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Bornhorst et al.

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(54) **PORTABLE POWER AND SIGNAL DISTRIBUTION SYSTEM FOR A CONTROLLABLE SYSTEM INCLUDING MULTIPLE DEVICES**

(58) **Field of Classification Search**
USPC 174/34, 50, 481; 316/627; 362/149; 363/79; 439/211, 215, 687
See application file for complete search history.

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(21) Appl. No.: **13/526,744**

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(65) **Prior Publication Data**

Primary Examiner — Xiaoliang Chen

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Related U.S. Application Data

(57) **ABSTRACT**

(63) Continuation of application No. 11/190,494, filed on Jul. 26, 2005, now Pat. No. 8,203,828.

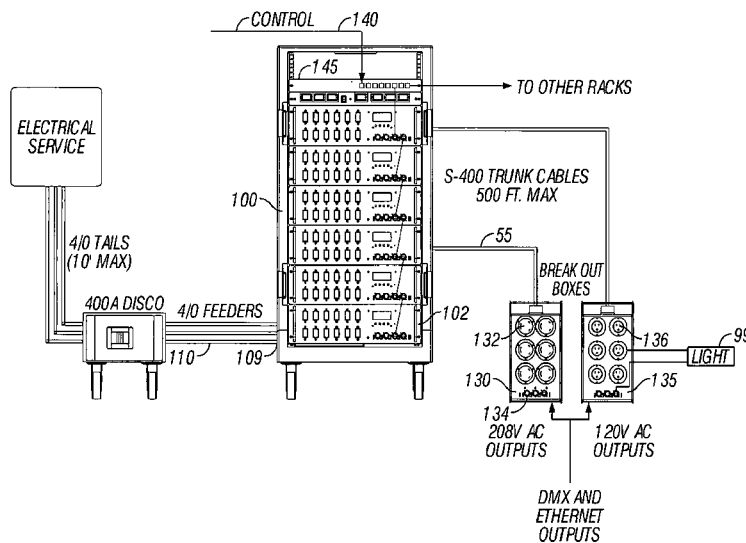
A power supply assembly which can drive a number of different devices at different voltages. A rack holds a number of breaker modules, and each breaker module can connect to one or many breakout boxes. The breakout boxes are keyed to the breaker modules, so that the breaker boxes will not be energized with power unless they are the proper voltage and/or configuration to receive that power. The coil of a contactor in the breaker module is powered by a key wire that is connected through specified pins in the breakout box. Therefore, no power is ever provided to the breakout box unless it is of the proper voltage configuration. In addition, feeder power to the power supply assembly is provided over bolted connections, without any wire connections between the power feed and the circuit breaker.

(60) Provisional application No. 60/647,922, filed on Jan. 27, 2005.

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H01B 11/02 (2006.01)
H04B 3/54 (2006.01)

(52) **U.S. Cl.**
CPC **H04B 3/54** (2013.01); **H04B 2203/5466** (2013.01); **H04B 2203/5445** (2013.01); **H04B 2203/547** (2013.01)
USPC **174/34**; 174/50; 174/481; 361/627; 362/149; 363/79; 439/211; 439/215; 439/687

13 Claims, 13 Drawing Sheets



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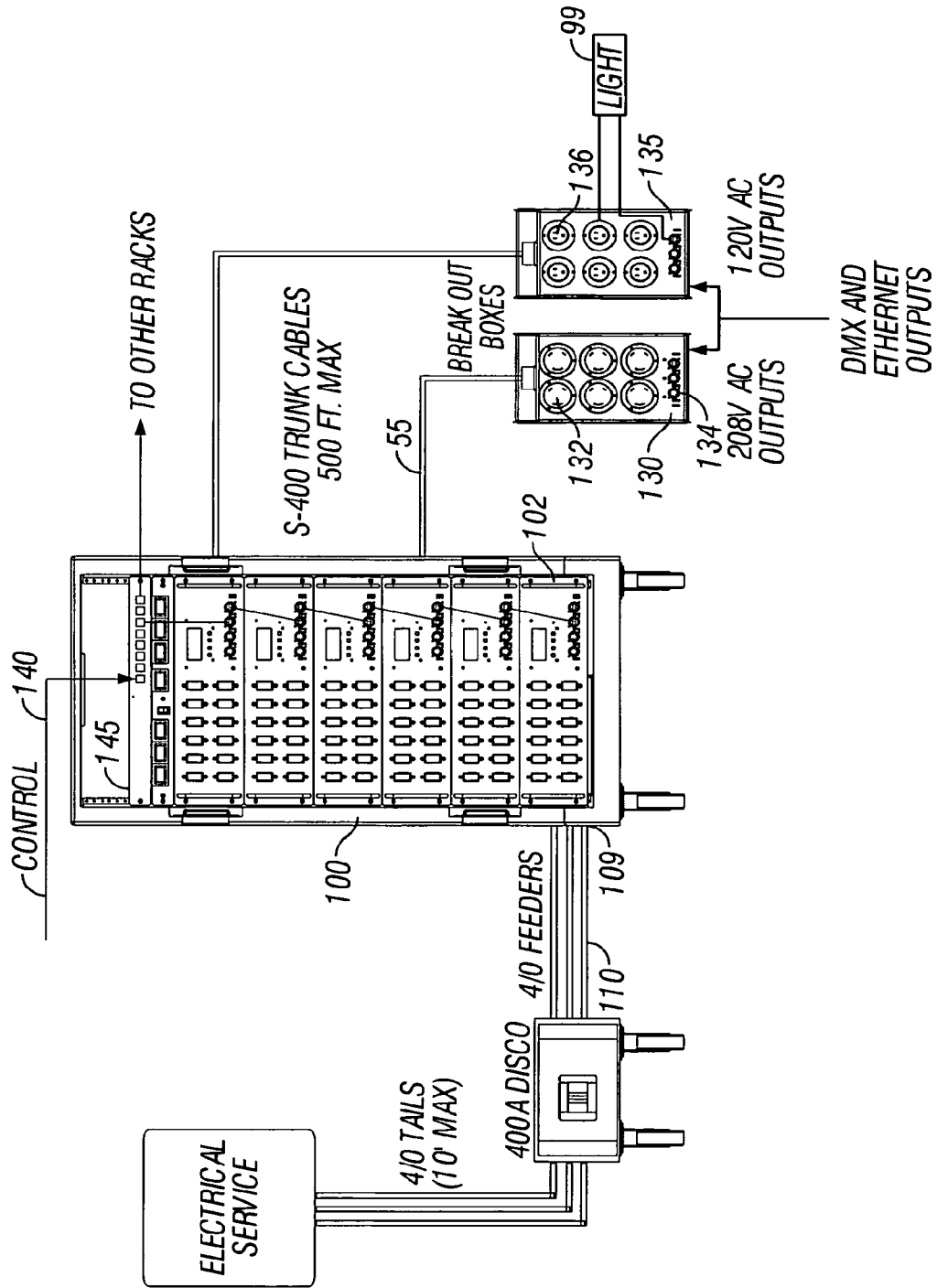


FIG. 1

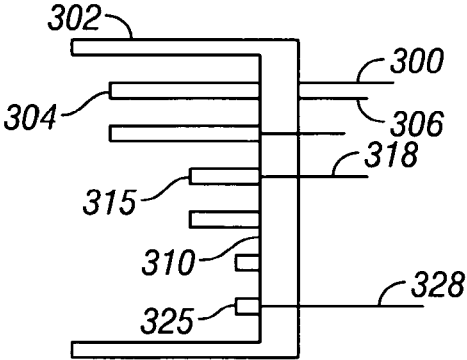


FIG. 3

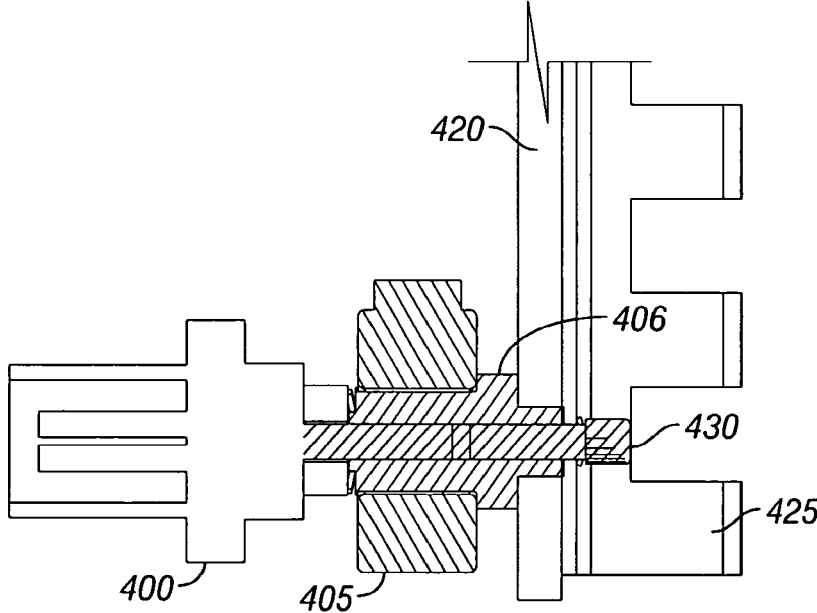


FIG. 4

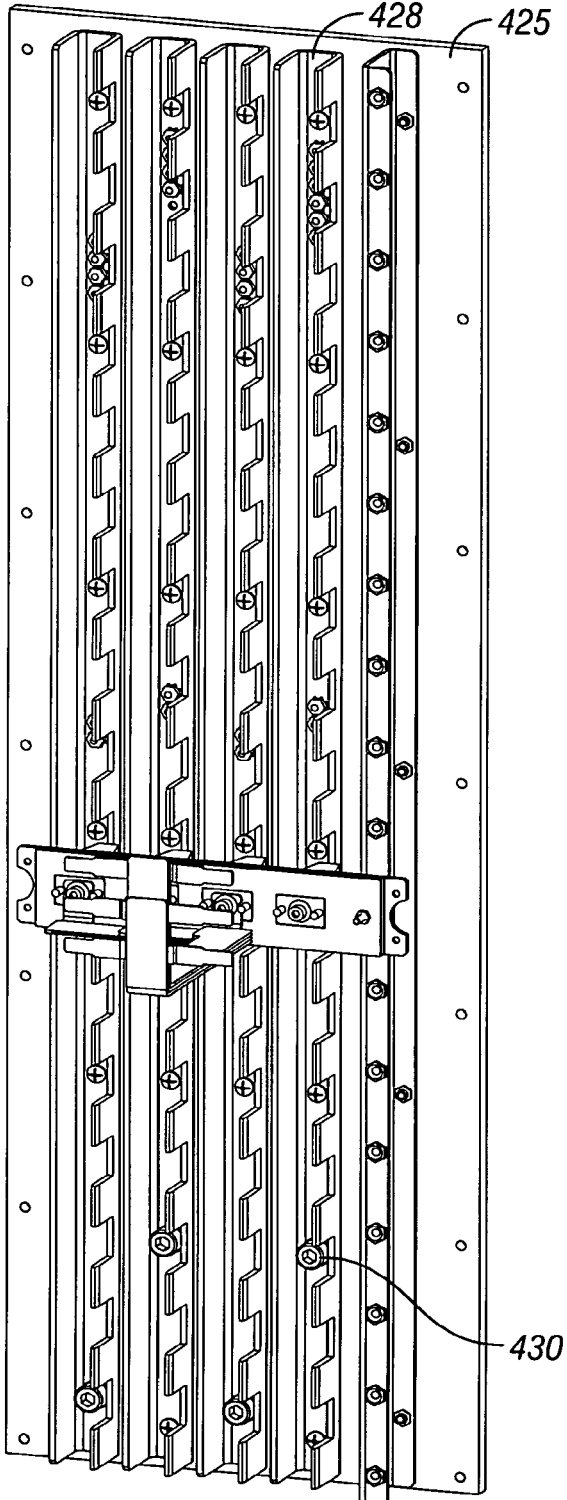


FIG. 5

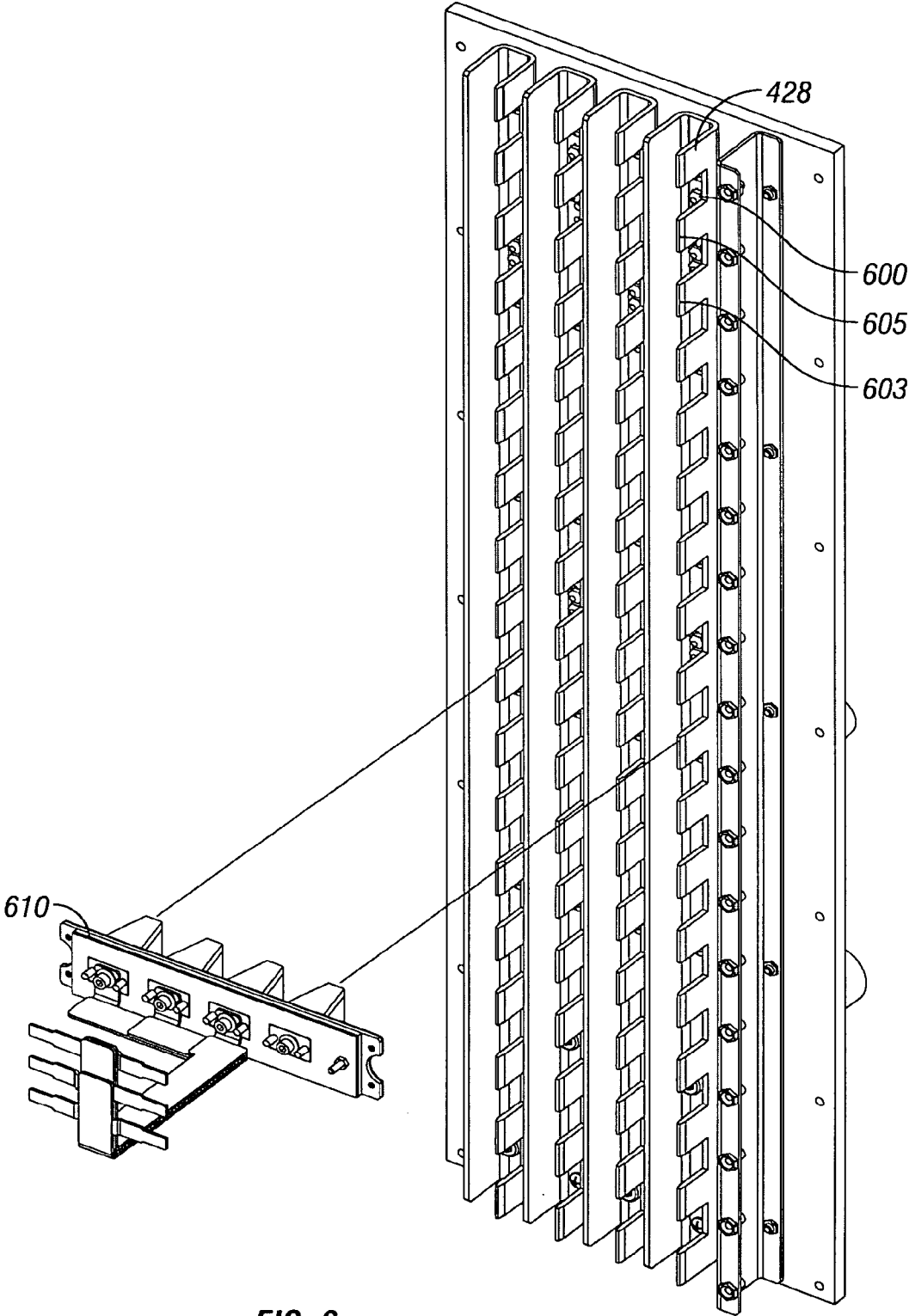


FIG. 6

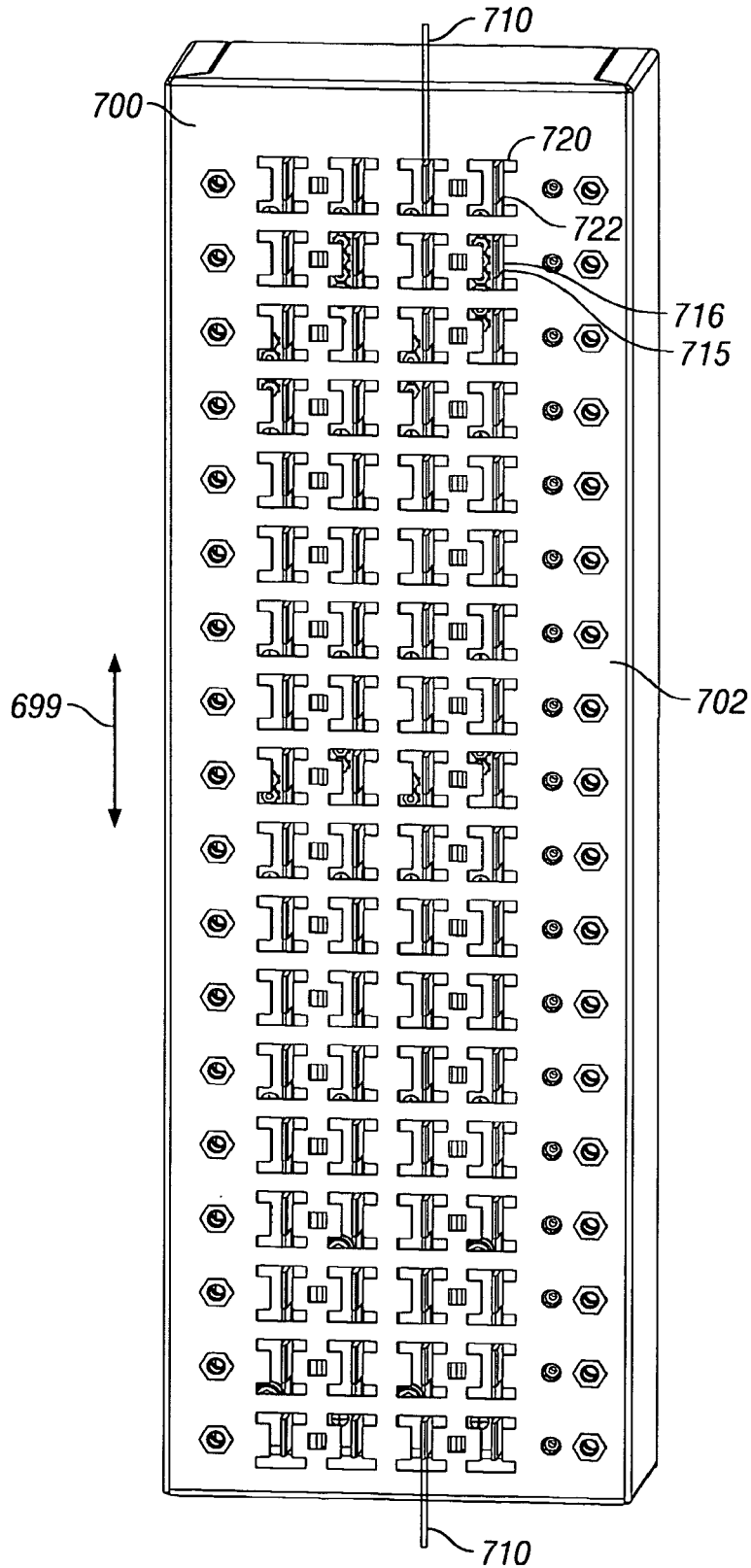


FIG. 7

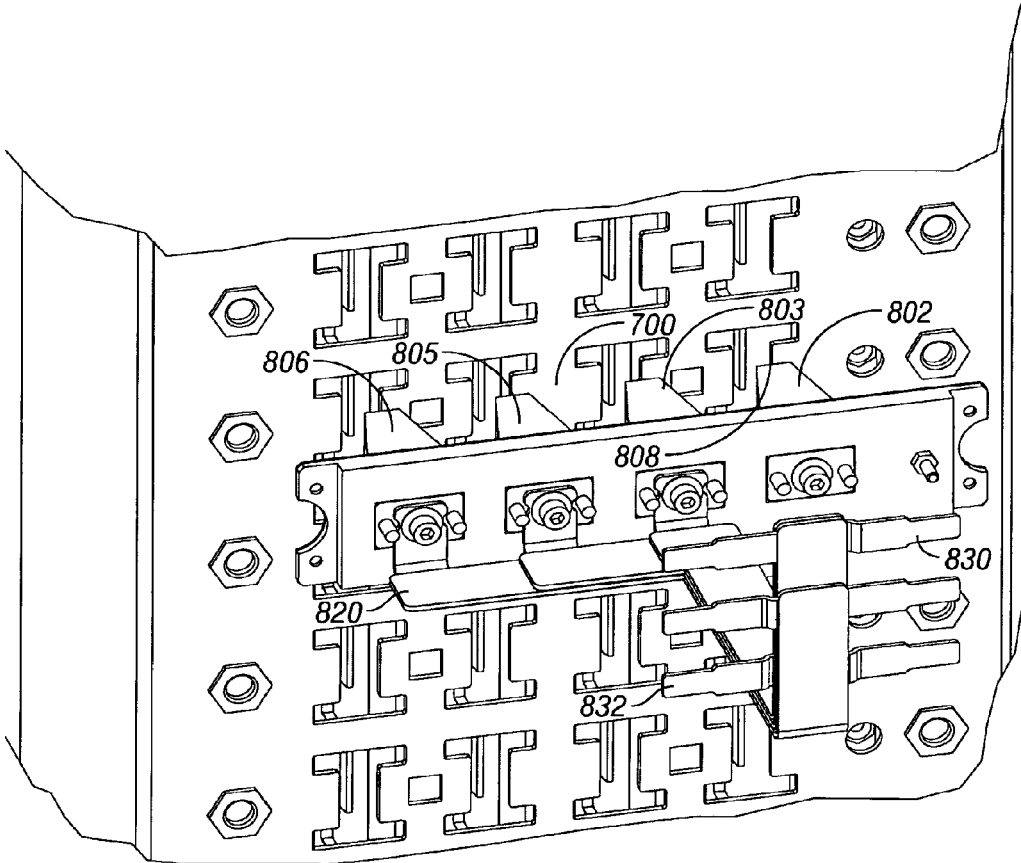


FIG. 8

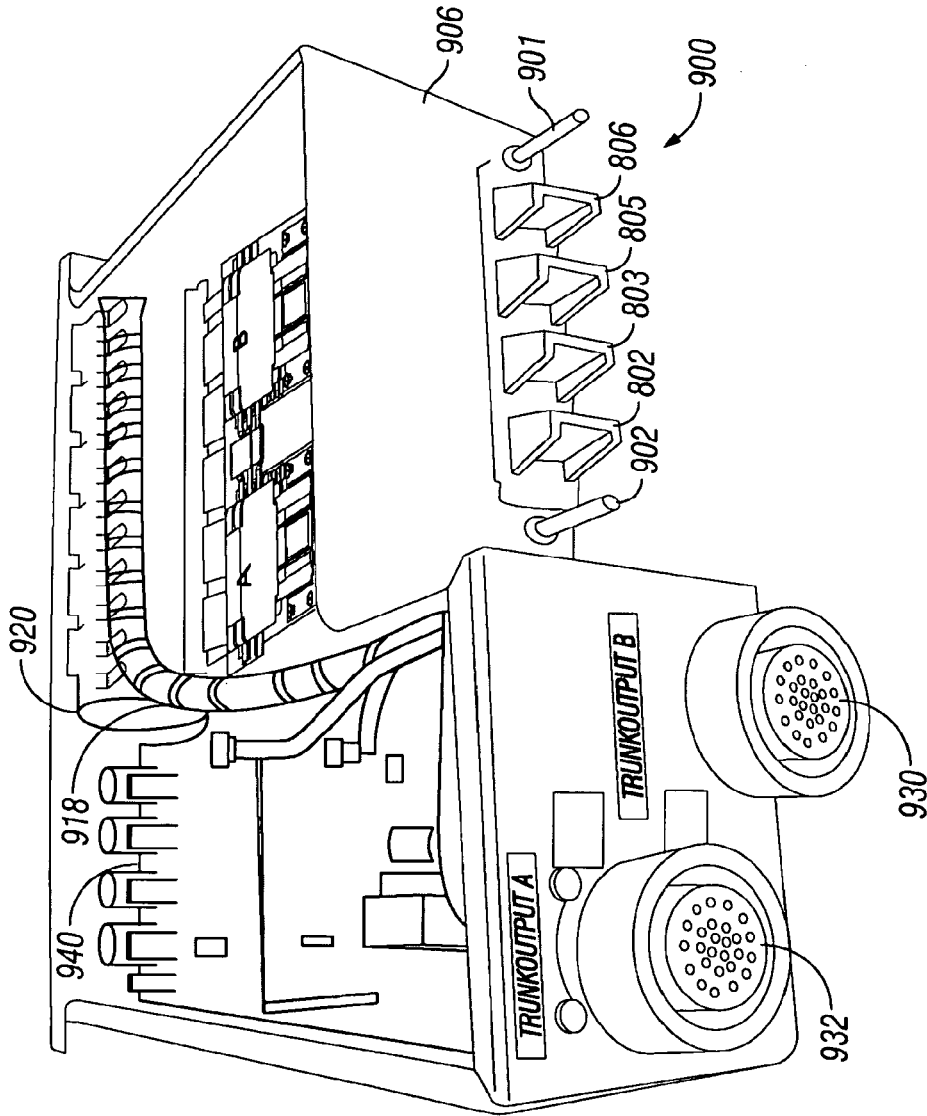


FIG. 9

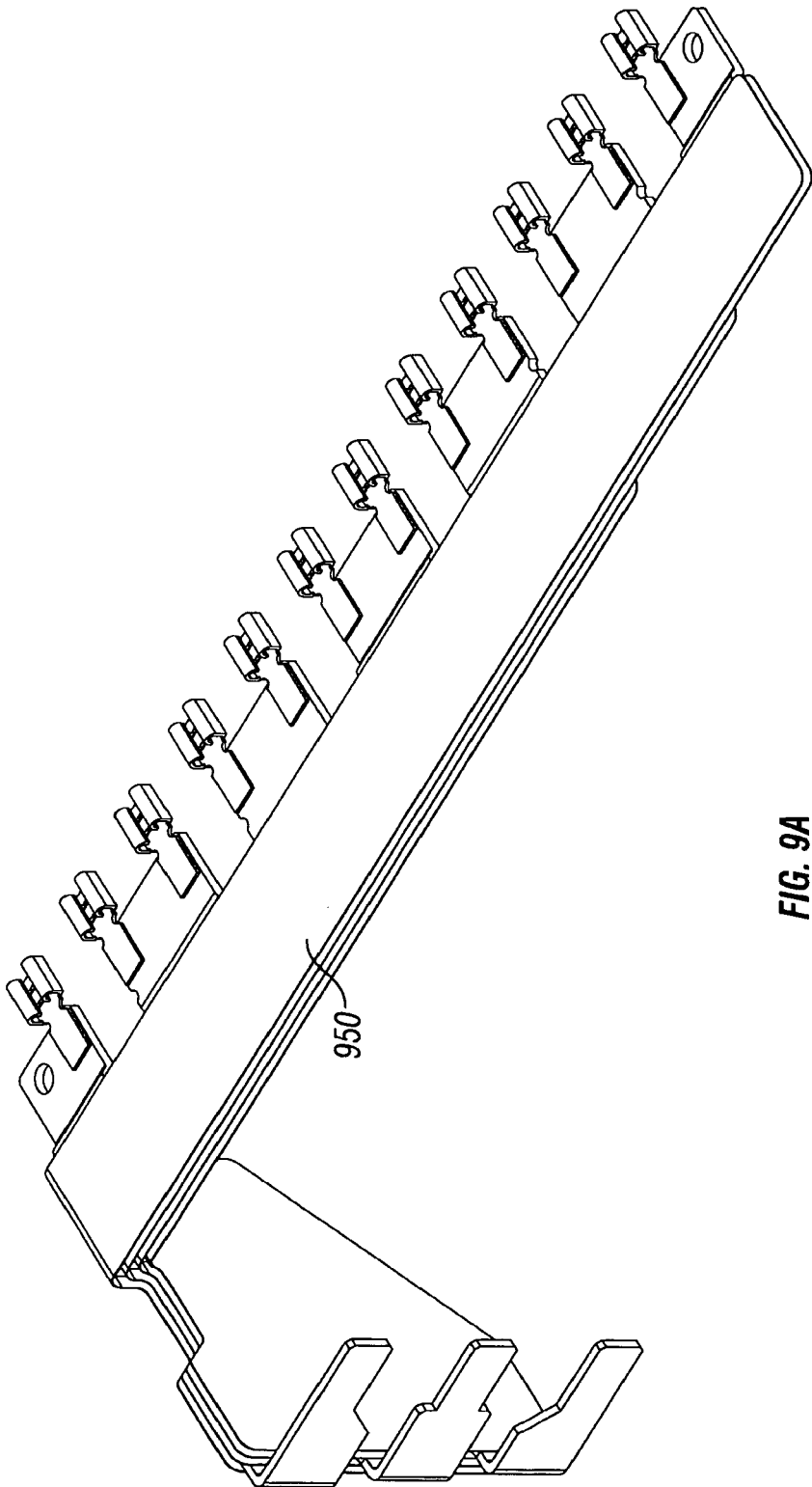


FIG. 9A

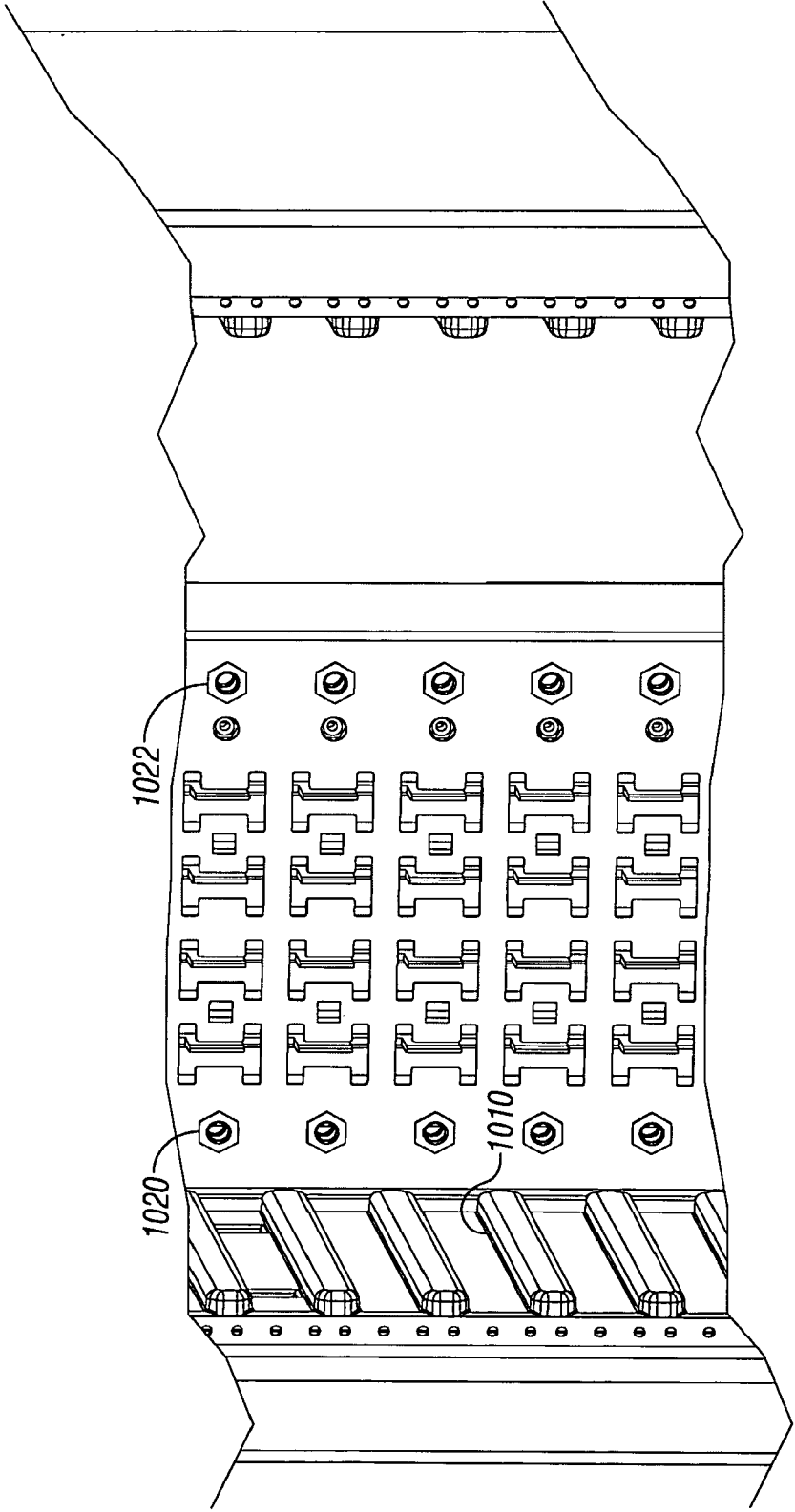


FIG. 10

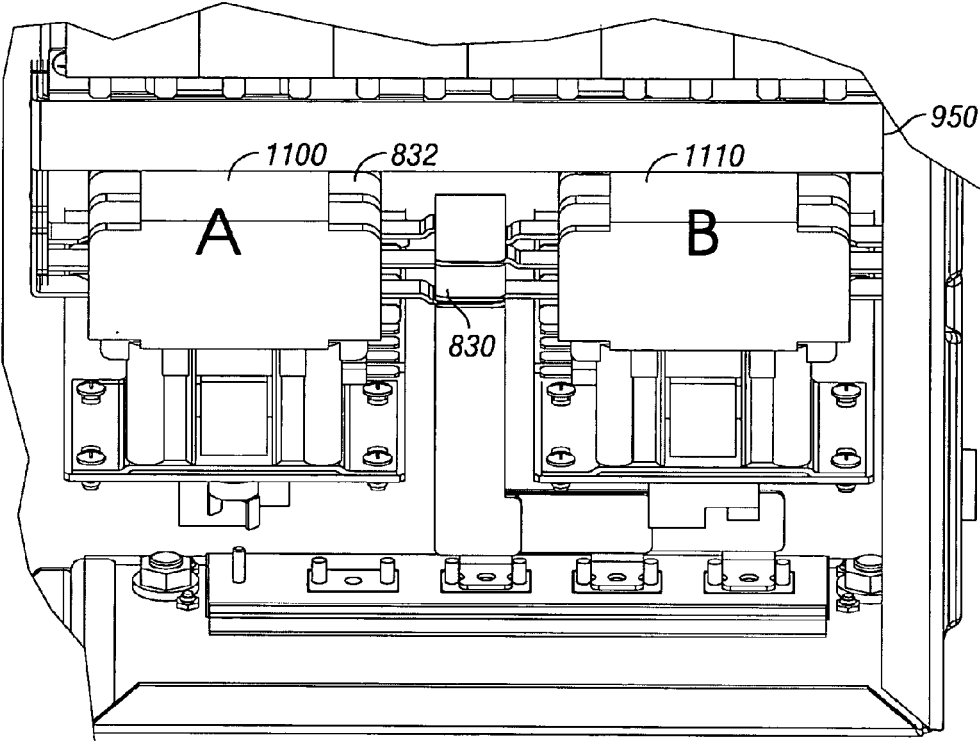


FIG. 11

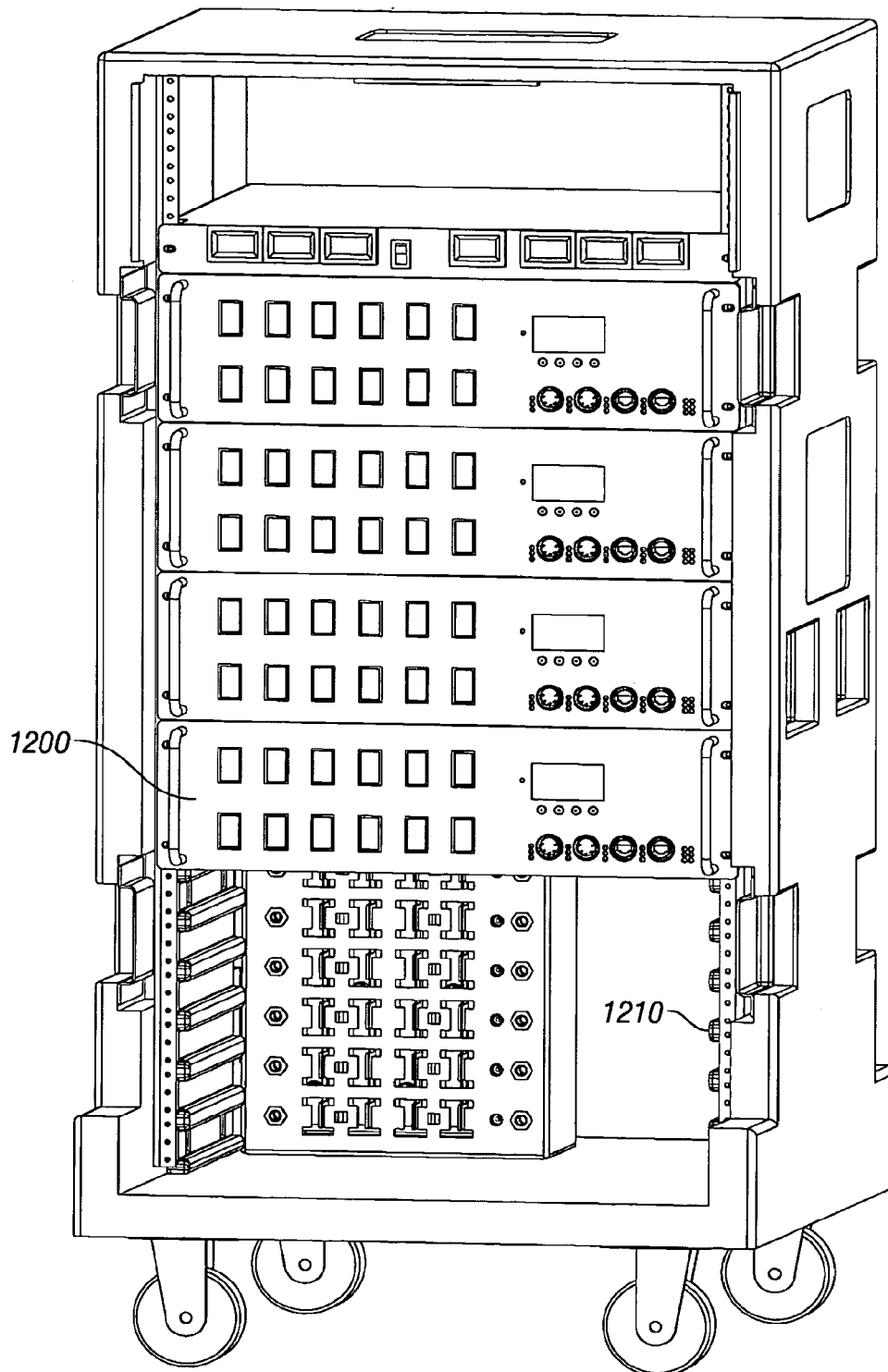


FIG. 12

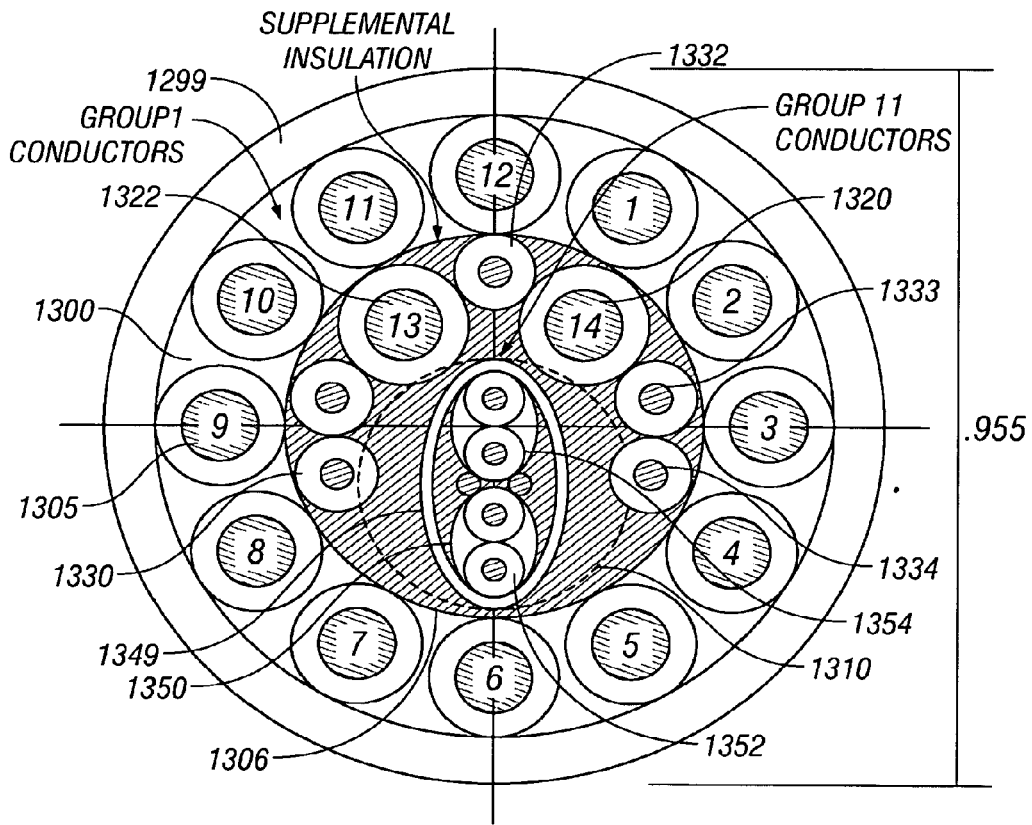


FIG. 13

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**PORTABLE POWER AND SIGNAL
DISTRIBUTION SYSTEM FOR A
CONTROLLABLE SYSTEM INCLUDING
MULTIPLE DEVICES**

This application is a continuation application of U.S. Ser. No. 11/190,494 filed Jul. 26, 2005, which claims priority from provisional application Ser. No. 60/647,922, filed Jan. 27, 2005, the contents of which are herein incorporated by reference.

BACKGROUND

A lighting effect is often created using many different devices. Each of the lights may use relatively high power lamps in order to produce the desired brightness. The high power lights correspondingly require large amounts of supply current. The current may be delivered from an electrical service to a distribution device, from which it is sent to the various lights. Exemplary lighting effects may include lighting a show on a stage or in concert, for example, in an exhibition, or to light an area that is too large to be lit by a single light. Moreover, a system of this type may include devices such as sound equipment, smoke machines, rigging motors, video projectors and video systems, all of which are driven from AC current.

Both power and controlling signals need to be sent to each of the multiple devices. It is desirable that the distribution of the power from a high current source to the lights be relatively convenient, and very safe. Moreover, the lights may be powered from different kinds of power, e.g. different voltages, e.g., 120 and 208 volts. It may be dangerous to power a lower voltage light from a higher voltage supply. For example, plugging a light intended for 120 volts into a 208 volt supply may cause dangerous arcing or other hazards.

Previous systems have used separate cabling for control, and separate cabling for power distribution. Each of these different cable systems requires time and labor to assemble, and each requires separate cables and connectors, each of which add cost to the system.

The controlling signals are used to control the individual lights. The lights may be controlled via a control network, such as Ethernet or DMX control or DMX over Ethernet, or any other controlling format. This has typically been done by distributing control lines to each of the lights. It is also important that the signals distributed to the lights be relatively free of electrical noise.

SUMMARY

Techniques are disclosed which enable distributing both power and signals to a plurality of controlled devices. A number of different embodiments enhance the safety and convenience of the system.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a block diagram of the basic system and its basic parts;

FIG. 2 shows a wiring diagram of the power supply;

FIG. 3 shows a cross-section across a connector;

FIG. 4 shows a screw connection between power feed and busbars;

FIGS. 5 and 6 illustrate the busbars and their connections;

FIG. 7 illustrates a safety cage for the busbars;

FIG. 8 illustrates a connector assembly for the busbars;

FIG. 9 illustrates the breaker module and its connection;

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FIG. 9A illustrates the connector that is used to extend between the contactor and the circuit breakers.

FIG. 10 illustrates the busbars and the safety cage as used; FIG. 11 illustrates the connection between the contactors and circuit breakers;

FIG. 12 illustrates the overall rack; and

FIG. 13 illustrates a hypothetical cross-section of combined power/signal cables.

DETAILED DESCRIPTION

The general structure and techniques, and more specific embodiments which can be used to effect different ways of carrying out the more general goals are described herein.

FIG. 1 shows an overall block diagram of an embodiment which distributes both power and control signals to remotely-located lamps such as 99. Each of the lamps 99 are connected to receive both power and controlling signals from a breakout box. The distribution rack 100 is a rack formed with a number of breaker modules such as 102, each of which controls a specified output. The distribution rack 100 receives electrical power 55, for example from 4/0 feeder cables providing 400 amp, 3 phase power for distribution. The distribution rack 100 also receives a control signal shown as 140, which in this case is an Ethernet signal sent to an Ethernet switch 145. Both three phase power and control signals are distributed to each of the breaker modules 102. Each of the breaker modules 102 produces a combined power and signal output 120 over a specially-configured cable which includes both power and control conductors.

The output 120 is connected to a breakout box 130. There are multiple different configurations of breakout boxes. A different output from a different breaker module is connected to breakout box 135, of a different configuration than breakout box 130. For example, breakout box 130 is configured for 208 volts AC, and has 208 volt outlets 132, as well as control connections 134.

The control can be in any form that controls one or many lights, for example Ethernet, the industry standard DMX, or any other addressable, timeslot controlled, or other type control line. Analogously, the breakout box 135 includes 120 volt AC outlets 136.

The distribution rack 100 divides the high current feed 120 into a number of separately breakered power feeds. These feeds are distributed over the same cable that also carries the control therein. Note however, that multiple voltages may be simultaneously present in the distribution rack 100. An embodiment may apply different voltages to different breakout boxes. An alternative embodiment can allow different voltages to be output to different outlets on the same breakout box.

If a 120 volt outlet were connected to receive 208 volt power, however, damage to the lights and safety issues could occur. Each breakout box is wire coded according to its configuration. A wire loopback technique using "key wires" ensures that the proper voltage(s) are provided to the specific breakout box. No voltage at all will be provided unless and until a properly-configured breakout box is connected to the breaker module.

In the embodiment, the breakout box has a loopback connection over key wires that is coded according to its intended voltage. The embodiment may have individual wires that are used as hardwired key wires. The breakout box includes a loopback that requires compatibility before energizing the breakout box properly. For example, the individual key wires may include 5 different possible wire connections, with two of those five wires being connected for any individual con-

nection. For example, a 120 volt breakout box may have wire 2 connected to wire 5. A 120 volt breaker module will not output any output voltage to the breakout box outlets until and unless wire 2 is connected to wire 5. Therefore, no output power will be supplied until a properly configured breakout box is connected to the breaker module.

This protects against application of the wrong voltage to the breakout box.

As an additional safety mechanism, power is not connected to the breakout box until the breakout box and all intermediate connections have been completely connected. Therefore, power is not applied to the cable 120 until a compatible breakout box has been connected. Therefore, any unterminated trunk connector is never powered live. People handling the connector are not in danger, even if they are in dangerous surroundings, such as standing in water.

FIG. 2 shows the electrical connection between the distribution rack 100 and the breakout box 135. The main power trunk 110 is input to a 3 phase bus bar system 200, formed of busbars 210, 211, 212, 213 within the distribution rack, as described in further detail herein. It should also be understood that each of the relays shown in FIG. 2 may use pilot relays—where two relays in series are used in place of one single relay. The use of two series connected pilot relays avoids the need to source or sink large amounts of power through the relay coil.

The bus bar system 200 provides power in parallel to each of the breaker modules, including the breaker module 201 as shown. The power from the bus bar is applied via a high current contactor 220. In the embodiment, a 75 amp contactor may be used. The contacts 221, 222 are in series between the busbars 200, the power line 230 and the trunk cable 120. The open or closed position of the contactor is controlled by a contactor coil 223. When the contactor coil 223 is energized, the contacts 221 and 222 are connected. The power line 230 provides power to the outlet 136 within the breakout box. The contactor switches all phases of the power.

The contactor feeds a set of circuit breakers 241 as described herein. The output of each of the breakers is sent down the trunk cable to outlets 136. The individual breakers each control power to an individual set of outlets.

A five wire bundle shown generally as 240 is used to provide 10 different combinations, allowing 10 different unique breakout box/breaker module combinations. Of course, any number of wires can be used for this purpose, allowing any number of unique configurations.

The energization 224 for the contactor control coil 223 may be connected in series via the proper key wires. Therefore, the contactor can only be energized when the proper key wires are connected to one another, so that the contactor coil receives power across a complete path. The connection between the key wires is provided by an internal connection within the breakout box. If the coding of the breaker module does not match the coding of the breakout box, then the relay coil circuit is not completed, and no power is supplied.

In operation, the control for the contactors are energized via power over the key wires. A contactor can only be energized when the two key wires 232, 234 are connected within the breakout box. The breakout box 135 includes the provision to accept all five of the wires, but only a specified pair of the wires is connected at 250. In FIG. 2, the wire 232 is connected to the wire 234. This ensures that the voltage and/or other characteristics of the breakout box 135 is matched to the specific breaker modules 201, before applying power.

A master bus 266 is also used for an additional degree of safety. A master relay 271 has contacts 263 which are in series between the power supply 264 and the coil 223 of the master

contactor 220. The contacts 263 of the master relay 271 must be closed in order for any power to be supplied.

A master bus power supply 265 provides power for many devices in the rack. A master switch 262 is in series between the power supply 265 and the master bus 266. In the embodiment, the master bus 266 is formed by a fifth busbar within the system. The coil 264 for the master relay 271 is energized from the master bus. When power is present on the master bus, the contacts 263 are closed, thereby enabling the contactor 220 to supply power when those conditions are met. However, should the master switch 262 be opened, it automatically turns off all power to all breakout boxes, thereby opening all of the relays is also provided. The power for the contactor coil 223, and for the loopback/key lines, comes from a low-voltage power supply 264. Switch 262 is placed in series between the low-voltage power supply 264 and the contactor coil 223. When the switch is open, the current through the contactor coils is interrupted. Each of the contactors open, thus shutting down current to all the loads connected to the breakout boxes. Thus, the master switch 262 is an emergency switch that shuts down all power out of the rack, e.g., can be used for emergency or for convenience. This may eliminate the need for an operator to switch off all 72 circuit breakers on the breakout modules configured in a rack.

The above describes the low-voltage power supply providing power to the relay coils such as 272 and 223. Many high power relays, however, require 120 V power to the relays. The use of a pilot relay may allow a low-voltage power such as 264 to be connected to the coil of the pilot relay, with the switchable contacts of the pilot relay then providing 120 V power to the main coil.

For example, if the breaker module 201 is configured to provide 120 volt power, then a specified pair of wires, here 232 and 234, are required for loopback. This ensures that the 120 volt power will only be provided over a breakout box that is configured with 120 volt outlets.

An internal loopback connection 250 is maintained within the breakout box. This internal loopback connection in this embodiment loops back between wires 232 and 234 to indicate that the breakout box 135 is a 120 volt breakout box. For example, a different connection between wires may be used for a different loopback connection. The five different wires provide the capability to provide 10 different combinations of loopback, and hence 10 different possible configurations of breakout boxes.

The cable 120 carries power, ground and signal, however, has no power connected to the power-containing hot lines until the loopback is established to energize the contactor. Once the loopback is established, the contactor 220 is energized, and power is applied to line 230 to provide power to the outlets 136. Until then, however, the cable remains unpowered; other than the controlling power on the key lines.

Alternatively, while the above has described 120 volt connections, it should be understood that this system can also be used with 208 volt connections and with any other voltages. For a 208 volt signal, the operation may be adapted to provide six 15 amp outlets, or three 30 amp outlets, or any combination thereof. The system may also use multiple phase controls and connections. For example, a breakout box may be configured to supply 3 phase power to outlets on the box. Each unique breakout box power configuration can use a different loopback connection. The system therefore prevents the wrong breakout box from being used relative to the voltage output which is provided.

For further safety, the loopback voltages may be current controlled and/or ground fault interrupt protected.

In addition to the key wires, there is also a control cable **260** in **120** which is distributed from the distribution rack **100** to the breakout boxes **135**. This control cable may provide controlling signals for the lights that are powered by the outlets. For example, this control may be one or many universes of DMX control, Ethernet control, or any other control protocol for devices or combinations thereof. Naturally, the protocol can only be those which are compatible with the wire or signal carrier within the cable. For example, any protocol that can travel over twisted pair can be used.

Another aspect is enabled by the pin configuration of the connector pins. FIG. 3 shows a detailed diagram of the end of cable **300** and an exemplary cross section showing the connector pins **302**. The connector **302** includes a plurality of pins at different heights relative to the bottom surface **310** of the connector. Each of the pins are connected to corresponding wires within the cable **300**. There may be multiples of each kind of pin. FIG. 3 shows 2 of each kind of pin, but it should be understood that there may be many, e.g., between 1 and 15 of each kind of pin, for example.

Pin **304** is connected to wire **306** within the cable. Pin **304** represents the safety ground, and the wire **306** is hence connected to the safety ground. Pins **304** extend out the furthest relative to the bottom surface **310** of the connector. Therefore, when the connector is mated, the pins **304** make contact first, thereby insuring that the safety ground contact is established first. This makes sure, for example, that the breakout boxes are grounded first during connection.

Pins **315** make contact second, and are connected to wires **318** which represent the power connection, e.g., AC power such as 120 volts and/or 208 and/or 220 volts. Note, as above, that these wires are not energized until the contactors are energized via the key lines.

Pins **325** extend the shortest distance up, and are connected to the wires such as **328** which represent the signal lines. The signal lines include the key lines discussed above, as well as other signals such as Ethernet and DMX.

Each of the sets of pins are recessed relative to the other, sufficiently to ensure a full connection of one set of pins, before the next set of pins is able to obtain a connection. For example, the recess amount may be by about 1 mm, but more generally any recess amount between 0.3 mm and 5 mm may be appropriate, depending on the size of the connector and other parameters.

In this way, and in operation, the safety ground is established first, based on the furthest out pins **304** making the first connection. After the safety ground is established, power wires are connected over pins **315**, but the breakout box will not actually be powered until the contactor is energized based on the key lines. Finally, the key lines and the Ethernet and other control lines are connected, which powers up the contactor, providing power to the system.

Another problem with systems of this type is that connections can come loose. This becomes especially problematic for high current connections that are established from within the rack. An aspect of this system, therefore, maintains all connections via solid metal to metal bolting; from the beginning entry portion **109**, all the way to the connections out of the contactors. This metal to metal bolting can minimize the voltage drop and can prevent wires from being pulled loose. The bolting of solid metal connectors eliminates crimped connections of standard wires. The crimped connections to high current conductors are often difficult to properly apply, and can come loose over time. This itself causes a safety hazard. A loose crimp heats under a high current load, and will also oxidize over time, and become an even poorer connection.

The crimp is also an added connection between the conductor and the intended termination. Each connection may cause a voltage drop. This system may eliminate the need for stranded wire and crimp connections in any of the high current conductor portions, since the entire portion is formed by metal to metal bolting.

The power connection is illustrated in FIGS. 4-9. The input power line **109** is attached to a standard type of cam lock connector **400** which has a threaded output **402**. The threaded output **402** of the cam lock connector is screwed into a solid standoff **410**. A current transformer **405** surrounds the solid metal threaded standoff **410**. The cam lock connector screws into one side. A bolt **430** secures the busbar to the insulator **420** and screws into the other side. The current transformer provides output signals which can be used for control and/or meters that determine and/or display total consumed current.

The second bolt is screwed directly to bus bars **425**. A separate bus bar is provided for each of the phases and for neutral.

FIG. 5 shows a front on view of the insulator sheet, **420**, along with the bus bar **428** and its connection bolt **430**. The insulator sheets may be fiberglass, for example.

Each of the bus bars are formed of 1/8 inch thick copper, nickel plated, arranged with indented portions **600**, and extending portions **605**. The extending portions **605** on the bus bars form connecting tangs for connection to appropriately configured connectors on breaker modules. Each leading edge **603** of the extending portion **605** has a slight bevel, making it thinner at the front edge to facilitate connection. The bus bar tangs are formed in 1 "U" increments, where each U or unit is 1 3/4 inches vertically.

FIG. 6 shows a side view of the bus bars such as **428**, showing the indented portion **600** and the extending portions **605** forming the tangs.

"Crown" connectors **610** fit on the tangs to make contact therewith, again without wire connections.

Each of the four bus bars, for example, can carry a different part of the electrical supply. For example, the four bus bars shown in FIG. 5 may carry electrical neutral, electrical phase A, electrical phase B and electrical phase C. Each of the extending portions, or "tangs" on the bus bar, are sized to connect to a corresponding crown connector as shown above.

A safety cage **700** is shown in FIG. 7. The safety cage includes a front surface **702** which faces towards the modules in the unit. The safety cage also includes a plurality of openings such as **705**. The central portion of each of these openings is spaced at the same pitch as the pitch between tangs of the bus bar. Each of the bus bars extend longitudinally along the axis **699** in FIG. 7. A bus bar is shown as **710** in FIG. 7. A plurality of openings **705** are provided in registration with each of the tangs of the bus bar. For example, bus bar **710** extends past openings **715**, **720**, and other openings in that series. Each tang of the bus bar **710** is aligned with one of the openings in the safety cage, for example, tang **716** is aligned with opening **715**; tang **722** is aligned with opening **720**. However, at all times, the bus bar **710** is behind the front surface **702**, thereby protecting the user against the high voltage on the bus bars.

Of course, any number of bus bars, e.g., 2 or 3, or 4 or 5, or more, can be used. The safety cage is shown with substantially I shaped openings through which the connectors extend; however the openings can be other shapes, such as rectangular or circular in shape.

FIG. 8 shows a connector assembly **800** used in the breaker modules that connect to the bus bars. The connectors **800** include crown connectors **802** which plug into correspondingly located tangs **804** on the bus bars. There may be four

crown connectors on each connector depending on the phases: **802**, **803**, **805** and **806**. Each crown connector is sized and spaced to connect into a respective one of the bus bars. The openings **715**, **720** in the safety cage **700** are also spaced to allow the crown connectors to extend therethrough and to contact the bus bars. Therefore, the leading surface **808** of the crown connector **802** extends through a hole in the safety cage and connects to tang **804**. The crown connectors have a substantially beveled outer shape. These may use Elcon Blind Mate connectors.

In operation, each of a plurality of breaker modules is connected into corresponding slots within the rack. Each of the breaker modules may have wheels that allow them to roll along tracks **1010** in the housing; see FIG. **10**.

FIG. **9** shows a rear view of a breaker module. The breaker module includes a connector area **900** which includes the crown connectors **802**, **803**, **805** and **806**. Each of these connectors is intended to receive a different phase of the electric supply from a corresponding bus bar to which it connects. For example, in FIG. **9**, the connector **802** receives neutral, and the connector **803** receives the x phase. In the case of single phase electricity, some of the connectors may not be present, or may simply be connected at the bus bar and unconnected at the other end.

In addition, the connector area includes ground pins **902**, **904**. These ground pins extend out further from the rear surface **906** of the breaker module than the furthest extending ends of the crown connectors. Accordingly, when the breaker modules roll into place in the housing, the ground lugs **902**, **904** make contact prior to the crown connectors and hence prior to power being applied, hence providing a level of safety.

The breaker module in FIG. **9** plugs into the rack areas shown in FIG. **10**. Note that the rack area includes side guiding supports **1010**. The breaker modules may have wheels to allow them to roll on the supports **1010**. In addition, however, each area includes corresponding female receptacles **1020**, **1022** which are bonded to the guard cage. The ground lug **902** extends into the ground hole **1022**. This provides a ground connection immediately, prior to power application, and also provides structural support for the unit. After both ground pins are connected, that is ground lug **902** is connected to hole **1022**, and ground lug **904** is connected to hole **1020**, the unit can be slid further into place. At this time, the crown connectors extend through the corresponding holes in the guard plate, and make contact with the corresponding bus bars.

The contact from the busbar connects to the breaker module **800** (FIG. **8**), and is connected to a screw in unit **820** in FIG. **8** which includes metal bus bars connected to each of the three phases, and extending to a contactor connector **830**, which itself connects to the contactor that screws onto the bus bar output portions such as **832**.

Again, the connector **820** is screwed to each of the three phases, and leads via solid metal to each of the tabs such as **832** on the connector **830**. FIG. **11** shows how the connector **830** is connected to each of two contactors, **1100**, **1110**. Each of the contactors may be, for example, a 3 pole, double break, normally open contactor. The connector end **832** screws directly to the input terminal of the contactor.

The contactors are normally open and therefore maintain power off at their output.

The outputs of the contactors are connected via busbars **950** to a row of breakers **920**, each breaker controlling a specific one of the outlets on the breakout box. The busbars **950** are shown in detail in FIG. **9a**. The same busbar is used on the top and bottom, with the busbar simply being turned upside down for the bottom row. Each of these circuit break-

ers receives power that has been switched by the contactor in the way described above. The circuit breakers control the output of power to individual branch circuits.

The output of the circuit breakers is protected by the action of the circuit breaker, and hence overloads and overheating caused by overloading and short circuits can be protected. These outputs, switched via the breakers are connected via wires **918**, to the trunk output connectors shown as **930**, **932**.

The breaker modules handle not only the electrical power, but also control signals. Both electrical power and control signals are output on the connectors **930** and **932**.

Control electronics **940** may include a processor which controls specified control signals. For example, in an embodiment, the control signal for DMX is transmitted over an Ethernet line.

According to this system, the processor allows receiving control signals, and handling those control signals. For the embodiment of DMX, those control signals will be described as though they are DMX control signals controlling multiple different DMX universes. When the processor sees a new DMX universe, it asks the user to name the DMX universe. Then, that DMX universe is available everywhere on the Ethernet system, that is on each of the different breaker modules described above. The processor controls each of the different DMX universes, and allows selection of which universe appears on the trunk outputs **930**, **932**, and hence which breakout box will receive those universes. Each breakout box can accommodate 2 or more different DMX universes and the Ethernet signal. A user interface allows the DMX universe to be named. In operation, when the control circuit **940** recognizes a new DMX universe, it prompts the user to enter a name for it. The DMX can be received directly, or can be received over Ethernet, for example.

The devices may be all connected together, as shown in FIG. **12** or connected in smaller groups allowing multiple Ethernet and/or Local Area Networks (LANs) to exist. Each breaker module such as **1200** controls output voltage and outputs control signals for a specified one or more breakout boxes. Each breaker module carries a specified voltage. For example, breaker modules **1200** produces a 208 volt output and hence is arranged to interface with breakout boxes that are configured for 208 volts. Breaker modules **1205** support breakout boxes with 120 volt outputs.

Trunk outputs **932** and **930** carry the output signals which are sent to the breakout boxes. Note that the connectors include both power and signals for the breakout box in the same cable, as well as the safety key wires and safety ground connections.

A special cable assembly is used to carry the AC power and signals. The cable assembly includes an integrated cable assembly that combine six circuits of AC power, two twisted pairs of shielded high-speed data, five low-voltage key lines, and two safety ground lines.

A cross-section of the composite cable is shown in FIG. **13**. The composite cable is formed of coaxially arranged groups of conductors. An outer layer **1299** of insulation surrounds the entire cable. The coaxial ring of group I conductors **1300** is just inside the outer layer **1299**. The group I conductors **1300** are formed of 12 individual power cables, each of which is separately identified, e.g., by color-coding. The power cables, for example, can be #12 Copper stranded power cables, with 600 volt insulation. These form the wires that carry the individually circuit breaker controlled power to the breakout boxes.

A supplemental insulation layer **1306** is located inside the group I conductors, and provides insulation between the

group I conductors, and the group II conductors 1310 which themselves are coaxially located inside the group I conductors.

The group II conductors include a number of different wires of different wire types. The conductors 1320, 1322 are copper conductors, e.g., #12 wire, connected to earth ground. These form the safety ground connections. In one embodiment, each of the safety grounds has the same amount of current carrying capability as the each of the group I conductors. By using two safety conductors, a redundant safety circuit provides an extra level of safety.

The key wires are coaxially located in the group II connectors, formed of wires 1330, 1331 1332, 1333 and 1334. Two of these wires are connected together at the distal end to form the loopback connection as described above. Each of these wires may be individually color-coded. The key lines also carry DC power, e.g. on line 224 to the breakout box to power its internal electronics. The earth ground system is used to return this current back to the low voltage DC supply 264 within the breaker box.

In addition, Ethernet lines 1350 form another wire layer, separated from the Group II wires by a separate insulation area 1349. The Ethernet lines are formed from two twisted pairs 1352 and 1354, and are configured to conduct Ethernet signals over a distance of up to 500 feet.

Each of the three wire layers are separately insulated. Each of the insulation layers 1299, 1306 and 1349 may also include metal shields therein. The metal shields are preferably connected together to a ground connection.

Other embodiments are contemplated, and the disclosure is intended to encompass all embodiments and modifications which might be predictable based on the disclosed subject matter. For example, it should be apparent that other numbers of wires could be used, besides those specifically stated herein. Larger or smaller gauge wires can also be used. Also, different kinds of wire are contemplated. While the above describes the key wires requiring specified wires in the cable, it should be understood that the keying can be carried out in other ways, e.g. by using a specified voltage with different voltages for different breakout boxes, or a specified waveform, such as a square, wave for 120 V, a sinewave for 220, or any other kind of control signal.

Also, only those claims which use the words “means for” are intended to be interpreted under 35 USC 112, sixth paragraph. Moreover, no limitations from the specification are intended to be read into any claims, unless those limitations are expressly included in the claims.

What is claimed is:

1. A method comprising:

connecting a first breakout box for power to a power system which is capable of outputting multiple types of power, said first breakout box having connections for a first type of power, and connected to a first connection type on said power system;

automatically preventing a power type other than said first type of power from being applied to said first breakout box when connected to said first connection type;

connecting a second breakout box for power to said first connection type on said power system, said second breakout box having connections for a second type of power,

and where said connection for the second type of power are different than the connections for the first type of power; and

automatically preventing a power type other than said second type of power from being applied to said second breakout box when connected to said second connection type.

2. A method as in claim 1, wherein said automatically preventing comprises providing a plurality of wires in a connection between said first breakout box and said power system, providing a first control signal on a first of the plurality of wires, and allowing power output only when said second control signal is received on a second of said plurality of wires.

3. A method as in claim 1, wherein said different types of power are different phases of power.

4. A method as in claim 1, wherein said different types of power are different voltages.

5. A method as in claim 2, wherein said automatically preventing comprises providing a plurality of wires in a connection between said first breakout box and said power system, providing a first control signal on a first of the plurality of wires, and allowing power output only when said second control signal is received on a second of said plurality of wires; and

providing the plurality of wires in a connection between said second breakout box and said power system, providing the first providing a third control signal on a third of the plurality of wires and allowing power output only when a fourth control signal is received on a fourth of said plurality of wires.

6. A method as in claim 1, further comprising supplying both power and control signals on a single connector.

7. A method as in claim 6, further comprising network-based signals within said power system, and said network-based signals are also present on said single connector.

8. A method as in claim 1, wherein said automatically preventing comprises maintaining deenergized a relay that is in series with said power.

9. A method as in claim 8, wherein said maintaining deenergized comprises connecting a coil of said relay to said second wire, so that said coil is driven by said second control signal being received only on said second wire.

10. A method as in claim 1, further comprising providing a power connection between input power and at least one circuit breaker, where the power connection comprises busbars and all metal-to-metal bolted connections between said connection to each busbar, and a connection to said circuit breakers.

11. A method as in claim 10, wherein said power connection includes a plurality of bus bars, and further comprising shielding the bus bars using a cage with holes.

12. A method as in claim 11, wherein at least a plurality of said holes are grounded holes.

13. A method as in claim 1, wherein said connection is via a connector, and further comprising connecting said connector by connecting ground pins first, signal pins second, and power pins third.

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