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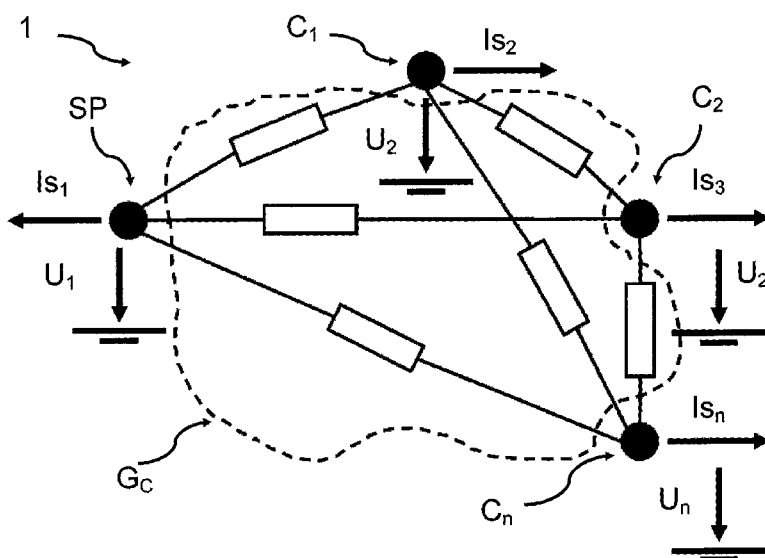


Fig. 3

(57) Abstract: The invention proposes a method for detecting loss or malfunctions in a meshed electrical distribution network. The method comprises a step of receiving average measured voltage values and average measured current values associated with one or more points of supply within the electrical distribution network, and a step of receiving average measured voltage values and average measured current values associated with a plurality of points of consumption within the electrical distribution network. Furthermore, the method comprises the step of calculating first conductivity parameters based on said received average measured voltage values and average measured current values and the step of receiving further average measured voltage values and average measured current values associated with said points of supply within the electrical distribution network. Still further the method comprises the steps of receiving further measured average voltage values and average current values associated with said points of consumption within the electrical distribution network and analyzing said fur-

ther received average measured voltages and average measured currents using said calculated conductivity parameters to detect any deviations of measured currents values from calculated currents values with respect to a given point of consumption or point of supply.

Detection of loss or malfunctions in electrical distribution networks

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The present invention relates to the field of power measurement.

10 Detection of non-technical loss of electrical energy is a problem for any electric utility. If electrical energy is lost due to fraudulent actions, e.g. by use of a connection to the network bypassing the respective electricity meter, it is very difficult for the utility to analyze the location of the theft as well as the time/duration as well as the value of the theft.

15 Although the awareness grows, there exist markets where more than 10 % of the provided energy is consumed by theft or without authorization, thereby causing a significant threat to revenues.

20 Even where accurate values, e.g. measured by smart meters, are available, it has not been possible to accurately detect the location, time and amount of an electrical energy theft.

Still further, it is difficult to provide legal proof of an electrical energy theft after it is detected.

25 Additionally, loss may also be an indication of malfunctions within different power distribution networks, such as on chip-level, apparatus level, isolated networks, e.g. within a vehicle, consumer networks within a plant or a household, or any other appropriate distribution network.

30 There exist solutions which are based on data mining and neural networks. However none of the known methods is accurate enough to provide an accurate indication of the location, time and amount of an electrical energy theft. The majority of these methods are based on comparisons with historical data and load profiles or others. These methods are in general only able to provide an indication that there is a fraudulent action while they do not provide an indication of the theft time and amount.

Furthermore, there exist solutions within a smart meter intended to detect direct manipulation of the meter itself. However, one such smart meter is not able to detect a bypass thereof.

Additionally one may compare measurements by a group of meters which are located in the point of delivery, i.e., within a certain feed, with the combined readings from the meters of the supplied consumers. However, since the load within a distribution network and the portions thereof varies neither the exact location nor the amount of an electrical energy theft can be determined.

Even if one would combine two or more of the different solutions, the resulting solution fails to provide an accurate indication of the location, time and amount of the theft.

It is therefore an object of an embodiment of the invention to provide a method which allows for providing an accurate detection of loss in electrical distribution networks.

The problem is solved by a method for detecting loss or malfunctions in an electrical distribution network. In a first step average measured voltage values and average measured current values associated with one or more points of supply within the electrical distribution network are received. In another step average measured voltage values and average measured current values associated with a plurality of points of consumption within the electrical distribution network are received. Based on said received average measured voltage values and average measured current values conductivity parameters are calculated. Thereafter, in a further step further average measured voltage values and average measured current values from said points of supply within the electrical distribution network are received. In another step further average measured voltage values and average measured current values from said points of consumption within the electrical distribution network are received. Thereafter said further received average measured voltages and average measured currents are analyzed using said calculated conductivity parameters to detect any deviation of measured current values from calculated current values with respect to a given point of consumption or point of supply.

In an embodiment of the invention the received average measured voltage values and average measured current values are averaged over a predetermined period of time.

In a further embodiment of the invention from the analysis of points is determining a location of loss is determined.

In yet another embodiment of the invention from the analysis of points an amount of loss is determined.

- 5 According to still another embodiment of the invention the calculation of conductivity parameters is based on an optimization method.

In a further embodiment the optimization method is selected from the group comprising Quasi Newton, Conjugated Gradient, Simplex Method, Fuzzy Logic, Evolution Methods.

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In a still further embodiment of the invention based on said received further average measured voltage values and further average measured current values second conductivity parameters are calculated and by comparing said first conductivity parameters to said second conductivity parameters are analyzed.

15

According to yet another embodiment the result of the analysis can be visualized.

The problem is also solved by a system adapted for detecting loss or malfunctions in an electrical distribution network. The System comprises a first logical receiver adapted for receiving average measured voltage values and average measured current values associated with one or more points of supply within the electrical distribution network, and a second logical receiver for receiving average measured voltage values and average measured current values associated with a plurality of points of consumption within the electrical distribution network. Additionally said system comprises a Calculation Unit adapted for calculating conductivity parameters based on said received average measured voltage values and average associated with current values. Said first logical Receiver is further adapted for receiving further average measured voltage values and average measured current values associated with said points of supply within the electrical distribution network and said second logical Receiver is further adapted for receiving further measured average voltage values and average current values associated with said points of consumption within the electrical distribution network. Said Calculation Unit is further adapted for analyzing said further received average measured voltages and average measured currents using said calculated conductivity parameters to detect any deviations of measured current values from calculated current values with respect to a given point of consumption or point of supply.

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According to another embodiment of the invention the Calculation Unit is further adapted to average said received average measured voltage values and average measured current values over a predetermined period of time.

- 5 Still in a further embodiment according to the invention said Calculation Unit is further adapted for determining from the analysis of points a location of loss.

In yet another embodiment said Calculation Unit is further adapted for determining from the analysis of points an amount of loss.

10

According to a further embodiment according to the invention said Calculation Unit is further adapted for calculating of conductivity parameters based on an optimization method.

- 15 In a further embodiment of the invention the optimization method is selected from the group comprising Quasi Newton, Conjugated Gradient, Simplex Method, Fuzzy Logic, and Evolution Methods.

Still in another embodiment of the invention said Calculation Unit is further adapted for visualizing the result of the analysis.

20

- In a still further embodiment of the invention said Calculation Unit is further adapted for calculating second conductivity parameters based on said received further average measured voltage values and further average measured current values calculating second conductivity parameters; and said Calculation Unit is further adapted for analyzing by
25 comparing said first conductivity parameters to said second conductivity parameters.

Brief Description of the Figures

- 30 Some embodiments of apparatus and/or methods in accordance with embodiments of the present invention are now described, by way of example only, and with reference to the accompanying drawings, in which:

- Figure 1 shows schematically an exemplary electrical distribution network,
Figure 2 shows schematically an equivalent circuit of the exemplary electrical distribution
35 network of Figure 1,

Figure 3 shows schematically an equivalent circuit of the exemplary electrical distribution network of Figure 1 being used within Detection,

Figure 4 shows a table of numerical results derived by a method according to an embodiment of the invention,

5 Figure 5 shows a graphical representation of numerical results derived by a method according to an embodiment of the invention,

Figure 6 shows an exemplary flow diagram according to different embodiments of the invention,

Figure 7 shows schematically exemplary system according to the invention,

10 Figure 8 shows a table of numerical results derived by a method according to an embodiment of the invention, and

Figure 9 shows a graphical representation of numerical results derived by a method according to an embodiment of the invention.

15 The following embodiments of the invention will be described with respect to the figures.

In Figure 1 an exemplary electrical distribution network 1 in one embodiment is shown.

20 Within said network 1, a power supplier SP is indicated on the right side of the figure. The power supplier SP delivers a current I_1 at a certain potential U_1 towards the network.

Furthermore, said network 1 comprises a plurality of consumers C_1 , C_2 ... and C_n , where n represents a predetermined integer.

25 Each Consumer consumes at a certain voltage (or potential difference) certain current. Said current may be understood as a measured current at a measured voltage. For example, Consumer C_1 consumes power which may be evaluated by the measured current I_2 and the measured voltage U_2 , Consumer C_2 consumes power which may be evaluated by the measured current I_3 and the measured voltage U_3 and Consumer C_n consumes power which may be evaluated by the measured current I_n and the measured voltage U_n .

30 Said network 1 may be meshed in any given arrangement as indicated in the Figure, i.e. it may even comprise loops, i.e. connections of different consumers via different pathes. I.e. Consumer C_1 is interconnected to Consumer C_2 or C_n via a first path P1 (dotted line) and via a second path P2 (dashed line).

35

Meshed network topologies are complex and do not allow for adopting solutions known to hierarchal organized networks.

5 The distribution network can be completely unknown in its topology and conductivity for the procedure.

Every load, be it consumption or supply, in the network leads to a negative or positive voltage drop that has an influence on the voltages in the whole network.

10 The network of Figure 1 and the associated loads may be described as a network of conductance as shown in Figure 2.

There, the plurality of consumers C_1 , C_2 and C_n and the Power Supplier SP are connected one another by certain conductance.

15 A consumer represents a point of consumption while a power supplier represents a point of supply.

The network of conductance is represented by a dashed cloud G_C .

20 Within said network each supplier and each consumer measures the voltage and current. It is understood that these measured voltage and current may also be averages themselves, i.e. averages over a given period.

25 For convenience, and without loss of generality, it will be assumed in the following that the measured potential and currents are measured at the same time. If the measured potential and currents concern averages themselves it is assumed that they are as well averages with respect to the same time period, e.g. with respect to a certain amount of minutes, e.g. 1 min, 5 min, 15 min, 30 min, 60 min, ...

30 Now, assuming that there is a conductance in between each element – supplier(s) and consumer(s) – in the electrical distribution network 1, one can state, that there is a voltage drop across each element. Said voltage drop may be calculated in the following manner on basis of the measured value across each element of the electrical distribution network:

$$\begin{aligned}\delta U_{11} &= U_1 - U_1 \\ &\vdots \\ \delta U_{1n} &= U_1 - U_n\end{aligned}$$

Based on the derived voltage drop, one may determine a simulated current through each element as follows:

$$\begin{aligned}I_{s1} &= g_{11} * \delta U_{11} + g_{12} * \delta U_{12} + \dots + g_{1n} * \delta U_{1n} \\ &\vdots \\ I_{sn} &= g_{n1} * \delta U_{n1} + g_{n2} * \delta U_{n2} + \dots + g_{nn} * \delta U_{nn}\end{aligned}$$

where I_s represents a simulated current through a network element.

In this instance, I_{s1} represents a simulated current from the power supplier SP; I_{s2} represents a simulated current to Consumer C_1 , I_{s3} represents a simulated current to Consumer C_2 , and I_{sn} represents a simulated current to Consumer C_n .

These simulated currents are based on the network of conductance expressed as a matrix as follows:

$$G_C = \begin{pmatrix} g_{11} & \dots & g_{1n} \\ \vdots & \ddots & \vdots \\ g_{n1} & \dots & g_{nn} \end{pmatrix}$$

The conductivity matrix G_C is determined based on the following understanding:

$$\begin{aligned}Err(t) &= (I_1 - I_{s1})^2 + \dots + (I_n - I_{sn})^2 \\ Err(t_1 \dots t_k) &= Err(t_1) + Err(t_2) + \dots + Err(t_k)\end{aligned}$$

where $t_1 \dots t_k$ indicates a time period.

It can be shown that the number of criteria provided by the two equations above needs to be sufficiently high such that the number of unknown matrix elements may be calculated.

The number of unknown matrix elements depends on the size of the network which impacts the coupling of matrix elements. I.e. the larger the network is the less impact is to expected from elements within the network elements which are distant to each other. This finding may be used to assume that a certain number of matrix elements are held to be 0, i.e. there is no need to determine these matrix elements.

Assuming a smaller network and, hence, a stronger coupling, the number of unknown matrix elements p may be determined as follows:

$$p = 0.5 * n * (n + 1),$$

where n is the number of criteria.

5

Assuming a larger network and, hence a looser coupling, the number of unknown matrix elements p may be defined as follows:

$$p < 0.5 * n * 50.$$

10 Here, the calculation is based on an estimated band matrix. As can be seen from the above, it is assumed that once a concerned network comprises more than 50 nodes, one may assume loose coupling. This estimation is a good assumption and reduces the overall necessary calculations. Nevertheless, if calculation time is of no concern, there is no necessity to assume loose coupling.

15

It can be shown that the number of criteria n given by equations $\text{Err}(t)$ and $\text{Err}(t_1 \dots t_k)$ are equal to or higher than the number of unknown matrix elements p .

Per time period $t_1 \dots t_k$, the number of criteria is n . By considering the above inequality

20 $p < 0.5 * n * 50$ in case of loose coupling, one would need 25 time periods for the calculation of G_C .

The unknown matrix elements g_{mn} are calculated using any appropriate optimization methods, such as Quasi Newton, Conjugated Gradient, Simplex Method, Fuzzy Logic,
25 Evolution Methods, etc.

The optimization method may be chosen such that further parameters are taken into account such as time necessity and / or accuracy and / or efficiency.

30 It is understood that the intended target of the optimization is to minimize $\text{Err}(t_1 \dots t_k)$ to be as close to zero as possible by varying the matrix elements g_{mn} until the intended target given is reached.

After the matrix is determined, the detection of loss may be performed.

35

The analysis of time and location is based on the following equations:

$$\begin{aligned}
Err_1(t_1) &= (I_1 - Is_1)^2 \\
&\vdots \\
Err_n(t_n) &= (I_n - Is_n)^2
\end{aligned}$$

While the analysis on an amount of an electrical energy theft is based on the following equations:

$$\begin{aligned}
If_n(t_1) &= (I_1 - Is_1) \\
&\vdots \\
If_n(t_n) &= (I_n - Is_n)
\end{aligned}$$

Now turning to a network comprising a Supplier SP and 3 Customers C_1 , C_2 and C_n as indicated in Figure 1, and assuming that the elements within the conductance matrix G_C are already determined, it is assumed that the values displayed in the table shown in Figure 4 are received and further processed.

Within a first time period T_1 average currents and average voltage drops from the Supplier and the Customers are received. From these received values, the differential voltage drops $\delta U_{11} \dots \delta U_{1n}$ are determined as well as the simulated currents $Is_1 \dots Is_n$ with respect to each supplier and consumer.

In theory, the simulated current and the measured current shall be identical. However, due to some numerical computation as well as varying voltages and varying load, a certain amount of deviation may be assumed as normal. In the present case it is assumed that a deviation within 5 % is within normalcy. This value may be subject to further fine tuning depending on numerical accuracy, time period for averaging, network size, etc.

The same is repeated for further time periods $T_2 \dots T_7$.

Now turning to Time period T_3 . There it can be seen that Consumer C_2 shows a deviation of more than 5 %. While the measured values leads to a simulated current Is_2 of 5,9831162, the measured current displays only 2,017319.

Hence, the above approach not only allows for detecting the location of a theft, customer 2, but also for quantifying the theft as almost 4 units within the time period T_3 .

The results shown in the table may also be visualized in Figure 5. There it can easily be detected that within time period T_3 customer 2 has consumed more power than measured.

Thus an employee of the power distributor may easily detect the fraud and trigger a service employee to check the respective installation and / or to instigate legal actions. This may nevertheless also be automated and once a fraud is detected it would be possible to instruct services employees to check in an automated manner as well as instigating legal actions by means of a form letter.

Hence, a method according to the invention may be summarized as follows:

Average measured voltage values U_1 and average measured current values I_1 associated with one or more points of supply - such as supply locations - SP within the electrical distribution network 1 are received in a step 100.

In a further step 200 average measured voltage values U_2, U_3, U_n and average measured current values I_2, I_3, I_n associated with a plurality of points of consumption – such as all consumer locations - C_1, C_2, C_n within the electrical distribution network 1 are received.

The steps 100 and 200 are repeated as long as necessary to provide enough criteria for calculating the matrix elements. Therefore, it is decided in a step 250 whether there are sufficient criteria available or not. If the number is not sufficient, the steps 100 and 200 are performed another time (No-branch) while if the number is sufficient, the method continues with step 300 (Yes-branch).

Based on said received average measured voltage values U_1, U_2, U_3, U_n and average measured current values I_1, I_2, I_3, I_n first conductivity parameters of Matrix G_C are calculated in a step 300.

Once the first conductivity parameters are determined further average measured voltage values U_1 and average current values I_1 associated with said points of supply SP within the electrical distribution network 1 are received in a step 400 and in a step 500 further average measured voltage values U_2, U_3, U_n and average measured current values I_2, I_3, I_n associated with said points of consumption C_1, C_2, C_n within the electrical distribution network 1 are received.

Thereupon, said further received average measured voltages and average measured currents using said calculated first conductivity parameters are analyzed in step 600 to detect any deviation of measured current values from calculated current values with respect to a given point of consumption or point of supply.

5

It is understood that the calculation may need updates from time to time to reflect a varying electrical distribution network 1. The update may be triggered by construction works in the distribution network 1 and / or may be repeated periodically, e.g. every week, every month, etc. This update may lead to a periodical (re-)start of the method.

10

In an embodiment of the invention the received measured average voltage values and average current values are averaged over a predetermined period of time. A predetermined time may be any suitable time period, e.g. 1 min, 5 min, 15 min, 30 min, 60 min,

15 In an embodiment, the method may be complemented by a step 700 following analysis, said step concerning determination from the analysis of points a location of loss. This determination may be based on a certain threshold, i.e. once a certain threshold is exceeded the deviation is determined to be a theft. Such a threshold may be any suitable value, e.g. 5 %. Said value may be subject to further fine-tuning.

20

In still a further embodiment, the step of analyzing 600 may be followed by a step 800 in which it is determined from the analysis of points an amount of loss. This amount is based on the deviation of calculated and measured current values of the respective network element.

25 In a still further embodiment the calculation of conductivity parameters of step 300 is based on an optimization method. The unknown matrix elements g_{mn} are calculated through any appropriate optimization methods, such as Quasi Newton, Conjugated Gradient, Simplex Method, Fuzzy Logic, Evolution Methods, etc.

30 In a still further embodiment the method also comprises a step 900 in which the results of the analysis provided in steps 600 and / or 700 and / or 800 are visualized.

Turning now to a different field of application, the invention may also be used for detection of malfunctions.

35

Malfunctions can be of two types, i.e. a quick degradation as it is experienced by a line cut or a short cut and slow degradation as it is experienced when lines or devices are showing a change in resistance e.g. due to aging processes.

- 5 Slow and quick as used herein are however not a fixed sizes but are connected to the methods and the repeated use.

Malfunctions lead to change in conductivity in between the concerned nodes. Suppose that Path P1 in Figure is damaged such that there is an increased resistance or that the line is
10 completely interrupted.

A malfunction representing a quick degradation will be perceived as a change in error function in the process as described before. Quick in that sense may be within a small number of time periods compared to the number of time periods forming base of calculation
15 of conductivity matrix. E.g. if the number of time periods necessary for calculating the conductivity matrix is 25 then a quick degradation may be within 10 or less time periods.

As can be seen in Figures 8 and 9 the deviations as derived in the process described before are rather low for different time periods T_1 to T_6 . However, in time period T_7 at two nodes
20 represented by Customer C_2 and C_3 almost the same deviation is experienced. As the deviation is not pertaining to a single customer but to two nodes, it may be deduced that the interconnection between Customer C_2 and C_3 is damaged, i.e. it experiences a fast degradation. This determination may be based on a certain threshold, i.e. once a certain threshold is exceeded the deviation is determined to be a theft. Such a threshold may be any
25 suitable value, e.g. 5 %. Said value may be subject to further fine-tuning.

Hence, the analysis performed in step 600 may provide both an understanding were power is lost and an understanding were lines are malfunctioning due to fast degradation events.

30 However if the malfunction represents a slow degradation such as when a customer or a link in between customers and/or a supplier is aging leading to a slow change of resistance, the conductivity matrix G_c will follow such a change and a malfunction representing a slow degradation may not be derivable via error functions. Slow in that sense may be within a certain number of time periods compared to the number of time periods forming base of
35 calculation of conductivity matrix. E.g. if the number of time periods necessary for calculating the conductivity matrix is 25 then a slow degradation may be within 10 or more time periods.

However, such a slow degradation can rather easily be detected by comparing conductivity matrixes over time.

5 Suppose a first matrix $G_{c,1}$ with first conductivity parameters is calculated at a point in time t_1 and another matrix $G_{c,2}$ with second conductivity parameters is calculated at a point in time t_2 which is different from t_1 than if no change in the distribution network is to be observed the conductivity matrix should almost be identical.

10 However, if the lines or a customer or a supplies experiences a slow degradation than the first and second conductivity parameters pertaining to a malfunctioning customer or supplier, and / or lines in between customer(s) and/or suppliers, will deviate over time.

Hence, by comparing conductivity matrixes respectively parameters pertaining to a second
15 time period to previous ones, i.e. conductivity matrixes respectively parameters pertaining to a first time period, it is possible to detect even malfunctions representing slow degradations. This determination may be based on a certain threshold, i.e. once a certain threshold is exceeded the deviation is determined to be a theft. Such a threshold may be any suitable value, e.g. 5 %. Said value may be subject to further fine-tuning.

20 Obviously, detecting slow degradation may be performed stand alone as it is not necessary to calculate current values based on calculated conductivity parameters and received average measured voltages and average measured currents.

25 On the other hand it may easily be integrated as conductivity parameters calculation may be performed repeatedly.

In another embodiment of the invention, the above method is incorporated in a system 10 adapted for detecting loss in an electrical distribution network.

30 Such a system 10 may be embodied in a computer or a controller comprising a first logical receiver RX_{SP} adapted for receiving average measured voltage values and average measured current values associated with one or more point of supply within the electrical distribution network, and a second logical Receiver RX_C for receiving average measured
35 voltage values and average measured current values associated with a plurality of points of consumption within the electrical distribution network 1.

Said logical receivers RX_{sp} and RX_c may be embodied in one or more network cards connected to respective meters located at the Supplier(s) SP and Customers C_1, C_2, C_n . As indicated said logical receivers RX_{sp} and RX_c may be embodied in a common physical Receiver NIC.

Said system 10 also comprises a Calculation Unit ALU adapted for calculating first conductivity parameters based on said received average measured voltage values and average measured current values. A respective Calculation Unit ALU may be any kind of a microprocessor, microcontroller, FPGA, ASIC, or the like.

Said first logical receiver RX_{sp} is further adapted for Receiving further measured average voltage values and average current values associated with said points of supply SP within the electrical distribution network 1 and said second logical Receiver RX_c is further adapted for Receiving further measured average voltage values and average current values associated with said points of consumption C_1, C_2, C_n within the electrical distribution network 1.

Said logical receivers RX_{sp} and RX_c may be embodied in one or more network cards connected to respective meters located at the Supplier(s) SP and Customers C_1, C_2, C_n . As indicated said logical receivers RX_{sp} and RX_c may be embodied in a common physical Receiver NIC.

Said Calculation Unit ALU is further adapted for analyzing said further received average measured voltages and average measured currents using said calculated conductivity parameters to detect any deviation of measured current values from calculated current values with respect to a given point of consumption or point of supply.

If the ALU does not provide a memory sufficient for calculating, a conventional memory MEM may be provided which allows for storing of results, calculation intermediates and for retrieving said data, either for calculation and / or for displaying purposes. In particular, said memory may be arranged for storing one or more previously calculated conductivity parameter matrixes for detecting deviations pertaining to slow degradation of connections.

In a further embodiment of the invention the Calculation Unit ALU is further adapted to average said received measured average voltage values and average current values over a predetermined period of time.

- 5 In still a further embodiment of the invention, the Calculation Unit ALU is further adapted for determining from the analysis of points a location of loss.

In yet another embodiment of the invention the Calculation Unit ALU is further adapted for determining from the analysis of points an amount of loss.

10

According to another embodiment of the invention the Calculation Unit ALU is further adapted for calculating of conductivity parameters based on an optimization method. The optimization method is selected from the group comprising Quasi Newton, Conjugated Gradient, Simplex Method, Fuzzy Logic, and Evolution Methods.

15

In a further embodiment of the invention the Calculation Unit ALU is further adapted for calculating second conductivity parameters based on said received further average measured voltage values and further average measured current values calculating second conductivity parameters and the Calculation Unit ALU is further adapted for analyzing by
20 comparing said first conductivity parameters to said second conductivity parameters.

It is however understood, that any appropriate method may be chosen. The optimization method may be chosen such that further parameters are taken into account such as time necessity and / or accuracy and / or efficiency.

25

The target of the optimization is to minimize Error, i.e. while calculating the matrix elements, the matrix elements are varied such that the difference between a measured current and a simulated current is minimized and eventually reaches 0, i.e. there is no error but the model is a true equivalent circuit of the electrical distribution network 1.

30

Still in another embodiment of the invention the Calculation Unit ALU is further adapted for visualizing the result of the analysis.

Such visualization may be performed by an internal WWW-Server which offers graphical
35 data based on the calculations via a Transmitter TX of a network interface card NIC or it may be provided as a video-signal DIS directed to monitor.

By means of the invention it is now possible without knowing the exact network set-up of the distribution network to detect theft merely by receiving measured values and calculating. Thereby, it is not only achieved that the method is inexpensive but also that the method does
5 not need special trained personnel.

The accuracy is highly increased by allowing detecting not only the time of theft but also detecting the location and amount of theft.

10 While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments.

Other variations to be disclosed embodiments can be understood and effected by those
15 skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference
20 signs in the claims should not be construed as limiting scope.

The present invention may be embodied in other specific apparatus and/or methods. The described embodiments are to be considered in all respects as only illustrative and not
25 restrictive.

It should be appreciated by those skilled in the art that any block diagrams herein represent conceptual views of illustrative circuitry embodying the principles of the invention.

In particular, the scope of the invention is indicated by the appended claims rather than by
30 the description and figures herein. All changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

Claims

1. Method for detecting loss or malfunctions in a meshed electrical distribution network, comprising
 - 5 receiving average measured voltage values and average measured current values associated with one or more points of supply within the electrical distribution network;
 - receiving average measured voltage values and average measured current values associated with a plurality of points of consumption within the electrical
 - 10 distribution network;
 - based on said received average measured voltage values and average measured current values calculating first conductivity parameters;
 - receiving further average measured voltage values and average measured current values associated with said points of supply within the electrical
 - 15 distribution network;
 - receiving further average measured voltage values and average measured current values from said points of consumption within the electrical distribution network; and
 - analyzing said further received average measured voltage values and
 - 20 average measured current values using said first calculated conductivity parameters to detect any deviations of measured current values from calculated current values with respect to a given point of consumption or point of supply.
- 25 2. Method according to claim 1, wherein the received average measured voltage values and average measured current values are averaged over a predetermined period of time.
3. Method according to claim 1 or 2, further comprising determining from the analysis of
- 30 points a location of loss.
4. Method according to any of the preceding claims, further comprising determining from the analysis of points an amount of loss.

5. Method according to any of the preceding claims, wherein the calculation of conductivity parameters is based on an optimization method.
6. Method according to claim 5, wherein the optimization method is selected from the group comprising Quasi Newton, Conjugated Gradient, Simplex Method, Fuzzy Logic, Evolution Methods.
7. Method according to any of the preceding claims, further comprising visualizing the result of the analysis.
8. Method according to any of the preceding claims, further comprising the steps of
- based on said received further average measured voltage values and further average measured current values calculating second conductivity parameters;
 - analyzing by comparing said first conductivity parameters to said second conductivity parameters.
9. System adapted for detecting loss or malfunctions in a meshed electrical distribution network, comprising:
- a first logical receiver adapted for receiving average measured voltage values and average current values associated with one or more points of supply within the electrical distribution network,
 - a second logical receiver for receiving average measured voltage values and average measured current values associated with a plurality of points of consumption within the electrical distribution network,
 - a Calculation Unit adapted for calculating first conductivity parameters based on said received average measured voltage values and average measured current values,
- wherein said first logical Receiver is further adapted for receiving further average measured voltage values and average measured current values associated with said points of supply within the electrical distribution network
- wherein said second logical Receiver is further adapted for receiving further average measured voltage values and average measured current values associated with said points of consumption within the electrical distribution network
- wherein said Calculation Unit is further adapted for analyzing said further received average measured voltages and average measured currents using

said calculated conductivity parameters to detect any deviation of measured current values from calculated current values with respect to a given point of consumption or point of supply.

- 5 10. System according to claim 9, wherein the Calculation Unit is further adapted to average said received average measured voltage values and average measured current values over a predetermined period of time.
- 10 11. System according to claim 9 or 10, wherein said Calculation Unit is further adapted for determining from the analysis of points a location of loss.
12. System according to any of the preceding claims 9 to 11, wherein said Calculation Unit is further adapted for determining from the analysis of points an amount of loss.
- 15 13. System according to any of the preceding claims 9 to 12, wherein said Calculation Unit is further adapted for calculating of conductivity parameters based on an optimization method.
- 20 14. System according to claim 13, wherein the optimization method is selected from the group comprising Quasi Newton, Conjugated Gradient, Simplex Method, Fuzzy Logic, Evolution Methods.
15. System according to any of the preceding claims 9 to 14, wherein said Calculation Unit is further adapted for visualizing the result of the analysis.
- 25 16. System according to any of the preceding claims 9 to 15,
- wherein said Calculation Unit is further adapted for calculating second conductivity parameters based on said received further average measured voltage values and further average measured current values calculating second conductivity parameters; and
 - wherein said Calculation Unit is further adapted for analyzing by comparing said first conductivity parameters to said second conductivity parameters.
- 30

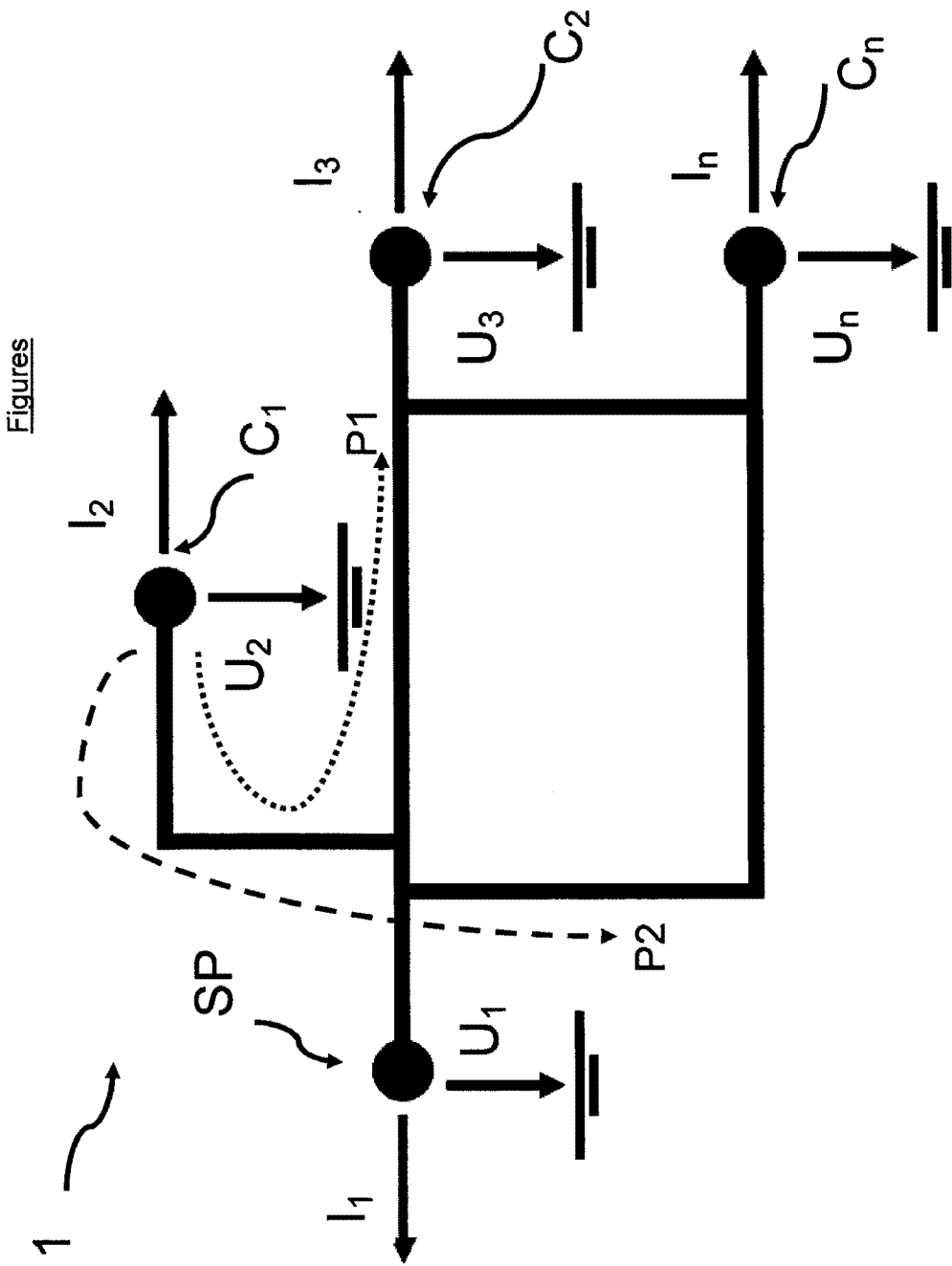


Fig .1

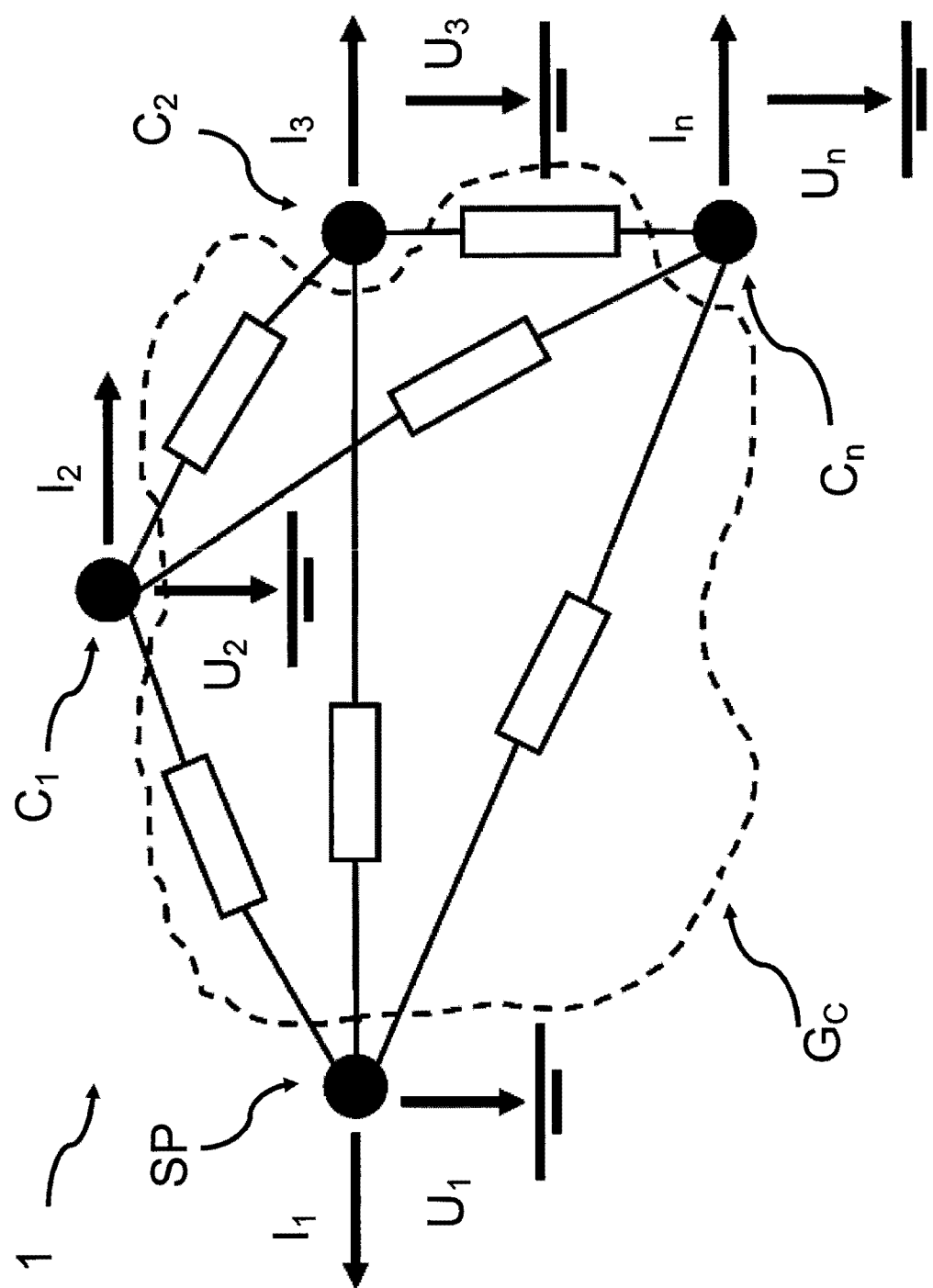


Fig. 2

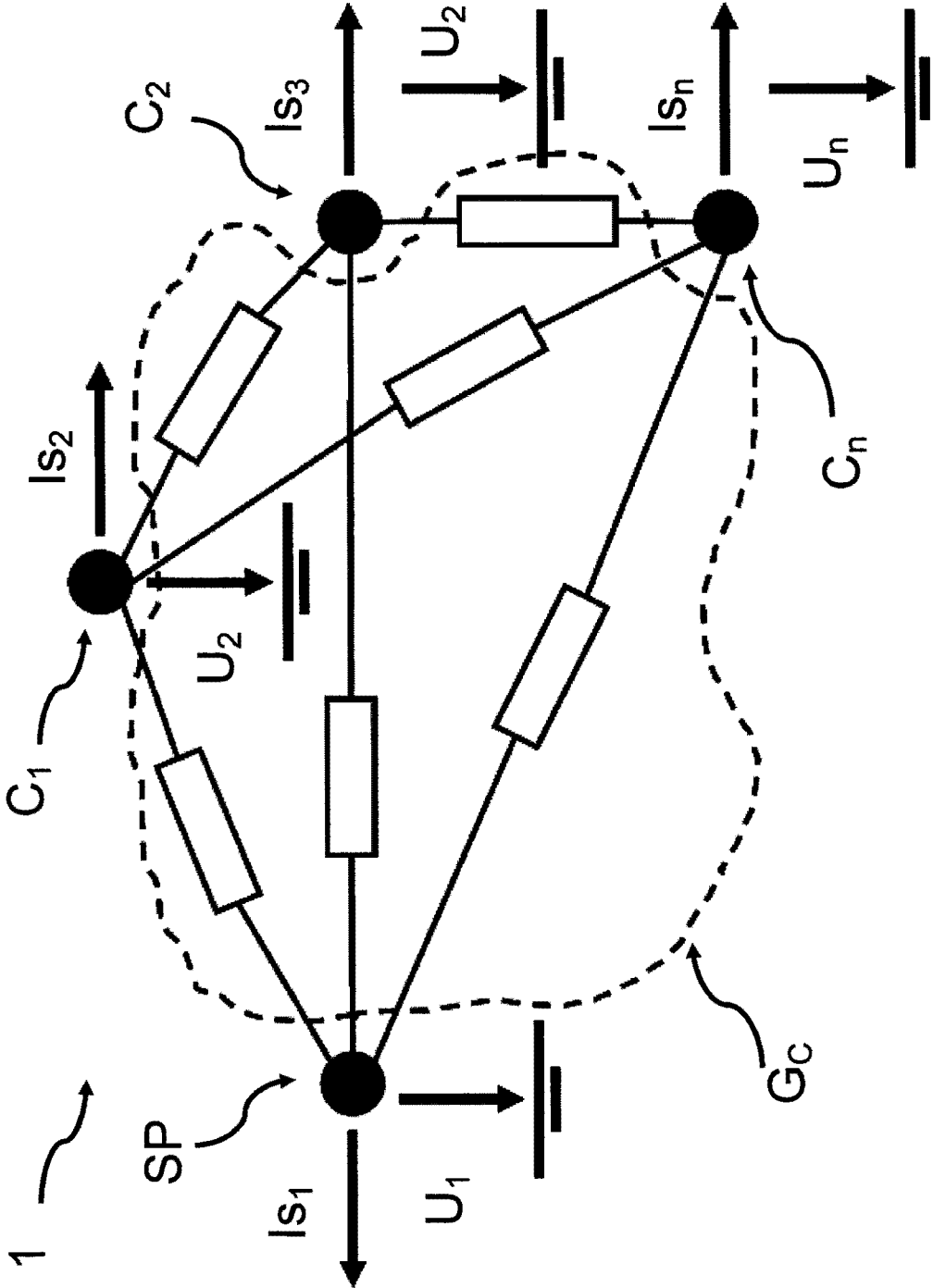


Fig. 3

Time	Voltage / Potential				Current	1,00%			
T1	delta U1	delta U2	delta U3	delta U4	Is	I	Err_n (t)	I_fraud	Err (t)
	0	16,5	18	26			16,56862065		
1	-0,0001	-0,6659	-0,6665	0,00036	-22,97481	-22,9303851	0,001973355	0,04	
2	-0,6659	1,33523	-0,6671	0,00028	10,03087	10,05255144	0,000470233	0,02	
3	-0,6665	-0,6671	2,33726	-0,9999	5,06734	5,015564881	0,002680672	0,05	
4	0,00036	0,00028	-0,9999	1,00003	8,008143	8,018657948	0,00011057	0,01	0,005234831
T2	delta U1	delta U2	delta U3	delta U4					
	0	12,5	19	29					
1	-0,0001	-0,6659	-0,6665	0,00036	-20,97645	-21,0006373	0,000585008	0,02	
2	-0,6659	1,33523	-0,6671	0,00028	4,023681	4,003794445	0,000395464	0,02	
3	-0,6665	-0,6671	2,33726	-0,9999	7,073425	7,049554964	0,00056979	0,02	
4	0,00036	0,00028	-0,9999	1,00003	10,00727	10,06997941	0,003932341	0,06	0,005482603
T3	delta U1	delta U2	delta U3	delta U4					
	0	3	4,5	6,5					
1	-0,0001	-0,6659	-0,6665	0,00036	-4,994525	-4,99389059	4,01844E-07	0,00	
2	-0,6659	1,33523	-0,6671	0,00028	1,00558	0,996330061	8,55676E-05	0,01	
3	-0,6665	-0,6671	2,33726	-0,9999	2,017319	5,9831162	15,72754431	3,97	
4	0,00036	0,00028	-0,9999	1,00003	2,001721	1,996864266	2,35831E-05	0,00	15,72765386
T4	delta U1	delta U2	delta U3	delta U4					
	0	2	2,5	3,5					
1	-0,0001	-0,6659	-0,6665	0,00036	-2,996754	-3,01169165	0,000223139	0,01	
2	-0,6659	1,33523	-0,6671	0,00028	1,003702	1,000933883	7,66269E-06	0,00	
3	-0,6665	-0,6671	2,33726	-0,9999	1,009462	0,991614873	0,000318525	0,02	
4	0,00036	0,00028	-0,9999	1,00003	1,001045	0,992367382	7,53082E-05	0,01	0,000624635
T5	delta U1	delta U2	delta U3	delta U4					
	0	100,5	141	207					
1	-0,0001	-0,6659	-0,6665	0,00036	-160,8225	-160,461564	0,130272344	0,36	
2	-0,6659	1,33523	-0,6671	0,00028	40,18813	40,04202607	0,021345629	0,15	
3	-0,6665	-0,6671	2,33726	-0,9999	55,54036	55,37477712	0,027418522	0,17	
4	0,00036	0,00028	-0,9999	1,00003	66,05584	66,02662999	0,000853493	0,03	0,179889988
T6	delta U1	delta U2	delta U3	delta U4					
	0	17	32,5	42,5					
1	-0,0001	-0,6659	-0,6665	0,00036	-32,96545	-33,7457328	0,608847126	0,78	
2	-0,6659	1,33523	-0,6671	0,00028	1,030196	1,004974519	0,000636102	0,03	
3	-0,6665	-0,6671	2,33726	-0,9999	22,12644	22,13568487	8,538E-05	0,01	
4	0,00036	0,00028	-0,9999	1,00003	10,01097	9,972957046	0,001444687	0,04	0,611013295
T7	delta U1	delta U2	delta U3	delta U4					
	0	19,5	37,5	40,5					
1	-0,0001	-0,6659	-0,6665	0,00036	-37,96325	-38,1141622	0,022774895	0,15	
2	-0,6659	1,33523	-0,6671	0,00028	1,03223	1,006009173	0,000687525	0,03	
3	-0,6665	-0,6671	2,33726	-0,9999	34,1447	34,02313622	0,0147779	0,12	
4	0,00036	0,00028	-0,9999	1,00003	3,012328	2,990393717	0,000481113	0,02	0,038721433

Fig. 4

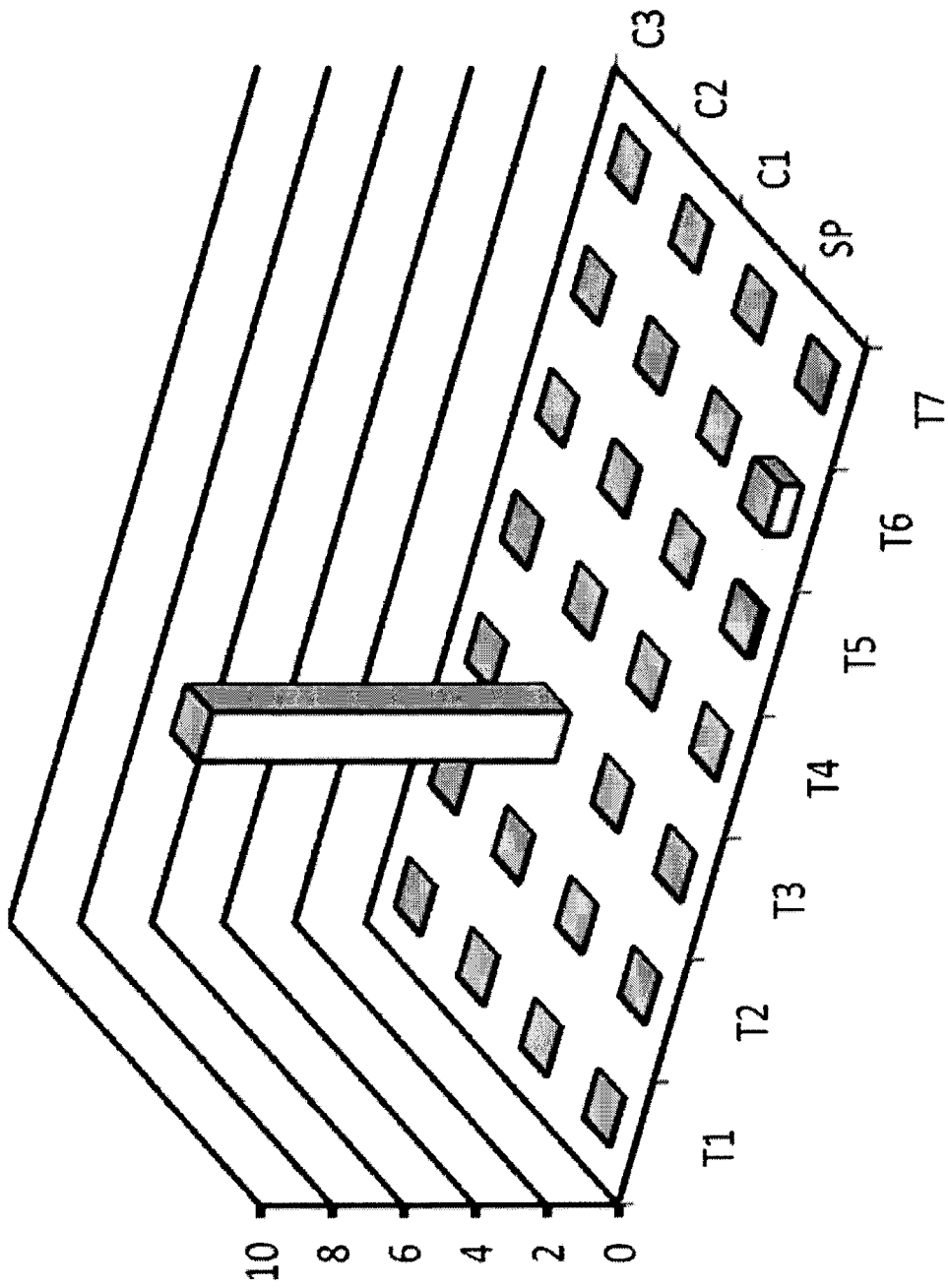


Fig. 5

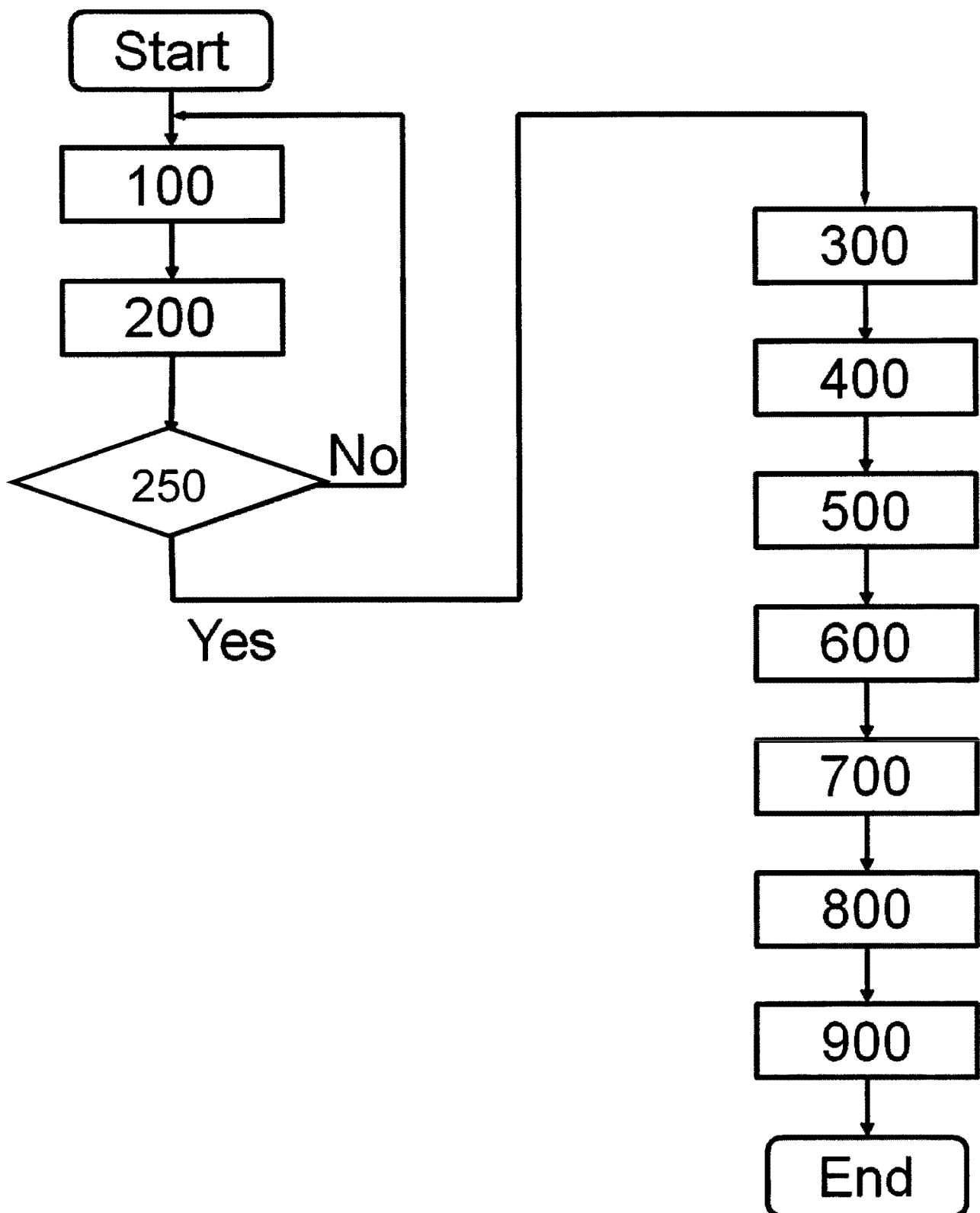


Fig. 6

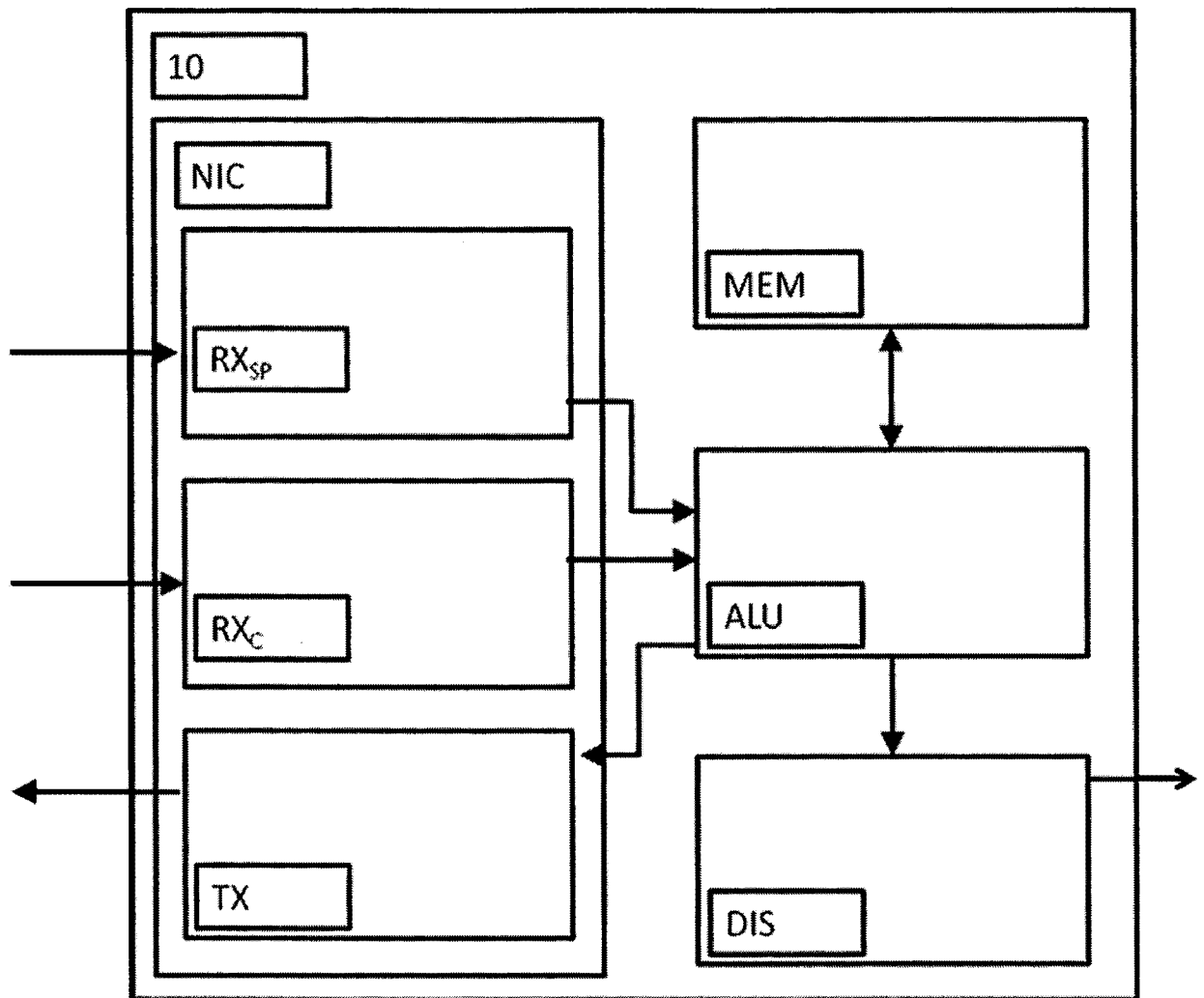


Fig. 7

Time	Voltage/Potential				Current		1,00%	Err_n(t)	Err (t)
	delta U1	delta U2	delta U3	delta U4	I _{II}	I _I			
T1	0	16,5	18	26				5,42555982	
	1	-0,0001	-0,6658	-0,6675	-0,0002	-23,00598	-22,87187	0,01798655	
	2	-0,6658	1,3326	-0,6661	-0,002	9,947022	9,97966088	0,0010653	
	3	-0,6675	-0,6661	2,33116	-1,0002	4,967025	5,00605173	0,00152309	
	4	-0,0002	-0,002	-1,0002	0,9997	7,9570743	7,99389454	0,00135573	0,02193067
	delta U1	delta U2	delta U3	delta U4					
T2	0	12,5	19	29					
	1	-0,0001	-0,6658	-0,6675	-0,0002	-21,01083	-20,989536	0,00045337	
	2	-0,6658	1,3326	-0,6661	-0,002	3,944368	3,99931412	0,00301907	
	3	-0,6675	-0,6661	2,33116	-1,0002	6,9619486	7,01848841	0,00319675	
	4	-0,0002	-0,002	-1,0002	0,9997	9,9642021	9,98244291	0,00033273	0,00700192
	delta U1	delta U2	delta U3	delta U4					
T3	0	3	4,5	6,5					
	1	-0,0001	-0,6658	-0,6675	-0,0002	-5,002454	-4,9833162	0,00036627	
	2	-0,6658	1,3326	-0,6661	-0,002	0,9875402	0,99714985	9,2346E-05	
	3	-0,6675	-0,6661	2,33116	-1,0002	1,9910679	2,00190642	0,00011747	
	4	-0,0002	-0,002	-1,0002	0,9997	1,9915395	2,00029822	7,6716E-05	0,0006528
	delta U1	delta U2	delta U3	delta U4					
T4	0	2	2,5	3,5					
	1	-0,0001	-0,6658	-0,6675	-0,0002	-3,001056	-3,0276972	0,00070973	
	2	-0,6658	1,3326	-0,6661	-0,002	0,9930697	0,99519925	4,5351E-06	
	3	-0,6675	-0,6661	2,33116	-1,0002	0,9952586	1,00051369	2,7616E-05	
	4	-0,0002	-0,002	-1,0002	0,9997	0,9946563	0,99351642	1,2993E-06	0,00074318
	delta U1	delta U2	delta U3	delta U4					
T5	0	100,5	141	207					
	1	-0,0001	-0,6658	-0,6675	-0,0002	-161,0721	-160,07041	1,00330135	
	2	-0,6658	1,3326	-0,6661	-0,002	39,598329	39,863964	0,07056171	
	3	-0,6675	-0,6661	2,33116	-1,0002	54,723599	54,8423558	0,01410318	
	4	-0,0002	-0,002	-1,0002	0,9997	65,720899	66,2560116	0,28634501	1,37431125
	delta U1	delta U2	delta U3	delta U4					
T6	0	17	32,5	42,5					
	1	-0,0001	-0,6658	-0,6675	-0,0002	-33,02078	-32,865025	0,02425838	
	2	-0,6658	1,3326	-0,6661	-0,002	0,9222386	0,99900957	0,00589379	
	3	-0,6675	-0,6661	2,33116	-1,0002	21,93331	22,0179134	0,0071577	
	4	-0,0002	-0,002	-1,0002	0,9997	9,9494932	9,96035563	0,00011799	0,03742787
	delta U1	delta U2	delta U3	delta U4					
T7	0	19,5	37,5	42					
	1	-0,0001	-0,6658	-0,6675	-0,0002	-38,02261	-38,259587	0,05616006	
	2	-0,6658	1,3326	-0,6661	-0,002	0,9245634	1,00506677	0,0064808	
	3	-0,6675	-0,6661	2,33116	-1,0002	32,424048	33,7860267	1,85498493	
	4	-0,0002	-0,002	-1,0002	0,9997	4,4438199	3,00650772	2,06586634	3,98349213

Fig. 8

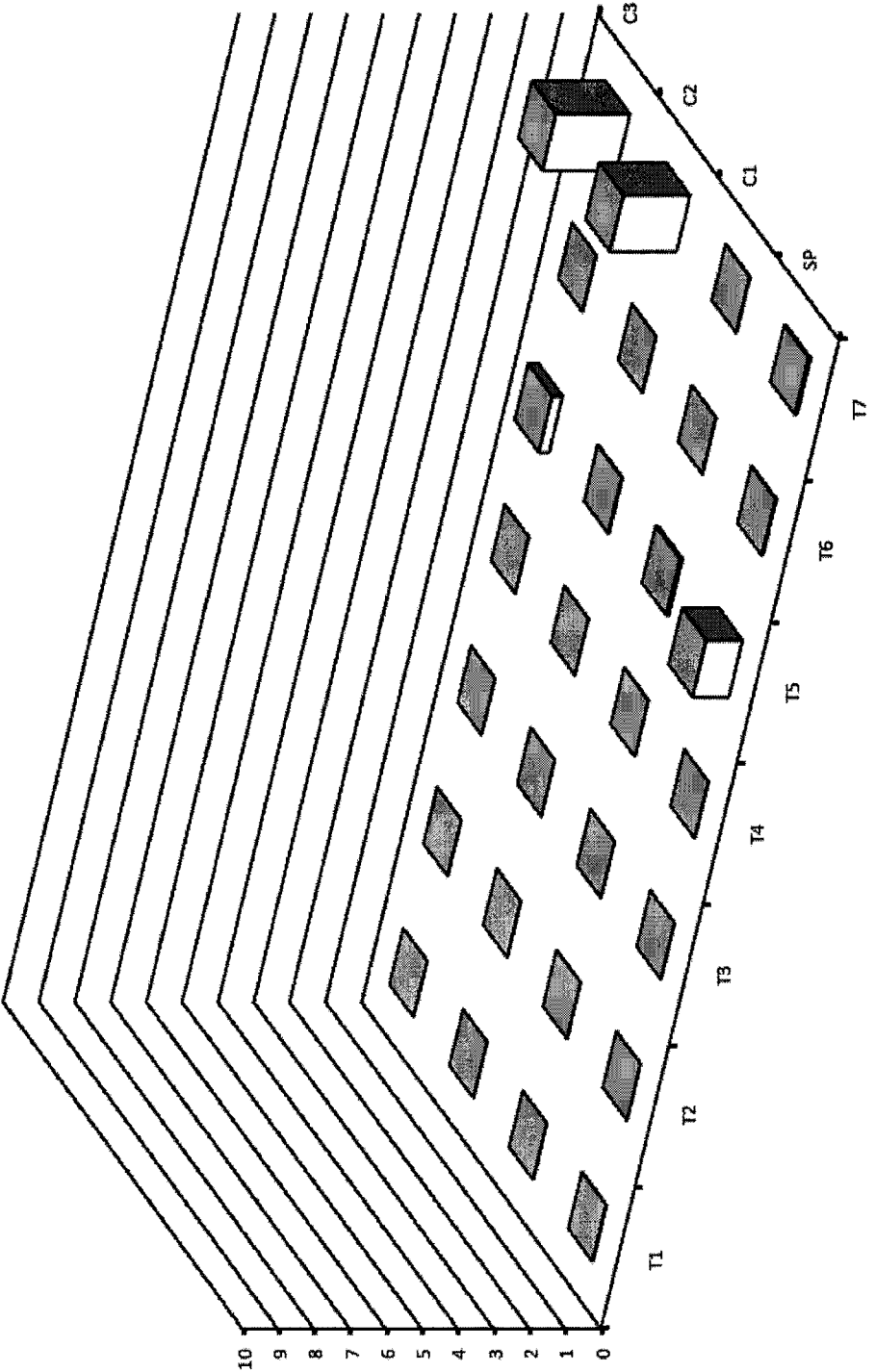


Fig. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2011/063277

A. CLASSIFICATION OF SUBJECT MATTER INV. G01D4/00 G01R31/02 H02J4/00 G06Q50/00 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) G01D G01R H02J G06Q		
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 practical, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/251339 A1 (ARAKI M S [US] ET AL) 10 November 2005 (2005-11-10)	1-16
Y	the whole document -----	1-16
X	WO 2009/063481 A2 (MAHARASHTRA STATE ELECTRICITY [IN]; MANE UTTAM SHIVRAM [IN]; BAGUL KIS) 22 May 2009 (2009-05-22)	1-16
Y	the whole document -----	1-16
X	DE 32 33 647 A1 (HEIDE GERHARD DIPL ING) 15 March 1984 (1984-03-15)	1-16
Y	the whole document -----	1-16
X	US 2007/021936 A1 (MAROVITZ DANIEL J [US] MAROVITZ DANIEL JORDAN [US]) 25 January 2007 (2007-01-25)	1-16
Y	paragraph [0012] - paragraph [0017] paragraph [0023] - paragraph [0029] -----	1-16
-/-		
☒ Further documents are listed in the continuation of Box C. ☒ 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 "E" earlier document but published on or after the international filing date "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 14 October 2011	Date of mailing of the international search report 21/10/2011	
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Kallinger, Christian	

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2011/063277

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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