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(54) **WIRELESS POWER AND COMMUNICATION UNIT FOR PROCESS FIELD DEVICES**

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See application file for complete search history.

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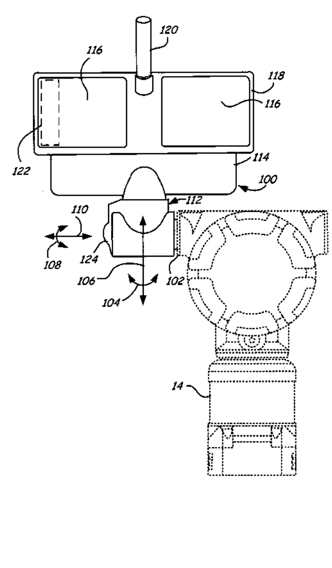
(57) **ABSTRACT**

A wireless power and communication unit for field devices is configured to connect to a field device and provide operating power and wired digital communication between the unit and the field device. RF circuitry in the unit is configured for radio frequency communication. In one embodiment, power supply circuitry in the unit includes one or more solar power cells that convert solar energy into electricity to power both the unit and the field device. The unit interacts with the field device in accordance with a standard industry communication protocol. The unit communicates wirelessly with an external device, such as a control room, based upon the interaction with the field device.

31 Claims, 9 Drawing Sheets



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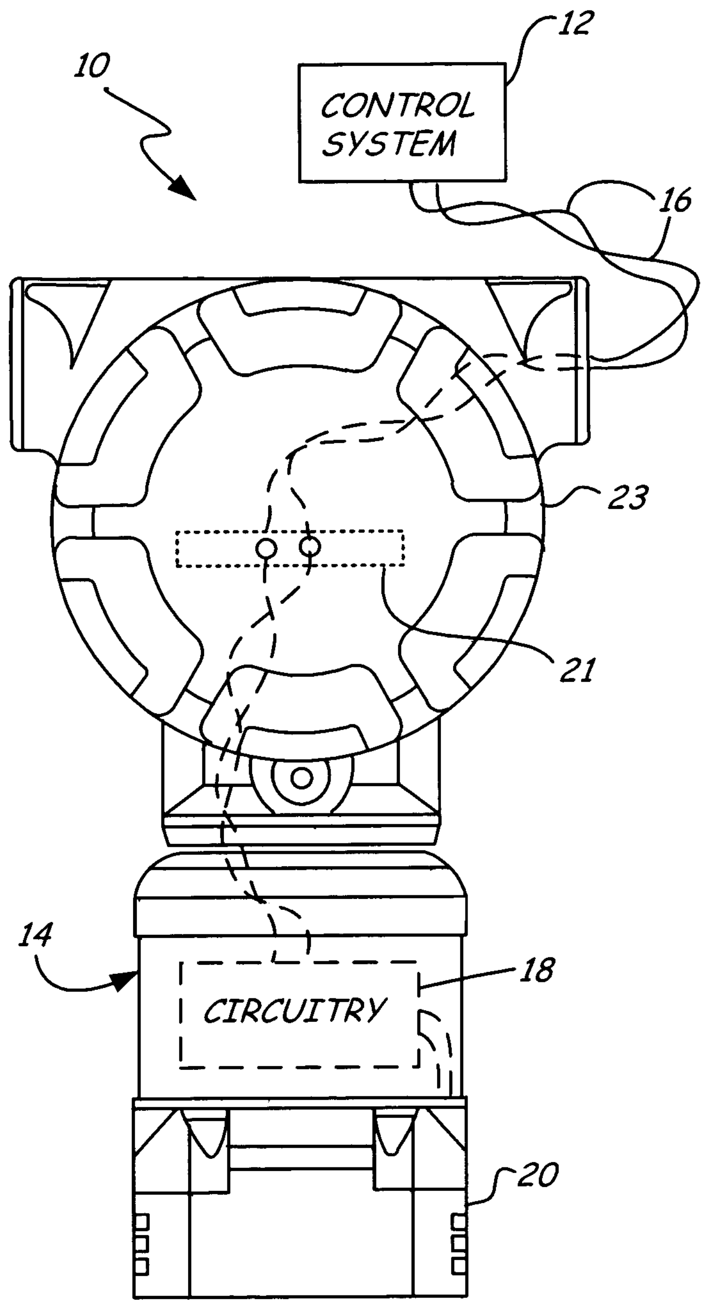

Fig. 1
(PRIOR ART)

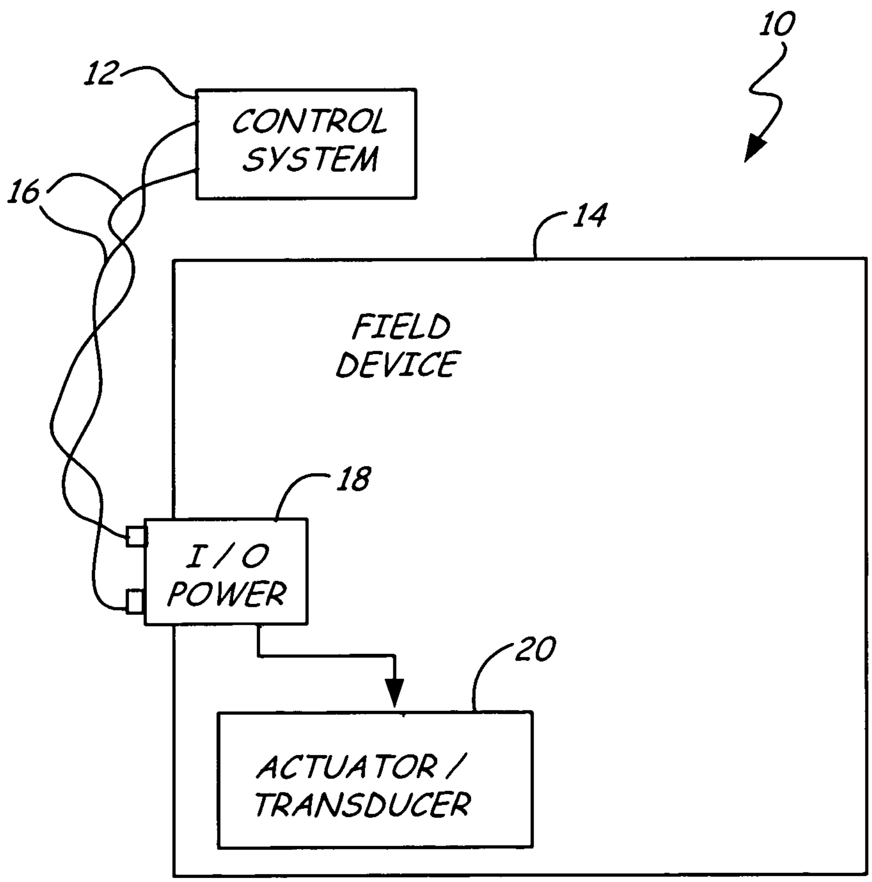

Fig. 2
(PRIOR ART)

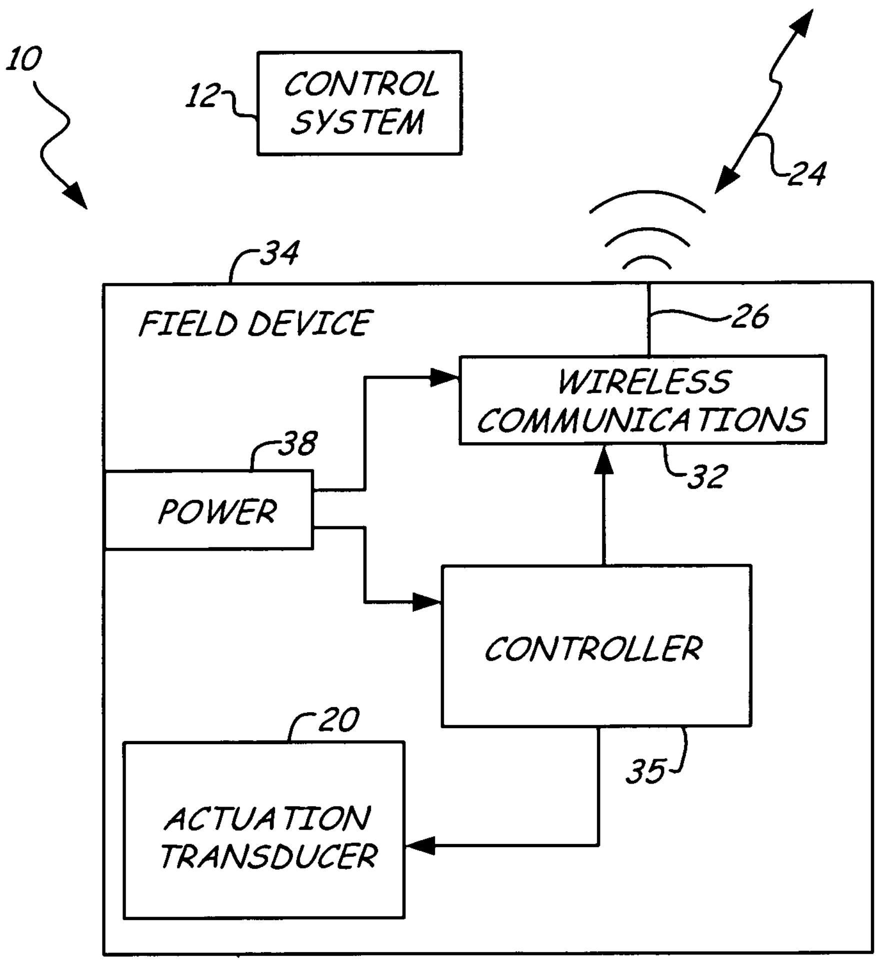

Fig. 3
(PRIOR ART)

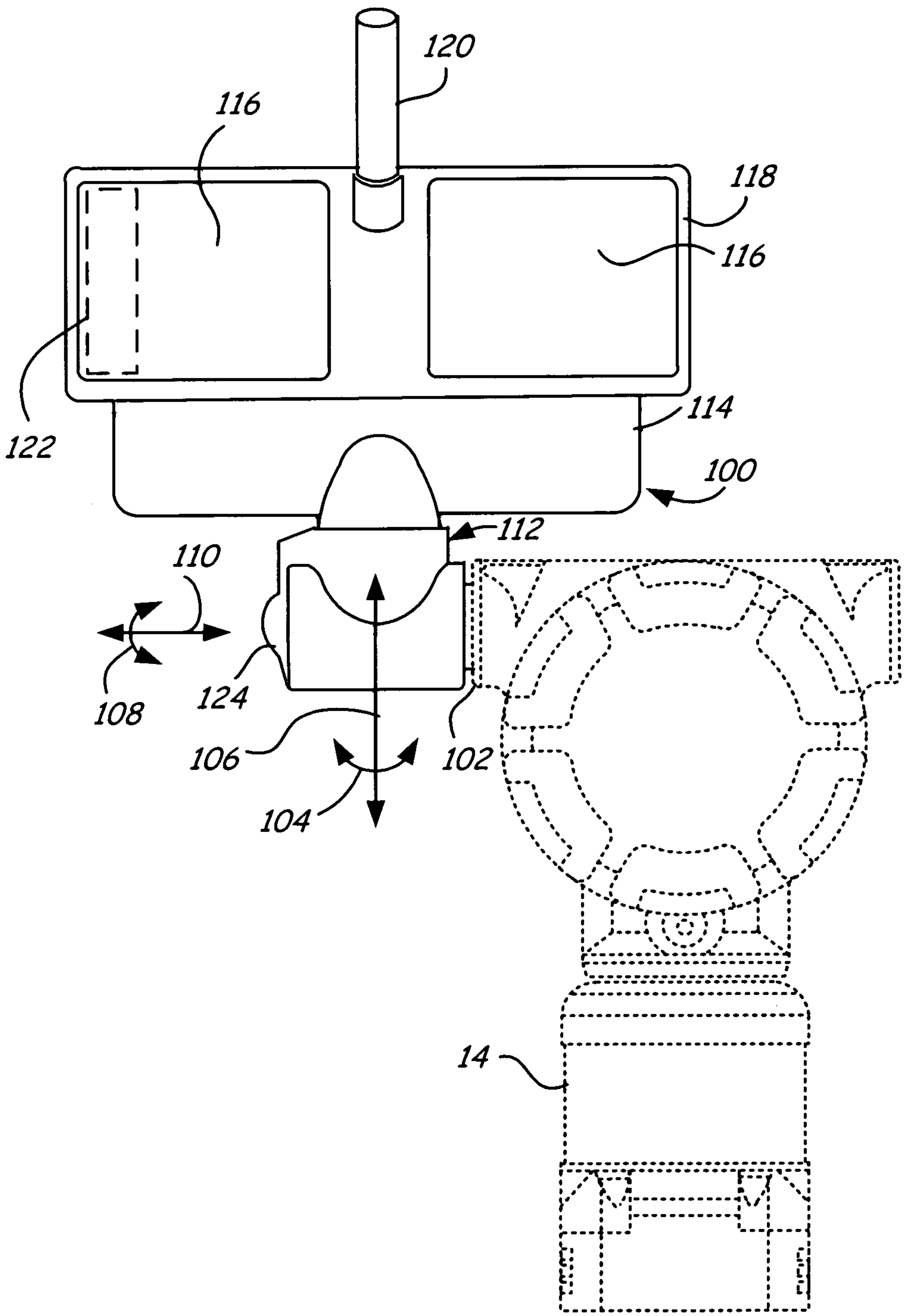

Fig. 4

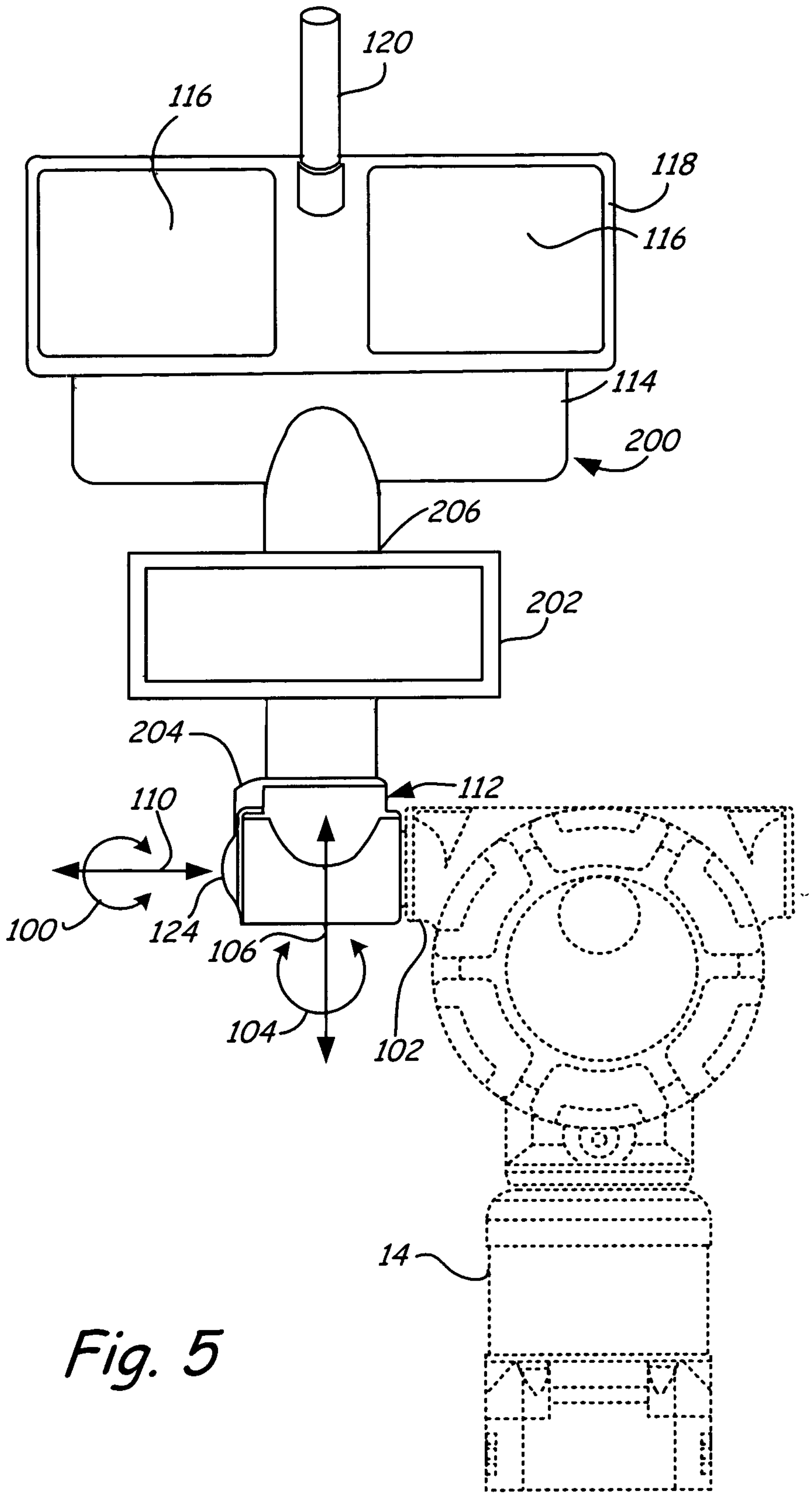
120
116
118
116
114
200
206
202
204
112
110
100
124
106
104
102
14

Fig. 5

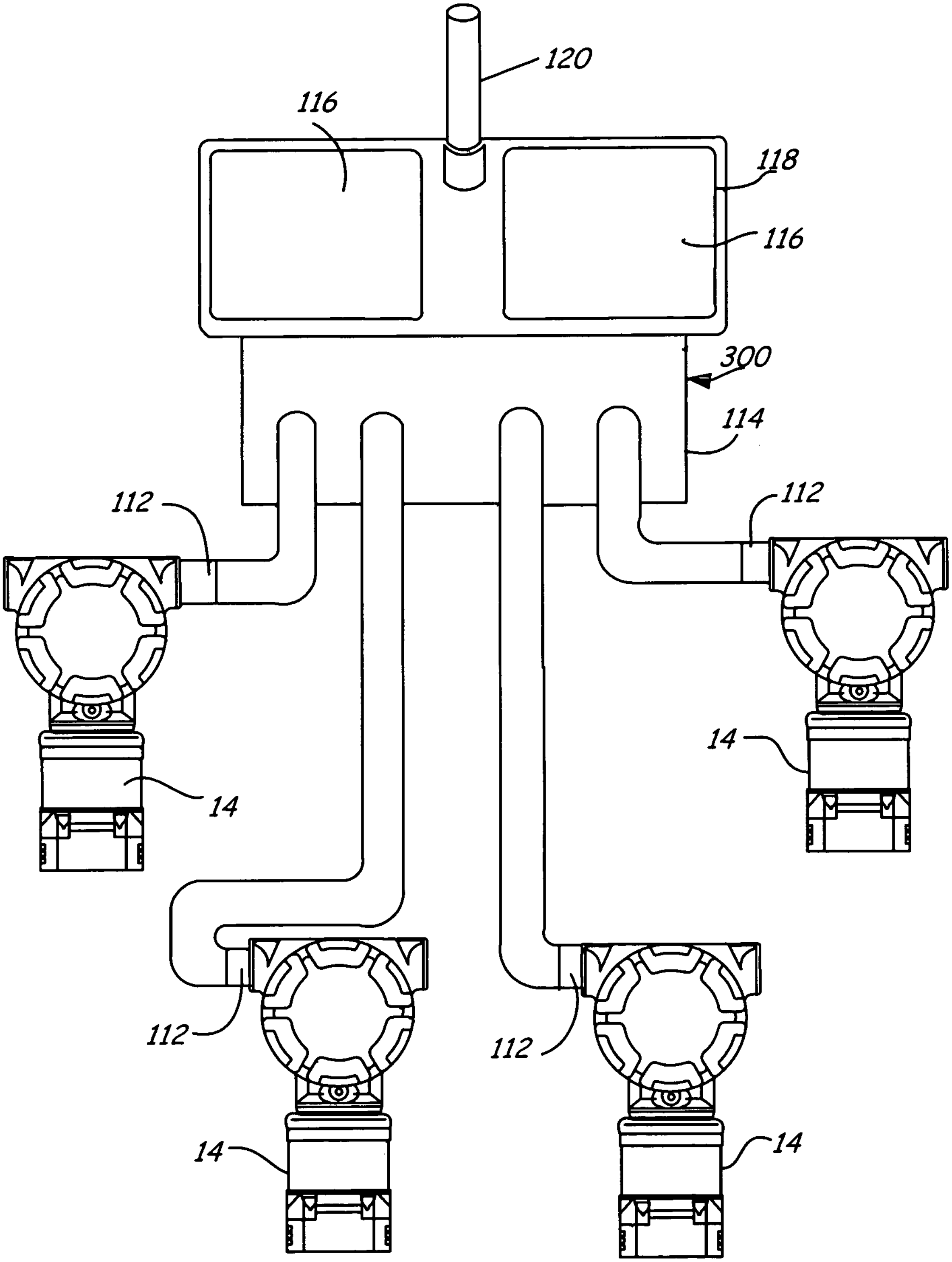

Fig. 6

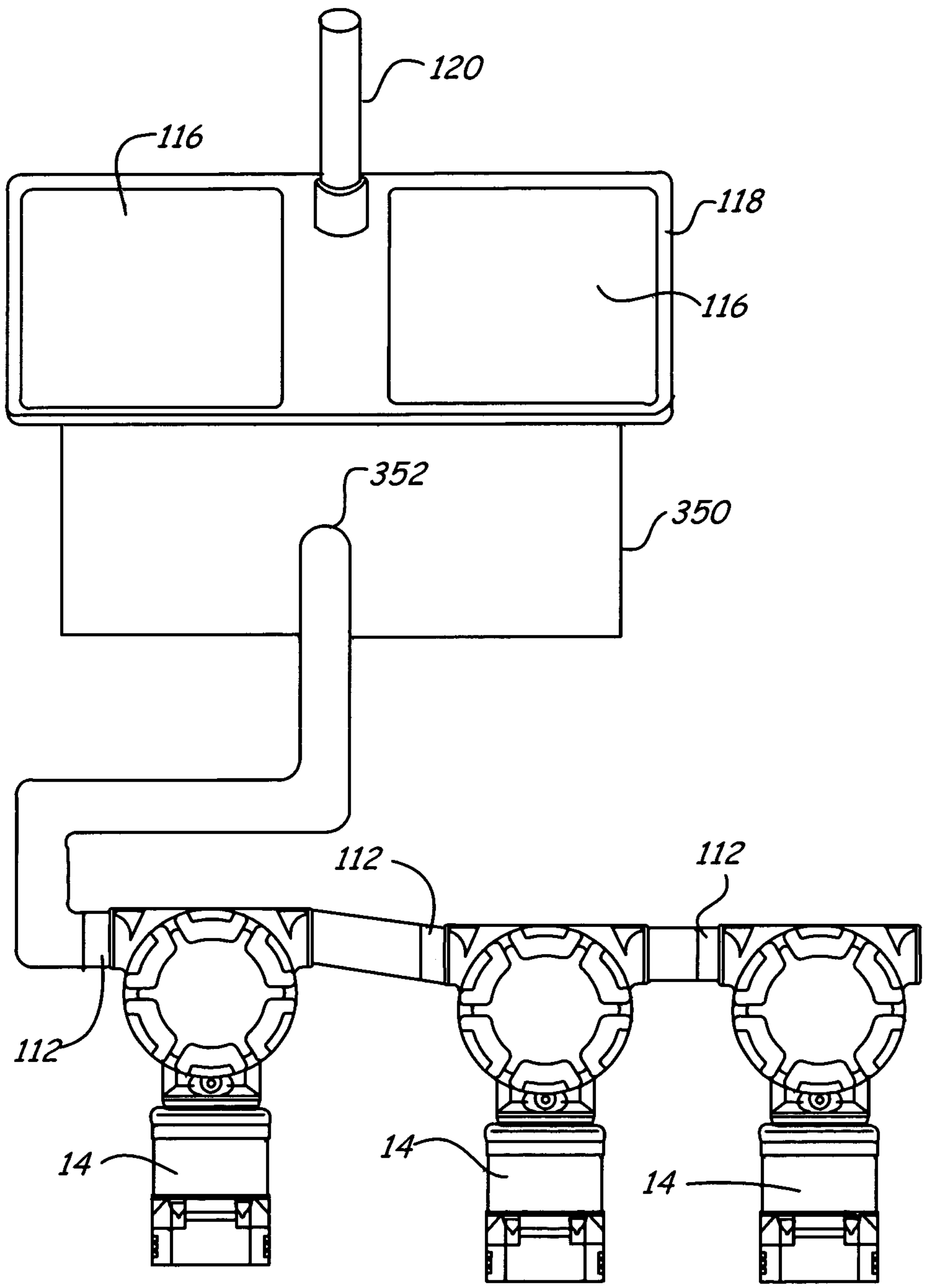

Fig. 7

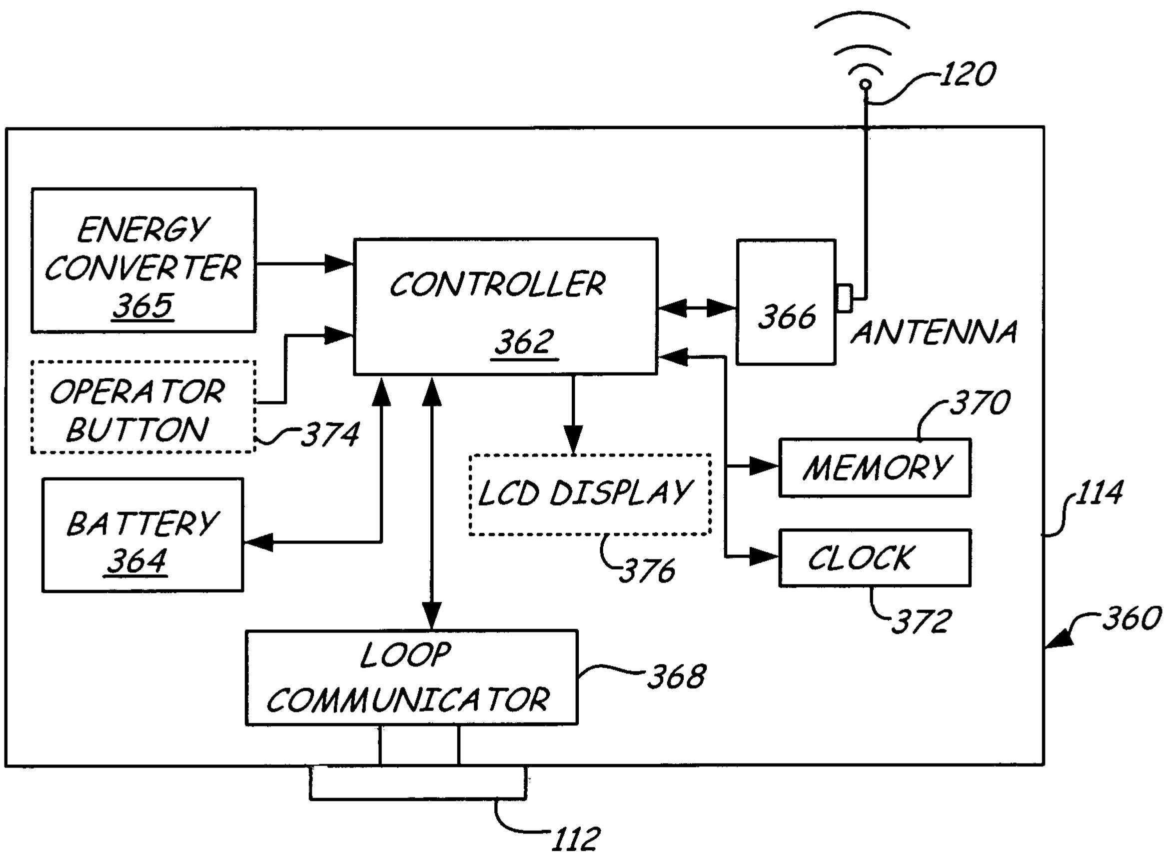
120
ENERGY CONVERTER 365
CONTROLLER 362
366
ANTENNA
OPERATOR BUTTON
374
370
MEMORY
LCD DISPLAY
114
BATTERY 364
376
CLOCK
372
360
LOOP COMMUNICATOR
368
112

Fig. 8

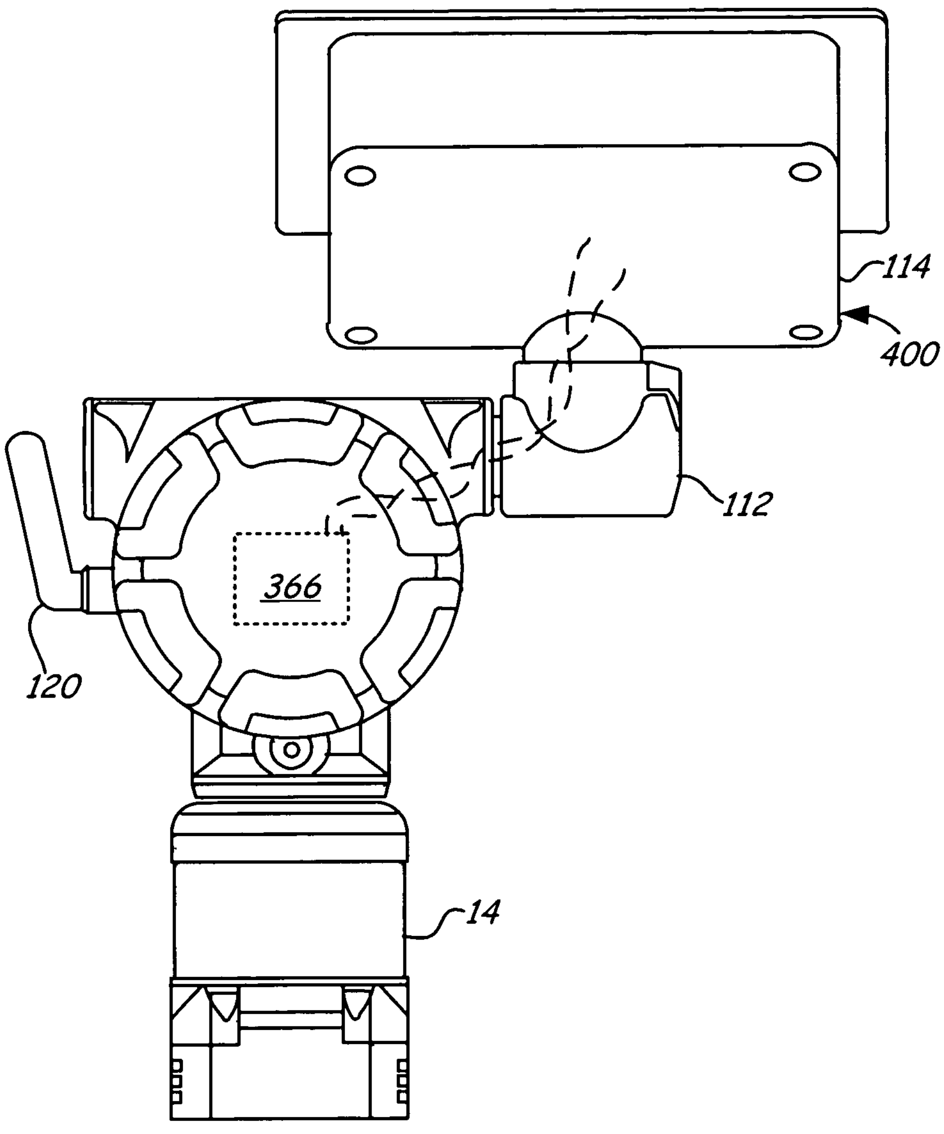

Fig. 9

WIRELESS POWER AND COMMUNICATION UNIT FOR PROCESS FIELD DEVICES

This application is a continuation-in-part application of and claims priority to U.S. patent application Ser. No. 29/204,502, filed Apr. 29, 2004.

BACKGROUND OF THE INVENTION

The present invention relates to industrial process control or monitoring systems. More specifically, the present invention relates to a system that adds wireless capability to field devices in such systems.

In industrial settings, control systems are used to monitor and control inventories of industrial and chemical processes, and the like. Typically, the control system performs these functions using field devices distributed at key locations in the industrial process and coupled to the control circuitry in the control room by a process control loop. The term "field device" refers to any device that performs a function in a distributed control or process monitoring system, including all devices used in the measurement, control and monitoring of industrial processes.

Some field devices include a transducer. A transducer is understood to mean either a device that generates an output signal based on a physical input or that generates a physical output based on an input signal. Typically, a transducer transforms an input into an output having a different form. Types of transducers include various analytical equipment, pressure sensors, thermistors, thermocouples, strain gauges, flow transmitters, positioners, actuators, solenoids, indicator lights, and others.

Typically, each field device also includes communication circuitry that is used for communicating with a process control room, or other circuitry, over a process control loop. In some installations, the process control loop is also used to deliver a regulated current and/or voltage to the field device for powering the field device. The process control loop also carries data, either in an analog or digital format.

Traditionally, analog field devices have been connected to the control room by two-wire process control current loops, with each device connected to the control room by a single two-wire control loop. Typically, a voltage differential is maintained between the two wires within a range of voltages from 12-45 volts for analog mode and 9-50 volts for digital mode. Some analog field devices transmit a signal to the control room by modulating the current running through the current loop to a current proportional to the sensed process variable. Other analog field devices can perform an action under the control of the control room by controlling the magnitude of the current through the loop. In addition to, or in the alternative, the process control loop can carry digital signals used for communication with field devices. Digital communication allows a much larger degree of communication than analog communication. Field devices that communicate digitally can respond to and communicate selectively with the control room and/or other field devices. Further, such devices can provide additional signaling such as diagnostics and/or alarms.

In some installations, wireless technologies have begun to be used to communicate with field devices. Wireless operation simplifies field device wiring and setup. Wireless installations are currently used in which the field device is manufactured to include an internal battery, potentially charged by a solar cell, or other technique to obtain power without any sort of wired connection. Problems exist in using an internal battery as the energy demands of wireless devices may vary

greatly depending on numerous factors such as the device reporting rate, device elements, et cetera. A power and communication system that is external to the field device for wireless communication would be a significant improvement in this area.

SUMMARY

A wireless power and communication unit for field devices is configured to connect to a field device and provide operating power and wired, preferably digital, communication between the unit and the field device. RF circuitry configured to provide radio frequency communication. In one embodiment, power supply circuitry in the unit includes one or more solar power cells that convert solar energy into electricity to power both the unit and the field device. The wireless power and communication unit powers the field device and interacts with the field device in accordance with a standard industry communication protocol. The unit communicates wirelessly with an external device, such as a control room, based upon the interaction with the field device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagrammatic view of an exemplary field device with which the wireless power and communication unit in accordance with the present invention is particularly useful.

FIG. **2** is a block diagram of the field device shown in FIG. **1**.

FIG. **3** is a block diagram of a field device including wireless communication circuitry for communicating with a remote device such as a display or hand held unit.

FIG. **4** is a front elevation view of a wireless power and communication unit in accordance with embodiments of the present invention mounted to a field device.

FIG. **5** is a front elevation view of a wireless power and communication unit in accordance with another embodiment of the present invention.

FIGS. **6** and **7** are diagrammatic views of a wireless power and communication unit operating with a plurality of field devices in accordance with embodiments of the present invention.

FIG. **8** is a block diagram of a wireless power and communication unit in accordance with embodiments of the present invention.

FIG. **9** is a rear elevation view of a wireless power and communication unit in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

The present invention includes a wireless power and communication unit for allowing field devices that are designed for wired communication to operate wirelessly. While some devices are currently being developed which add wireless communication to wired devices, such developments do not function to untether legacy wired type field devices from their control loops since they still are wired to and receive power from their control loops.

FIGS. **1** and **2** are diagrammatic and block diagram views of an exemplary field device with which a wireless power and communication unit in accordance with the present invention is particularly useful. Process control or monitoring system **10** includes a control room or control system **12** that couples to one or more field devices **14** over a two-wire process control loop **16**. Examples of process control loop **16** include analog 4-20 mA communication, hybrid protocols which include both analog and digital communication such as the Highway Addressable Remote Transducer (HART®) standard, as well as all-digital protocols such as the FOUNDATION™ Fieldbus standard. Generally process control loop protocols can both power the field device and allow communication between the field device and other devices.

In this example, field device **14** includes circuitry **18** coupled to actuator/transducer **20** and to process control loop **16** via terminal board **21** in housing **23**. Field device **14** is illustrated as a process variable (PV) generator in that it couples to a process and senses an aspect, such as temperature, pressure, pH, flow, et cetera of the process and provides and indication thereof. Other examples of field devices include valves, actuators, controllers, and displays.

Generally field devices are characterized by their ability to operate in the "field" which may expose them to environmental stresses, such as temperature, humidity and pressure. In addition to environmental stresses, field devices must often withstand exposure to corrosive, hazardous and/or even explosive atmospheres. Further, such devices must also operate in the presence of vibration and/or electromagnetic interference. Field devices of the sort illustrated in FIG. **1** represent a relatively large installed base of legacy devices, which are designed to operate in an entirely wired manner.

FIG. **3** is a block diagram of a wireless field device in accordance with the prior art. Field device **34** includes internal power supply module **38**, controller **35**, wireless communication module **32**, and actuator/transducer **20**. Power supply module **38** typically includes a battery that powers field device **34** for a period of time, until the battery needs to be replaced. Some field devices include a built-in solar cell. The power from supply **38** energizes controller **35** to interact with actuator/transducer **20** and wireless communications module **32**. Wireless communications module **32**, in turn, interacts with other devices as indicated by reference numeral **24** via antenna **26**. One drawback with providing the wireless capability of device **34** internally, is that if a battery, solar cell, or wireless communications module should be damaged, the entire field device must be repaired or replaced. Another disadvantage of using an internal battery is that some users of wireless devices require much more energy than other users. For example, if the field device is activated once per minute, versus once per hour, the energy consumption is greatly increased. The energy usage also varies widely based on whether the device is configured with minimum system elements or is fully configured. Thus, the use of an internal power source is not scalable in the sense that varying energy demands from various users cannot be accommodated well.

FIG. **4** is a front elevation view of a wireless power and communication unit **100** attached to a field device **14**, shown in phantom. Unit **100** preferably attaches to device **14** via a standard field device conduit **102**. Examples of suitable conduit connections include 1/2-14 NPT, M20x1.5, G1/2, and 3/8-18 NPT. Unit **100** may include a joint allowing rotation **104** about axis **106** and rotation **108** about axis **110**. Further, attachment region **112** of unit **100** is preferably hollow in order to allow conductors therein to couple unit **100** to device **14**. In embodiments where positional adjustment of the housing is not desired, attachment region **112** could simply be a piece of conduit.

Unit **100** includes housing **114** that is mounted upon attachment region **112**. Housing **114** contains circuitry (described with respect to FIG. **8**) to allow unit **100** to power and communicate with device **14** in accordance with a standard industry protocol such as 4-20 mA, HART®, FOUNDATION™ Fieldbus, Profibus-PA, Modbus, or CAN. Preferably, the protocol accommodates digital communication in order to enhance the level of interaction between unit **100** and device **14**.

FIG. **4** also illustrates one or more photovoltaic cells **116** mounted proximate a top surface **118** of housing **114**. In one embodiment, the photovoltaic cells(s) **116** form part of a sealed lid for the housing **114**. In such embodiments, a clear cover preferably extends over cell(s) **116** to protect them from exposure. Cells **116** are preferably inclined at an angle of about 30 degrees and transform light falling thereon into electrical energy in order to power unit **100** and device **14**. Since unit **100** is external to device **14**, multiple variations of unit **100** can be provided with varying photovoltaic cell configurations and/or sizes depending upon the specific power requirements of the field device to which the unit will be attached. Unit **100** also preferably includes wireless communication circuitry (not shown in FIG. **4**) which is coupled to antenna **120**. Providing external antenna **120** facilitates wireless communication in comparison to internal antennas since many field-hardened enclosures are metal and would likely attenuate the wireless signal. However, embodiments with an internal antenna proximate a radio-transparent portion of housing **114**, or cell(s) **116** can be practiced as well. External antenna embodiments, however, are particularly advantageous where unit **100** is field hardened in order to withstand environments similar to those for which field devices are designed.

In accordance with one aspect of the invention, unit **100** includes a local user interface. Accordingly unit **100** may include a display, such as an LCD display **122** that may be mounted proximate one of cells **116**. In order to receive local user input, unit **100** can include one or more local inputs such as button **124**. A local user interface is important because when the combined unit/field device system is operating totally wirelessly, it is more convenient for a technician to interact with the local user interface rather than wirelessly trying to access the device via a handheld computing device or the like. The local interface can be used to access the unit, the field device, or both. As defined herein "local user interface" means having either local user input(s) (such as a button), local user output(s) (such as an LCD), or a combination of the two. As illustrated in FIG. **4**, the LCD can be co-located with cell(s) **116**.

FIG. **5** is a front elevation view of a wireless power and communication unit in accordance with another embodiment of the present invention. Wireless power and communication unit **200** bears many similarities to wireless power and communication unit **100** and like components are numbered similarly. The primary difference between wireless power and communication unit **200** and wireless power and communication unit **100** is the configuration of the local user interface display. Specifically, unit **200** does not include a display proximate or co-located within the photovoltaic cell(s) **116**. Instead, display **202** is integrated into attachment region **112**. Preferably, display **202** is independently rotatable about axis **106** by approximately 270°.

Providing a user interface display proximate attachment region **112** increases the modularity of unit **200**. Specifically, housings **114** and all components therein can be manufactured similarly to achieve economies of scale. In installations where a local user display is desirable, it can simply be added as a module between housing **114** and joint **204** of attachment region **112**. Such modularity is also useful in embodiments where one unit **200** is used to operate and communicate with multiple field devices as will be described in greater detail with respect to FIGS. **6** and **7**. Thus, as installation site needs dictate, the power system, which includes the solar cell and antenna can be remotely mounted by utilizing an adapter fitted with a cable gland that connects to the top **206** of LCD display **202**. An adapter base is then used for mounting the housing **114** and bringing the interconnecting cable via a cable gland. This allows positioning housing **114** in an optimal performance location while keeping a local user interface proximate each field device.

FIG. **6** is a diagrammatic view of a wireless power and communication unit **300** in accordance with an embodiment of the present invention. Wireless power and communication unit **300** is adapted for mounting remote from one or more field devices **14**. Unit **300** includes suitable power generation and storage capabilities to power field devices **14** simultaneously, sequentially, or asynchronously. As illustrated in FIG. **6**, each field device **14** is coupled individually to unit **300** by an attachment region **112** illustrated diagrammatically in FIG. **6**. As stated above with respect to FIG. **5**, attachment region **112** preferably includes a local user interface, such as button **124** and/or display **202**. Since each field device **14** is individually coupled to unit **300**, analog or digital communication with individual field devices **14** can be effected. While it is preferred that user interfaces are included in attachment regions **112** in the embodiment illustrated in FIG. **6**, some embodiments may provide an additional, or alternative user interface embodied within unit **300**.

FIG. **7** is a diagrammatic view of unit **350** in accordance with another embodiment of the present invention. Unit **350** is illustrated with a single connection **352** to a plurality of field devices **14**. Those skilled in the art will appreciate that the configuration illustrated in FIG. **7** has the ability to drastically reduce interconnection wiring and efforts for coupling field devices **14** to unit **350**. In order to be able to communicate with individual field devices **14**, unit **350** preferably employs digital communication utilizing either a hybrid-type protocol or an all-digital industry standard protocol. Further, such a protocol is used to power all of field devices **14**, simultaneously, sequentially, or asynchronously as desired. FIG. **7** also illustrates each of field devices **14** coupling to the network utilizing an attachment region **112** illustrated diagrammatically. Thus, each of field devices **14** may still have a local user interface comprising a local user input and/or a local user output such as an LCD display.

FIG. **8** is a block diagram of a wireless power and communication unit in accordance with embodiments of the present invention. Unit **360** includes controller **362**, power storage device **364** (illustrated as a battery), energy converter **365**, loop communicator **368**, and wireless communication interface module **366**.

Controller **362** preferably includes a low-power microprocessor and appropriate charging circuitry to convey suitable amounts of energy from cell(s) **116** and/or storage device **364** to power unit **360** and any field devices coupled to attachment region **112**. Additionally, controller **362** also directs excess energy from cell(s) **116** to storage device **364**. Controller **362** can also be coupled to optional temperature measurement circuitry such that controller **362** can reduce charging current to storage device **364** if device **364** begins to overheat. For example, the temperature measuring circuit may contain a suitable temperature-sensing element, such as a thermocouple coupled to storage device **364**. An analog-to-digital converter could convert the signal from the thermocouple to a digital representation thereof, and provide the digital signal to controller **362**.

Controller **362** can be configured, through hardware, software, or both to actively manage power for itself and attached field devices. In this regard, controller **362** can cause itself or any desired field devices to enter a low-power sleep mode. Sleep mode is any operating mode where power consumption is reduced. With respect to field devices, sleep mode could result from commanding the field device to set its operating current at its lowest allowable current rail. Events which may precipitate entering low-power mode could include: the expiration of an activity period, an input from one or more of the local user inputs, communication from one or more attached field devices, or wireless communication. Such events could also be used to cause unit **360** and/or any attached field devices to awaken from sleep mode. Additionally, controller **362** can selectively cause any attached field device to enter sleep mode based upon any logic or rules contained in programming instructions within controller **362** and/or wireless communication received via wireless communication module **366**. Preferably, local inputs, such as button **124** are user configurable. Thus a single button could be used to awaken a field device for a user-selectable period of time, and if so configured, depressed again to cause the field device to return to sleep mode. In one embodiment, the configurable local input button uses a jumper or switch to preset the following functions:

Button Depress Time to Activate—select either 1, 1.5, 2 or 3 seconds. Field device ignores button presses having durations shorter than the preset.

Unit On Time—select either 10, 15, 30 seconds, or 5, 15, 30, 60 minutes.

If the button is pressed twice in close succession, the field device stays on for a preset period (for example 60 minutes) after which it returns to sleep mode.

If the button is pressed a second time after a preset interval (for example 5 seconds) the field device will return to sleep mode.

Controller **362** can also preferably cause portions of circuitry within unit **360** or attached field devices to enter sleep mode. For example, wireless communication module **366** may be a commercially available General Packet Radio Service (GPRS) cell phone module, that has both a normal operating mode and a sleep mode. A signal from controller **362** could cause module **366** to enter sleep mode when significant wireless communication is not warranted.

Energy converter **365** can be any device that is able to convert potential energy in the environment proximate unit **360** into electrical energy. In the preferred embodiments, converter **365** is simply one or more photo-voltaic cells **116**. However, converter **365** can be any device, known or later developed, that can translate potential energy near unit **360** into electricity. Thus converter **365** can include a generator coupled to a movable member such that environmental motion, such as waves or wind generate electricity. Further, converter **365** can employ thermopile devices to generate electricity from disparate temperatures using the Peltier Effect. Further still, the process may provide a source of energy in the form of compressed gas or the like, that could be transformed into electricity. Finally, in embodiments where the power storage device has a relatively large capacity in comparison to the energy needs of the application, converter **365** may be omitted.

Wireless communication module **366** is coupled to controller **362** and interacts with external wireless devices via antenna **120** based upon commands and/or data from controller **362**. Depending upon the application, wireless communication module **366** may be adapted to communicate in accordance with any suitable wireless communication protocol including, but not limited to: wireless networking technologies (such as IEEE 802.11b wireless access points and wireless networking devices built by Linksys of Irvine, Calif.), cellular or digital networking technologies (such as

Microburst® by Aeris Communications Inc. of San Jose, Calif.), ultra wide band, free space optics, Global System for Mobile Communications (GSM), General Packet Radio Service (GPRS), Code Division Multiple Access (CDMA), spread spectrum technology, infrared communications techniques, SMS (Short Messaging Service/text messaging), or any other suitable wireless technology. Further, known data collision technology can be employed such that multiple units can coexist within wireless operating rage of one another. Such collision prevention can include using a number of different radio-frequency channels and/or spread spectrum techniques.

Wireless communication module **366** can also include transducers for a plurality of wireless communication methods. For example, primary wireless communication could be performed using relatively long distance communication methods, such as GSM or GPRS, while a secondary, or additional communication method could be provided for technicians, or operators near the unit, using for example, IEEE 802.11b or Bluetooth.

Some wireless communications modules may include circuitry that can interact with the Global Positioning System (GPS). GPS can be advantageously employed in unit **360** for mobile devices to allow finding the individual unit **360** in a remote location. However, location sensing based upon other techniques can be used as well.

Memory **370** is illustrated in FIG. **8** as being separate from controller **362**, but may, in fact, be part of controller **362**. Memory **370** can be any suitable type of memory including volatile memory (such as Random Access Memory), non-volatile memory (such as flash memory, EEPROM memory, etc.) and any combination thereof. Memory **370** may contain program instructions for controller **362** as well as any suitable administrative overhead data for unit **360**. Memory **370** may contain a unique identifier for unit **360**, such that unit **360** can distinguish wireless communications meant for it among other wireless communications. Examples of such an identifier could include, a Media Access Controller (MAC) address, Electronic Serial Number, global phone number, Internet Protocol (IP), or any other suitable identifier. Moreover, memory **370** may include information about attached field devices, such as their unique identifiers, configurations, and abilities. Finally, controller **362**, using memory **370** can cause the output of unit **360** to be provided in any suitable form. For example, configuration and interaction with unit **360** and/or one or more associated field devices could be provided as HyperText Markup Language (HTML) web pages.

Clock **372** is illustrated as being coupled to controller **362**, but may also be part of controller **362**. Clock **372** allows controller **362** to provide enhanced operation. For example, clock **372** can be used to time the periods set forth above with respect to configurable button **125**. Additionally, controller **362** can store information from one or more attached field devices, and correlate the information with time in order to recognize trends. Further still, controller **362** can supplement information received from one or more field devices with time information before transmitting it via wireless communication module **366**. Further still, clock **372** can be used to automatically generate periodic sleep/awaken commands for unit **360** and/or field devices. Another form of periodic use for clock **372** is to cause controller **362** to issue, via module **366**, a heartbeat type signal to periodically indicate an acceptable status to an external wireless device.

Loop communicator **368** is coupled to controller **362** and interfaces controller **362** to one or more field devices coupled to one or more attachment regions **112**. Loop communicator **368** is known circuitry that generates appropriate signals in order to communicate in accordance with an industry protocol, such as those set forth above. In embodiments where unit **360** is coupled to a plurality of field devices that communicate in accordance with different protocols, it is conceivable that multiple loop communicators could be used to allow controller **362** to interact with the various field devices. The physical connection(s) made through attachment region **112** allows unit **360** to power and communicate with the field devices. In some embodiments, this can be done by providing power over the same conductors used for communication, such as a two-wire loop. However, it is also contemplated that embodiments of the invention can be practiced where power is provided to the field device on separate conductors than those used for communication. For ease of technician access, unit **360** may include two or more terminals proximate loop communicator **368** or attachment region **112** in order to facilitate the coupling of a handheld configuration device, such as the Model 375 Handheld device available from Rosemount, Inc. of Eden Prairie, Minn.

FIG. **8** also illustrates optional operator button block **374** and LCD display block **376** in phantom being coupled to controller **362**. This illustration is intended to show that all local inputs, be they on individual field devices, wireless power and communication unit **360**, or both are coupled to controller **362**. Additionally, local user displays, on each field device, wireless power and communication unit **360**, or both are also coupled to controller **362**. This allows controller **362** to interact with each local display individually based upon inputs from the field device, the configurable button associated with the field device, one or more buttons or inputs disposed proximate unit **360**, or from wireless communication.

FIG. **9** is a rear elevation view of a wireless power and communication unit in accordance with an embodiment of the present invention. Wireless unit **400** is coupled to field device **14** as in previous embodiments. However, wireless communication module **366** and/or antenna **120** can be located within field device **14** instead of within housing **114** of unit **400**. Wireless communication module **366** and/or antenna **120** can be added to field device **14** as a feature board. Further, wireless communication module **366** could be an integral part of field device **14**. Thus, in some embodiments, module **366** may be coupled to a controller within unit **400** via attachment region **112**. In other embodiments, module **366** may be integral with the field device, and in such embodiments, unit **400** could simply provide operating power.

In operation, wireless power and communication units in accordance with embodiments of the present invention can add significant capabilities to process monitoring and control. While the wireless output of the wireless power and communication units may be simply indications of process variable, they may also contain much more information. For example, the wireless output could also include diagnostic and/or maintenance information. Further, the wireless power and communication unit could also provide alarms wirelessly if one or more of the field devices, or even the unit itself, generates a fault. The unit may direct the wireless alarm to the same entity as it normally sends wireless information to (such as a control room), or it may send to an alternate entity, such as a technician's pager. Further, in embodiments where the unit is coupled to more than one field device, the wireless output may be indicative of a combination of process variable, or a higher level output. Further still, in embodiments where the multiple field devices include PV generators, and one or more actuators that can effect a change in the process variable, the units themselves may actually provide local closed-loop process control autonomously without control room interaction, but still subject to wireless communication.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

What is claimed is:

1. A process communication system comprising:

a process variable generator coupleable to the process, the process variable generator being operably coupled to a transducer and having communication circuitry for communication over a process control loop and receiving electrical power from the process control loop to power the process variable generator;

a wireless power and communication unit for providing wireless operation to the process variable generator, the unit including:

a housing;

an attachment region coupling the housing to the process variable generator through a standard field device conduit;

a power storage device disposed within the housing and configured to power the process variable generator;

a loop communicator connected to the process variable generator via the attachment region and configured to interact with the process variable generator via the communication circuitry;

a controller coupled to the power storage device and loop communicator, the controller being configured to interact with the process variable generator using the loop communicator and configured to actively manage power for the wireless power and communication unit and the process variable generator;

a wireless communication module coupled to the controller and being configured for wireless communication based upon interaction with the process variable generator; and

a local user interface;

wherein the power management includes causing the process variable generator to enter a sleep mode; and

wherein the power management includes causing at least a portion of the wireless power and communication unit to enter a sleep mode.

2. The system of claim **1**, wherein the power storage device is a battery.

3. The system of claim **1**, and further comprising a energy converter coupled to the controller and being adapted to convert a source of environmental potential energy into electricity.

4. The system of claim **3**, wherein the energy converter includes at least one photo-voltaic cell.

5. The system of claim **4**, wherein the at least one photo-voltaic cell seals a portion of the housing.

6. The system of claim **3**, wherein the controller is adapted to recharge the power storage device with electricity from the energy converter.

7. The system of claim **3**, and further comprising a temperature sensor operably coupled to the controller and disposed to sense a temperature of the energy storage device, and wherein the controller selectively charges the energy storage device based at least in part upon a signal from the temperature sensor.

8. The system of claim **7**, wherein the temperature sensor is operably coupled to the controller through an analog-to-digital converter.

9. The system of claim **1**, wherein the conduit has a size selected from the group consisting of a 3/8-18 NPT, a 1/2-14 NPT, a M20x1.5, and a G1/2.

10. The system of claim **1**, wherein the attachment region includes at least one degree of freedom.

11. The system of claim **1**, wherein the attachment region allows the housing to be rotatable about a first axis.

12. The system of claim **11**, wherein the attachment region allows the housing to the rotatable about a second axis that is substantially orthogonal to the first axis.

13. The system claim **1**, and further comprising a photo-voltaic cell disposed near a top surface of the housing at an angle of approximately 30 degrees with respect a bottom surface of the housing.

14. The system of claim **1**, wherein the local user interface includes a button.

15. The system of claim **14**, wherein the button is user configurable.

16. The system of claim **14**, wherein the button is disposed proximate the attachment region.

17. The system of claim **1**, wherein the user interface includes a display.

18. The system of claim **17**, wherein the display is an LCD display.

19. The system of claim **17**, wherein the display is located proximate a top surface of the housing.

20. The system of claim **19**, wherein the display is located proximate a photo-voltaic cell.

21. The system of claim **17**, wherein the display is mounted proximate the attachment region.

22. The system of claim **21**, wherein the display is rotatable about the attachment region.

23. The system of claim **1**, wherein the housing is field-hardened.

24. The system of claim **1**, and further comprising an additional attachment region, the additional attachment region being configured to couple the wireless power and communication unit to an additional process variable generator and power and communicate with both process variable generators.

25. The system of claim **24**, wherein the loop communicator is adapted to communicate digitally with both process variable generators.

26. The system of claim **1**, wherein the controller includes a microprocessor.

27. The system of claim **1**, wherein the loop communicator is configured to sense a current ranging between 4 and 20 milliamps.

28. The system of claim **1**, wherein the loop communicator provides a two-wire connection to the process variable generator, which two wire connection provides power and communication with the process variable generator.

29. The system of claim **1**, wherein the power management includes causing the process variable generator to enter a sleep mode.

30. The system claim **1**, wherein the controller causes the portion of the wireless power and communication unit to enter a sleep mode based upon user input.

31. The system of claim **1**, wherein the power storage device is selected based upon a scale of power required by the process variable generator.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,538,560 B2
APPLICATION NO. : 10/850828
DATED : September 17, 2013
INVENTOR(S) : Gregory Brown et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page, Item (63)

Related U.S. Application Data

filed on April 29, 2005 should be --filed on April 29, 2004--.

Signed and Sealed this
Tenth Day of December, 2013

Margaret A. Focarino
Commissioner for Patents of the United States Patent and Trademark Office