of a meter readout value from an image, in accordance with an embodiment of the present invention, showing the ability to interpret the meter serial number along with the dial scaling factors;

Fig. 5 is a simplified illustration of automated extraction of a meter readout value from an image, in accordance with another embodiment of the present invention; and

Fig. 6 is a simplified illustration of a VMR unit, constructed and operative in accordance with an embodiment of the present invention, including a protective enclosure with a solar panel and electronics.

DETAILED DESCRIPTION OF EMBODIMENTS

The visual meter readout (VMR) system 10 of the present invention is a comprehensive solution that addresses upgrade needs for automatic periodical readout of meters which have no electrical output signals. The invention can be implemented in various applications, such as but not limited to, water meters, electricity meters, gas meters, hydraulic or air pressure gages, tachometers, and other meters and indicators.

Some non-limiting features of embodiments of the invention include a self contained, fully enclosed solution, which may be completely self sufficient for years. As seen in Fig. 6, there may be provided a built in power source 12, such as a solar panel or other renewable or disposable long endurance source. The system may have low energy consumption combined with power management for increased endurance. The system may have user adjustable periodical readings in addition to on-demand readings at any time. The system may include timed data acquisition (image or other I/O) synchronized with other VMR units to obtain a system-wide reading at sub-second synchronization resolution.

The system may include anti-vandalism measures, such as but not limited to, a vibration and tilt sensor 14, a tamper-resistant enclosure 16 that protects the VMR system and the meter itself, and an internal electro-mechanical lock 18 with onsite actuation empowered by a remote release from a control center 20 (Fig. 2). The opening process starts with the release of the VMR unit from the remote system control center for a period of minutes. During that period a technician may open the VMR unit through a direct connection. By actuating the electro-mechanical lock, the VMR unit reverts to its normal state after the release period. If the unit was not opened during that period then a new release authorization must be initiated through the control center. Locking the unit can be accomplished at any tine without specific action by the remote control center.

In accordance with a non-limiting embodiment of the invention, e.g., for large meters, a mounting method is provided that not only protects the VMR unit but also the meter itself (Fig. 6). Features of the mounting method include but are not limited to, attachment to the existing meter using the meter's bolt pattern to center the VMR unit above the meter's face. The method of mounting is modular– there may be provided a base plate module 22, electronics and camera module 24, cover 26 and renewable energy module 28 (which may include the solar panel). The base plate can be customized to accommodate a large range of meter types and sizes. The cover may be attached in bayonet style to the base plate, secured through small angular rotation.

In accordance with a non-limiting embodiment of the invention, the system may include without limitation, a tamper-resistant enclosure that houses all system components and a processor (which may perform, without limitation, any or all of the following: control system processes, image and data acquisition including camera control, lighting control, multiple image storage management, data analysis of other peripheral I/O, management of communication with the control center and image transmission, management of network communication with other VMR units and long distance uplink to a command center when appropriate, linear and nonlinear control of external devices and/or processes, power management and monitoring of battery charge and condition), which may be contained locally or at a centralized Data Collection Node (herein referred to as a DPN - a VMR with long distance communication capabilities and enhanced processor capabilities). The system may also include the software needed to perform data analysis including onsite image analysis and interpretation/decoding into a numerical representation of the meter readout value. The system may also include one or more miniature cameras and one or more primary long distance communication devices, e.g., to communicate on a network with other VMRs.

As seen in Fig. 2, the system may include a plurality of networked VMR units 10, which communicate with a cellular service provider 30 that may be in communication with portable computers 32, cell phone clients 34, and a VMR control center 35, and which may communicate via the Internet 36 and a VMR gateway router 38 with client control center 20, client headquarters 40 and external systems 42.

As seen in Fig. 3, the system may also include, without limitation, a miniaturized atomic clock, a GPS receiver, or other devices with either sub-second cumulative drift (similar to an atomic clock) or with a globally available clock with sub-second data availability delays (such as the GPS clock), at least one power storage device (or energy devices such as a fuel cell, solar panel, etc.), and one or more lighting modules to illuminate the meter at the time of image acquisition. The system schematic in Fig. 3 illustrates components that may be combined in the VMR, power and signal transmission between components.

In accordance with a non-limiting embodiment of the invention, the system and method may enable the user full control over data acquisition timing through two programmable operation modes:

1. Programmable Periodical (meter) Reading (PPR) – incorporates a method for minimal power consumption.

2. On-Demand (meter) Reading (ODR)

The invention also provides for two image processing modes:

1. Image Transmission Mode (ITM) – a compressed raw image of the meter's face is transmitted to the DPN and is then processed to extract the meter reading value.

2. Reading Processing Mode (RPM) – the meter reading is extracted from the image and the numerical value is transmitted to the DPN.

In cases where both image processing modes are available, a method may be implemented that permits selecting either low power consumption (lower performance) or high performance (higher power consumption). In this case mode selection may be determined automatically (through the use of predetermined conditions, such as but not limited to, rate of change, threshold values, etc.), autonomously (through the use of logic to handle unpredictable system states or meter readings), or through remote user input.

In another non-limiting aspect of the invention, data delivery robustness may be enhanced through the use of an onsite data buffer. The buffer may store sufficient data points to enable on-site manual data extraction in cases of fatal communication failure or for data recovery during intermittent communication periods.

In accordance with a non-limiting embodiment of the present invention, the system may have different operating modes. For example, the system may have two image processing variations, Image Transmission Mode (ITM) and Reading Processing Mode (RPM).

In ITM, the system captures an image of the meter face (e.g., a digital camera takes a picture of the meter face) and transmits the image after compression to a central processing location (referred to as DPN) for image processing where the image is reconstructed and the meter reading is extracted through the use of image analysis algorithms (e.g., character recognition algorithms, well known in the art, may be used to identify the numerals of the meter reading). The central processing location is where meter readings from several locations are processed and stored.

In RPM, the image is processed locally; the meter reading is extracted using image analysis algorithms and only a numerical value is transmitted to the central processing location.

The system also has two modes of operation, Programmable Periodical (meter) Reading (PPR) and On-Demand (meter) Reading (ODR).

In PPR operation mode the system powers up at preprogrammed intervals, takes a VMR of the meter's face and transmits the compressed image to the DPN.

In ODR mode, the system takes a reading asynchronously on demand when requested by the user.

The system of the invention may have robustness against transmission failures. For example, the VMR may have a local data buffer to enhance robustness and independence from communication performance issues. In the event that a reliable communication link to the central processing location is not available, the VMR continues with data acquisition. Once communication with the central processing location is reestablished, the VMR initiates a buffer download to transmit the data accumulated during the period of communication outage. Provisions are also made for user initiated downloading through physical connections (RS232, USB, or other).

Transceiver Functionality: The system's power-up sessions may be determined through the use of two programmable timers; the primary timer to time the system hibernation periods and the secondary timer to initiate PPR. While the primary timer determines the maximum acquisition rate, the secondary timer determines the period of normal, automatic acquisition rate. The secondary timer operates at or below the primary timer's rate (i.e., it is just as fast or slower). Both timers may be remotely adjustable through a user command to adjust both the scheduled automatic reading acquisition rate, and the maximum possible rate of on-demand meter reading sessions. VMR initiates a communication session at a programmable rate using its primary timer. During each primary period the system transmits a signal that it is functioning properly (about 30 ms). The transmitter remains on briefly (about 10 ms) to enable reception of a request to perform an unscheduled (on-demand) reading of the meter. If a request for an unscheduled reading is not received, the system does nothing and the transmitter is turned off. During periodical (e.g., scheduled) reading sessions, the VMR uses a secondary programmable timer to initiate a reading session.

Power Management: VMR may use off the shelf lead-acid batteries as its power storage (although the invention is not limited to such batteries). A transmission power management scheme, illustrated in Fig. 1, may be used to extend the battery's energy endurance over a period measured in years without recharging. This feature makes the system completely self-sufficient.

During hibernation periods, the system is completely powered off except for minimal power to the processor and modem to keep them in sleep mode. In sleep mode, the modem is listening and awakes in response to an incoming transmission. The processor operates at low capacity to monitor the internal clock. It wakes the system upon reception of either a transmission or when it is time to perform tasks. In addition the processor may trigger the parts of the system at the end of the programmable hibernation period by powering up the transceiver.

When a hibernation period does not coincide with a PPR, i.e., the secondary timer has not lapsed, the system does nothing more at this stage but allow the transceiver to warm up for about 30 ms.

As illustrated in Fig. 1, when a hibernation period coincides with a PPR, the system may also power the lighting. After a 10 ms delay, the camera may be powered to take an image and send it to the processor. In RPM, the processor may then extract the numerical value of the meter reading and store it in the buffer. In ITM the image may be stored unprocessed in the buffer. At the end of the 30 ms processing and transmitter warm-up period, the transmitter may transmit and accept a command signal during a 10 ms session. If the hibernation period does not coincide with a PPR, the transmission may consist of a short message to convey system health to the DPN (or other clients).

Otherwise, the transmission may contain of an image (if in ITM) or of the numerical value (if in RPM).

If a command is received for an on-demand reading, the system may enter the ODR mode and promptly initiate a reading session that may be identical in action sequence to that of a hibernation period, which coincides with a PPR, except that it may be an asynchronous session. At the end of the transmission session the system may promptly return to hibernation.

It will be appreciated by persons skilled in the art that the present invention is not limited by what has been particularly shown and described hereinabove. Rather the scope of the present invention includes both combinations and subcombinations of the features described hereinabove as well as modifications and variations thereof which would occur to a person of skill in the art upon reading the foregoing description and which are not in the prior art.

CLAIMS

What is claimed is:

1. A system for reading meters comprising:

a visual meter readout (VMR) system that comprises:

at least one image capture device;

a processor in communication with said at least one image capture device and adapted to process images received from said at least one image capture device;

at least one power source;

at least one light source for illuminating a meter face with intensity for capturing an image of the meter face with said at least one image capture device; and

a tamper-resistant encapsulating enclosure for housing said processor and said at least one image capture device.

2. The system according to claim 1, wherein said processor is adapted to extract meter dial angles and indicia on the meter face and translate then into digitized numerical values.

3. The system according to claim 1, further comprising a transceiver for communication of data and images between said processor and a control center.

4. The system according to claim 1, further comprising a plurality of said VMR systems connected by networked telecommunication.

5. The system according to claim 4, further comprising a processor adapted to manage said VMR systems with at least one of rerouting, multi-hopping and mesh capabilities.

6. The system according to claim 1, further comprising a remotely enabled internal locking mechanism disposed in said VMR system that selectively locks at least one component of said VMR system.

7. A method for upgrading a meter, comprising:

mounting a VMR system on an existing meter at an installation site of said meter, said VMR system comprising:

at least one image capture device;

a processor in communication with said at least one image capture device and adapted to process images received from said at least one image capture device;

at least one power source;

at least one light source for illuminating a meter face of the existing meter with intensity for capturing an image of the meter face with said at least one image capture device; and

a tamper-resistant encapsulating enclosure for housing said processor and said at least one image capture device.

8. The method according to claim 7, further comprising extracting meter dial angles and indicia on the meter face and translating then into digitized numerical values.

9. The method according to claim 7, further comprising communicating data and images between said processor and a control center.

10. The method according to claim 7, further comprising networking together a plurality of said VMR systems.

11. The method according to claim 10, further comprising managing said VMR systems with at least one of rerouting, multi-hopping and mesh capabilities.

12. The method according to claim 7, further comprising managing power consumption and condition of said at least one power source.

13. The method according to claim 7, further comprising performing data analysis of measurements of said meter.

14. The method according to claim 7, further comprising performing reading of the meter automatically in programmable intervals.

15. The method according to claim 7, further comprising performing reading of the meter asynchronously on demand.

16. The method according to claim 7, wherein the upgrading is performed without dismantling the meter.

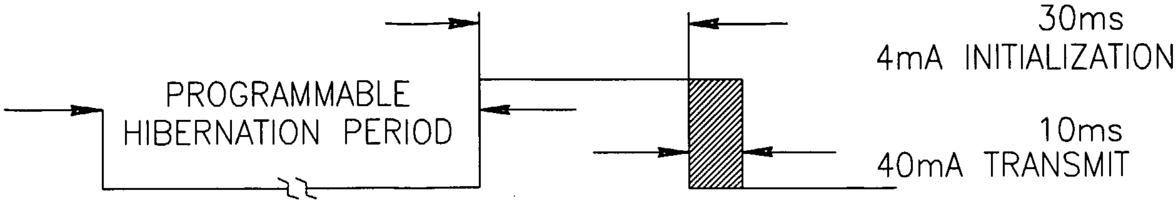
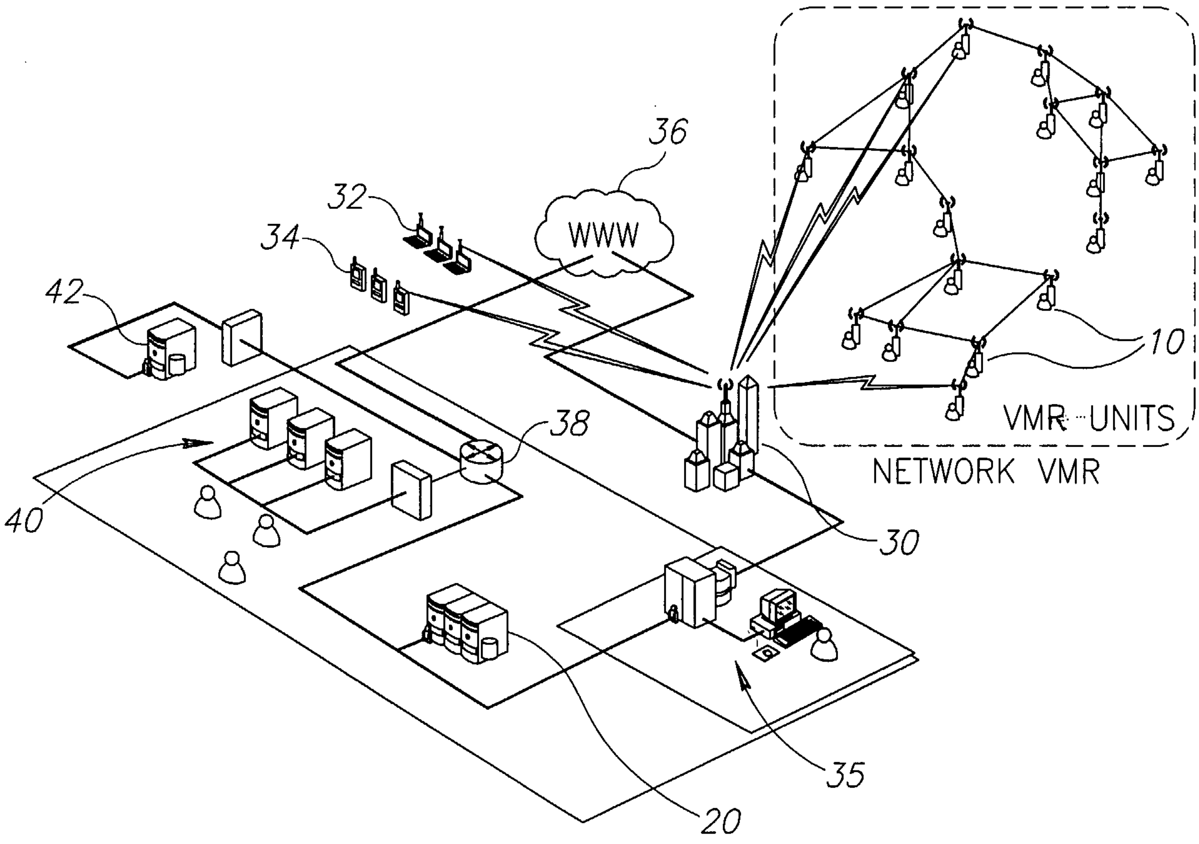

30ms
4mA INITIALIZATION
PROGRAMMABLE
HIBERNATION PERIOD
10ms
40mA TRANSMIT

FIG.1


36
WWW
32
34
42
38
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VMR UNITS
NETWORK VMR
30
35
20

FIG.2

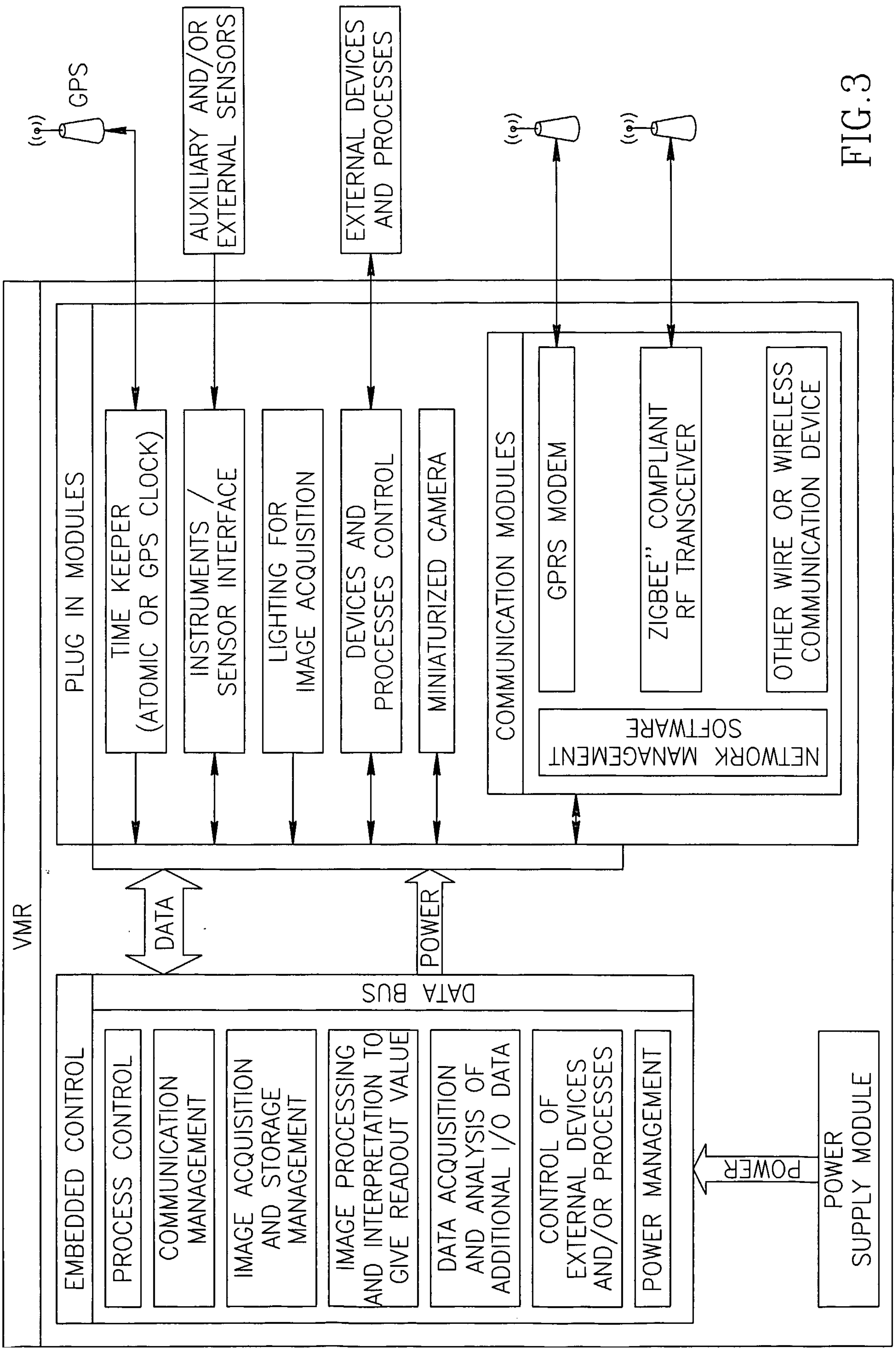
GPS
AUXILIARY AND/OR EXTERNAL SENSORS
EXTERNAL DEVICES AND PROCESSES
VMR
PLUG IN MODULES
TIME KEEPER (ATOMIC OR GPS CLOCK)
INSTRUMENTS / SENSOR INTERFACE
LIGHTING FOR IMAGE ACQUISITION
DEVICES AND PROCESSES CONTROL
MINIATURIZED CAMERA
COMMUNICATION MODULES
GPRS MODEM
ZIGBEE'' COMPLIANT RF TRANSCEIVER
OTHER WIRE OR WIRELESS COMMUNICATION DEVICE
NETWORK MANAGEMENT SOFTWARE
DATA
POWER
DATA BUS
EMBEDDED CONTROL
PROCESS CONTROL
COMMUNICATION MANAGEMENT
IMAGE ACQUISITION AND STORAGE MANAGEMENT
IMAGE PROCESSING AND INTERPRETATION TO GIVE READOUT VALUE
DATA ACQUISITION AND ANALYSIS OF ADDITIONAL I/O DATA
CONTROL OF EXTERNAL DEVICES AND/OR PROCESSES
POWER MANAGEMENT
POWER
POWER SUPPLY MODULE

FIG.3

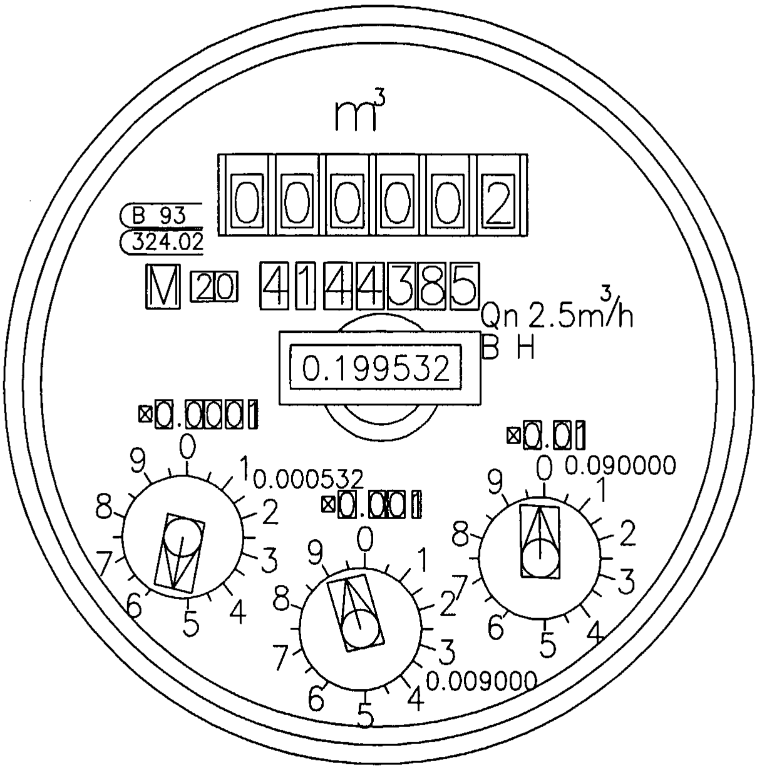
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FIG.4

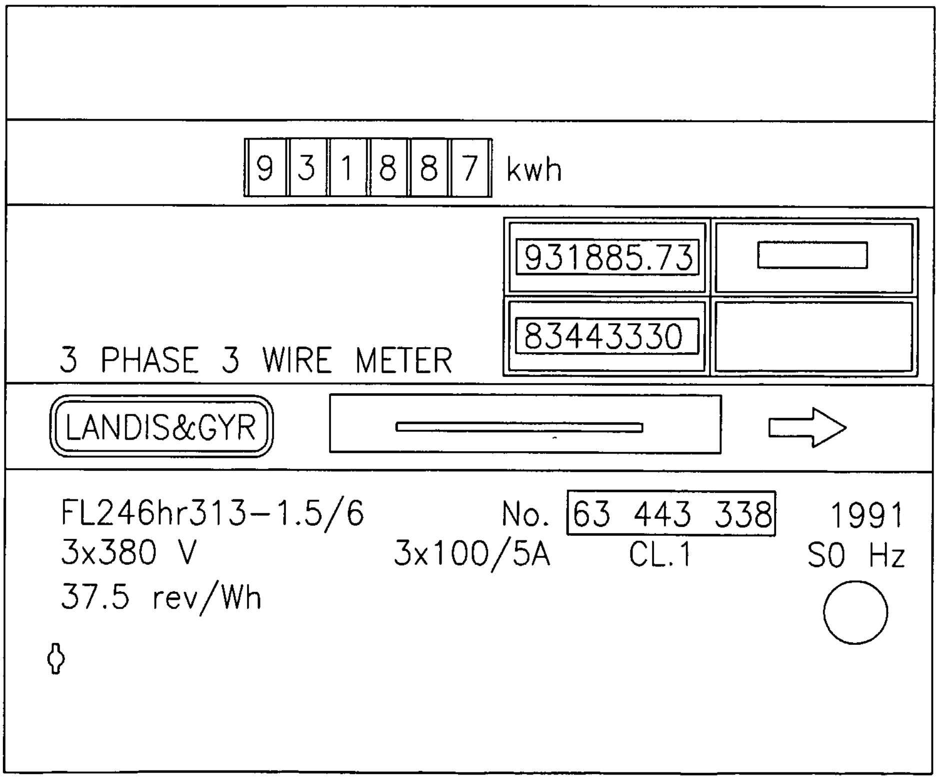
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FIG.5

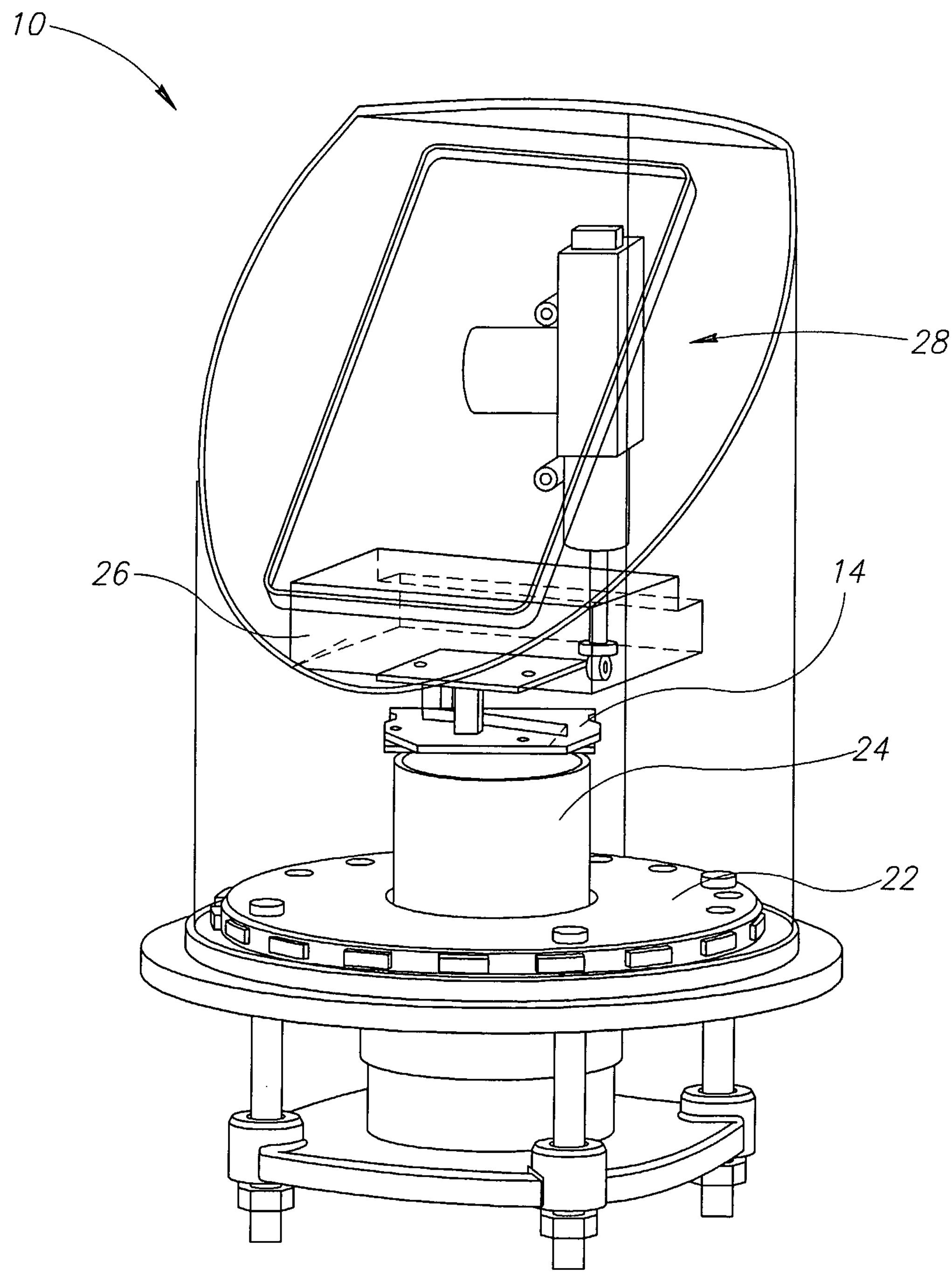

FIG.6