HIGH VOLTAGE DIRECT CURRENT CONFIGURATIONS

Monopole and earth return

In a common configuration, called monopole, one of the terminals of the rectifier is connected to earth ground. The other terminal, at a potential high above, or below, ground, is connected to a transmission line. Theearthed terminal may or may not be connected to the corresponding connection at the inverting station by means of a second conductor.

If no metallic conductor is installed, current flows in the earth between the earth electrodes at the two stations. The issues surrounding earth-return current include

Electrochemical corrosion of long buried metal objects such as pipelines

Underwater earth-return electrodes in seawater may produce chlorine or otherwise affect water chemistry.

An unbalanced current path may result in a net magnetic field, which can affect magnetic navigationalcompasses for ships passing over an underwater cable.

These effects can be eliminated with installation of a metallic return conductor between the two ends of the monopolar transmission line. Since one terminal of the converters is connected to earth, the return conductor need not be insulated for the full transmission voltage which makes it less costly than the high-voltage conductor. Use of a metallic return conductor is decided based on economic, technical and environmental factors[8].

Modern monopolar systems for pure overhead lines carry typically 1500 MW[9]. If underground or seacables are used the typical value is 600 MW.

Bipolar

In bipolar transmission a pair of conductors is used, each at a high potential with respect to ground, in opposite polarity. Since these conductors must be insulated for the full voltage, transmission line cost is higher than a monopole with a return conductor. However, there are a number of advantages to bipolar transmission which can make it the attractive option.

Under normal load, negligible earth-current flows, as in the case of monopolar transmission with a metallic earth-return; minimising earth return loss and environmental effects.

When a fault develops in a line, with earth return electrodes installed at each end of the line, current can continue flow using the earth as a return path, operating in monopolar mode.

Since for a given power rating bipolar lines carry only half the current of monopolar lines, the cost of the second conductor is reduced compared to a monopolar line of the same rating.

In very adverse terrain, the second conductor may be carried on an independent set of transmission towers, so that some power may continue to be transmitted even if one line is damaged.

A bipolar system may also be installed with a metallic earth return conductor.

Bipolar systems may carry as much as 6400 MW at voltages of +/-800 kV. Under sea cable installations initially commissioned as a monopole may be upgraded with additional cables and operated as a bipole.

Back to back

A back-to-back station is a plant in which both static inverters are in the same area, usually even in the same building and the length of the direct current line is only a few meters. HVDC back-to-back stations are used for

coupling of electricity mains of different frequency (as in Japan)

coupling two networks of the same nominal frequency but no fixed phase relationship

different frequency and phase number (for example, as a replacement for traction current converter plants)

different modes of operation (as until 1995/96 in Etzenricht, Dürnrohr and Vienna).

In contrast to HVDC long-distance lines, the DC voltage in the intermediate circuit can be selected freely at HVDC back-to-back stations because of the short conductor length. The DC voltage is as low as possible, in order to build a small valve hall and to avoid parallel switching of valves. For this reason at HVDC back-to-back stations the strongest available static inverter valves are used.

Tripole - Current Modulating Control

A newly patented scheme (US Patent 6714427) is particularly applicable to conversion of existing AC transmission lines to HVDC. Two of the three circuit conductors are operated as a bipole. The third conductor is used as a parallel monopole, equipped with reversing valves (or parallel valves connected in reverse polarity). The parallel monopole periodically relieves current from one pole or the other, switching polarity over a span of several minutes. The bipole conductors would be loaded to either 1.37 or 0.37 of their thermal limit, with the parallel monopole always carrying +/- 1 times its thermal limit current. The combined RMS heating effect is as if each of the conductors was always carrying 1.0 of its rated current. This allows heavier currents to be carried by the bipole conductors, and full use of the installed third conductor for energy transmission. The higher current compared to AC operation may also help prevent ice build-up during winter storms. The system can be arranged to circulate high currents through the line conductors even if load demand is low.

Combined with the higher average power possible with a DC transmission line for the same line to ground voltage, a tripole conversion of an existing AC line could allow up to 80% more power to be transferred using the same transmission right-of-way, towers, and conductors. Some AC lines cannot be loaded to their thermal limit due to system stability, reliability, and reactive power concerns, which would not exist with an HVDC link.

The system operates without earth-return current. Since a single failure of a pole converter or a conductor results in only a small loss of capacity and no earth-return current, reliability of this scheme would be high. No time would be lost in switching if a conductor broke. The valves would inherently have an emergency overload rating in bipole mode. This would possibly allow great increase in power transmission with significant effect in congested transmission systems, where consequences of a single line failure limit the allowed loading of other parallel transmission lines. While capital costs are higher than for a bipole conversion operating at the same voltage class, the extra power capability reduces incremental cost per megawatt. Depending on transmission line physical configuration, replacement of insulators may be required to achieve the highest power rating, to insure proper line-to-line clearance distances.

As of 2005 no tri-pole conversions are in operation, although a transmission line in India has been converted to bipole HVDC.

See Presentation on Current-Modulated Control

United States Department of Energy comments received on an inquiry into power transmission bottlenecks

Corona discharge

Corona discharge is the creation of ions in a fluid (such as air) by the presence of a strong electric field.Electrons are torn from un-ionised air, and either the positive ions or else the electrons are attracted to the conductor, whilst the charged particles drift. This effect can cause considerable power loss, create audible and radio-frequency interference, generate toxic compounds such as oxides of nitrogen and ozone, and lead to arcing.

Both AC and DC transmission lines can generate coronas, in the former case in the form of oscillating particles, in the latter a constant wind. Due to the space charge formed around the conductors, an HVDC system may have about half the loss per unit length of a high voltage AC system carrying the same amount of power. With monopolar transmission the choice of polarity of the energised conductor leads to a degree of control over the corona discharge. In particular, the polarity of the ions emitted can be controlled, which may have an environmental impact on particulate condensation (particles of different polarities have a different mean-free path). Negative coronas generate considerably more ozone than positive coronas, and generate it further downwind of the power line, creating the potential for health effects. The use of a positive voltage will reduce the ozone impacts of monopole HVDC power lines.

Applications

Overview

The controllability of current-flow through HVDC rectifiers and inverters, their application in connecting unsynchronized networks, and their applications in efficient under sea cables mean that HVDC cables are often used at national boundaries for the exchange of power. Offshore windfarms also require undersea cables, and their turbines are unsynchronized. In very long-distance connections between just two points, for example around the remote communities of Siberia, Canada, and the Scandinavian North, the decreased line-costs of HVDC also makes it the usual choice. Other applications have been noted throughout this article.

The development of insulated gate bipolar transistors and gate turn-off thyristors has made smaller HVDC systems economical. These may be installed in existing AC grids for their role in stabilizing power flow without the additional short-circuit current that would be produced by an additional AC transmission line. One manufacturer calls this concept "HVDC Light", and has extended the use of HVDC down to blocks as small at a few tens of megawatts and lines as short as a few score kilometres of overhead line.

System configurations

A HVDC link in which the two AC-to-DC converters are housed in the same building, the HVDC transmission existing only within the building itself, is called a back-to-back HVDC link. This is the common configuration for interconnecting two unsynchronised grids or for changing frequency or for stabilizing an AC network.

HVDC back-to-back stations can also be designed to deliver single phase AC. This is required for Traction current converter plants.

The most common configuration of an HVDC link is a station-to-station link, where two inverter/rectifier stations are connected by means of a dedicated HVDC link. This is also a configuration commonly used in connecting unsynchronised grids, in long-haul power transmission, and in undersea cables.

Multi-terminal HVDC links, connecting more than two points, are rare. The configuration of multiple terminalscan be series, parallel, or hybrid (a mixture of series and parallel). Parallel configuration tends to be used for large capacity stations, and series for lower capacity stations. An example is the 2000 MW Quebec - New England Transmission system opened in 1992, which is currently the largest multi-terminal HVDC system in the world[10].

Source : http://engineering.wikia.com/wiki/HVDC