ZARK BEDALOV

PRACTICAL POWER PLANT ENGINEERING

A GUIDE FOR EARLY CAREER ENGINEERS

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A Guide for Early Career Engineers

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Vancouver
BC, CA

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Preface – Why This Book?

This book is a result of 50 years of practical experience from working in a number of industries with ever-changing technologies and by associating with many experienced engineers; electrical and other engineering backgrounds.

Starting as an engineer is not easy. You are facing a big transition. I'm certain this book will help get you through the most critical phase of your development as an electrical engineer and make you the confident and knowledgeable professional that you wanted to be when you decided to be an engineer.

There are a lot of books on the market explaining the theory of electrical engineering, but there are no books on practical engineering and experience. There used to be the old Westinghouse (now ABB) TD (blue) Book and Donald Beeman, General Electric Co. 1955: Industrial Power Systems Handbook, both of which I have proudly used as a young engineer. Both books now seem to be largely outdated. Computers have taken over much of the handmade calculations.

The information contained in this book is by no means all encompassing. An attempt to present the entire subject of practical electrical engineering would be impractical. However, this book does present guidelines to provide the reader with a fundamental knowledge sufficient to understand the concepts and methods of practical design and equipment selection and operations.

The first hint of a book came in Venezuela. After three years on a job with a local engineering company heading the engineering department, I decided to move on. The boss called me with a special request, saying: "Please stay on for another 3 months and write a book on how to do electrical engineering. You seem to do this work with a lot of common sense. I thank you for your help in leading and teaching our younger engineers. So, stay on, please."

The above dialog happened three years after seeing the movie Papillion (1978) filmed in Venezuela with Steve McQueen. The day after the movie, I fell into a snowy ditch somewhere north of Toronto. I had to leave the car and walk alone in the snow for a couple of hours in a total whiteout. A day later I spoke to my wife, we were going to Venezuela. Both of us loved the tropics and had it enough of Canadian winters.

Einstein: Theory is when everything is known but nothing works.

Experience is when everything works but no one knows why.

When we join theory and experience nothing works and no one knows why.

We quit our jobs, sold everything, and went to Caracas. "How smart was that," I heard it many times? Once in Caracas, I left my resume with six major engineering companies and then we went to a beach. Two weeks later, we returned to the Hotel Sabana Grande in Caracas. The owner said that I had many calls. I had five job interviews and took a job with a company that had a contract to build a 4 × 400 MW power plant. They badly needed an experienced electrical engineer. At that time, I had about 10 years of experience with a great company called Shawinigan Engineering from Montreal, Canada. That company was later taken over by SNC-Lavalin, Inc., my last employer.

Three years later, after the plant was built, I told my Venezuelan boss that I enjoyed it greatly, but I gotta be moving on. I moved on to Riyadh, Saudi Arabia. It was 1981. It seemed I was at the right place at the right time. There was so much going on in Saudia. At that time, some large generation existed in the Eastern province for oil production and barely in the cities of Riyadh and Jeddah. We began the electrification of the country in a major way. After Saudia, I went to several other international posts with companies like Fluor and Bechtel. Finally, I ended up with SNC-Lavalin for the past 17 years as a commissioning engineer. That makes it a total of 50 years as a lead design and commissioning engineer for power plants, heavy industrial plants, and power systems. Of that, 10 years were as an independent engineer on my own.

In the years after Venezuela, I often lectured younger engineers on many engineering issues and had discussions with companies to create a manual that would help their electrical engineers to follow and practice good engineering. It took a while. Finally, in 2015, I agreed to do a book. It took me one and half years to complete a draft copy. Now, it is here in your hands.

As an experienced electrical engineer I have noted huge obstacles young engineers were facing to become experienced engineers. I'm not talking about civil or mechanical, but electrical engineers. Let me explain. For mechanical engineers, everything is visible. Here's a pump, pipe, valve, filter, and strainer. All of it, recognizable objects. What's on the drawing is what you see in the real life. Open a valve and water or oil flows. You see it, hear it. If it leaks, you see it and you replace a gasket or clean a clogged filter.

Electrical engineers, however, in the same environment face an invisible world. Some call it "The mystery world". You may be able to recognize a few pieces of equipment from the drawings, but this is not what matters. In the electrical engineering, it is what you don't see that matters. If something goes wrong, you don't know which way to look. There are no electrons anywhere to be seen? Where do you start? Well, the first several years will be difficult, but with some experience and guidance, you start seeing the invisible. One young engineer told me that he came to his first job interview ready to solve a bunch of differential equations, but all that school teaching didn't seem to matter.

It is clear that mechanical engineers have a head start in the plants and the plant designs. Right off the bat, they are confident about themselves, of what they are seeing, doing, and learning. They will eventually become project managers and will boss the electrical engineers. I have seen this over and over again, anywhere in the world. Young mechanical engineers talk job immediately with confidence and are liked by the bosses because they talk the same language. Meanwhile electrical engineers are fearful to ask questions or suggest anything. They struggle for years. The bosses seem don't know how to talk to them.

So, while our mechanical engineering colleagues confidently talk about the things they do, and advance in their experience and carriers, we the electrical engineers appear shy and aimless, struggling in the world that has no resemblance to what we studied so diligently for many years.

Even the language is different. Here come buzzwords. Everyone uses buzzwords and most of them you don't understand. If that is bad enough, it gets even worse. Young mechanical engineers appear to be smarter. They seem to be learning faster every day in their *visual* world. As they say, a picture is worth 1000 words. On the other hand, a young electrical engineer gets very little visual information and thus retains less. Mechanical engineers are immediately immersed into the overall (big) picture of the plant, while the electrical engineers are pinned down to look at details.

Without an experienced engineer to explain things and to guide him, a young electrical engineer is lost. It would help if he only knew the questions. Not even that. He goes home after work and wonders: What is the reason for having me there? Will I ever be useful?

Let me give you an idea what happens on your first day on the job. You graduated from a difficult faculty of electrical engineering. It was tough and struggle, but you studied hard and endured, and felt you were on the top of the world. The world is yours. What a great feeling of accomplishment and exuberation that you can do anything.

Then you start looking for a job, and soon realize that the world is not all yours. The employers are not looking at your grades but at your experience, of which you have not much to show for. You cannot choose your job and will be happy to take anything that comes along. Finally, after three months of job searching, an engineering company was willing to give you a try.

You will be working on a new project. On the first day, you are introduced to your colleagues from all the disciplines and given a lot of drawings and reports to read. The material is mostly process and mechanical, to give you an orientation of what the project is all about. You were also told to talk to everyone and ask any questions you might have regarding the material you were reading as well as to acquaint yourself with the things the others were doing.

Then after a month of "doing nothing" your lead electrical engineer gives you for instance a couple of tender documents for a 10 MVA transformer just received from the bidders. One is for a transformer with 8% impedance and the other with 9.5%. The first one is more expensive than the other. The Lead tells you to evaluate the cost benefit of one over the other and if you have any questions feel free to ask. Since you were a junior engineer and need a bit of a help, he reminds you that the larger impedance causes more Watt and Var losses and higher voltage drop, while the lower impedance allows for higher fault level on the downstream bus, which may force the project to use more expensive equipment.

Wow, what now? That day back at home you look through your text books and find nothing relevant to help you out. Well, of course not. The text books tell you about the transformers and the transformation in general, but nothing specific for a particular application. That may be the last time you looked at your school books.

This actually is your first day at work. Remember that exuberating feeling when you graduated? You could do anything? Well, your Lead lowered you down to the real world. Now you feel hopeless and lacking confidence. You start asking questions all around and gradually acquire some knowledge but you are still far away from being able to decide which transformer to recommend. Fortunately, your Lead had already made that decision. Of course, he wouldn't let his junior engineer to decide on such an important matter. He just wanted to test you on how you think, how you formulate your questions, and how you deal with the engineers around you.

Welcome to the job. It'll be tough and it'll take time. All of us have started like this. You'll be doing fine if you immerse yourself into the project and start building up your practical experience over several years of working with experienced engineers on a variety of projects. This also includes those of other disciplines to learn what is important to them and how to select the electrical equipment to drive and automate their equipment. This real world book will help you get there.

This book is a result of 50 years of design and field engineering by experienced engineers and teaching others to do the same. As an experienced engineer with acquired practical knowledge, I'm ready to share it with the new coming engineers and lead them through a transition for which there is no blueprint or book, until now. This book provides useful information as a reference guide for all the electrical engineers. It fills the gap between the Academia and being an experienced engineer. If you read this book, you will learn a half of it you need to know and all the proper questions you should ask.

Hopefully this book will spawn others to write books. Your first job is a step into the open, away from your school. As soon as you start reading it, you realize this is a different world and it won't be easy. I agree, it won't be easy, but this unique book in your hands will give you a kick start, help you interact with other engineers and understand what is going on in the design office and in the field around you.

Why not searching on Google? Yes, there is plenty of this stuff and hundreds of answers on the internet. Well, if you only knew what you were looking for and had knowledge to properly assess it for your application? Without proper feedback, you don't know what is right and what is wrong and how to resolve doubts. "The Internet often seems to be a source of befuddlement rather than enlightenment," as Gregg Easterbrook eloquently put it in his outstanding book "Sonic Boom." This book gets straight to the point of what you need to know.

It's not an easy task to cover all the electrical engineering activities into a single readable 500+ page book. Many chapters would require a book by itself. The goal was to summarize the engineering activities and to direct the reader onto the right path and base from which he (she) can build experience needed to make proper engineering decisions. Everything in it, this author has experienced and then confirmed through commissioning and discussions with other engineers.

The theory is essential. It forms your basic knowledge fundamentals. The fact is this; our professors teach us to become professors. That's fair enough. The best students in our class became professors. An engineer you become with practical experience by associating with other engineers, facing multiple engineering applications and problems, making mistakes and reaching accomplishments.

Recently, I spoke to a professor about Variable frequency drives (VFDs), Chapter 15. I was telling him how I use them to regulate the plant flows on demand so I can employ smaller storage tanks, etc., while he was talking about flux vectors inside the rectifiers. "I'm not trying to make rectifiers. I'm just applying them for various useful plant applications," I told him? That's the difference. Because of this issue, many engineering schools are changing. Nowadays, students are forced to work between the semesters. Students are telling me that it's a hard go, as it is not easy to land summer jobs as unfinished engineers.

If you happen to get a job with a manufacturer, your life may be a bit easier. You will be trained for a specific job to work on some electrical equipment, such as improving a lightning arrester, rectifier, or a grounding switch. Soon, you will notice that designing a piece of electrical equipment is mostly of making it smaller, cooler, and with different materials. Then, you also realize that the job is 10% electrical and 90% mechanical engineering, and start wondering: "Is that it?" Well, maybe you'll like it. I didn't.

I graduated with a diploma on power transformers. My first job for two years was mostly how to make better cooling for transformers. I worked on hollow conductors for cooling water passing through them. There was nothing electrical about that. Why didn't they hire a mechanical engineer to do that, I wondered? On the other hand, if you get a job to design power systems for various plants it's a different story. It's an electrical story.

So, between you and me, I had enough of mechanical engineering and them taking advantage of us and bossing us around by saying; "I was not smart enough, so I went into mechanical engineering." I heard that line a lot. With this book, I want to even out the playing field and help you young electrical engineers stand your ground, be productive, and contribute almost immediately.

One of my first job interviews was at Toronto Hydro. An engineer showed me a picture and asked me if I knew what it was? I saw six bushings and said that it was a transformer. I was wrong. It was a high voltage oil circuit breaker. I failed that job interview. I should have known that a breaker had six identical insulators. Transformer has 3 + 3 unequal bushings.

I moved on, looking for my first job in Canada and ended up at Pinkerton Glass for a job interview. A secretary gave me a test sheet to fill in before meeting an engineer. The sheet said "Practical test for electricians." I filled it up as best as I could, guessing on a half of it. I failed that one too. None of those famous differential equations could have helped me. It was so bad; the Engineer didn't even waste his time to see me.

Many years later I was already an experienced engineer. Our company, Fluor, had a project with the Xerox Corp. in NY State. As a lead electrical engineer I was invited to visit the plant and scope the work for adding a new ink toner line to the existing plant. We started touring this large plant. As an electrical engineer I prefer to look first at the plant overall one line diagram. This is the Chapter 2 in this book. Having acquired the big picture, then I visit the plant and observe it from my electrical perspective. Well, anyway, we started touring as soon as I got there. The mechanical engineer, my tour guide, looked at me and said: "You are an electrical engineer, right?"

"Yes, any problem with that," I answered jokingly?

"No nothing, but, let me pass one by you. Here we have a problem," he started talking. "We've been struggling for 2 years now with it. Occasionally, we have light flickers in the plant. It happens suddenly and then nothing for a few days and then again. The whole plant flickers and then everything is back to normal. Do you have any suggestion what that might be," he asked?

"I really don't know. It can be anything," I answered. "Does it happen at night or day, high load, low load," I inquired? Suddenly, I realized I was in an invisible world of electrical engineering.

"Well, I agree," the plant engineer said. "It's unpredictable; anytime. We checked it with the local utility. They said that it must be something internal within our plant as they don't experience flickers on their system."

"If I were you I would look at the main transformer since the whole plant is flickering. It may be coming from there," I said. "Otherwise, you may have to shut down the plant and megger all the major electrical equipment, starting from the incoming transformer."

"Hmm, I'll mention it to my electrician," he answered.

So much for that, I thought. We continued touring and got into a rather noisy room. My guide pointed to their 2000 HP, 5 kV compressor, the biggest drive in the plant. I came closer to the compressor and spotted a drop of oil below its big cabinet on which it read: “Surge Pack.” I told him that there was no reason for the oil to be on the floor here and suggested that if he wouldn’t mind we open the cabinet.

“Don’t worry about the oil, I’ll call our cleaning staff to clean it up,” my tour guide mentioned it somewhat embarrassed. I insisted and we opened the cabinet. Inside it I saw more oil, obviously leaking from the surge capacitor. I turned to him and said: “This may be your source of flicker. The capacitor is leaking and occasionally breaks down and creates a brief short circuit to discharge itself.”

Weeks later, he called me and thanked me for the discovery. They replaced the capacitor and, thank goodness, resolved the issue. I wrote back to him, “We were lucky to be in the room before the cleaning lady had a chance to remove the oil drop. Please don’t fire that lady.”

In the invisible electrical world, you often have to be lucky.

Read this book and practice it. If you have read it and understood 80% of it, you don’t need more schooling, though it would help. Not even calculus. I have nothing against math. I was pretty good at it. Nowadays, since the use of computers for power system studies, the highest level of math I have used was $\sqrt{3}$ and cos ϕ on my calculator. True, I have been using “per unit” a lot in my conservative short circuit fault calculations, though. Most of all, I needed know how to prepare estimates for various project options and calculate percentage power losses or voltage drops in power lines. And, of course, it was always important to be able to answer questions right on the spot during the project meetings with the project owners.

This book will not make you an expert on any of these subjects. For that you will need a lot of experience and hopefully some good mentoring. But it will give you a good start and capability to discuss the subject with some confidence and ask good questions during your job interviews. With this knowledge, you can start your job from a solid base, rather than starting from nothing.

Hopefully, this book will point to you the path on how engineers think in planning and resolving the problems and the basic elements of the engineering considerations; scope of work – big picture, engineering tasks, economics (cost of equipment and production), reliability, and automation requirements.

A few more notes.

As a junior engineer, I grasped from other engineers the concept of looking at the big picture, and what matters, while leaving other things for later. These are likely to change anyway, so why bother thinking of them now. Looking at a big picture means developing a design criteria for all parts of the project right at the start, such as, determining the short circuit levels (by computer) at various plant busses, allowable voltage drops, outage contingencies, big motor start, etc. Then, I develop overall key one line diagram. Once I have done that and have it on paper, I have my base and reference and talking points for everything that fits inside. It’s not frozen in concrete. I can adapt it as I go along. If you do this once, you can replicate it again and again on other projects, based on the clients' requirements and new requests, capacity of production and levels of automation and security demanded.

Most employers do look for individuals who talk in terms of looking forward and grasping the whole concept of the project. One day at SNC-Lavalin, I had a chance to see my file they made after my job interview and it read, "Impressive view of looking at big picture."

Also, as a beginner engineer, I was once interviewed by an American company. In their books of potential candidates, next to my name was written: "Capable of looking and seeing a bigger picture. Hire him, when opportunity comes up." I heard that little jewel from a head hunter who called me up and offered me other positions. Head hunters dig out their information from their contacts in the HR (Human Resources) of the companies they deal with. I was not born with it. I looked up to and learned it from other engineers who had impressed me.

When you do your work, share it with others. Be a team worker to be able to succeed in this type of work. There are other disciplines involved on the project and often you will find out something that will help you make a proper decision or make a modification you didn't notice before. So, be a team player. Then, when you are done with an assignment, tell your boss that you are done. He loves to hear that. If you are holding it back, soon it will be noticed. Bosses like to hold onto their best producers and keep them busy.

When you are finished with your assignment, tell your lead engineer to give you feedback. Don't be afraid of his review. Don't work in isolation. Share the ownership of your assignment with him. Involve him as you work on it. He will appreciate that. Besides, he is likely far more experienced than you are and experience is what counts in electrical engineering. He may have a different approach for certain parts. Broaden your thinking, evaluate his input and implement it if beneficial and more economical.

Always show interest. I was always curious. As a kid I wanted to be an engineer. Being a medical doctor also crossed my mind. Later on I realized that being a doctor would have been a mistake. I was not made for it. I function by logical thinking. I don't want to learn anything by heart. I learn and gain experience through logical interaction. Most of it was by observing and listening to others. Being interested puts you in front of the events. Many a time I was sent to investigate a situation about which I had not a clue. Nobody else on the project had a clue either. So, others rejected it and declined to be involved. I always went for it, tried my best and most of the time I found solutions.

Enjoy engineering. This has been your biggest investment so far. Go for it.

Vancouver, BC, Canada
16 June 2019 *Zark Bedalov*

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The first three I knew as experienced electrical engineers who readily shared their valuable experience on me and other young engineers. The forth one was a junior engineer just like me when we worked on some power projects. He took great interest in the grounding issues on the projects. Then he wrote the first computer program to calculate the substation grounding requirements. If one searches on the net anything to do with grounding, his name will appear as one of the greatest authorities in this area, including on so many IEEE papers.

About the Author

Zark Bedalov explains that as a kid he was always intrigued by electricity. He would turn a light switch on and off for hours and observed the light to come on. If the switch sparked, that intrigued him even more. There was no one there to explain to him what was going on in the wires. In his early school days, he was punished for smashing a capacitor to pieces for trying to see what was inside. A lot of greasy paper was inside.

He graduated at University of Electrical Engineering, Zagreb, Croatia, in 1965. Also, attended some master degree studies at the University of Toronto.

His first job was in a factory for power transformers. Soon he realized that making a transformer is 90% mechanical and 10% electrical. That was not what he was expecting. So he skipped over the border to Wiena, Austria, and arranged for immigration to Canada. Finding a job in Canada was not easy, in particular if you are an engineer. Being an engineer comes with responsibility and that requires "Canadian Experience." It took him about six months to start as a draftsman on mining projects. Had a lot of support from many senior engineers and three years later was certified a "Professional Engineer."

From thereon, Zark was in his domain and in demand. Early on, he changed companies every three to four years to learn more. He worked for almost 50 years on large projects, power plants, and heavy industries, all around the world, employed by major international engineering companies, such as Bechtel, Fluor, Atomic Energy of Canada, SNC Lavalin, and often independent, teaching along the way and enjoying the work and life. Now retired, he writes on electricity and teaches young engineers on how the electricity makes the factories and power plants function.

1

Plant from Design to Commissioning

CHAPTER MENU

1.1 Planning

The electrical power distribution systems have to be designed to fit the plant electrical requirements. The power systems must be well planned, considering the technological process, cost, reliability, maintenance, control, operating flexibility, and future growth. Furthermore, the undertaking must take into account

Practical Power Plant Engineering: A Guide for Early Career Engineers, First Edition. Zark Bedalov.

the safety of people and equipment, continuity of power supply, installation, and operating costs.

Electrical engineers' responsibility is to prepare design criteria and single-line diagrams, power system studies, calculate fault currents, locate load centers within the plant, estimate load diversity, select the grounding system, define the routes of overhead lines, prepare plant layouts, and develop the electrical protection system, all of it to suit the plant location and the prevailing standards. Furthermore, he/she must procure the equipment and participate in the plant construction and commissioning.

The basic concept for a single-line diagram representing the *power plant* power distribution is generally established by the utilities. The main engineering effort is on implementing the power system around the generating units. Depending on the generator unit MW size, a decision will be made on having generator breakers next to the generators or employing high voltage (HV) breakers instead, in the switchyard to serve as the unit breakers for the generator/transformer groups. That is one of the most significant factors that define the overall concept of the diagram. The power plant station service generally uses less than 5% of power of the generator MW rating, thus, the one-line diagram for a power plant is relatively simple in comparison to the industrial plants (see Chapter 18 for more details).

One-line diagrams for industrial plants vary significantly from industry to industry. The load is fully distributed around the various operating activities, such as crushing, grinding, mixing, drying, pumping, batching, each of which requires a considerable engineering effort and decision making process to arrive at an optimal economic diagram that can be scaled and readily expanded in the future.

This book is written in 26 chapters to cover all the technical aspects of electrical engineering and to transfer practical experience onto young electrical engineers. In order to present it in a meaningful way, the book explains the technical details around a fictitious, though realistic power plant and industrial projects. An industrial project offers a greater variety of requirements and lends itself better for practical analysis.

This analysis can be applied to other plants that use similar electrical equipment, such as transformers, motors, generators, variable frequency drives (VFDs), cables, switchgear, overhead lines, fire protection, control systems, grounding, lighting, etc.

The project is commenced by an investor (company) who have decided to build a power or an industrial plant (cement factory, steel manufacturing, oil refinery, wood mill, plastic cups, fruit canning, etc.) on a particular location for a particular operating capacity (produced MW, tons of cement, tons of steel, tons of paper, tons fruit, etc.).

The investor company had already prepared a rough estimate proposal for a project with a simple budget estimate of ±40% accuracy and had received

Project development steps

Owner	Initial feasibility study → 40% Estimate → Bank
Engineer/ owner	Conceptual design → 20% Estimate for bank loan Review of process alternatives Eng. drawings: flow, P&ID, one lines, based on projections procurement of major long lead equipment
Engineer	Detailed design based on actual procurement engineering specifications and drawings procurement: mechanical, electrical and control site construction of infrastructure
Engineer/ contractor/ engineer	Project construction Civil → mechanical, Electrical, controls Precommissioning: individual equipment commissioning: system by system
Contractor/ owner	Release to production ownership and production

Figure 1.1 Project development.

positive indications of financing from a bank to develop a feasibility study and a more detailed cost estimate. Figure 1.1 shows the steps of the project development.

From the electrical power system perspective, the first step is to review the project flow diagrams produced by mechanical engineers and on that basis prepare electrical design criteria and develop a **key one-line diagram** (see Chapter 2). The key one-line diagram will envelop all the process facilities within the plant starting from the power source down to the individual equipment users and services. This is followed by preparing a (±20%) budget cost estimate as part of the conceptual design inclusive of the cost for engineering and construction and then present it to the bank to secure a loan.

1.1.1 Plant Design Procedure

Plant design is a joint effort by multiple engineering disciplines: process, mechanical, civil, electrical, architectural, structural, estimating, scheduling, procurement, document controls, and project management. Every department is doing its work in strict coordination with others to insure everyone is "on the same page" and that nothing falls "between the cracks." Lead engineers of all the disciplines are on the email circulation of everything that is happening on the project to insure all the design decisions and project changes are being communicated and implemented, both "vertically and horizontally" through the project organization chart. Regular meetings are held on a weekly basis to assess the progress, critical path schedule, any design changes, manpower shortfalls, and any delays in design, procurement, fabrication, and installation and their impact on the project schedule. Design options and temporary measures are being reviewed to overcome the delays in the equipment deliveries and/or equipment failures.

1.1.2 Codes and Standards

The publications listed below form a part of this book. Each publication shall be the latest revision and addendum in effect at the time of issue of contract and design specifications, unless noted otherwise.

ANSI	American National Standards Institute
CSA	Canadian Standards Association
IEEE	Institute of Electrical and Electronic Engineers
IEC	International Electro-technical Commission
ISA	Instrument Society of USA
ISO	International Standards Organization
NACE	The Worldwide Corrosion Authority
NEMA	National Electrical Manufacturer's Association
NEC	National Electrical Code
NFPA	National Fire Protection Association
UL	Underwriters Laboratories of USA

Standards, codes, and guidelines listed above and referenced in every chapter of this book are widely used by the engineers in the industry, both as directives and guides. When working in another country, the local standards must also be applicable. This book refers to and often presents data courtesy of these engineering standards, which are considered one of the major sources of guidelines and good engineering practices for engineers.

The standards and codes are extremely important. Actually, there are three parts to your success as an experienced engineer:

(1) Understanding the applicable standards and knowing how and where to apply them.
(2) Referring to the suppliers' equipment catalogs and reviewing the graphs and performance data sheets to determine the proper equipment ratings and supplies for your specific applications.
(3) Building experience by field reviews of the equipment performance and its related hardware.

1.2 Project Development

1.2.1 Type of Project

A typical project referred to in this book is an ore-bearing property, owned by an investor, which according to the exploration figures contains a large ore body of Cu/Zn ore. This can equally be a mining property of coal, silver, and gold, or it may be a brewery batch plant or a large harbor development.

On the power industry side, this may be a hydro development project, for which a catchment area is defined and dammed to create a head and estimate the flow of water that can be controlled from the area. The electrical part of the project, though large, is relatively small in comparison with the huge civil infrastructure required to be built. Utilities typically take ownership of these large projects.

1.2.2 Conceptual Design for Feasibility Study

If the project gets a go ahead by the investment partners, the investors or their bank will provide initial funding to engage an engineering company to investigate the project a bit closer. There are a number of different engagements possible between the owner and the engineer that can be employed. That may be a subject of another book.

The project team with all the engineering disciplines has been given an assignment to develop conceptual drawings and budget estimate. The conceptual design includes plant layouts, load flow diagrams, electrical design criteria for all the electrical activities and equipment, a key one-line diagram, and a reasonable accurate capital cost estimate to be presented as a "bankable feasibility study." This document will also serve as a basis for the future detail engineering design to build the project, should the project proceed further.

The design calculations in this conceptual study will use the system and equipment characteristics from previous projects similar to this one to generate the design parameters for the new project. The budget estimate is obtained from the various budget quotations, previous projects, and earlier work done in the country of the project with their labor rates.

During this three to six months of engineering phase, some major long lead mechanical and electrical equipment may be ordered on the basis of a possibility of cancelling the orders if things don't "pan out." The electrical lead equipment may include the main transformers and HV switching equipment.

The flow diagrams show the flow of the ore, through the various plant processes, including additions of other ingredients: water, heat, and fuel to process it and take it to the final product. In this case, the final products are bars of

Cu and Zn. Where there is Cu, there is a chance of minor percentage of gold, while silver is never far off from a deposit of Zn.

From the electrical design perspective, design criteria, major cable routing, and one-line diagrams will define the shape of the plant power distribution and other aspects of the electrical equipment and plant operation.

1.2.3 Detailed Design

Detail design will follow the conceptual phase. This "detailed" phase may last anywhere from 9 to 18 months for an industrial plant or two to four years for a power plant, depending on the type of plant. The conceptual drawings will be reworked and expanded. Procurement phase will commence by preparing the purchase specifications to specify equipment performance requirements and also to make the interface diagrams to tie up with the related mechanical equipment. Often, the electrical design may have to wait a while for the mechanical design to near its completion and their suppliers' drawings are in hands to determine the electrical ratings and the interfacing connections needed.

The first effort will be to update the electrical plant design criteria and the key one-line diagram from the conceptual design phase. These two items are your two big pictures, and the foundations for everything else you plan to build on.

System studies: The detailed design will present final one-line diagrams with the actual impedances and equipment characteristics. It will use the data based on the results from power system studies: load flows, motor start, voltage drops, phase and ground short circuits, arc flash, insulation coordination, and step and touch potential. The studies will determine more precise and factual system characteristics and prove that the selected equipment ratings conform to the requirements set out in the design criteria. For these calculations, we will use the software from various system houses, such as Easy Power, ETAP, Cyme, and others. The plant data will be laid out on a computer and let the computer do the math. Not only that, the computer teaches you the power system functioning. One can introduce changes and alternatives and then observe the impact of the changes on the power system performance. It allows you to select the optimal solutions.

Interfaces: At this time, schematic and wiring diagrams for all the motors and valves, cable lists, and plant layouts will be prepared.

One of my bosses once told me: "Project usually fails at the interfaces." He was right. The projects require a huge effort by many personnel working on the project, ranging from secretaries to the managers. Possibilities of errors are ever-present. The interface changes may be due to a late design modification initiated by other engineering departments. If not well communicated and reconfirmed, the changes may not get on the drawings. This applies also for the communications between the engineering departments, the suppliers, and fabricators. If the equipment arrives to site with incorrect connections, it will lead to a lot of confusion on site, "throwing blame around of who said what, and so on." This is where the experience comes in from working on large projects and by recognizing how the equipment is supposed to work and how it relates to the other equipment. Experienced engineers would notice problems if incorrect drawings cross their desks.

Every discipline can use approximations, add (+) or delete (−) a few inches or feet here and there on the drawings. The electrical engineers have no such a benefit. We have to produce drawings that match the equipment perfectly. Electrical drawings show several hundreds of thousands of wires, power, and controls interfacing between the various electrical and mechanical equipment. The only grace we get is that we can bend the plant cables around in the cable trays.

You may have done your job to perfection, but unfortunately, when you come to the construction site, you may face some disappointments. You will notice the supplier's actual equipment does not match the drawings you received to prepare your diagrams from. The suppliers have just got confused and sent you drawings they had engineered for a previous customer, or they had made changes but failed to inform you.

Do not panic now. This is something to get used to. It happens. Once the wires are connected, you may notice different problems stemming from errors, suppliers' incorrect designs, and of course, the wiring errors. This is where pre-commissioning and commissioning comes into play to make sure everything is properly tested and made to work as intended.

Everyone can make mistakes. Let us be honest about it. Even mechanical engineers can make a mistake here and there. But there is nothing like what the electrical engineers face. Thousands and thousands of wires are laid out in the field, and each one must find its proper place or it may turn out to be a major mistake and error, which will have to be troubleshooted later during the plant commissioning. Fortunately, with the advances in technology, a half of wiring in the modern plant is now replaced by communication cables, coax, a pair of wires, etc., carrying thousands of signals which can be shaped and configured as part of the plant control system. But that is another story. That certainly is a wiring relief, but our problems will now likely resurface in the software during commissioning (see Chapter 17).

You as an electrical engineer will prepare or work on the following drawings and documents:

- Equipment and installation specifications.
- *System studies*: Load flow for voltage drops, short circuits for the equipment ratings, large motor starts, and relay coordination.
- One-line diagrams.
- Design criteria.

- Layouts for electrical equipment, lighting, cable trays, load Lists, cable schedules and terminations, embedded grounding, equipment grounding, lightning, and power corridors.
- Prepare schematic and wiring diagrams for each motor, valve, and feeder,
- Review of civil, mechanical, and instrumentation drawings.
- Review of suppliers' drawings, and more.

That is a lot. A project of this magnitude may require thousands of electrical drawings and hundreds of documents.

1.2.3.1 Cost of Change

At the project meetings, you will note that the design is still open to changes. With the design criteria and key single-line diagram in hand, you will be discussing with your civil, process, and mechanical counterparts on what is possible and reasonable and what is not, and what will cost "an arm and a leg" and what may be a more reasonable option. The developer may suddenly decide to add another process line in the plant, which may stretch your "almost finished" power distribution system or completely change it. Remember, a plant change on paper is 10 times less costly than doing it during construction (Figure 1.2).

1.2.4 Engineering Documents

During the plant design, an electrical engineer with his team of designers must prepare the following documents:

Drawings: Drawings are being prepared for the specific electrical equipment and as layouts for the equipment installations. The former are included with corresponding equipment specifications, while the latter are part of the construction (installation) specifications. The drawings are to be prepared by experienced designers with a help and under the supervision of a lead engineer.

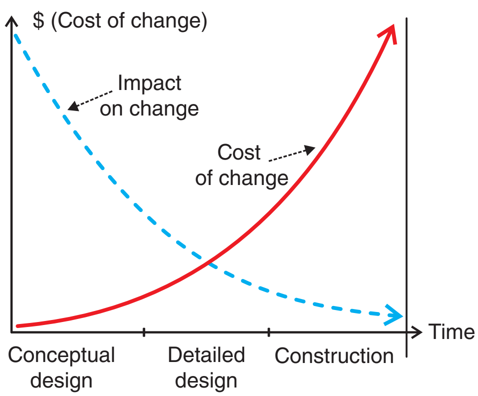

Figure 1.2 Cost of change.

Initially, the drawings are prepared as preliminary and issued to various suppliers for tendering purposes. Once a winning bidder is selected, the preliminary drawings are updated and finalized based on the fabrication drawings received from the selected supplier and finally issued for construction. The drawings must be marked with appropriate revisions as they are being revised and issued.

There are different methods of marking the drawing revisions. Here's one. The preliminary issues of the drawings are labeled with revisions, Rev. A, B, C, … or PA, PB, PC, …. The final drawings for construction are marked as Rev. 0, 1, 2, 3. Minor changes not affecting the contents or performance may be modified without raising the revision number.

Reports: During the project, many situations are encountered where the engineer is required to prepare official reports to evaluate various options and make recommendations of possible changes and improvements to the project. The changes may be due to the project cost reductions, technological changes, or changes to the site or operating conditions.

Coordination with other engineering disciplines: The electrical engineer must also review the mechanical, process, and civil engineering drawings to familiarize themselves with the buildings and mechanical equipment, as well as to insure the mechanical equipment includes appropriate electrical parameters specific for the project.

1.2.5 Equipment Specifications and Data Sheets

These documents will be prepared by the lead engineers for the electrical equipment, such as transformers, motor control centers (MCCs), VFDs, switchgear, etc. Revisions to these documents may follow the same procedures as identified for the drawings. Following a receipt of the tenders from the suppliers, the engineer prepares technical tender evaluations with appropriate conclusions, recommendations, and specific conditions for purchasing the equipment. As part of the award of contract, the specifications and data sheets are updated to match that of what was agreed on "as purchased" (see Chapter 24 for some specification details and data sheets).

A typical small or big project requires a number of specifications with data sheets to be written. The specifications define the equipment performance requirements and workmanship. The data sheets cover the specific equipment rating requirements. The specification for a particular piece of equipment can be updated from project to project with some minor changes. It is the data sheet that changes in a big way as the application and ratings may be completely different from project to project.

Hopefully, the new specifications will be similar to those of your previous projects. Often, one can change the project name and the spec number and then revise the data sheet to suit the equipment you need for your new project.

Try not to repeat yourself in the documents. Sooner than you think, someone will call and ask you: “What do you want: 1000 A breaker written in the specification or 1200 A breaker listed in the Data Sheet.” If you want to talk about the breaker in the specification, just note: “For the ratings, refer to the Data Sheet.”

From project to project, try to maintain the same ID number for the same design product, if the project permits it. For instance:

Specification and data sheet, respectively, for MCCs on project ABC: ABC – xxx – TS31 – DS31
Specification and data sheet, respectively, for MCCs on project XYZ: XYZ – xxx – TS31 – DS31

Try to group the documents for the type of equipment and services. Leave some gaps as there are differences in scope from project to project. When you are dealing with equipment like MCCs located in various different parts of a plant, write a common spec with several data sheets added to it for different areas.

Here is a list of specifications from a recent project in Minnesota on a 55 MW power plant using turkey litter as fuel:

(1) Electrical contribution to mechanical engineers’ specifications.

TS01	Electrical requirements for mechanical equipment
TS02	Electrical requirements for 480 V motors up to 200 kW
TS03	Electrical requirements for medium voltage (MV) motors over 200 kW

(2) Main power distribution

TS11	Switchyard equipment and hardware
TS13	Large transformers
TS14	Standby diesel generator
TS15	Relay protection panels
TS17	13.8 kV transformers
TS21	13.8 kV switchgear

(3) Plant equipment

TS23	MV motor controllers
TS24	MV VFDs