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(54) **Title:** MONITORING OF A MICROGRID

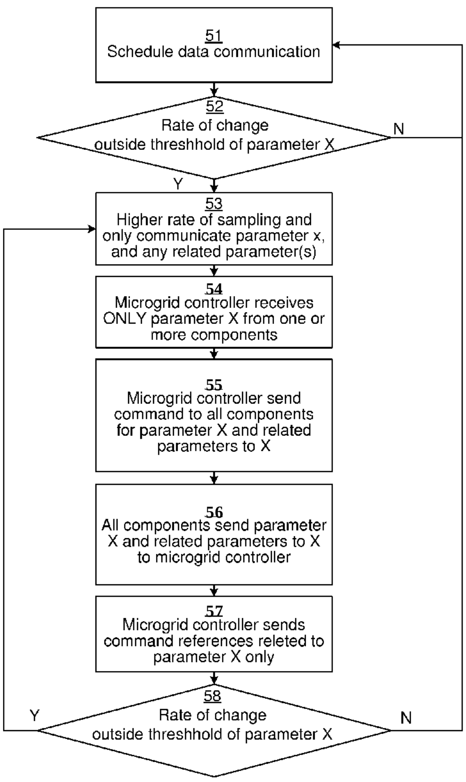

Fig. 5a

(57) Abstract: The present disclosure relates to a method performed by a component 3 in an electrical microgrid 1. The method comprises obtaining measurements of a plurality of parameters in the microgrid. The method also comprises reporting the parameter measurements periodically to a controller 2 in the microgrid at a first rate. The method also comprises observing that at least one of the measured plurality of parameters deviates from a predetermined range. The method also comprises, in response to said observing, switching from reporting the measurements of all the plurality of parameters to only reporting the measurements of a reduced group of parameters of the plurality of parameters to the controller, said reduced group of parameters comprising the deviating parameter. The present disclosure also relates to a corresponding method performed by the controller 2, as well as to a component and a controller of the microgrid.

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MONITORING OF A MICROGRID

TECHNICAL FIELD

The present disclosure relates to methods and devices for monitoring an electrical microgrid based on periodical measurements of predetermined parameters of the microgrid.

BACKGROUND

A sustainable and energy efficient site such as an industrial site consists not only of buildings and offices, but also means of generating energy from clean sources such as solar power, and possibly wind power, and will also have means for storing excess energy produced thereby. Such a typical site is a microgrid and comprises Distributed Generators (DGs), storages, loads, controllers etc.

A microgrid is a localized grouping of electricity generation, energy storage, and loads that normally operates connected to a traditional centralized grid (macrogrid) via a point of common coupling (PCC). This single point of common coupling with the macrogrid can be disconnected, islanding the microgrid. Microgrids are part of a structure aiming at producing electrical power locally from many small energy sources, distributed generators (DGs). In a microgrid, a DG is connected via a converter which controls the output of the DG, i.e. the current injected into the microgrid.

A microgrid (in grid connected mode, i.e. connected to the macrogrid) supplies the optimized or maximum power outputs from the connected DG sites and the rest of the power is supplied by the macrogrid. The microgrid is connected to the macrogrid at a PCC through a controllable switch. This grid connection is lost during grid fault and the microgrid is islanded.

In such a microgrid, it is desired that the main system controller (microgrid controller) will be able to monitor system parameters such as voltage at different locations, system frequency as well as active and reactive power output of the DGs at different locations in the microgrid in order to ensure stable operation, optimize energy usage, improve power quality and minimize loss. This requires each of the components of the microgrid (e.g. DG, storage, loads etc.) to communicate these measured quantities to the microgrid controller after a certain time interval and typically these monitoring time scales can vary from seconds to minutes.

During disturbances or deviations of certain measured parameters beyond the desired threshold, it is necessary to change associated reference quantities to bring them within acceptable bandwidth and that requires to monitor these parameters with higher sampling rate. However, the bandwidth available for communication within the microgrid may be limited, e.g. when the communication is wireless, why such a higher sampling rate may lead to congestion in the communication network of the microgrid.

SUMMARY

It is an objective of the present invention to reduce the risk of congestion in a communication network of a microgrid, while still allowing adequate reporting rate of sampled parameters.

According to an aspect of the present invention, there is provided a method performed by a component in an electrical microgrid. The method comprises obtaining measurements of a plurality of parameters in the microgrid. The method also comprises reporting the parameter measurements periodically to a controller in the microgrid at a first rate. The method also comprises observing that at least one of the measured plurality of parameters deviates from a predetermined range. The method also comprises, in response to said observing, switching from reporting the measurements of all the plurality of parameters to only reporting the measurements of a reduced group of parameters of the plurality of parameters to the controller, said reduced group of parameters comprising the deviating parameter, and, optionally, associated parameter(s) which are related to the deviating parameter (e.g. voltage and storage power output in case of voltage drop near to that energy storage).

According to another aspect of the present invention, there is provided an electrical microgrid. The component comprises processor circuitry, and a storage unit storing instructions executable by said processor circuitry whereby said component is operative to obtain measurements of a plurality of parameters in the microgrid. The component is also operative to report the parameter measurements periodically to a controller in the microgrid at a first rate. The component is also operative to observe that at least one of the measured plurality of parameters deviates from a predetermined range. The component is also operative to, in response to said observing, switch from reporting the measurements of all the plurality of parameters to only reporting the measurements of a reduced group of parameters of the plurality of parameters to the controller, said reduced group of parameters comprising the deviating parameter, and, optionally, associated parameter(s) which are related to the deviating parameter (e.g. voltage and storage power output in case of voltage drop near to that energy storage).

According to another aspect of the present invention, there is provided a method performed by a controller in an electrical microgrid. The method comprises receiving measurements of a plurality of parameters periodically from each of a plurality of components in the microgrid at a first rate. The method also comprises observing that at least one component of the plurality of components has switched from reporting the measurements of all the plurality of parameters to only reporting the measurements of a reduced group of parameters of the plurality of parameters, whereby only the measurements of said reduced group of parameters are received from said at least one component. The method also comprises, in response to said observing, sending instructions to each of the plurality of components other than said at least one component, to switch from reporting the measurements of all the plurality of parameters to only reporting the measurements of the reduced group of parameters. After said sending instructions, the controller only receives the measurements of the reduced group of parameters from the plurality of components.

According to another aspect of the present invention, there is provided a controller for an electrical microgrid. The controller comprises processor circuitry, and a storage unit storing instructions executable by said processor circuitry whereby said controller is operative to receive measurements of a plurality of parameters periodically from each of a plurality of components in the microgrid at a first rate. The controller is also operative to observe that at least one component of the plurality of components has switched from reporting the measurements of all the plurality of parameters to only reporting the measurements of a reduced group of parameters of the plurality of parameters, whereby only the measurements of said reduced group of parameters are received from said at least one component. The controller is also operative to, in response to said observing, send instructions to each of the plurality of components other than said at least one component, to switch from reporting the measurements of all the plurality of parameters to only reporting the measurements of the reduced group of parameters, whereby, after said sending instructions, the controller only receives the measurements of the reduced group of parameters from the plurality of components.

According to another aspect of the present invention, there is provided an electrical microgrid comprising an embodiment of the component of the present disclosure, and an embodiment of the controller of the present disclosure.

According to another aspect of the present invention, there is provided a computer program comprising computer program code which is able to, when run on processor circuitry of a component in a microgrid, cause the component to obtain measurements of a plurality of parameters in the microgrid. The code is also able to cause the component to report the parameter measurements periodically to a controller in the microgrid at a first rate. The code is also able to cause the component to observe that at least one of the measured plurality of parameters deviates from a predetermined range. The code is also able to cause the component to, in response to said observing, switch from reporting the measurements of all the plurality of parameters to only reporting the measurements of a reduced group of parameters of the plurality of parameters to the controller, said reduced group of parameters comprising the deviating parameter, and, optionally, associated parameter(s) which are related to the deviating parameter (e.g. voltage and storage power output in case of voltage drop near to that energy storage).

According to another aspect of the present invention, there is provided a computer program comprising computer program code which is able to, when run on processor circuitry of a controller in a microgrid, cause the controller to receive measurements of a plurality of parameters periodically from each of a plurality of components in the microgrid at a first rate. The code is also able to cause the controller to observe that at least one component of the plurality of components has switched from reporting the measurements of all the plurality of parameters to only reporting the measurements of a reduced group of parameters of the plurality of parameters, whereby only the measurements of said reduced group of parameters are received from said at least one component. The code is also able to cause the controller to, in response to said observing, send instructions to each of the plurality of components other than said at least one component, to switch from reporting the measurements of all the plurality of parameters to only reporting the measurements of the reduced group of parameters, whereby, after said sending instructions, the controller only receives the measurements of the reduced group of parameters from the plurality of components.

According to another aspect of the present invention, there is provided a computer program product comprising an embodiment of a computer program of the present disclosure and a computer readable means on which the computer program is stored.

By only reporting the measured parameters of a reduced number of parameters to the controller, and correspondingly limiting reporting from other components of the microgrid, e.g. DGs, loads and/or storages, bandwidth is preserved for allowing increased sampling and reporting rate of the reduced number of parameters without increased congestion in the communication network of the microgrid.

Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, apparatus, component, means, step, etc." are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any method disclosed herein do not have to be performed in the exact order disclosed, unless explicitly stated. The use of "first", "second" etc. for different features/components of the present disclosure are only intended to distinguish the features/components from other similar features/components and not to impart any order or hierarchy to the features/components.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments will be described, by way of example, with reference to the accompanying drawings, in which:

Fig 1 is a schematic block diagram of an embodiment of a microgrid and the communication therein before deviation of a parameter, in accordance with the present invention.

Fig 2 is a schematic block diagram of another embodiment of a microgrid and the communication therein after observing deviation of a parameter, in accordance with the present invention.

Fig 3 is a graph illustrating deviation of a parameter and increased rate of reporting measurements of said parameter in response thereto, in accordance with the present invention.

Fig 4 is a schematic block diagram of another embodiment of a microgrid and the communication therein after the controller having instructed all components to only report the reduced number of parameters, in accordance with the present invention.

Fig 5a is a schematic flow chart illustrating example methods of the present invention.

Fig 5b is a schematic flow chart illustrating a more specific example of the example methods of fig 5a.

Fig 6 is a schematic block diagram of an embodiment of a component of the present invention.

Fig 7 is a schematic block diagram of an embodiment of a controller of the present invention.

Fig 8 is a schematic illustration of an embodiment of a computer program product in accordance with the present invention.

Fig 9 is a schematic flow chart of an embodiment of a method of the present invention.

Fig 10 is a schematic flow chart of an embodiment of another method of the present invention.

DETAILED DESCRIPTION

Embodiments will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments are shown. However, other embodiments in many different forms are possible within the scope of the present disclosure. Rather, the following embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art. Like numbers refer to like elements throughout the description.

A problem handled by embodiments of the present invention is to provide a communication scheme applied for monitoring purposes of a microgrid which can handle the deviation or fluctuation of certain system parameters during disturbance with efficacy and without investing higher bandwidth requirements. It is noted that the purpose here is not to act on primary control of the DGs or storages in the microgrid which are based on local measurements, rather monitoring and reference variable correction as secondary control is employed with the efficient use of the communication infrastructure.

Several communication technologies, both wired and wireless, may be considered for use with the present invention. However considering ease and cost of installation, especially in difficult terrain, wireless communication can be one option. Numerous low cost and self-organizing wireless communication technologies exist which do not support high bandwidth and fast communication, and intermediate nodes are used to forward packets from source to destination. Though fast communication is not required when all the parameters of the microgrid are within normal range, high bandwidth or high data rate may be required when one of the parameters is outside its desired range during a disturbance. In this case all the actors/components in the microgrid may report the measured value associated with this parameter to the controller more frequently. This may overwhelm the communication network and cause packet loss in the intermediate forwarding nodes. Embodiments of the present invention alleviate this problem by reducing the number of measured parameters reported.

By means of embodiments to the present invention there is provided an adaptive communication scheme that enables a microgrid component to notify the controller of a signal fluctuation without sending an additional message/signal. Further, the communication scheme may accommodate both normal mode and disturbance/fluctuation mode of operation while retaining the amount of lost data packets during a disturbance below a suitable limit. Embodiments of the invention enable the controller 2 to receive more highly sampled values of the fluctuating parameter until it return back to a value within a desired range. This facilitates an effective microgrid monitoring system and automatic switchover to selective communication during signal fluctuations, resulting in a better packet reception ratio. This scheme may be beneficial for low cost communication technologies, which cannot guarantee high data rate a low latency communication. The same communication infrastructure may be used for microgrid monitoring as well as system services like frequency restoration, voltage profiling etc. The automatic detection of the fluctuated signal and selective information exchange from all microgrid components and microgrid controller may be provided. Embodiments of the inventive methods may be scalable and may adapt to changes in the microgrid structure.

Figure 1 illustrates a microgrid 1 comprising numerous components 3 connected thereto, e.g. DGs 3a, loads 3b and storages 3c, as well as a microgrid controller 2 which acts as a secondary controller of the components 3 for overall stability and control of the microgrid 1. The microgrid controller 2 may e.g. provide new reference values (set-points) to the primary controls of the respective components 3. The microgrid controller 2 may typically be a central control, but alternatively it may be a de-centralised controller which is distributed among the components 3, e.g. co-located with the primary controls in the components 3. The dashed lines in the figure indicate communication paths within the microgrid 1, e.g. wireless communication paths. Next to each component 3 and the controller 2 in the figure, as an example, the different parameters which are measured and reported by each component 3 and the instructions e.g. reference values sent by the controller 2 are noted. In the example of figure 1, each component periodically reports (to the controller 2) the locally measured values of the parameters voltage, frequency, active power output/consumption and reactive power output/ consumption. The loads 3b also report the load control and the storages 3c also reports its current state of charge. Correspondingly, the controller sends instructions/information such as reference values for the parameters reported by the components 3, here voltage reference, and active and reactive power references (which may be the same or different for each component 3), and instructions for energy optimisation and load scheduling as well as control mode. The communication network may e.g. be a low cost e.g. wireless network with limited bandwidth. The communication network may be a mesh network which means that there are multiple paths from a source to the destination and intermediate nodes acts as forwarders of the packets. The low cost wireless technology is not expected to support high speed communication and may be considered for applications with less stringent timing and low data rate requirements such as monitoring of the microgrid l with communication of multiple measured parameters.

However, as illustrated in figure 2, in case of fluctuations of a measured parameter (in disturbances, e.g. voltage in a DG 3a as shown in figure 2), the sampling rate of measured voltage may increase from the concerned DG 3a (see figure 3). This high sampled data have to be communicated, thereby requiring a higher data rate. However, in accordance with the present invention, the affected DG 3a in this case starts to only report the voltage measurements (at the higher rate), not congesting the network with measurements of the other parameters.

Figure 3 is a graph illustrating the measurement of a parameter m. When the measured/sampled value of the parameter is stable, then the measurement is made and reported at a standard rate, see measurements mi, m2, m3 and m9, mio, mil, but when the magnitude of the measured value fluctuates the rate is increased, see m4, m15, m6, *my* and m8.

When a parameter fluctuates outside of its predetermined range, the voltage at the DG 3a as exemplified herein, only the measured voltage is sent from the DG 3a to the microgrid controller 2. This not only balances the high sampling data transfer requirement but also give an indication to the controller 2 that the particular quantity (voltage) is fluctuating or not within the desired range. Thus, the controller 2 is made aware that the voltage is fluctuating at the DG 3a and a command may be sent from the microgrid controller 2 to all other components 3, requesting that only information related to the deviating parameter (voltage) is sent to the controller. This will further reduce the traffic in the network, leading to less packet losses in the forwarding nodes. In order to ensure that all the components 3 receive the command, the message can be broadcasted e.g. flooded in the network. This means that when a node receives the command, it will send it to all other nodes within its range. The receiving nodes will do the same if they have not forwarded the message before.

As a result, as illustrated in figure 4, the microgrid controller 2 would receive measurements only of the fluctuating parameter (voltage), and any other parameter deemed relevant (the reactive power in the example of figure 4) from all other components 3 (DGs, storage etc.). In return, only adjusted reference values (based on microgrid control) related to the fluctuating parameter (voltage) and associated parameters are sent from the microgrid controller 2 to all the microgrid components 3 such as DG, storage etc. The process of selective monitoring and reference adjustment is continued until the fluctuating parameter comes back within its acceptable range.

Figure 5a illustrates embodiments of a method performed in the control system (microgrid controller 2 and associated local (e.g. primary) controllers in the respective components 3) in accordance with the present invention. Data communication is scheduled 51 (cf. figure 1) it is continually checked 52 at each component 3 whether the rate of change of a parameter X is above its predetermined threshold. If yes, then a higher rate of sampling 53 is used and only the measurements of parameter X are communicated to the controller 2. Thus, the microgrid controller 2 only receives 54 measurements of parameter X (and possibly other essential parameter(s)) from one or more component(s) 3. If e.g. the voltage fluctuates at one component 3, it is not uncommon that the voltage also fluctuates at other components 3. In response to the received 54 measurements of fewer parameters, the controller 2 sends 55 a command to the other components 3 that they should each only report parameter X and related parameter (s). Then, in response to having received the sent 55 command, each of the components reports 56 only measurements, typically also at the higher second sampling rate, of parameter X and related parameter(s) to the controller 2. Also, the controller 2 sends 57 commands and references related to only parameter X, and possibly the other reported related parameters. It is continuously checked 58 whether parameter X is still fluctuating outside its predetermined range, and when it is determined that parameter X has stabilised once again, the regular reporting of all parameters at the regular lower rate is resumed.

Figure 5b shows a more specific example of the method embodiments of figure 5a, where the parameters of voltage, frequency, active power and reactive power are regularly reported 51, until the voltage starts to fluctuate 52 at the DG 3. Thus, the voltage corresponds to the parameter X in figure 5a.

Figure 6 schematically illustrates an embodiment of a component 3 of the present invention. The component 3 comprises processor circuitry 61 e.g. a central processing unit (CPU). The processor circuitry 61 may comprise one or a plurality of processing units in the form of microprocessor(s). However, other suitable devices with computing capabilities could be comprised in the processor circuitry 61, e.g. an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or a complex programmable logic device (CPLD). The processor circuitry 61 is configured to run one or several computer program(s) or software (SW) 81 (see also figure 8) stored in a data storage 62 of one or several storage unit(s) e.g. a memory. The storage unit is regarded as a computer readable means 82 (see figure 8) as discussed herein and may e.g. be in the form of a Random Access Memory (RAM), a Flash memory or other solid state memory, or a hard disk, or be a combination thereof. The processor circuitry 61 may also be configured to store data in the storage 62, as needed. The component 3 also comprises a communication interface 63 e.g. for wired or wireless communication with the controller 2.

Figure 7 schematically illustrates an embodiment of a controller 2 of the present invention. The controller 2 comprises processor circuitry 71 e.g. a central processing unit (CPU). The processor circuitry 71 may comprise one or a plurality of processing units in the form of microprocessor(s). However, other suitable devices with computing capabilities could be comprised in the processor circuitry 71, e.g. an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or a complex programmable logic device (CPLD). The processor circuitry 71 is configured to run one or several computer program(s) or software (SW) 81 (see also figure 8) stored in a data storage 82 of one or several storage unit(s) e.g. a memory. The storage unit is regarded as a computer readable means 82 (see figure 8) as discussed herein and may e.g. be in the form of a Random Access Memory (RAM), a Flash memory or other solid state memory, or a hard disk, or be a combination thereof. The processor circuitry 71 may also be configured to store data in the storage 72, as needed. The controller 2 also comprises a communication interface 73 over which control signals are sent to the components 3, e.g. DG 3a, of the microgrid 1 for controlling the same.

Figure 8 illustrates a computer program product 80. The computer program product 100 comprises a computer readable medium 82 comprising a computer program 101 in the form of computer-executable components 81. The computer program/computer-executable components 81 may be configured to cause a controller 2 or a component 3, e.g. as discussed herein, to perform an embodiment of the methods of the present invention. The computer program/computer-executable components may be run on the processor circuitry 61/71 of the component3/controller 2 for causing it to perform the method. The computer program product 80 may e.g. be comprised in a storage unit or memory 62/72 comprised in the component 3/controller 2 and associated with the processor circuitry 61/71. Alternatively, the computer program product 80 may be, or be part of, a separate, e.g. mobile, storage means, such as a computer readable disc, e.g. CD or DVD or hard disc/drive, or a solid state storage medium, e.g. a RAM or Flash memory.

Figure 9 is a flow chart illustrating some embodiments of the method performed in a component 3, in accordance with the present invention. The component 3 obtains Si measurements (e.g. performs the measurements or receives the measurement values from a measurement unit of the component) of a plurality of parameters in the microgrid 1. The component 3 also reports S2 the parameter measurements periodically to a controller 2 in the microgrid at a first rate. At some point in time, the component observes S3 that at least one of the measured plurality of parameters deviates from a predetermined range. In response to said observing S3, the component switches S4 from reporting the measurements of all the plurality of parameters to only reporting the measurements of a reduced group of parameters (e.g. only one parameter) of the plurality of parameters to the controller 2, said reduced group of parameters comprising the deviating parameter. In some embodiments, the component also receives S5 reference values for at least some of the plurality of parameters from the controller 2, wherein, after the switching S4, only reference values relating to parameters comprised in the reduced group of parameters are received S5 from the controller.

Figure 10 is a flow chart illustrating some embodiments of the method performed in a controller 2, in accordance with the present invention. The microgrid controller 2 receives S11 measurements of a plurality of parameters periodically from each of a plurality of components 3 in the microgrid at a first rate. At some point in time, the controller observes S12 that at least one component 3 of the plurality of components has switched from reporting the measurements of all the plurality of parameters to only reporting the measurements of a reduced group of parameters of the plurality of parameters, whereby only the measurements of said reduced group of parameters are received S11 from said at least one component 3. In response to said observing S12, the controller 2 sends S13 instructions to each of the plurality of components 3 other than said at least one component (but possibly also including said at least one component, e.g. if the instructions are broadcasted), to switch from reporting the measurements of all the plurality of parameters to only reporting the measurements of the reduced group of parameters. After said sending instructions S13, the controller 2 only receives the measurements of the reduced group of parameters from the plurality of components 3. In some embodiments, the controller also sends S14 reference values for at least some of the plurality of parameters to each of the plurality of components 3, wherein, after the sending S13 of instructions, only reference values relating to parameters comprised in the reduced group of parameters are sent S14.

In some embodiments of the present invention, the rate at which the parameter measurements are reported S2 by the component and received S11 by the controller 2 is increased from the first rate to a second rate in response to the observing S3 that at least one of the measured plurality of parameters deviates from the predetermined range. Thus, in some embodiments, the rate at which the parameter measurements are received S11 by the controller 2 from the at least one component 3 is increased from the first rate to a second rate when only the measurements of said reduced group of parameters are received. The rate at which the parameter measurements are received S11 from all of the plurality of components 3 may e.g. be increased from the first rate to the second rate after the sending S13 of instructions.

In some embodiments of the present invention, the plurality of parameters comprise any of voltage, frequency and power flow locally measured at one or more points in the microgrid 1 by the component 3.

In some embodiments of the present invention, the reduced group of parameters consists only of the deviating parameter. In other embodiments, also at least one parameter related to the deviating parameter is also included in the reduced group.

In some embodiments of the present invention, the component 3 is, or is comprised in, a distributed generator (DG) 3a; a power storage 3c; or a load 3b of the microgrid 1, e.g. in a monitoring and/or controlling unit therein e.g. co-located with its primary control.

In some embodiments of the present invention, the controller 2 is a central or distributed, secondary controller.

Example - Simulation

Simulation Parameters	Simulation Parameters Name/Value
Simulation Tool	Qualnet 5.0.2.
Technology	Wireless-IEEE 802.15.4/Zigbee
Application	Constant Bit Rate (CBR)

Maximum data rate supported	250kbps

Table 1: Simulation parameters

Under normal operating conditions (cf. figure 1) each DG 3a, load 3b and storage 3c is sending S2 periodic information to the microgrid controller 2 in form of CBR application in which 100 items of 64 bytes each are sent at 100 ms interval. In this case, each of the parameters such as voltage, frequency, active power, reactive power etc. is assumed to be of 8 bytes each. So if each of the components sends eight such parameters then in total 64 bytes are sent. In this setup, there are only few frames lost during communication from source to destination. This is because of the wireless communication channel which gets exaggerated during interference from other sources. It is even more severe as the distance between source and destination increases, with intermediate nodes relaying the frames to the destination. If the traffic is high, the intermediate nodes can drop the frames leading to the increase in the frame loss. Thus, on average the percentage of frames received is 88.5% with a loss of 11.5%.

However, since the application can tolerate some data loss without losing required accuracy of the measured parameters for monitoring, a low cost communication infrastructure with such a loss rate can be used.

However, if for example the voltage in a DG 3a is not within the desired range, then the DG increases the sampling rate of the voltage and the sampled information is communicated to the controller 2 as soon as it is available. In this case it is assumed that the sampling rate of voltage in the DG is increased from 100 ms to 1 ms and DG is sending 2000 items of 64 bytes in the given simulation time. The rest of the components 3 are sending 100 items of 64 bytes per 100 ms interval. The DG 3a sends more number of frames as compared to other components 3. However, due to increase in traffic, only on average 31.35%, with loss of 68.65%, of the frames are received by the controller 2.

According to the present invention, only voltage related readings are sent to the controller 2 from the other components 3, assuming that it is the parameter that is outside the normal range. Thus, while the DG 3a continues to send 2000 items of 64 bytes in every 1 ms interval, the other components reduce the number of items to 10 while maintaining the size of the items (64 bytes) and interval (100 ms) same as before. This reduces the traffic in network. The result shows that the percentage of frames received increases to 85.38%, with losses of only 14.72%.

Below follow some other aspects of the present invention.

According to an aspect of the present invention, there is provided a component 3 for an electrical microgrid 1, the component comprising means (e.g. the processing circuitry 61 running appropriate SW 81, e.g. in cooperation with a measurement unit) for obtaining Si measurements of a plurality of parameters in the microgrid. The component also comprises means (e.g. the processing circuitry 61 running appropriate SW 81, typically in cooperation with the communication interface 63) for reporting S2 the parameter measurements periodically to a controller 2 in the microgrid at a first rate. The component also comprises means (e.g. the processing circuitry 61 running appropriate SW 81) for observing S3 that at least one of the measured plurality of parameters deviates from a predetermined range. The component also comprises means (e.g. the processing circuitry 61 running appropriate SW 81) for, in response to said observing S3, switching S4 from reporting the measurements of all the plurality of parameters to only reporting the measurements of a reduced group of parameters of the plurality of parameters to the controller 2, said reduced group of parameters comprising the deviating parameter.

According to another aspect of the present invention, there is provided a computer program product 80 comprising computer-executable components 81 for causing a component 3 to perform an embodiment of a method of the present disclosure when the computer-executable components are run on processor circuitry 61 comprised in the component.

According to another aspect of the present invention, there is provided a controller 2 for an electrical microgrid 1, the controller comprising means (e.g. the processing circuitry 71 running appropriate SW 81, typically in cooperation with the communication interface 73) for receiving S11 measurements of a plurality of parameters periodically from each of a plurality of components 3 in the microgrid at a first rate. The controller also comprises means (e.g. the processing circuitry 71 running appropriate SW 81) for observing S12 that at least one component 3 of the plurality of components has switched from reporting the measurements of all the plurality of parameters to only reporting the measurements of a reduced group of parameters of the plurality of parameters, whereby only the measurements of said reduced group of parameters are received S11 from said at least one component. The controller also comprises means (e.g. the processing circuitry 71 running appropriate SW 81, typically in cooperation with the communication interface 73) for, in response to said observing S12, sending S13 instructions to each of the plurality of components 3 other than said at least one component, to switch from reporting the measurements of all the plurality of parameters to only reporting the measurements of the reduced group of parameters. After said sending instructions S13, the controller 2 only receives the measurements of the reduced group of parameters from the plurality of components 3.

According to another aspect of the present invention, there is provided a computer program product 80 comprising computer-executable components 81 for causing a controller 2 to perform an embodiment of a method of the present disclosure when the computer-executable components are run on processor circuitry 71 comprised in the controller.

The present disclosure has mainly been described above with reference to a few embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the present disclosure, as defined by the appended claims.

CLAIMS

1. A method performed by a component (3) in an electrical microgrid (1), the method comprising:

obtaining (Si) measurements of a plurality of parameters in the microgrid;

reporting (S2) the parameter measurements periodically to a controller (2) in the microgrid at a first rate;

observing (S3) that at least one of the measured plurality of parameters deviates from a predetermined range; and

in response to said observing (S3), switching (S4) from reporting the measurements of all the plurality of parameters to only reporting the measurements of a reduced group of parameters of the plurality of parameters to the controller (2), said reduced group of parameters comprising the deviating parameter.

2. The method of claim 1, further comprising:

receiving (S5) reference values for at least some of the plurality of parameters from the controller (2), wherein, after the switching (S4), only reference values relating to parameters comprised in the reduced group of parameters are received (S5) from the controller.

3. The method of any preceding claim, wherein the rate at which the parameter measurements are reported (S2) to the controller (2) is increased from the first rate to a second rate in response to the observing (S3).

4. A method performed by a controller (2) in an electrical microgrid (1), the method comprising:

receiving (S11) measurements of a plurality of parameters periodically from each of a plurality of components (3) in the microgrid at a first rate;

observing (S12) that at least one component (3) of the plurality of components has switched from reporting the measurements of all the plurality of parameters to only reporting the measurements of a reduced group of parameters of the plurality of parameters, whereby only the measurements of said reduced group of parameters are received (S11) from said at least one component; and

in response to said observing (S12), sending (S13) instructions to each of the plurality of components (3) other than said at least one component, to switch from reporting the measurements of all the plurality of parameters to only reporting the measurements of the reduced group of parameters;

whereby, after said sending instructions (S13), the controller (2) only receives the measurements of the reduced group of parameters from the plurality of components (3).

5. The method of claim 4, further comprising:

sending (S14) reference values for at least some of the plurality of parameters to each of the plurality of components (3), wherein, after the sending (S13) of instructions, only reference values relating to parameters comprised in the reduced group of parameters are sent (S14).

6. The method of claim 4 or 5, wherein the rate at which the parameter measurements are received (S11) from the at least one component (3) is increased from the first rate to a second rate when only the measurements of said reduced group of parameters are received.

7. The method of claim 6, wherein the rate at which the parameter measurements are received (S11) from all of the plurality of components (3) is increased from the first rate to the second rate after the sending (S13) of instructions.

8. The method of any claim 4-7, wherein said sending (S13) instructions comprises broadcasting the instructions to all the plurality of components (3).

9. The method of any preceding claim, wherein the plurality of parameters comprise any of voltage, frequency and power flow locally measured at one or more points in the microgrid (1) by the component (3).

10. The method of any preceding claim, wherein the reduced group of parameters consists only of the deviating parameter.

11. The method of any preceding claim 1-9, wherein the reduced group of parameters also comprises associated parameter(s) which are related to the deviating parameter.

12. The method of any preceding claim, wherein the component (3) is, or is comprised in, a distributed generator, DG (3a); a power storage (3c); or a load (3b) of the microgrid, e.g. in a monitoring and/or controlling unit therein.

13. The method of any preceding claim, wherein the controller (2) is a central or distributed, secondary controller.

14. A component (3) for an electrical microgrid (1), the component comprising:

processor circuitry (61); and

a storage unit (62) storing instructions (81) executable by said processor circuitry (61) whereby said component (3) is operative to:

obtain measurements of a plurality of parameters in the microgrid;

report the parameter measurements periodically to a controller (2) in the microgrid at a first rate;

observe that at least one of the measured plurality of parameters deviates from a predetermined range; and

in response to said observing, switch from reporting the measurements of all the plurality of parameters to only reporting the measurements of a reduced group of parameters of the plurality of parameters to the controller, said reduced group of parameters comprising the deviating parameter.

15. A controller (2) for an electrical microgrid (1), the controller comprising:

processor circuitry (71); and

a storage unit (72) storing instructions (81) executable by said processor circuitry (71) whereby said controller (2) is operative to:

receive measurements of a plurality of parameters periodically from each of a plurality of components (3) in the microgrid at a first rate;

observe that at least one component of the plurality of components has switched from reporting the measurements of all the plurality of parameters to only reporting the measurements of a reduced group of parameters of the plurality of parameters, whereby only the measurements of said reduced group of parameters are received from said at least one component; and

in response to said observing, send instructions to each of the plurality of components other than said at least one component, to switch from reporting the measurements of all the plurality of parameters to only reporting the measurements of the reduced group of parameters;

whereby, after said sending instructions, the controller only receives the measurements of the reduced group of parameters from the plurality of components.

16. An electrical microgrid (1) comprising:

a component (3) of claim 14; and

a controller (2) of claim 15.

17. A computer program (81) comprising computer program code which is able to, when run on processor circuitry (61) of a component (3) in a microgrid (1), cause the component (3) to:

obtain (Si) measurements of a plurality of parameters in the microgrid;

report (S2) the parameter measurements periodically to a controller (2) in the microgrid at a first rate;

observe (S3) that at least one of the measured plurality of parameters deviates from a predetermined range; and

in response to said observing (S3), switch (S4) from reporting (S2) the measurements of all the plurality of parameters to only reporting the measurements of a reduced group of parameters of the plurality of parameters to the controller, said reduced group of parameters comprising the deviating parameter.

18. A computer program (81) comprising computer program code which is able to, when run on processor circuitry (71) of a controller (2) in a microgrid (1), cause the controller (2) to:

receive (S11) measurements of a plurality of parameters periodically from each of a plurality of components (3) in the microgrid at a first rate;

observe (S12) that at least one component of the plurality of components has switched from reporting the measurements of all the plurality of parameters to only reporting the measurements of a reduced group of parameters of the plurality of parameters, whereby only the measurements of said reduced group of parameters are received from said at least one component; and

in response to said observing (S12), send (S13) instructions to each of the plurality of components other than said at least one component, to switch from reporting the measurements of all the plurality of parameters to only reporting the measurements of the reduced group of parameters;

whereby, after said sending (S13) instructions, the controller (2) only receives (S11) the measurements of the reduced group of parameters from the plurality of components (3).

19. A computer program product (80) comprising a computer program (81) of claim 17 or 18 and a computer readable means (82) on which the computer program is stored.

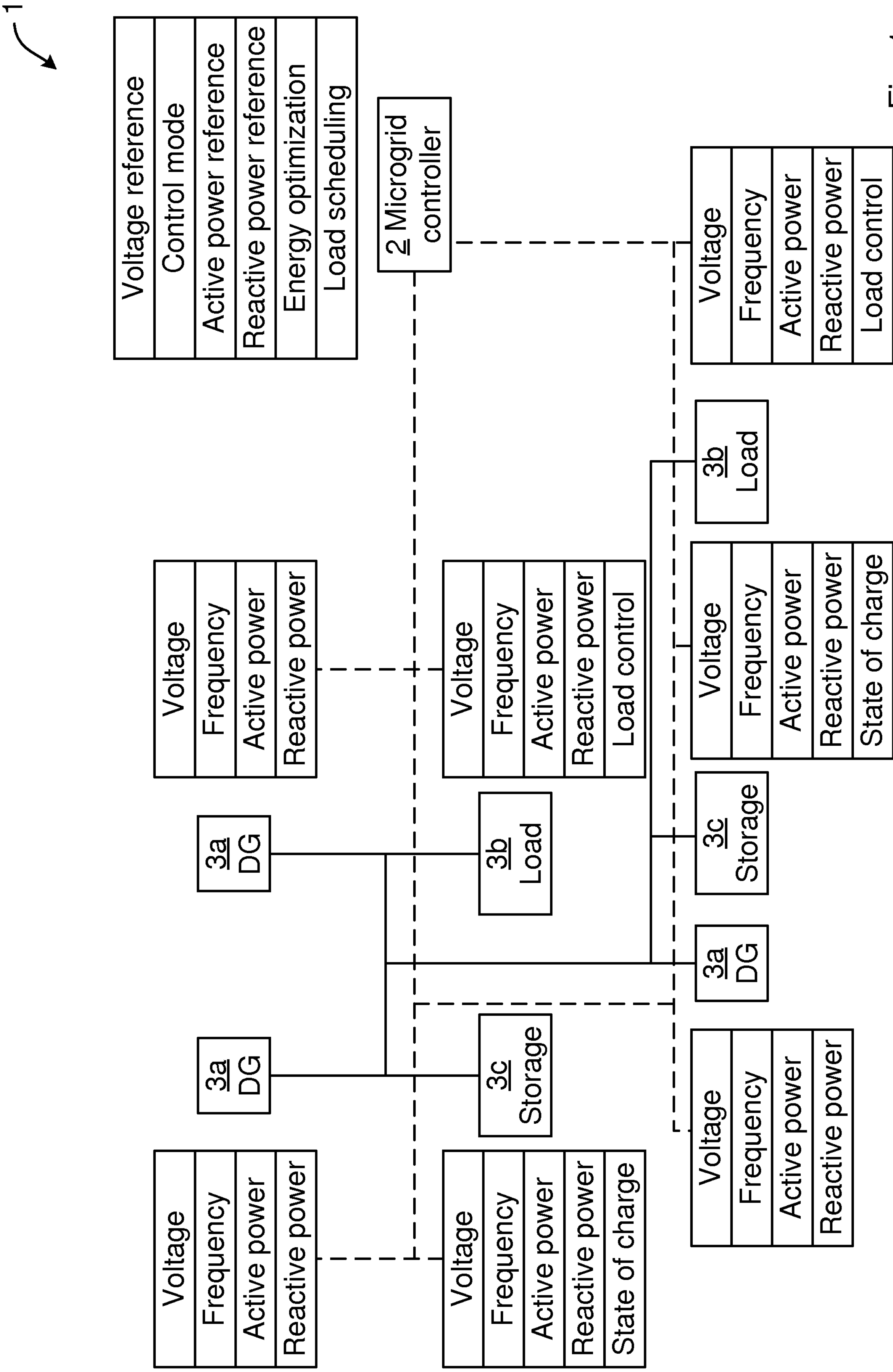

1
Voltage reference
Control mode
Active power reference
Reactive power reference
Energy optimization
Load scheduling
2 Microgrid controller
Voltage
Frequency
Active power
Reactive power
Load control
3b Load
Voltage
Frequency
Active power
Reactive power
Voltage
Frequency
Active power
Reactive power
Load control
Voltage
Frequency
Active power
Reactive power
State of charge
3a DG
3b Load
3c Storage
3a DG
3a DG
3c Storage
Voltage
Frequency
Active power
Reactive power
Voltage
Frequency
Active power
Reactive power
Voltage
Frequency
Active power
Reactive power
State of charge

Fig. 1

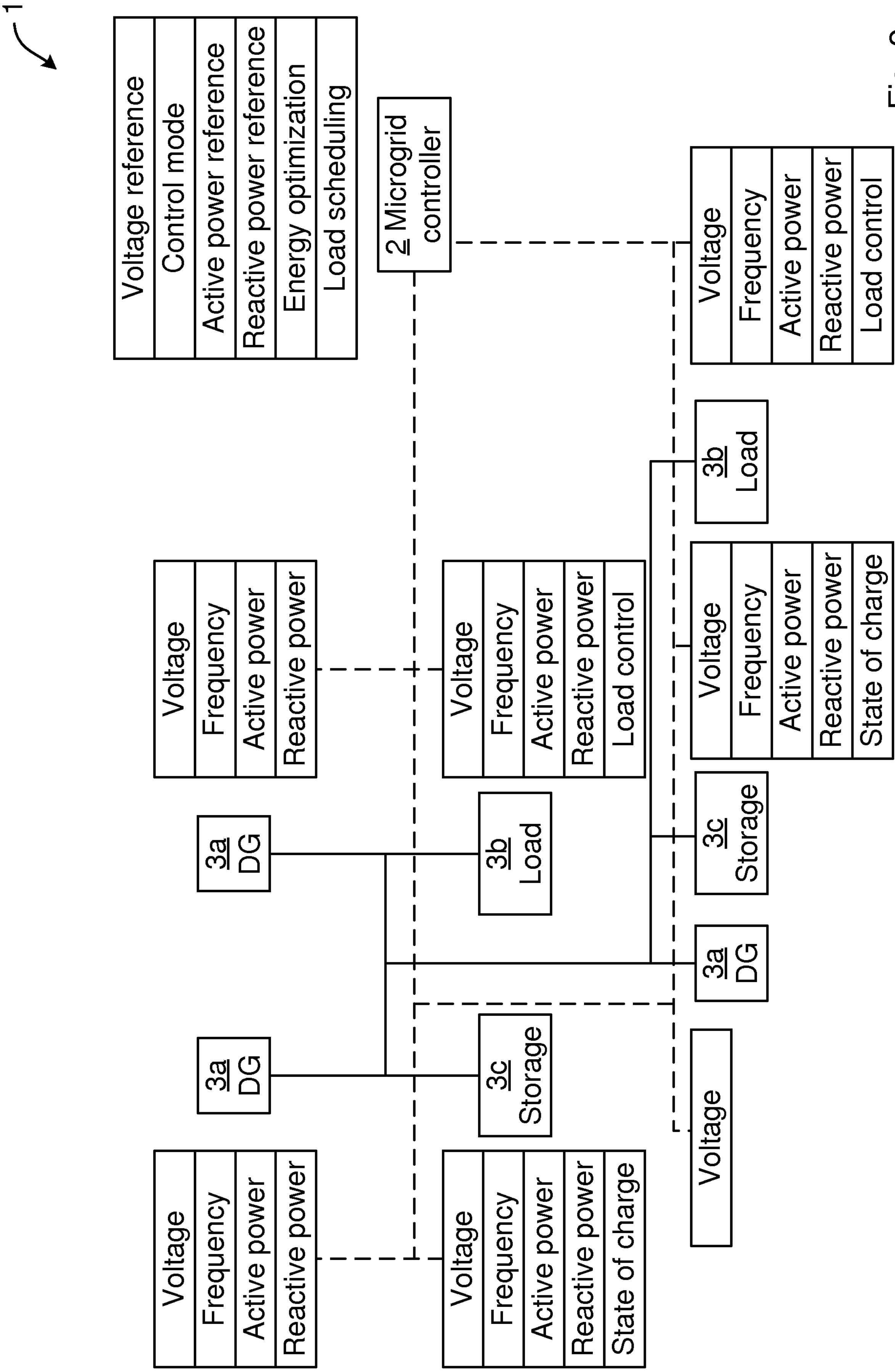
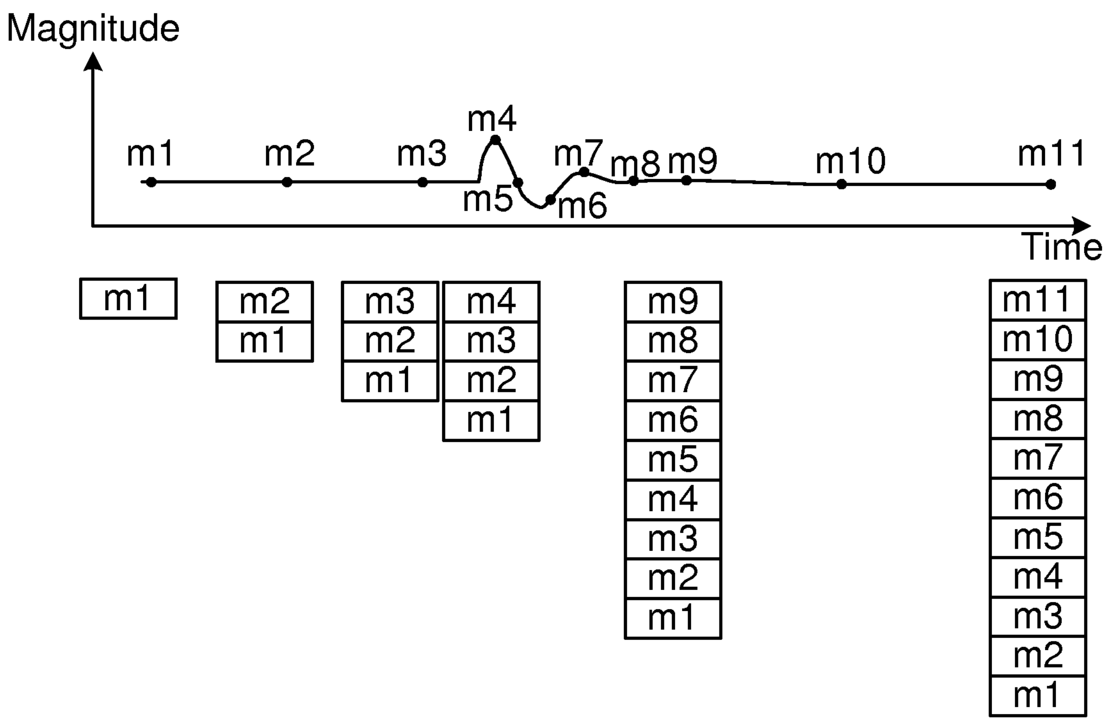

1
Voltage reference
Control mode
Active power reference
Reactive power reference
Energy optimization
Load scheduling
2 Microgrid controller
Voltage
Frequency
Active power
Reactive power
Load control
3b Load
Voltage
Frequency
Active power
Reactive power
Voltage
Frequency
Active power
Reactive power
Load control
Voltage
Frequency
Active power
Reactive power
State of charge
3a DG
3b Load
3c Storage
3a DG
3a DG
3c Storage
Voltage
Voltage
Frequency
Active power
Reactive power
Voltage
Frequency
Active power
Reactive power
State of charge

Fig. 2


Magnitude
m1
m2
m3
m4
m5
m6
m7
m8
m9
m10
m11
Time
m1
m2
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m3
m2
m1
m4
m3
m2
m1
m9
m8
m7
m6
m5
m4
m3
m2
m1
m11
m10
m9
m8
m7
m6
m5
m4
m3
m2
m1

Fig. 3

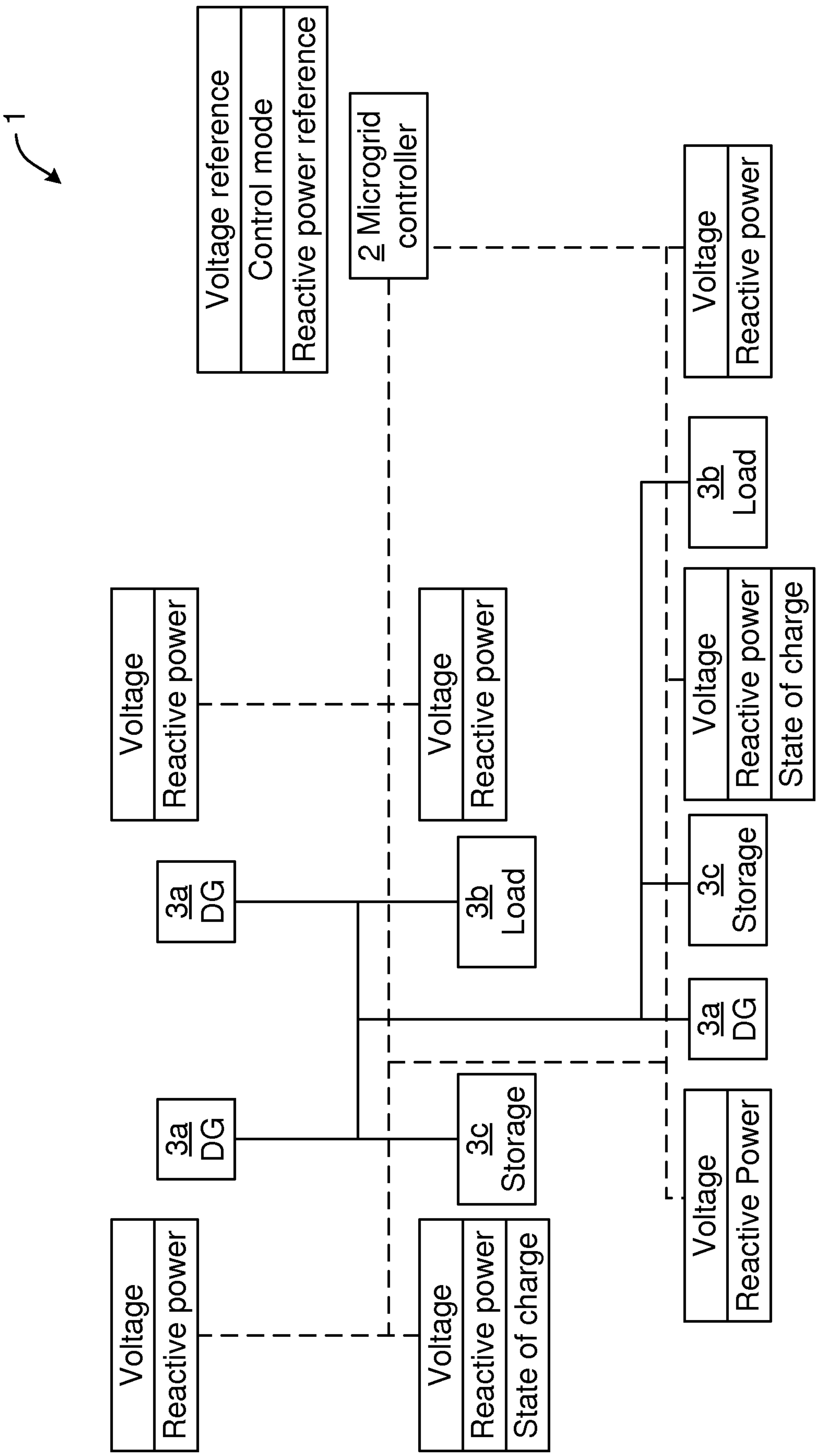
1
Voltage reference
Control mode
Reactive power reference
2 Microgrid controller
Voltage
Reactive power
3a DG
3b Load
3c Storage
Voltage
Reactive power
State of charge
Voltage
Reactive Power

Fig. 4

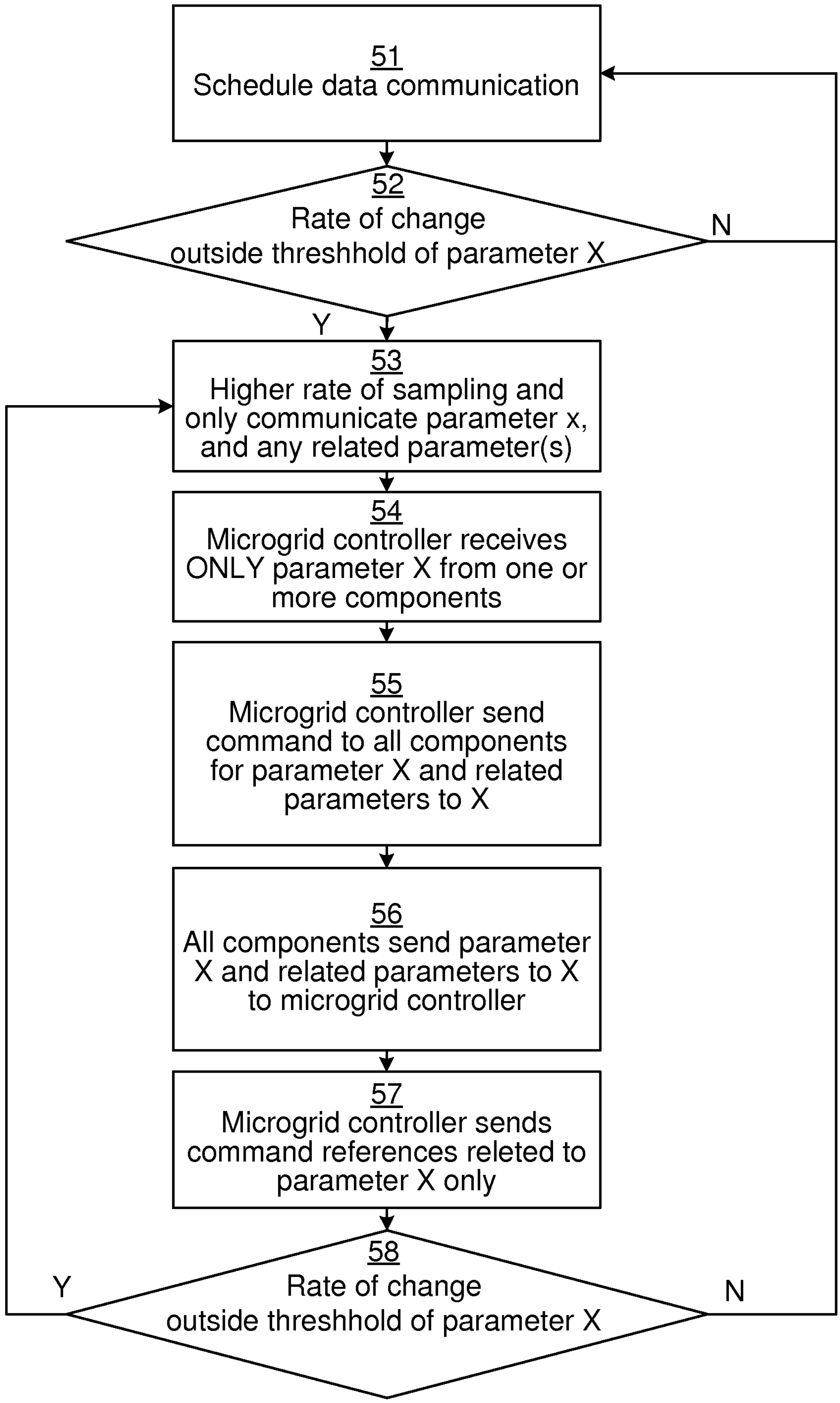
51
Schedule data communication
52
Rate of change
outside threshhold of parameter X
N
Y
53
Higher rate of sampling and
only communicate parameter x,
and any related parameter(s)
54
Microgrid controller receives
ONLY parameter X from one or
more components
55
Microgrid controller send
command to all components
for parameter X and related
parameters to X
56
All components send parameter
X and related parameters to X
to microgrid controller
57
Microgrid controller sends
command references releted to
parameter X only
58
Rate of change
outside threshhold of parameter X
Y
N

Fig. 5a

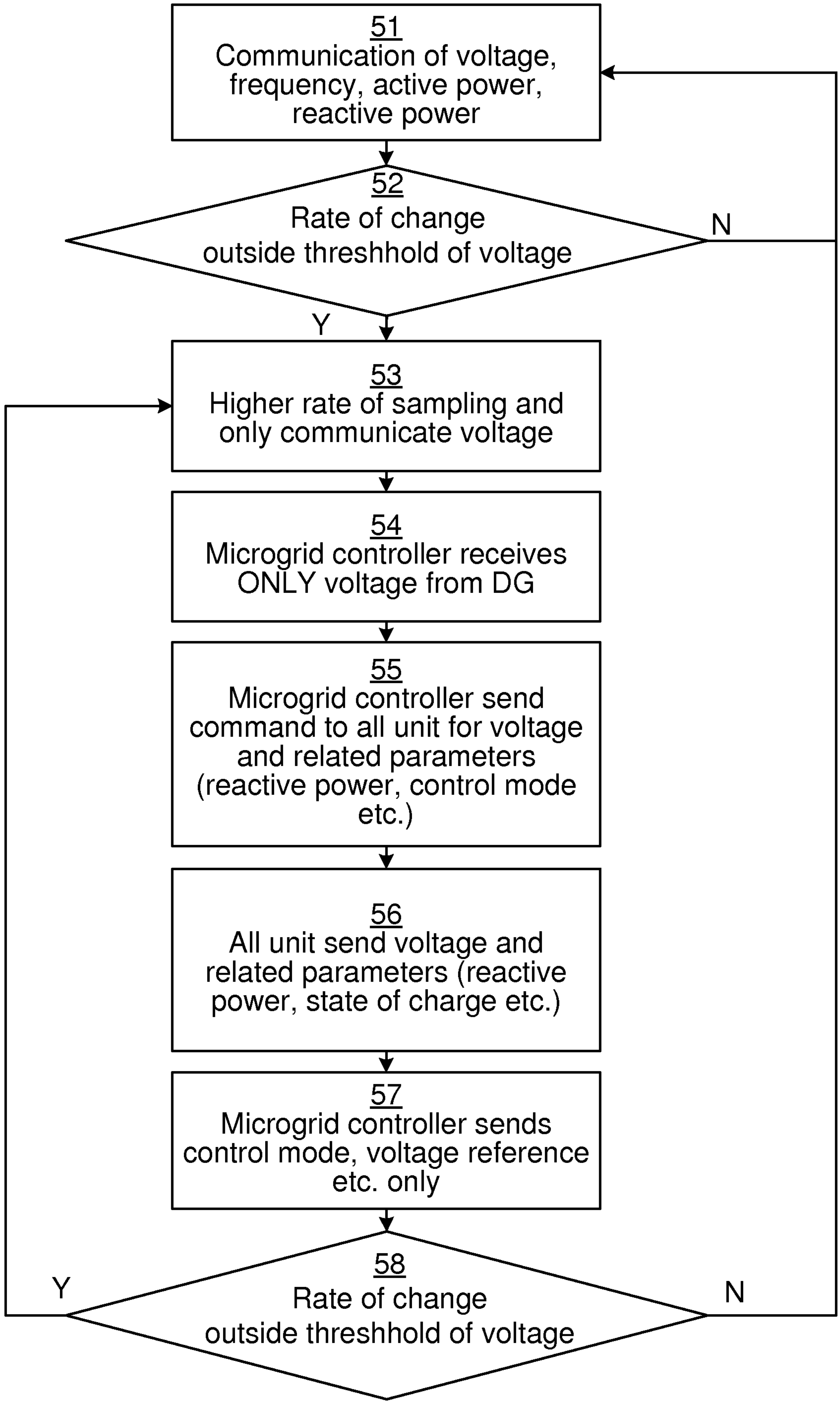
51
Communication of voltage, frequency, active power, reactive power
52
Rate of change outside threshhold of voltage
N
Y
53
Higher rate of sampling and only communicate voltage
54
Microgrid controller receives ONLY voltage from DG
55
Microgrid controller send command to all unit for voltage and related parameters (reactive power, control mode etc.)
56
All unit send voltage and related parameters (reactive power, state of charge etc.)
57
Microgrid controller sends control mode, voltage reference etc. only
58
Rate of change outside threshhold of voltage
Y
N

Fig. 5b

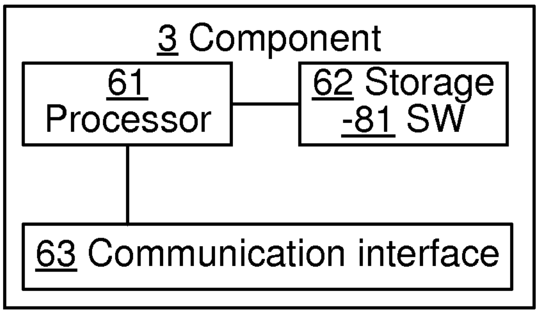

Fig. 6

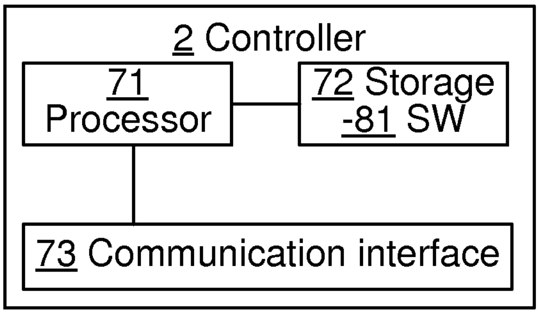

Fig. 7

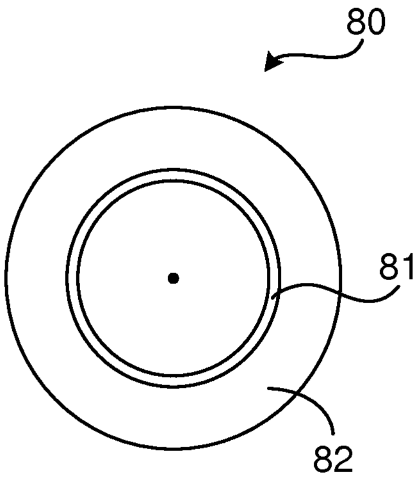

Fig. 8

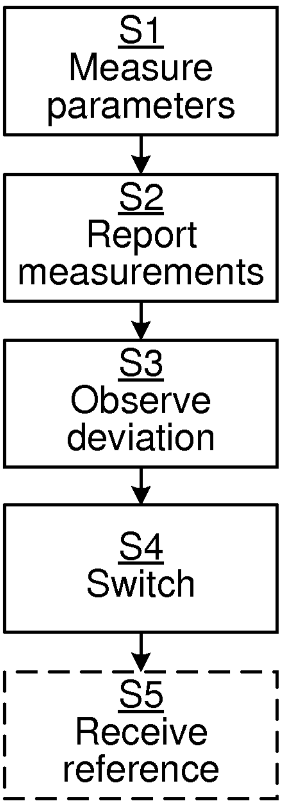

Fig. 9

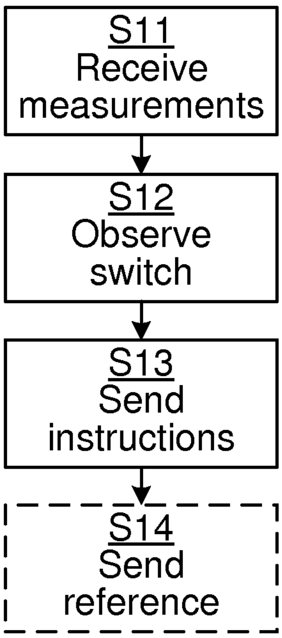

Fig. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/067510

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02J13/00 H02J3/38 G05B23/02 H04W52/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H02J H04L G05B H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 101 184 160 Bl (CATHOLIC UNIV IND ACAD COOP [KR]) 18 September 2012 (2012-09-18)	1,3, 9-14, 17, 19
Y	paragraphs [0025] - [0026], [0031] - [0037]; figures 1-2 paragraph [0053]; figure 4 paragraph [0060] - paragraph [0066]; figure 5 paragraph [0088] - paragraph [0089] -----	2,4-8, 15, 16, 18
Y	WO 00/40976 Al (SIEMENS POWER TRANSM & DISTRIB [US]; GRIFFIN PAUL M JR [US]; JENRETTE) 13 July 2000 (2000-07-13) page 18 - page 27; figure 7 -----	2,5
Y	AU 2012 241 193 Al (ACCENTURE GLOBAL SERVICES LTD) 8 November 2012 (2012-11-08) paragraph [0090] - paragraph [0091] -----	4-8, 15, 16, 18
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 April 2015	20/04/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Chabas, Julien

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	GARGI BAG ET AL: "Low Cost Wireless Sensor Network in Distributed Generation", SMART GRID COMMUNICATIONS (SMARTGRIDCOMM), 2010 FIRST IEEE INTERNATIONAL CONFERENCE ON, IEEE, PISCATAWAY, NJ, USA, 4 October 2010 (2010-10-04), pages 279-284, XP031790239, ISBN: 978-1-4244-6510-1 Sections II and III -----	2,5
A	ANCILLOTTI EMILIO ET AL: "The role of communication systems in smart grids: Architectures, technical solutions and research challenges", COMPUTER COMMUNICATIONS, vol. 36, no. 17, 30 November 2013 (2013-11-30), pages 1665-1697, XP028769084, ISSN: 0140-3664, DOI: 10.1016/J.COMCOM.2013.09.004 Section 2.3.3 Section 5.1.1 Section 5.3.3 Section 5.4 -----	1-19

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2014/067510

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			CA	2353929	A1	13-07-2000
			DE	69905614	D1	03-04-2003
			DE	69905614	T2	18-09-2003
			EP	1141732	A1	10-10-2001
			US	6675071	B1	06-01-2004
			WO	0040976	A1	13-07-2000
AU 2012241193	A1	08-11-2012	NONE			