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Method for replacing sections of electrically conductive phases in a DC two phase power system

Abstract

The present invention relates to replacing conductors in a high-voltage power transfer system. The method provides, for example, a method for maintaining sections of electrically conductive phases in a direct current (DC) two phase power conductor line, wherein the two phases are parallel and spaced apart. The phases are strung between support structures and supported above the ground. Maintenance work, which include replacement or repair, is performed on sections of the two phases without interrupting a power load in any one of the three phases and without transposing the relative positions of the phases.

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Background/Summary

FIELD OF THE INVENTION
(1) The present invention relates generally to high voltage power transfer systems. In particular, the present invention relates to replacing conductors in a high voltage power transfer system.
BACKGROUND OF THE INVENTION
(2) Users of large amounts of electrical power such as cities, manufacturing facilities, and other high-power users are often located quite a distance away from sources of electrical power such as hydroelectric dams and power plants. In order to deliver large amounts of power from the source of generation to the power consumers, large, high-capacity, high-voltage power lines are used.
(3) Typically, alternating current (“AC”) is generated in a three-phase configuration. For the purposes of this document, the three phases will be referred to as A, B and C phase. A phase, B phase and C phase are all transported over separate conductors. In some instances direct current (DC power) is used in which case two conductors are used and are referred to as A and C phase. Typically, the conductors are comprised of long wires supported on large support structures such as towers or power poles. The separate A, B and C phase conductors are typically attached to the same support structures on insulators.
(4) From time to time, the power lines transporting the power may require maintenance. For example, a section of the conductor may need to be replaced, an insulator insulating the power line from the support structure may need to be replaced, or, the support structure itself may need repair or replacement. In some cases, conductors may be functioning properly, but need to be replaced by higher-capacity conductors in order to transport more power.
(5) Typical maintenance on power lines requires that the power be shut off before the line can be worked on. High induction currents may be induced into a conductor located in the proximity of other high voltage conductors, thus creating a hazard in order to work on a particular conductor.
(6) Shutting off the power creates a disruption of power delivery to customers. A power user may

be forced to do without power during the time the power line is maintained, which is undesirable for a variety of reasons. To provide consumers power while a particular line is being worked on, the load may be shifted to other power lines to deliver the power to the end user. Unfortunately, shifting power to other transmission lines is not always possible because redundant systems may not exist, or transmission lines may already be operating at or near capacity level and not able to deliver the required power.

(7) Previously, the applicant developed methods for conducting maintenance work on energized high voltage conductors in electrical transmission systems, such as the methods described in the U.S. Pat. No. 7,535,132 issued on May 19, 2009 to Quanta Associates, L. P. One of the methods taught in U.S. Pat. No. 7,535,132 involves moving each of the conductors needing replacement to a temporary position, stringing new conductors in or near the originating positions of the old conductors, transferring the power load from each of the old conductors to each of the new conductors using transfer buses, and removing the old conductors.

(8) However, one problem that often occurs during the execution of the methods described in U.S. Pat. No. 7,535,132 is that the movement of each of the old conductors requiring replacement to temporary positions at the same time will often result in the transposition of the conductors carrying phases A, B and C, whereby, for example, if the phases were originally arranged in the relative horizontal positions of A-B-C prior to moving the phases to their temporary positions, the relative horizontal positions may often end up in the positions B-A-C after the movement has occurred. Furthermore, in order to achieve moving all three phases to temporary positions at the same time using the methods described in U.S. Pat. No. 7,535,132, it is often necessary to utilize long jumper cables to connect the temporarily relocated section of conductor to the remaining sections, which jumper cables for one phase must necessarily cross over the conductors of another phase while carrying a power load, as illustrated in FIG. 35 of U.S. Pat. No. 7,535,132. These are examples of what the Applicant refers to as illegal transpositions of the phase conductors. The disclosure of U.S. Pat. No. 7,535,132 is incorporated herein in its entirety, and is hereinafter referred to as the '132 patent.

(9) Both scenarios described above results in the transposition of the phase conductors, leading to an imbalance in the impedances of the phase conductors and therefore, fluctuations in the voltage and current carried on the phase conductors. Such fluctuations, if large enough, will cause the protective relays to trip the breakers, causing a disruption in the delivery of power on the transmission lines being worked upon. To avoid this result, the owner of the power transmission line may choose to disable the safety relays while a live reconductoring project is underway. However, disabling the safety relays results in a risk that a sudden fluctuation in the voltage and current during the live reconductoring project may damage the transmission network.

(10) Accordingly, it is desirable to provide an improved method to allow high voltage power transmission lines to be worked on, replaced or maintained without requiring power to stop being delivered or diverted over to other remote transmission lines, and without resulting in the illegal transposition of the phase conductors that could lead to faults in the transmission line.

SUMMARY

(11) One example embodiment of the present invention provides a method for maintaining a section of an electrified, three-phase power conductor line, wherein the three phases are in a common plane, in an ordered sequence and strung between a set of support structures, wherein at least two equal potential zones are employed in communication with at least one of said three phases, the method comprising steps of: a) positioning at least one auxiliary support substantially adjacent the set of support structures so as to support an electrified section of a first phase-needing-maintenance, b) moving said section of said first phase-needing-maintenance so as to be strung upon said at least one auxiliary support and said at least two auxiliary dead end supports, wherein said first and second dead end junctures are supported by said at least two auxiliary dead end supports, c) stringing a first new phase conductor between the set of support structures where the

section was moved from, d) electrically connecting a first transfer bus and a second transfer bus to said first new phase conductor, e) electrically connecting said second conductor of said first transfer bus and said second conductor of said second transfer bus to a second phase section of a second phase-needing-maintenance that is proximate to said first phase-needing-maintenance, wherein said second phase section comprises a third dead end juncture and a fourth dead end juncture, f) electrically connecting said first transfer bus so as to bring said first new phase conductor to an electrical potential that is equal to said second phase-needing maintenance, g) completing a first electrically parallel connection between said first new phase conductor and said second phase-needing-maintenance, h) electrically connecting said new phase conductor to a first segment of said second phase-needing-maintenance on opposite sides of said third dead end juncture, and electrically connecting said first new phase conductor to a second segment of said second phase-needing-maintenance on opposite sides of said fourth dead end juncture, so as to complete a second electrically parallel connection between said first new phase conductor and said second phase-needing-maintenance, i) electrically disconnecting said section of said second phase-needing-maintenance so as to isolate said second phase section of said second phase-needing-maintenance from said first and second segments of said second phase-needing-maintenance and said first new phase conductor, and j) maintaining said second phase section of said second phase-needing-maintenance.

(12) Another example embodiment of the present invention provides a method for maintaining sections of electrically conductive phases in a three phase power conductor line, the three phases denoted as the A, B and C phases, wherein the three phases are parallel and spaced apart in an ordered sequence wherein the A phase is proximate to the B phase and the B phase is proximate to the C phase, but the A phase is not proximate to the C phase, and wherein the A, B and C phases are strung between support structures supporting the three phases suspended above a ground, and wherein maintenance work is performed on sections of the three phases without interruption of a power load in any one of the three phases and without transposing the relative positions of the A, B and C phases out of their ordered sequence, wherein at least two equal potential zones are employed in communication with at least one of said A, B and C phases.

(13) Another example embodiment of the present invention provides a method of maintaining sections of electrically energized phases in a three phase power conductor line, the three phases being an A phase, a B phase and a C phase, the method comprising: a) providing, between two support structures above a ground surface, the A phase is proximate to the B phase, the B phase is proximate to the C phase and the B phase is located between the A phase and the C phase with the phases all in a common plane; b) without interrupting an alternating current power of the A phase, the B phase and the C phase, performing maintenance work on sections of the A phase, the B phase and the C phase; c) without interrupting an alternating current power of the A phase, the B phase and the C phase, non-transposing the relative positions of the A phase, the B phase and the C phase; and, d) employing at least two equal potential zones in conjunction with at least one of said A phase, B phase and C phase.

(14) As described in the '132 patent entitled Live Conductor Stringing and Splicing Method and Apparatus, the disclosure of which is incorporated herein by reference in its entirety, a person ordinarily skilled in the art will readily understand how to employ the aforementioned stringing method described above, including the construction of equal potential zones, the use of hot line tools and live line work methods that are described in the '132 patent specification. In particular, see FIGS. 57 through 98 and column 22, line 48 through column 33, line 60 of patent ′132.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a schematic diagram illustrating a power transfer system for transferring power in three electrical phases, one electrical phase being transferred per conductor.

(2) FIG. **2** is a side view of a support structure for a power transfer system showing a temporary support structure located proximate to a permanent support structure configured for the temporary relocation of a phase conductor at a distance substantially equal to the phase spacing between the other phase conductors.

(3) FIG. **3** is a schematic diagram illustrating the power transfer system of FIG. **1** showing temporary support structures added in accordance with the invention.

(4) FIG. **4** is a side view of the support structure of FIG. **2**, illustrating the relocation of a phase conductor from its permanent support structure to a temporary location on a temporary support structure.

(5) FIG. **5** is a schematic diagram illustrating the power transfer system of FIG. **3** showing the relocation of a phase conductor to a temporary location on temporary support structures.

(6) FIG. **6** is a schematic diagram illustrating the power transfer system of FIG. **5** showing the relocation of a first dead end to a temporary location.

(7) FIG. **7** is a schematic diagram illustrating the power transfer system of FIG. **6** showing the relocation of a second dead end to a temporary location.

(8) FIG. **8** is a schematic diagram illustrating the power transfer system of FIG. **7** showing new conductor installed between new dead end structures.

(9) FIG. **9** is a schematic diagram illustrating the power transfer system of FIG. **8** showing a first temporary transfer bus partially installed.

(10) FIG. **9**A is a detail view of a portion of the schematic diagram illustrating the power transfer system of FIG. **9** showing the electrical connection between a first temporary transfer bus and a phase conductor.

(11) FIG. **10** is a schematic diagram illustrating the power transfer system of FIG. **9** showing a second temporary transfer bus partially installed.

(12) FIG. **11** is a schematic diagram illustrating the power transfer system of FIG. **10** showing the first temporary transfer bus fully installed.

(13) FIG. **12** is a schematic diagram illustrating the power transfer system of FIG. **11** showing the second temporary transfer bus fully installed.

(14) FIG. **13** is a schematic diagram illustrating the power transfer system of FIG. **12** showing a new conductor electrically connected to the B phase conductor across the second transfer bus that is connected to a closed breaker.

(15) FIG. **14** is a schematic diagram illustrating the power transfer system of FIG. **13** showing a new conductor connected in parallel to the B phase conductor across two transfer buses that are each connected to a closed breaker.

(16) FIG. **15** is a schematic diagram illustrating the power transfer system of FIG. **14** showing a jumper cable connecting the original B phase conductor to the new phase conductor across a dead end on the B phase conductor and a dead end located between the original A phase conductor and the new conductor.

(17) FIG. **16** is a schematic diagram illustrating the power transfer system of FIG. **15** showing two jumper cables removed from around a dead end on the B phase conductor.

(18) FIG. **17** is a schematic diagram illustrating the power transfer system of FIG. **16** showing a jumper cable connecting the original B phase conductor to the new phase conductor across a dead end on the B phase conductor and a dead end located between the original A phase conductor and the new conductor.

(19) FIG. **18** is a schematic diagram illustrating the power transfer system of FIG. **17** showing two jumper cables removed from around a dead end on the B phase conductor.

(20) FIG. **19** is a schematic diagram illustrating the power transfer system of FIG. **18** showing the breaker connected to the first temporary transfer bus set to the open position and breaking parallel between the new conductor and the original B phase conductor.
(21) FIG. **20** is a schematic diagram illustrating the power transfer system of FIG. **19** showing the breaker connected to the second temporary transfer bus set to the open position and breaking the electrical connection between the new conductor and the original B phase conductor.
(22) FIG. **21** is a schematic diagram illustrating the power transfer system of FIG. **20** showing the second transfer bus disconnected from the breaker and removed from the power transfer system.
(23) FIG. **22** is a schematic diagram illustrating the power transfer system of FIG. **21** showing the first transfer bus disconnected from the breaker and removed from the power transfer system.
(24) FIG. **23** is a schematic diagram illustrating the power transfer system of FIG. **22** showing new conductor installed between dead end structures on the original B phase conductor line.
(25) FIG. **24** is a schematic diagram illustrating the power transfer system of FIG. **23** showing a first and second temporary transfer bus installed between the C phase conductor and the new D phase conductor wherein the two temporary transfer buses are each connected to an open breaker.
(26) FIG. **25** is a schematic diagram illustrating the power transfer system of FIG. **24** showing the new conductor connected in parallel to the C phase conductor across two transfer buses that are each connected to a closed breaker.
(27) FIG. **26** is a schematic diagram illustrating the power transfer system of FIG. **25** showing two jumper cables each connecting the original C phase conductor to the new phase conductor across dead end junctures on the C phase conductor and dead end junctures located between the original B phase conductor and the new conductor and the jumper cables surrounding the two dead end junctures on the original C phase conductor removed.
(28) FIG. **27** is a schematic diagram illustrating the power transfer system of FIG. **26** showing the two breakers each connected to a temporary transfer bus set to an open position breaking parallel between the original C phase conductor and the new conductor.
(29) FIG. **28** is a schematic diagram illustrating the power transfer system of FIG. **27** showing new conductor installed between dead end structures on the original C phase line and the two temporary transfer buses removed from the power transfer system.
(30) FIG. **29** is a schematic diagram illustrating the power transfer system of FIG. **28** showing two temporary transfer buses each connected to a breaker set in the open position and installed between the new D phase conductor and the new C phase conductor.
(31) FIG. **30** is a schematic diagram illustrating the power transfer system of FIG. **29** showing the new D phase conductor connected in parallel to the new C phase conductor across two temporary transfer buses that are each connected to a closed breaker.
(32) FIG. **31** is a schematic diagram illustrating the power transfer system of FIG. **30** showing the removal of the two jumper cables illustrated in FIG. **30** each connecting the original C phase conductor to the new C phase conductor across dead end junctures and showing the installation of new jumper cables across the two dead end junctures on the new C phase conductor line.
(33) FIG. **32** is a schematic diagram illustrating the power transfer system of FIG. **31** showing each of the two breakers connected to the two temporary transfer buses set to an open position breaking parallel between the new C phase conductor and the D phase conductor.
(34) FIG. **33** is a schematic diagram illustrating the power transfer system of FIG. **32** showing two temporary transfer buses each connected to a breaker set in the open position and installed between the D phase conductor and the new B phase conductor.
(35) FIG. **34** is a schematic diagram illustrating the power transfer system of FIG. **33** showing the D phase conductor connected in parallel to the new B phase conductor across two temporary transfer buses that are each connected to a closed breaker.
(36) FIG. **35** is a schematic diagram illustrating the power transfer system of FIG. **34** showing the removal of the two jumper cables illustrated in FIG. **34** each connecting the original B phase

conductor to the new phase conductor across dead end junctures and showing the installation of new jumper cables across the two dead end junctures on the new B phase conductor line.
(37) FIG. **36** is a schematic diagram illustrating the power transfer system of FIG. **35** showing each of the two breakers connected to the two temporary transfer buses set to an open position breaking parallel between the new B phase conductor and the D phase conductor.
(38) FIG. **37** is a schematic diagram illustrating the power transfer system of FIG. **36** showing two temporary transfer buses each connected to a breaker set in the open position and installed between the D phase conductor and the original A phase conductor located in a temporary position.
(39) FIG. **38** is a schematic diagram illustrating the power transfer system of FIG. **37** showing the D phase conductor connected in parallel to the original A phase conductor across two temporary transfer buses that are each connected to a closed breaker.
(40) FIG. **39** is a schematic diagram illustrating the power transfer system of FIG. **38** showing the removal of the two jumper cables illustrated in FIG. **38** each connecting the original A phase conductor to the temporarily relocated section of A phase conductor across dead end junctures and showing the installation of new jumper cables across the two dead end junctures on the new A phase conductor line.
(41) FIG. **40** is a schematic diagram illustrating the power transfer system of FIG. **39** showing each of the two breakers connected to the two temporary transfer buses set to an open position breaking parallel between the new A phase conductor and the original A phase conductor.
(42) FIG. **41** is a schematic diagram illustrating the power transfer system of FIG. **40** showing the removal of the two temporary transfer buses and the two breakers from the power transfer system.
(43) FIG. **42** is a schematic diagram illustrating the power transfer system of FIG. **41** showing the removal of the de-energized original A phase conductor from the power transfer system.
(44) FIG. **43** is a side view of a temporary transfer bus suspended from two tangent insulators each supported on a phase conductor and connected to a closed breaker with jumper cables.
(45) FIG. **44** is a top view of an air break switch in a closed position.
(46) FIG. **45** is a top view of an air break switch in an opened position.
(47) FIG. **46** is a side view of a portable breaker in accordance with one embodiment of the invention.
(48) FIG. **47** is a side view of a support structure for a power transfer system showing a temporary support structure attached to a permanent support structure and insulators configured to carry double conductors (two conductors per phase).
(49) FIG. **48** is a side view of a temporary transfer bus suspended from two tangent insulators each supported on a phase conductor and the two rigid conductors of the transfer bus electrically connected to each other by a jumper cable.
(50) FIG. **49** is a front elevation view of a support structure for a power transfer system showing three adjacent phases A, B and C.
(51) FIG. **50** depicts the addition of a temporary support structure, a transfer of the C phase conductor to the temporary support structure and the stringing of a first replacement conductor where the C phase was moved from.
(52) FIG. **51** depicts the transfer of the electrical load from the B phase to the first replacement conductor (D phase) and the stringing of a second replacement conductor where the B phase was located.
(53) FIG. **52** depicts the transfer of the electrical load from the A phase to the second replacement conductor (the new conductor strung in FIG. **51**) and the stringing of a third replacement conductor where the A phase was located.
(54) FIG. **53** depicts the transfer of the electrical load from the second replacement conductor to the third replacement conductor.
(55) FIG. **54** depicts the transfer of the electrical load from the first replacement conductor to the second replacement conductor.

(56) FIG. **55** depicts the transfer of the electrical load from the C phase conductor to the first replacement conductor.

(57) FIG. **56** depicts the three replacement conductors each carrying the three phases A, B and C in the ordered sequence of FIG. **49**, the temporary support structure and the original C phase having been removed.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

(58) The invention will now be described with reference to the Figures, in which like reference numerals refer to like parts throughout. An embodiment in accordance with one aspect of the present invention provides an improved method for replacing high-voltage power transmission conductors without affecting power users or power suppliers. The method avoids a requirement of having the power transmitted by the conductors shut off or diverted to other remote power transmissions systems. The method also avoids an illegal transposition of the phase conductors when transferring the power loads from a phase conductor to a proximate phase conductor during the maintenance or repair work, which illegal transposition may otherwise lead to faults in the transmission line.

(59) As stated above, power delivery systems such as high voltage power lines often transport Alternating Current ("AC") power in a three phase configuration. Direct Current ("DC") power systems transfer power over two phases. Each phase is transferred over a separate conductor. For the purposes of this specification, each of the letters A, B, and C will represent one of three phases of a three-phase AC system. The methods and apparatus described herein can be adapted for use in a DC system by applying the methods and apparatus described herein for the A and B phases for the two phases of a DC system and where reference is made, for example in the claims, to the A, B and C phases, such references are intended to include merely the A and B phases for a DC implementation. Systems carrying voltages of 44 kV or higher are contemplated in the embodiments of the present invention.

(60) In addition, throughout this specification there is often reference to a fourth phase conductor, referred to as the "D phase" conductor. The D phase conductor, as that term is used in this specification, denotes a section of a phase conductor that is not electrically connected to any of the phase conductors that are carrying the A, B or C phases. In other words, the D phase is not carrying the current of any of the A, B, or C phases. Throughout the Figures illustrating examples of embodiments of the present invention, a phase conductor labelled as the "D phase" conductor in one figure may be labelled as an A, B or C phase conductor in the next Figure, where the "D phase" conductor becomes electrically connected to another phase conductor carrying the A, B or C phase current. For example, see FIGS. **12** and **13**, wherein the "D phase" conductor **114** in FIG. **12** becomes a "B phase" conductor **114** in FIG. **13**, upon establishing an electrical connection between the conductor **114** and the original B phase conductor **102** (B) when the breaker **142** connected to the second transfer bus **118**″ is closed. In each Figure of this specification, a phase conductor is either labelled "D phase", when it is electrically isolated from any other phase conductors in the power transfer system **100**, or it is labelled "A phase", "B phase" or "C phase" when the phase conductor is carrying the A, B or C phase current, or is otherwise electrically connected to a phase conductor that carries either the A, B or C phase current.

(61) In an embodiment of the invention, a section of a first conductor located between two dead end junctures is moved to a temporary position on temporary support structures. The dead end junctures of the section of the first conductor are also transferred to the temporary positions on the temporary support structures. A new conductor is then strung in or near the old conductor's originating position, and the power load from a first proximate phase-needing-maintenance is transferred to the new conductor. Once the power load from the first proximate phase-needing-maintenance is transferred to the new conductor, a section of the old conductor of the first proximate phase-needing-maintenance is removed and replaced with a second new conductor. Once the second new conductor is in place, the power load of a second proximate phase-needing-

maintenance is transferred to the second new conductor, enabling work to be conducted on a section of the second proximate phase-needing-maintenance conductor. This procedure is repeated until all of the proximate phase conductors requiring maintenance work have had their power loads transferred to other phase conductors. Once all of the maintenance work is complete, the power loads of each phase are consecutively transferred to the phase conductors strung into the positions where each phase was originally carried. This procedure provides for maintenance work to be conducted on high voltage transmission lines, without having to interrupt the supply of power to users and avoiding the illegal transposition of the respective phase conductors during the transfer of the power load from one phase conductor to an adjacent phase conductor.
(62) FIGS. **1** through **43** generally show, in schematic diagrams, a power transfer system **100** undergoing consecutive stages of a method in accordance with an embodiment of the invention, so that a section of a phase conductor to be worked on may be electrically isolated from the system power. As used herein, the term “maintenance work” includes the replacement of the phase conductor, and may also include maintenance of the conductor, replacement of insulators, resagging of the conductor, all without disrupting the transmission of power to downstream power customers.
(63) In many instances there may be miles between dead end junctures. If the distance between the dead end junctures for a particular section of phase conductor to be worked upon is too great for pulling new conductors through the system **100**, then new or temporary dead end junctures may be constructed as described later herein.
(64) The temporary relocation of a phase conductor, the stringing of new phase conductor in a position at or near the originating position of the phase conductor, and the process of successively transferring the power load from an adjacent phase to the new conductor such that the next phase may be isolated and worked upon, will now be described with reference to FIGS. **1-43**.
(65) FIG. **1** is a schematic diagram for power transfer system **100**. The power transfer system **100** includes three conductors **102**, labeled A phase, B phase and C phase, indicating that each of the conductors **102** carries one of the A, B, or C phase load. The system **100** transfers power in the form of AC, although this is not intended to be limiting as the method described herein may be used for DC power systems. The conductors **102** are supported by support structures **104**. Each support structure **104** may include or be in the form of a power pole or a tower. One example of a support structure **104**, not intended to be limiting, is seen in FIG. **2**. Other support structures are seen in FIGS. 53, 55 and 56 of the '132 patent. A conductor **102** is attached to dead end support structures **103** via insulators in tension **106** (hereinafter insulators **106**). As seen in FIG. **1**, dead end junctures **110′**, **110″** are formed by a pair of insulators **106** when in-line with conductors **102** and under tension with conductors **102**. Jumper cables **108**, as shown in FIG. **1**, electrically connect conductors **102** around insulators **106** and dead end support structures **103** to an oppositely disposed section of conductors **102**.
(66) Another way conductor **102** may be supported by support structure **104** is shown for example in FIG. **2**. The conductor **102** hangs from tangent insulator **116**. Tangent insulator **116** is supporting both the conductor tension and the weight of conductor **102**. When the weight of conductor **102** is being supported by tangent insulator **116**, jumper cables **108** are not required.
(67) In some embodiments of the present invention, a temporary support structure (otherwise referred to as an auxiliary support) **112** is constructed near the location of an existing support structure **104**, as shown in FIGS. **2** and **3**. The temporary support structure **112** is preferably located near or adjacent the location of an existing support structure **104**, whereby the distance L between the original location **95** and the temporary location **96** of the A phase conductor **102** is substantially equivalent to the phase spacing J between phases A and B and between phases B and C, when those phase conductors, **102** (A), **102** (B) and **102** (C) respectively, are suspended on the existing support structure **104**. The temporary support structure **112** may be located adjacent the existing support structure **104**, or in the alternative the temporary support structure **112** may be connected to the

support structure **104** as shown in FIG. 54 in the '132 patent, for example.

(68) Once the temporary support structures **112** are in place, a section **87** of the A phase conductor **102** (A) located between dead end junctures **110**′ and **110**″ is removed from the original location **95** on the existing support structures **104** and transferred to the temporary position **96** on the temporary support structure **112**. FIG. **4** shows the transfer of the A phase conductor **102** (A) from its original location **95** on support structure **104** to the temporary location **96** on temporary support structure **112**, using a robotic mechanical arm device **101**, such as the Remote Manipulator for Manipulating Multiple Sub-conductors in a Single Phase Bundle described in the Applicant's U.S. Pat. No. 8,573,562, or similar robotic mechanical arm device adapted to manipulate heavy energized conductors such as the A phase conductor **102** (A).

(69) As seen in FIG. **5**, although there are only two temporary support structures **112**, it will be appreciated by a person ordinarily skilled in the art that a section of phase conductor **102** to be replaced may be supported by numerous support structures **104** and that more than two temporary support structures **112** may be required to support the section of the phase conductor **102** that needs to be transferred to a temporary location **96**. Furthermore, it will be appreciated by a person skilled in the art that a section of a different phase conductor, such as a section of the C phase conductor **102** (C) illustrated in FIG. **3**, may alternatively be moved to a temporary position **96** adjacent the originating position **95** of conductor **102** (C) in accordance with the procedure described above with respect to conductor **102** (A) and that such procedure would be within the scope of the present invention described herein.

(70) As illustrated in FIGS. **6** and **7**, once the section **87** of phase conductor **102** (A) that is the subject of maintenance work has been moved to temporary support structures **112**, each of the dead end junctures **110**′, **110**″ at either end of the section **87** of phase conductor **102** (A) are transferred to temporary dead end poles (otherwise referred to as auxiliary dead end supports) **113**′, **113**″. It will be readily understood by a person ordinarily skilled in the art, having read this specification, that although two temporary support structures **112**, **112** are illustrated in FIG. **7**, that it is possible to carry out the procedure described herein utilizing a single temporary support structure **112**, or otherwise to utilize more than two temporary support structures **112**, to support a section **87** of phase conductor **102** (A).

(71) The section **87** of conductor **102** (A) is mounted to the temporary dead end pole **113**′, **113**″ while the jumper cable **108** remains attached to the phase conductor **102** (A), such that the power load on the phase conductor **102** (A) continues to be transferred around the dead end juncture **110**′, **110**″ by the jumper cables **108** while the section **87** of phase conductor **102** (A) is being relocated. FIG. **8** shows a first new phase conductor **114** (also referred to as the D phase) strung into the original location **95** of the A phase conductor **102** (A). The first new phase conductor **114** becomes the D phase conductor, as the new phase conductor **114**, with the exception of any induced current caused by the surrounding current-carrying phases, initially does not carry any power load after being strung into place.

(72) In many of the schematic diagrams of this patent specification, beginning with FIG. **8**, an ellipse or a circle is sometimes used to highlight a feature illustrated in the schematic diagram that has been added or which has changed from the immediately preceding Figure. For example, FIG. **8** shows an ellipse around the new phase conductor **114** strung into the original location **95** of the A phase conductor **102** (A), which is a new feature not illustrated in the immediately preceding FIG. **7**. It is understood that such ellipses and circles are merely included to clearly illustrate the changes that occur in the sequential steps of a preferred embodiment of the present method invention described herein, and are not themselves representing features of the power transfer system **100**.

(73) Once the new phase conductor **114** is in place, the power load is transferred from an adjacent phase conductor **102** to the new D phase conductor **114**. In the example illustrated in FIGS. **9-20**, the B phase load in conductor **102** (B) will be transferred to the D phase conductor **114**. One way to accomplish the power transfer is with a temporary transfer bus **118**′, **118**″.

(74) FIG. **43** shows a preferred embodiment of a temporary transfer bus **118** constructed of substantially rigid conductors **120**, **120**, an insulator **94** located between the two conductors **120**, **120**, arranged in a substantially co-linear relationship with respect to the conductors **120**, **120**, bus clamps **123**, **123** and a plurality of connectors **121** for temporarily attaching a jumper cable **108** or other conductor to one of the conductors **120** of the transfer bus **118**. Each of the conductors **120** of the transfer bus **118** are attached to a tangent insulator **116** by means of a bus clamp **123**. Each tangent insulator **116** is suspended from either an existing phase conductor **102** or a new phase conductor **114**. Once the temporary transfer bus **118** is in place, there is no electrical connection between the rigid conductors **120** of the transfer bus **118** due to the intervening transfer bus insulator **94**. An electrical connection may be established across the insulator **94** of the transfer bus **118** by means of a jumper cable **108** attached to one or more of a plurality of connectors **121** located on each of the rigid conductors **120**. Optionally, and as further discussed below and illustrated in FIG. **43**, the electrical connection across the insulator **94** of the transfer bus **118** may also be established by means of a switch **140** (illustrated in FIGS. **44** and **45**) or preferably, a breaker **142**, whereby jumper cables **148**, **150** are used to connect each of the first and second bushings, **144**, **146** of the breaker **142** to the first and second rigid conductors **120**, **120** respectively of the transfer bus **118**.

(75) As mentioned above, care must be taken when connecting or disconnecting an energized conductor from another conductor in high voltage applications such as the voltages associated with high voltage power lines, because when the conductors are near each other, either before connection or after the disconnection, a large potential will exist between the energized conductor and the non-energized conductor. Due to the large electrical potential between the conductors, large arcs can form between the conductors if the difference in potential is high enough.

(76) Thus, there are three options for establishing and breaking an electrical connection between the rigid conductors **120** of the transfer bus **118** across the insulator **94**. First, live line equipment such as hot sticks may be used to physically connect each end of a jumper cable **108** to a conductor **120** of the transfer bus **118**, as illustrated in FIG. **48**. Second, a conductor including a switch **140** may be connected to each conductor **120** of the transfer bus **118**. The switch **140** will initially be set in the open position before the connection of the switch to each conductor **120** of the transfer bus **118** is made, and each conductor **120** of the transfer bus **118** may then be connected to a phase conductor **102** or new phase conductor **114** using jumper cables **134** (see FIGS. **9** and **9***a*) and hot sticks. Once each of the two conductors **120**, **120** of the transfer bus **118** are electrically connected to either the phase conductor **102** or phase conductor **114**, the switch **140** may be closed to establish the electrical connection between the two conductors **102**, **114**. Similarly, the third option of establishing an electrical connection between two conductors **120**, **120** across the insulator **94** of a transfer bus **118** is similar to the second option described above, except that a breaker **142** is used in place of the switch, as shown in FIG. **43**, and will not be repeated here.

(77) Which method to use, the hot sticks and jumper cable, the switch or the breaker depends on several factors. Two factors to consider are the electrical potential between the conductors to be connected and the mass of the non-energized conductor that is to be connected to the energized conductor across the transfer bus **118**. If the mass of the conductor to be connected and/or the voltage potential is relatively minor, the two conductors may be connected across the transfer bus by a jumper cable **108** using hot sticks. As the mass of the conductor to be connected to the energized conductor increases and/or the voltage difference between the two conductors increases, a switch may be used to establish the electrical connection across the insulator **94** of the transfer bus **118**; finally, with conductors having a large mass and/or a large voltage potential between the conductors, a breaker **142** is used to establish the connection across the insulator **94** of the transfer bus **118**. In the preferred embodiment of the method described below, which is not intended to be limiting in any way, the electrical connection is established across the insulator **106** of the transfer bus **118** by means of a breaker **142**; however, it will be well understood by a person ordinarily

skilled in the art that the electrical connection may also be established across the insulator **94** of the transfer bus **118** by means of a switch **140** or by means of a length of a conductor, such as for example a jumper cable **108**, depending on factors which include the electrical potential and the mass of the non-energized conductor that is to be connected to an energized conductor, as described above.

(78) Once the D phase conductor **114** is in place, the power load is transferred from the conductor **102** (B) of the B phase line onto the D phase conductor **114** over the course of several steps. FIG. **9** shows that one rigid conductor **120** of a first transfer bus **118′** is electrically connected to the D phase conductor **114** by means of a jumper cable **134**. FIG. **10** shows one rigid conductor **120** of a second transfer bus **118″** is electrically connected to the D phase conductor **114** by means of a second jumper cable **134**. In FIGS. **9** and **10**, although it appears that the rigid conductors **120** of each of the transfer buses **118′**, **118″** that are opposite of the rigid conductors **120** connected to the D phase conductor **114** by means of the jumper cables **134**, **134** are in close proximity to the B phase conductor **102** (B), there is no physical or electrical connection between those rigid conductors **120** of the transfer buses **118′**, **118″** and the B phase conductor **102** (B), as the transfer buses **118**, **118** are positioned either above, or preferably, below the B phase conductor **102** (B).

(79) As illustrated in FIGS. **11** and **12**, once the breaker **142** of each transfer bus **118′**, **118″** is confirmed to be set in the open position, a jumper cable **134** is used to electrically connect a rigid conductor **120** of each transfer bus **118′**, **118″** to a section **90** of the B phase conductor **102** (B) located between two dead end junctures **110′**, **110″**. As illustrated in FIG. **12**, once the first rigid conductors **120** of each transfer bus **118′**, **118″** are each connected to the D phase conductor **114** and the second rigid conductors **120** of each transfer bus **118′**, **118″** are connected to the B phase conductor **102** (B), the breaker **142** on each transfer bus **118′**, **118″** remains in the open position and therefore the D phase conductor **114** remains de-energized.

(80) In FIG. **13**, the breaker **142** of transfer bus **118″** is closed, thereby establishing an electrical connection between the energized B phase conductor **102** (B) and the new phase conductor **114**, whereby the new phase conductor **114** is brought to the same voltage potential difference as the B phase conductor **102** (B). Because the new phase conductor **114** shown in FIG. **13** is connected to the B phase conductor **102** (B) at only one location, current is flowing only over the B phase conductor **102** (B) and not over the new phase conductor **114**. The new phase conductor **114** has the same electrical potential as the B phase conductor **102** (B), but the new phase conductor **114** does not yet transport a power load.

(81) In order for current to flow through the new phase conductor **114**, the breaker **142** of the transfer bus **118′** must be closed, as shown in FIG. **14**. Once the breakers **142**, **142** on each of the transfer buses **118′**, **118″** are closed, a parallel path is created for the B phase current to run through both the new phase conductor **114** and the original B phase conductor **102** (B).

(82) As illustrated in FIG. **15**, at one of the dead end juncture **110′** on opposite ends of section **90** of the original B phase conductor **102** (B), one end of a long jumper cable **111** is connected to a section **91** of the original B phase conductor **102** (B) that is oppositely disposed on dead end juncture **110′**, and the other end of the long jumper cable **111** is connected to the new phase conductor **114**, creating a parallel connection for the B phase current to flow around the dead end juncture **110′**. As shown in FIG. **16**, jumper cables **108**, **108** are removed from around one dead end juncture **110′** on the B phase conductor **102** (B). The removal of the jumper cables **108**, **108** can, if the voltage and/or the mass of the conductor **102** (B) is low enough, be removed by using hot sticks. If the voltage and/or mass of the conductor **102** (B) are too high, other means of breaking the connection around the dead end juncture **110′** may be used which may include a switch or breaker described in greater detail above.

(83) As shown in FIG. **17**, at the second dead end juncture **110″** on the opposite end of the section **90** of the original B phase conductor **102** (B), one end of a long jumper cable **111** is connected to a section (or otherwise referred to as a “segment”) **92** of the B phase conductor **102** (B) that is

oppositely disposed of dead end juncture **110″**, and the other end of the long jumper cable **111** is connected to the new phase conductor **114**, creating a parallel connection for the B phase current to flow around the second dead end juncture **110″**. As shown in FIG. **18**, jumper cables **108**, **108** are removed from around the second dead end juncture **110″** of the original B phase conductor **102** (B).

(84) In FIG. **19**, the breaker **142** of transfer bus **118′** is opened. The effect of opening one breaker **142** is that the current no longer flows through the section **90** of the original B phase conductor located between the dead end junctures **110′**, **110″**. All of the B phase current now flows through the new conductor **114** rather than the original B phase conductor **102** (B). However, because the breaker **142** of the other transfer bus **118″** remains closed, an electrical connection still exists between the original B phase conductor **102** (B) and the new conductor **114** at one point; therefore, the electrical potential between the original B phase conductor **102** (B) and the new phase conductor **114** remains the same.

(85) To electrically isolate the section **90** of the original B phase conductor **102**, the breaker **142** of the second transfer bus **118″** is opened, as shown in FIG. **20**. In other embodiments of the present invention, if the voltage and/or the mass of the original B phase conductor **102** is low enough, either a switch or a jumper cable may be substituted for the breaker **142** to establish and break the electrical connection between the rigid conductors **120**, **120** of the transfer bus **118″**. Upon opening the second transfer bus **118″**, section **90** of the original B phase conductor becomes electrically isolated from the system (except for currents which may be induced in section **90** of phase conductor **102** due to the electromagnetic effects of the surrounding current-carrying phase conductors), and the original B phase conductor therefore becomes the D phase conductor, as it no longer carries the B phase current or any phase current of the power transfer system **100**.

(86) One of the jumper cables **134** connecting a first end of the transfer bus **118″** to the new B phase conductor **114** is removed, de-energizing the open breaker **142**. The second jumper cable **134** connecting a second end of the transfer bus **118″** to the original B phase conductor **102** (which is now de-energized and therefore has become the D phase conductor **102**) is also removed, and the temporary transfer bus **118″** is then removed from the power transfer system **100**, as illustrated in FIG. **21**. Similarly, the two jumper cables **134**, **134** connecting the transfer bus **118′** at the first end to the new B phase conductor **114** and at the second end to the D phase conductor **102** are removed, and then the transfer bus **118′** is removed from the power transfer system **100**, as shown in FIG. **22**.

(87) The section **90** of the D phase conductor **102** between the dead end junctures **110′**, **110″** is now isolated from all B phase potential by both dead end junctures **110′**, **110″**. All current formerly carried by the D phase conductor **102** now travels through the new B phase conductor **114**. It is important to note that section **90** of the D phase conductor **102**, now isolated from the system **100** power load, is not void of potential. The isolated section **90** of the D phase conductor **102** is, and should be treated as, a live conductor, because the isolated section **90** of the D phase conductor **102** is subject to induced currents caused by the surrounding current-carrying phase conductors **102**, **114** and may still have a large potential with respect to ground.

(88) At this stage in the procedure, the isolated section **90** of the original B phase conductor may be broken down, worked on, or replaced without disrupting downstream power delivery. For example, as illustrated in FIG. **23**, the section **90** of the original B phase conductor **102** is removed and a second new phase conductor **115** is strung, sagged, dead ended and clipped into the position of the original B phase conductor **102**. In some embodiments of the invention, the original B phase line **102** is not removed but is rather worked on in other ways, such as replacing an insulator **106**. One skilled in the art can appreciate that other types of work may be done on the isolated section **90** of the B phase conductor **102** in accordance with the invention.

(89) The above describes the procedure, illustrated in FIGS. **1-23**, for moving the A phase conductor **102** (A) to a temporary location **96**, stringing a first new phase conductor **114** in or near the original location **95** of the A phase conductor **102** (A), transferring the power load from the B phase conductor **102** (B) to the D phase conductor **114**, electrically isolating the section **90** of the B

phase conductor **102** (B) located between two dead end junctures **110′**, **110″** from the power transfer system **100**, and replacing the electrically isolated section **90** of the B phase conductor **102** with a second new phase conductor **115**. The procedure for transferring the power load from the C phase conductor **102** (C) to the new D phase conductor **115** in accordance with the invention, described below and illustrated in FIGS. **24-28**, is similar to the procedure for transferring the power load from the B phase conductor **102** (B) to the new phase conductor **114** described above.
(90) As shown in FIG. **24**, a section **97** of the C phase conductor **102** (C), located between two dead end junctures **110′**, **110″** requires replacement or other maintenance or repair work. A first transfer bus **118′**, with a breaker **142** connected to each of the two rigid conductors **120** of the transfer bus **118**, is connected at one end to the D phase conductor **115** with a jumper cable **134**, and the opposite end of the first transfer bus **118′** is connected to the section **97** of the C phase conductor **102** (C) with a second jumper cable **134**. A second transfer bus **118″** with a breaker **142** connected to each of the two rigid conductors **120** of the transfer bus **118″**, is connected at one end to the D phase conductor **115** with a third jumper cable **134**, and the opposite end of the second transfer bus **118″** is connected to the section **97** of the C phase conductor **102** (C) with a fourth jumper cable **134**. The electrical connections described above between the transfer buses **118′**, **118″** and the phase conductors **115**, **102** (C) are established after first checking to confirm that the breaker **142** attached to each transfer bus **118′**, **118″** is open.
(91) The breaker **142** attached to the first transfer bus **118′** is closed, thereby energizing the new phase conductor **115** at the same electrical potential as the C phase conductor **102** (C). However, because an electrical connection between the new D phase conductor **115** and the C phase conductor **102** (C) has only been established through the first transfer bus **118′**, although the new phase conductor **115** is energized it does not carry any current. The breaker **142** attached to the second transfer bus **118″** is then closed, bringing the new phase conductor **115** in parallel with the C phase conductor **102** (C). Upon closing the breakers **142**, **142** on each of the transfer buses **118′**, **118″**, the C phase current runs in parallel on both the new phase conductor **115** and the C phase conductor **102** (C), as illustrated in FIG. **25**.
(92) Once the C phase current is carried in parallel over the new phase conductor **115** and the original C phase conductor **102** (C), the section **97** of the original C phase conductor **102** (C) located between two dead end junctures **110′**, **110″** is electrically isolated from the power transfer system **100**. As shown in FIG. **26**, at the first dead end juncture **110′** a first long jumper cable **111** is connected at a first end to a first section **98** of the original C phase conductor **102** (C) extending from the first dead end juncture **110′** oppositely to section **97**, and a second end of the first long jumper cable **111** is connected to the new phase conductor **115**, establishing a parallel path around the first dead end juncture **110′** for the C phase current to flow. Similarly, at the second dead end juncture **110″** a second long jumper cable **111** is connected at a first end to a second section **99** of the original C phase conductor **102** (C) extending from the second dead end juncture **110″** oppositely to section **97**, and a second end of the second long jumper cable **111** is connected to the new phase conductor **115**, establishing a parallel path around the second dead end juncture **110″** for the C phase current.
(93) The breaker **142** connected to the first transfer bus **118′** is opened, breaking the parallel circuit between the original C phase conductor **102** and the new phase conductor **115**. However, the section **97** of the original C phase conductor **102** remains at the same electrical potential as the new phase conductor **115** until the breaker **142** connected to the second transfer bus **118″** is opened, as illustrated in FIG. **27**. When each of the breakers **142**, **142** connected to the transfer buses **118′**, **118″** are open, the section **97** of the original C phase conductor **102** is electrically isolated from the new C phase conductor **115** and becomes the D phase conductor. Although the D phase conductor **102** is de-energized at this stage of the reconductoring or maintenance procedure, it is again important to note that section **97** of the original C phase conductor **102**, while isolated from the system **100** power load, is not void of potential. The isolated section **97** of the original C phase

conductor **102** is, and should be treated as, a live conductor, because the isolated section **97** of the original C phase conductor **102** is subject to induced currents caused by the surrounding current-carrying phase conductors **102** (C), **115**, **114** and may still have a large potential with respect to ground.

(94) The isolated section **97** of the original C phase conductor **102** may be broken down, worked on, or replaced without disrupting downstream power delivery. For example, as illustrated in FIG. **28**, the two transfer buses **118′**, **118″** are removed, section **97** of the original C phase conductor **102** is removed, and a third new phase conductor **117** is strung, sagged, dead ended and clipped into the position of the original C phase conductor **102**. In some embodiments of the invention, the original C phase line **102** is not removed but is rather worked on in other ways, such as replacing an insulator **106**. One skilled in the art will appreciate that other types of work may be done on the isolated section **97** of the phase conductor **102** within the scope of the invention.

(95) Once the reconductoring, maintenance and/or repair work is completed on the sections of the A, B and C phase conductors located between the dead end junctures **110′**, **110″**, the power load may be transferred to conductors located in the originating positions of the A, B and C phase conductors, as described below and illustrated in FIGS. **29-42**.

(96) As illustrated in FIG. **29**, a first transfer bus **118′** attached to an open breaker **142** is connected at a first end of the transfer bus **118′** to the new D phase conductor **117** using a jumper cable **134**, and a second end of the transfer bus **118′** is connected to the new phase conductor **115** using a second jumper cable **134**. A second transfer bus **118″** attached to an open breaker **142** is connected at a first end of the transfer bus **118″** to the new D phase conductor **117** using a third jumper cable **134**, and a second end of the second transfer bus **118″** is connected to the C phase conductor **115** using a fourth jumper cable **134**.

(97) As illustrated in FIG. **30**, the breaker **142** attached to the first transfer bus **118′** is then closed, thereby energizing the new D phase conductor **117** and bringing the new D phase conductor **117** to the same electrical potential as the C phase conductor **115**. The breaker **142** attached to the second transfer bus **118″** is closed, thereby bringing the new D phase conductor **117** into parallel with the C phase conductor **115**, whereby the C phase current flows through both the C phase conductor **115** and the D phase conductor **117**, as shown in FIG. **30**.

(98) Next, as illustrated in FIG. **31**, two jumper cables **108**, **108** are used to connect the section **98** of the original C phase conductor **102** (C) opposite the new phase conductor **117** across the first dead end juncture **110′** to the new phase conductor **117**. Two additional jumper cables **108**, **108** are used to connect the section **99** of the original C phase conductor **102** (C) opposite the new phase conductor **117** across the second dead end juncture **110″** to the new C phase conductor **117** across the second dead end juncture **110″**. Once the permanent jumper cables **108** are in place, the temporary long jumper cables **111**, **111** connecting each of the sections **98**, **99** of the original C phase conductor **102** to the C phase conductor **115** are removed. The connection of the jumper cables **108** and the disconnection of the temporary long jumper cables **111** is accomplished using live line equipment, such as hot sticks. Once this jumpering procedure is complete, whereby the new permanent jumper cables **108** are installed and the temporary long jumper cables **111** are removed, the C phase current continues to flow in parallel through both the new C phase conductor **117** and the phase conductor **115**, through the circuit path provided by the closed breakers **142** on the two temporary transfer buses **118′**, **118″** as shown in FIG. **31**.

(99) The breaker **142** connected to the first transfer bus **118′** is then opened, thereby breaking the parallel circuit between the new C phase conductor **117** and the phase conductor **115**. However, the phase conductor **115** remains energized and at the same electrical potential as the new C phase conductor **117**. The breaker **142** connected to the second transfer bus **118″** is then opened, thereby de-energizing the phase conductor **115**, which becomes the D phase conductor because the phase conductor **115** no longer carries the C phase current, or any phase current, as illustrated in FIG. **32**. At this stage, the two temporary transfer buses **118′**, **118″** may be removed from the power transfer

system **100**. Although the phase conductor **115** is de-energized and is not carrying current at this point in the reconductoring procedure, it must still be treated as a live conductor because the isolated D phase conductor **115** is subject to induced currents caused by the surrounding current-carrying phase conductors **114**, **117** and may still have a large potential with respect to ground.

(100) As illustrated in FIG. **33**, two temporary transfer buses **118**′, **118**″ connected to breakers **142**, **142** set in the open position are temporarily installed between the D phase conductor **115** and the B phase conductor **114**, by utilizing jumper cables **134** to firstly connect a first end of each transfer bus **118**′, **118**″ to the D phase conductor **115** near each of the dead end junctures **110**′, **110**″, and then secondly using jumper cables **134** to connect a second end of each transfer bus **118**′, **118**″ to the B phase conductor **114** near each of the dead end junctures **110**′, **110**″. Once the temporary transfer buses **118**′, **118**″ are installed with the breakers **142**, **142** remaining open, the B phase current continues to flow through the sections **91**, **92** of the original B phase conductor **102** (B) opposite of the D phase conductor **115** on opposing sides of the dead end junctures **110**′, **110**″ and through the B phase conductor **114**. As such, the B phase current continues to bypass the D phase conductor **115** while the breakers **142**, **142** remain open.

(101) The breaker **142** connected to the first temporary transfer bus **118**′ is closed, energizing the D phase conductor **115** and bringing the phase conductor **115** to the same electrical potential difference as the B phase conductor **114**. The breaker **142** connected to the second temporary transfer bus **118**″ is closed, thereby providing a parallel path for the B phase current to flow through both the phase conductors **114** and **115**, as illustrated in FIG. **34**. Once each of the two breakers **142**, **142** connected to the two transfer buses **118**′, **118**″ are closed, the B phase current flows through the section **91** of the original B phase conductor **102** (B) opposite the new phase conductor **115** across the first dead end juncture **110**′, through the long jumper cable **111** to the B phase conductor **114**, through the temporary transfer buses **118**′, **118**″ and the closed breakers **142**, **142** to the new B phase conductor **115**, and through the second long jumper cable **111** to the section **92** of the original B phase conductor **102** (B) located opposite the new phase conductor **115** across the second dead end juncture **110**″.

(102) As illustrated in FIG. **35**, two jumper cables **108**, **108** are used to connect the section **91** of the original B phase conductor **102** (B) opposite the new phase conductor **115** across the first dead end juncture **110**′ to the new B phase conductor **115**. Two additional jumper cables **108**, **108** are used to connect the section **92** of the original B phase conductor **102** (B) opposite the new phase conductor **115** across the second dead end juncture **110**″ to the new phase conductor **115**. Once the permanent jumper cables **108** are in place, the temporary long jumper cables **111**, **111** connecting each of the sections **91**, **92** of the original B phase conductor **102** (B) to the new B phase conductor **115** are removed. The connection of the jumper cables **108** and the disconnection of the temporary long jumper cables **111** is accomplished using live line equipment, such as hot sticks. Once this jumpering procedure is complete, whereby the new permanent jumper cables **108** are installed and the temporary long jumper cables **111**, **111** are removed, the B phase current continues to flow in parallel through both the new B phase conductor **115** and the B phase conductor **114**, through the path provided by the closed breakers **142**, **142** connected to each of the two temporary transfer buses **118**′, **118**″, shown in FIG. **35**.

(103) The breaker **142** connected to the first transfer bus **118**′ is then opened, thereby breaking the parallel circuit between the new B phase conductor **115** and the phase conductor **114**. However, the phase conductor **114** remains energized and at the same electrical potential as the new B phase conductor **115** once only one of the breakers **142** connected to the transfer buses **1181**, **118**″ has been opened. The breaker **142** connected to the second transfer bus **118**″ is then opened, thereby de-energizing the phase conductor **114**, which becomes the D phase conductor because the phase conductor **114** no longer carries the B phase current, as shown in FIG. **36**. At this stage, the two temporary transfer buses **118**′, **118**″ may be removed from the power transfer system **100**. Although the phase conductor **114** is de-energized and is not carrying current at this point in the

reconductoring procedure, it must still be treated as a live conductor because the electrically isolated phase conductor **114** is subject to induced currents caused by the surrounding current-carrying phase conductors **115**, **102** (A) and may still have a large potential with respect to ground.

(104) As illustrated in FIG. **37**, a first transfer bus **118′** connected to an open breaker **142** is connected at one end of the transfer bus **118′** to the D phase conductor **114** using a jumper cable **134**, and a second end of the first transfer bus **118′** is connected to the original A phase conductor **102** (A) using a second jumper cable **134**. A second transfer bus **118″** connected to an open breaker **142** is connected at a first end of the transfer bus **118″** to the D phase conductor **114** using a third jumper cable **134**, and a second end of the second transfer bus **118″** is connected to the original A phase conductor **102** (A) using a fourth jumper cable **134**.

(105) The breaker **142** connected to the first transfer bus **118′** is then closed, thereby energizing the D phase conductor **114** and bringing the D phase conductor **114** to the same electrical potential as the original A phase conductor **102** (A). The breaker **142** connected to the second transfer bus **118″** is closed, thereby bringing the new phase conductor **114** into parallel with the original A phase conductor **102** (A), whereby the A phase current flows through both the original A phase conductor **102** (A) and the new A phase conductor **114**, as shown in FIG. **38**.

(106) As illustrated in FIG. **39**, two jumper cables **108**, **108** are used to connect the section **88** of the original A phase conductor **102** (A) located opposite the new A phase conductor **114** across the first dead end juncture **110′** to the new A phase conductor **114**. Two additional jumper cables **108**, **108** are used to connect the section **89** of the original A phase conductor **102** (A) located opposite the new A phase conductor **114** across the second dead end juncture **110″** to the new A phase conductor **114**. Once the permanent jumper cables **108** are in place, the temporary long jumper cables **111**, **111** connecting each of the sections **88**, **89** of the original A phase conductor **102** (A) to the new A phase conductor **114** are removed. The connection of the jumper cables **108** and the disconnection of the temporary long jumper cables **111** is accomplished using live line equipment, such as hot sticks.

(107) Once this jumpering procedure is complete, whereby the new permanent jumper cables **108** are installed and the temporary long jumper cables **111** are removed, the A phase current continues to flow in parallel through both the new A phase conductor **114** and the original A phase conductor **102** (A), through the path provided by the closed breakers **142** connected to each of the two temporary transfer buses **118′**, **118″** as shown in FIG. **39**.

(108) The breaker **142** connected to the first transfer bus **118′** is then opened, thereby breaking the parallel circuit between the new A phase conductor **114** and the original A phase conductor **102** (A). However, the original A phase conductor **102** remains energized and at the same electrical potential as the new A phase conductor **114**. The breaker **142** connected to the second transfer bus **118″** is then opened, thereby de-energizing the original A phase conductor **102** (A), which becomes the D phase conductor because the original A phase conductor **102** (A) no longer carries the A phase current or any other current, as illustrated in FIG. **40**.

(109) At this stage, the two temporary transfer buses **118′**, **118″** and the breakers **142**, **142** connected to the transfer buses **118′**, **118″** may be removed from the power transfer system **100**, as illustrated in FIG. **41**. Although the original A phase conductor **102** (A), which is de-energized and is not carrying current at this point in the reconductoring procedure and has therefore become the D phase, it must still be treated as a live conductor because the electrically isolated phase conductor **102** is subject to induced currents caused by the surrounding current-carrying phase conductor **114** and may still have a large potential with respect to ground. As shown in FIG. **42**, the original A phase conductor **102** (A) may be removed from the temporary support structures **112**, **112**; optionally, the temporary support structures **112** may also be removed from the power transfer system **100**.

(110) As a person ordinarily skilled in the art will appreciate, the improved method for conducting repairs and maintenance on live conductors described herein provides the ability to replace,

maintain or repair one or more phase conductors without interrupting the supply of power to downstream customers by relocating a section of a phase conductor located between two dead end junctures to a temporary location, transferring the power load from a section of an adjacent conductor located between two dead end junctures to the temporarily relocated conductor, performing maintenance or repair work on the adjacent conductor, or in the alternative, replacing the adjacent conductor with a new conductor, and then repeating the steps of transferring power loads and conducting repair, maintenance or replacement on each adjacent conductor until all of the desired repair, maintenance or replacement work is complete.
(111) Importantly, this improved method described herein enables repair, maintenance or replacement work to be conducted on live conductors while avoiding the illegal transposition of the phase conductors throughout the entire procedure. Because of the effect of induced currents and impedance on a phase conductor caused by the close proximity of additional live phase conductors, it is possible that transposing one phase conductor with respect to the other phase conductors may result in an electrical surge in one or more of the phase conductors, which in turn may trip a protective relay and result in the disruption of power delivery to downstream customers.
(112) By way of illustrating an example of illegal transposition, consider three phase conductors carrying phases A, B and C that are arranged horizontally with respect to each other in the following order: A-B-C. In the method described herein, as illustrated in FIGS. **1-42**, the relative position of each of the phase conductors, “A-B-C”, remains the same at each step of the re-conductoring procedure. In other words, at no point during the procedure described herein does the relative positions of the A, B and C phase conductors change from the original A-B-C relative arrangement; that is, at no point in the example illustrated and described herein does the method result in transposition of the phase conductors to, for example, an A-C-B arrangement or a C-A-B arrangement or any other transposed arrangement.
(113) Furthermore, in the example of the procedure described herein and illustrated in FIGS. **1-42** (see in particular, FIGS. **4** and **5**), the A phase conductor **102** is relocated to temporary position **96** at a distance L from the originating position **95** of the A phase conductor **102**, wherein the distance L is substantially equal to the phase spacing distance J between C phase conductor **102** and B phase conductor **102**, and L is also substantially equal to the phase spacing distance J between B phase conductor **102** and the originating position **95** of the A phase conductor **102**. Temporarily relocating A phase conductor **102** to a temporary position **96** at a distance L from the originating position **95** that is substantially equal to the existing phase spacing J between the A, B and C phase conductors minimizes the induced current and resulting impact on the impedance on the phase conductors A, B and C that may otherwise occur if distance L was substantially shorter or longer than phase spacing J, and/or if the positions of any of the phase conductors A, B and C were to be transposed from their original A-B-C relative positioning at any point during the maintenance and repair work described herein.
(114) An example of a procedure for stringing a de-energized, new phase conductor into a transmission system, such as for example the D phase conductor **114** illustrated in FIG. **8**, involves connecting a traveler to a support structure, stringing a pull line (or pulling line) with at least one non-conductive end through the traveler, connecting the pull line via a swivel and a flexible isolator to the conductor, pulling the pull line through the traveler and thereby causing the conductor to be strung through the traveler, attaching the conductor to the support structure, removing the traveler from the support structure, and disconnecting the pull line from the conductor. It is known by a person ordinarily skilled in the art to use a di-electric tested section of rope installed between the pulling line and the new conductor being strung onto the support structure to provide the non-conductive end of the pull line. The Applicant recently filed U.S. application Ser. No. 14/664,724 filed on Mar. 20, 2015, entitled Flexible Electrical Isolation Device, the disclosure of which is incorporated herein in its entirety, describes a flexible elongated insulator having couplings mounted at either end of the insulator. This isolation device, otherwise referred to as a flexible

isolator or flexible insulator, consists of a flexible, bendable or otherwise deformable (herein collectively referred to as flexible) member to accommodate the bending radius of a traveler and is composed of a high tensile strength, dielectric material with attachment points, or couplings, on each end. The attachment points or couplings are constructed so as to control both rotation imparted by the cables and bi-directional shear induced when the couplings or attachment points pass through the conductive travelers.

(115) A switch **140** may be used in place of the breaker for lighter applications. Operation using the switch in place of a breaker is basically the same and will not be repeated. The switch **140** is a typical air break disconnect switch. It has a disconnect blade **141** that can be operated to a closed position (see FIG. **44**) and an open position (see FIG. **45**). The switch **140** has connectors **145** on each end that permits conductors **120**, **120** of the transfer bus **118** to be electrically connected to the switch **140**. When the disconnect blade **141** is in the closed position, it provides an electrical connection between the two conductors **120**, **120** via the switch **140**. When the disconnect blade **141** is in the open position, there is no electric connection between the two conductors **120**, **120**.

(116) The switch **140** has an actuator **143** that operates the disconnect blade **141**. The opening and closing of the switch is controlled by the actuator **143**. The switch **140** is supported on a frame **147** that provides mechanical support for the switch **140**. The frame **147** is insulated from the conductors by insulators **149**. According to some embodiments of the invention, the switch **140** may be mounted on temporary support structure or a lift apparatus, such as a boom of a vehicle or, for example, preferably a robotic mechanical arm device **101** adapted to manipulate heavy energized conductors such as the phase conductors **102** described in the Applicant's U.S. Pat. No. 8,573,562, for ease and convenience in practicing some embodiments of the invention.

(117) The breaker **142** shown schematically in FIGS. **9-40** and **43** will now be further illustrated and described with reference to FIG. **46**. In some embodiments of the invention, the breaker **142** is a single pole (phase) of a 345 kV breaker that has been modified to be portable. A typical breaker of this magnitude consists of three single pole breakers mechanically connected together to be a three phase breaker and break all three circuits at once. The three phase breaker includes three breakers connected together and configured to act in unison. Because only a single phase needs to be disconnected or energized at once in many embodiments of the invention, only one pole (or phase) of a breaker is needed. To make the breaker more portable, one pole is separated from the three phase unit and modified to be portable as described in more detail below.

(118) A breaker **142** in accordance with the invention may be, as an example not intending to be limiting, a 2,000 amp SF.sub.6 breaker wherein SF.sub.6 is an insulating gas that is used in the breaker **142**. In other embodiments of the invention, the breaker **142** could be a minimum oil breaker, or any other breaker suited to the applied voltage. The breaker **142** has two insulated bushings **144**, **146** projecting from a housing **156**. Jumpers **148**, **150** are attached to an end of the bushings **144**, **146** for connecting the breaker **142** to conductors.

(119) The breaker **142** has a closed position that permits an electrical connection from a conductor connected to one bushing **144** via jumper **148** through the breaker **142** to a conductor connected to the other bushing **146** via jumper **150**. When it is desired to break the electrical connection between the two conductors **120**, **120** of the transfer bus **118**, the breaker **142** is operated to achieve an open position. In the open position, the two jumpers **148**, **150** connected to the two bushings **144**, **146** are isolated from each other.

(120) Normally, a breaker **142** having the capacity for high voltage power is located in fixed locations, such as for example power generating faculties, terminals, switching stations or substations, and consists of three poles or phases. In accordance with the invention, a standard breaker **142**, such as a 345 kilovolt, 2,000 amp SF.sub.6 breaker, is used. Because these types of breakers have three poles or phases, a single pole or phase is separated out from the other two phases and is modified so as to be portable. As shown in FIG. **46**, the breaker **142** is mounted onto a trailer **158**. A support structure **160** mounts the breaker **142** to the trailer **158**. Optionally, the

breaker **142** could be mounted on a truck bed or some other suitable type of vehicle.
(121) The breaker **142** has a housing **156** from which two insulated bushings **144**, **146** project. One of the bushings **144** is located on what is referred to as the line side **162**, meaning that that bushing **144** connects to the conductor, for example phase conductor **102**, that is connected to a power source. The other side **164** of the breaker **142** is referred to as the load side **164** and includes the other bushing **146**. Within the housing **156** a non-conductive gas, SF.sub.6 for example, is used for electrical insulation. Other breakers in accordance with the invention may be oil-filled breakers or other types of breakers suitable for the applied voltage.
(122) A control panel **166** for operating the breaker **142** is located on the trailer **158** and operatively connected to the breaker **142**. Optionally, the control panel **166** may be the same one that would normally operate a standard non-portable breaker. A portable power generator **168** is located on the trailer **158** and is operatively connected to the breaker **142** and/or control panel **166** to provide power to operate the breaker **142**. The generator **168** may be gasoline powered and is of sufficient capacity to permit operation of the breaker **142**, including charging of the springs in the breaker **142**. Preferably, the generator **168** can produce 120 volts.
(123) Additional containers **170** of SF.sub.6 gas are kept on the trailer **158** in order to permit recharging of the breaker **142** with gas if necessary. The manufacturer's recommendations for gas pressure in the breaker **142** should be observed.
(124) The exact modifications necessary to make the breaker **142** portable will vary depending on the type of breaker is being modified. A person ordinarily skilled in the art after reviewing this disclosure will be able to appropriately fashion a portable breaker **142**.
(125) Before use of the breaker **142**, the tow vehicle is detached and the trailer **158** is held in place by jacks **172** and a wheel chocks **174**. The trailer **158** and the breaker **142** is bonded to ground with grounding cables **176**. A temporary protective fence **178** is constructed around the trailer **158**.
(126) FIGS. **49** to **56** depict a method of replacing energized high-voltage power transmission conductors while they remain energized.
(127) FIG. **49** is a front, elevation view of a schematic of a support structure **104** that is supporting three phases of conductors **102**A, **102**B and **102**C by insulators **116**. Each of the conductors **102**A, **102**B and **102**C carry an electrical load. The A phase conductor **102** A is positioned on the support structure **104** in a first conductor position **400**. The B phase conductor **102**B is positioned on the support structure **104** in a second conductor position **402**. The C phase conductor **102**C is positioned on the support structure **104** in a third conductor position **404**. The configuration of the support structure **104** depicted in FIGS. **49** to **56** and, in particular the first, second and third conductor positions **400**, **402**, **404** may be in different positions upon the support structure **104** and the positions depicted are not intended to be limiting. While the first, second and third conductor positions **400**, **402**, **404** are depicted as being in one single, horizontal plane, these positions can be in a single plane that is not horizontal, for example it may be substantially vertical or between a horizontal plane and a vertical plane or may not be in a single plane at all. The ordered sequence of the three phases of conductors **102**A, **102**B and **102**C is maintained with the conductor **102**A adjacent conductor **102**B but not adjacent conductor **102**C. Conductor **102**B is adjacent, or in between, both of conductor **102**A and conductor **102**C.
(128) FIG. **50** depicts a step of installing, providing, or using an existing temporary structure **112** along side the support structure **104**. In this example, the temporary structure **112** provides a fourth conductor position **406**. The C phase conductor **102**C is transferred in step **200** from the support structure **104** to the fourth conductor position **406** on the temporary structure **112**. A first replacement conductor **300** is strung in to the position on the support structure **104** where the C phase conductor **102**C was located, in other words at the third conductor position **404**.
(129) FIG. **51** depicts a transferring step **202** wherein the electrical load of the B phase conductor **102**B is transferred to the first replacement conductor **300** in the third conductor position **404**. The B phase conductor **102**B is replaced by a second replacement conductor **302**. At this step in this

method, the electrical load of the C phase conductor **102**C is carried through the C phase conductor **102**C, which is supported on the fourth conductor position **406** by the temporary structure **112**. The electrical load of the B phase conductor **102**B is carried through the first replacement conductor **300** in the third conductor position **404**.

(130) FIG. **52** depicts transferring step **204** wherein the electrical load of the A phase conductor **102**A is transferred to the second replacement conductor **302** in the second conductor position **402**. The A phase conductor **102**A is the replaced by a third replacement conductor **304**.

(131) FIG. **53** depicts transferring step **206** wherein the electrical load on the second replacement conductor **302** is transferred to the third replacement conductor **304**.

(132) FIG. **54** depicts transferring step **208** wherein the electrical load on the first replacement conductor **300** is transferred to the second replacement conductor **302**.

(133) FIG. **55** depicts transferring step **210** wherein the electrical load from the C phase conductor **102**C is transferred to the first replacement conductor **404**.

(134) During this method, the electrical load of the C phase is transferred from the third conductor position **404** to the fourth conductor position. The electrical load of the B phase is transferred from the second conductor position **402** to the third conductor position **404**. The electrical load of the A phase is transferred from the first conductor position **400** to the second conductor position **402**. Between each of these transfer steps, an old conductor is replaced with a new, replacement conductor wire. Then the steps are reversed with the electrical load of the A phase being transferred back to the first conductor position **400** from the second conductor position **402**, the electrical load of the B phase being transferred back to the second conductor position **402** from the third conductor position **404**, the electrical load of the C phase being transferred back to the third conductor position **404** from the fourth conductor position **406**. In this fashion illegal transpositions of the A, B and C phases are avoided while the electrical loads of the A, B and C phases are returned to their original conductor positions, now carried through new conductor lines **300**, **302**, **304**, as depicted in FIG. **56**.

(135) The various embodiments of the method of the invention described herein, temporarily relocating a phase conductor **102**, stringing a D phase conductor into place and using the D phase conductor to successively and in sequence transfer the electrical loads from proximate conductors, permits sections of new conductors, located between dead end junctures, to be strung one at a time. If it is desired to string new conductors along the entire length of a system **100**, or a length longer than practical for stringing conductors, then the re-conductoring methods are used for lengths that are practical and repeated along the length of the system until a desired length of new conductor is installed along the system.

(136) It is appreciated by one skilled in the art, that in some power transfer systems **100**, more than one conductor **102** carries the power load for a particular phase. This may be done in instances when a power load is greater than a single-phase conductor can accommodate. In such cases, multiple (bundled) phase conductors **102** are often located next to each other and may hang from the same insulator **116** as shown in FIG. **47**. The conductors may be separated by spacers **198**. Such bundle conductor systems **100** may be re-conductored in accordance with the invention by application of the procedures described herein to each conductor **102**.

(137) While the above disclosure describes certain examples of the present invention, various changes, adaptations and modifications of the described examples will also be apparent to those skilled in the art. The scope of the claims should not be limited by the examples provided above; rather, the scope of the claims should be given the broadest interpretation that is consistent with the disclosure as a whole.

Claims

1. A method for maintaining one or more sections of electrically conductive phases in a direct current (DC) two phase power system without interrupting power in either of the two phases, the two DC phases denoted as A and B phases, and wherein the two phases are parallel and are spaced apart, and wherein the A and B phases have corresponding A and B loads and at least one of the A and B phases has, of the one or more sections, a section needing maintenance, and the A and B phases are strung between two support structures supporting the two phases suspended above a ground, the method comprising steps of: (a) enabling a D phase located proximal to an existing one of the A and B phase needing maintenance by methods chosen from: providing a new D phase in the DC two phase power system adjacent the A phase when the A phase is the phase needing maintenance or de-energizing, the new D phase configured to be located proximal to the A phase needing maintenance, while the A and B phases are strung, so that the new D phase that is located proximal to the A phase needing maintenance becomes the D phase, and wherein the providing the new D phase includes: providing an auxiliary support structure substantially adjacent the two support structures and proximal the A phase, moving the section of the one or more sections of the A phase needing maintenance to the auxiliary support structure, stringing a new D phase section between the two support structures while removing the section of the one or more sections of the A phase needing maintenance from the DC two phases and treating the new D phase section to form an energized conductor, wherein the stringing of the new D phase section further comprising: providing a pulling line having at least one non-conductive end, connecting the at least one non-conductive end of the pulling line to a leading end of the new D phase section, providing first and second equal potential zones at opposite ends of a stringing path where along the new D phase section is to be strung, wherein the first and second equal potential zones are grounded, electrically connecting the pulling line to the first equal potential zone, electrically connecting the new D chase section to the second equal potential zone, electrician connecting pulling equipment at the first equal potential zone to the first equal potential zone and electrically connecting pay-out equipment at the second equal potential zone to the second equal potential zone, pulling the pulling line along the stringing path using the pulling and payout equipment so as to pull the pulling line into the first equal potential zone while paying-out the new D phase section along the stringing path from the second equal potential zone, (b) paralleling with and transferring a power load carried by the phase needing maintenance to the D phase by: (i) initiating transfer of the power load by establishing a parallel electrical connection between the phase needing maintenance and the D phase through a pair of jumpers extending in electrical connection between the phase needing maintenance and the D phase wherein the pair of jumpers do not cross over the other energized phase in the DC two phase power system; and (ii) completing transfer of the power load to the D phase by de-energizing the phase needing maintenance; and (c) maintaining the de-energized phase needing maintenance while maintaining its position relative to other phase in the DC two phase power system.
2. The method of claim 1, wherein a first lateral distance between the new D phase section and the section of the one or more sections of the A phase needing maintenance supported on the auxiliary support structure is substantially no less than a phase-to-phase lateral separation.
3. The method of claim 1, wherein the section of the one or more sections of the A phase needing maintenance strung on the auxiliary support structure is substantially parallel to the new D phase section strung between the two support structures.
4. The method of claim 1, wherein the at least one non-conductive end of the pulling line is a flexible electrical isolator.