

(12) **United States Patent**
DeLoach, Jr.

(10) **Patent No.:** **US 9,271,057 B2**
(45) **Date of Patent:** **Feb. 23, 2016**

(54) **METHODS AND APPARATUS FOR TIME SYNCHRONIZATION AND MEASUREMENT OF POWER DISTRIBUTION SYSTEMS**

2009/0055031 A1* 2/2009 Slota et al. 700/287
2009/0184835 A1* 7/2009 Deaver et al. 340/660
2009/0187285 A1* 7/2009 Yaney et al. 700/292
2009/0289637 A1* 11/2009 Radtke 324/629
2013/0054183 A1* 2/2013 Afzal et al. 702/141

(75) Inventor: **James Douglass DeLoach, Jr.**, San Diego, CA (US)

FOREIGN PATENT DOCUMENTS

(73) Assignee: **QUALCOMM Incorporated**, San Diego, CA (US)

DE 102008046737 A1 3/2010
JP H1051981 A 2/1998

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 637 days.

(Continued)

OTHER PUBLICATIONS

(21) Appl. No.: **12/709,771**

International Search Report & Written Opinion—PCT/US2011/025769—International Search Authority, European Patent Office, May 26, 2011.

(22) Filed: **Feb. 22, 2010**

(Continued)

(65) **Prior Publication Data**
US 2011/0208364 A1 Aug. 25, 2011

Primary Examiner — Bob Phunkulh
(74) *Attorney, Agent, or Firm* — Darren M. Simon

(51) **Int. Cl.**
H04J 3/06 (2006.01)
H04Q 9/04 (2006.01)

(57) **ABSTRACT**

(52) **U.S. Cl.**
CPC **H04Q 9/04** (2013.01); **Y02E 60/728** (2013.01); **Y04S 10/265** (2013.01)

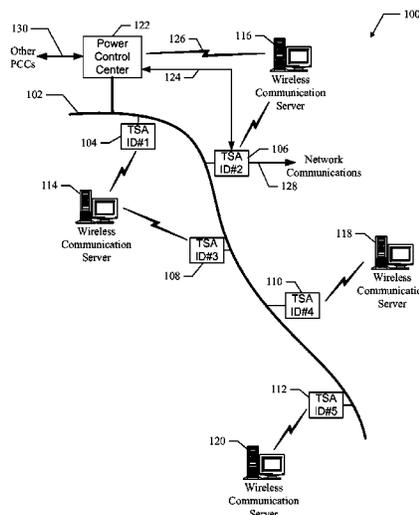
Methods and apparatus for time synchronization and measurement of power distribution systems. A method includes receiving a synchronized wireless communication signal, synchronizing to the synchronized wireless communication signal to produce synchronized time, performing one or more power distribution measurements based on the synchronized time to produce synchronized power distribution measurements, and transmitting the synchronized power distribution measurements to a power control center. An apparatus includes a receiver configured to receive a synchronized wireless communication signal and to synchronize to the synchronized wireless communication signal to produce synchronized time, a measurement module configured to perform one or more power distribution measurements based on the synchronized time to produce synchronized power distribution measurements, and a transmitter configured to transmit the synchronized power distribution measurements to a power control center.

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**
U.S. PATENT DOCUMENTS

7,944,868	B2 *	5/2011	Kokku et al.	370/311
2007/0002772	A1 *	1/2007	Berkman et al.	370/257
2007/0005234	A1	1/2007	Kashiwase et al.	
2007/0058659	A1 *	3/2007	Ayyagari et al.	370/445
2007/0286079	A1 *	12/2007	Mollenkopf et al.	370/236
2008/0077336	A1	3/2008	Fernandes	
2008/0109387	A1 *	5/2008	Deaver et al.	705/412
2008/0122642	A1 *	5/2008	Radtke et al.	340/660
2008/0204054	A1 *	8/2008	Wells	324/713

64 Claims, 5 Drawing Sheets



(56)

References Cited

FOREIGN PATENT DOCUMENTS

JP	2002345172	A	11/2002
JP	2004132762	A	4/2004
JP	2005106696	A	4/2005
JP	2005318494	A	11/2005
JP	2007013486	A	1/2007
JP	2008008669	A	1/2008
JP	2010537622	A	12/2010
TW	200845601	A	11/2008
WO	WO-2009032161	A2	3/2009

OTHER PUBLICATIONS

European Search Report—EP13020010—Search Authority—Munich Jul. 2, 2013.

Taiwan Search Report—TW100105861—TIPO—Oct. 6, 2013.

McGhee J., et al., “Smart High Voltage Substation Based on IEC 61850 Process Bus and IEEE 1588 Time Synchronization”, Smart Grid Communications (SmartGridComm), 2010 First IEEE International Conference on, IEEE, Piscataway, NJ, USA, Oct. 4, 2010, pp. 489-494, XP031790276, ISBN: 978-1-4244-6510-1.

* cited by examiner

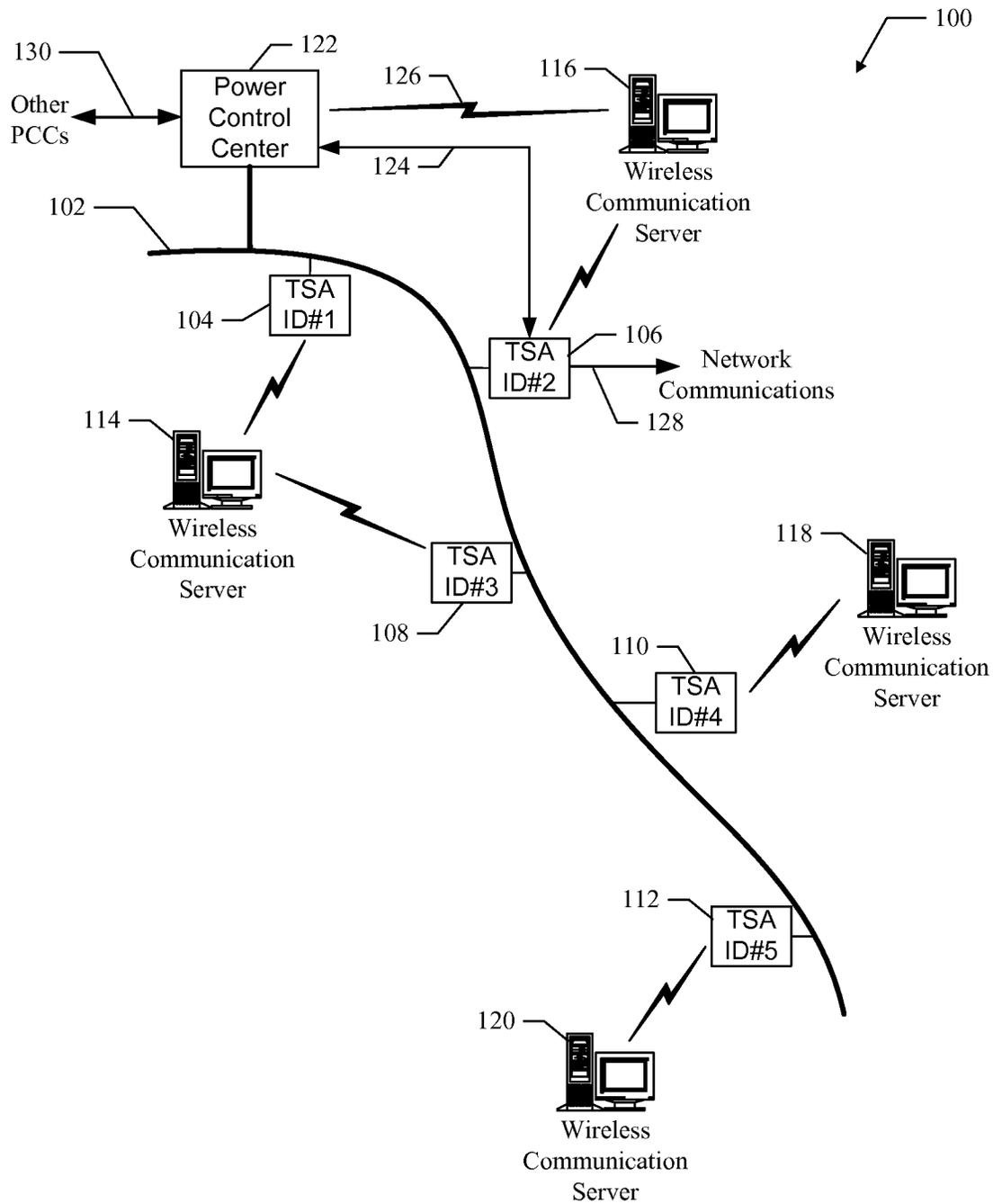


FIG. 1

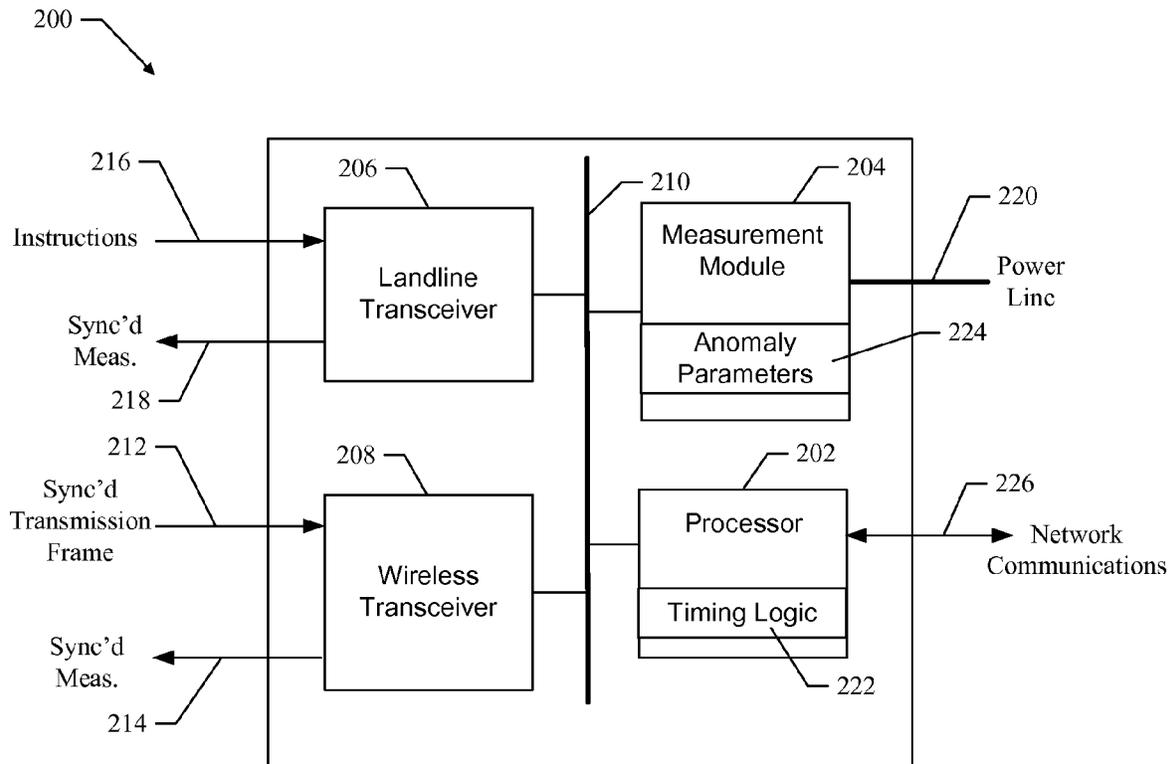


FIG. 2

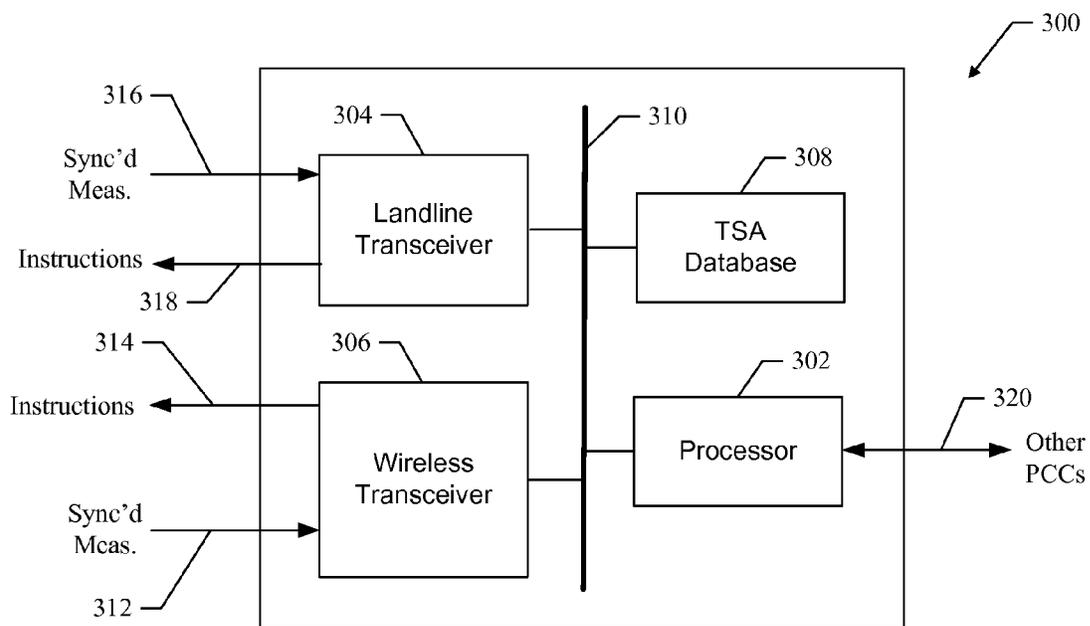


FIG. 3

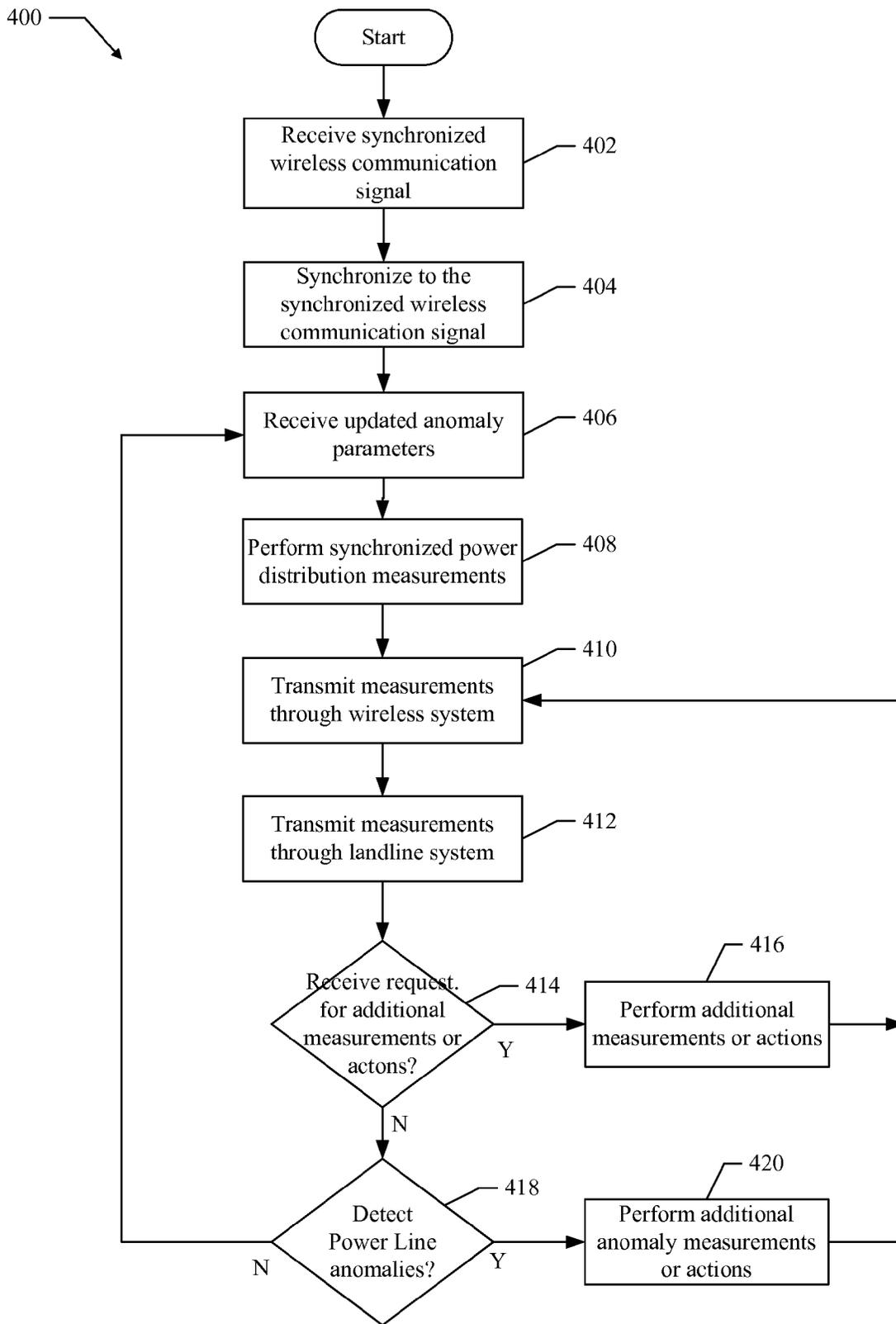


FIG. 4

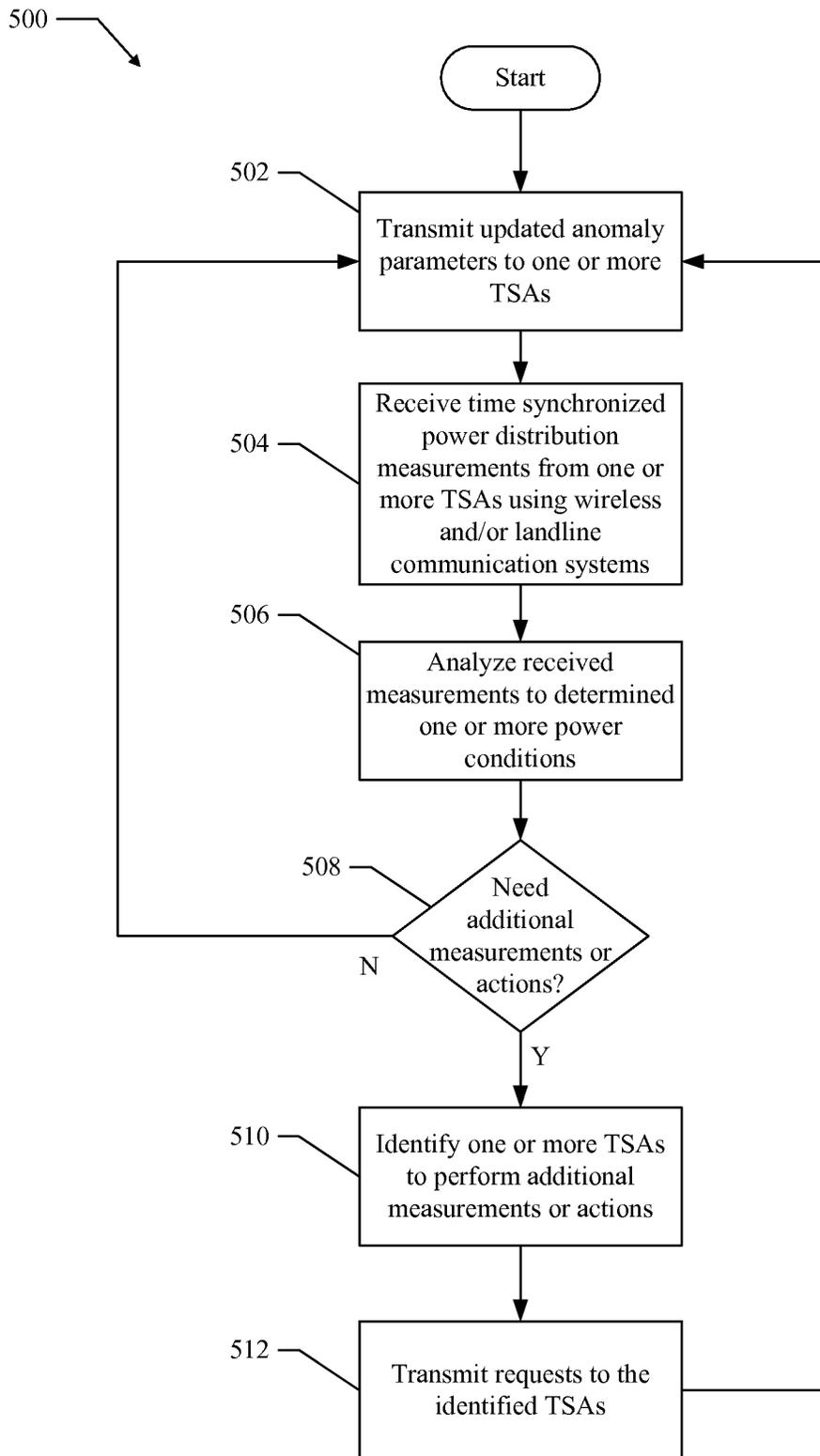


FIG. 5

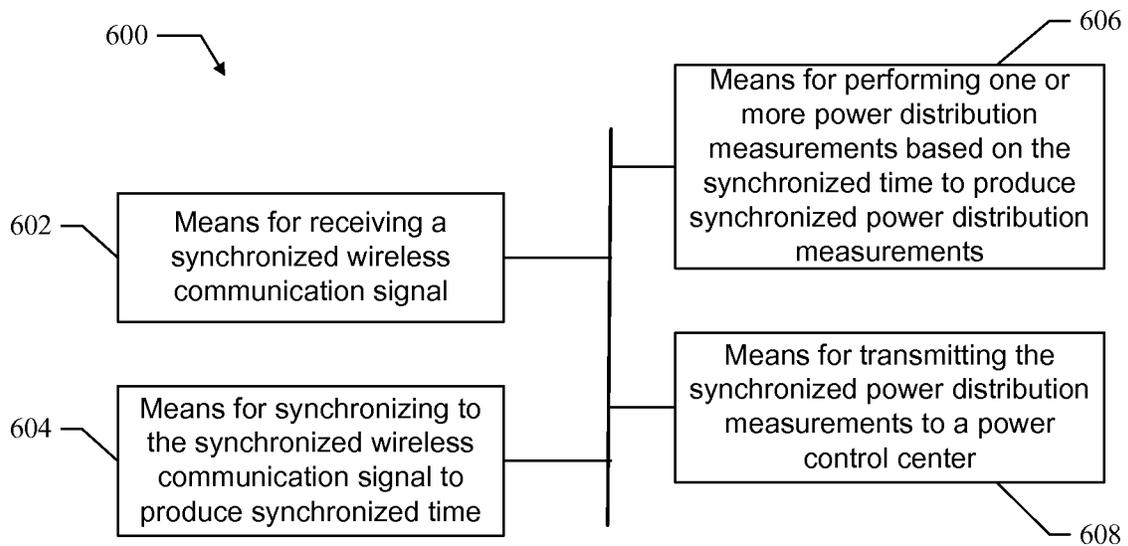


FIG. 6

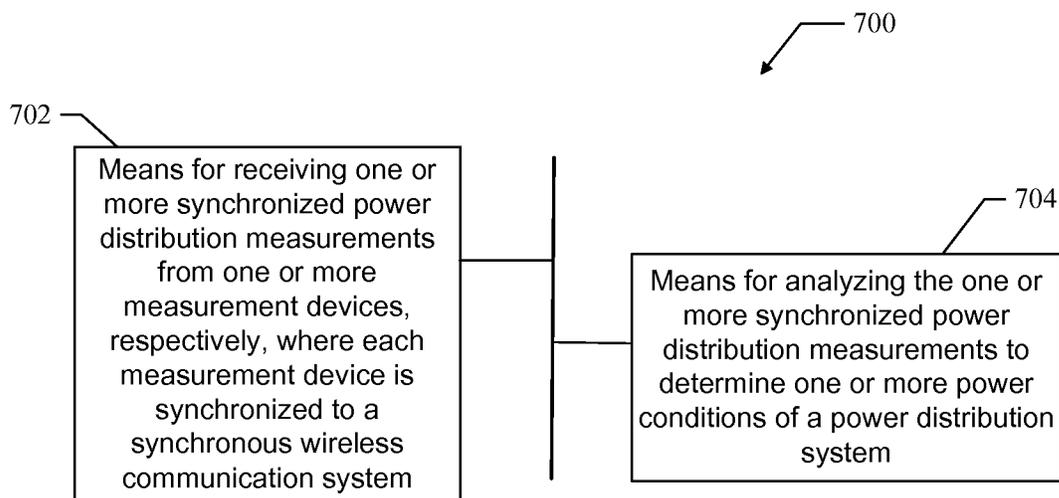


FIG. 7

METHODS AND APPARATUS FOR TIME SYNCHRONIZATION AND MEASUREMENT OF POWER DISTRIBUTION SYSTEMS

BACKGROUND

1. Field

The present application relates generally to the operation of power distribution systems, and more particularly, to methods and apparatus for time synchronization and measurement of power distribution systems.

2. Background

The electricity industry is going through a metamorphosis with utilities rolling out what is known as the "Smart Grid". The "Smart Grid" is an intelligent, managed, controlled, network communication overlay on top of the existing electric distribution network. Essentially the Smart Grid links utility computer servers to grid infrastructure devices and new "smart electricity meters." Several Smart Grid services require that precise time be known. For example, synchronized phasor measurements (time-stamped measurements of alternating current phase), Time of Use (TOU) metering, and scheduled load shedding are just a few of these services.

However, determining precise synchronized time across the smart grid can be challenging and expensive. Some higher end utility infrastructure components use Global Positioning System (GPS) modules to maintain precise time, but these modules are too expensive to be deployed in individual smart meters. Thus, smart meters must use other, less accurate and less expensive, means of acquiring and maintaining time.

Typically, smart meters use the power line frequency itself to measure the passing of time, filling in with expensive real-time clock components to cover power outages. Unfortunately, this adds significant cost to the meter, and time accuracy errors tend to accumulate over periods of usage. The result is that time in smart meters is nowhere near accurate enough to enable synchronized phasor measurements, and it is barely adequate for Time of Use metering.

Therefore, it would be desirable to have a simple cost effective mechanism that operates to provide time synchronization and measurement for improved monitoring and failure detection for power distribution systems.

SUMMARY

A time synchronization (TS) system, comprising methods and apparatus, is provided that operates to provide time synchronization and measurement for improved monitoring and failure detection for power distribution systems.

In an aspect, a method is provided for time synchronization in a power distribution system. The method comprises receiving a synchronized wireless communication signal, synchronizing to the synchronized wireless communication signal to produce synchronized time, performing one or more power distribution measurements based on the synchronized time to produce synchronized power distribution measurements, and transmitting the synchronized power distribution measurements to a power control center.

In an aspect, an apparatus is provided for time synchronization in a power distribution system. The apparatus comprises means for receiving a synchronized wireless communication signal, means for synchronizing to the synchronized wireless communication signal to produce synchronized time, means for performing one or more power distribution measurements based on the synchronized time to produce synchronized power distribution measurements, and means

for transmitting the synchronized power distribution measurements to a power control center.

In an aspect, an apparatus is provided for time synchronization in a power distribution system. The apparatus comprises a receiver configured to receive a synchronized wireless communication signal and to synchronize to the synchronized wireless communication signal to produce synchronized time, a measurement module configured to perform one or more power distribution measurements based on the synchronized time to produce synchronized power distribution measurements, and a transmitter configured to transmit the synchronized power distribution measurements to a power control center.

In an aspect, a computer program product is provided for time synchronization in a power distribution system. The computer program product comprises a computer-readable medium embodying codes executable by a processor to receive a synchronized wireless communication signal, synchronize to the synchronized wireless communication signal to produce synchronized time, perform one or more power distribution measurements based on the synchronized time to produce synchronized power distribution measurements, and transmit the synchronized power distribution measurements to a power control center.

In an aspect, a method is provided for time synchronization in a power distribution system. The method comprises receiving one or more time synchronized power distribution measurements from one or more measurement devices, respectively, wherein each measurement device is synchronized to a synchronous wireless communication system, and analyzing the one or more time synchronized power distribution measurements to determine one or more power conditions of the power distribution system.

In an aspect, an apparatus is provided for time synchronization in a power distribution system. The apparatus comprises a transceiver configured to receive one or more time synchronized power distribution measurements from one or more measurement devices, respectively, wherein each measurement device is synchronized to a synchronous wireless communication system, and a processor coupled to the transceiver and configured to analyze the one or more time synchronized power distribution measurements to determine one or more power conditions of the power distribution system.

Other aspects will become apparent after review of the hereinafter set forth Brief Description of the Drawings, Description, and the Claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing aspects described herein will become more readily apparent by reference to the following Description when taken in conjunction with the accompanying drawings wherein:

FIG. 1 shows an exemplary time synchronization system for use in a power distribution system;

FIG. 2 shows an exemplary time synchronization apparatus constructed in accordance with the time synchronization system;

FIG. 3 shows an exemplary power control center constructed in accordance with the time synchronization system;

FIG. 4 shows an exemplary method for time synchronization and measurement in accordance with the time synchronization system;

FIG. 5 shows an exemplary method for receiving and processing time synchronized measurements in accordance with the time synchronization system;

FIG. 6 shows an exemplary time synchronization apparatus constructed in accordance with the time synchronization system; and

FIG. 7 shows an exemplary power control center constructed in accordance with the time synchronization system.

DESCRIPTION

The following description describes aspects and implementations of a time synchronization system that operates to provide time synchronization and measurement for improved monitoring and failure detection for power distribution systems.

FIG. 1 shows an exemplary time synchronization system **100** for use in a power distribution system. A power distribution line **102** is shown that is part of a distribution grid that distributes power over a selected geographic region. For example, the power distribution line **102** may distribute power over a neighborhood, community, city, county, or any other region. Coupled to the power distribution line **102** are time synchronization apparatuses (TSAs) **104**, **106**, **108**, **110**, and **112**. For example, the TSAs may be located at businesses, residences, government buildings, selected geographic locations, or at any location where it may be desirable to monitor the power distribution line **102**. Each TSA is operable to communicate with a wireless communication server. For example, the TSAs **104** and **108** can communicate with wireless communication with server **114**, and the TSAs **106**, **110**, and **112** can communicate with wireless communication with the servers **116**, **118** and **120**, respectively.

In one implementation, the wireless communication servers **114**, **116**, **118**, and **120** are part of a code division multiple access (CDMA) wireless communication system that provides synchronous wireless communications to allow multiple nodes to communicate with each other and with other entities coupled to a network infrastructure. The CDMA system derives its time synchronization from a universal time system, such as a global positioning system (GPS). Thus, all communications are performed in a time synchronized manner. It should be noted that the time synchronization system is suitable for use with any wireless communication system operable to provide synchronous communications and is not limited to use with only CDMA systems.

Each TSA is assigned an identifier that identifies the TSA and provides a mechanism to establish its position relative to the power distribution line **102**. Each TSA comprises a wireless modem/radio allowing it to utilize signals transmitted from the wireless communication servers to acquire time synchronization from these signals. As a result, all TSAs become synchronized to within a particular threshold or accuracy. For example, utilizing CDMA signal transmissions, the TSAs may achieve time synchronization to within one microsecond.

In one implementation, knowledge of time developed inherently in the radio modem is output to clock processing circuitry at the TSAs and any measurements taken by the TSAs are tagged with this highly accurate time source. This enables each TSA to perform highly accurate phasor measurements, perform power measurements in precise intervals of time, perform any other type of measurement, and schedule tasks very precisely.

Synchronizing to the synchronous wireless transmissions allows the TS system to prevent or eliminate the problem of accumulating time errors found in conventional systems. For example, each TSA acquires and maintains time synchronization based on received radio transmissions from the time synchronized wireless servers. Thus, each TSA maintains

accurate time synchronization with no accumulating time errors, unlike conventional systems which utilize local timing circuits that may experience accumulating time errors.

Once synchronized, the TSAs operate to perform any desired power line measurements. For example, the TSAs operate to measure phase, voltage, current, power utilization or any other parameters associated with the power distribution line **102**. This results in a set of measurements at known locations along the power distribution line **102** that are accurately time synchronized. For example, it is possible to obtain a set of time synchronized phase measurements along the power distribution line **102**.

Referring now to TSA **106** having identifier #2, the TSA **106** acquires time synchronization utilizing received wireless signals from wireless server **116**. The TSA **106** then makes desired power line measurements to produce synchronized power line measurements. The TSA **106** then transmits these synchronized measurements to a power control center (PCC) **122**. The measurements are transmitted wirelessly using the wireless server **116**, as illustrated by path **126**, or by using a landline communication system, as illustrated by path **124**. The landline communication system comprises telephone, network, fiber optic communication systems or other type of wired communication system, including using the power line **102**.

The phase measurements effectively measure the line frequency of the power distribution line **102**. Typically, the frequency of the power waveform is a 60 hertz sine wave. By measuring this frequency at one microsecond time intervals, the frequency (and associated phase) can be finely resolved. During processing, the measurements are correlated in real time across the entire grid to determine phase variations that may be problematic. The identity of each TSA is mapped to a geographic position which allows the locations of excessive phase variations to be determined. All TSAs shown in FIG. 1 perform the same functions as TSA **106** and also transmit their synchronized measurements to the power control center **122**.

The power control center **122** operates to receive the synchronized measurement transmissions from TSAs located along the power distribution line **102**. The PPC **122** is aware of the position of each TSA through its identifier. The synchronized measurements are received wirelessly or through the landline system. The power control center **122** operates to analyze the synchronous measurements to determine various conditions or operating states of the power distribution line **102**. For example, the power control center **122** can determine from the synchronized measurements and the TSA identifiers whether there is an unacceptable power or phase variation at a particular location along the power distribution line **102**. The power control center **122** can also send commands or instructions to the TSAs to adjust when synchronized measurements are to be performed and which measurements to perform. Using the TSA identifiers, the power control center **122** can also communicate with selected TSAs to request that additional measurements or other actions be taken. Additionally, the PCC **122** can communicate anomaly parameters to dynamically control how TSA detect anomaly conditions on the power line **102**. A more detailed description of the anomaly parameters is provided below.

Furthermore, the PCC **122** supports a communication channel **130** that allows communication with other PCCs of the distribution grid. The communication channel **130** allows information to be exchanged between PCCs and/or allows distributed processing of power line measurements performed by the TSAs

In another implementation, each TSA may “self-locate” its position and report its position to the appropriate PCC. For example, each TSA utilizes one or more position determining capabilities of the wireless modem/radio to determine a geographic position. These position determining capabilities include, but are not limited to, cell sector identification and Advanced Forward Link Trilateration (AFLT). In AFLT, a TSA takes measurements of signals from nearby cellular base stations (towers) and reports the time/distance readings back to the PCC, which are then used to calculate an approximate location of the TSA. In general, three surrounding base stations are used to get an optimal position determination.

In another implementation, a TSA may determine its own position by interfacing to other servers or network entities. For example, each TSA comprises a network interface **128** to exchange any type of information with other network entities to determine its own position.

As a result of using one or more of the self locating techniques, each TSA reports an approximate latitude and longitude (with a known uncertainty) to the PCC to provide positional context to each power measurement. This simplifies the management of the system since the PCC would operate to self learn TSA positions rather than having to carefully maintain a database tying TSA identities to addresses and corresponding locations.

Alternatively, if the PCC does maintain a position database, having an approximate latitude and longitude delivered by the TSAs can be used to spot errors in such a database. Note that a very accurate self location determination would not be necessary. Even a basic cell sector position capability (provided by many wireless technologies) would be adequate to determine the location of grid problems or to maintain the position database.

It should be noted that a TSA can be part of every node on the distribution grid. Compared to conventional systems, which utilize a few high end infrastructure components each having expensive position finding electronics, the TSAs can be implemented with relatively minor cost and provide a virtually unlimited number of synchronized measuring points throughout the grid.

Therefore, the time synchronization system operates to provide time synchronization and measurement in a power distribution system. The system allows a large number of synchronized measurements to be acquired in a cost effective manner, and these measurements are communicated to a power control center for analysis. For example, the large number of synchronized measurements allows slight phase variations across the distribution grid to be detected. The system also allows the power control center to communicate requests for additional measurements or other actions to one or more TSAs to allow more detailed investigations of distribution conditions or inefficiencies.

FIG. 2 shows an exemplary TSA **200** for use in accordance with the time synchronization system. For example, the TSA **200** is suitable for use as the TSA **106** shown in FIG. 1. The TSA **200** comprises processor **202**, measurement module **204**, landline transceiver **206**, and wireless transceiver **208** all coupled to communicate using data bus **210**. It should be noted that the TSA **200** is just one implementation and that other implementations are possible.

The wireless transceiver **208** comprises hardware and/or hardware executing software that operates to allow the TSA **200** to communicate data or other information with other entities using a wireless communication system. In one implementation, the transceiver **208** comprises a radio modem that is configured to communicate over a wireless communication system. For example, the transceiver **208**

comprises a receiver portion that is operable to receive synchronized transmission frames **212** from a wireless communication server, such as a server operating in a CDMA communication system.

The transceiver **208** includes a transmitter portion that is operable to send data or other information to other entities using the wireless communication system. Thus, the transceiver **208** utilizes the radio modem to communicate using the wireless communication system to receive instructions from a power control center through the transmission frames **212** or may transmit synchronized measurements **214** to the power control center.

The transceiver **208** also acquires time synchronization utilizing the transmission signals of the wireless communication system. For example, during communication with the wireless communication system, the transceiver **208** inherently acquires accurate time synchronization and passes this time synchronization to timing logic **222** of the processor **202**.

The landline transceiver **206** comprises hardware and/or hardware executing software that operates to allow the TSA **200** to communicate data or other information with other entities using a landline communication system. The landline communication system comprises telephone, network, or fiber optic communication systems or other type of wired communication system, including using the power line itself. For example, the transceiver **208** is operable to send or receive data or other information to other entities using the landline communication system. For example, the transceiver **208** comprises transmitter and receiver portions that can communicate using the landline communication system to receive instructions **216** from a power control center or may transmit synchronized measurements **218** to the power control center.

The measurement module **204** comprises hardware and/or hardware executing software that operates to receive a sync signal from the processor **202** and perform one or more measurements of a power line **220**. For example, the processor **202** controls when and which measurements are to be performed by the measurement module **204**. The measurements comprise power, voltage, current, phase, usage history and/or any other type of measurement. Voltage, current, and phase are primary measurements. Power; however is a derived measurement in that it is derived from other primary measurements. The measurement module **204** is operable to determine any type of derived measurements, including load factor, harmonic content, other reactive qualities, or any other type of derived measurement. The measurements are synchronized by the received sync signal and passed to the processor **202**.

In one implementation, the measurement module **204** operates to measure the steady-state average “phase offset” of a TSA relative to a fixed point in the network. This enables an estimate of distance between any two TSAs. Phase offset generally does not become ambiguous for at least 5,000 kilometers, thus for all practical purposes it is unambiguous within any power operator’s territory. The difference in phase offset between any two TSAs is an estimate of the difference in distance that the power took to travel to the two respective positions. If one TSA that is supposed to be in a particular neighborhood or region has a much different phase than other TSAs in the region, then an error condition is indicated which may require further investigation.

The measurement module **204** also comprises anomaly parameters **224**. The anomaly parameters **224** identify power line anomaly conditions to be detected by the measurement module **204**. The anomaly conditions may require the measurement module **204** to determine derived measurements.

The anomaly parameters set bounds and thresholds for the primary and derived measurements associate with each anomaly condition. If the bounds or thresholds associated with an anomaly condition are exceeded, then it is determined that the anomaly condition exists. Thus, the anomaly parameters provide the bounds or thresholds for anomaly detection and in addition, the actions to be taken should one or more anomaly conditions be detected.

In one implementation, the measurement module **204** operates to detect the power line anomaly conditions asynchronously, such that any time an identified anomaly condition occurs, it will be quickly detected by the measurement module **204**.

In one implementation, the anomaly parameters **224** are pre-configured at the measurement module **204**. For example, the anomaly parameters are configured at manufacture or installation of the TSA **200**. In another implementation, the anomaly parameters **224** are configured, updated, and maintained by a PCC. For example, at any time a PCC may download anomaly parameters **224** using the transceiver **208** or the transceiver **206**. This allows the PCC to dynamically control anomaly detection performed by the TSA **200**.

Furthermore, the anomaly parameters **224** identify additional measurements associated with each anomaly condition. The additional measurements are measured when the corresponding anomaly condition is detected. For example, the measurement module **204** detects a particular anomaly condition based on the anomaly parameters **224**. The measurement module **204** then accesses the anomaly parameters **224** to determine additional measurements to be performed based on the detected anomaly condition. The additional measurements are performed and the detected anomaly and associated measurements are passed to the processor **202** for transmission to the PCC.

The processor **202** comprises at least one of a CPU, processor, gate array, hardware logic, memory elements, and/or hardware executing software. The processor **202** operates to control the measurement module **204** to perform selected measurements. The processor **202** comprises timing logic **222** that generates a sync signal that is sent to the measurement module **204** to control when measurements are to be taken. The timing logic **222** obtains synchronization from the transceiver **208** which has acquired its synchronization from received wireless transmission frames. For example, received synchronized transmission frames are received by the transceiver **208** and are analyzed by the transceiver **208** to determine an exact time reference which is indicated to the timing logic **222**, which then generates the sync signal to indicate the precise time at which particular measurements are to be performed by the measurement module **204**.

The processor **202** also comprises interface logic to support communication link **226**, which provides network communication with various network entities. For example, the processor **202** may communicate with other network entities using the link **226** to self locate the position of the TSA **200**. Any suitable location techniques may be performed and the results are reported by the processor **202** to a PCC using the transceiver **206** and/or transceiver **208**.

The processor **202** is also operable to receive instructions from a power control center using a wireless communication system or a landline communication system. For example, the power control center may encode the instructions into the received wireless transmission frames **212** that are received by the wireless transceiver **208**. The power control center may also encode the instructions into landline communications

216 that are received by the landline transceiver **206**. In either case, the received instructions are passed to the processor **202**.

The processor **202** decodes the instructions and determines if any actions are necessary. For example, if additional measurements are requested, the processor **202** controls the measurement module **204** to perform the additional measurements. The processor **202** then transmits the additional measurements to the power control center using either the landline transceiver **206** or the wireless transceiver **208**. The processor **202** may also perform any other action requested by the power control center and is not limited to obtaining just additional power line measurements. For example, the instructions may include anomaly parameters **224** that are stored at the measurement module **204**. The anomaly parameters **224** are used to allow a PCC to dynamically control anomaly detection and processing. A more detailed description of the operation of the TSA **200** is provided in another section below.

FIG. **3** shows an exemplary power control center **300** constructed in accordance with the time synchronization system. For example, the PCC **300** is suitable for use as the PCC **122** shown in FIG. **1**. The PCC **300** comprises processor **302**, landline transceiver **304**, wireless transceiver **306**, TSA database **308**, all coupled to communicate using data bus **310**. It should be noted that the PCC **300** is just one implementation and that other implementations are possible.

The wireless transceiver **306** comprises hardware and/or hardware executing software that operate to allow the PCC **300** to communicate data or other information with other entities using a wireless communication system. For example, the transceiver **306** comprises a transmitter portion that is operable to transmit information, instructions, or other data to one or more TSAs using synchronized transmission frames **314** of a synchronized wireless communication system, such as a CDMA communication system. The transceiver **308** also comprises a receiver that is operable to receive synchronized measurements **312** from one or more TSAs using the synchronized wireless communication system.

The landline transceiver **304** comprises hardware and/or hardware executing software that operate to allow the PCC **300** to communicate data or other information with other entities using a landline communication system. For example, the transceiver **304** comprises a receiver portion that is operable to receive synchronized measurements **316** from one or more TSAs using the landline communication system. The transceiver **304** also comprises a transmitter that is operable to transmit instructions **318** or other data to one or more TSAs using the landline communication system.

The TSA database **308** comprises information about TSAs stored in any suitable memory that is accessible via the bus **310**. The database **308** identifies TSAs by their assigned identifier and includes any other information necessary to process synchronized measurements received from any TSA. The database also associates TSA identifiers with geographic locations so that a location for each received synchronized measurement can be determined.

The processor **302** comprises at least one of a CPU, processor, gate array, hardware logic, memory elements, and/or hardware executing software. The processor **302** operates to process synchronized measurements received by the transceivers **304** and **306** to determine one or more power line conditions associated with a power distribution line. For example, the received synchronized measurements are associated with identified TSAs and the processor **302** is able to access the TSA database to determine a location associated with each received synchronized measurement. The proces-

processor **302** is then able to determine one or more power line conditions by analyzing the measurements taken at each location. For example, if one or more TSAs report low voltage conditions, the processor **302** can access the TSA database **308** to determine the location of the low voltage conditions. Similarly, synchronized phase measurements reported by the TSAs can be correlated in real time by the processor **302** to determine the location of any phase variation that may indicate loading problems or a potential blackout condition.

The processor **302** is also operable to determine if any additional measurements or actions are desired from one or more TSAs. If so, the processor **302** can control the wireless transceiver **306** to transmit instructions in the synchronized transmission frames to one or more TSAs. The instructions instruct the particular TSAs to take additional measurements, update anomaly parameters, or perform additional actions and report back the results.

The processor **302** also supports a communication channel **320** that allows communication with other PCCs of the distribution grid. The communication channel **320** allows information to be exchanged between PCCs and allows distributed processing of power line measurements performed by the TSAs. The communication channel **320** comprises any suitable communication link allowing multiple PCCs to communicate.

FIG. 4 shows an exemplary method for time synchronization and measurement in accordance with the time synchronization system. For clarity, the method **400** is described below with reference to the TSA **200** shown in FIG. 2. In one implementation, the processor **202** executes one or more sets of codes to control the TSA **200** to perform the functions described below.

At block **402**, synchronized wireless communication signals are received. For example, the wireless communication signals are received from a synchronized wireless communication system, such as a CDMA system, or from any other type of system that can provide synchronized communication signals. In one implementation, the transceiver **208** receives the synchronized wireless communication signals from a wireless communication server, such as the server **116** shown in FIG. 1.

At block **404**, time synchronization is acquired by synchronizing to the synchronized wireless communication signal. In one implementation, the transceiver **208** determines time synchronization from the received synchronized wireless communication signals. For example, the received synchronized wireless communication signals comprise transmission frames which are synchronized to a GPS time standard. The transceiver **208** is able to analyze these received frames to acquire (or lock in) time synchronization. For example, using CDMA transmission frames, time synchronization can be determined to within one microsecond so that any device receiving the transmission frames can synchronize to this level of accuracy. The time synchronization is then indicated to the timing logic **222** which generates a corresponding sync signal.

At block **406**, updated anomaly parameters are received. In one implementation, the anomaly parameters are received by the transceiver **208** and stored at the measurement module **204** as anomaly parameters **224**. The anomaly parameters identify power line anomalies to be detected and actions to be taken in response.

At block **408**, synchronized power distribution measurements are performed. In one implementation, the timing logic **222** provides the sync signal or trigger to the measurement module **204**. The measurement module **204** responds by measuring the phase or other parameters of a power distribution

line. The measurement module **204** is operable to measure the phase to any desired level of accuracy and its measurement is synchronized by the sync signal. The measurement module is also operable to perform any other type of power line measurement.

At block **410**, the measurements are transmitted to a power control center using the wireless communication system. For example, the measurement module **204** controls the wireless transceiver **208** to transmit the synchronized phase measurements to the power control center using the wireless communication link **214**.

At block **410**, in an optional operation, the synchronized phase measurements are transmitted to a power control center using a landline communication system. For example, the measurement module **204** controls the landline transceiver **206** to transmit the synchronized phase measurements to the power control center using the landline communication links **218**. The landline communication system comprises telephone, network, or fiber optic communication systems or other type of wired communication system, including using the power line itself.

At block **412**, a determination is made as to whether a request for additional measurements or other actions has been received. For example, a request for additional measurements may be generated by a PCC and transmitted to the TSA **200** using the wireless transmission frames **212**. If a request for additional measurements or other actions has not been received, the method proceeds to block **418**. If a request for additional measurements or other actions has been received, the method proceeds to block **416**. The processor **202** makes this determination.

At block **416**, additional measurements or actions are performed. For example, the processor **202** controls the measurement module **204** to perform the additional phase measurements or other power distribution measurements. Once the additional measurements or actions are performed, the method proceeds to block **410** to transmit the measurements.

At block **418**, a determination is made as to whether any power line anomalies are detected. For example, in one implementation, the measurement module **204** is pre-configured with anomaly parameters **224** that identify a set of power line anomalies to be checked. These anomalies include excessive power usage, voltage or current spikes, or any other type of anomaly associated with the power line **102**. In another implementation, the PCC provides the anomaly parameters at block **406**. For example, the PCC can dynamically adjust the anomalies to be detected by providing and/or updating the anomaly parameters **224** at any time. The anomaly parameters identify boundaries and thresholds for primary or derived measurements. If the boundaries or thresholds are exceeded, the measurement module determines which if any anomaly conditions exist. If one or more anomaly conditions exist, the method proceeds to block **420**. If no anomaly conditions exist, the method proceeds to block **406**.

At block **420**, additional measurements or actions are performed. For example, the anomaly parameters **224** comprise additional measurements to be performed for each detected anomaly. For example, if a low voltage anomaly is detected; additional measurements, such as power or current measurements may be performed. The processor **202** controls the measurement module **204** to perform the additional measurements based on the anomalies detected and corresponding measurements identified in the anomaly parameters **224**. Once the additional measurements or actions are performed, the method proceeds to block **410** to transmit the results to a PCC.

Therefore, in one implementation, the method **400** is performed by a TSA at any location associated with a power distribution line to determine synchronized phase measurements or other power distribution parameters and to transmit those measurements to a power control center using wireless and/or landline transmission links. It should be noted that the method **400** is just one implementation and that the operations of the method **400** may be rearranged or otherwise modified within the scope of the various implementations. Thus, other implementations are possible.

FIG. **5** shows an exemplary method **500** for receiving and processing synchronized measurements in accordance with the time synchronization system. For clarity, the method **500** is described below with reference to the PCC **300** shown in FIG. **3**. In one implementation, the processor **302** executes one or more sets of codes to control the PCC **300** to perform the functions described below.

At block **502**, updated anomaly parameters are transmitted to one or more TSAs. For example, the processor **302** generates the anomaly parameters and transmits them to the identified TSAs using the transceiver **306**.

At block **504**, synchronized power distribution measurements are received from one or more TSAs. For example, the synchronized power distribution measurements are received from a landline communication system using the transceiver **304** or a wireless communication system using the transceiver **306**. Each of the synchronized power distribution measurements is associated with an identified TSA.

At block **506**, the received measurements are analyzed to determine one or more power line conditions. For example, the processor **302** analyzes measurements from multiple TSAs to determine fluctuations in power, voltage, current, phase or any other parameter. In one implementation, the processor **302** determines a location of a particular power line condition indicated by one or more TSAs by determining the location of the TSAs from the TSA database **308**. For example, to determine phase variations, the processor **302** correlates received synchronized phase measurement in real time to detect any phase variations that may be problematic. The locations of the detected phase variations can then be determined based on the TSA identifiers and corresponding locations obtained from the TSA database **308**.

At block **508**, a determination is made as to whether additional measurements or actions are desired. For example, additional measurements may be desired from one or more TSAs to fully analyze a particular power line condition. If no additional measurements or actions are required, the method ends. If additional measurements or actions are required, the method proceeds to block **508**. The processor **302** makes this determination.

At block **510**, one or more TSAs are identified to perform additional measurements or actions. For example, the processor **302** determines one or more power line conditions based on previous synchronized measurements and identifies one or more TSAs from which additional measurements are desired to perform further analysis. The TSAs are identified by their location and/or unique identifier. For example, if a phase variation is detected at a particular location, the processor **302** operates to request additional phase measurements from TSAs located at or near that location.

At block **512**, requests for additional measurements or actions are transmitted to the identified TSAs. The processor **302** identifies the TSAs and associated measurements to be obtained in one or more requests. The requests are forwarded to the wireless transceiver **306** for transmission to the identified TSAs using the transmission frames **312** of the wireless

communication system. The method then proceeds to block **502** to update anomaly parameters.

Therefore, the method **500** is operable to analyze synchronized measurements reported by a plurality of TSAs and if desired, request additional measurements or actions from one or more particular TSAs. It should be noted that the method **500** is just one implementation and that the operations of the method **500** may be rearranged or otherwise modified within the scope of the various implementations. Thus, other implementations are possible.

FIG. **6** shows an exemplary time synchronization apparatus **600** constructed in accordance with the time synchronization system. For example, the TSA **600** is suitable for use as the TSA **200** shown in FIG. **2**. In an aspect, the TSA **600** is implemented by at least one integrated circuit comprising one or more modules configured to provide aspects of a time synchronization system as described herein. For example, in one implementation, each module comprises hardware and/or hardware executing software.

The TSA **600** comprises a first module comprising means (**602**) for receiving a synchronized wireless communication signal, which in an aspect comprises the transceiver **208**. The TSA **600** also comprises a second module comprising means (**604**) for synchronizing to the synchronized wireless communication signal to produce synchronized time, which in an aspect comprises the transceiver **208**. The TSA **600** also comprises a third module comprising means (**606**) for performing one or more power distribution measurements based on the synchronized time to produce synchronized power distribution measurements, which in an aspect comprises the measurement module **204**. The TSA **600** also comprises a fourth module comprising means (**608**) for transmitting the synchronized power distribution measurements to a power control center, which in an aspect comprises the transceiver **208**.

FIG. **7** shows an exemplary power control center **700** constructed in accordance with the time synchronization system. For example, the PCC **700** is suitable for use as the PCC **300** shown in FIG. **3**. In an aspect, the PCC **700** is implemented by at least one integrated circuit comprising one or more modules configured to provide aspects of a time synchronization system as described herein. For example, in one implementation, each module comprises hardware and/or hardware executing software.

The PCC **700** comprises a first module comprising means (**702**) for receiving one or more time synchronized power distribution measurements from one or more measurement devices, respectively, wherein each measurement device is synchronized to a synchronous wireless communication system, which in an aspect comprises the transceiver **306**. The PCC **700** also comprises a second module comprising means (**704**) for analyzing the one or more time synchronized power distribution measurements to determine one or more power conditions of the power distribution system, which in an aspect comprises the processor **302**.

In one or more exemplary embodiments, the functions described may be implemented in hardware, software to be executed by a computer, firmware, or any combination thereof. If implemented in software, the functions may be stored on or transmitted over as one or more instructions or codes on a computer-readable medium. Computer-readable medium includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage media may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage

13

or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media.

The various illustrative logics, logical blocks, modules, and circuits described in connection with the aspects disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but, in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

The description of the disclosed aspects is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these aspects may be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects, e.g., in an instant messaging service or any general wireless data communication applications, without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the aspects shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein. The word "exemplary" is used exclusively herein to mean "serving as an example, instance, or illustration." Any aspect described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects.

Accordingly, while aspects of a time synchronization system have been illustrated and described herein, it will be appreciated that various changes can be made to the aspects without departing from their spirit or essential characteristics. Therefore, the disclosures and descriptions herein are intended to be illustrative, but not limiting, of the scope of the invention, which is set forth in the following claims.

What is claimed is:

1. A method for time synchronization in a power distribution system, the method comprising:
 receiving a synchronized wireless communication signal from a terrestrial wireless communication system;
 synchronizing a clock to a synchronized time based on the synchronized wireless communication signal;
 receiving a first anomaly parameter, the first anomaly parameter identifying an action to be taken in response to detecting a first anomaly;

14

producing a synchronized result based on one or more power distribution measurements and the synchronized time;

transmitting the synchronized result; and

receiving a second anomaly parameter in response to transmitting the synchronized result, the second anomaly parameter configured to replace a value of the first anomaly parameter.

2. The method of claim 1, wherein:

the terrestrial wireless communication system includes a cellular communication system,

the first anomaly parameter identifies a particular action to be taken in response to detecting a power line anomaly that is associated with the cellular communication system, and

the particular action includes a phase measurement.

3. The method of claim 1, further comprising receiving a third anomaly parameter before transmitting the synchronized result, wherein the terrestrial wireless communication system comprises a code division multiple access (CDMA) system, and wherein the first anomaly parameter and the third anomaly parameter identify one or more power line anomalies associated with the CDMA system.

4. The method of claim 1, wherein the clock is synchronized based on transmission frames in the synchronized wireless communication signal, wherein the one or more power distribution measurements are based on the transmission frames, and further comprising:

identifying power line anomaly conditions based on the one or more power distribution measurements and based on at least the first anomaly parameter; and
 determining whether one or more additional power distribution measurements are to be performed in response to identifying the power line anomaly conditions.

5. The method of claim 4, further comprising:

determining a particular power distribution measurement of the one or more additional power distribution measurements based on identifying a particular power line anomaly condition of the power line anomaly conditions;

performing the particular power distribution measurement in response to identifying the particular power line anomaly condition to generate measurement results; and
 transmitting the measurement results to a power control center.

6. The method of claim 1, wherein:

the one or more power distribution measurements are performed by a measurement module, and

the first anomaly parameter identifies:

a threshold for detecting the first anomaly, and

a particular action to be taken at the measurement module in response to the measurement module detecting the first anomaly.

7. The method of claim 1, further comprising receiving anomaly parameters corresponding to power line anomaly conditions, the anomaly parameters including the first anomaly parameter, wherein the power line anomaly conditions include an excessive power usage, a voltage spike, a current spike, or a combination thereof, and wherein the anomaly parameters include a power threshold, a voltage threshold, a current threshold, or a combination thereof.

8. The method of claim 1, wherein the one or more power distribution measurements are performed by a measurement module, and further comprising:

identifying a location of the measurement module using advanced forward link trilateration; and
 transmitting the location to a power control center.

15

9. The method of claim 1, wherein the first anomaly parameter includes a threshold, and further comprising identifying an anomaly condition in response to a first power distribution measurement of the one or more power distribution measurements exceeding the threshold.

10. An apparatus for time synchronization in a power distribution system, the apparatus comprising:

means for synchronizing a clock to a synchronized time based on a synchronized wireless communication signal that is received from a terrestrial wireless communication system;

means for receiving a first anomaly parameter that identifies an action to be taken in response to detecting a first anomaly;

means for producing a synchronized result based on one or more power distribution measurements and the synchronized time; and

means for performing transmission of the synchronized result, the means for receiving configured to receive a second anomaly parameter in response to the transmission, the second anomaly parameter configured to replace a value of the first anomaly parameter.

11. The apparatus of claim 10, wherein:

the terrestrial wireless communication system comprises a synchronous communication system,

the first anomaly parameter identifies a particular action to be taken in response to detecting a power line anomaly that is associated with the synchronous communication system, and

the particular action includes a phase measurement.

12. The apparatus of claim 10, wherein the means for receiving is configured to receive a third anomaly parameter before the transmission, wherein the terrestrial wireless communication system comprises a code division multiple access (CDMA) system, and wherein the first anomaly parameter and the third anomaly parameter identify one or more power line anomalies associated with the CDMA system.

13. The apparatus of claim 10, wherein the clock is synchronized based on transmission frames in the synchronized wireless communication signal, wherein the one or more power distribution measurements are based on the transmission frames, and further comprising:

means for identifying power line anomaly conditions based on the one or more power distribution measurements and based on at least the first anomaly parameter; and

means for determining whether one or more additional power distribution measurements are to be performed in response to identifying the power line anomaly conditions.

14. The apparatus of claim 10, wherein the synchronized result is associated with one or more synchronized primary power line measurements, one or more synchronized secondary power line measurements, or a combination thereof.

15. The apparatus of claim 10, wherein the one or more power distribution measurements include a power measurement, a current measurement, a voltage measurement, a phase measurement, or a combination thereof.

16. The apparatus of claim 10, wherein the means for performing transmission is configured to transmit the synchronized result to a power control center using a wireless transmission, a landline transmission, or a combination thereof.

17. The apparatus of claim 10, wherein the means for synchronizing, the means for receiving, the means for producing, and the means for performing transmission are each coupled to a data bus.

16

18. The apparatus of claim 10, wherein:

the means for receiving is configured to receive a request for one or more additional measurements;

the means for producing is configured to produce one or more additional results based on performance of the one or more additional measurements; and

the means for performing transmission is configured to transmit the one or more additional results.

19. An apparatus for time synchronization in a power distribution system, the apparatus comprising:

a data bus;

a processor coupled to the data bus and configured to determine a synchronized time based on a synchronized wireless communication signal received from a terrestrial wireless communication system;

a receiver coupled to the data bus and configured to receive a first anomaly parameter that identifies an action to be taken in response to detecting a first anomaly;

a measurement module coupled to the data bus and configured to perform one or more power distribution measurements based on the synchronized time, the processor further configured to produce a synchronized result based on the one or more power distribution measurements; and

a transmitter coupled to the data bus and configured to perform transmission of the synchronized result, the receiver further configured to receive a second anomaly parameter in response to the transmission, the second anomaly parameter configured to replace a value of the first anomaly parameter.

20. The apparatus of claim 19, wherein:

the terrestrial wireless communication system comprises a synchronous communication system,

the synchronous communication system comprises a code division multiple access (CDMA) system,

the first anomaly parameter identifies a particular action to be taken in response to detecting a power line anomaly that is associated with the CDMA system, and

the particular action includes a phase measurement.

21. The apparatus of claim 19, wherein the data bus, the processor, the receiver, the measurement module, and the transmitter are included within a common housing.

22. The apparatus of claim 19, wherein a clock in the processor is configured to be synchronized based on transmission frames in the synchronized wireless communication signal.

23. The apparatus of claim 19, wherein the synchronized result is associated with one or more synchronized primary power line measurements, one or more synchronized secondary power line measurements, or a combination thereof, and wherein the one or more power distribution measurements include a power measurement, a current measurement, a voltage measurement, a phase measurement, or a combination thereof.

24. The apparatus of claim 19, wherein the measurement module is further configured to:

identify power line anomaly conditions based on the one or more power distribution measurements and based on at least the first anomaly parameters; and

determine whether one or more additional power distribution measurements are to be performed in response to the identified power line anomaly conditions.

25. The apparatus of claim 19, wherein the transmission includes a wireless transmission.

26. The apparatus of claim 19, wherein the transmission includes a landline transmission.

17

27. The apparatus of claim 19, wherein the receiver is further configured to receive a request for one or more additional measurements, wherein the measurement module is further configured to perform the one or more additional measurements to produce one or more additional results, and wherein the transmitter is further configured to transmit the one or more additional results.

28. A non-transitory computer-readable medium comprising instructions which, when executed by a processor cause the processor to:

receive a synchronized wireless communication signal from a terrestrial wireless communication system;
synchronize a clock to a synchronized time based on the synchronized wireless communication signal;
receive a first anomaly parameter that identifies an action to be taken in response to detecting a first anomaly;
produce a synchronized result based on one or more power distribution measurements and the synchronized time;
initiate transmission of the synchronized result; and
receive a second anomaly parameter in response to the transmission, the second anomaly parameter configured to replace a value of the first anomaly parameter.

29. The non-transitory computer-readable medium of claim 28, wherein:

the terrestrial wireless communication system comprises a synchronous communication system,
the synchronous communication system comprises a code division multiple access (CDMA) system,
the first anomaly parameter identifies a particular action to be taken in response to detecting a power line anomaly that is associated with the CDMA system, and
the particular action includes a phase measurement.

30. The non-transitory computer-readable medium of claim 28, wherein the instructions further cause the processor to:

generate a synchronization signal; and
control timing of at least one of the one or more power distribution measurements based on the synchronization signal.

31. The non-transitory computer-readable medium of claim 28, wherein the instructions further cause the processor to:

initiate performance of the one or more power distribution measurements at a measurement module;
identify a location of the measurement module using cell sector identification; and
transmit the location to a power control center.

32. The non-transitory computer-readable medium of claim 28, wherein the instructions further cause the processor to:

initiate performance of the one or more power distribution measurements on a power line; and
determine one or more synchronized primary measurements, one or more synchronized secondary measurements, or a combination thereof.

33. The non-transitory computer-readable medium of claim 28, wherein the one or more power distribution measurements include a power measurement, a current measurement, a voltage measurement, a phase measurement, or a combination thereof.

34. The non-transitory computer-readable medium of claim 28, wherein the instructions when executed by the processor cause the synchronized result to be transmitted via a wireless transmission.

18

35. The non-transitory computer-readable medium of claim 28, wherein execution of the instructions by the processor causes the synchronized result to be transmitted via a landline transmission.

36. The non-transitory computer-readable medium of claim 28, wherein the instructions are executable to further cause the processor to:

receive a request for one or more additional measurements;
initiate performance of the one or more additional measurements to produce one or more additional results; and
initiate transmission of the one or more additional results.

37. A method for time synchronization in a power distribution system, the method comprising:

receiving time synchronized power distribution measurements from a plurality of measurement devices, wherein each measurement device is time synchronized based on a synchronized wireless communication signal from a terrestrial wireless communication system, and wherein the one or more time synchronized power distribution measurements include a first phase offset associated with a first measurement device of the plurality of measurement devices and a second phase offset associated with a second measurement device of the plurality of measurement devices;

analyzing the one or more time synchronized power distribution measurements to determine one or more power conditions of the power distribution system; and
determining an error condition based on a comparison of the first phase offset and the second phase offset.

38. The method of claim 37, further comprising:
associating the one or more time synchronized power distribution measurements with one or more geographic locations; and

correlating the one or more time synchronized power distribution measurements based on the one or more geographic locations to determine a measurement variation.

39. The method of claim 37, wherein the first phase offset is a first difference in phase between first power measurement data collected by the first measurement device and second power measurement data collected by a fixed device, and wherein the second phase offset is a second difference in phase between third power measurement data collected by the second measurement device and the second power measurement data.

40. The method of claim 37, wherein the terrestrial wireless communication system comprises a code division multiple access (CDMA) system.

41. The method of claim 39, wherein the first phase offset corresponds to a first distance between the first measurement device and the fixed device, and wherein the second phase offset corresponds to a second distance between the second measurement device and the fixed device.

42. The method of claim 37, wherein each of the one or more time synchronized power distribution measurements is associated with a power line of the power distribution system, and wherein the one or more time synchronized power distribution measurements comprise a power measurement, a current measurement, a voltage measurement, a phase measurement, or a combination thereof.

43. The method of claim 37, wherein the one or more time synchronized power distribution measurements are received via a landline transmission.

44. An apparatus for time synchronization in a power distribution system, the apparatus comprising:

means for receiving one or more time synchronized power distribution measurements from a plurality of measurement devices, wherein each measurement device is time

19

synchronized based on a synchronized wireless communication signal from a terrestrial wireless communication system, and wherein the one or more time synchronized power distribution measurements include a first phase offset associated with a first measurement device of the plurality of measurement devices and a second phase offset associated with a second measurement device of the plurality of measurement devices;

means for analyzing the one or more time synchronized power distribution measurements to determine one or more power conditions of the power distribution system; and

means for determining an error condition based on a comparison of the first phase offset and the second phase offset.

45. The apparatus of claim 44, further comprising:

means for associating the one or more time synchronized power distribution measurements with one or more geographic locations; and

means for correlating the one or more time synchronized power distribution measurements based on the one or more geographic locations to determine a measurement variation.

46. The apparatus of claim 44, wherein the one or more time synchronized power distribution measurements are received from a server in the terrestrial wireless communication system.

47. The apparatus of claim 44, wherein the terrestrial wireless communication system comprises a code division multiple access (CDMA) system.

48. The apparatus of claim 44, wherein each of the one or more time synchronized power distribution measurements is associated with a power line of the power distribution system.

49. The apparatus of claim 44, wherein the one or more time synchronized power distribution measurements comprise a power measurement, a current measurement, a voltage measurement, a phase measurement, or a combination thereof.

50. The apparatus of claim 44, wherein the one or more time synchronized power distribution measurements are received via a landline transmission.

51. An apparatus for time synchronization in a power distribution system, the apparatus comprising:

a transceiver configured to receive one or more time synchronized power distribution measurements from a plurality of measurement devices, wherein each measurement device is time synchronized based on a synchronized wireless communication signal from a terrestrial wireless communication system, and wherein the one or more time synchronized power distribution measurements include a first phase offset associated with a first measurement device of the plurality of measurement devices and a second phase offset associated with a second measurement device of the plurality of measurement devices;

a processor coupled to the transceiver and configured to: analyze the one or more time synchronized power distribution measurements to determine one or more power conditions of the power distribution system; and

determine an error condition based on a comparison of the first phase offset and the second phase offset.

52. The apparatus of claim 51, wherein the processor is configured to:

associate the one or more time synchronized power distribution measurements with one or more geographic locations; and

20

correlate the one or more time synchronized power distribution measurements based on the one or more geographic locations to determine a measurement variation.

53. The apparatus of claim 51, wherein the one or more time synchronized power distribution measurements are received from a server in the terrestrial wireless communication system.

54. The apparatus of claim 51, wherein the terrestrial wireless communication system comprises a code division multiple access (CDMA) system.

55. The apparatus of claim 51, wherein each of the one or more time synchronized power distribution measurements is associated with a power line of the power distribution system.

56. The apparatus of claim 51, wherein the one or more time synchronized power distribution measurements comprise a power measurement, a current measurement, a voltage measurement, a phase measurement, or a combination thereof.

57. The apparatus of claim 51, wherein the one or more time synchronized power distribution measurements are received via a landline transmission.

58. A non-transitory computer-readable medium comprising instructions, which when executed by a processor cause the processor to:

receive one or more time synchronized power distribution measurements from a plurality of measurement devices, wherein each measurement device is time synchronized based on a synchronized wireless communication signal from a terrestrial wireless communication system, and wherein the one or more time synchronized power distribution measurements include a first phase offset associated with a first measurement device of the plurality of measurement devices and a second phase offset associated with a second measurement device of the plurality of measurement devices;

analyze the one or more time synchronized power distribution measurements to determine one or more power conditions of a power distribution system; and

determine an error condition based on a comparison of the first phase offset and the second phase offset.

59. The non-transitory computer-readable medium of claim 58, wherein the instructions are executable by the processor to:

associate the one or more time synchronized power distribution measurements with one or more geographic locations; and

correlate the one or more time synchronized power distribution measurements based on the one or more geographic locations to determine a measurement variation.

60. The non-transitory computer-readable medium of claim 58, wherein the one or more time synchronized power distribution measurements are received from a server in the terrestrial wireless communication system.

61. The non-transitory computer-readable medium of claim 58, wherein the terrestrial wireless communication system comprises a code division multiple access (CDMA) system.

62. The non-transitory computer-readable medium of claim 58, wherein each of the one or more time synchronized power distribution measurements is associated with a power line of the power distribution system.

63. The non-transitory computer-readable medium of claim 58, wherein the one or more time synchronized power distribution measurements comprise a power measurement, a current measurement, a voltage measurement, a phase measurement, or a combination thereof.

64. The non-transitory computer-readable medium of claim 58, wherein the one or more time synchronized power distribution measurements are received via a landline transmission.

* * * * *