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About Parallel Arcs & Series Arcs

A Prerequisite for Understanding Electronic Arc-Flash Suppression

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Describing Arcs

There are two fundamental types of arcs, **T-Arcs** and **F-Arcs**, that are defined by their initiation mechanisms[1]. Beyond this, however, arcs can be broadly categorized using a combination of three respective pairs of opposite adjectives: **Expected** or **Unexpected**, **Desired** or **Undesired**, **Controlled** or **Uncontrolled** (Fig. I). For example:

- An **arc-lamp** may be categorized as "*desired, expected, and controlled.*"
- An **electronic power contact arc** (part of the **Wet Power Contact Cycle**)[2] may be categorized as "*undesired, expected, and controlled.*"
- A deadly **arc-flash** event may be categorized as "*undesired, unexpected, and uncontrolled.*"

The above **T-Arcs** and **F-Arcs** can also occur as either a **Series Arc** (**S-Arc**) or a **Parallel Arc** (**P-Arc**).

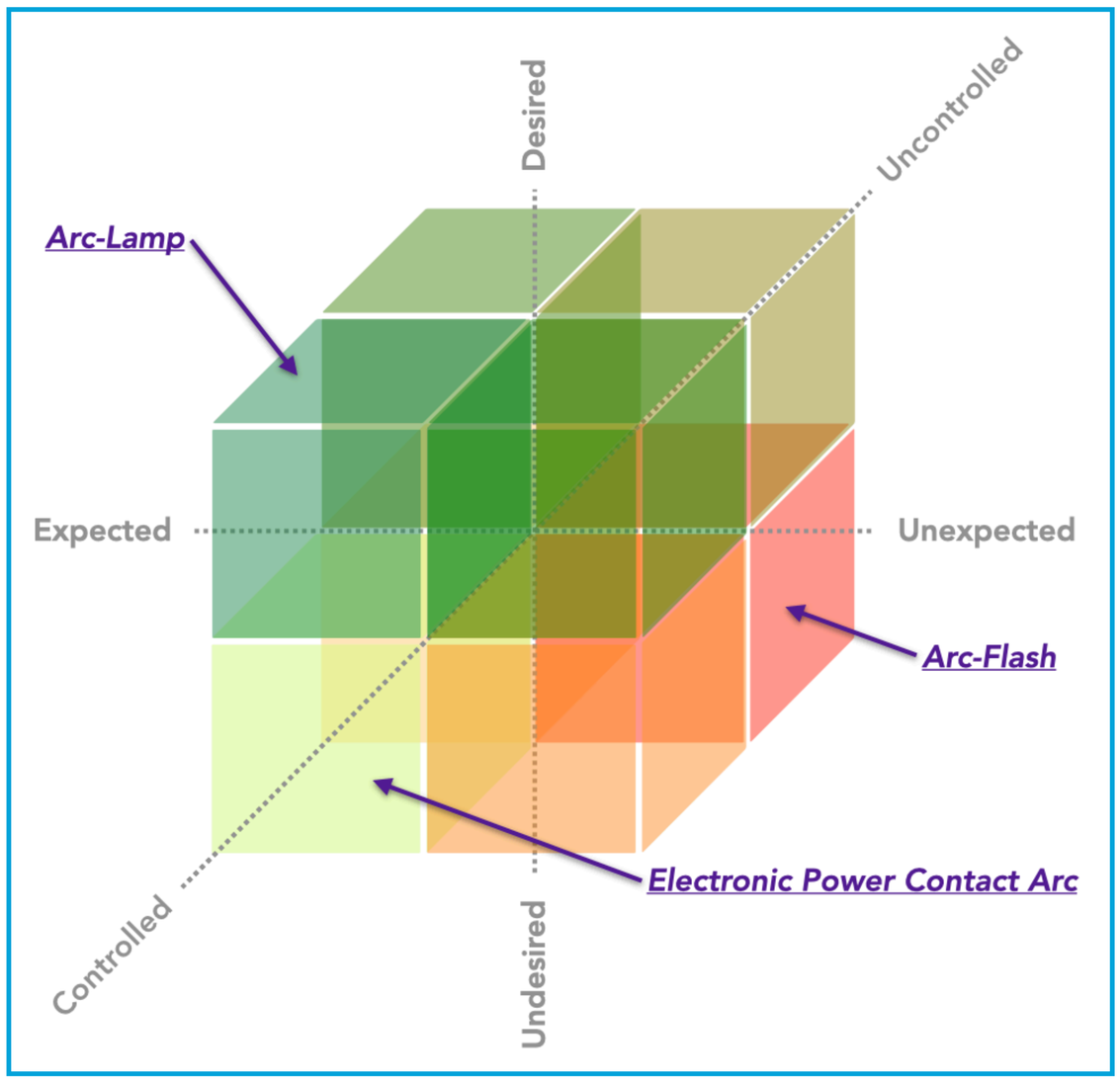

Figure I: *Matrix of Descriptive Adjectives for Arcs; Expected or Unexpected (X-axis), Desired or Undesired (Y-Axis), and Controlled or Uncontrolled (Z-axis)*

Series Arcs

A **S-Arc** ignites in series with the power load, and is an added resistance to the load. The **S-Arc** burns between two electrodes in series with the load and is limited by the load resistance. An arc occurring across the electrodes of a load switching electronic power contact is a **S-Arc**.

An electronic power contact arc is a **Series Arc** (**S-Arc**) that initiates while the contact transitions during its ***MAKE*** and ***BREAK*** states[2]. Both **F-Arcs** and **T-Arcs** are elements of power contact arcing[1,2], which are undesired, yet expected and controlled. Power contact arcing is normal and occurs during typical circuit operation. The arc resistance is connected in-series with the load. Its plasma burn is load-current-supported, and occurs in the gap between the two contact electrodes, with plasma current limited by the load resistance.

Parallel Arcs

A **Parallel Arc** (**P-Arc)** ignites in parallel with the power source. The **P-Arc** presents a low resistance load directly to the power source, burns between the two power conductors and is limited only by the power infrastructure resistance. An arc-flash is mainly limited by the short circuit current capacity of the power source.

An arc-flash is a **P-Arc** that is initiated by an unexpected dielectric breakdown (**F-Arc**) and/or an accidental metallic contact (**T-Arc**) between power conductors. The arc-flash resistance is connected in parallel to the two power conductors. Its plasma burn is fault current supported, and occurs in the gap between the two power conductors, with its plasma current limited only by the power infrastructure resistance.

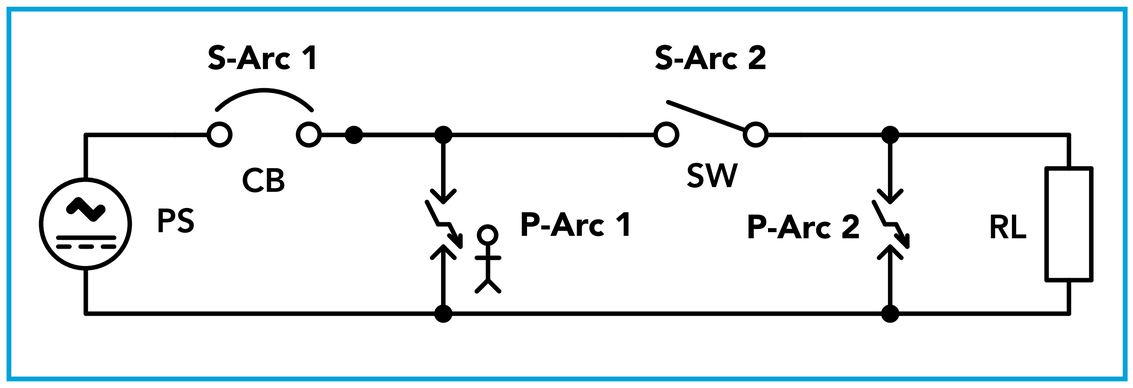

Figure II: *Circuit Diagram showing location of Series Arcs (S-Arc) and Parallel Arcs (P-Arc). Other elements: Circuit Breaker (CB), Load Resistance (RL), Power Source (PS), and Load Switch (SW)*

Type of Arc	Arc-Flash	Contact Arc
Modality	In-Parallel	In-Series
Arc Plasma	Power Bridging	Contact Bridging
Cause	Flashover or Short Circuit	Contact Make or Break
Condition	Abnormal	Normal
Connection	In-Parallel with the Power	In-Series with Load
Current Limiter	Infrastructure Resistance	Load Resistance
Current Type	Fault Current	Load Current

Table I: *Summary of Arc Characteristics*

Conclusion

Arc-faults range from minor to major, with an arc-flash being a major arc-fault. The burning Arc-Flash plasma is a non-linear circuit component with negative resistance; meaning: the more current, the less resistance … and the less resistance, the more powerful the arc-flash. This results in the exponential growth of a "self feeding, ever growing, monster," destroying everything in its path.

In spite of the $1.9billion (2020) annual spending on protection equipment, combined with even more on mitigation measures and training, there are still more than 30,000 annual arc-flash incidents just in the U.S. alone. These events have an average cost of from $750,000 each (without hospitalization) to more than $4million each (with hospitalization), and significantly more costly for each arc-flash-caused death.[3,4,5]

Electronic arc-flash suppression differs greatly from efforts-to-date that have limited success, despite preventative measures and arc-flash-mitigating equipment. Realizing the difference between Series Arcs and Parallel Arcs yields the insights required to suppress arc-flash events in microseconds (**µs**), thus preventing the arc-flash altogether.

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