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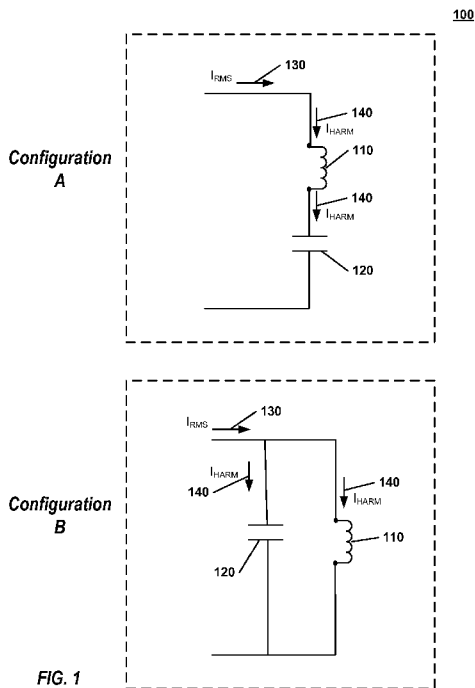
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(54) Title: METHOD AND SYSTEM FOR APPLYING POWER HARMONICS TO LOADS



(57) Abstract: A system and method for harvesting and applying power harmonics (e.g., harmonic distortion) comprises a shunt filter that is harmonically tuned for one or more connected loads (410, 415, 420). The shunt filter generally comprises at least one inductor connected to at least one capacitor. The output leg of the capacitor is connected to at least one load. Operatively, the shunt filter separates harmonic current and, in some instances, the fundamental current from the root mean square current originating from a power source (405) delivering power to the one or more connected loads. The neutral current originating from the one or more filter connected loads is then returned back to the power source.

WO 2012/129096 A1

TITLE

[0001] METHOD AND SYSTEM FOR APPLYING POWER HARMONICS TO
LOADS

5 CROSS-REFERENCE TO RELATED APPLICATIONS

[0002] This application claims the benefit of U.S. Provisional Application No. 61/454,086, filed March 18, 2011, and U.S. Provisional Application No. 61/592,956, filed January 31, 2012, the entire contents of which are incorporated herein by reference as if fully set forth.

10

BACKGROUND

[0003] In most modern power applications, a power source is used to provide power to a load. Frequently, the current and voltage wave forms generated by the power source suffer from harmonic distortion which lowers the quality of power provided to a load, causing the load to draw power inefficiently (e.g., the harmonic distortion generally being expressed as heat in a connected load). Harmonic distortion and the resulting low true power factor may cause an increase in energy costs and may also cause equipment to wear out over time due to the low quality of power.

[0004] Harmonic distortion in power systems is typically abated and/or cancelled at the power source or at the connected load generally using active filter technologies. In cancelling the harmonic distortion, only a single benefit results – improved power quality. The improved power quality is expressed as more efficient operation of a connected load and more efficient power utilization.

[0005] Current practices, however, do not allow for the harvesting of the harmonic distortion (e.g., power source system and/or load harmonics) to act as a secondary power source for one or more connected loads. Such lacking results in substantial inefficient power utilization – i.e., with current practices the identified harmonic distortion is discarded or removed from a power system. By not harvesting and reusing the harmonic distortion, a power system is not capable of operating at its full efficiency.

[0006] Advantageously, it is beneficial to harvest the harmonic distortion (e.g., power system harmonics and/or load derived power harmonics) found in power applications and power source connected systems to act as a power source for connected loads (e.g., primary and/or secondary loads). As such, a two-fold benefit can result – firstly a

reduction in the harmonic distortion being delivered to connected loads to a power source (e.g., a primary load, and/or secondary loads) which can result in prolonged operating life for the connected loads and secondly, substantial efficiency in the amount of overall power required to run the connected loads – e.g., in an illustrative configuration, the same amount
5 of power that is typically used to provide power to run a single hundred watt (100W) light bulb could be used to power the first 100W light bulb, as well as an additional 100W light bulb. Such systems and methods would directly impact power use optimization and utilization management.

[0007] From the foregoing it is appreciated that there exists a need for systems and
10 methods to ameliorate the shortcomings of existing practices.

SUMMARY

[0008] The herein described systems and methods described below are not limited to the particular systems, methodologies or protocols described, as these may vary. The
15 terminology used in this document is for the purpose of describing particular embodiments only, and is not intended to limit the scope of the present disclosure.

[0009] As used in this document and in the appended claims, the singular forms “a,” “an,” and “the” include plural reference unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used in this document have the
20 same meanings as commonly understood by one of ordinary skill in the art. As used in this document, the term “comprising” means “including, but not limited to.”

[0010] In an illustrative implementation, a system for harvesting and applying power harmonics comprises a shunt filter that is harmonically tuned for one or more connected loads primary source and is connected between a primary power source, a first load, and a
25 secondary load. The shunt filter generally comprises at least one inductor connected serially to at least one capacitor. Operatively, the shunt filter separates harmonic current and the fundamental current from the root mean square current originating from a power source delivering the fundamental current to the first load. Illustratively, the harmonic current is directed to the secondary load to power the secondary load. The neutral current
30 originating from the secondary load is then returned back to the power source.

[0011] In another illustrative implementation, a system for harvesting and applying power harmonics comprises a shunt filter that is harmonically tuned for a primary source and is connected to the power system’s load. The shunt filter generally comprises at least

one inductor connected serially to at least one capacitor. Operatively, the shunt filter separates harmonic current and the fundamental current from the root mean square current originating from a power source delivering the harmonic current to drive the power system's load.

5 [0012] Other features of the herein described systems and methods are further described below.

[0013] Additional aspects of the invention are as follows:

[0014] Aspect 1. A system for harvesting and applying power harmonics as part of power management, comprising: a power source; a first load; a second load; and a shunt filter comprising at least one inductor and at least one capacitor to create a shunt filter circuit, the shunt filter being harmonically tuned to the power source, the shunt filter being electrically connected between the power source and the second load and electrically connected in series to the second load to create a shunt filter second load serial combination, the first load being electrically connected in parallel to the power source and being electrically connected in parallel to the shunt filter second load serial combination.

15 [0015] Aspect 2. The system as recited in any of Aspects 1 and 3-9, wherein the second load comprises two or more serially connected loads.

[0016] Aspect 3. The system as recited in any of Aspects 1, 2, and 4-9, wherein a neutral side of the second load is connected to a neutral side of the power source.

20 [0017] Aspect 4. The system as recited in any of Aspects 1-3 and 5-9, wherein a neutral side of the first load is connected to a neutral side of the power source.

[0018] Aspect 5. The system as recited in any of Aspects 1-4 and 6-9, wherein the power source generates root mean square current (I_{RMS}) to the shunt filter.

[0019] Aspect 6. The system as recited in Aspect 5, wherein the shunt filter separates the delivered root mean square current (I_{RMS}) into harmonic current (I_{HARM}) and fundamental current (I_{FUND}) components.

[0020] Aspect 7. The system as recited in Aspect 6, wherein the harmonic current (I_{HARM}) is delivered by the shunt filter to the second load.

[0021] Aspect 8. The system as recited in any of Aspects 1-7 and 9, wherein the power source comprises any of a single phase three wire power source, single phase four wire power source, three phase three wire power source, and three phase four wire power source.

- [0022] Aspect 9. The system as recited in any of Aspects 1-8, wherein the shunt filter comprises two or more shunt filter circuits.
- [0023] Aspect 10. A system for harvesting and applying power harmonics as part of power management, comprising: a power source; a load; and a shunt filter comprising at least one inductor and at least one capacitor, the combination being harmonically tuned to the power source, the shunt filter being connected between the power source and the load and connected in series to the load to create a shunt filter load serial combination, the load being electrically connected to the power source.
- [0024] Aspect 11. The system as recited in any of Aspects 10 and 12-18, wherein the load comprises two or more serially connected loads.
- [0025] Aspect 12. The system as recited in any of Aspects 10, 11, and 13-18, wherein a neutral side of the load is electrically connected to a neutral side of the power source.
- [0026] Aspect 13. The system as recited in any of Aspects 10-12 and 14-18, wherein the power source generates root mean square current (I_{RMS}) to the shunt filter.
- [0027] Aspect 14. The system as recited in any of Aspects 13 and 18, wherein the shunt filter separates the delivered root mean square current (I_{RMS}) into harmonic current (I_{HARM}) and fundamental current (I_{FUND}) components.
- [0028] Aspect 15. The system as recited in any of Aspects 13, 14, and 18, wherein the root mean square current (I_{HARM}) is delivered by the shunt filter to the load.
- [0029] Aspect 16. The system as recited in any of Aspects 10-15, 17, and 18, wherein the power source comprises any of a single phase three wire power source, single phase four wire power source, three phase three wire power source, and three phase four wire power source.
- [0030] Aspect 17. The system as recited in any of Aspects 10-16 and 18, wherein the shunt filter comprises two or more shunt filter circuits.
- [0031] Aspect 18. The system as recited in any of Aspects 10-17, wherein root mean square current (I_{HARM}) is generated by the first load and captured by the shunt circuit for delivery to the secondary load.
- [0032] Aspect 19. A method for harvesting and applying power harmonics as part of power management, comprising: tuning a shunt filter to a selected harmonic of a power source; placing the shunt filter in series in between the power source and a first load; and connecting a neutral side of the first load to a neutral side of the power source.

[0033] Aspect 20. The method as recited in Aspect 19, further comprising placing a second load in parallel to the power source.

BRIEF DESCRIPTION OF THE DRAWINGS

5 [0034] FIG. 1 illustrates an illustrative implementation of an exemplary shunt circuit for use in accordance with the herein described systems and methods;

[0035] FIG. 2 illustrates an illustrative implementation of an exemplary power harmonic harvesting and application system;

[0036] FIG. 3 illustrates the interaction of various components and the connectivity of components of an illustrative implementation of an exemplary power harvesting and application system; and

10 [0037] FIG. 4 illustrates an alternative implementation of an exemplary power harmonic harvesting and application system.

15 DETAILED DESCRIPTION

[0038] In an illustrative implementation, an exemplary system is provided to capture harmonic currents that are produced at the non-linear load (i.e., computer power supplies, lighting ballasts, variable frequency drives, etc.) as well as imported system harmonics (i.e., from the power source). In an illustrative operation, the harmonic current (e.g., higher than fundamental current) can be used to power the connected loads and/or can be re-injected in to an exemplary power system to increase power system efficiency.

20 [0039] Figure 1 shows an exemplary circuit that is used to capture power system and/or load harmonics. As is shown in Figure, 1, exemplary harmonic capture circuit 100 comprises inductor 110 electrically coupled to capacitor 120, which together are electrically connected to a power source that, illustratively operatively, is tuned to a selected harmonic resonant frequency. With previous practices, the harmonic currents in a power system are shunted to ground and therefore abated in the power system, not harvested and applied to the loads of a power system as practiced by the herein described systems and methods.

30 [0040] As is shown in Figure 1, exemplary harmonic capture circuit 100 can be illustratively deployed in two configurations, Configuration A and Configuration B. It should be understood that the harmonic capture circuit 100 shown in Figure 1, as well as the other harmonic capture circuits described in this application, are often referred to in the

art as shunt filters and that these two terms are used interchangeably in the specification and claims. As is shown in Configuration A, inductor 110 is connected in series to capacitor 120 in the exemplary harmonic capture circuit 100. In Configuration B, inductor 110 is connected in parallel to capacitor 120 in exemplary harmonic capture circuit 100.

5 One of ordinary skill in the art will appreciate that the configurations described in Figure 1 are merely illustrative as the inventive concepts described herein apply to various circuits that can be tuned to a selected resonant frequency to operate in a manner as described herein.

[0041] In an illustrative operation, as is shown in Figure 1, the harmonic current (I_{HARM})
10 140 is harvested from the root mean square current (I_{RMS}) 130 for application to a connected load (not shown). In an illustrative implementation, not shown in Figure 1 but shown in Figures 2, 3, and 4, the harmonic current (I_{HARM}) can be then routed so that it drives power to various connected loads.

[0042] Figure 2 shows an illustrative implementation of an exemplary configuration of
15 cooperating components of exemplary power system 200 that practices harmonic power harvesting and application of harvested harmonics. As is shown, exemplary power system comprises power source 205, exemplary harmonic capture circuit 100 (of Figure 1), primary load 225, and various secondary loads, i.e., secondary load A 210, secondary load B 215, up to and including secondary load N 220. In an illustrative implementation, power
20 source 205 comprises one or more of a single phase or three phase type power supply having three or four wires.

[0043] The dotted connection line between secondary load B and secondary load N merely indicates that there could be numerous loads connected in series between secondary load B and secondary load N.

25 [0044] As is shown in Figure 2, in an illustrative implementation, power source 205 is connected in parallel to the serial combination of harmonic capture circuit 100 and secondary loads, 210, 215, and 220, which combination is, in turn, connected in parallel to primary load 225. Further, as is shown in Figure 2, the non-load connected leg of the last serially connected secondary load is electrically connected to the neutral side of power
30 source 205.

[0045] In an illustrative operation, power source 205 generates root mean square current (I_{RMS}) which is broken down by harmonic capture circuit 100 to fundamental current (I_{FUND}) and harmonic current (I_{HARM}). As is shown, I_{HARM} is delivered to secondary loads

210, 215, and 220 to provide power to secondary loads 210, 215, and 220. In the illustrative operation, the separated I_{FUND} is then driven to primary load 225 to deliver power to primary load 225. Further, as is shown in Figure 2, additional harmonic current I_{HARM} is imported from the power system (e.g., primary load 225) and directed to harmonic capture circuit 100 for delivery to secondary loads, 210, 215, and 220.

[0046] Although Figure 2 shows an exemplary configuration of cooperating components of a harmonic harvesting enabled power system, it should be understood that such configuration is merely a description of one of many possible configurations. One skilled in the art will appreciate that the inventive concepts described herein can be applied to a harmonic harvesting enabled power system having various numbers and types of loads in various configurations and using various numbers and types of harmonic harvest capture circuits as well as various types of power sources.

[0047] Figure 3 shows an illustrative implementation of an exemplary power system 300 having multiple loads, and the interconnectivity of such loads. As is shown in Figure 3, exemplary power system 300 comprises power source 305, various harmonic capture circuits 100 (A-E), load A 310, load B 315, load C 320, load D 325, load E 330, load F 335, load G 340, load H 345, up to and including load N 350 and load N+1 355. In an illustrative implementation, power source 305 comprises one or more of a single phase or three phase type power supply having three or four wires.

[0048] In an illustrative implementation, power source 305 is electrically connected to harmonic capture circuit 100 (A), which in turn is illustratively electrically connected to a load pair comprising load A 310 and load B 315, as is shown. Load B 315 is electrically connected to harmonic capture circuit 100 (B), which is electrically connected to a load pair comprising load C 320 and load D 325, as is shown. Load D 325 is electrically connected to harmonic capture circuit 100 (C), which is electrically connected to a load pair comprising load E 330 and load F 335, as is shown. Load F 335 is electrically connected to harmonic capture circuit 100 (D), which is electrically connected to a load pair comprising load G 340 and load H 345, as is shown. Load H is electrically connected to harmonic capture circuit 100 (E), which is electrically connected to up to and including a load pair comprising load N 350 and load N+1 355, as is shown. As is shown, there can be endless number of harmonic capture circuits 100 and load pairs, though these quantities may be generally limited by the amount of power that can be delivered by power source 305.

[0049] In an illustrative implementation, harmonic capture circuit 100 can comprise a single circuit that has federated circuits (not shown) and remotely located that are electronically connected as described in Figure 3, or can comprise individual harmonic circuits individually connected and proximately located to the loads as described in Figure 3.

[0050] In an illustrative implementation, exemplary power system 300 can be representative of a conventional lighting circuit found in conventional commercial building and or industrial buildings. In this illustrative implementation, with the use and selected deployment of five harmonic capture circuits 100 interconnected as described in Figure 3, the same amount of power that would conventionally power only five (5) loads is optimized to power ten (10) loads through the use of captured harmonic currents (as described by Figures 2 and 3).

[0051] In an illustrative operation, power source 305 delivers I_{RMS} to each of the harmonic capture circuits 100 (A, B, C, D, and E) that is separated into I_{HARM} , which drives the secondary load of each of the load pairs (load A 310, load C 320, load E 330, load G 340, and up to and including load N 350), and I_{FUND} , which drives the primary loads (load B 315, load D 325, load F 335, load H 345, and up to and including load N+1 355) of each of the load pairs.

[0052] Although Figure 3 shows an exemplary configuration of cooperating components of a harmonic harvesting enabled power system, it should be understood that such configuration is merely a description of one of many possible configurations. One skilled in the art will appreciate that the inventive concepts described herein can be applied to a harmonic harvesting enabled power system having various numbers and types of loads in various configurations and using various numbers and types of harmonic harvest capture circuits, as well as various types of power sources.

[0053] Figure 4 shows an illustrative implementation of an exemplary configuration of cooperating components of exemplary power system 400 that practices harmonic power harvesting and application of harvested harmonics. As is shown, exemplary power system comprises power source 405, exemplary harmonic capture circuit 100 (of Figure 1), and various loads, secondary load A 410, secondary load B 415, and up to and including secondary load N 420. The dotted connection line between secondary load B 415 and secondary load N 420 merely indicates that there could be numerous loads connected in series between secondary load B 415 and secondary load N 420. In an illustrative

implementation, power source 405 comprises one or more of a single phase or three phase type power supply having three or four wires.

[0054] As is shown in Figure 4, in an illustrative implementation, power source 405 is connected in parallel to the serial combination of harmonic capture circuit 100 and loads 410, 415, and 420. Further, as is shown in Figure 4, the non-load connected leg of the last
5 serially connected load is electrically connected to the neutral side of power source 405.

[0055] In an illustrative operation, power source 405 generates root mean square current (I_{RMS}) which is broken down by harmonic capture circuit 100 to capture the harmonic current (I_{HARM}) components of I_{RMS} . As is shown, I_{HARM} is delivered to loads 210, 215,
10 and 220 to provide power to loads 210, 215, and 220.

[0056] Although Figure 4 shows an exemplary configuration of cooperating components of a harmonic harvesting enabled power system, it should be understood that such configuration is merely a description of one of many possible configurations. One skilled in the art will appreciate that the inventive concepts described herein can be applied to a
15 harmonic harvesting enabled power system having various numbers and types of loads in various configurations and using various numbers and types of harmonic harvest capture circuits well as various types of power sources.

[0057] While several illustrative implementations have been described in this document by way of example, those skilled in the art will appreciate that various modifications,
20 alterations, and adaptations to the described embodiments may be realized without departing from the spirit and scope of the invention, as defined by the appended exemplary claims.

CLAIMS

1. A system for harvesting and applying power harmonics as part of power management, comprising:
 - a power source;
 - a first load;
 - a second load; and
 - a shunt filter comprising at least one inductor and at least one capacitor to create a shunt filter circuit, the shunt filter being harmonically tuned to the power source, the shunt filter being electrically connected between the power source and the second load and electrically connected in series to the second load to create a shunt filter second load serial combination, the first load being electrically connected in parallel to the power source and being electrically connected in parallel to the shunt filter second load serial combination.
2. The system as recited in claim 1, wherein the second load comprises two or more serially connected loads.
3. The system as recited in claim 1, wherein a neutral side of the second load is connected to a neutral side of the power source.
4. The system as recited in claim 1, wherein a neutral side of the first load is connected to a neutral side of the power source.
5. The system as recited in claim 1, wherein the power source generates root mean square current (I_{RMS}) to the shunt filter.
6. The system as recited in claim 5, wherein the shunt filter separates the delivered root mean square current (I_{RMS}) into harmonic current (I_{HARM}) and fundamental current (I_{FUND}) components.
7. The system as recited in claim 6, wherein the harmonic current (I_{HARM}) is delivered by the shunt filter to the second load.

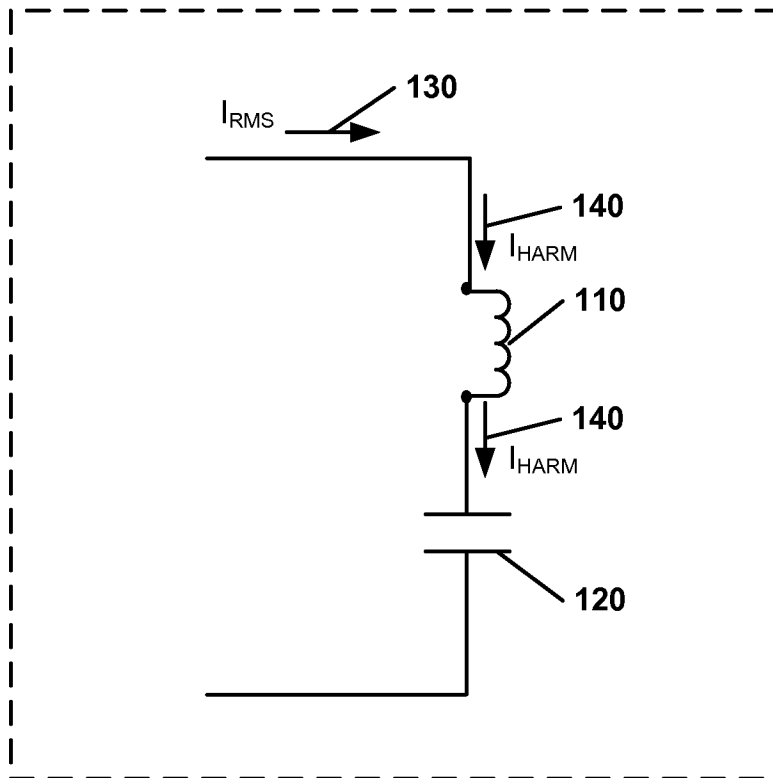
8. The system as recited in claim 1, wherein the power source comprises any of a single phase three wire power source, single phase four wire power source, three phase three wire power source, and three phase four wire power source.
9. The system as recited in claim 1, wherein the shunt filter comprises two or more shunt filter circuits.
10. A system for harvesting and applying power harmonics as part of power management, comprising:
 - a power source;
 - a load; and
 - a shunt filter comprising at least one inductor and at least one capacitor, the combination being harmonically tuned to the power source, the shunt filter being connected between the power source and the load and connected in series to the load to create a shunt filter load serial combination, the load being electrically connected to the power source.
11. The system as recited in claim 10, wherein the load comprises two or more serially connected loads.
12. The system as recited in claim 10, wherein a neutral side of the load is electrically connected to a neutral side of the power source.
13. The system as recited in claim 10, wherein the power source generates root mean square current (I_{RMS}) to the shunt filter.
14. The system as recited in claim 13, wherein the shunt filter separates the delivered root mean square current (I_{RMS}) into harmonic current (I_{HARM}) and fundamental current (I_{FUND}) components.
15. The system as recited in claim 14, wherein the root mean square current (I_{HARM}) is delivered by the shunt filter to the load.

16. The system as recited in claim 10, wherein the power source comprises any of a single phase three wire power source, single phase four wire power source, three phase three wire power source, and three phase four wire power source.
17. The system as recited in claim 10, wherein the shunt filter comprises two or more shunt filter circuits.
18. The system as recited in claim 1, wherein root mean square current (I_{HARM}) is generated by the first load and captured by the shunt circuit for delivery to the secondary load.
19. A method for harvesting and applying power harmonics as part of power management, comprising:
 - tuning a shunt filter to a selected harmonic of a power source;
 - placing the shunt filter in series in between the power source and a first load; and
 - connecting a neutral side of the first load to a neutral side of the power source.
20. The method as recited in claim 19, further comprising placing a second load in parallel to the power source.

1/4

100

**Configuration
A**



**Configuration
B**

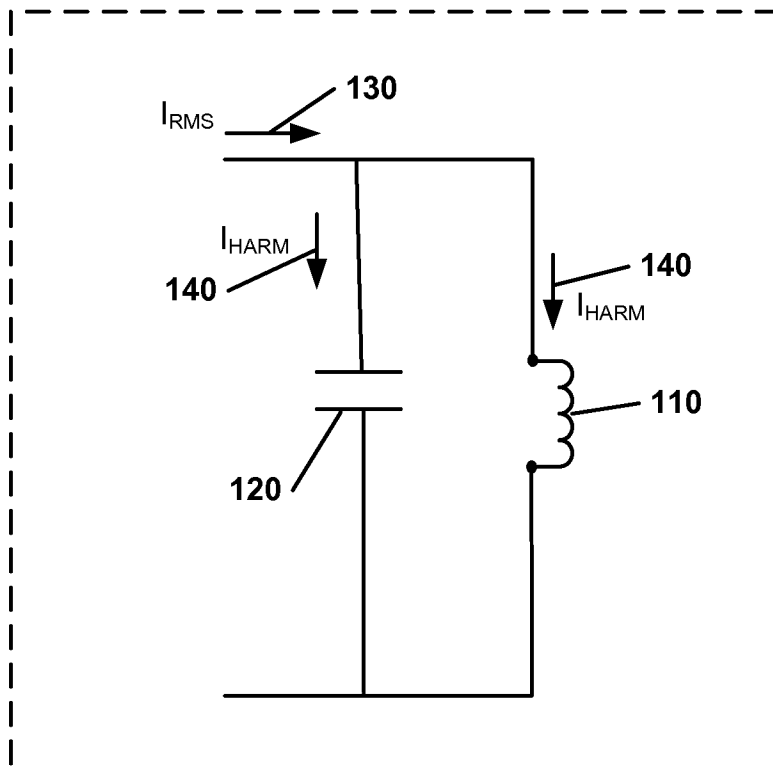


FIG. 1

2/4

200

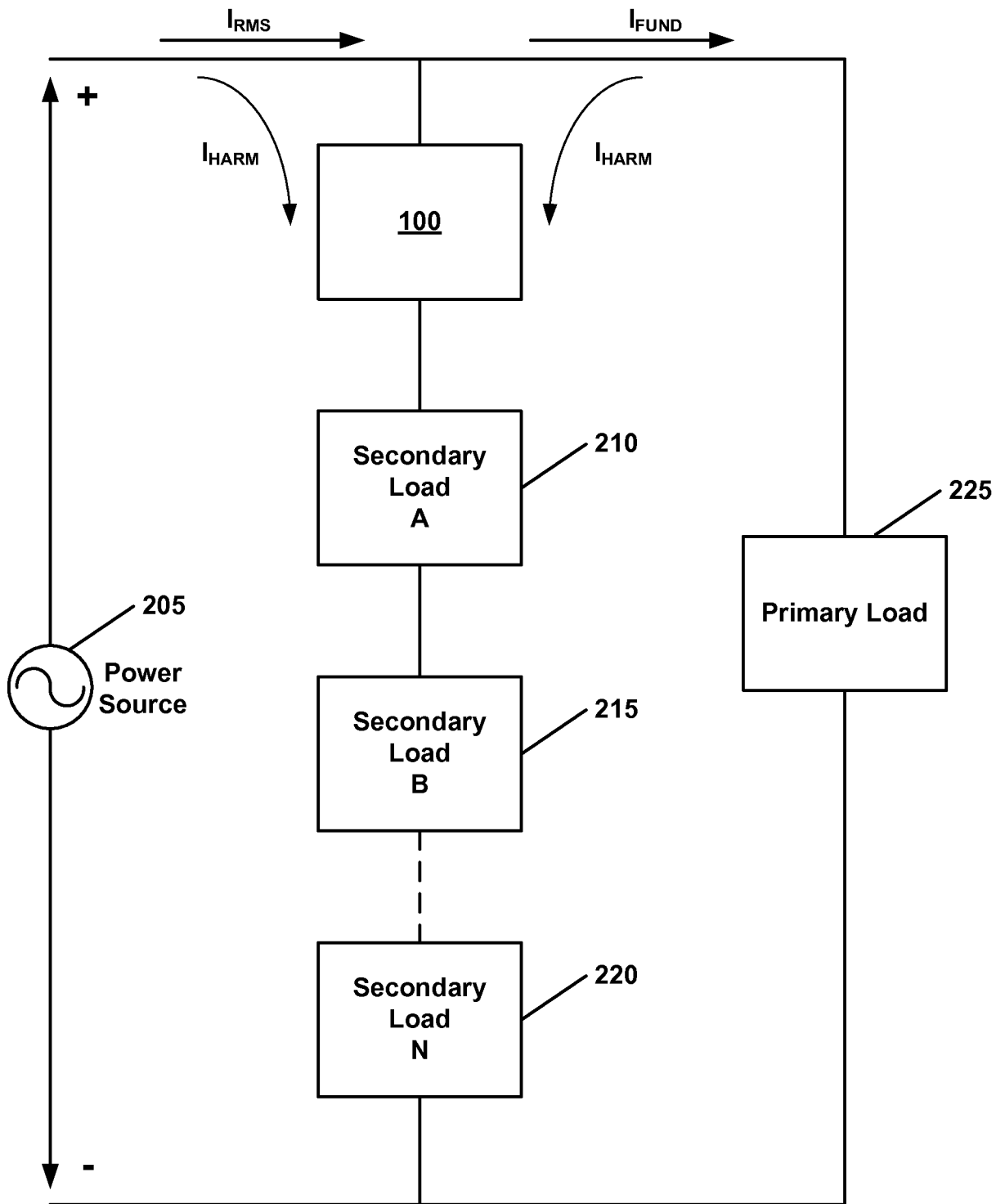


FIG. 2

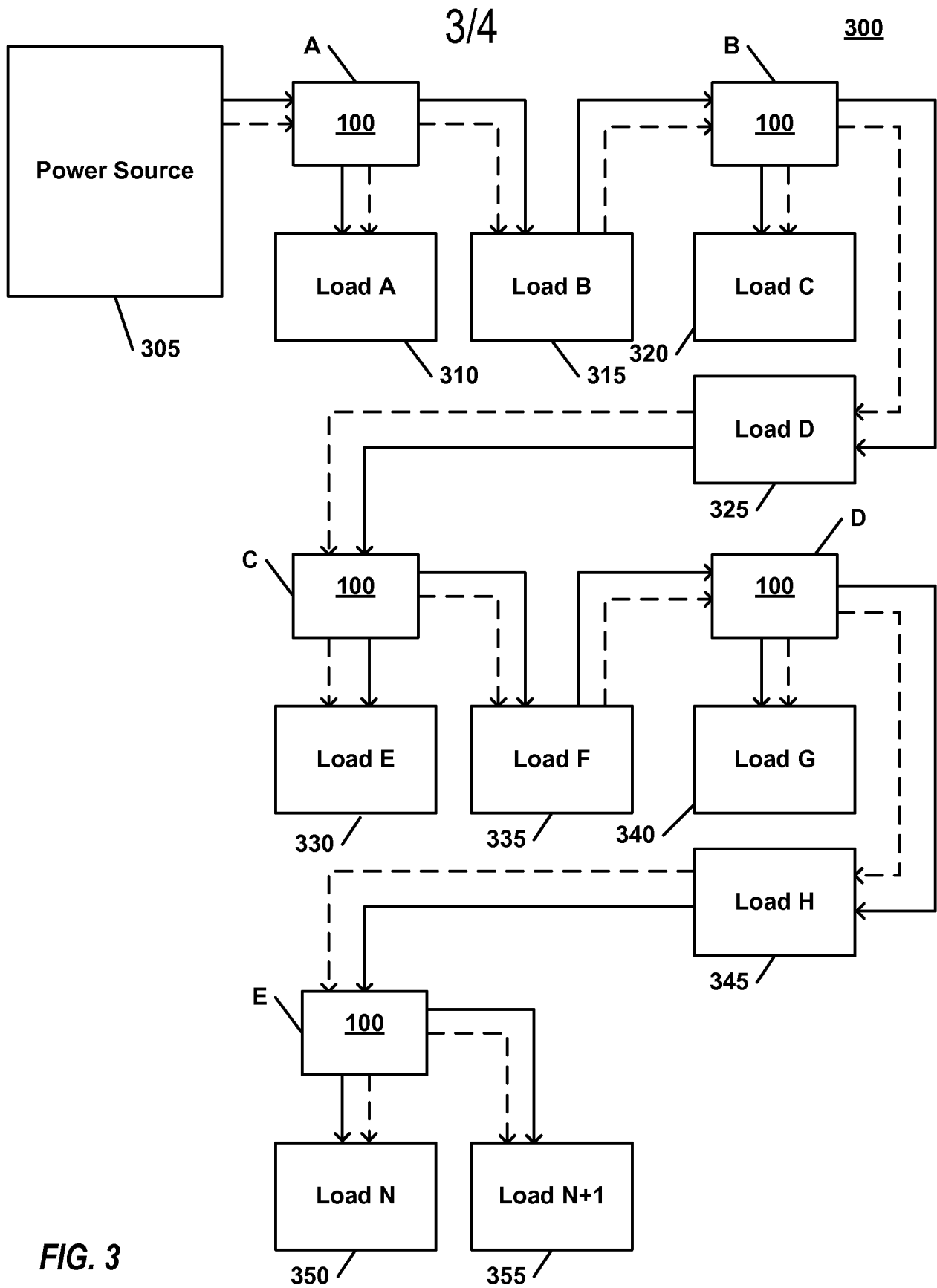


FIG. 3

4/4

400

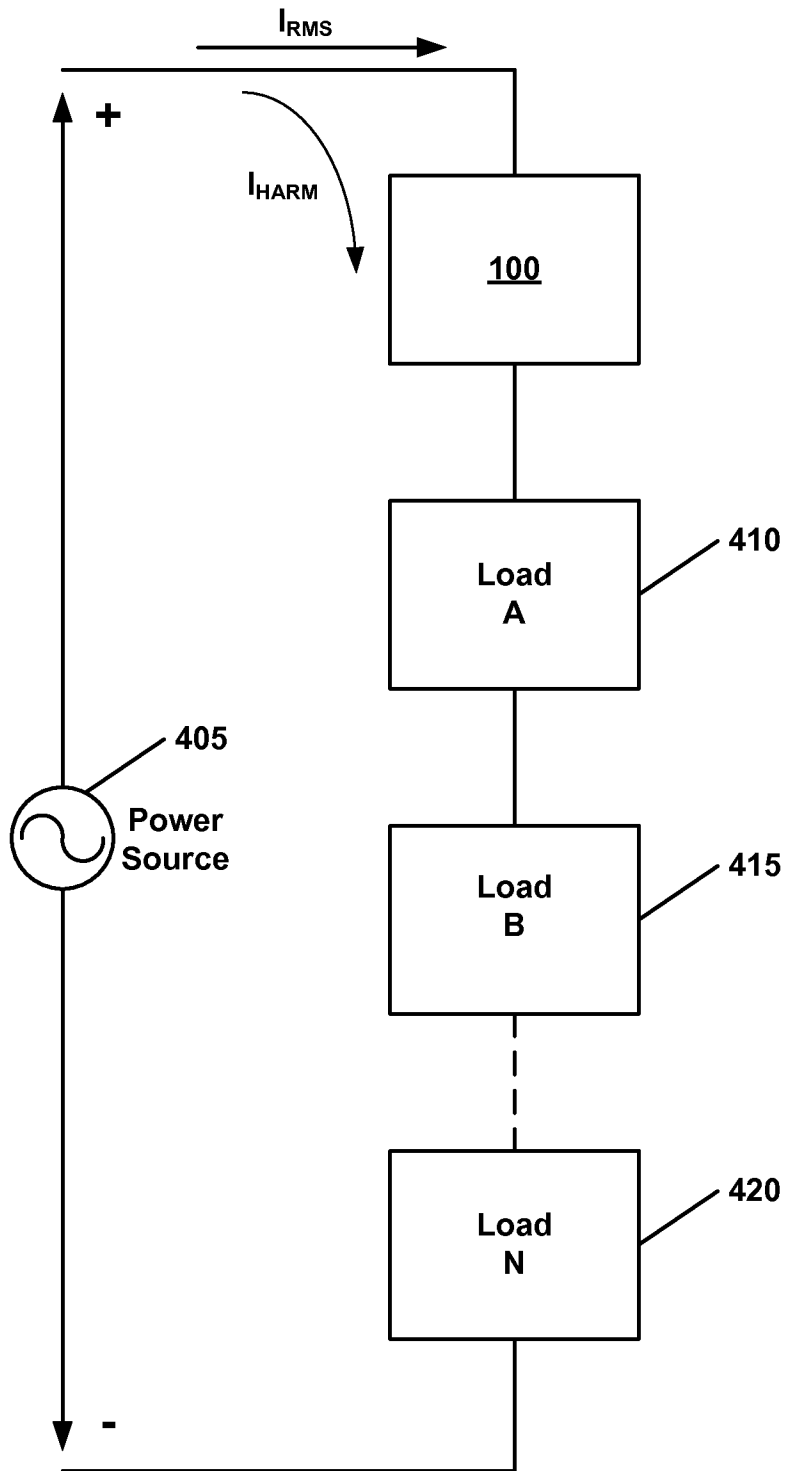


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/029460

A. CLASSIFICATION OF SUBJECT MATTER
 INV. H02J3/01
 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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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| A | US 2010/156194 A1 (NAVID HAMID [CA] ET AL) 24 June 2010 (2010-06-24) abstract | 1-20 |
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Further documents are listed in the continuation of Box C.
 See patent family annex.

* Special categories of cited documents :

| | |
|---|---|
| <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"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)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> | <p>"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</p> <p>"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</p> <p>"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</p> <p>"&" document member of the same patent family</p> |
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| Date of the actual completion of the international search | Date of mailing of the international search report |
| 25 June 2012 | 04/07/2012 |

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| 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 <p style="text-align: center;">Poth, Hartwig</p> |
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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| International application No PCT/US2012/029460 |
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