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Preface to the Second Edition

2011

The primary focus of power system relaying is to detect and isolate short circuits in the primary zones that make up the power system. Correctly designing and setting power system protection systems are complex skills to master. The systems need to meet dependability, security, sensitivity, selectivity, and speed requirements to detect and separate faulted zones from the power system. Many relay engineers focus their entire careers on short-circuit protection.

It is a small wonder that many engineers find themselves in unfamiliar territory when designing and setting relaying systems for synchronous generators—where short-circuit protection is only a small subset of the protective elements that are applied. Many of the electrical protective elements are there to detect abnormal operating conditions that, if not detected, could result in extensive mechanical and electrical damage to significant assets.

Unlike most other zones of the power system where faults can be cleared by opening all electrical sources to the faulted element, a synchronous generator is a system with mechanical (prime mover, inertia), dc electrical (field), and ac electrical (power system) sources of energy. An understanding of the interaction of these various energy sources is necessary to properly protect a synchronous generator.

In 1995, the Power System Relaying Committee published 95 TP 102 *Tutorial on the Protection of Synchronous Generators* to familiarize practicing relay engineers with the principles and practices for protecting synchronous generators. In 1995, I was a relative newcomer to relay engineering and found myself very uncomfortable when confronted with protection problems relating to large synchronous generators. The tutorial was an extremely helpful tool in learning and understanding the schemes. Here was a document that distilled the concepts to a manageable level with concise articles on each subject.

Fifteen years later, the state of the art (and science) has evolved a great deal. All of the IEEE guides relating to the subject have been extensively revised. New hazards have been identified, and new protection practices for mitigating those hazards have been brought into common usage. New technologies and algorithms to improve protection that were not previously available have been developed. Microprocessor technology (in its infancy in 1995) has nearly completely taken over the industry.

For these reasons, the Power System Relaying Committee of the IEEE Power and Energy Society formed a working group to update the *Tutorial on the Protection of Synchronous Generators*. We hope that the 2011 version of the tutorial lives up to the high bar set by the original. At this time, it would be appropriate to acknowledge the authors of the original tutorial. Each of the authors of the new tutorial started from the excellent material provided by the original authors.

AUTHORS OF ORIGINAL TUTORIAL BY CHAPTER

Ch	Title	Authors
1	Fundamentals	C. J. Mozina
2	Generator Stator Phase Fault Protection	G. C. Parr
3	Field Ground Protection	A. C. Pierce
4	Stator Winding Ground Fault Protection	S. E. McPadden and T. S. Sidhu
5	Abnormal Frequency Protection	E. C. Fennell and M. Bajpai
6	Overexcitation and Overvoltage Protection	K. C. Kozminski, W. G. Hartmann, and S. E. McPadden
7	Voltage Transformer Signal Loss	J. D. Gardell
8	Loss of Field Protection	M. V. V. S. Yalla
9	Out-Of-Step Relay Protection of Generators	D. W. Smaha
10	Current Unbalance (Negative-Sequence) Protection	P. W. Powell
11	System Backup Protection	P. W. Powell
12	Inadvertent Generator Energizing	C. J. Mozina and G. C. Parr
13	Generator Breaker Failure	S. C. Patel, H. J. King, and M. V. V. S. Yalla
14	Generator Tripping	E. C. Fennell and K. C. Kozminski

The new tutorial has been reorganized from the original, and chapters have been added. The content of the tutorial is divided into the following sections:

1. Fundamentals
2. Fault Protection
3. Abnormal Operating Condition Protection
4. Offline and Special Operating Mode Protection
5. System Design

In addition to the authors who are credited to each chapter, it is important to also acknowledge the working group members who provided technical review of each of the chapters. Their efforts helped to ensure technical accuracy and clarity of the information presented.

The working group would like to acknowledge the professional editorial review and formatting services provided by the Marketing Communications Department at Schweitzer Engineering Laboratories, Inc. Their contributions have ensured the professional appearance of the document.

Sincerely,
Michael Thompson
Chair, IEEE, PES, PSRC Working Group J8

Preface to the First Edition

1995

In the early 1990s, the Power System Relaying Committee conducted a survey to determine how major synchronous generators in North America were protected from short circuits and other abnormal electrical conditions. The result surprised those who conducted the survey. The major results of the survey indicated clearly that the responding protection engineering population, with a few notable exceptions, appeared to have little knowledge about the electrical protection of synchronous generators. In retrospect, this response was probably not altogether unexpected. In the past ten years, utilities have built few new generating plants. During this same period, many companies have downsized. These two factors have resulted in the loss of engineering expertise in the area of generator protection.

Survey findings also indicated that despite the clear need to upgrade older generator protection schemes to meet current IEEE/ANSI C37 guide recommendations, utilities seemed reluctant to go into existing power plants to make needed modifications. This may be due to several factors: a lack of expertise, a misguided belief that generators do not fail often enough to warrant proper protection, a belief that operating procedures will cover protection design deficiencies. Also, there was little understanding of new concepts and protection schemes such as inadvertent energizing, 100 percent stator ground protection, and sequential tripping.

The response of the Power System Relaying Committee to the survey results has been twofold:

1. We are strengthening our C37 guides, which relate to generator protection, to more clearly indicate the need for the described protection and the risks of not providing it.
2. We have prepared this tutorial that we hope will provide the background necessary to better understand our C37 guides that relate to this subject and to publicize that these guides exists.

Contrary to the belief of some, generators do fail due to short circuits or abnormal electrical conditions. In many cases, these failures can be prevented by proper generator protection. Generators, unlike some other power system components, need to be protected not only from short circuits but also from abnormal operating conditions such as overexcitation, overvoltage, loss of field, unbalance currents, and abnormal frequency conditions. When subjected to these abnormal conditions, damage or complete failure can occur within seconds thus requiring automatic detection and isolation.

In preparing the tutorial, we have drawn on the considerable expertise that resides in the Power System Relaying Committee. We used a Task Force approach to write the document. The Task Force tried to focus on the needs of utility and consulting engineers who are involved in generator protection. We concentrated on those areas of generator protection our survey indicated were the most misunderstood. In many cases, we explained our C37 guides, which relate to specific protection areas. There are fourteen (14) sections of the tutorial. References, included in each section, provide even more detail.

The individuals participating in this tutorial effort have generously donated their time and effort to produce what I believe is a very valuable document. I would like to express my appreciation to all the members of the Tutorial Task Force who worked so hard to produce and edit this document in record time. I'd like to specifically thank the individual section authors. Without their efforts, this document would not have been completed. It is our hope that this effort will contribute to the better understanding of this important subject.

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