

Preface to the Second Edition

The first edition of this book was published in the beginning of 2008. These intervening years have seen a steadily growing adaption of this technology to improve the monitoring, protection, and control of the power systems around the world. Many countries are busily installing phasor measurement units (PMUs) and wide area measurement systems (WAMS) on their networks. In the USA, activities related to this technology continue to be supported by various electric utilities, government agencies—particularly the US Department of Energy—and many other industry groups. Although the number of substations equipped by PMUs and WAMS remains small compared to the size of the US power grid, an excellent start has been made, and in general, individual US utilities continue their efforts to improve the coverage provided by WAMS.

In our view, the new frontier in this area is the development of new applications of PMUs and WAMS. Work on new applications continues in many organizations around the world. Postmortem analysis after major system disturbances is a very useful application which assists in determining the causes and timelines of events which contributed to the system disturbance. To this end, obtaining and keeping records of such events are important, requiring selection of important data from WAMS which will validate system models used in simulations of the postmortem analysis. At present, there is no convenient tool which will examine all the saved data and determine which data segments are of most interest. We expect applications to achieve such a data selection task to be one of the outcomes of the present research.

State estimation using PMU measurements alone or in conjunction with SCADA is being developed in many organizations. A new development in this regard is to perform state estimation in phase coordinates, rather than using positive sequence estimation. Protection and control using WAMS is also being developed by many organizations, and some of those research results are reported in this book.

We have clarified many sections in this book which we hope will make our ideas clearer.

A particularly beneficial feature of this revision is that we have been able to draw upon the latest work done by our colleagues. Instead of paraphrasing their work

ourselves, we invited them to make direct contributions to this book. Three colleagues and friends have made such contributions, which have been attributed to them at appropriate places in this book. Dr. Anamitra Pal, a former graduate student at Virginia Tech, has contributed to several sections in this book, and in addition, he contributed Chap. 9, which deals with the advanced developments in the area of control using wide area measurement systems. Kenneth E. Martin has been leading the effort to create PMUs and WAMS standards in the Power System Relaying Committee of the Power and Energy Society, as well as the parallel effort in IEC to make the standards more precise and relevant to the evolving technology. He has contributed the new Sect. 5.6, which deals with the present state of these standards. We recognize that standards are a moving target, and they will surely be modified in the coming years as newer developments in this technology emerge. The work on the calibration of instrument transformers and estimating the transmission network parameters was originally developed by Dr. Zhongyu Wu while she was a Ph.D. student at Virginia Tech. She has continued to work in this area and has contributed to Sect. 7.6 bringing together the latest developments in this field.

We are grateful to Dr. Pal, Mr. Martin, and Dr. Wu for their important contributions to our book. We believe this has added greatly to the overall coverage of the subject.

Finally, we wish to thank many colleagues throughout the world who have used our book and have corresponded with us on questions of mutual interest. We hope this new edition of this book will continue to be of interest to students, researchers, and industry practitioners.

Wilsonville, Oregon
Blacksburg, Virginia
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Synchronized phasor measurements have become the measurement technique of choice for electric power systems. They provide positive sequence voltage and current measurements synchronized to within a microsecond. This has been made possible by the availability of Global Positioning System and the sampled data processing techniques developed for computer-relaying applications. In addition to positive sequence voltages and currents, these systems also measure local frequency and rate of change of frequency and may be customized to measure harmonics, negative and zero-sequence quantities, as well as individual phase voltages and currents. At present, there are about two dozen commercial manufacturers of phasor measurement units (PMUs), and industry standards developed in the Power System Relaying Committee of IEEE have made possible the interoperability of units from different manufacturers.

Recent spate of spectacular blackouts on power systems throughout the world has provided an added impetus to wide-scale deployment of PMUs. Positive sequence measurements provide the most direct access to the state of the power system at any given instant. Many applications of these measurements have been discussed in the technical literature, and no doubt many more applications will be developed in the coming years.

The authors have been associated with this technology since its birth, and they and their colleagues and students have produced a rich body of literature on the subject of phasor measurement technology and its applications. Other researchers around the world have also made significant contributions to the field. Our aim in writing this book is to present to the interested reader a coherent account of the development of the technology and of the emerging applications of these measurements. It is our hope that this book will help power system engineers understand the basics of synchronized phasor measurement systems. This technology is bound to inaugurate an era of improved monitoring, protection and control of power systems.

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Applications

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