SUMMARY OF THE INVENTION

A first aspect of ~~T~~the present invention provides a terminal connection device for connecting an end of a medium- or high-voltage power cable to a connection point, the terminal connection device comprising

a) an interface cable having first and second end portions, comprising an inner conductor and a conductive or semiconductive layer,

b) a first stress control tube comprising a stress control element, and an insulating layer arranged around the stress control element, wherein the first stress control tube is mounted on the first end portion of the interface cable;

c) a first cable connector for connecting the interface cable to the power cable, the first cable connector being connected to the second end portion of the interface cable;

d) a second stress control tube comprising a stress control element, and an insulating layer arranged around the stress control element, wherein the second stress control tube is mounted over the second end portion of the interface cable and at least a portion of the first cable connector;

e) one or more tubular shrinkable sleeves, at least a portion of one of the tubular shrinkable sleeves extending over at least a portion of the first stress control tube and at least a portion of one of the tubular shrinkable sleeves extending over at least a portion of the second stress control tube, wherein the portion of the tubular shrinkable sleeve extending over at least a portion of the first stress control tube is shrunk down around at least a portion of the first stress control tube.

The terminal connection device is effectively an integrated splice and termination with an interface cable between the two portions. Because of its integrated features, the terminal connection device allows for making a quick and straight-forward connection between a cut off power cable and a connection point in a confined space. The terminal connection device according to embodiments of the present invention facilitates easily connecting a power cable to the device and easily connecting the device to a connection point. In addition, its integrated features also may reduce the possibility of making mistakes during installation, which can potentially be an issue with a termination that has many individual elements that must be attached to the cable and/or connection point. The connection point may be on a piece of equipment such as a generator or transformer or may be a switchgear pole or bus bar. In particular, the terminal connection device is useful when an existing terminal device, which connects an installed power cable to a connection point, is

removed by cutting off the portion of the power cable on which the terminal device is installed. The remaining installed cable is then too short to reach the connection point. A suitable new terminal device must be installed. Because the terminal connection device according to embodiments of the present invention may use a section of commercially available cable for its interface cable, terminal connection devices according to embodiments of the present invention may be easily made in many different lengths and using different types of power cable without adding additional manufacturing costs and, therefore, can accommodate the needs for a variety of lengths and sizes and types of cable terminal devices.

In the terminal connection device according to embodiments of the present invention, a power cable can very easily be connected to the first cable connector. The first cable connector is fixedly connected and arranged within the terminal connection device. A power cable attached to a mating second cable connector can be easily connected to the first cable connector in that the mating second cable connector is inserted into portions of the second stress control tube and tubular sleeve that are held in an expanded state by support cores so as to make electrical connection with the first cable connector by simply plugging the second cable connector into the first cable connector, or *vice versa*. If an intermediate connector is used, the second cable connector can just as easily be plugged into the intermediate connector. Additionally, a rigid sleeve may be secured around the first cable connector and may extend sufficiently beyond the mating face of the first cable connector to cover the second cable connector once it is mated to the first cable connector. Accordingly, no portion of the terminal connection device needs a parking position or any free space on the power cable.

In a specific ~~aspect~~ embodiment of the invention, a portion of at least one of the tubular shrinkable sleeves is shrunk down around a portion of the interface cable.

In another ~~aspect~~embodiment, the tubular shrinkable sleeve extending over at least a portion of the second stress control tube comprises a portion adapted to be shrunk down around a portion of the power cable.

In a further ~~aspect~~embodiment, the first end portion of the interface cable is attached to a lug.

In a yet further ~~aspect~~embodiment, the stress control element of one or both of the first and second stress control tubes is a geometric stress control element or a capacitive stress control element.

In a particular ~~aspect~~ embodiment of the invention, the tubular shrinkable sleeve extending over at least a

portion of the first stress control tube comprises, on an outer side, one or more skirts for reducing tracking current.

In another ~~aspect~~embodiment, the interface cable further comprises an insulating layer arranged concentrically around at least an axial section of the inner conductor, and the terminal connection device comprises a capacitive voltage sensor including a printed circuit board element. The printed circuit board element may be placed over an electrically isolated piece of conductive or semiconductive material. The electrically isolated piece of conductive or semiconductive material may be arranged on the insulating layer of the interface cable and operable to form an electrode of a sensing capacitor for sensing a voltage of the inner conductor. The insulating layer may be operable to form a dielectric of the sensing capacitor.

In a further ~~aspect~~embodiment, the terminal connection device further comprises additional semiconductive material, arranged concentrically around at least an axial section of the insulating layer on either side of the electrically isolated piece of conductive or semiconductive material. The additional semiconductive material may comprise two semiconductive axial sections, electrically isolated from the electrically isolated piece of conductive or semiconductive material by non-conductive axial sections.

Some or all of the electrically isolated piece of conductive or semiconductive material or of the additional semiconductive material may be affixed adhesively to the insulating layer.

In a specific ~~aspect~~embodiment, the printed circuit board element comprises a patterned gold-plated copper layer in electrical contact with the electrically isolated piece of conductive or semiconductive material.

In another ~~aspect~~ embodiment of the invention, the electrically isolated piece of conductive or semiconductive material comprises a portion of the semiconductive layer of the interface cable.

A second aspect of ~~T~~the present invention ~~also~~ provides a method of connecting an end of a medium- or high-voltage power cable to a connection point, comprising the steps of

a) providing a terminal connection device as ~~described above~~defined in the first aspect;

b) providing a medium- or high-voltage power cable;

c) connecting the terminal connection device to the end of the power cable by connecting the interface cable to the end of the power cable via the first cable connector; and

d) connecting the terminal connection device to the connection point by connecting the first end portion of the interface cable to the connection point.

In at least one embodiment of the present invention, after the first cable connector is mated to the second cable connector, the second stress control tube is shrunk down around the mated connectors and a portion of the power cable, then the portion of a tubular sleeve extending over a portion of the second stress control tube is shrunk down over the second stress control tube and a portion of the power cable. Because the terminal connection device includes an integrated splice portion and a termination portion, it allows for easy connection to the power cable using the splice portion and easy connection to the connection point using the termination portion.

The first cable connector of the terminal connection device according to at least one embodiment of the invention may be configured as a socket or plug. To ensure that a socket-and-plug connection is capable of carrying high electric currents, the prior art offers various contact techniques as e.g. disclosed in EP-A-0 716 474, DE-A-38 13 001, and DE-A-29 39 600.

If an intermediate connector is used, it can be flexible, partially flexible or rigid. A flexible or partially flexible intermediate connector serves for a facilitated application of a power cable to be connected to the first cable connector. This is advantageous when using the preassembled terminal connection device in a narrow space.

The mechanical and electrical connection between the interface cable and the second cable and their respective connectors, which in turn are to be connected to each other, according to one embodiment of the present invention, is realized by crimping or fastening screws or similar fastening elements. Preferably, the fastening screws are configured as shearable screws. Examples of fastening elements suitable for the connection between a cable (or a stop end element) and a second cable connector are disclosed in WO-A-95/25229, WO-A-96/31706, EP-B-0 470 388, EP-B-0 688 960, EP-B-0 692 643, EP-A-0 769 825, EP-B-0 819 222, EP-B-0 984 176, and US-A-6 045 373.

Generally, both heat and cold shrinkable elements can be used for the pre-assembled terminal connection device according to embodiments of the invention. However, in order to avoid the application of heat for shrinking down the tubes and sleeves, cold shrinkable materials are preferred. These materials are generally known in the art, and preferably silicone or EPDM is used. In case of a cold shrinkable sleeve or tube, a portion of the sleeve or tube can be held in a radially expanded

It is normally necessary to use one tubular sleeve for a splice and one tubular sleeve for a termination. This can be done in the terminal connection device according to embodiments of the present invention in which separate tubular sleeves cover the splice and termination portions of the device. Alternatively, a single tubular sleeve may cover both the splice and termination portions of the device. If two separate tubular sleeves are used, they may overlap between the two portions, typically over a portion of the interface cable. It is also possible to arrange the two tubular sleeves so that they don't overlap. In this case, the outer insulative jacket typically needs to remain in the exposed portion of the interface cable or the interface cable needs to be insulated with a third tubular sleeve or some other type of insulating material. If the terminal connection device uses a particularly long piece of cable for the interface cable, it may be most efficient and economical to leave the insulating jacket on the interface cable.

In at least one embodiment of the present invention, the terminal connection device is pre-assembled in that the first cable connector and the interface cable are fixedly arranged in the stress control tubes and an outer tubular sleeve prior to the use of the terminal connection device for connecting to and terminating a power cable. Pre-assembling is advantageous in that it may make field assembly obsolete. Field assembly of a terminal connection device may be difficult, because the interface cable, which may be relatively short, needs to be stripped and prepared for mounting the stress control tubes and the first cable connector. Preparing the interface cable and mounting stress control tubes and the first cable connector on it in the field poses an increased risk of having dirt particles and air pockets entrapped between layers of the terminal connection device. These particles and air pockets may lead to partial discharges and potential damage to the terminal connection device.

In a further embodiment of the invention, one or more sensors may be integrated into the terminal connection device. Such sensors can be used to sense, measure, record and save or transmit information regarding the condition or operation of the power cable such as current, voltage, temperature, etc.. The sensor can be integrated in the terminal connection device according to embodiments of the invention during its construction. A preferred location for the integration of the sensor would be the area between the connector and termination sections or in the termination section. The sensor will typically include some type of information transmission system to transmit the information to an external information collecting and/or processing device. The transmission system may be any suitable system including hard wiring or a wireless transmission system. The sensor may be located on a layer of conductive or semiconductive material that is electrically isolated from the conductive or semiconductive layer of the interface cable. However,

CLAIMS

1. Terminal connection device for connecting an end of a medium- or high-voltage power cable (42) to a connection point, the terminal connection device (10) comprising

   a) an interface cable (12) having first and second end portions, comprising an inner conductor (14) and a conductive or semiconductive layer (18),

   b) a first stress control tube (36) comprising
   - a stress control element (38), and
   - an insulating layer (40) arranged around the stress control element (38),
   wherein the first stress control tube (36) is mounted on the first end portion of the interface cable (12);

   c) a first cable connector (24) for connecting the interface cable (12) to the power cable (42), the first cable connector (24) being connected to the second end portion of the interface cable (12);

   d) a second stress control tube (36') comprising
   - a stress control element (38), and
   - an insulating layer (40) arranged around the stress control element (38), wherein the second stress control tube (36') is mounted over the second end portion of the interface cable (12) and at least a portion of the first cable connector (24);

   e) one or more tubular shrinkable sleeves (52, 52', 52''),
   at least a portion of one of the tubular shrinkable sleeves (52, 52', 52'') extending over at least a portion of the first stress control tube (36), and at least a portion of one of the tubular shrinkable sleeves (52, 52', 52'') extending over at least a portion of the second stress control tube (36'),
   wherein the portion of the tubular shrinkable sleeve (52, 52'') extending over at least a portion of the first stress control tube (36) is shrunk down around at least a portion of the first stress control tube (36).

2. Terminal connection device according to claim 1, wherein the first cable connector (24) is adapted to be connected to the power cable (42) by engagement between the first cable connector (24) and a mating second cable connector (26) mounted on an end of the power

cable (42).

3. Terminal connection device according to claim 1 or claim 2, wherein a portion of at least one of the tubular shrinkable sleeves (52, 52', 52") is shrunk down around a portion of the interface cable (12).

4. Terminal connection device according to any one of the preceding claims, wherein the tubular shrinkable sleeve (52, 52') extending over at least a portion of the second stress control tube (36') comprises a portion adapted to be shrunk down around a portion of the power cable (42).

5. Terminal connection device according to any one of the preceding claims, wherein the first end portion of the interface cable (12) is attached to a lug (34).

6. Terminal connection device according to any one of the preceding claims, wherein the stress control element (38) of one or both of the first and second stress control tubes (36, 36') is a geometric stress control element or a dielectric stress control element.

7. Terminal connection device according to any one of the preceding claims, wherein the tubular shrinkable sleeve (52, 52") extending over at least a portion of the first stress control tube (36) comprises, on an outer side, one or more skirts (56) for reducing tracking current.

8. Terminal connection device according to any one of the preceding claims, wherein the interface cable (12) further comprises an insulating layer (40) arranged concentrically around at least an axial section of the inner conductor (14),
and wherein the terminal connection device (10) comprises a capacitive voltage sensor (102) including a printed circuit board element, the printed circuit board element placed over an electrically isolated piece of conductive or semiconductive material, the electrically isolated piece of conductive or semiconductive material arranged on the insulating layer (40) of the interface cable (12) and operable to form an electrode of a sensing capacitor for sensing a voltage of the inner conductor (14), and wherein the insulating layer (40) is operable to form a dielectric of the sensing capacitor.

9. Terminal connection device according to claim 8, wherein the terminal connection device (10) further comprises additional semiconductive material, arranged concentrically around at least an axial section of the insulating layer (40) on either side of the electrically isolated

piece of conductive or semiconductive material, the additional semiconductive material comprising two semiconductive axial sections, electrically isolated from the electrically isolated piece of conductive or semiconductive material by non-conductive axial sections (100).

10. Terminal connection device according to any one of claims 8 through 9, wherein some or all of the electrically isolated piece of conductive or semiconductive material or of the additional semiconductive material is affixed adhesively to the insulating layer (40).

11. Terminal connection device according to any one of claims 8 through 10 wherein the printed circuit board element comprises a patterned gold-plated copper layer in electrical contact with the electrically isolated piece of conductive or semiconductive material.

12. Terminal connection device according to any one of claims 8 through 11 wherein the electrically isolated piece of conductive or semiconductive material comprises a portion of the semiconductive layer (18) of the interface cable (12).

13. Method of connecting an end of a medium- or high-voltage power cable (42) to a connection point, comprising the steps of

a) providing a terminal connection device (10) according to any one of claims 1 through 12;

b) providing a medium- or high-voltage power cable (42);

c) connecting the terminal connection device (10) to an end of the power cable (42) by connecting the interface cable (12) to the end of the power cable (42) via the first cable connector (24); and

d) connecting the terminal connection device (10) to the connection point by connecting the first end portion of the interface cable (12) to the connection point.