

Preface

We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.

T.S. Eliot, *Four Quartets*

In the development of the AC power systems, long transmission lines and overhead lines (OHL) have been considered for many years an indissoluble binomial, whereas the use of HV and EHV insulated cables was devoted mostly to DC submarine links; in the last decades, a strengthened sensibility towards the environment, with consequent big hindrances to OHL installations, and an increased reliability of high quality extruded insulations (cross-linked polyethylene – XLPE) of cables have induced the transmission system planners and grid owners to install numerous AC HV and EHV cable lines: they have unquestionable qualities of adaptability to the problems given by the territory when realizing modifications, widening or reinforcement of the transmission network. Nowadays, in the jargon of electrical engineering, words such as *undergrounding*, *UGC* (Underground Cables) and *mixed lines* (a cascade composition of OHL and UGC) have a clear meaning.

The planning of any new line (OHL, UGC or mixed line) in the electrical grid must be always validated by extensive network simulations, among which power flow, short circuit, transient analyses; generally those studies ought to be preceded by a propedeutical investigation, in order to assist the system planner in the configuration, comparison and choice of the more suitable solutions, chiefly when the field of choice can be very wide as in the insulated cable market. In fact, a target of this book was the development of this propedeutical phase regarding the *electric energy transmission standpoint* with particular attention to the operating requirements.

Starting from the classical equations of transmission lines, developed more than a century ago, and by rearranging them with original procedures, the authors have created some novel capability charts (for UGCs in Chapter 3, for mixed lines in Chapter 4) which immediately visualize the best possible performances within the limits of current and voltage compatible with the line lifetime and power quality. These capability charts (which take into account the steady state ampacity and voltage levels, subtransient voltages, shunt compensation degree and other important parameters) are of primary importance (in the same way of power circle diagrams): they offer an original and efficient guide extremely useful for both the planning of

UGC or mixed line systems and a full compatibility of their insertion in the power network.

Through the book, there are also several occasions of cultural widening in the field of the circuit theory: one of the most meaningful contributions is the *recovery* of Ossanna's theory, completely developed in 1926 (and in the book newly presented in Section 3.9.2). It gives a simple but extremely elegant and powerful analytical direct computation of the possible voltage regimes obtainable in any AC power system by fixing the complex power at one of its ports, so avoiding the iterative procedures up till now largely used. This method, particularly useful to complete the line performance analysis, ought to be also generally appreciated as one of the more important tool in the circuit theory.

Also, the authors' attempt in Chapter 6 of framing the economical comparison between UGC and OHL on an engineering fair basis takes aim at helping the involved stakeholders to clear the field of subjective impressions.

Briefly, the book offers:

- a wide panorama of the large EHV cable installations which has been enhanced by means of some detailed reports of *paradigmatic* installations (Chapter 1);
- an outline of positive sequence modelling to analyse the steady state regimes of typical OHLs, of cross-bonded (with phase transpositions) cable systems and of gas insulated lines (Chapter 2);
- call to the constant use of some international rules and national standards;
- novel capability charts (with a lot of examples both for UGCs and mixed lines) which offer a throughout visualization of transmission line performances compatible with chosen current and voltage constraints;
- criteria regarding the energization and de-energization phenomena of no-load transmission lines (UGC and mixed lines);
- criteria for the dimensioning and check of the shunt reactive compensation of UGC (uniformly or lumped);
- comments of educational purpose on the physical meaning of some formal analytical expressions;
- introduction to the multiconductor analysis of undergrounding with self-made power frequency matrix procedures (Chapter 5), which allows investigating the electrical behaviours of all cable conductors (phases and sheaths) with some case studies and offers the possibility of comparing and validating simplified approaches;
- a technical and economical comparative procedure between overhead and cable lines which can contribute to the Environmental Impact Assessment recommended by the European community (Chapter 6).

The authors hope to have given the electric engineers a modern and sound tool to face the challenges of the future electrical grids where the undergrounding will play a key role.

EHV AC Undergrounding Electrical Power
Performance and Planning

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