

DC CIRCUIT BREAKER AND DISCONNECTOR

The present invention relates to circuit breakers and in particular to direct current circuit breakers.

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Direct current power delivery systems are in widespread use, e.g. in delivering power to conductor rails of transport systems. Examples include railway and tramway infrastructure, where DC current is supplied to a live, e.g. positive voltage, conductor rail such as a live third rail track or a live overhead cable. Such power delivery systems require automatic circuit breaker protection to quickly and automatically disconnect the live conductor rail from a power supply in the event of an overcurrent status. Such overcurrents may be caused by numerous types of event such as damage to a cable support structure, dislodgement of a cable or rail, accidental shorting of a live conductor rail to ground, or overload condition in a load device using the power delivery system. JP 2005-190671 describes a DC circuit breaker for a railway supply circuit in which two DC circuit breakers are connected in parallel between a power line and a feeder line of the railway to enable inspection of one circuit breaker while the feeder line remains in operation.

The power delivery systems also require a mechanism for placing the conductor rail in a safe, e.g. grounded, maintenance condition when it is necessary for personnel to work on the infrastructure. This is so that any inadvertent connection of the conductor rail to a source of power, or a lightning strike on the conductor rail somewhere in the network, does not cause damage or harm to other parts of the infrastructure or to personnel working on the infrastructure while the live conductor rail is out of service.

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In existing infrastructure, one approach to providing a safe maintenance condition of the conductor rail is to manually attach a shorting bar or clamp between the conductor rail and a negative voltage return rail or a grounded rail.

It is an object of the invention to provide an alternative and / or improved apparatus for enabling functionality of both (i) automatic circuit breaker protection and (ii) grounding of a conductor rail to a 'maintenance' or 'out-of-service' condition.

According to one aspect, the present invention provides a circuit breaker / disconnecter apparatus for use in a power delivery system comprising:

a unidirectional DC circuit breaker having a first terminal and a second terminal and configured to automatically open during an overcurrent condition in a forward direction and to remain closed independent of current level in a reverse direction;

a disconnecter switch in series with the circuit breaker, the disconnecter switch having a first terminal for connecting to a first polarity connector of a power supply, a second terminal for connecting to a second polarity connector of the power supply and a common terminal connected to the first terminal of the circuit breaker;

- 5 the disconnecter switch having at least a first position in which the first terminal is connected to the common terminal and a second position in which the second terminal is connected to the common terminal.

10 The circuit breaker may include a manually operable trip switch configured to force the circuit breaker into an open condition. The disconnecter switch may be interlocked to prevent switching between the first and second positions while the circuit breaker is in a closed condition. The second terminal of the circuit breaker may be coupled to a first conductor rail of a power delivery system. The first terminal of the disconnecter switch may be connected to a first polarity connector of the power supply and the second terminal
15 of the disconnecter switch may be connected to a second polarity connector of the power supply. The second polarity connector of the power supply may be coupled to a track of a transport system and the first polarity connector of the power supply may be coupled to an overhead cable or third rail of a transport system. The forward direction may correspond to current flow from the first terminal to the second terminal of the circuit
20 breaker and the reverse direction may correspond to current flow from the second terminal to the first terminal of the circuit breaker. The disconnecter switch may include a third position in which both the first and second terminals are electrically isolated from the common terminal. The disconnecter switch may be configured to be operated by manual operation. The disconnecter switch may include a visual position indicator indicating its
25 status in the first or second position.

According to another aspect, the invention provides a method of configuring a power delivery system comprising:

- 30 providing a DC power supply having a first polarity terminal and a second polarity terminal;

 coupling a disconnecter switch to the DC power supply, such that the disconnecter switch has a first terminal connected to the first polarity terminal of the DC power supply and a second terminal connected to the second polarity terminal of the power supply, the disconnecter switch having at least a first position in which the first terminal is connected

to a common terminal and a second position in which the second terminal is connected to the common terminal;

connecting the common terminal of the disconnecter switch to a first terminal of a unidirectional DC circuit breaker having a first terminal and a second terminal and
5 configured to automatically open during an overcurrent condition in a forward direction and to remain closed independent of current level in a reverse direction;

connecting the second terminal of the circuit breaker to a first power line; and

connecting the second terminal of the disconnecter switch and the second polarity terminal of the DC power supply to a second power line.

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The method may include placing the first and second power lines in an in-service condition by switching the disconnecter switch to the first position and then setting the circuit breaker to a closed configuration. The method may include placing the first and second power lines in a safe maintenance condition by setting the circuit breaker to an open
15 configuration, then switching the disconnecter switch to the second position, then setting the circuit breaker to a closed configuration.

Embodiments of the present invention will now be described by way of example and with reference to the accompanying drawings in which:

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Figures 1A to 1D are schematic diagrams showing a power delivery system for a railway infrastructure in four states illustrating the switching of the conductor rails of the railway from a service (powered) condition to a safe maintenance condition.

Figure 1 shows a schematic representation of a high voltage power delivery system for
25 delivering power to the conductor rails of a railway infrastructure. A DC power supply 1 has a positive output terminal 2 and a negative output terminal 3. The DC power supply 1 may be a rectifier receiving an AC input. The positive output terminal 2 is connected to a busbar 4 via a circuit breaker 5. The bus bar 4 is connected to a disconnecter switch 10 which is connected to a unidirectional circuit breaker 20. The negative output terminal 3
30 of the power supply 1 is connected to a negative return conductor rail 6 of the railway infrastructure. The circuit breaker 20 is connected to a positive conductor rail 7 of the railway infrastructure.

In one configuration, the positive conductor rail 7 may be an overhead cable or catenary
35 suitable for current collection by a pantograph. In another configuration, the positive

conductor rail may be a live third rail, e.g. a rigid conductor placed alongside or between the rails of a railway track. The negative return conductor rail 6 may be a railway track or tram track.

- 5 The disconnecter switch 10 has a first terminal 11 which is electrically connected to the busbar 4 and, thereby, to the positive output terminal 2 of the power supply 1. The disconnecter switch 10 has a second terminal 12 which is electrically connected to the negative output terminal 3 of the power supply 1 and to the negative return conductor rail 6. The disconnecter switch 10 has a third terminal which may be described as a common
- 10 terminal 13 which is connected to a first terminal 21 of the unidirectional circuit breaker 20. The disconnecter switch 10 has a first position in which its first terminal 11 is electrically connected to the common terminal 13, and a second position in which its second terminal 12 is connected to the common terminal 13, e.g. a single pole, two position configuration.
- 15 The circuit breaker 20 has a first terminal 21 and a second terminal 22 and is unidirectional in the sense that it is configured to automatically open contacts of the circuit breaker upon detection of an overcurrent condition in a first (forward) direction, in this instance for current flowing from the first terminal 21 to the second terminal 22, whereas it does not automatically open contacts of the circuit breaker in the event of current flow or overcurrent
- 20 flow in the reverse direction, i.e. current flowing from the second terminal 22 to the first terminal 21.

The busbar 4 may feed other disconnecter and circuit breaker apparatus not shown in the drawings, e.g. those configured to feed other segments of the conductor rails 6, 7, of the

25 railway infrastructure.

In use, the power delivery system would be in a normal service condition as shown in figure 1A in which power is delivered from the power supply 1 to the rails 6 and 7 by the circuit breaker 5 being closed (as labelled), the disconnecter switch 10 being in the first

30 position as shown (terminals 11 and 13 connected) and the circuit breaker 20 being closed (as labelled).

To bring the power delivery system into a safe condition for maintenance, not only must the connection between the busbar 4 and the positive conductor rail 7 be broken, but also

35 the positive and negative rails 6, 7 must be shorted together.

In a first step, as shown in figure 1B, the circuit breaker 20 is set to an open condition, e.g. by intentionally tripping the circuit breaker with a manual override or electronic actuation, or by an actual overcurrent fault condition which caused the circuit breaker to open
5 automatically. It can be seen that the disconnecter switch 10 is now off-load and can be safely switched to the second position (terminals 12 and 13 connected) as indicated in figure 1C.

In figure 1C, the disconnecter switch 10 is now in the second position connecting the
10 second terminal 12 to the common terminal 13, and thus the negative conductor rail 6 and negative terminal 3 of the power supply 1 are coupled to the circuit breaker first terminal 21. At this time, the circuit breaker 20 is reset or otherwise made to close the circuit breaker contacts and effectively short together the positive conductor rail 7 and the negative conductor rail 6, leaving the conductor rail 7 in a safe condition for maintenance
15 etc, as shown in figure 1D.

The unidirectionality of the circuit breaker 20 thereby now ensures that, in the configuration of figure 1D, an inadvertent or accidental connection of the rail 7 to a power supply or its exposure to an electrical discharge such as a lightning strike will not trip the circuit breaker
20 to an open condition which would leave the conductor rail 7 potentially live and unsafe. Instead, the circuit breaker will remain closed and will allow the current to flow to ground via the negative return rail 6.

To reconnect the power delivery system to an in-service condition, the steps discussed
25 above are reversed.

The configuration of power delivery system described herein offers an advantage in that the apparatus for both circuit breaking function and grounding can be integrated into a common apparatus comprising an off-load disconnecter and a circuit breaker, and the
30 circuit breaker can be used to place the disconnecter into an off-load condition for both connection and disconnection.

Another possible advantage is that by addition of a simple changeover off-load disconnecter 10 into the circuit, an already-present fully rated circuit breaker 20 can be
35 used to achieve the fault-make, (load-break, if necessary) and short-time current duty

requirements of an earthing device, whilst still providing forward protection and switching functions. A circuit breaker 20 is generally a much more robust device than a conventional earthing switch due to its extended range of operating duties often required by international standards.

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Another potential advantage is that the disconnecter 10 only need be capable of withstanding the passage of current (short term withstand current or STC rating) and is more compact than a comparable fault-make, STC (and load-break) rated switching device and can be installed in the rear of a circuit breaker cubicle without needing a separate panel or external cabling. Thus, manufacturer and user costs can be saved.

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The disconnecter may generally be a simpler and more reliable device than a comparable switching device and can be rated for an extended number of mechanical operations without maintenance. Because it can be operated only as an off-load device, the disconnecter 10 need not suffer arcing across any contacts and is therefore not prone to wear and requires minimal maintenance.

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Various modifications may be made to the configuration shown in figure 1. In the arrangement shown, the positive terminal 2 of the power supply 1 has a first polarity and is connected to the disconnecter switch 10, circuit breaker 20 and "live" conductor rail 7, while the negative terminal 3 has a second polarity and is connected to a "safe" negative return rail 6 which is generally held at or close to ground potential. It will be recognised that this could be reversed with a positive terminal 2 of the power supply being connected as a "safe" potential at or near ground potential and the negative terminal 3 providing power to the "live" conductor rail 7. In this respect, the first and second polarities of the power supply terminals can be reversed.

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The disconnecter switch 10 may also be provided with a third, stable, position (not shown in the figures) corresponding to an intermediate or "isolation" position in which neither the first terminal 11 nor the second terminal 12 is electrically connected to the common terminal 13, such that both the first and second terminals 11, 12 are electrically isolated from the common terminal 13. In this way, the conductor rail 7 can be completely isolated from the positive and negative output terminals 2, 3 of the power supply 1.

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The disconnecter switch 10 may be configured to operate entirely manually, or with automatic actuation or with a combination of both. The disconnecter switch may include an emergency manual operation facility.

5 The disconnecter switch 10 may include a visual position indicator indicating its status in any of the first, second and/or third positions. The visual position indicator could be provided by a driven indicator semaphore, or a window giving sight of the relevant moving parts. Other types of visual position indicator are possible.

10 The circuit breaker 20 can be configured to trip in the forward direction at any suitable current level considered as an overcurrent condition.

The circuit breaker 20 may comprise any device or assembly or other suitable arrangement for providing a means of breaking the circuit upon detection of an overcurrent condition in
15 a forward direction and to remain closed independent of current level in a reverse direction. For example, a circuit breaker as defined could comprise a switch or circuit breaking device that can be triggered with a protection relay via a shunt trip coil. The switch or circuit breaking device could be triggered by any suitable separate mechanism for detecting the appropriate fault or overload condition.

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The power delivery system has been described in the context of a power delivery system for delivering power to the conductor rails 6, 7 of a railway or tramway infrastructure. However, it can be applied more generally to any power delivery system in which conductor network normally at a live high potential must be grounded or shorted to a
25 conductor at a safe potential when in a maintenance or out-of-service condition.

The power delivery system may be modified to include an interlock system which prevents the disconnecter switch 10 from being operated in one or both directions when the circuit breaker 20 is in the closed condition. If the disconnecter switch 10 is provided with a third
30 ('isolation') position as discussed above, the interlock system may be configured to prevent the disconnecter switch from being operated to transition from or to any one or more of the first, second and third positions.

Other embodiments are intentionally within the scope of the accompanying claims.

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CLAIMS

1. A circuit breaker / disconnecter apparatus for use in a power delivery system comprising:
 - 5 a unidirectional DC circuit breaker (20) having a first terminal (21) and a second terminal (22) and configured to automatically open during an overcurrent condition in a forward direction and to remain closed independent of current level in a reverse direction;
a disconnecter switch (10) in series with the circuit breaker (20), the disconnecter switch having a first terminal (11) for connecting to a first polarity connector (2) of a power supply (1), a second terminal (12) for connecting to a second polarity connector (3) of the power supply (1) and a common terminal (13) connected to the first terminal (21) of the circuit breaker (20);
the disconnecter switch (10) having at least a first position in which the first terminal (11) is connected to the common terminal (13) and a second position in which the second terminal (12) is connected to the common terminal (13).
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2. The apparatus of claim 1 in which the circuit breaker (20) includes a manually operable trip switch configured to force the circuit breaker into an open condition.
- 20 3. The apparatus of claim 1 in which the disconnecter switch (10) is interlocked to prevent switching between the first and second positions while the circuit breaker is in a closed condition.
4. The apparatus of claim 1 in which the second terminal (22) of the circuit breaker (20) is coupled to a first conductor rail (7) of a power delivery system.
- 25 5. The apparatus of claim 1 or claim 4 in which the first terminal (11) of the disconnecter switch (10) is connected to a first polarity connector (2) of the power supply (1) and the second terminal (12) of the disconnecter switch (10) is connected to a second polarity connector (3) of the power supply (1).
- 30 6. The apparatus of claim 5 when dependent on claim 4 in which the second polarity connector (3) of the power supply (1) is coupled to a track (6) of a transport system and in which the first polarity connector (2) of the power supply (1) is coupled to an overhead cable (7) or third rail of a transport system.
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7. The apparatus of claim 1 in which the forward direction corresponds to current flow from the first terminal (21) to the second terminal (22) of the circuit breaker (20) and the reverse direction corresponds to current flow from the second terminal to the first terminal of the circuit breaker.
8. The apparatus of claim 1 in which the disconnect switch (10) includes a third position in which both the first and second terminals (11, 12) are electrically isolated from the common terminal (13).
9. The apparatus of claim 1 in which the disconnect switch (10) is configured to be operated by manual operation.
10. The apparatus of claim 1 in which the disconnect switch (10) includes a visual position indicator indicating its status in the first or second position.
11. A method of configuring a power delivery system comprising:
providing a DC power supply (1) having a first polarity terminal (2) and a second polarity terminal (3);
coupling a disconnect switch (10) to the DC power supply (1), such that the disconnect switch has a first terminal (11) connected to the first polarity terminal (2) of the DC power supply and a second terminal (12) connected to the second polarity terminal (3) of the power supply, the disconnect switch having at least a first position in which the first terminal (11) is connected to a common terminal (13) and a second position in which the second terminal (12) is connected to the common terminal (13);
connecting the common terminal (13) of the disconnect switch (10) to a first terminal (21) of a unidirectional DC circuit breaker (20) having a first terminal (21) and a second terminal (22) and configured to automatically open during an overcurrent condition in a forward direction and to remain closed independent of current level in a reverse direction;
connecting the second terminal (22) of the circuit breaker (20) to a first power line (7); and
connecting the second terminal (12) of the disconnect switch (10) and the second polarity terminal (3) of the DC power supply (1) to a second power line (6).

12. The method of claim 11 further including placing the first and second power lines (7, 6) in an in-service condition by switching the disconnect switch (10) to the first position and then setting the circuit breaker (20) to a closed configuration.

- 5 13. The method of claim 11 or claim 12 further including placing the first and second power lines (7, 6) in a safe maintenance condition by setting the circuit breaker (20) to an open configuration, then switching the disconnect switch (10) to the second position, then setting the circuit breaker (20) to a closed configuration.

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