“To err is human; to describe the error properly is sublime.”
— Cliff Swartz, Physics Today 37 (1999), 388.

Short Circuit Fault Current and Arc Flash Hazard Analysis Online at www.arcadvisor.com

What services do you offer?

We help facilities create safer working environments for individuals who service electrical systems by providing novel on-line tools for short circuit and arc flash hazard analysis. Our service includes resources and tools allowing you to perform the analysis yourself. In addition, we are commited to 24 hour technical support and immediate project assistance.

What are the major service benefits for the consumer offered by ArcAd ?

We offer online tools for fault current and arc flash hazard analysis. As far as we are aware, none of the competition offers similar services online. Advantages include:

* **input data error propagation analysis**
* No need for software installation
* No risk associated with virus threat
* System can be accessed, operated and shared from anywhere, anytime, on any platform connected to the Internet
* Access to most recent services and updates
* Most competitive price in the industry
* Routine data backup

The ArcAd tool performs more than just tedious calculations. We have implemented a parameter of tolerances to our service, which has an effect on final results within the analysis. Many other procedures do not take into account room for error, which can distort final values. A lack of understanding of basic error analysis has led some very bright scientists and engineers to make some incredible blunders. ArcAd's short circuit online calculator features input data analysis and hard coded error propagation rules ensuring that **the results are not more precise than justified by the accuracy of input data.**

Typical commercial software has more interfaces and graphic content, which make them more appealing and expensive. ArcAd's on-line tool is user friendly, performs error propagation analysis - **very important but widely ignored issue**, and is offered at a reasonable price .

We strongly believe that **if a resulting fault current margin of error can't be quantified, then it's not engineering, but only a guess**. As far as we are aware, none of the available competing products performs proper error analysis. It wouldn't be a problem if most accurate system equipment data were available. Experience shows that by far most real world studies are built upon approximate and therefore more or less accurate input data. The concept of precision is very important indeed and can impact results in surprising ways.

Bad things can happen if error analysis is ignored
The derailment at Gare Montparnasse, Paris, 1895

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What else makes your short circuit calculator different?

1 **Ability to accurately handle** motor and generator contributions. Many programs and procedures of this type do not properly account for motor loads as they simply have the user add the motor contribution to the utility source KVA. Some programs make short circuit fault current assumptions based on transformer size etc. This inadvertently distorts short circuit fault current values and blurs the safety margin. The calculator allows motors and generators to be placed anywhere in the network. The contribution from each motor and the utility source is vectorally added at every point where they intersect. This provides an extremely accurate analysis of the maximum short circuit MVA any node can be subjected to.

2 By performing short circuit MVA analysis for positive, negative and zero sequences, **symmetrical three phase and unsymmetrical phase-to-ground, phase-to-phase and double phase-to-ground fault currents can be resolved.**

How to use the short circuit calculator?

1. Briefly review the website examples and frequently asked questions to see the procedure in action and learn the resource capabilities.

2. Create an account if you don't already have one, and log onto the page where you can add components one by one to build up a radial electrical distribution system. The components can be a power source, transformers, bus ducts, cables, motors and generators, or "special" components whereby the user can define his own X and R values for a non-standard device. Short circuit MVA values contributed both by source and the system equipment are calculated for each portion of the system.

Your account gives you the advantage of saving the entered system diagram. This is practical for systems with multiple scenarios of interconnections where the system goes through ongoing changes over a period of time. You may continue your analysis without having to re-enter your data from the beginning.

www.arcadvisor.com **Short Circuit Analysis**

Username: admin
Security Level: 1
[Logout]

Tabulated Distribution System Diagram

ID	* Label	SC MVA	Error, %	X/R	Error, %	Description	Parent
1	Power Co.	500.00	1	7.00	0	500MVA 34.4kV Service Entrance	0
2	TRSFRM 2	14.00	0	7.00	0	750kVA, 5.75%Z, 208V Secondary	1
3	MOTORS 2	1.70	0	7.00	0	350kVA Motor Load, 20%Z, 208V	2
4	TRSFRM 3	17.40	0	7.00	0	1000kVA, 5.75%Z, 480V Secondary	1
5	MOTORS 3	2.50	0	7.00	0	500kVA Motor Load, 20%Z, 480V	4
6	GENerator	1.80	0	7.00	0	300HP Synch. Generator	1
7	TRSFRM 4	17.40	0	7.00	0	1000kVA, 5.75%Z, 480V Secondary	1
8	MOTORS 4	4.40	0	7.00	0	1000kVA Motor Load, 23%Z, 480V	7

Fig. 1. Portion of input screen

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The Results of SC MVA Calculations:

- Power Co.[500(7.00X/R) + 11.870(7.00X/R) = 51 X 10^{1} (7.00X/R)]
  - TRSFRM 2[13.6(7.0X/R) + 1.70(7.00X/R) = 15 (7.0X/R)]
    - MOTORS 2[1.70]
  - TRSFRM 3[16.8(7.0X/R) + 7.102(7.00X/R) = 24 (7.0X/R)]
    - MOTORS 3[2.50]
    - 75ft.Cable[16.1(7.0X/R) + 4.834(7.00X/R) = 21 (7.0X/R)]
      - MOTORS3_1[1.00]
      - 50ft.Cable[11.5(7.0X/R) + 4.30(7.00X/R) = 16 (7.0X/R)]
        - TRSF3_1[4.30]
  - GENerator[1.80]
  - TRSFRM 4[16.8(7.0X/R) + 4.40(7.00X/R) = 21 (7.0X/R)]
    - MOTORS 4[4.40]
  - TRSFRM Li[12.7(7.0X/R) + 0.00(7.00X/R) = 13 (7.0X/R)]
    - void[0.00]

Fig. 2. Portion of output screen showing resulting short circuit MVA values

How does your program track input data error propagation while performing the calculations?

“Error” in science and engineering does not mean a mistake. It rather means inevitable uncertainty that happens because of empirical measurements and cannot be perfectly corrected. All measurements in practice and even in principle have some error associated with them; no measured quantity can be determined with infinite precision and zero deviation. Without proper error analysis, no valid scientific conclusions can be drawn. In fact, wrong results can happen if error analysis is ignored.

We tend to use the words accuracy and precision synonymously but in science and engineering they are clearly distinguished. Accuracy refers to how close a measurement is to the expected value.

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Fig. 3. High accuracy

Using an archery target analogy where an arrow represents a measurement and the bulls-eye represents the expected or accepted value, accuracy corresponds to the distance between the arrows and the bulls-eye.

Using the same analogy, precision is the distance between each arrow, irrespective of where they lie on the target with respect to the bulls-eye. The grouping of arrows could be tightly clustered but a long way from the bulls-eye.

Mathematically, accuracy is the maximum error we introduce because we truncate the digits. Therefore, accuracy refers to the number of significant digits in a number.

On the other hand, precision is the number of digits available to represent the mantissa (the part of the number after the decimal point). **But beware!** It is possible to have high precision with poor accuracy.

Fig. 4. High precision with poor accuracy

ArcAd online short circuit calculator carefully handles input data tolerances and tracks error propagation through massive computations associated with short circuit analyzes. Listed are some rules for approximate calculations adopted by the calculator:

1. When quantities are being added or subtracted, the number of decimal places (not significant digits) in the answer should be the same as the least number of decimal places in any of the numbers being added or subtracted.
2. In calculations involving multiplication and division, the number of significant digits in an answer should equal the least number of significant digits in any one of the numbers being multiplied or divided.
3. When finding the square root of a number, the result has the same accuracy as the number.
4. When doing multiple-step calculations, keep one more significant digit than required by the rules above in intermediate results. This digit is dropped off the final result. In this manner, phenomenon known as "round-off error" is effectively avoided.
5. If one of the original factors has more significant digits than the other, round the more accurate number to one more significant digit than appears in the less accurate number. The extra digit protects the answer from the effects of multiple rounding.

In conventional error propagation theory, errors always increase when quantities are added, subtracted, multiplied, divided or operated on in any other fashion so the errors always combine in the worst possible way. The calculator hard coded error propagation rules take into consideration the fact that the error in one variable happens to cancel out some of the error in the other variable and so, on the average, the total error will be less than the sum of the errors in its parts. It can be proved that the results calculated using the rules above contain significant digits only.

What tools do I use to assess arc flash hazards?

A free online calculator based on IEEE 1584 Guide for Performing Arc-Flash Hazard Calculations was developed as an easy to use and comprehensive tool for calculating arc incident energy, flash protection boundary and risk category required by N.E.C when work is to be performed on or near the energized equipment.

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The calculator takes equipment configuration, gap between electrodes, grounding type, short circuit fault current value and system voltage on input, and determines the arcing fault current at a potential point of fault. Next, the incident energy, flash protection boundary and level of personnel protective equipment are determined based on equipment configuration, arc duration and working distance.

For protective devices operating in the steep portion of their time-current curves, a small change in current causes a significant change in operating time. Incident energy is linear with time, so arc current variation may have a huge effect on incident energy. The solution is to make two arc current and energy calculations; one using the calculated expected arc current and one using a reduced arc current that is 15% lower.

The calculator makes both calculations possible for each case considered. It requires that an operating time be determined for both the expected arc current and the reduced arc current. Incident energy is calculated for both sets of arc currents and operating times and the larger incident energy is taken as the model result.

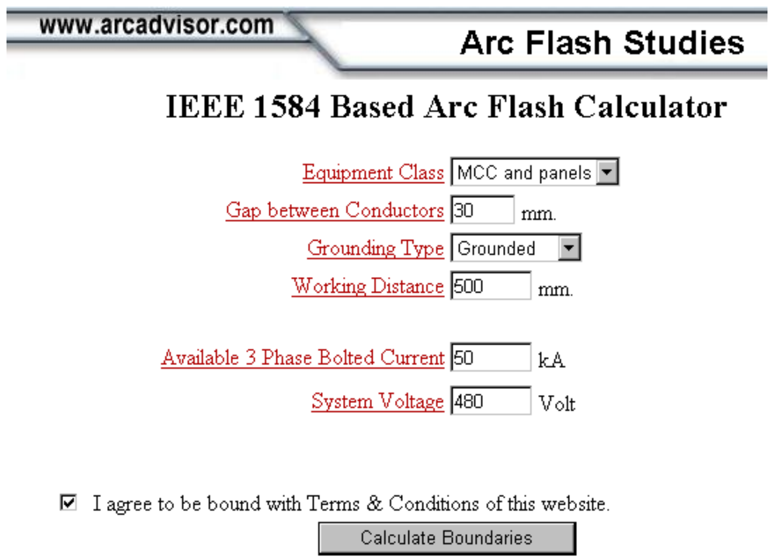

Fig. 5. Free Arc-Flash Calculator Input Screen

The IEEE 1584 empirically derived model was chosen for the analyzing arc flash faults since the model is able to accurately account for a variety of setup parameters: open and box equipment configurations, grounding of all types, gap between conductors of 3 to 152 mm, bolted fault currents in the range of 700A to 106kA, system voltages in the range of 208V to 15kV, and working distances. Reference data listing most typical configurations and detailed procedure for IEEE 1584 based arc flash calculations are provided. Besides input data validation, the calculator comes accompanied with a novel online short-circuit calculator which allows one to quickly obtain accurate potential short circuit currents at each bus in a radial electric power distribution system.

The IEEE 1584 Guide complements and generalizes existing procedures suitable when specifying the manufacturer's protective devices only or limited to 600V systems and most typical set parameters only.