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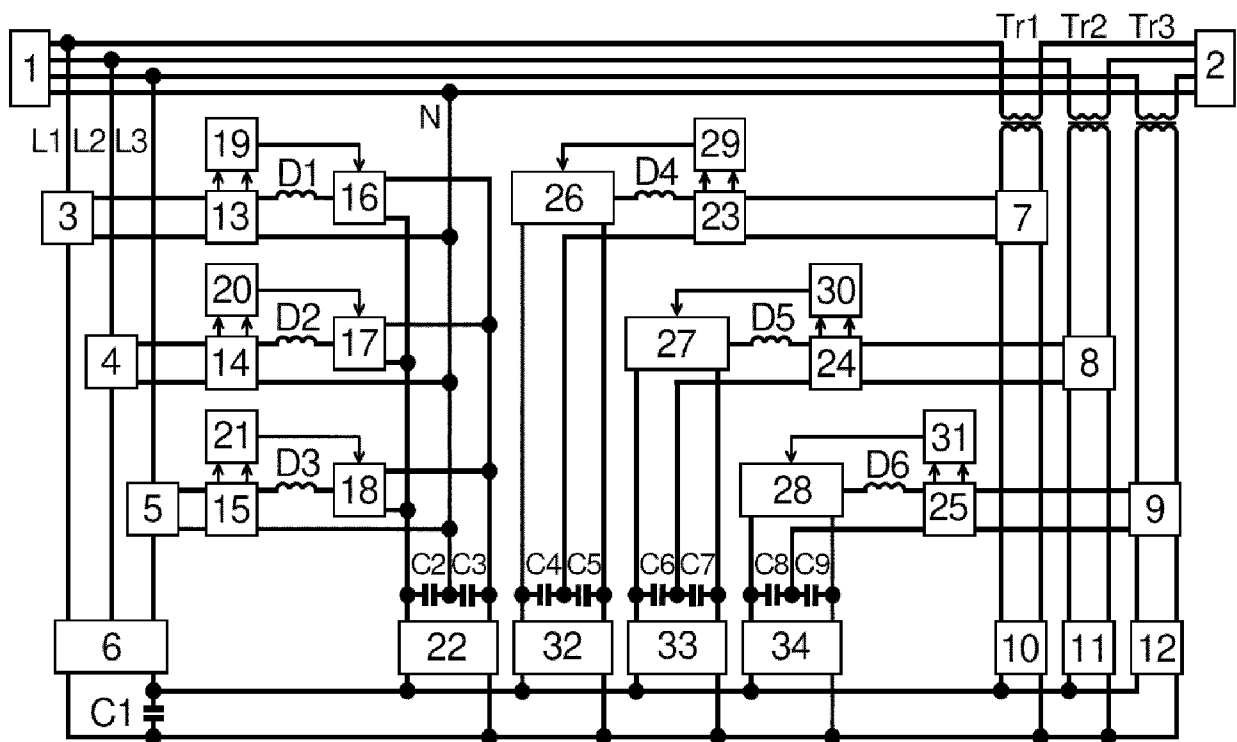
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(54) **SYSTEM FOR IMPROVING QUALITY OF ELECTRICAL ENERGY**

(57) A system is composed of an active parallel compensator comprising coupling filters (3,4,5) in each phase conductor (L1, L2, L3) and an AC/DC power electronic converter, and/or a dynamic voltage restorer system comprising in each phase conductor a transformer (Tr1, Tr2, Tr3) and a coupling filter (7, 8, 9) and AC/DC power electronic converters (10, 11, 12) and an energy storage in the form of a storage capacitor (C1) included at DC terminals of said converters (6, 10, 11, 12). In each phase conductor in the LCLR type coupling filters (3, 4, 5; 7, 8, 9) each of resistors is replaced by an energy recovery system composed of a half-bridge system of power electronic switch (16, 17, 18; 26, 27, 28) connected by means of chokes (D1, D2, D3; D4, D5, D6) and a voltage and current measurement block (13, 14, 15; 23, 24, 25) to the coupling filter in place of a replaced resistor, and signal conductors of the voltage and current measurement block are connected to the switch. In the active parallel compensator circuit, capacitors (C2, C3) connected in series are coupled to both outputs of each of the switches

(16, 17, 18) and form an intermediate energy storage, wherein the latter by means of a power electronic converter (22), with an input circuit being galvanically isolated from a DC/DC output circuit, is connected to terminals of a storage capacitor (C1). Common point of the capacitors (C2, C3) is connected to a neutral conductor (N) and by means of the voltage and current measurement blocks (13, 14, 15) to one of the outputs of the coupling filters (3, 4, 5). In the dynamic voltage restorer system circuit, separately for each phase, capacitors in series (C4, C5; C6, C7; C8, C9) are coupled to both outputs of each of the power electronic switches (26, 27, 28) and by means of individual converters (32, 33, 34) they are connected to the storage capacitor (C1). For each phase respectively, common point of the capacitors (C4, C5; C6, C7; C8, C9) is connected by means of the voltage and current measurement block (23, 24, 25) to one of the outputs of the coupling filter (7, 8, 9).



Description

[0001] The present invention relates to a system for improving quality of electrical energy. This system allows to reduce energy losses in power electronic systems that have been used so far for improving quality of electrical energy and for providing proper voltage parameters. These are compensator systems of different kinds, such as active parallel compensators (APC) also referred to as active power filters (APF), dynamic voltage restorers (DVR), unified power quality conditioners (UPQC) applicable in industrial power electronic systems and wherever high quality energy is required.

[0002] From CN102097793 a power quality conditioning device for a power distribution system is known, which comprises current limiting inductors, transformers and connecting inductors. Under the conditions of linear and nonlinear loads, the device uses voltage and current sources connected to the circuit in series and in parallel. The current limiting inductors are connected in parallel with switches for switching different running modes of the device. The device comprises a fault current limiter, a dynamic voltage restorer and an active power filter. The device limits a short circuit current, compensates voltage sag by the series-wound current converter. When operated as the failure current limiter, the device does not consume active power and has the advantage of saving energy. The device satisfies the needs of different loads in power supply voltages, effectively prevents the nonlinear load from polluting the system and reduce the short circuit current.

[0003] Known compensators having the purpose of improving quality of electrical energy are connected to a power network via LCL or LCLR circuits which limit passing of high-frequency harmonic currents and voltages to this network that are associated with the pulse width modulation used in inverters of these compensators while providing a low attenuation of harmonic currents and voltages within the compensated range. A resonant frequency of these circuits should be therefore sufficiently high to ensure the required pass band corresponding to the range of compensated harmonic currents and voltages. This requires the use of sufficiently high operating frequency of a pulse modulation system of the inverters in order to ensure the system stability or the provision of attenuation of the resonance occurring in filters by means of additional resistive elements for energy dissipation. The last mentioned solution, despite the advantages of a simpler control system of inverter systems, is reluctantly used due to considerable energy losses in filter resistive elements of these systems leading to considerable efficiency reduction of the compensators.

[0004] A system according to the invention is composed of an active parallel compensator system comprising a coupling filter in each phase conductor and a power electronic converter AC/DC, and/or of a dynamic voltage restorer system comprising in each phase conductor a transformer and a coupling filter and power electronic

converters AC/DC. The system also comprises an energy storage in the form of a storage capacitor included at DC terminals of said power electronic converters.

[0005] The essence of the solution is that in each phase conductor in the LCLR type coupling filters of the active parallel compensator system, as well as in the LCLR coupling filters of the dynamic voltage restorer system each of resistors is replaced by an energy recovery system. Each of these energy recovery systems is composed of a half-bridge switch system, connected by means of a choke and a voltage and current measurement block to the coupling filter in place of a replaced resistor. Signal conductors of each voltage and current measurement block are connected to the switches in each energy recovery system respectively.

[0006] Moreover, to the two remaining outputs of each of the power electronic switches in the active parallel compensator circuit two capacitors connected in series are coupled that form an intermediate energy storage, which by means of a power electronic converter, with an input circuit being galvanically isolated from an output circuit DC/DC, is connected to terminals of a storage capacitor. In the active parallel compensator circuit, a common point of the capacitors that form intermediate energy storages is connected to a neutral conductor of a power network and by means of the voltage and current measurement blocks to one of the outputs of each coupling filter.

[0007] Whereas to the two remaining outputs of each of the power electronic switches present in the dynamic voltage restorer system circuit, separately for each phase, two capacitors connected in series are coupled that form intermediate energy storages. These capacitors by means of individual power electronic converters, with an input circuit being galvanically isolated from an output circuit DC/DC, are connected to the storage capacitor. In the dynamic voltage restorer system circuit, for each phase respectively, a common point of the capacitors that form intermediate energy storages, is connected by means of the voltage and current measurement block to one of the outputs of the coupling filter.

[0008] The advantage of the system, according to the solution presented herein and allowing to achieve resonance attenuation in coupling circuits of active parallel compensators and dynamic voltage restorer systems, is the simplification of a control system of these systems while significantly reducing energy losses due to a possibility of recovering electrical energy used to performing the attenuation process. This solution provides a high output current dynamics and effective resonance attenuation in coupling circuits.

[0009] The subject of the invention is illustrated in a drawing in the form of a system block diagram.

[0010] A system is composed of an active parallel compensator system (APC) comprising a power electronic converter 6 connected to a power network 1 or a load 2 by means of LCLR coupling filters 3, 4, 5 and of a dynamic voltage restorer system (DVR) comprising power elec-

tronic converters 10, 11, 12 connected to the power network 1 or the load 2 by means of coupling filters LCLR 7, 8, 9, respectively, and transformers Tr1, Tr2, Tr3, respectively. These systems have a common DC circuit in which a storage capacitor C1 acts as an energy storage. In each of the LCLR type filters, by means of which these systems are connected to the power network or to the load, a resistor is replaced by an energy recovery system. An effect of this energy recovery system in the filter circuit is similar to a load realised by a resistor, but the energy resulting from functioning of this system is not lost in the form of heat, as in a conventional resistor, but after being reduced by energy losses due to the processing, it is transferred to the energy storage, i.e., the storage capacitor C1.

[0011] The energy recovery system connected in place of a replaced resistor in the LCLR type coupling filters 3, 4, 5 of the active parallel compensator is composed of half-bridge power electronic switches 16, 17, 18, each of which is connected by means of chokes D1, D2, D3 and current and voltage measurement blocks 13, 14, 15, respectively, to outputs of the filters 3, 4, 5 in place of replaced resistors. Measurement signals from the current and voltage measurement blocks 13, 14, 15 are transmitted respectively to control blocks 19, 20, 21 of the power electronic switches 16, 17, 18, respectively. These switches are controlled in such a way that the mean value of input current for the pulse repetition period of each of the switches is proportional to the mean value of voltage in place of a replaced resistor, in a given pulse repetition period of each of the switches such as to meet the condition of the product of this current value, for the pulse repetition period of each of the switches, and of the required resistance setpoint value equal to the resistance of the replaced resistor, being equal to the mean value of input voltage, for the pulse repetition period of each of the switches. A pulse repetition period of the power electronic switches 16, 17, 18 is set such as to be many times smaller than a period of the highest significant harmonic component in the output voltage curve present in place of a replaced resistor. Energy drawn from the circuits of the coupling filters 3, 4, 5 in the pulse controlling process of the power electronic switches 16, 17, 18 is transferred to capacitors C2, C3 connected in series and acting as an intermediate energy storage, wherefrom via a power electronic converter 22 it is returned to the storage capacitor C1, acting as an energy storage of the overall system for improving quality of electrical energy. The power electronic converter 22 is a DC/DC converter which transfers energy from the capacitors C2, C3 acting as intermediate energy storages in the circuit to the main energy storage, i.e. the storage capacitor C1, while providing galvanic isolation between mentioned circuits. A common point of the capacitors C2, C3 is connected to a neutral conductor N of the power network and by means of the voltage and current measurement blocks 13, 14, 15 to one of the outputs of the coupling filters 4, 5, 6.

[0012] Similarly to the active parallel compensator sys-

tem, in the second part of the system for improving quality of electrical energy comprising the dynamic voltage restorer system, energy recovery systems are connected in place of a replaced resistor in the LCLR type coupling filters 7, 8, 9 and are composed of half-bridge power electronic switches 26, 27, 28, each of which is connected by means of chokes D4, D5, D6 and current and voltage measurement blocks 23, 24, 25, respectively, to outputs of the filters 7, 8, 9 in place of replaced resistors. Measurement signals from the current and voltage measurement blocks 23, 24, 25 are respectively connected to control blocks 29, 30, 31 of power electronic switches 26, 27, 28, respectively. These switches are controlled in such a way that the mean value of input current for the pulse repetition period of each of the switches is proportional to the mean value of voltage in place of a replaced resistor, in a given pulse repetition period of each of the switches such as to meet the condition of the product of this current value, for the pulse repetition period of each of the switches, and of the required resistance setpoint value equal to the resistance of the replaced resistor, being equal to the mean value of input voltage, for the pulse repetition period of each of the switches. A pulse repetition period of the power electronic switches 26, 27, 28 is set such as to be many times smaller than a period of the highest significant harmonic component in the output voltage curve present in place of a replaced resistor.

[0013] Energy drawn from the circuit of the coupling filter 7 in the pulse controlling process of power electronic switches 26 is transferred to capacitors C4, C5 connected in series and acting as an intermediate energy storage, wherefrom via a power electronic converter 32, DC/DC, it is returned to the storage capacitor C1, acting as an energy storage of the overall system for improving quality of electrical energy. A common point of the capacitors C4, C5 is connected to one of the outputs of the coupling filter 7 by means of the voltage and current measurement block 23.

[0014] Energy drawn from the circuit of the coupling filter 8 in the pulse controlling process of power electronic switches 27 is transferred to capacitors C6, C7 connected in series and acting as an intermediate energy storage, wherefrom via a power electronic converter 33, DC/DC, it is returned to the storage capacitor C1, acting as an energy storage of the overall system for improving quality of electrical energy. A common point of the capacitors C6, C7 is connected to one of the outputs of the coupling filter 8 by means of the voltage and current measurement block 24,

[0015] Energy drawn from the circuit of the coupling filter 9 in the pulse controlling process of power electronic switches 28 is transferred to capacitors C8, C9 connected in series and acting as an intermediate energy storage, wherefrom via a power electronic converter 34, DC/DC, it is returned to the storage capacitor C1, acting as an energy storage of the overall system for improving quality of electrical energy. A common point of the capacitors C8, C9 is connected to one of the outputs of the

coupling filter 9 by means of the voltage and current measurement block 25.

[0016] In the presented systems, known systems (not illustrated in the drawing) for precharging the capacitors C2 - C9 to the voltage level present on them during a normal system operation have been used, ensuring the correct system operation during start-up when voltages on these capacitors are equal to zero.

[0017] In the presented exemplary solution, the system was used for resonance attenuation in the coupling circuit filters 3, 4, 5, 7, 8, 9 of the active parallel compensator APC and of the dynamic voltage restorer system DVR with voltage source inverters VSI connected to a supply network by means of coupling circuits requiring the use of a 7.5 Ohm resistor in each filter branch. To the outputs of the power electronic switches 16, 17, 18, 26, 27, 28 electrolytic capacitors C2 - C9, each having a capacitance of 800 μ F for a voltage of 400 V, and chokes D1 - D6 having an inductance of 900 μ H have been connected. As power electronic switches C2M0160120D transistors have been used which were keyed by control blocks 16, 17, 18, 26, 27, 28 with a frequency of 64 kHz. An energy transfer from the capacitors C2 - C9 to the capacitor C1 has been effected by means of power electronic converters DC/DC with a galvanic isolation from a voltage level of 270 V to a voltage level of 800 V.

List of reference numerals

[0018]

1, 2	power network or load
3, 4, 5	coupling filters of the active parallel compensator
6	power electronic converter of AC/DC type
7, 8, 9	coupling filters of the dynamic voltage restorer system
10, 11, 12	power electronic converters of AC/DC type
C1	storage capacitor

in an energy recovery circuit of the active parallel compensator

13, 14, 15	current and voltage measurement blocks
16, 17, 18,	power electronic switches
19, 20, 21	control blocks
D1, D2, D3	chokes
C2, C3	capacitors that form an intermediate energy storage
22	power electronic converter with an input circuit being galvanically isolated from an output circuit DC/DC

in an energy recovery circuit dynamic voltage restorer

23, 24, 25	current and voltage measurement blocks
26, 27, 28,	power electronic switches

29, 30, 31	control blocks
D4, D5, D6	chokes
C4 - C9	capacitors that form intermediate energy storages
32, 33, 34	power electronic converters with an input circuit being galvanically isolated from an output circuit DC/DC
Tr1, Tr2, Tr3	transformers

Claims

1. A system for improving quality of electrical energy composed of an active parallel compensator system comprising a coupling filter in each phase conductor and a power electronic converter AC/DC, and/or of a dynamic voltage restorer system comprising in each phase conductor a transformer and a coupling filter and power electronic converters AC/DC, as well as an energy storage in the form of a storage capacitor included at DC terminals of said power electronic converters, **characterised in that** in each phase conductor (L1, L2, L3) in the LCLR type coupling filters (3, 4, 5) of the active parallel compensator system and/or the LCLR type coupling filters (7, 8, 9) of the dynamic voltage restorer system each of resistors is replaced by an energy recovery system, wherein each of these energy recovery systems is composed of a half-bridge system of power electronic switch (16, 17, 18) (26, 27, 28) connected by means of a choke (D1, D2, D3) (D4, D5, D6) and a voltage and current measurement block (13, 14, 15) (23, 24, 25) to the coupling filter (3, 4, 5) (7, 8, 9) in place of a replaced resistor, and signal conductors of the voltage and current measurement block (13, 14, 15) (23, 24, 25) are connected to the power electronic switch (16, 17, 18) (26, 27, 28) in each energy recovery system respectively, moreover, in the active parallel compensator circuit, to the two remaining outputs of each of the power electronic switches (16, 17, 18) two capacitors (C2, C3) connected in series are coupled that form an intermediate energy storage, wherein the latter by means of a power electronic converter (22), with an input circuit being galvanically isolated from an output circuit DC/DC, is connected to terminals of a storage capacitor (C1), and a common point of the capacitors (C2, C3) is connected to a neutral conductor (N) of a power network and by means of the voltage and current measurement blocks (13, 14, 15) to one of the outputs of the coupling filters (3, 4, 5), whereas in the dynamic voltage restorer system circuit, to the two remaining outputs of each of the power electronic switches (26, 27, 28), separately for each phase, two capacitors (C4-C5, C6-C7, C8-C9) connected in series are coupled that form intermediate energy storages and by means of individual power electronic converters (32, 33, 34), with an input circuit being galvanically iso-

lated from an output circuit DC/DC, they are connected to the storage capacitor (C1), and a common point of the capacitors (C4-C5, C6-C7, C8-C9), for each phase respectively, is connected by means of the voltage and current measurement block (23, 24, 25) to one of the outputs of the coupling filter (7, 8, 9).

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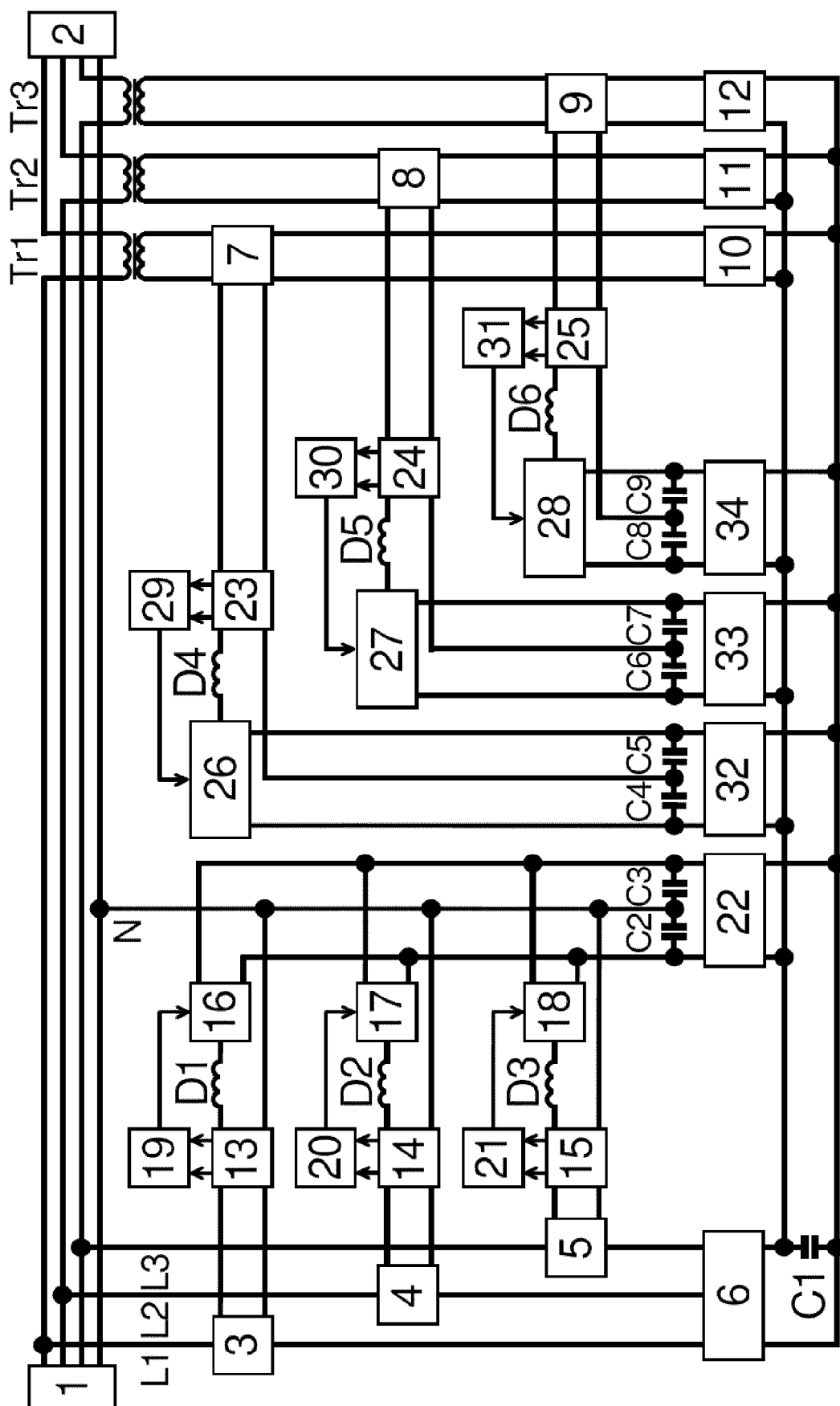
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EUROPEAN SEARCH REPORT

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 4 September 2018	Examiner Chaumeron, Bernard
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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