

Incredibly powerful, yet unexpectedly easy.

*How a software innovation results in Easy, Fast, Smart, and Green
electrical engineering design of the power distribution system in buildings*

By James Khalil, P.E.

“Engineers apply the principles of science and mathematics to develop solutions to technical problems. Their work is the link between scientific discoveries and the commercial applications that meet societal and consumer needs.”¹

For the most part, an engineer’s work is about *numbers*.

In designing for the (1) transmission of electricity in the power grid or (2) distribution of power inside the building, extensive calculations are necessary. Existing software addresses the transmission of electricity in the power grid. But the other half of the delivery system - that is the distribution of power inside the building - has *not* been adequately addressed by software solutions.²

Design calculations related to transmission are concerned with insuring that connected systems (1) within the power grid itself or (2) between the power grid and the power distribution system in a building are compatible and in harmony. These calculations typically are “studies” focused on the *analysis* of an engineering design to check that connected systems act together as one electrical system. These analyses include: fault current studies, harmonic current studies, power flow studies, and similar calculations related to transmission in the power grid, including the connection of the building’s power distribution system to the power grid/electrical service.

Unlike its relatively “high tech” sibling on the transmission side, software focused on the actual *engineering design* of the power distribution system inside the building is, at best, *limited*.

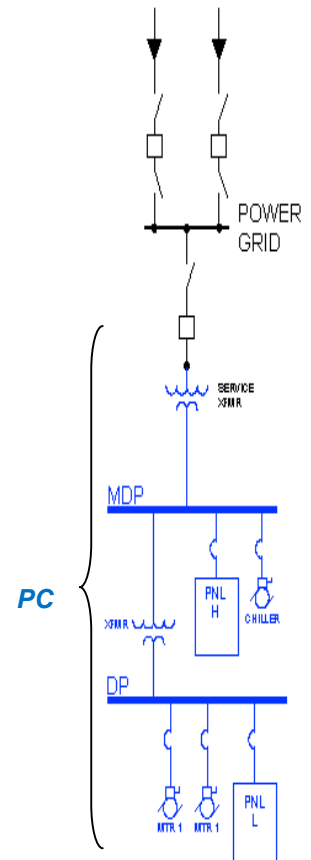


Fig.1 **PowerCalc** (PC) designs the power distribution system from the light bulb to the electrical service entrance.

¹ U.S. Bureau of Labor Statistics. (2010). *Occupational Outlook Handbook, 2010-2011 Edition*. Washington, DC: U.S. Government Printing Office. Retrieved from <http://www.bls.gov/oco/ocos027.html>.

² There is some confusion in the profession as to the distinction between the *transmission* of electricity in the power grid and the *distribution* of electricity in the power distribution system inside a building. Although not correct, the term “distribution” is used interchangeably with “transmission” to describe the power grid. There appears to be related confusion that software used for electrical design in the power grid can also be used to design the power distribution system inside the building. This is *not* true: *distribution* of electricity in the power distribution system inside the building must meet code and regulatory requirements which are *very different* from those applicable to the *transmission* of electricity in the power grid.

This white paper is about this limitation and the need for a single integrated software solution for *easy, fast, smart*, and *green* electrical engineering design in buildings.

The Issues

From the light bulb to the connection with the power grid/electrical service, electrical engineers today use one-off calculations/software, handheld calculators, makeshift spreadsheets, and “rule of thumb” guidelines to design the power distribution system in buildings.

And that is not the total process. Once calculated, the electrical engineer must then check his results by consulting the 800+ page *National Electrical Code*³ with its lengthy and tedious tables. This is necessary to insure that output complies with the building code.

To put this in perspective, a typical 2-story office building of 10,000 SF averages over 20,000 electrical calculations, with the possibility of up to 70% of these (or 14,000) being re-calculated for changes⁴. And then as described, the results of these calculations must be checked for compliance with the NEC.

The sheer quantity of calculations involved in this process raises questions: (1) can an engineer comply with this process? (2) can a business complying with this process be competitive? and (3) can a quality engineering design result from this process?

What is the state of the art in this 21st century world? Instead of the electrical engineer designing based on *numbers* as trained, the power distribution system in a building is more often based on “rule of thumb” values. In today’s “high tech” world, there must be a better solution.

The Challenge

Current electrical engineering practice for the design of power distribution systems in buildings is like herding cats.

No matter how often the calculations are checked, the process streamlined, the number of engineers increased, the process is never quite under control. Progress is typically slow and getting the project out is hectic, time-consuming, and difficult.

³ The National Electrical Code (NEC) is the standard adopted in most state and local jurisdictions in the United States and generally recognized as the most stringent standard in the world. The NEC is concerned with safety, i.e. minimizing fire, electrocution, and similar risks related to “hazards arising from the use of electricity”. See NEC Article 90. In other jurisdictions, the relevant code must be consulted.

⁴ Multiple changes in construction projects from initial design through completion occur throughout the construction process.

How many Calculations?

A 10,000 SF office building averages 20,000 electrical calculations.

Can the electrical engineer using currently practiced design procedures do all of these calculations?

Problems with Current Engineering Practices:

- Repetitive, Tedious Calculations
- Lengthy, Time-Consuming Process
- Oversized Equipment
- Costs
- Design Build
- Inaccuracies
- Streamlined Design Process

1. *Repetitive, Tedious Calculations.* Much of the chatter on *Linked In* is about how to end repetitive tedious calculations and get home at a reasonable hour without working weekends. For electrical engineers, current practice does not provide much hope considering: (1) the sheer quantity of calculations required and (2) the fact that the electrical engineering design is last in the design process with other disciplines⁵ often having “last minute” changes.⁶

2. *Lengthy, Time-Consuming Process.* Returning to the example of the 2-story 10,000 SF office building, completion of the electrical engineering design of the power distribution system would likely take 6 to 8 months from design development to the construction document.

3. *Overdesign/Underdesign.* As the electrical engineering design process is based on “rule of thumb” values, electrical engineers often “overdesign” the equipment. This practice insures that there is always plenty of electrical power available, *but at what cost?* Examples include overdesigning for step-down transformers, electrical panel frame capacity, and emergency generators.⁷ Overdesign is a material and unnecessary increase in the cost of a building’s electrical equipment. And, the flip side of this concern is underdesign which leads to safety concerns.

4. *Costs.* The client has unnecessary costs due to the overdesign of equipment and unnecessary design time. The engineering firm bears the cost of unnecessary design time, lack of competitive pricing, design errors, and process inefficiencies. For underdesign or incorrect design, the engineering firm also bears the costs for correction of design mistakes and liability for unsafe conditions.

5. *Inaccuracies.* The nature of the current practice can lead to inaccuracies due to the repetitive and tedious calculations required when coupled with the need to check calculations for code compliance.

PowerCalcPaK [®]				
© 2001-2010 Electric Power Calc Holdings Inc. Covered By US Patent #7,636,650				
Equipment Designation				HA
CKT	OCPD			
No	Trip	Pole	McLD Type	kVA
1	20	1	L	3.5
3	20	1	L	3.0
5	20	1	L	3.8
7	20	1	L	2.2
9	20	2	M2	0.5
11			M2	0.5
13	20	3	H	4.0
15			H	4.0
17			H	4.0
19	20	3	AC	2.4
21			AC	2.4
23			AC	2.4
25	20	2	P2	15
27			P2	15
29	20	2	SL	3.0
31			SL	3.0
33	20	2	XL	2.8
35			XL	2.8
37				
39				
41				

⁵ Other disciplines would include mechanical, structure, plumbing, and civil engineering as well as architecture. As the power distribution system must provide electricity throughout the building, virtually any change in another part of the design also requires a change in the electrical engineering design of the building’s power distribution system.

⁶ Re-calculations for changes ordered by the owner, architect, or others are the “norm” when designing the power distribution system in today’s building industry.

⁷ The NEC states the minimum standards required due to safety concerns, but does not limit or state any maximum standards.

6. *Design Build*. In today's construction industry, a preferred method for construction is design build. The design build process combines the design of the structure with the construction cost in one price submitted to the Owner. In order to bid, the Design Build Contractor needs to know the cost of the proposed equipment and materials.

Fig. 2 *PowerCalc*: Thumbnail of Branch Circuit Panelboard

Currently, the bid for a design build construction project is based on estimates using "rule of thumb" electrical engineering design. What electrical equipment is actually required for construction of the project *cannot* be determined until the design phase of the project is complete.

The completion of the design phase is marked by finalization of drawings with input on AutoCAD. The electrical contractor then performs "quantity take-offs" of the electrical equipment to calculate the final price prior to the start of construction.⁸

Know the Numbers:
PowerCalc calculates actual numbers... no more engineering based on "rule of thumb" values. Increases accuracy, code compliance, and design quality.

The point: the actual quantity and price of the electrical equipment for the power distribution system is *not*, and *cannot* be known, until the architectural and engineering design of the building is final. No actual *numbers* are known at the time of the bid.

This process leaves a lot of room for error in pricing as actual *numbers* are *not* known at the time of bid. It is especially risky for the Design Build Contractor who (1) will not be competitive if he overbids and (2) loses money if he underbids actual costs.

7. *What's the Future? A Streamlined Process*. For the electrical engineer, the *competitive* engineering firm will be the business that streamlines its process using technology to automate the *entire* electrical engineering design from calculations to placement on the building plans. *And then goes a step further into the future*, automating cost estimating, specifying the electrical equipment, and even placing the order with the electrical equipment delivered to the construction site - all as part of the design process.

Solution: A single integrated software solution that designs the entire power distribution system in a building.

The Solution

The answer is a single integrated software solution that designs the entire power distribution system in a building: *just one big bundled calculation tied to a proprietary database* for compliance with the NEC. This smart software solution needs to *automate* the electrical engineering design for the power distribution system, and then *automatically re-calculate* for any design change.

Smart software: One big bundled calculation tied to a proprietary database for compliance with the NEC.

⁸ The electrical contractor goes through the final design drawings on AutoCAD and hand tabulates the electrical equipment to determine the quantity and types of electrical equipment required for construction of the building.

With a single integrated software solution, the following can be expected:

- ✓ Reduced costs for design
- ✓ Reduced costs for electrical equipment
- ✓ Reduced design time
- ✓ Reduced design errors
- ✓ Reduced inefficiencies in the design
- ✓ Reduced code compliance/building department comments
- ✓ Reduced bid issues as output meets standards for bid documents
- ✓ Increased competitiveness
- ✓ Increased profits
- ✓ Improved design quality
- ✓ Improved client satisfaction
- ✓ Improved user friendly output as panelboard format mirrors actual panel installed by electrical contractor in the field
- ✓ Improved process from design through to electrical equipment delivery
- ✓ Adaptable to different codes and standards both inside and outside the United States

Patent protected innovation: automatically calculates the initial design, and then automatically re-calculates for changes, all in real time.

PowerCalc: Patent-Protected Innovation⁹

PowerCalc is the pioneer of software solutions for the electrical engineering design of the power distribution system in any size building or group of buildings.¹⁰ Over 7 million equations are bundled into one integrated software solution tied to a proprietary data base for compliance with the NEC.¹¹ It is smart software with a proprietary database with completed electrical values (no fill in the blanks).

Panelboards automatically generated: first the branch circuit panelboard and simultaneously the distribution and main panelboards as well as the equipment worksheets.

1. *Circuit-by-Circuit for 300 NEC Compliant Outputs.*¹² It is a unique approach: **PowerCalc** starts at the beginning by calculating and aggregating data from each branch circuit to the power grid/electrical service.¹³ For each

⁹ **PowerCalc** is covered by US Patent # 7,636,650.

¹⁰ **PowerCalc** designs the power distribution system in a building or multiple buildings located on the same power distribution system such as a college campus.

¹¹ **PowerCalc** has also been used for compliance with codes other than the NEC, such as metric systems in Canada and the Middle East.

¹² **PowerCalc** incorporates most NEC selection tables.

¹³ Other electrical engineering software programs provide analysis applicable to the power grid and how the power distribution system in a building and the power grid link together. There are a few software programs claiming to design the power distribution system in a building, but they are based on a flawed concept: calculating from the power grid *down* to the branch circuit. In contrast, **PowerCalc** aggregates from the branch circuit *up* to the power grid - the logical basis to design the power distribution system in a building as a single integrated software solution.

branch circuit, there are 3 inputs: electrical load in kVA, number of poles (1, 2, or 3 poles), and electrical load type (LTG, Heating, AC, etc.).

2. Panelboards Automatically Generated. Then, each load associated with a single circuit is input, the branch circuit panelboards are generated, and simultaneously the distribution panelboards, the main distribution panelboard, and equipment worksheets. Over 300 NEC compliant outputs are aggregated and automatically populate the panelboard worksheets. What previously took weeks or months of design time, now takes hours.

The electrical engineering design is put in the panelboard format, as it mirrors the actual panelboard/panel box installed by the electrical contractor in the building. Other software programs and systems use the panelboard merely as a placeholder for data, simple mathematical calculations, or power system analysis instead of for the design of the power distribution system.¹⁴

In contrast, *PowerCalc's* panelboard *is the software* that performs all the electrical value calculations. Each cell is packed with algorithms. Simple “placeholder” or even tabulation is replaced with a software system which integrates calculations across the design.

3. Really fast. *PowerCalc* in action is like watching an animated movie as it automatically populates all the panelboard worksheets upstream and downstream with each input: branch circuit values, panelboard values, feeder size, branch circuit wire size, conduit size, overcurrent protection device, equipment disconnect, voltage drop, and voltage hierarchy. For the power distribution system within the referenced 2-story 10,000 SF office building, this is tens of thousands of calculations.

4. Changes - Automatically Re-calculated. And, when a change is necessary, input the new values and re-calculation is instantaneous upstream and downstream across the design. Just watch the numbers fly.(parametric)

5. Manual Override. The electrical engineer can manually override the outputs to meet specific design and client criteria.

6. Build Your One-Line Diagram. *PowerCalc* automatically generates a graphic Electrical One Line Diagram or Electrical Riser Diagram throughout the design process. The designer is always informed about his design beginning, middle, and end.

7. Know the Costs of the Electrical Equipment. No longer is it necessary to have a single mark on a drawing in AutoCAD in order to determine what electrical equipment is necessary and its cost. Using *PowerCalc*, the

PowerCalc - the patent protected innovation:

- 3 inputs = 300 NEC compliant outputs
- Design circuit-by-circuit out to the power grid
- Panelboards automatically generated
- Changes automatically re-calculated instantaneously
- Build your one line diagram

¹⁴ A true electrical value calculation includes amperage, feeders, overcurrent protection device, voltage drop, conduit sizes, etc. Please refer to the list of *PowerCalc's* outputs included in this article.

electrical equipment is determined at an early stage of the project – *long before* the final design document is generated on AutoCAD and *long before* the design build project is bid.

PowerCalc means that the design build contractor has fewer cost surprises at the end of the construction project. It also means that the design is done based on *numbers* from electrical engineering calculations, instead of counting up the electrical equipment on construction documents.

8. **Directly Export to AutoCAD.** Directly export **PowerCalc** to AutoCAD for placement on the building plans.

9. **Unmatched Accuracy.** Minimizes human errors/no training necessary.

10. **Warnings and Notices.** Pop-ups guide the user through the design process.

11. **Outputs.** **PowerCalc**'s 300 NEC compliant outputs for a single phase or 3-phase power distribution system include the following:

Branch Circuit Conductor Size
Branch Circuit Breaker Trip Amps
Branch Circuit Ground Conductor Size
Branch Circuit Conduit Size
Branch Circuit %Voltage Drop (%VD)
Branch Circuit Maximum Length of Conductor
Conductor Length Required to Maintain %VD
Step Down Transformer (kVA)
Step Down Transformer Primary Feeder Size
Step Down Transformer Secondary Feeder Size
Load Tabulation by Type of Electrical Load
(Lighting, Motors, Receptacles, etc.)

Connected Load
Energy Reduction and Saving Electricity
User input Demand Load Factors
Panelboard Frame Size (Amps)
Panelboard Mains Rating (Amps)
Panelboard Main Feeder Conductor Size
Panelboard Multiple Feeders Run in Parallel
Feeder Branch Temp Correction Factor
Branch Circuit Temp Correction Factor
Analysis Notes (Tracks Inputs and Outputs)
Branch Feeder Running Amps
Motor Circuits OCPD Fuse

Branch Circuit Multiple Runs in Parallel
Branch Circuit Running Amps
User Defined Load Types
Motor Circuits OCPD Breaker
Motor Circuits FLA
Motor Circuits Branch Circuit Size (Wire and Conduit)
Motor Circuits Ground Conductor Size
Motor Circuits Disconnect Frame Size
Motor Circuits Enclosed Circuit Breaker Size
Demand Load - Industry Default Factors
Ground Conductor Size Increase at the Same Ratio of
Increasing Branch Circuit Conductors or Feeder
Branch Conductors

12. **Energy Savings Module.** Now, that the electrical engineering design can be produced by a single integrated software solution, it is finally possible to do some “fancy” calculations all the way down to the size of the conductors/wires. ¹⁵

Back to Engineering 101, resistivity¹⁶ is a law of physics recognized as applicable to electrical power. Simply, electricity is not hot, but conductors/wires transmitting electricity become hot indicating energy

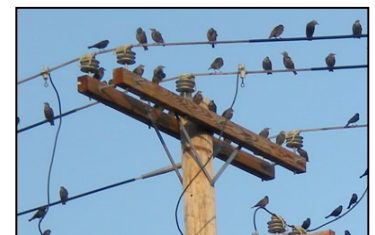


Fig.3 Birds sit on wires in power grid enjoying heat lost in transmission of electricity.

¹⁵ **PowerCalc** is included on the U.S. Department of Energy's Building Energy Software Tools Directory. The US DOE is on the lookout for “sustainable design, improving energy efficient, or incorporating renewable energy concepts in buildings.” And, **PowerCalc** meets their criteria.

¹⁶ Resistivity is the law of physics which recognizes that when the flow of electricity is obstructed by “friction”, that heat is produced/energy is lost. Due to fire concerns, the NEC limits how small conductor/wires can be, but not how large. See NEC Table 310.16. As to conduit size, it is *unlikely* that conduits would need to be “sized up” because, whether in new construction or retrofits, the rule is that conductors/wires cannot exceed 40% of the conduit's cross sectional area. This is a lot of space. See NEC Chapter 9, Table 1 *Percent of Cross Section of Conduit and Tubing for Conductors*.

lost during transmission. This heat is generated by electrons and other atoms colliding in the material conducting the electrical current. Provide more room for electrons to move (increase the conductor/wire size), and less heat is generated/less energy is lost.

To save energy, applying resistivity is compelling. The conductors/wires which transmit electricity are the single largest link between the generation and end-use consumption of electricity. Whether in the power grid or inside the building, the heat lost through the conductors/wires during the transmission of electricity can be reduced to save energy.¹⁷

Applying this concept, *PowerCalc* can save up to 7%, and likely a lot more, of the building's energy consumption by reducing heat generated/energy lost during the distribution of electricity inside a building.

Returning to the example of the 2-story 10,000 SF office building, there are likely over 500 circuits requiring over 20,000 calculations for the electrical engineering design. And then add to these many calculations, the detailed and repetitive calculations needed to compare conductor/wire sizes. *PowerCalc* not only does these calculations, but for the *first time* provides a way for conductor/wire sizes to be calculated as an integral part of the electrical engineering design in the building to save energy.

Only *PowerCalc* can automatically calculate and compare different conductor/wire sizes to minimize heat generation/energy lost and maximize energy savings. *PowerCalc's* Energy Savings Module also determines simple return on investment which is usually under 2 years by increasing the wire to one size larger.¹⁸

Conclusion

The construction industry continues to become more competitive in terms of price, the client's expectations, and technical advances. Electrical engineering design must move forward responsively using a seamless software solution that provides *easy, fast, smart*, and *green* electrical engineering design in buildings.

PowerCalc: the green solution - Save up to 7%, and likely more, of a building's energy consumption.

Innovate with PowerCalc:

- *Be price/cost competitive*
- *Be technically ahead of the rest*
- *Exceed your client's expectations*
- ***Be green***

¹⁷ In the power grid, energy can be saved by applying resistivity. Cables, however, are generally "large" to insure electrical capacity for entire neighborhoods. These large size cables rarely operate at full capacity so there is less "friction", less heat generated, and less energy lost during the transmission of electricity. But inside the building, the conductor/wire is sized for each electrical load (piece of equipment). When a particular light is on, the related conductor/wire is typically distributing the maximum amount of current and running "hot" due to friction. Increasing the size of the conductors/wires inside the building will reduce this friction, heat generated, and energy lost. Increasing the conductor/wire sizes inside the building provides a significant opportunity to reduce energy use/energy loss/energy costs.

¹⁸ An example is from a #12 AWG to #10 AWG conductor/wire size.



About the inventor: James Khalil, P.E. is President, Founder, and Inventor of *PowerCalc*. He has 30+ years of experience at his MEP firm in Delray Beach, FL and with Carter Burgess (now Jacobs) in Fort Worth, TX; Mason & Hanger (now Zimmerman) in Lexington, KY; and Gee & Jenson (now CH2M) in West Palm Beach, FL. He received his B.S. Electrical Engineering from the University of Texas. His experience includes projects for both private and public sectors including the governments of Saudi Arabia and Qatar; the US Departments of Energy, State, and Defense; and universities, public and private schools, healthcare, and performing arts centers.