Close and Return

FACTS FOR OPTIMUM UTILISATION OF CABLE NETWORKS IN POWER SYSTEMS

Rolf GRÜNBAUM, ABB Power Technologies AB, (Sweden), rolf.grunbaum@se.abb.com
Johan KARLSTRAND, ABB Power Systems AB, (Sweden), johan.p.karlstrand@se.abb.com

ABSTRACT

An important line of development in power transmission is the growing importance of cable networks. In particular, the increasing use of offshore installations such as oil and gas platforms, as well as large offshore wind farms, will see a growing use of undersea cables for connection to mainland grids.

FACTS is a powerful means to come to grips with a number of challenges associated with the proliferation of cable networks in power transmission. The paper gives an introduction to FACTS, therein primarily SVC and series compensation, as well as elaborates on various applications to address the challenges in cable networks as presented below.

KEYWORDS

XLPE Cables, Reactive power, FACTS, SVC, Series Compensation, Voltage control, Load balancing.

INTRODUCTION

There is a direct connection between reactive power control in power transmission systems and control of system voltage. In networks more or less dominated by HV and EHV cables, the large reactive power generation associated with cables will inevitably set its mark on voltage regulation. At low load, unless remedied, cable generation may give rise to unwanted voltage rises. At high load, on the other side, cable generation can be used to benefit for voltage support.

A common measure to avoid over-voltage at low load is to provide cables with shunt reactors at their ends. This is a crude measure, however, since it loads the cable at all times and prevents it from being fully utilized at high grid load. A better way is to apply reactive power compensation with dynamic control, thereby enabling reactive power balance in the grid at all times. Several benefits to grid operation follow from this, which are the subject of this paper.

Another cable specific characteristic is its low series impedance in comparison with overhead lines. Unless properly dealt with, serious mismatch between load flows in cables and overhead lines may follow. As is shown, FACTS can mitigate or even eliminate this mismatch and thereby improve power transmission capacity in grids.

The term "FACTS" (Flexible AC Transmission Systems) covers several power electronics based systems used for AC power transmission [1]. Given their nature, FACTS solutions are particularly beneficial in applications requiring one or more of the following qualities:

- o Rapid dynamic response
- o Ability for frequent variations in output
- o Smoothly adjustable output.

Important FACTS devices are SVC (Static Var Compensators), STATCOM, and Series capacitors.

XLPE CABLES IN NORMAL OPERATION

An increasing number of land and submarine links are supposed to be built in Europe in the near future [2]. A considerable part of these links may be built as cable systems, due to mainly environmental concerns associated with OH-lines. Extruded cable transmission links, either operated at AC or DC voltage, must then be able to transmit power reliably and with full control over short and long distances across borders and undersea.

When integrating XLPE cables into the existing transmission network one has to know how the cable itself and the rest of the network react on such integration. A key issue is then to have power flow and voltage control. Consequently, the impedance characteristics of cables must be known.

Line/shunt impedance of XLPE cables

Compared to an OH-line, an XLPE cable has much higher capacitance but normally a lower line inductance. The latter is however also true for single-core submarine cables even if the spacing is large since the sheath/armouring is both ends bonded. Thus, the inductance may for single-core submarine cables be defined solely between conductor and sheath/armour.

The positive sequence impedance for XLPE cables is defined according to equation 1:

$$Z_1 = R_c + \frac{X_s^2}{R_s^2 + X_s^2} \cdot R_s + j\left(X_c - \frac{X_s^2}{R_s^2 + X_s^2} \cdot X_s \right) \quad [1]$$

Equation 1 may be written:

$$Z_1 = \left(R_c + \alpha \cdot R_s\right) + j\left(X_c - \alpha \cdot X_s\right) \quad [2]$$

R_c	resistance of conductor
R_s	resistance of sheath/armour
X_c	reactance between phase conductors
X_s	reactance between conductor-sheath/armour

From equation 2 it can be noticed that we have two extremes:

1. $X_s >> R_s$: $\alpha \to 1$
2. $X_s << R_s$: $\alpha \to 0$

Case 1 may be an extreme situation for a submarine single-core cable having a large armour cross-section, i.e. with