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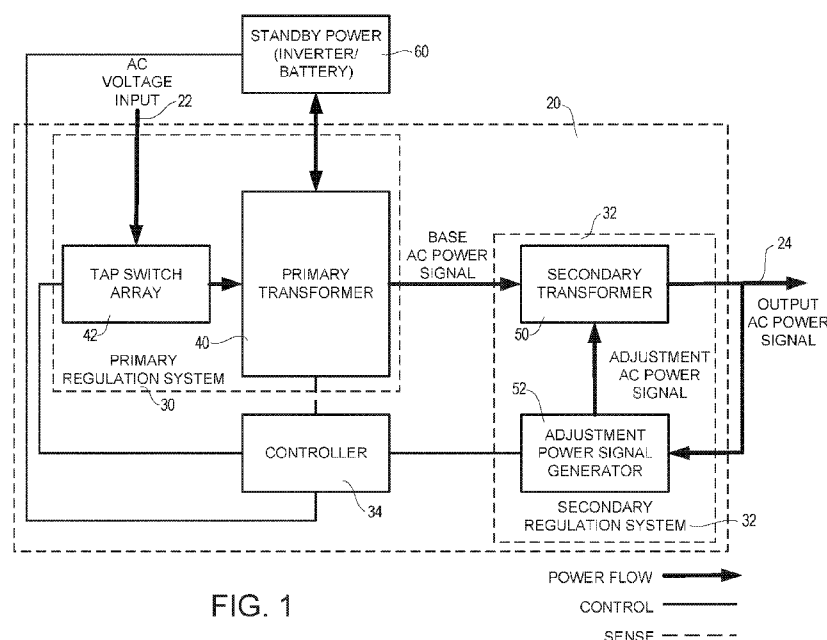


FIG. 1

(57) Abstract: A power supply system comprises a primary regulation system, a secondary regulation system, and a controller. The primary regulation system comprises a primary transformer and a primary tap switch array. The secondary regulation system comprising a secondary transformer and an adjustment power signal generator. The controller is configured to control the adjustment power signal generator to apply an adjustment power signal to the secondary transformer. The secondary transformer is configured to combine the adjustment power signal with a base power supply signal from the primary transformer.

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VOLTAGE REGULATED AC POWER SUPPLY SYSTEMS AND METHODS

RELATED APPLICATIONS

[0001] This application (Attorney's Ref. No. P219507pct) claims benefit of U.S. Provisional Patent Application Serial No. 62/532,896 filed July 14, 2017, currently pending.

[0002] The contents of the related application listed above are incorporated herein by reference.

TECHNICAL FIELD

[0003] The present invention relates to power supply systems and methods for regulating AC voltages and, more specifically, to high efficiency power supply systems and methods with active voltage regulation.

BACKGROUND

[0004] Electrical power supply systems are used to provide power from a source of electrical power such as an electric utility, generator, solar power system or the like to a load. The electrical power supply system may be configured to perform functions such as disconnecting the load from the source of electrical power under certain conditions, regulating the power signal supplied to the load, converting direct current (DC) signals to alternating current (AC) signals, converting AC signals to DC signals, and combining power signals from different sources of electrical power. To conserve energy, electrical power supply systems should be configured to reduce losses when providing power from the source to the load.

[0005] The need exists for improved electrical power supply systems for providing power from a source to a load.

SUMMARY

[0006] The present invention may be embodied as a power supply system comprises a primary regulation system, a secondary regulation system, and a controller. The primary regulation system comprises a primary transformer and a primary tap switch array. The secondary regulation system comprising a secondary transformer and an adjustment power signal generator. The controller is configured to control the adjustment power signal generator to apply an adjustment power signal to the secondary transformer. The secondary transformer is configured to combine the adjustment power signal with a base power supply signal from the primary transformer.

[0007] The present invention may also be embodied as a power supply system for providing power to an output from an input comprising a primary regulation system, a secondary regulation system, and a controller. The primary regulation system comprising a primary transformer and a primary tap switch array. The secondary regulation system comprising a secondary transformer and an adjustment power signal generator. The primary regulation system is configured to generate a base power signal based on an input power signal at the input. The controller is configured to control the adjustment power signal generator to apply an adjustment power signal to the secondary transformer. The secondary transformer is configured to combine the adjustment power signal with the base power supply signal to apply an output power signal at the output.

[0008] The present invention may also be embodied as a method of providing power to an output from an input comprising the following steps. A primary transformer and a primary tap switch array are arranged to form a primary

regulation system. A secondary transformer and an adjustment power signal generator are arranged to form a secondary regulation system. The primary tap switch array is controlled such that the primary regulation system generates a base power signal based on an input power signal at the input. The adjustment power signal generator is controlled to generate an adjustment power signal. The adjustment power signal is applied to the secondary transformer such that the adjustment power signal is combined with the base power signal to obtain an output power signal at the output.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 is a block diagram illustrating a first example power supply system of the present invention;

[0010] Figure 2 is a schematic diagram illustrating a second example power supply system of the present invention;

[0011] Figure 3 is a schematic diagram illustrating a third example power supply system of the present invention.

[0012] Figure 4 is a schematic diagram illustrating a fourth example power supply system of the present invention;

[0013] Figure 5 is a schematic diagram illustrating a fifth example power supply system of the present invention.

[0014] Figure 6 is a schematic diagram illustrating a sixth example power supply system of the present invention;

[0015] Figure 7 is a schematic diagram illustrating a seventh example power

supply system of the present invention; and

[0016] Figure 8 is a schematic diagram illustrating an eighth example power supply system of the present invention.

DETAILED DESCRIPTION

[0018] The present invention may be embodied in different forms. Several different examples of embodiments of the present invention will be discussed separately below.

I. First Example Embodiment

[0019] Referring initially to Figure 1 of the drawing, depicted therein is a first example power supply system 20 constructed in accordance with, and embodying, the principles of the present invention. The example power supply system 20 defines an input 22 and an output 24. The example power supply system 20 accepts an input AC power signal at the input 22 and supplies an output AC power signal at the output 24.

[0020] The first example power supply system 20 comprises a primary regulation system 30, a secondary regulation system 32, and a controller 34. The example primary regulation system 30 comprises a primary transformer 40 and a tap switch array 42. The example secondary regulation system 32 comprises a secondary transformer 50 and an adjustment power signal generator 52. The first example power supply system 20 is further configured to operate in a standby mode in which the output AC power signal is generated based on a standby power system 60. The standby power system 60 may be operatively connected to a standby power source (not shown) such as a battery, a generator, or a solar panel array and possibly an inverter (not shown).

[0021] The primary regulation system 30 is configured to regulate a voltage of the output AC power signal within a first voltage range. In particular, the controller 34 controls the tap switch array 42 based on the output AC power signal to connect the input 22 to the primary transformer 40 such that a base AC

power signal output from the primary regulation system 30 is maintained within the first range. The secondary regulation system 32 is configured to regulate the voltage of the output AC power signal within a second voltage range. In particular, the controller 34 controls the adjustment power signal generator 52 based on the output AC power signal, and the secondary transformer 50 combines (e.g., sums) an adjustment AC power signal generated by the adjustment power signal generator 52 to the output of the primary transformer 40 such that the output AC power signal is maintained within the second range. The second voltage range is smaller than the first voltage range.

[0022] More specifically, the controller 34 senses voltage and/or current representative of the input AC power signal and controls the tap switch array 42 as necessary to accommodate the AC output power signal. For example, if the controller 34 determines that a sensed voltage indicates that a voltage of the AC output power signal is not within a predetermined first desired voltage range (e.g., 80-90 VAC), the controller 34 operates the tap switch array 42 such that the primary transformer 40 increases the voltage of the AC output power signal such that the AC output power signal is within the predetermined first desired voltage range.

[0023] The controller 34 further senses one or more voltages and/or currents associated with the output AC power signal and controls the adjustment power signal generator 52 to generate the adjustment power signal such that the combination of the adjustment power signal and the output of the main transformer 40 yields an output AC power signal within a predetermined second desired voltage range or level. For example, if the primary transformer 40 is configured to supply a primary transformer output voltage of approximately 85 VAC (example predetermined desired voltage level) and the actual primary transformer output voltage droops to 84 VAC, the controller 34 will control the adjustment power signal generator 52 to generate the adjustment power signal

such that the adjustment power signal, in combination with the primary transformer output voltage, yields an actual output AC voltage signal that is at or near 85 VAC.

[0024] Typically, the controller 34 will include a digital microprocessor, analog-to-digital converters, memory, and associated circuitry. The microprocessor runs software capable of generating control signals (e.g., pulse-width modulate signals) for controlling the operation of the adjustment power signal generator 52 based on sense signals associated with at least a voltage of the output AC power signal. The details of the controller 34, the sense signals, the control signals, and the software running on the controller 34 are or may be conventional and will not be described herein in further detail.

II. Second Example Embodiment

[0025] Figure 2 of the drawing illustrates a second example power supply system 120 comprising a primary regulation system 130, a secondary regulation system 132, and a controller (not shown). The controller of the third example power supply system 120 is or may be the same as the controller 34 described above and will not be described herein in further detail.

[0026] Figure 2 illustrates that the second example power supply system 120 defines input terminals 122a and 122b and output terminals 124a and 124b. The example power supply system 120 accepts an input AC power signal across the input terminals 122a and 122b and supplies an output AC power signal across the output terminals 124a and 124b. The second example power supply system 120 further comprises optional standby input terminals 126a and 126b.

[0027] The example primary regulation system 130 comprises a primary transformer 140 and a tap switch array 142. The example primary transformer

140 is a linear transformer. The example secondary regulation system 132 comprises a secondary transformer 150 and a regulating inverter 152. The secondary transformer 150 is a linear transformer arranged in series with the main transformer 140. The regulating inverter 152 generates an adjustment power signal, and the secondary transformer 150 combines the adjustment power signal with the output of the primary transformer 140 to obtain the output AC power signal. The example regulating inverter 152 comprises a DC/AC converter 160 and an AC/DC converter 162.

[0028] The second example power supply system 120 may be embodied as or form a part of an uninterruptible power supply. When configured as an uninterruptible power supply, the second example power supply system 120 further optionally comprises a standby power system 164 that is operatively connected to the primary transformer 140. The standby power system 164 may comprise one or more of a battery and inverter, a generator, a solar power system, and the like. Should the input AC power signal be absent or outside of a predetermined operating range, the input terminals 122a and 122b may be disconnected from the primary transformer 140, and the output power AC signal may be generated based on a standby AC power signal generated by the standby power supply system 164.

[0029] The second example power supply system 120 thus regulates the voltage of the input AC power signal such that the output AC power signal is within predefined parameters. The second example power supply system 120 may be configured to use high efficiency linear transformers as the primary transformer 140 and the secondary transformer 150. The second example power supply system 120 thus can be configured to provide a regulated output AC regional power signal at efficiencies of approximately 95-98 percent.

[0030] In particular, the primary regulation system 130 is configured to regulate a voltage of the output AC power signal within a first voltage range. The secondary regulation system 132 is configured to regulate the voltage of the output AC power signal within a second voltage range. The second voltage range is smaller than the first voltage range. If the second example power supply system 120 is configured to provide power in the context of a broadband communications system, the output AC voltage power signal should not exceed 90 volts. The primary regulation system 130 thus allows the second example power supply 120 to adapt at a slow rate (e.g., twice a day) to relatively large voltage fluctuations (e.g., ± 5 volts). The secondary regulation system 132, on the other hand, allows the second example power supply system 120 to regulate the output AC voltage, within certain parameters, to accommodate small voltage fluctuations (e.g., ± 2 volts) of the input AC power signal at high frequency or substantially in real time. In the second example power supply system 120, the example first voltage range is approximately ± 5 volts, and the example second voltage range is approximately ± 2 volts. These ranges are provided by way of example only and may vary based on the requirements of a particular power supply environment.

[0031] The example primary transformer 140 comprises primary input windings 170, output windings 172, a shunt 174, and, optionally, secondary input windings 176. The primary input windings are arranged on a first side 178a of the shunt 174, while the output windings 172 and optional secondary input windings 176 are arranged on a second side 178b of the shunt 174. The example primary input windings 170 define primary input winding first and second end taps 170a and 170b and primary input winding first and second intermediate taps 170c and 170d. The example output windings 172 define output winding first and second end taps 172a and 172b. The example optional secondary windings 176 define secondary winding first and second end taps

172a and 172b. If used, the first and second end taps 172a and 172b are connected to the standby input terminals 126a and 126b.

[0032] The example tap switch array 142 comprises a first switch 180, a second switch 182, and a third switch 184. The example switches 180, 182, and 184 are single-pull double-through (SPDT) switches that can be controlled by the controller, operated manually, or both controlled by the controller and operated manually. The first switch 180 defines a first switch main terminal 180a, a first switch first contact terminal 180b, and a first switch second contact terminal 180c. The second switch 182 defines a second switch main terminal 182a, a second switch first contact terminal 182b, and a second switch second contact terminal 182c. The third switch 184 defines a third switch main terminal 184a, a third switch first contact terminal 184b, and a third switch second contact terminal 184c. The example secondary transformer 150 comprises first windings 190 and second windings 192. The example first windings 190 define first winding first and second end taps 190a and 190b. The example second windings 192 define second winding first and second end taps 192a and 192b.

[0033] The example DC/AC converter 160 comprises MOSFETs Q1, Q2, Q3, and Q4, an inductor L, and an output capacitor C1. The example AC/DC converter 162 comprises diodes D1, D2, D3, and D4 configured as a rectifier and rectifier capacitor C2. The DC/AC converter 160 defines first and second inverter terminals 152a and 152b. The example DC/AC converter 160 and the example AC/DC converter 162 operate as a full-bridge rectifier/converter that is or may be conventional and thus will not be described herein in detail. An optional filter capacitor F may be arranged to filter the output of the converter 160; in Figure 2, the filter capacitor F is connected between the first end terminal 192a of the second winding 192 of the secondary transformer 150 and the first inverter output terminal 152a.

[0034] The first switch main terminal 180a is connected to the first primary input terminal 122a. The first switch first contact terminal 180b is not connected to any other terminal, allowing the first switch to disconnect the power system from the input. The first switch second contact terminal 180c is connected to the second switch main terminal 182a. The second switch first contact terminal 182b is connected to the primary winding first end tap 170a. The second switch second contact terminal 182c is connected to the primary winding first intermediate tap 170c. The third switch main terminal 184a is connected to the second primary input terminal 122b. The third switch first contact terminal 184b is connected to the primary winding second intermediate tap 170d. The third switch second contact terminal 184c is connected to the primary winding second end tap 170b. The output winding first end tap 172a is connected to the first winding first end tap 190a. The output winding second end tap 172b is connected to the second output terminal 124b. The first winding second end tap 190b is connected to the first output terminal 124a. The second winding first end tap 192a is connected to one end of the inverter capacitor C1. The second winding first and second end terminals 192a and 192b are connected to the first and second inverter output terminals 152a and 152b.

[0035] The AC/DC converter 162 formed by the rectifier diodes D1-D4 and rectifier capacitor C2 is connected across the output terminals 124a and 124b such that a DC signal is present at the DC/AC converter 160. The switches formed by the MOSFETS Q1-Q4 are controlled (e.g., pulse-width modulated) based on the voltage of the output AC power signal or a voltage indicative of or proportional to the output AC power signal to generate the regulated power signal across the inverter output terminals 152a and 152b. The regulated power signal is applied across the second windings 192 of the secondary transformer 150 and are thus added to the adjustment AC power signal across the output winding first and second end terminals 172a and 172b. The sum of the voltage of the adjustment AC power signal and base AC power signal generated by the

primary regulation system 130 (e.g., across the output winding first and second end terminals 172a and 172b) is thus controlled to be within a predetermined range centered about a target output AC power signal voltage level.

[0036] When configured as an uninterruptible power supply, the standby input terminals 126a and 126b of the second example power supply system 120 may be connected to the standby power system 164 such that the standby power system 164 is operatively connected to the primary transformer 140. Should the example power system 120 not form a part of an uninterruptible power supply, the second input windings 176 and standby input terminals 126a and 126b may be omitted.

[0037] The second example power supply system 120 thus regulates the voltage of the input AC power signal such that the output AC power signal is within predefined parameters. The second example power supply system 120 may be configured to use high efficiency linear transformers as the primary transformer 140 and the secondary transformer 150. The second example power supply system 120 thus can be configured to provide a regulated output AC power signal at efficiencies of between 95-98 percent. In the second example power supply system 120, the inductor L is external to the secondary transformer 150.

III. Third Example Embodiment

[0038] Figure 3 of the drawing illustrates a third example power supply system 220 comprising a primary regulation system 230, a secondary regulation system 232, and a controller (not shown). The controller of the third example power supply system 220 is or may be the same as the controller 34 described above and will not be described herein in further detail.

[0039] Figure 3 illustrates that the third example power supply system 220 defines input terminals 222a and 222b and output terminals 224a and 224b. The example power supply system 220 accepts an input AC power signal across the input terminals 222a and 222b and supplies an output AC power signal across the output terminals 224a and 224b. The third example power supply system 220 further comprises optional standby input terminals 226a and 226b.

[0040] The third example primary regulation system 230 comprises a primary transformer 240 and a tap switch array 242. The example primary transformer 240 is a linear transformer. The example secondary regulation system 232 comprises a secondary transformer 250 and a regulating inverter 252. The secondary transformer 250 is a linear transformer arranged in series with the primary transformer 240. The regulating inverter 252 generates an adjustment power signal, and the secondary transformer 250 combines the adjustment power signal with the output of the primary transformer 240 to obtain the output AC power signal. The example regulating inverter 252 comprises a DC/AC converter 260 and an AC/DC converter 262.

[0041] The third example power supply system 220 may be embodied as or form a part of an uninterruptible power supply. When configured as an uninterruptible power supply, the third example power supply system 220 further optionally comprises a standby power system 264 that is operatively connected to the primary transformer 240. The standby power system 264 may comprise one or more of a battery and inverter, a generator, a solar power system, and the like. Should the input AC power signal be absent or outside of a predetermined operating range, the inputs 222a and 222b may be disconnected from the primary transformer 240, and the output power AC signal may be generated based on a standby AC power signal generated by the standby power supply system 264.

[0042] The third example power supply system 220 thus regulates the voltage of the input AC power signal such that the output AC power signal is within predefined parameters. The third example power supply system 220 may be configured to use high efficiency linear transformers as the primary transformer 240 and the secondary transformer 250. The third example power supply system 220 thus can be configured to provide a regulated output AC regional power signal at efficiencies of approximately 95-98 percent.

[0043] In particular, the primary regulation system 230 is configured to regulate a voltage of the output AC power signal within a first voltage range. The secondary regulation system 232 is configured to regulate the voltage of the output AC power signal within a second voltage range. The second voltage range is smaller than the first voltage range. If the third example power supply system 220 is configured to provide power in the context of a broadband communications system, the output AC voltage power signal should not exceed 90 volts. The primary regulation system 230 thus allows the third example power supply 220 to adapt at a slow rate (e.g., twice a day) to relatively large voltage fluctuations (e.g., ± 5 volts). The secondary regulation system 232, on the other hand, allows the third example power supply system 220 to regulate the output AC voltage, within certain parameters, to accommodate small voltage fluctuations (e.g., ± 2 volts) of the input AC power signal at high frequency or substantially in real time. In the third example power supply system 220, the example first voltage range is approximately ± 5 volts, and the example second voltage range is approximately ± 2 volts. These ranges are provided by way of example only and may vary based on the requirements of a particular power supply environment.

[0044] The example primary transformer 240 comprises primary input windings 270, output windings 272, a shunt 274, and, optionally, secondary input windings 276. The primary input windings are arranged on a first side 278a of

the shunt 274, while the output windings 272 and optional secondary input windings 276 are arranged on a second side 278b of the shunt 274. The example primary input windings 270 define primary input winding first and second end taps 270a and 270b and primary input winding first and second intermediate taps 270c and 270d. The example output windings 272 define output winding first and second end taps 272a and 272b. The example optional secondary windings 276 define secondary winding first and second end taps 276a and 276b. If used, the first and second end taps 276a and 276b are connected to the standby input terminals 226a and 226b.

[0045] The example tap switch array 242 comprises a first switch 280, a second switch 282, and a third switch 284. The example switches 280, 282, and 284 are single-pull double-through (SPDT) switches that can be controlled by the controller, operated manually, or both controlled by the controller and operated manually. The first switch 280 defines a first switch main terminal 280a, a first switch first contact terminal 280b, and a first switch second contact terminal 280c. The second switch 282 defines a second switch main terminal 282a, a second switch first contact terminal 282b, and a second switch second contact terminal 282c. The third switch 284 defines a third switch main terminal 284a, a third switch first contact terminal 284b, and a third switch second contact terminal 284c. The example secondary transformer 250 comprises first windings 290 and second windings 292. The example first windings 290 define first winding first and second end taps 290a and 290b. The example second windings 292 define second winding first and second end taps 292a and 292b.

[0046] The example DC/AC converter 260 comprises MOSFETs Q1, Q2, Q3, and Q4, an inductor L, and an output capacitor C1. In the third example power supply 220, the inductor L is integrally formed with the secondary transformer 250. The example AC/DC converter 262 comprises diodes D1, D2, D3, and D4 configured as a rectifier and rectifier capacitor C2. The DC/AC converter 260

defines first and second inverter terminals 252a and 252b. The example DC/AC converter 260 and the example AC/DC converter 262 operate as a full-bridge rectifier/converter that is or may be conventional and thus will not be described herein in detail. An optional filter capacitor F may be arranged to filter the output of the converter 260; in Figure 3, the filter capacitor F is connected between the first end terminal 292a of the second winding 292 of the secondary transformer 250 and the first inverter output terminal 252a.

[0047] The first switch main terminal 280a is connected to the first primary input terminal 222a. The first switch first contact terminal 280b is not connected to any other terminal, allowing the first switch to disconnect the power system from the input. The first switch second contact terminal 280c is connected to the second switch main terminal 282a. The second switch first contact terminal 282b is connected to the primary winding first end tap 270a. The second switch second contact terminal 282c is connected to the primary winding first intermediate tap 270c. The third switch main terminal 284a is connected to the second primary input terminal 222b. The third switch first contact terminal 284b is connected to the primary winding second intermediate tap 270d. The third switch second contact terminal 284c is connected to the primary winding second end tap 270b. The output winding first end tap 272a is connected to the first winding first end tap 290a. The output winding second end tap 272b is connected to the second output terminal 224b. The first winding second end tap 290b is connected, through the inductor L, to one side of the inverter capacitor C1 and to the first output terminal 224a. The second winding first end tap 292a is connected to inverter outputs 252a and 252b. The second winding first and second end terminals 292a and 292b are connected to the first and second inverter output terminals 252a and 252b.

[0048] The AC/DC converter 262 formed by the rectifier diodes D1-D4 and rectifier capacitor C2 is connected across the output terminals 224a and 224b

such that a DC signal is present at the DC/AC converter 260. The switches formed by the MOSFETS Q1-Q4 are controlled (e.g., pulse-width modulated) based on the voltage of the output AC power signal or a voltage indicative of or proportional to the output AC power signal to generate the regulated power signal across the inverter output terminals 252a and 252b. The regulated power signal is applied across the second windings 292 of the secondary transformer 250 and are thus added to the adjustment AC power signal across the output winding first and second end terminals 272a and 272b. The sum of the voltage of the adjustment AC power signal and base AC power signal generated by the primary regulation system 230 (e.g., across the output winding first and second end terminals 272a and 272b) is thus controlled to be within a predetermined range centered about a target output AC power signal voltage level.

[0049] When configured as an uninterruptible power supply, the standby input terminals 226a and 226b of the third example power supply system 220 may be connected to the standby power system 264 such that the standby power system 264 is operatively connected to the primary transformer 240. Should the example power system 220 not form a part of an uninterruptible power supply, the second input windings 276 and standby input terminals 226a and 226b may be omitted.

[0050] The third example power supply system 220 thus regulates the voltage of the input AC power signal such that the output AC power signal is within predefined parameters. The third example power supply system 220 may be configured to use high efficiency linear transformers as the primary transformer 240 and the secondary transformer 250. The third example power supply system 220 thus can be configured to provide a regulated output AC power signal at efficiencies of between 95-98 percent. In the third example power supply system 220, the inductor L is integrated into the secondary transformer 250.

IV. Fourth Example Embodiment

[0051] Figure 4 of the drawing illustrates a fourth example power supply system 320 comprising a primary regulation system 330, a secondary regulation system 332, and a controller (not shown). The controller of the fourth example power supply system 320 may be implemented in a manner similar to that of the controller 34 described above and will not be described herein in further detail.

[0052] Figure 4 illustrates that the fourth example power supply system 320 defines input terminals 322a and 322b and output terminals 324a and 324b. The example power supply system 320 accepts an input AC power signal across the input terminals 322a and 322b and supplies an output AC power signal across the output terminals 324a and 324b. The fourth example power supply system 320 further comprises optional standby input terminals 326a and 326b.

[0053] The example primary regulation system 330 comprises a primary transformer 340 and a tap switch array 342. The example primary transformer 340 is a linear transformer. The example secondary regulation system 332 comprises a secondary transformer 350 and a regulating inverter 352. The secondary transformer 350 is a linear transformer arranged in series with the primary transformer 340. The regulating inverter 352 generates an adjustment power signal, and the secondary transformer 350 combines the adjustment power signal with the output of the primary transformer 340 to obtain the output AC power signal. The example regulating inverter 352 comprises a DC/AC converter 360 and an AC/DC converter 362.

[0054] The fourth example power supply system 320 may be embodied as or form a part of an uninterruptible power supply. When configured as an uninterruptible power supply, the fourth example power supply system 320 further optionally comprises a standby power system 364 that is operatively

connected to the primary transformer 340. The standby power system 364 may comprise one or more of a battery and inverter, a generator, a solar power system, and the like. Should the input AC power signal be absent or outside of a predetermined operating range, the input terminals 322a and 322b may be disconnected from the primary transformer 340, and the output power AC signal may be generated based on a standby AC power signal generated by the standby power supply system 364.

[0055] The fourth example power supply system 320 thus regulates the voltage of the input AC power signal such that the output AC power signal is within predefined parameters. The fourth example power supply system 320 may be configured to use high efficiency linear transformers as the primary transformer 340 and the secondary transformer 350. The fourth example power supply system 320 thus can be configured to provide a regulated output AC regional power signal at efficiencies of approximately 95-98 percent.

[0056] In particular, the primary regulation system 330 is configured to regulate a voltage of the output AC power signal within a first voltage range. The secondary regulation system 332 is configured to regulate the voltage of the output AC power signal within a second voltage range. The second voltage range is smaller than the first voltage range. If the fourth example power supply system 320 is configured to provide power in the context of a broadband communications system, the output AC voltage power signal should not exceed 90 volts. The primary regulation system 330 thus allows the fourth example power supply 320 adapt at a slow rate (e.g., twice a day) to relatively large voltage fluctuations (e.g., ± 5 volts). The secondary regulation system 332, on the other hand, allows the fourth example power supply system 320 to regulate the output AC voltage, within certain parameters, to accommodate small voltage fluctuations (e.g., ± 2 volts) of the input AC power signal at high frequency or substantially in real time. In the fourth example power supply system 320, the

example first voltage range is approximately ± 5 volts, and the example second voltage range is approximately ± 3 volts. These ranges are provided by way of example only and may vary based on the requirements of a particular power supply environment.

[0057] The example primary transformer 340 comprises primary input windings 370, output windings 372, a shunt 374, and, optionally, secondary input windings 376. The primary input windings 370 are arranged on a first side 378a of the shunt 374, while the output windings 372 and optional secondary input windings 376 are arranged on a second side 378b of the shunt 374. The example primary input windings 370 define primary input winding first and second end taps 370a and 370b and primary input winding first and second intermediate taps 370c and 370d. The example output windings 372 define output winding first and second end taps 372a and 372b. The example optional secondary windings 376 define secondary winding first and second end taps 376a and 376b. If used, the first and second end taps 376a and 376b are connected to the standby input terminals 326a and 326b.

[0058] The example tap switch array 342 comprises a first switch 380, a second switch 382, and a third switch 384. The example switches 380, 382, and 384 are single-pull double-through (SPDT) switches that can be controlled by the controller, operated manually, or both controlled by the controller and operated manually. The first switch 380 defines a first switch main terminal 380a, a first switch first contact terminal 380b, and a first switch second contact terminal 380c. The second switch 382 defines a second switch main terminal 382a, a second switch first contact terminal 382b, and a second switch second contact terminal 382c. The third switch 384 defines a third switch main terminal 384a, a third switch first contact terminal 384b, and a third switch second contact terminal 384c. The example secondary transformer 350 comprises first windings 390 and second windings 392. The example first windings 390 define first winding first

and second end taps 390a and 390b. The example second windings 392 define second winding first and second end taps 392a and 392b.

[0059] The example DC/AC converter 360 comprises MOSFETs Q1 and Q2, an inductor L, and an output capacitor C1. In the fourth example power supply 320, the inductor L is external to the secondary transformer 350. The example AC/DC converter 362 comprises diodes D1 and D2 and a rectifier capacitors C2 and C3 configured as a rectifier. The DC/AC converter 360 defines first and second inverter terminals 352a and 352b. The example DC/AC converter 360 and the example AC/DC converter 362 operate as a half-bridge rectifier/converter that is or may be conventional and thus will not be described herein in detail. An optional filter capacitor F may be arranged to filter the output of the converter 360; in Figure 4, the filter capacitor F is connected between the first end terminal 392a of the second winding 392 of the secondary transformer 350 and the first inverter output terminal 352a.

[0060] The first switch main terminal 380a is connected to the first primary input terminal 322a. The first switch first contact terminal 380b is not connected to any other terminal, allowing the first switch to disconnect the power system from the input. The first switch second contact terminal 380c is connected to the second switch main terminal 382a. The second switch first contact terminal 382b is connected to the primary winding first end tap 370a. The second switch second contact terminal 382c is connected to the primary winding first intermediate tap 370c. The third switch main terminal 384a is connected to the second primary input terminal 322b. The third switch first contact terminal 384b is connected to the primary winding second intermediate tap 370d. The third switch second contact terminal 384c is connected to the primary winding second end tap 370b. The output winding first end tap 372a is connected to the first winding first end tap 390a. The output winding second end tap 372b is connected to the second output terminal 324b. The first winding second end tap

390b is connected to the first output terminal 324a. The second winding first and second end terminals 392a and 392b are connected to the first and second inverter output terminals 352a and 352b.

[0061] The AC/DC converter 362 formed by the rectifier diodes D1 and D2 and rectifier capacitors C2 and C3 connected across the output terminals 324a and 324b such that a DC signal is present at the DC/AC converter 360. The switches formed by the MOSFETS Q1 and Q2 are controlled (e.g., pulse-width modulated) based on the voltage of the output AC power signal or a voltage indicative of or proportional to the output AC power signal to generate the regulated power signal across the inverter output terminals 352a and 352b. The regulated power signal is applied across the second windings 392 of the secondary transformer 350 and are thus added to the adjustment AC power signal across the output winding first and second end terminals 372a and 372b. The sum of the voltage of the adjustment AC power signal and base AC power signal generated by the primary regulation system 330 (e.g., across the output winding first and second end terminals 372a and 372b) is thus controlled to be within a predetermined range centered about a target output AC power signal voltage level.

[0062] When configured as an uninterruptible power supply, the standby input terminals 326a and 326b of the fourth example power supply system 320 may be connected to the standby power system 364 such that the standby power system 364 is operatively connected to the primary transformer 340. Should the example power system 320 not form a part of an uninterruptible power supply, the second input windings 376 and standby input terminals 326a and 326b may be omitted.

[0063] The fourth example power supply system 320 thus regulates the voltage of the input AC power signal such that the output AC power signal is

within predefined parameters. The fourth example power supply system 320 may be configured to use high efficiency linear transformers as the primary transformer 340 and the secondary transformer 350. The fourth example power supply system 320 thus can be configured to provide a regulated output AC power signal at efficiencies of between 95-98 percent. In the fourth example power supply system 320, the inductor L is external to the secondary transformer 350.

V. Fifth Example Embodiment

[0064] Figure 5 of the drawing illustrates a fifth example power supply system 420 comprising a primary regulation system 430, a secondary regulation system 432, and a controller (not shown). The controller of the fifth example power supply system 420 may be implemented in a manner similar to that of the controller 34 described above and will not be described herein in further detail.

[0065] Figure 5 illustrates that the fifth example power supply system 420 defines input terminals 422a and 422b and output terminals 424a and 424b. The example power supply system 420 accepts an input AC power signal across the input terminals 422a and 422b and supplies an output AC power signal across the output terminals 424a and 424b. The fifth example power supply system 420 further comprises optional standby input terminals 426a and 426b.

[0066] The example primary regulation system 430 comprises a primary transformer 440 and a tap switch array 442. The example primary transformer 440 is a linear transformer. The example secondary regulation system 432 comprises a secondary transformer 450 and a regulating inverter 452. The secondary transformer 450 is a linear transformer arranged in series with the primary transformer 440. The regulating inverter 452 generates an adjustment power signal, and the secondary transformer 450 combines the adjustment

power signal with the output of the primary transformer 440 to obtain the output AC power signal. The example regulating inverter 452 comprises a DC/AC converter 460 and an AC/DC converter 462.

[0067] The fifth example power supply system 420 may be embodied as or form a part of an uninterruptible power supply. When configured as an uninterruptible power supply, the fifth example power supply system 420 further optionally comprises a standby power system 464 that is operatively connected to the primary transformer 440. The standby power system 464 may comprise one or more of a battery and inverter, a generator, a solar power system, and the like. Should the input AC power signal be absent or outside of a predetermined operating range, the input terminals 422a and 422b may be disconnected from the primary transformer 440, and the output power AC signal may be generated based on a standby AC power signal generated by the standby power supply system 464.

[0068] The fifth example power supply system 420 thus regulates the voltage of the input AC power signal such that the output AC power signal is within predefined parameters. The fifth example power supply system 420 may be configured to use high efficiency linear transformers as the primary transformer 440 and the secondary transformer 450. The fifth example power supply system 420 thus can be configured to provide a regulated output AC regional power signal at efficiencies of approximately 95-98 percent.

[0069] In particular, the primary regulation system 430 is configured to regulate a voltage of the output AC power signal within a first voltage range. The secondary regulation system 432 is configured to regulate the voltage of the output AC power signal within a second voltage range. The second voltage range is smaller than the first voltage range. If the fifth example power supply system 420 is configured to provide power in the context of a broadband

communications system, the output AC voltage power signal should not exceed 90 volts. The primary regulation system 430 thus allows the fifth example power supply 420 adapt at a slow rate (e.g., twice a day) to relatively large voltage fluctuations (e.g., ± 5 volts). The secondary regulation system 432, on the other hand, allows the fifth example power supply system 420 to regulate the output AC voltage, within certain parameters, to accommodate small voltage fluctuations (e.g., ± 2 volts) of the input AC power signal at high frequency or substantially in real time. In the fifth example power supply system 420, the example first voltage range is approximately ± 5 volts, and the example second voltage range is approximately ± 2 volts. These ranges are provided by way of example only and may vary based on the requirements of a particular power supply environment.

[0070] The example primary transformer 440 comprises primary input windings 470, output windings 472, a shunt 474, and, optionally, secondary input windings 476. The primary input windings are arranged on a first side 478a of the shunt 474, while the output windings 472 and optional secondary input windings 476 are arranged on a second side 478b of the shunt 474. The example primary input windings 470 define primary input winding first and second end taps 470a and 470b and primary input winding first and second intermediate taps 470c and 470d. The example output windings 472 define output winding first and second end taps 472a and 472b. The example optional secondary windings 476 define secondary winding first and second end taps 476a and 476b. If used, the first and second end taps 476a and 476b are connected to the standby input terminals 426a and 426b.

[0071] The example tap switch array 442 comprises a first switch 480, a second switch 482, and a third switch 484. The example switches 480, 482, and 484 are single-pull double-through (SPDT) switches that can be controlled by the controller, operated manually, or both controlled by the controller and operated

manually. The first switch 480 defines a first switch main terminal 480a, a first switch first contact terminal 480b, and a first switch second contact terminal 480c. The second switch 482 defines a second switch main terminal 482a, a second switch first contact terminal 482b, and a second switch second contact terminal 482c. The third switch 484 defines a third switch main terminal 484a, a third switch first contact terminal 484b, and a third switch second contact terminal 484c. The example secondary transformer 450 comprises first windings 490 and second windings 492. The example first windings 490 define first winding first and second end taps 490a and 490b. The example second windings 492 define second winding first and second end taps 492a and 492b.

[0072] The example DC/AC converter 460 comprises MOSFETs Q1 and Q2, an inductor L, and an output capacitor C1. In the fifth example power supply 420, the inductor L is internal to the secondary transformer 450. The example AC/DC converter 462 comprises diodes D1 and D2 and rectifier capacitors C2 and C3 configured as a rectifier. The DC/AC converter 460 defines first and second inverter terminals 452a and 452b. The example DC/AC converter 460 and the example AC/DC converter 462 operate as a half-bridge rectifier/converter that is or may be conventional and thus will not be described herein in detail. An optional filter capacitor F may be arranged to filter the output of the converter 460; in Figure 5, the filter capacitor F is connected between the first end terminal 492a of the second winding 492 of the secondary transformer 450 and the first inverter output terminal 452a.

[0073] The first switch main terminal 480a is connected to the first primary input terminal 422a. The first switch first contact terminal 480b is not connected to any other terminal, allowing the first switch to disconnect the power system from the input. The first switch second contact terminal 480c is connected to the second switch main terminal 482a. The second switch first contact terminal 482b is connected to the primary winding first end tap 470a. The second switch

second contact terminal 482c is connected to the primary winding first intermediate tap 470c. The third switch main terminal 484a is connected to the second primary input terminal 422b. The third switch first contact terminal 484b is connected to the primary winding second intermediate tap 470d. The third switch second contact terminal 484c is connected to the primary winding second end tap 470b. The output winding first end tap 472a is connected to the first winding first end tap 490a. The output winding second end tap 472b is connected to the second output terminal 424b. The first winding second end tap 490b is connected to the first output terminal 424a through the inductor L.

[0074] The AC/DC converter 462 formed by the rectifier diodes D1 and D2 and rectifier capacitors C2 and C3 are connected across the output terminals 424a and 424b such that a DC signal is present at the DC/AC converter 460. The switches formed by the MOSFETS Q1 and Q2 are controlled (e.g., pulse-width modulated) based on the voltage of the output AC power signal or a voltage indicative of or proportional to the output AC power signal to generate the regulated power signal across the inverter output terminals 452a and 452b. The regulated power signal is applied across the second windings 492 of the secondary transformer 450 and are thus added to the adjustment AC power signal across the output winding first and second end terminals 472a and 472b. The sum of the voltage of the adjustment AC power signal and base AC power signal generated by the primary regulation system 430 (e.g., across the output winding first and second end terminals 472a and 472b) is thus controlled to be within a predetermined range centered about a target output AC power signal voltage level.

[0075] When configured as an uninterruptible power supply, the standby input terminals 426a and 426b of the fifth example power supply system 420 may be connected to the standby power system 464 such that the standby power system 464 is operatively connected to the primary transformer 440. Should the

example power system 420 not form a part of an uninterruptible power supply, the second input windings 476 and standby input terminals 426a and 426b may be omitted.

[0076] The fifth example power supply system 420 thus regulates the voltage of the input AC power signal such that the output AC power signal is within predefined parameters. The fifth example power supply system 420 may be configured to use high efficiency linear transformers as the primary transformer 440 and the secondary transformer 450. The fifth example power supply system 420 thus can be configured to provide a regulated output AC power signal at efficiencies of between 95-98 percent. In the fifth example power supply system 420, the inductor L is integrated into the secondary transformer 450.

VI. Sixth Example Embodiment

[0077] Figure 6 of the drawing illustrates a sixth example power supply system 520 comprising a primary regulation system 530, a secondary regulation system 532, and a controller (not shown). The controller of the sixth example power supply system 520 may be implemented in a manner similar to that of the controller 34 described above and will not be described herein in further detail.

[0078] Figure 6 illustrates that the sixth example power supply system 520 defines input terminals 522a and 522b and output terminals 524a and 524b. The example power supply system 520 accepts an input AC power signal across the input terminals 522a and 522b and supplies an output AC power signal across the output terminals 524a and 524b. The sixth example power supply system 520 further comprises optional standby input terminals 526a and 526b.

[0079] The example primary regulation system 530 comprises a primary transformer 540 and a tap switch array 542. The example primary transformer

540 is a linear transformer. The example secondary regulation system 532 comprises a secondary transformer 550 and a regulating inverter 552. The secondary transformer 550 is a linear transformer arranged in series with the primary transformer 540. The regulating inverter 552 generates an adjustment power signal, and the secondary transformer 550 combines the adjustment power signal with the output of the primary transformer 540 to obtain the output AC power signal. The example regulating inverter 552 comprises a DC/AC converter 560 and an AC/DC converter 562.

[0080] The sixth example power supply system 520 may be embodied as or form a part of an uninterruptible power supply. When configured as an uninterruptible power supply, the sixth example power supply system 520 further optionally comprises a standby power system 564 that is operatively connected to the primary transformer 540. The standby power system 564 may comprise one or more of a battery and inverter, a generator, a solar power system, and the like. Should the input AC power signal be absent or outside of a predetermined operating range, the input 522a and 522b may be disconnected from the primary transformer 540, and the output power AC signal may be generated based on a standby AC power signal generated by the standby power supply system 564.

[0081] The sixth example power supply system 520 thus regulates the voltage of the input AC power signal such that the output AC power signal is within predefined parameters. The sixth example power supply system 520 may be configured to use high efficiency linear transformers as the primary transformer 540 and the secondary transformer 550. The sixth example power supply system 520 thus can be configured to provide a regulated output AC regional power signal at efficiencies of approximately 95-98 percent.

[0082] In particular, the primary regulation system 530 is configured to regulate a voltage of the output AC power signal within a first voltage range. The

secondary regulation system 532 is configured to regulate the voltage of the output AC power signal within a second voltage range. The second voltage range is smaller than the first voltage range. If the sixth example power supply system 520 is configured to provide power in the context of a broadband communications system, the output AC voltage power signal should not exceed 90 volts. The primary regulation system 530 thus allows the sixth example power supply 520 adapt at a slow rate (e.g., twice a day) to relatively large voltage fluctuations (e.g., ± 5 volts). The secondary regulation system 532, on the other hand, allows the sixth example power supply system 520 to regulate the output AC voltage, within certain parameters, to accommodate small voltage fluctuations (e.g., ± 2 volts) of the input AC power signal at high frequency or substantially in real time. In the sixth example power supply system 520, the example first voltage range is approximately ± 5 volts, and the example second voltage range is approximately ± 2 volts. These ranges are provided by way of example only and may vary based on the requirements of a particular power supply environment.

[0083] The example primary transformer 540 comprises primary input windings 570, output windings 572, a shunt 574, and, optionally, secondary input windings 576. The primary input windings are arranged on a first side 578a of the shunt 574, while the output windings 572 and optional secondary input windings 576 are arranged on a second side 578b of the shunt 574. The example primary input windings 570 define primary input winding first and second end taps 570a and 570b and primary input winding first and second intermediate taps 570c and 570d. The example output windings 572 define output winding first and second end taps 572a and 572b. The example optional secondary windings 576 define secondary winding first and second end taps 576a and 576b. If used, the first and second end taps 576a and 576b are connected to the standby input terminals 526a and 526b.

[0084] The example tap switch array 542 comprises a first switch 580, a second switch 582, and a third switch 584. The example switches 580, 582, and 584 are single-pull double-through (SPDT) switches that can be controlled by the controller, operated manually, or both controlled by the controller and operated manually. The first switch 580 defines a first switch main terminal 580a, a first switch first contact terminal 580b, and a first switch second contact terminal 580c. The second switch 582 defines a second switch main terminal 582a, a second switch first contact terminal 582b, and a second switch second contact terminal 582c. The third switch 584 defines a third switch main terminal 584a, a third switch first contact terminal 584b, and a third switch second contact terminal 584c. The example secondary transformer 550 comprises first windings 590 and second windings 592. The example first windings 590 define first winding first and second end taps 590a and 590b. The example second windings 592 define second winding first and second end taps 592a and 592b and an intermediate tap 592c.

[0085] The example DC/AC converter 560 comprises MOSFETs Q1 and Q2, an inductor L, and an output capacitor C1. In the sixth example power supply 520, the inductor L is external to the secondary transformer 550. The example AC/DC converter 562 comprises diodes D1-D4 configured as a rectifier and a rectifier capacitor C2. The DC/AC converter 560 defines first and second inverter terminals 552a and 552b. The example DC/AC converter 560 and the example AC/DC converter 562 operate as a full-bridge rectifier/push-pull converter (switch mode power supply) that is or may be conventional and thus will not be described herein in detail. An optional filter capacitor (not shown) may be arranged to filter the output of the converter 560.

[0086] The first switch main terminal 580a is connected to the first primary input terminal 522a. The first switch first contact terminal 580b is not connected to any other terminal, allowing the first switch to disconnect the power system

from the input. The first switch second contact terminal 580c is connected to the second switch main terminal 582a. The second switch first contact terminal 582b is connected to the primary winding first end tap 570a. The second switch second contact terminal 582c is connected to the primary winding first intermediate tap 570c. The third switch main terminal 584a is connected to the second primary input terminal 522b. The third switch first contact terminal 584b is connected to the primary winding second intermediate tap 570d. The third switch second contact terminal 584c is connected to the primary winding second end tap 570b. The output winding first end tap 572a is connected to the first winding first end tap 590a. The output winding second end tap 572b is connected to the second output terminal 524b. The first winding second end tap 590b is connected to the first output terminal 524a. The second winding first end tap 592a is connected to one end of the inverter capacitor C1. The second winding first and second end terminals 592a and 592b are connected to the first and second inverter output terminals 552a and 552b.

[0087] The AC/DC converter 562 formed by the rectifier diodes D1-D4 and rectifier capacitor C2 is connected across the output terminals 524a and 524b such that a DC signal is present at the DC/AC converter 560. The switches formed by the MOSFETS Q1 and Q2 are controlled (e.g., pulse-width modulated) based on the voltage of the output AC power signal or a voltage indicative of or proportional to the output AC power signal to generate the regulated power signal across the inverter output terminals 552a and 552b. The regulated power signal is applied across the second windings 592 of the secondary transformer 550 and are thus added to the adjustment AC power signal across the output winding first and second end terminals 572a and 572b. The sum of the voltage of the adjustment AC power signal and base AC power signal generated by the primary regulation system 530 (e.g., across the output winding first and second end terminals 572a and 572b) is thus controlled to be within a predetermined range centered about a target output AC power signal voltage level.

[0088] When configured as an uninterruptible power supply, the standby input terminals 526a and 526b of the sixth example power supply system 520 may be connected to the standby power system 564 such that the standby power system 564 is operatively connected to the primary transformer 540. Should the example power system 520 not form a part of an uninterruptible power supply, the second input windings 576 and standby input terminals 526a and 526b may be omitted.

[0089] The sixth example power supply system 520 thus regulates the voltage of the input AC power signal such that the output AC power signal is within predefined parameters. The sixth example power supply system 520 may be configured to use high efficiency linear transformers as the primary transformer 540 and the secondary transformer 550. The sixth example power supply system 520 thus can be configured to provide a regulated output AC power signal at efficiencies of between 95-98 percent. In the sixth example power supply system 520, the inductor L is not integrated into the secondary transformer 550.

VII. Seventh Example Embodiment

[0090] Figure 7 of the drawing illustrates a seventh example power supply system 620 comprising a primary regulation system 630, a secondary regulation system 632, and a controller (not shown). The controller of the seventh example power supply system 620 may be implemented in a manner similar to that of the controller 34 described above and will not be described herein in further detail.

[0091] Figure 7 illustrates that the seventh example power supply system 620 defines input terminals 622a and 622b and output terminals 624a and 624b. The example power supply system 620 accepts an input AC power signal across the

input terminals 622a and 622b and supplies an output AC power signal across the output terminals 624a and 624b. The seventh example power supply system 620 further comprises optional standby input terminals 626a and 626b.

[0092] The example primary regulation system 630 comprises a primary transformer 640 and a tap switch array 642. The example primary transformer 640 is a linear transformer. The example secondary regulation system 632 comprises a secondary transformer 650 and a regulating inverter 652. The secondary transformer 650 is a linear transformer arranged in series with the primary transformer 640. The regulating inverter 652 generates an adjustment power signal, and the secondary transformer 650 combines the adjustment power signal with the output of the primary transformer 640 to obtain the output AC power signal. The example regulating inverter 652 comprises a DC/AC converter 660 and an AC/DC converter 662.

[0093] The seventh example power supply system 620 may be embodied as or form a part of an uninterruptible power supply. When configured as an uninterruptible power supply, the seventh example power supply system 620 further optionally comprises a standby power system 664 that is operatively connected to the primary transformer 640. The standby power system 664 may comprise one or more of a battery and inverter, a generator, a solar power system, and the like. Should the input AC power signal be absent or outside of a predetermined operating range, the input 622a and 622b may be disconnected from the primary transformer 640, and the output power AC signal may be generated based on a standby AC power signal generated by the standby power supply system 620.

[0094] The seventh example power supply system 620 thus regulates the voltage of the input AC power signal such that the output AC power signal is within predefined parameters. The seventh example power supply system 620

may be configured to use high efficiency linear transformers as the primary transformer 640 and the secondary transformer 650. The seventh example power supply system 620 thus can be configured to provide a regulated output AC regional power signal at efficiencies of approximately 95-98 percent.

[0095] In particular, the primary regulation system 630 is configured to regulate a voltage of the output AC power signal within a first voltage range. The secondary regulation system 632 is configured to regulate the voltage of the output AC power signal within a second voltage range. The second voltage range is smaller than the first voltage range. If the seventh example power supply system 620 is configured to provide power in the context of a broadband communications system, the output AC voltage power signal should not exceed 90 volts. The primary regulation system 630 thus allows the seventh example power supply 620 adapt at a slow rate (e.g., twice a day) to relatively large voltage fluctuations (e.g., ± 5 volts). The secondary regulation system 632, on the other hand, allows the seventh example power supply system 620 to regulate the output AC voltage, within certain parameters, to accommodate small voltage fluctuations (e.g., ± 2 volts) of the input AC power signal at high frequency or substantially in real time. In the seventh example power supply system 620, the example first voltage range is approximately ± 5 volts, and the example second voltage range is approximately ± 2 volts. These ranges are provided by way of example only and may vary based on the requirements of a particular power supply environment.

[0096] The example primary transformer 640 comprises primary input windings 670, output windings 672, a shunt 674, and, optionally, secondary input windings 676. The primary input windings are arranged on a first side 678a of the shunt 674, while the output windings 672 and optional secondary input windings 676 are arranged on a second side 678b of the shunt 674. The example primary input windings 670 define primary input winding first and

second end taps 670a and 670b and primary input winding first and second intermediate taps 670c and 670d. The example output windings 672 define output winding first and second end taps 672a and 672b. The example optional secondary windings 676 define secondary winding first and second end taps 676a and 676b. If used, the first and second end taps 676a and 676b are connected to the standby input terminals 626a and 626b.

[0097] The example tap switch array 642 comprises a first switch 680, a second switch 682, and a third switch 684. The example switches 680, 682, and 684 are single-pull double-through (SPDT) switches that can be controlled by the controller, operated manually, or both controlled by the controller and operated manually. The first switch 680 defines a first switch main terminal 680a, a first switch first contact terminal 680b, and a first switch second contact terminal 680c. The second switch 682 defines a second switch main terminal 682a, a second switch first contact terminal 682b, and a second switch second contact terminal 682c. The third switch 684 defines a third switch main terminal 684a, a third switch first contact terminal 684b, and a third switch second contact terminal 684c. The example secondary transformer 650 comprises first windings 690 and second windings 692. The example first windings 690 define first winding first and second end taps 690a and 690b. The example second windings 692 define second winding first and second end taps 692a and 692b and an intermediate tap 692c.

[0098] The example DC/AC converter 660 comprises MOSFETs Q1 and Q2, an inductor L, and an output capacitor C1. In the seventh example power supply 620, the inductor L is internal to the secondary transformer 650. The example AC/DC converter 662 comprises diodes D1-D4 configured as a rectifier and a rectifier capacitor C2. The DC/AC converter 660 defines first and second inverter terminals 652a and 652b. The example DC/AC converter 660 and the example AC/DC converter 662 operate as a full-bridge rectifier/push-pull converter that is

or may be conventional and thus will not be described herein in detail. An optional filter capacitor (not shown) may be arranged to filter the output of the converter 660.

[0099] The first switch main terminal 680a is connected to the first primary input terminal 622a. The first switch first contact terminal 680b is not connected to any other terminal, allowing the first switch to disconnect the power system from the input. The first switch second contact terminal 680c is connected to the second switch main terminal 682a. The second switch first contact terminal 682b is connected to the primary winding first end tap 670a. The second switch second contact terminal 682c is connected to the primary winding first intermediate tap 670c. The third switch main terminal 684a is connected to the second primary input terminal 622b. The third switch first contact terminal 684b is connected to the primary winding second intermediate tap 670d. The third switch second contact terminal 684c is connected to the primary winding second end tap 670b. The output winding first end tap 672a is connected to the first winding first end tap 690a. The output winding second end tap 672b is connected to the second output terminal 624b. The first winding second end tap 690b is connected to the first output terminal 624a. The second winding first end tap 692a is connected to one end of the inverter capacitor C1. The second winding first and second end terminals 692a and 692b are connected to the first and second inverter output terminals 652a and 652b.

[0100] The AC/DC converter 662 formed by the rectifier diodes D1-D4 and rectifier capacitor C2 is connected across the output terminals 624a and 624b such that a DC signal is present at the DC/AC converter 660. The switches formed by the MOSFETS Q1 and Q2 are controlled (e.g., pulse-width modulated) based on the voltage of the output AC power signal or a voltage indicative of or proportional to the output AC power signal to generate the regulated power signal across the inverter output terminals 652a and 652b. The regulated power

signal is applied across the second windings 692 of the secondary transformer 650 and are thus added to the adjustment AC power signal across the output winding first and second end terminals 672a and 672b. The sum of the voltage of the adjustment AC power signal and base AC power signal generated by the primary regulation system 620 (e.g., across the output winding first and second end terminals 672a and 672b) is thus controlled to be within a predetermined range centered about a target output AC power signal voltage level.

[0101] When configured as an uninterruptible power supply, the standby input terminals 626a and 626b of the seventh example power supply system 620 may be connected to the standby power system 664 such that the standby power system 664 is operatively connected to the primary transformer 640. Should the example power system 620 not form a part of an uninterruptible power supply, the second input windings 676 and standby input terminals 626a and 626b may be omitted.

[0102] The seventh example power supply system 620 thus regulates the voltage of the input AC power signal such that the output AC power signal is within predefined parameters. The seventh example power supply system 620 may be configured to use high efficiency linear transformers as the primary transformer 640 and the secondary transformer 650. The seventh example power supply system 620 thus can be configured to provide a regulated output AC power signal at efficiencies of between 95-98 percent. In the seventh example power supply system 620, the inductor L is integrated into the secondary transformer 650.

VIII. Eighth Example Embodiment

[0103] Figure 8 of the drawing illustrates a eighth example power supply system 720 comprising a primary regulation system 730, a secondary regulation

system 732, and a controller (not shown). The controller of the eighth example power supply system 720 may be implemented in a manner similar to that of the controller 34 described above and will not be described herein in further detail.

[0104] Figure 8 illustrates that the eighth example power supply system 720 defines input terminals 722a and 722b and output terminals 724a and 724b. The example power supply system 720 accepts an input AC power signal across the input terminals 722a and 722b and supplies an output AC power signal across the output terminals 724a and 724b. The eighth example power supply system 720 further comprises optional standby input terminals 726a and 726b.

[0105] The example primary regulation system 730 comprises a primary transformer 740 and a primary tap switch array 742. The example primary transformer 740 is a linear transformer. The example secondary regulation system 732 comprises a secondary transformer 750 and a secondary tap switch array 752. The secondary transformer 750 is a linear transformer arranged in series with the primary transformer 740. The secondary tap switch array 752 applies an adjustment power signal to the secondary transformer 750, and the secondary transformer 750 combines the adjustment power signal with the output of the primary transformer 740 to obtain the output AC power signal. The example secondary tap switch array 752 comprises a first secondary switch 760 and a second secondary switch 762. Limited regulation may be accomplished by a secondary tap switch array comprising a single secondary switch, and a secondary tap switch array comprising more than two switches (e.g., 3 or more) will provide finer regulation of the output AC power signal.

[0106] The eighth example power supply system 720 may be embodied as or form a part of an uninterruptible power supply. When configured as an uninterruptible power supply, the eighth example power supply system 720 further optionally comprises a standby power system 764 that is operatively

connected to the primary transformer 740. The standby power system 764 may comprise one or more of a battery and inverter, a generator, a solar power system, and the like. Should the input AC power signal be absent or outside of a predetermined operating range, the input 722a and 722b may be disconnected from the primary transformer 740, and the output power AC signal may be generated based on a standby AC power signal generated by the standby power supply system 764.

[0107] The eighth example power supply system 720 thus regulates the voltage of the input AC power signal such that the output AC power signal is within predefined parameters. The eighth example power supply system 720 may be configured to use high efficiency linear transformers as the primary transformer 740 and the secondary transformer 750. The eighth example power supply system 720 thus can be configured to provide a regulated output AC regional power signal at efficiencies of approximately 95-98 percent.

[0108] In particular, the primary regulation system 730 is configured to regulate a voltage of the output AC power signal within a first voltage range. The secondary regulation system 732 is configured to regulate the voltage of the output AC power signal within a second voltage range. The second voltage range is smaller than the first voltage range. If the eighth example power supply system 720 is configured to provide power in the context of a broadband communications system, the output AC voltage power signal should not exceed 90 volts. The primary regulation system 730 thus allows the eighth example power supply 720 adapt at a slow rate (e.g., twice a day) to relatively large voltage fluctuations (e.g., ± 5 volts). The secondary regulation system 732, on the other hand, allows the eighth example power supply system 720 to regulate the output AC voltage, within certain parameters, to accommodate small voltage fluctuations (e.g., ± 2 volts) of the input AC power signal at high frequency or substantially in real time. In the eighth example power supply system 720, the

example first voltage range is approximately ± 5 volts, and the example second voltage range is approximately ± 2 volts. These ranges are provided by way of example only and may vary based on the requirements of a particular power supply environment.

[0109] The example primary transformer 740 comprises primary input windings 770, output windings 772, a shunt 774, and, optionally, secondary input windings 776. The primary input windings are arranged on a first side 778a of the shunt 774, while the output windings 772 and optional secondary input windings 776 are arranged on a second side 778b of the shunt 774. The example primary input windings 770 define primary input winding first and second end taps 770a and 770b and primary input winding first and second intermediate taps 770c and 770d. The example output windings 772 define output winding first and second end taps 772a and 772b. The example optional secondary windings 776 define secondary winding first and second end taps 776a and 776b. If used, the first and second end taps 776a and 776b are connected to the standby input terminals 726a and 726b.

[0110] The example primary tap switch array 742 comprises a first primary switch 780, a second primary switch 782, and a third primary switch 784. The example primary switches 780, 782, and 784 are single-pull double-through (SPDT) switches that can be controlled by the controller, operated manually, or both controlled by the controller and operated manually. The first primary switch 780 defines a first primary switch main terminal 780a, a first primary switch first contact terminal 780b, and a first primary switch second contact terminal 780c. The second primary switch 782 defines a second primary switch main terminal 782a, a second primary switch first contact terminal 782b, and a second primary switch second contact terminal 782c. The third primary switch 784 defines a third primary switch main terminal 784a, a third primary switch first contact terminal 784b, and a third primary switch second contact terminal 784c. The

example secondary transformer 750 comprises first windings 790 and second windings 792. The example first windings 790 define first winding first and second end taps 790a and 790b. The example second windings 792 define second winding first and second end taps 792a and 792b and second winding first and second intermediate taps 792c and 792d.

[0111] The example first and second secondary switches 760 and 762 of the example secondary tap switch array 752 are single-pull double-through (SPDT) switches that can be controlled by the controller, operated manually, or both controlled by the controller and operated manually. The first secondary switch 760 defines a first secondary switch main terminal 760a, a first secondary switch first contact terminal 760b, and a first secondary switch second contact terminal 760c. The second secondary switch 762 defines a second secondary switch main terminal 762a, a second secondary switch first contact terminal 762b, and a second secondary switch second contact terminal 762c. An optional filter capacitor (not shown) may be arranged to filter the output of the converter 760.

[0112] The first primary switch main terminal 780a is connected to the first primary input terminal 722a. The first primary switch first contact terminal 780b is not connected to any other terminal, allowing the first switch to disconnect the power system from the input. The first primary switch second contact terminal 780c is connected to the second primary switch main terminal 782a. The second primary switch first contact terminal 782b is connected to the primary winding first end tap 770a. The second primary switch second contact terminal 782c is connected to the primary winding first intermediate tap 770c. The third primary switch main terminal 784a is connected to the second primary input terminal 722b. The third primary switch first contact terminal 784b is connected to the primary winding second intermediate tap 770d. The third primary switch second contact terminal 784c is connected to the primary winding second end tap 770b. The output winding first end tap 772a is connected to the first winding first end

tap 790a. The output winding second end tap 772b is connected to the second output terminal 724b.

[0113] The first winding first end tap 790a of the secondary transformer 750 is connected to the output windings first end tap 772a of the primary transformer 740. The first winding second end tap 790b is connected to the first output terminal 724a. The second winding first end tap 792a of the secondary transformer 750 is connected to the first contact terminal 760a of the first secondary switch 760. The second winding second end tap 792b of the secondary transformer 750 is connected to the second contact terminal 762b of the second secondary switch 762. The second winding first intermediate tap 792c of the secondary transformer 750 is connected to the second contact terminal 760c of the first secondary switch 760. The second winding second intermediate tap 792d of the secondary transformer 750 is connected to the first contact terminal 762a of the second secondary switch 762. The first secondary switch main terminal 760a is connected to the second output terminal 724b, and the second secondary switch main terminal 762a is connected to the first output terminal 724a.

[0114] The first and second secondary switches 760 and 762 may be operated to connect the output AC power signal present across the output terminals 724a and 724b across a portion of the second winding 792 to define an adjustment AC power signal that is added to the output of the primary regulation system 730 to obtain the output AC power signal.

[0115] The regulated power signal is applied across the second windings 792 of the secondary transformer 750 and are thus added to the adjustment AC power signal across the output winding first and second end terminals 772a and 772b. The sum of the voltage of the adjustment AC power signal and base AC power signal generated by the primary regulation system 720 (e.g., across the

output winding first and second end terminals 772a and 772b) is thus controlled to be within a predetermined range centered about a target output AC power signal voltage level.

[0116] As generally discussed above, a secondary tap switch array comprising fewer (e.g., one) secondary switches would allow less granular regulation of the output AC power signal than the eighth example power supply 720 described herein, and a secondary tap switch array comprising more (e.g., three or more) secondary switches would allow more granular regulation of the output AC power signal than the eighth example power supply 720.

[0117] When configured as an uninterruptible power supply, the standby input terminals 726a and 726b of the eighth example power supply system 720 may be connected to the standby power system 764 such that the standby power system 764 is operatively connected to the primary transformer 740. Should the example power system 720 not form a part of an uninterruptible power supply, the second input windings 776 and standby input terminals 726a and 726b may be omitted.

[0118] The eighth example power supply system 720 thus regulates the voltage of the input AC power signal such that the output AC power signal is within predefined parameters. The eighth example power supply system 720 may be configured to use high efficiency linear transformers as the primary transformer 740 and the secondary transformer 750. The eighth example power supply system 720 thus can be configured to provide a regulated output AC power signal at efficiencies of between 95-98 percent.

What is claimed is:

1. A power supply system comprising:
a primary regulation system comprising a primary transformer and a primary tap switch array;
a secondary regulation system comprising a secondary transformer and an adjustment power signal generator; and
a controller; wherein
the controller is configured to control the adjustment power signal generator to apply an adjustment power signal to the secondary transformer; and
the secondary transformer is configured to combine the adjustment power signal with a base power supply signal from the primary transformer.
2. A power supply system as recited in claim 1, in which the secondary regulation system comprises an AC/DC converter and a DC/AC converter.
3. A power supply system as recited in claim 2, in which the DC/AC converter comprises an inductor that is external to the secondary transformer.
4. A power supply system as recited in claim 2, in which the DC/AC converter comprises an inductor that is integrated with the secondary transformer.
5. A power supply system as recited in claim 1, in which the secondary regulation system comprises a full-bridge rectifier and a DC/AC converter.

6. A power supply system as recited in claim 5, in which the DC/AC converter comprises an inductor that is external to the secondary transformer.

7. A power supply system as recited in claim 5, in which the DC/AC converter comprises an inductor that is integrated with the secondary transformer.

8. A power supply system as recited in claim 1, in which the secondary regulation system comprises a half-bridge rectifier and a DC/AC converter.

9. A power supply system as recited in claim 8, in which the DC/AC converter comprises an inductor that is external to the secondary transformer.

10. A power supply system as recited in claim 8, in which the DC/AC converter comprises an inductor that is integrated with the secondary transformer.

11. A power supply system as recited in claim 1, in which the secondary regulation system comprises a full bridge rectifier and a push-pull DC/AC converter.

12. A power supply system as recited in claim 11, in which the push-pull DC/AC converter comprises an inductor that is external to the secondary transformer.

13. A power supply system as recited in claim 11, in which the push-pull DC/AC converter comprises an inductor that is integrated with the secondary transformer.

14. A power supply system as recited in claim 1, in which the secondary regulation system comprises:

a plurality of taps formed by the secondary transformer; and
a secondary tap switch array that selectively connects an output of the power supply system across a pair of the plurality of taps.

15. A power supply system for providing power to an output from an input comprising:

a primary regulation system comprising a primary transformer and a primary tap switch array;
a secondary regulation system comprising a secondary transformer and an adjustment power signal generator; and

a controller; wherein

the primary regulation system is configured to generate a base power signal based on an input power signal at the input;

the controller is configured to control the adjustment power signal generator to apply an adjustment power signal to the secondary transformer; and

the secondary transformer is configured to combine the adjustment power signal with the base power supply signal to apply an output power signal at the output.

16. A power supply system as recited in claim 15, in which the secondary regulation system comprises an AC/DC converter and a DC/AC converter.

17. A power supply system as recited in claim 16, in which the DC/AC converter comprises an inductor that is external to the secondary transformer.

18. A power supply system as recited in claim 16, in which the DC/AC

converter comprises an inductor that is integrated with the secondary transformer.

19. A power supply system as recited in claim 18, in which the secondary regulation system comprises:

a plurality of taps formed by the secondary transformer; and
a secondary tap switch array that selectively connects the output power supply signal across a pair of the plurality of taps.

20. A method of providing power to an output from an input comprising:
arranging a primary transformer and a primary tap switch array to form a primary regulation system;
arranging a secondary transformer and an adjustment power signal generator to form a secondary regulation system; and
controlling the primary tap switch array such that the primary regulation system generates a base power signal based on an input power signal at the input;
controlling the adjustment power signal generator to generate an adjustment power signal;
applying the adjustment power signal to the secondary transformer such that the adjustment power signal is combined with the base power signal to obtain an output power signal at the output.

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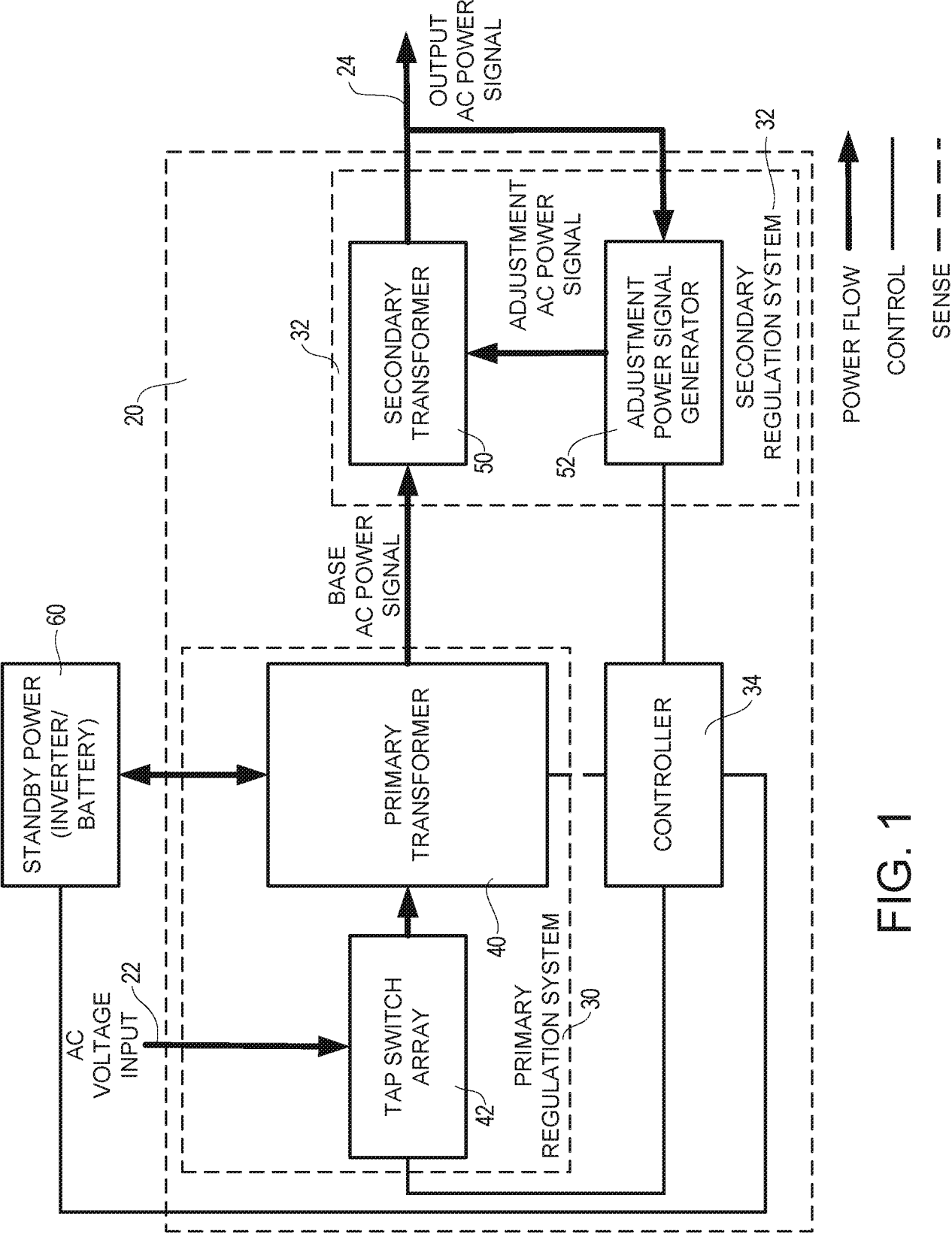


FIG. 1

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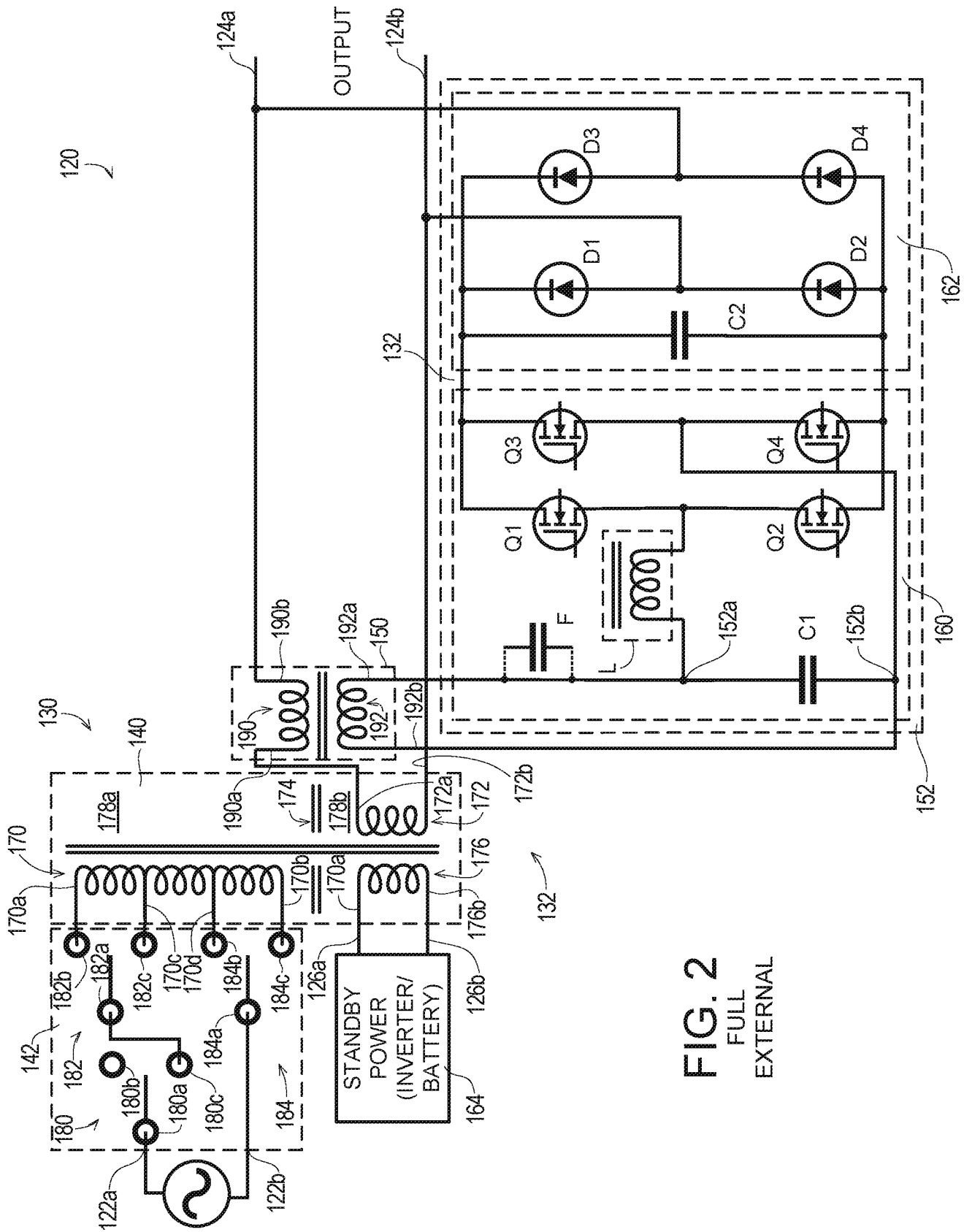


FIG. 2
FULL
EXTERNAL

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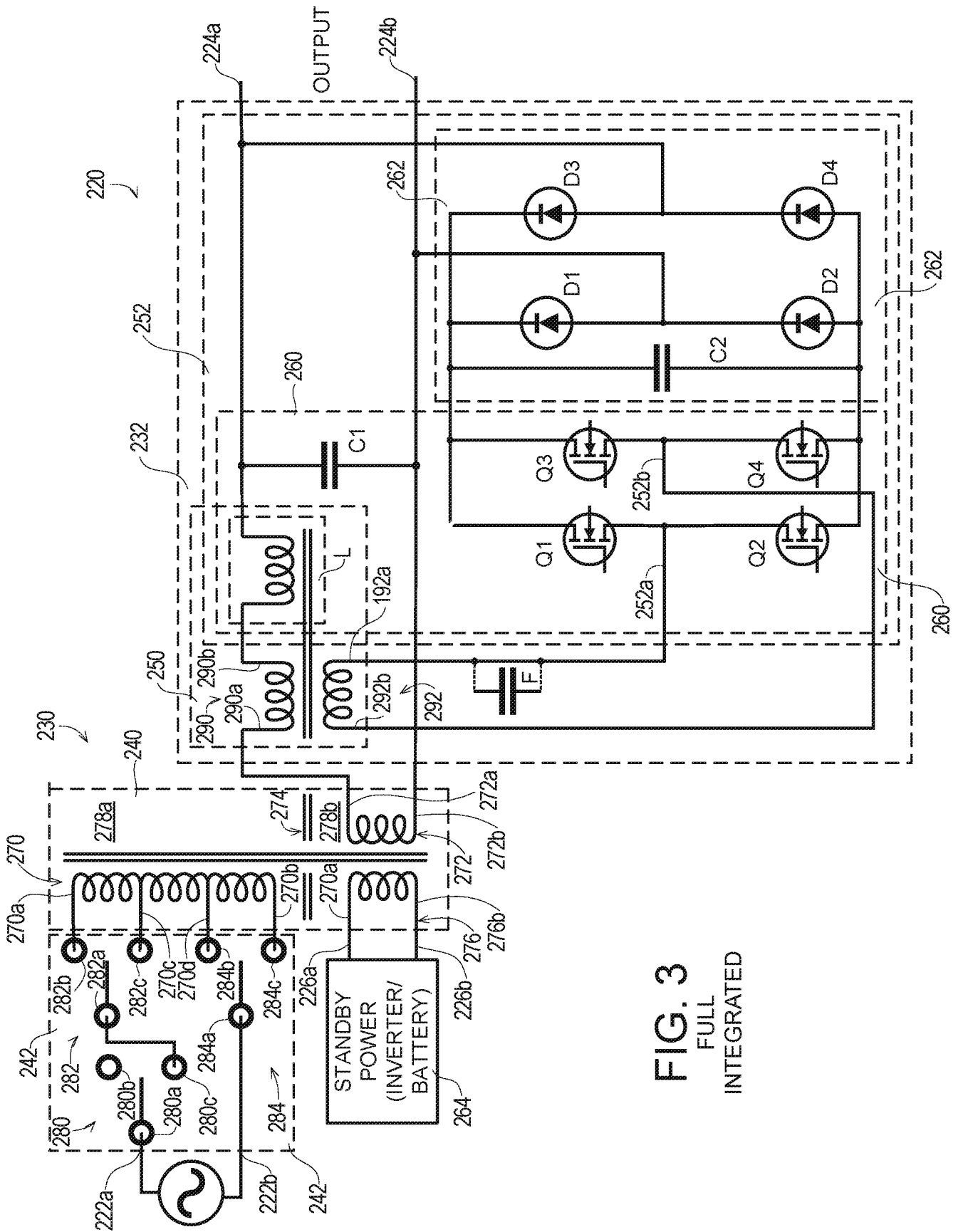


FIG. 3
FULL
INTEGRATED

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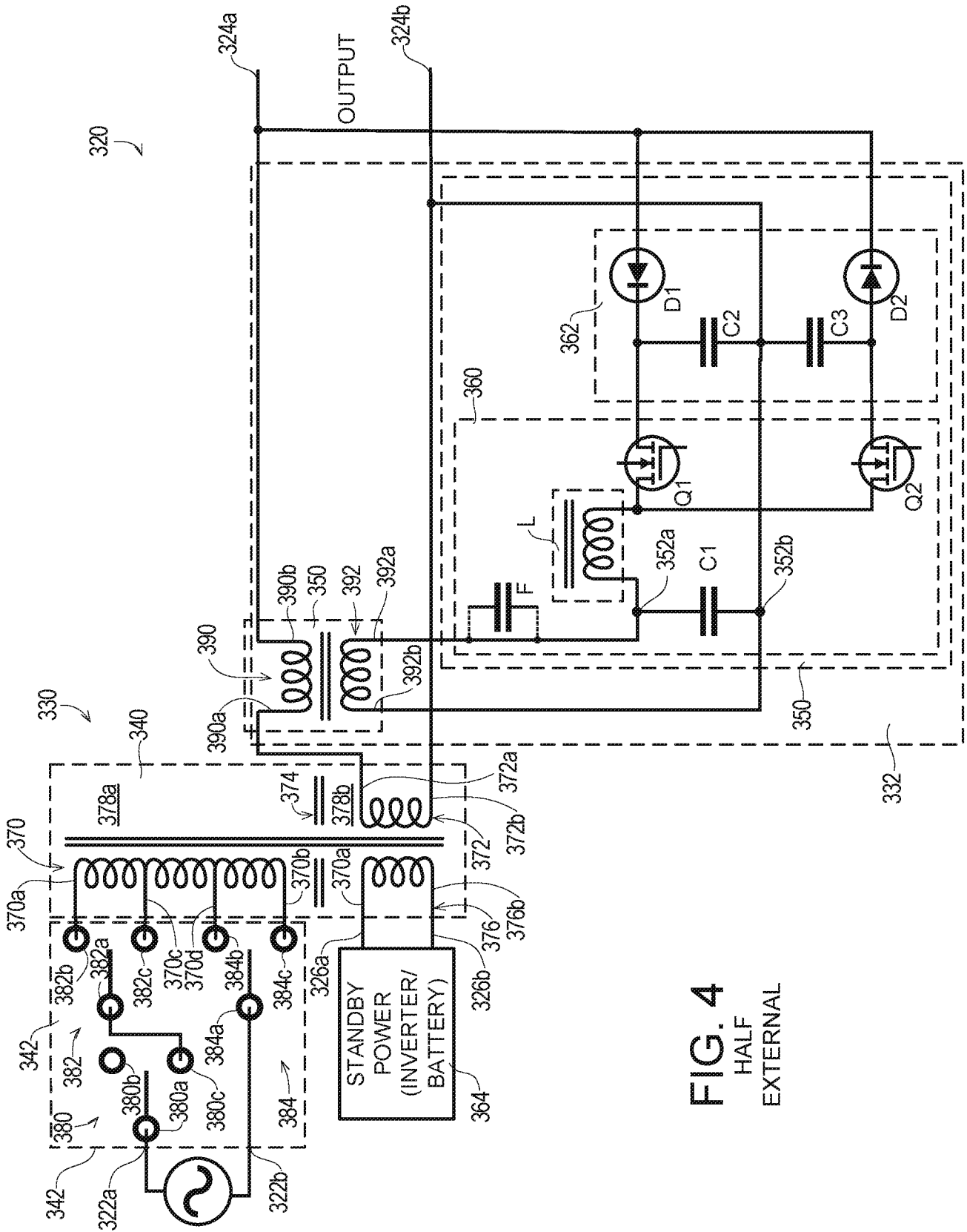


FIG. 4
HALF
EXTERNAL

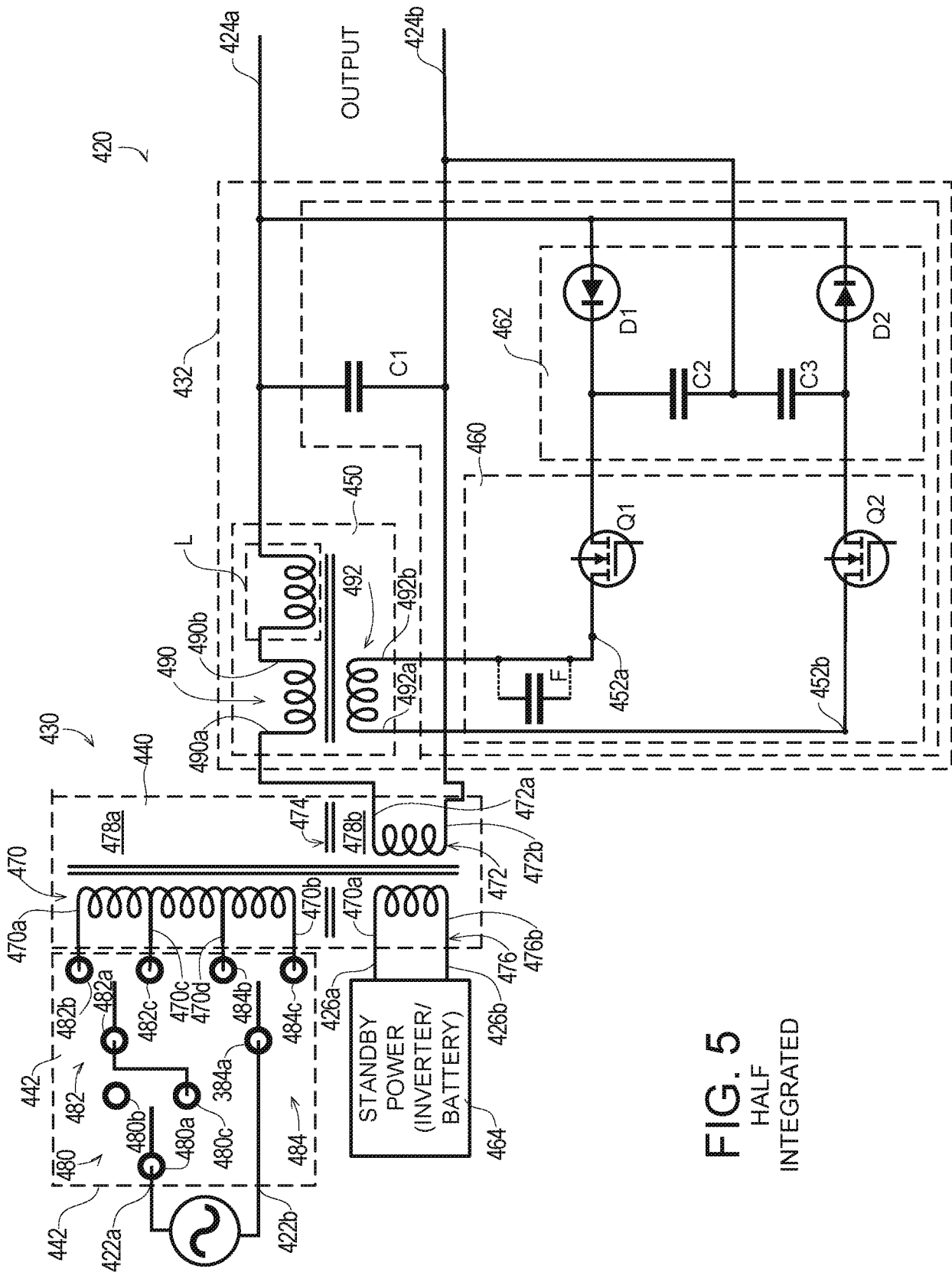


FIG. 5
HALF
INTEGRATED

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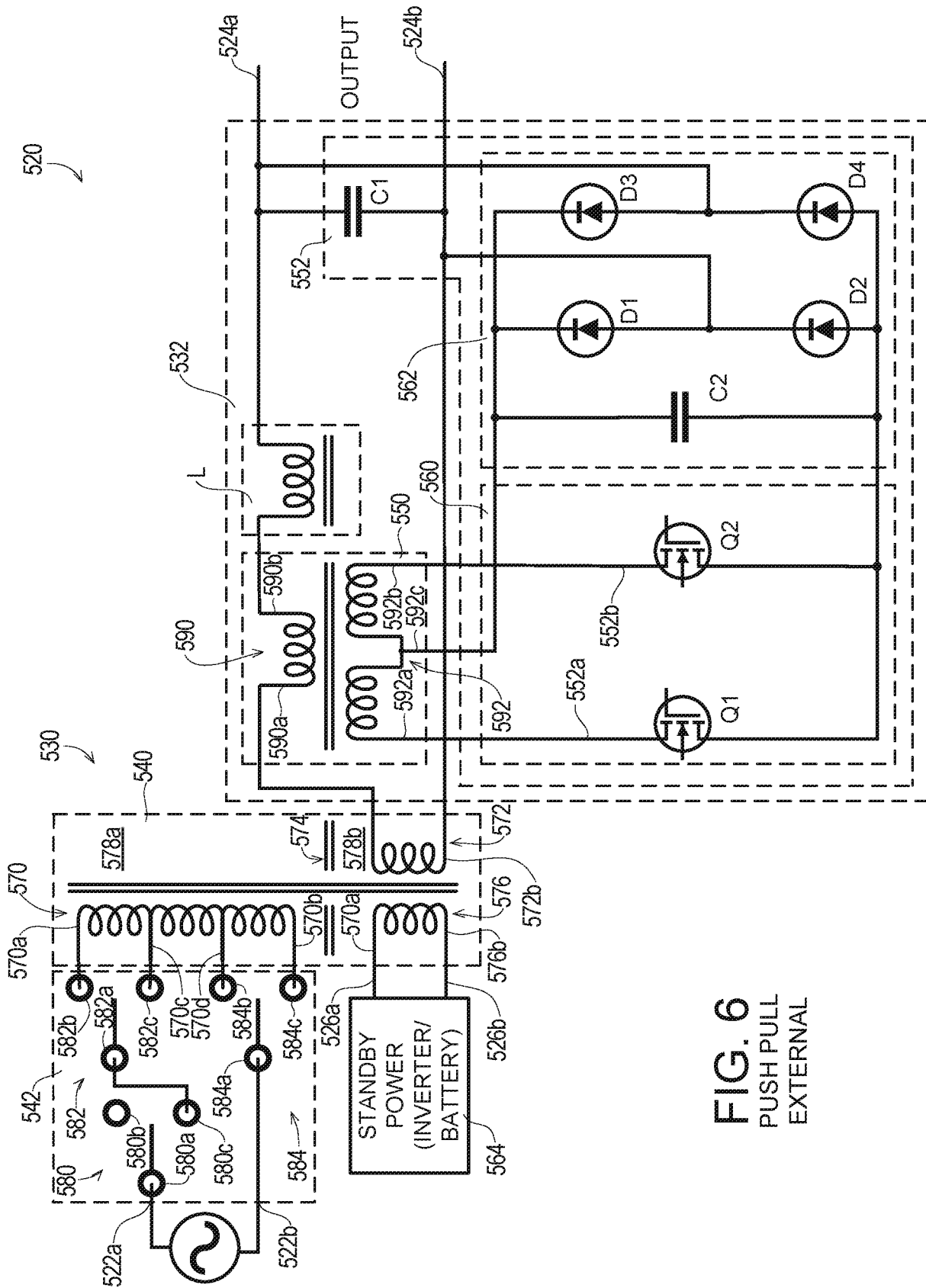


FIG. 6
PUSH PULL
EXTERNAL

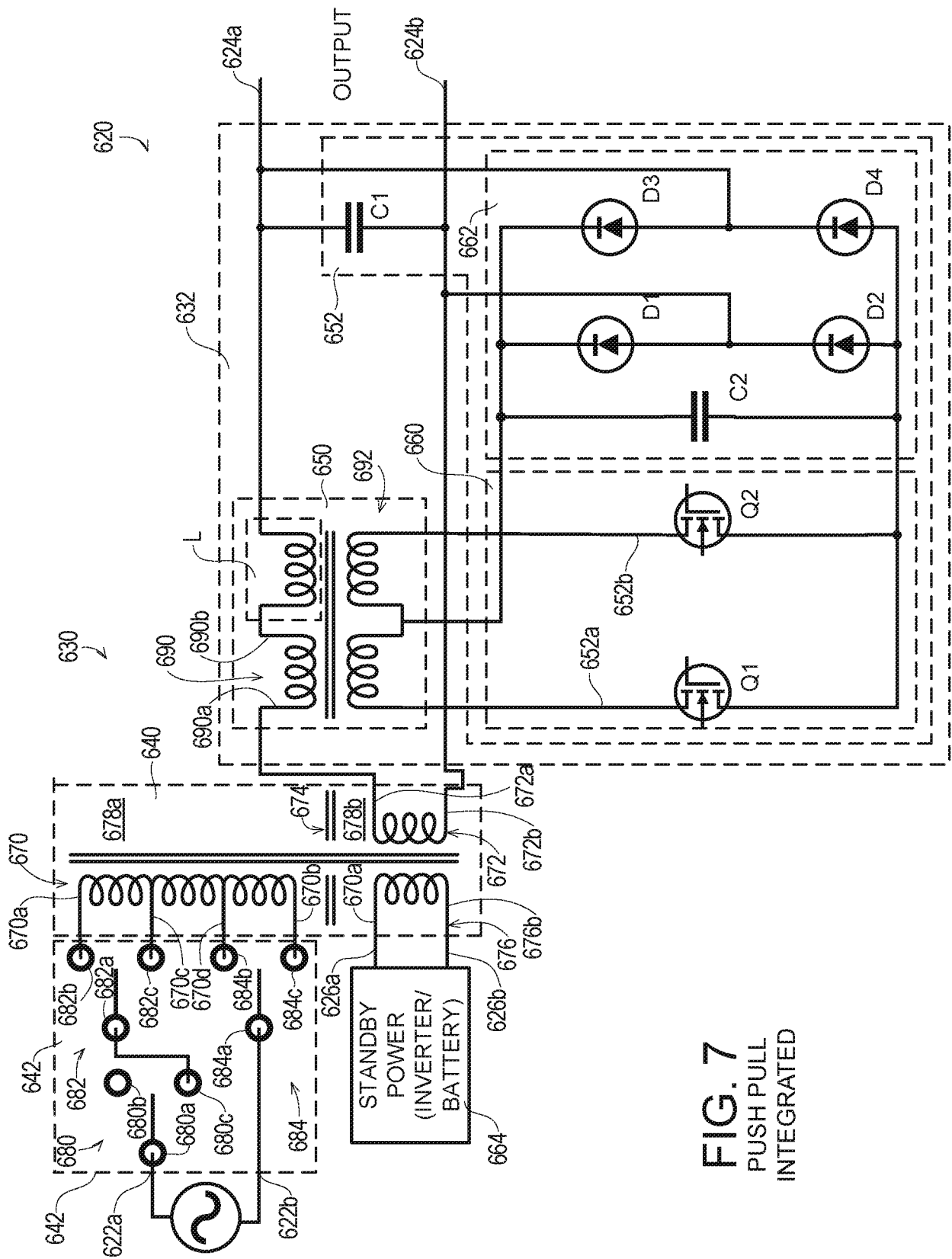


FIG. 7
PUSH PULL
INTEGRATED

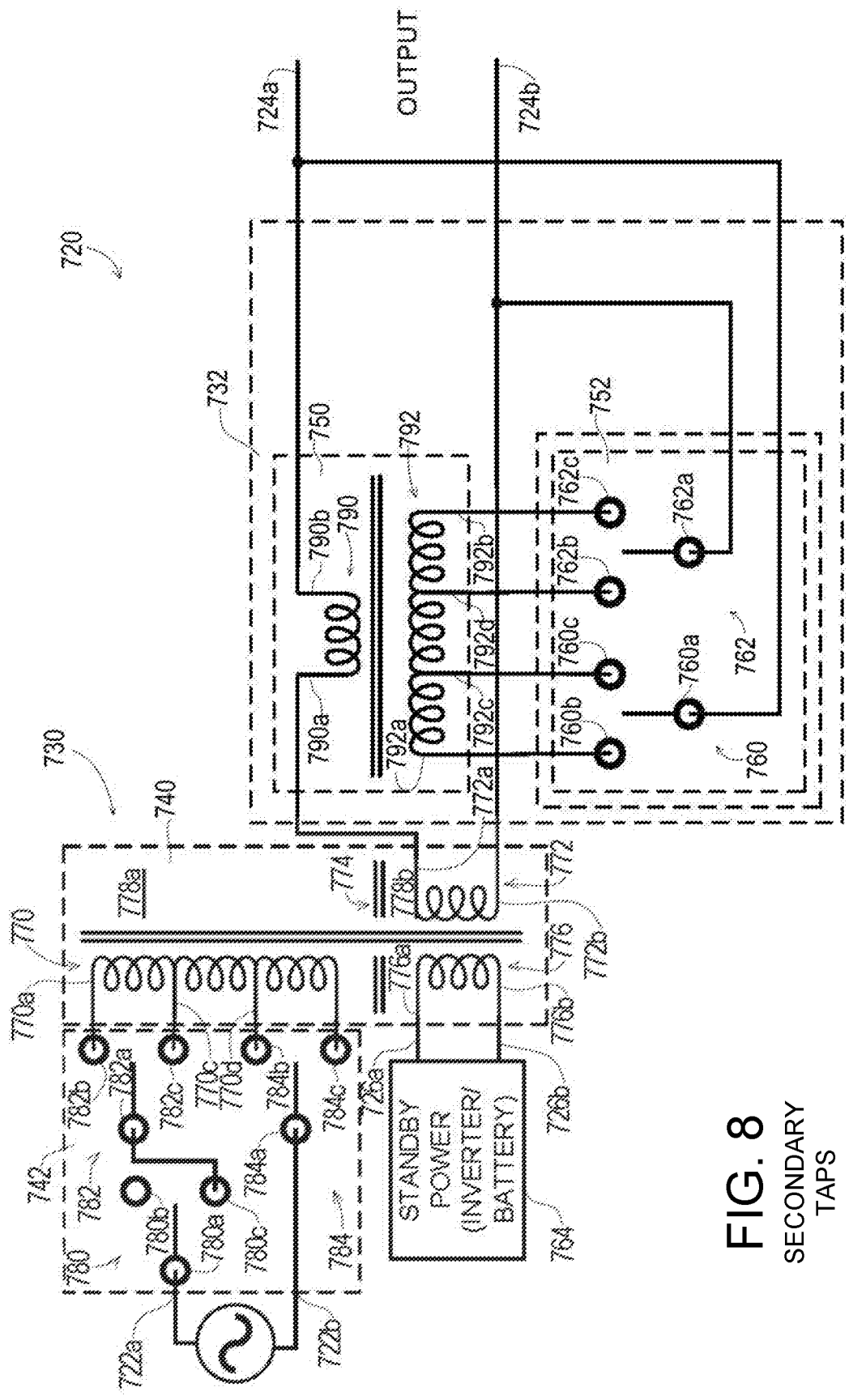


FIG. 8
SECONDARY
TAPS

INTERNATIONAL SEARCH REPORT	International application No. PCT/US 2018/042339																		
A. CLASSIFICATION OF SUBJECT MATTER G05F 1/10 (2006.01) H02M 5/10 (2006.01) H02M 7/162 (2006.01) 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) G05F 1/00, 1/10; H02M 5/00, 510, 7/00, 7/02, 7/04, 7/12, 7/145, 7/162 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) PatSearch, Esp@cenet, PAJ, USPTO, WIPO, RUPTO																			
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;">Category*</th> <th style="width: 70%;">Citation of document, with indication, where appropriate, of the relevant passages</th> <th style="width: 20%;">Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">Y</td> <td>WO 2013089448 A1 (GEUM JONG GWAN), 21.06.2013, [0023]-[0025], fig.1</td> <td style="text-align: center;">1-20</td> </tr> <tr> <td style="text-align: center;">Y</td> <td>US 2012/092894 A1 (MARTIN ALSINA NAVARRO), 19.04.2012, [0016], [0029]-[0038], fig.1</td> <td style="text-align: center;">1-20</td> </tr> <tr> <td style="text-align: center;">Y</td> <td>EP 2800230 A1 (EMERSON NETWORK POWER CO., et al.), 05.11.2014, [0015], [0041]-[0046]</td> <td style="text-align: center;">3, 5-13, 17</td> </tr> <tr> <td style="text-align: center;">Y</td> <td>US 2007/053211 A1 (CAMARSO WIRELESS TECHNOLOGIES, INC.), 08.03.2007, [0017]</td> <td style="text-align: center;">4, 7, 10, 13, 18, 19</td> </tr> <tr> <td style="text-align: center;">Y</td> <td>US 2015/061612 A1 (FREESCALE SEMICONDUCTOR, INC.), 05.03.2015, [0043]</td> <td style="text-align: center;">14, 19</td> </tr> </tbody> </table>		Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	Y	WO 2013089448 A1 (GEUM JONG GWAN), 21.06.2013, [0023]-[0025], fig.1	1-20	Y	US 2012/092894 A1 (MARTIN ALSINA NAVARRO), 19.04.2012, [0016], [0029]-[0038], fig.1	1-20	Y	EP 2800230 A1 (EMERSON NETWORK POWER CO., et al.), 05.11.2014, [0015], [0041]-[0046]	3, 5-13, 17	Y	US 2007/053211 A1 (CAMARSO WIRELESS TECHNOLOGIES, INC.), 08.03.2007, [0017]	4, 7, 10, 13, 18, 19	Y	US 2015/061612 A1 (FREESCALE SEMICONDUCTOR, INC.), 05.03.2015, [0043]	14, 19
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Y	US 2015/061612 A1 (FREESCALE SEMICONDUCTOR, INC.), 05.03.2015, [0043]	14, 19																	
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.																			
<table style="width: 100%;"> <tr> <td style="width: 50%; vertical-align: top;"> * 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 </td> <td style="width: 50%; vertical-align: top;"> "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 </td> </tr> </table>		* 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																
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Date of the actual completion of the international search 02 November 2018 (02.11.2018)	Date of mailing of the international search report 29 November 2018 (29.11.2018)																		
Name and mailing address of the ISA/RU: Federal Institute of Industrial Property, Berezhevskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993 Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37	Authorized officer S. Chernyakova Telephone No. 499-240-60-15																		