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Comprehensive Reference On Transient Protection Includes Supercaps

Design of Transient Protection Systems Including Supercapacitor Based Design Approaches for Surge Protection, Nihal Kularatna, Alistair Steyn Ross, Jayathu Fernando and Sisira James, published by Elsevier, 2019, ISBN: 978-0-12-811664-7

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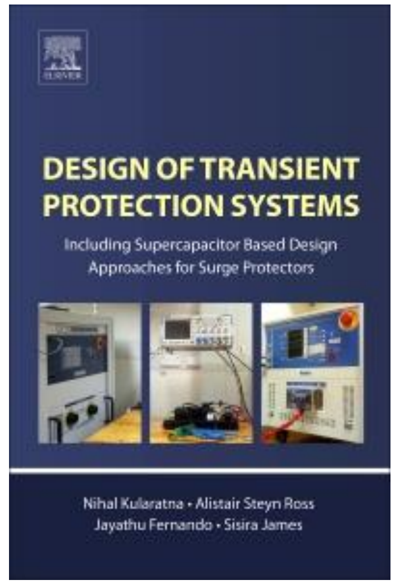


The book is composed of ten chapters and five detailed appendices. The first chapter sets the stage for the rest of the discussion and suggests the scope of the book by providing a review of the different types of transients. These include voltage surges and power line disturbances such as sags and overvoltage conditions. Lighting surges are covered in discussions with various protection devices. Supercapacitors are introduced as a new way to absorb energy. Their ability to absorb electrical energy as a protection device is presented.

This book would be useful for beginning engineers, experienced engineers as a review, and for engineers doing failure mode analysis. Transient energy paths are developed to address where the energy is diverted and absorbed to prevent damage to controllers or other sensitive electronic equipment. Here in my review, I provide highlights from each chapter.

Note that various figures and tables from the book are cited here, but not reproduced. There are simply too many to show here and the point is not so much to reproduce the data but to highlight the many useful sources of data in this book.

Chapter 1: Background To Surge Protection

Chapter 1 begins with defining the various electrical disturbances and surges. The various disturbance modes are explained and ways are introduced to analyze these disturbance modes so passive components can be used to protect sensitive circuits from dangerous voltage spikes.

Chapter 2: Surge Protection Standards And Practices

This chapter discusses standards from the International Electrotechnical Commission (IEC) American National Standards Institute (ANSI), Institute of Electrical and Electronic Engineers (IEEE), National Electrical Code, (NEC), National Electrical Manufacturers Association (NEMA) and Underwriter Laboratories (UL) as they apply to protection practices listed products.

Table 2.1 provides a summary of the surge and the surge protection device (SPD) used. Fig. 2.1 is from the ANSI/UL 1449 and the IEEE C62.41 listing the various protections needed in a home from the utility supply. Some of these topics were discussed in a December 2018 How2Power Today article, “Proper Design of the Power Supply’s Input EMI Filter Protects against Power Line Transients” (see the reference).

Three different surge waveforms are presented from the IEC 61000-4-5. These are the open-circuit voltage, short circuit current, and the 100-kHz ring wave. Table 2.2 discusses these and their levels as applied to protection that is needed.

Chapter 3: Components Used In Surge Protection Circuits

There are many components available to be used in surge protection circuits. These include carbon block spark gap, gas discharge tubes (GDTs), metal oxide varistors (MOVs), transient voltage surges (TVSs) diodes (surge-rated zener diodes), and thyristors also called SIDACs. Table 3.1 on page 39 is a summary of the devices along with their advantages and disadvantages.

Chapter 4: Supercapacitors For Surge Absorption

Supercapacitors are introduced as a new concept for absorbing transient voltages and currents. Backup data is listed in Appendix A and is an IEEE Transactions on Industrial Electronics, Vol. 58, October 2011, pp. 4942-4949.

Supercapacitors are able to absorb large amounts of energy and keep the IC supply voltages to a safe level. Data is presented comparing actual results as compared to simulations. Table 4.3 presents a summary of the supercapacitor manufacturer's data to failure using the surge tests applying the 6-kV 8/20-us waveform.

Chapter 5: Characterization Of MOVs And TVS Diodes

A main component used for transients is the metal oxide varistor (MOV). The MOV has a curve for the break down voltage at different currents. A mathematical model is created and values applied to commercial MOVs. The data was plotted using equation 1.

$$I = K_1 V^{\alpha 1} + K_2 V^{\alpha 2} \tag{1}$$

where I is the surge current, K_1 is model parameter, K_2 is model parameter, α^1 is the "off" model parameter and α^2 is the "on" model parameter.

Fig. 5.15 plots data and compares the results to actual test data. These results are used with MATLAB simulations.

Like the MOV, similar results are presented for transient voltage suppression (TVS) diodes. The TVS diode has a narrow voltage-breakdown range. The TVS comes is two different models. One is a back-to-back model and the other is a unidirectional model.

The back-to-back version is called a clipper, has a suffix designation as CA, and is useful for ac line applications. The non-C version is a single-ended type that is useful on power supply voltage rails.

There are many TVS devices used in the automotive industry. These are used for the automotive load dump. The book does not directly cover automotive applications. However, the information contained can be applied to the automotive transients seen in vehicles.

Chapter 6: Investigation Of Surge Propagation In Linear Systems

Transient propagation can be analyzed by using a linear network model. This process uses Laplace and Matlab simulations. Appendix C shows the calculation using Matlab. SPICE simulation was not fully developed. Many engineers have access to SPICE but not Matlab.

Chapter 7: Investigation Of Surge Propagation Through A TVSS

Chapter 7 looks at mathematical models of both an MOV and a TVS diode through simulations at a system level. These are models and not fully designed systems with other parasitic components. Model verifications are inspected compared to simulations for the various parts of the system. Appendix D is where the state equations and Matlab code are located.

Chapter 8: Design Of Surge Protectors With A Practical Approach

In a practical approach to designing surge protectors, a number of surge waveforms are presented to a simulation test. The results are verified using a Noise-Ken piece of test equipment. Table 8.3 is a summary of the test and waveforms between the input and the output of the input filter system.

Chapter 9: Development Of The Supercapacitor-Assisted Surge Absorber (SCASA) Technique

The common-mode input filter is the first and most popular filter in many pieces of electronic equipment. In this chapter, LT Spice simulations are presented to do the simulations. Tables 9.3 and 9.4 are presented with the results comparing the number of components and energy level the filter could absorb.

Chapter 10: Application Of Surge Protection Systems

This last chapter applies the UL 1449 and IEC C62 standard to protection of a household system. The fundamental concepts of lightning are applied to the system. In addition other items like electrostatic discharge (ESD) are discussed concerning machine, direct contact and human body models and the standards being applied. One application area that's presented is the controller area network (CAN) and the solutions not applied to protect the microprocessor from ESD events.

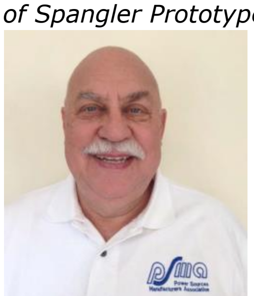
One area not discussed is automotive load dump in vehicles. This area of automotive transients is still progressing and newer standards are being considered. This is where the Society of Automotive Engineers, SAE, working across the various manufacturers has weekly and monthly calls to discuss the type of voltage and approaches to use to deliver safe and protected products to the consuming public.

Reference

"Proper Design of the Power Supply's Input EMI Filter Protects against Power Line Transients" by James Spangler and Kevin Parmenter, How2Power Today, December 2018 issue.

About The Author

Jim Spangler is a Life Member of the IEEE with over 40 years of electronics design experience and is president of Spangler Prototype Inc. (SPI). His power electronics engineering consulting firm's priority is helping companies to place products into production, assisting them to pass government regulations and agency standards such as UL, FCC, ANSI, IES, and the IEC.



For many years, he worked as a field applications engineer (FAE) for Motorola Semiconductor, On Semiconductor, Cirrus Logic, and Active Semiconductor, assisting customers in using semiconductors. He published numerous application notes and conference papers at a variety of conferences: APEC, ECCE, IAS, and PCIM. Topics included power factor correction, lighting, and automotive applications. As a FAE, he traveled internationally giving switch-mode power supply seminars in Australia, Hong Kong, Taiwan, Korea, Japan, Mexico, and Canada.

Jim has a master's degree from Northern Illinois University (NIU) and was a PhD candidate at Illinois Institute of Technology (IIT). He taught senior and first-level graduate student classes: Survey of Power Electronics, Fields and Waves, and Electronic Engineering at IIT and Midwest College of Engineering. Jim is a member of the IEEE: IAS, PELS, PES; the Illuminating Engineering Society (IES), and the Power Sources Manufacturers Association (PSMA) where he is co-chair of the Safety and Compliance Committee.

For further reading on power supply-related safety and compliance issues, see How2Power's special section on Power Supply Safety and Compliance.