

Preface

For more than a century, overhead lines have been the most commonly used technology for transmitting electrical energy at all voltage levels, especially on the highest levels. However, in recent years, an increase in both the number and length of HVAC cables in the transmission networks of different countries like Denmark, Japan or United Kingdom has been observed. At the same time, the construction of offshore wind farms, which are typically connected to the shore through HVAC cables, increased exponentially.

As the number of HVAC cables increased, the interest in the study of electromagnetic phenomena associated to their operation, among them electromagnetic transients, increased as well. Transient phenomena have been studied since the beginning of power systems, at first using only analytical approaches, which limited studies to more basic phenomena; but as computational tools became more powerful, the analyses started to expand for the more complex phenomena.

Being old phenomena, electromagnetic transients are covered in many publications, and classic books such as the 40-year-old Greenwood's "Electric Transients in Power Systems" are still used to this day. However, the majority of publications tend to ignore HVAC cables, which is understandable as the use of long HVAC cables was not very common until recent years.

This book proposes to address some of the transient phenomena that may occur when operating power networks with HVAC cables. The book is written as a textbook and it tries to give comprehensive explanations of the different phenomena and focus on describing different scenarios. It is the authors' opinion that this approach allows for a better understanding of the physical principles and for readers to adapt their analyses accordingly when handling different cases concerning HVAC cables.

An important topic that is not covered in this book is measurements protocols/methods. The protocols used when performing measurements on a cable depend on what is to be measured, the available equipment and accessibility. Readers interested in the topic are referred to search for this information in Ph.D. theses and scientific papers.

However, the book is not only intended for students. It can also be used by engineers who work in this area and need to understand the challenges/problems they are facing or who need to learn how to prepare their simulation models.

Chapter 1, “Components Description”, describes the several layers of a cable as well as their function. It also shows how to calculate the different electric parameters of a cable, resistance, inductance, capacitance, and how to use those values to calculate the positive-sequence and zero-sequence impedance, including how to adapt the datasheet values for more accurate calculations.

The chapter introduces the different bonding configurations typically used for the screens of cables (both-ends bonding and cross-bonding) and also presents methods that can be used to estimate the maximum current of a cable for different types of soils, i.e. thermal calculations.

The end of the chapter introduces the shunt reactor, which is an important element in cable-based network as it consumes locally the reactive power generated by the cables.

Chapter 2, “Simple Switching Transients”, reviews the principles of the Laplace transform and uses it to study simple switching transients, RC–RL–RLC loads for both AC and DC sources.

In other words, the chapter demonstrates how analytical analysis of simple systems can be made. These principles will be used in later chapters in the study of more complex scenarios.

Chapter 3, “Travelling Waves and Modal Domain”, reviews the Telegraph equations and how to calculate the loop and series impedance matrices as well as the shunt admittance matrix of a cable in function of the frequency.

The chapter also introduces the different modes of a cable, how to calculate their impedance and velocity, as well as their frequency dependence. The knowledge of modal theory is of utmost importance when working in transient in cables. It is true that in many cases, software is used to run simulations, and the reader may be tempted to think that only those designing the software need to know how to use modal theory. However, several phenomena require at least a minimum knowledge of the topic and for that reason, the book provides a thorough explanation of the subject.

Chapter 3 also studies the frequency spectrum of a cable for different bonding configurations.

Chapter 4, “Transient Phenomena”, describes several electromagnetic phenomena that may occur in HVAC cables. The chapter starts by explaining the energisation of a single cable for both-ends bonding and cross-bonding, showing the waveforms for different scenarios and demonstrating how the modal theory can be used to explain the transient waveforms; after this, other phenomena such as the energisation of cables in parallel, zero-missing, transient recovery voltages and restrikes are addressed.

Hybrid cable-OHLs are also considered in this chapter, and it is demonstrated how an overvoltage may be very high for some configurations as well as the influence of the bonding configuration in the magnitude of the overvoltage.

The interaction between a cable which is highly capacitive and a transformer which is highly inductive is also analysed and some possible resonance scenarios are explained, as well as ferroresonance.

To finish the chapter, we study short-circuits in cables, which can be rather different from short-circuit in OHLs, because of the current returning in the screen. The screen can also be bonded on different configurations, influencing both the magnitude of the short-circuit current and of the transient recovery voltage.

[Chapter 5](#), “System Modelling and Harmonics”, starts by proposing a method that can be used when deciding how much of the network to model when doing a simulation of an energisation/restrike together with the possible limitations of the method.

The chapter continues by analysing the frequency-spectrums of cable-based networks which have lower resonance frequencies than usual because of the larger capacitance of the cables. At the same time, a technique that may help save time when plotting the frequency spectrum of a network is proposed.

The chapter ends by proposing a systematic method that can be used when doing the insulation co-ordination study for a line, as well as the modelling requirements, both modelling depth and modelling detail of the equipment, for the study of the different types of transients followed by a step-by-step generic example.

<http://www.springer.com/978-1-4471-5235-4>

Electromagnetic Transients in Power Cables

Faria da Silva, F.M.; Leth Bak, C.

2013, XIII, 229 p. With online files/update., Hardcover

ISBN: 978-1-4471-5235-4