Preface

All truth passes through three stages. First, it is ridiculed; second, it is violently opposed; and the third, it is accepted as being self-evident…

Arthur Schopenhauer (1788–1860)

Having taught the subject of power systems to a large number of students over several years the authors felt that a re-look is necessary at some conventional methods of analysis. In this book, the authors have subjected the time-honoured load flow to a close scrutiny. Books on electrical circuits do not go beyond the usual electrical domain, i.e. all sources are voltage/current sources, or their variants. Power source does not find mention anywhere. *Scalar* power driving *phasor*-governed ac electrical circuits appears to be alien to prevalent thinking, but that is how it is! Turbine-driven synchronous generators perform precisely this role in power systems. Given the power source, how does one then find the voltages and currents spread all over the network? How does the power quantum of generator get distributed among network elements? We try to find answers to these interesting questions in this book. The analysis is an eye opener. We enter into a *wonderland* where all final entities, such as flows, losses, voltage magnitudes are real numbers, or quanta! Phasors that hitherto constituted the so-called state of the system do not appear either in the input or in the output. We thus discover a new load flow procedure—Modular Load Flow—which works with only scalars!

Historically power systems have had a structure of vertical integration. In a given geographical area, generation, transmission and distribution systems all belonged to one commercial agency. Connections to neighbouring systems belonging to another commercial agency were through tielines. In such a structure, it was easy to settle commercial issues like payments for power exchange between the two systems. With the increase in number of new generation and transmission facilities and with the increase in the number of stakeholders, concept of horizontal integration emerged about two decades ago. Multiple agencies pumped power into a large interconnected grid with transmission lines belonging to different agencies.

While this trend had the beneficial effect of competition and cost reduction, problems arose in determining the extent of use of a given transmission facility by a specific agency.

A restructured and deregulated system is all about injection of electrical powers—quanta—into the network where stakeholders may desire to know for commercial reasons, their individual contributions to flows, losses and voltages in the system. Modular load flow provides an effective tool for this purpose. To cap it all, the procedure is one-shot, a closed form solution! Ever since mid-1950s only the iterative load flow has been in vogue in almost all studies in power systems. It has had its own problems though, namely, non-convergence in ill-conditioned, or, heavily loaded systems, and multiple solutions. Continuation load flow and various other improvisations to ensure convergence are well-known workarounds. A fact that is not usually recognised is that the output of a conventional load flow is only a *possibility* and not a *solution* that would indicate reality. What if studies were conducted with a different slack bus? What if the voltage specifications at PV buses were different in different studies? There would be a different solution every time though one knows for sure that the generator injection pattern has not changed at all. Somewhere there appears to be a disconnect. It is as if the system operator expects generating stations to adjust reactive powers and voltages in sync with those used by him in the load flow and, to continuously keep him updated about reactive power limits and voltages. Switching of PV bus to PQ bus, when the limits are violated, crucially depends on this information. In deregulated systems, these expectations are not only far-fetched but are highly, if not totally, irrelevant. Modular load flow is different in this respect. Only information that is necessary is the values of injected real and reactive powers. These measurements are usually available in control centres. There are no issues of convergence. Solution is analytically exact. Errors, if any, occur due to minor approximation in passive circuit formulation or, in the data.

Kirchhoff state is a new concept introduced by the authors. It offers a new way of viewing the decoupling that naturally exists in power systems but does not seem to have been reported in the literature. The decoupling offers many advantages especially in deregulated systems. Outage analysis, economic optimization and voltage stability problems are posed in new formats. Authors have preferred to hand-hold student readers by giving numerical examples to illustrate every new concept or procedure when it is introduced.

Contingency analyses use distribution factors which are generally straightforward to calculate in centrally administered power systems. A global base case load flow is a prerequisite for this purpose. This cannot be reliably conducted in restructured multi-area systems. Modular load flow can deal with this situation easily. Security aspects of a part of Indian grid preceding the blackout on 30 and 31 July 2012 are discussed.

Deregulation has come to stay, and tracking of power flow is needed to segregate electrical contributions of various commercial agencies. System analysts have to find new tools to meet analytical requirement of such new developments. Analysis given in this book fulfils this need. We hope suggestions made in the book will find acceptance among power system teachers, graduate students and professionals interested in the analysis of restructured systems. It should be of help to regulators in resolving conflicts. There is an elegant theory based on orthogonality, Hilbert spaces and Dirac structures behind this analysis. Informal and brief discussion on this theory in Chap. 10 should entice avid researchers.

The unique analytical experiment, that is, modular load flow is presented in the form of lecture notes and illustrated with several examples. Only steady-state performance has been addressed in the book. Dynamic aspects are under research.

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