The Deliberately Weak Link

Mike Murphy

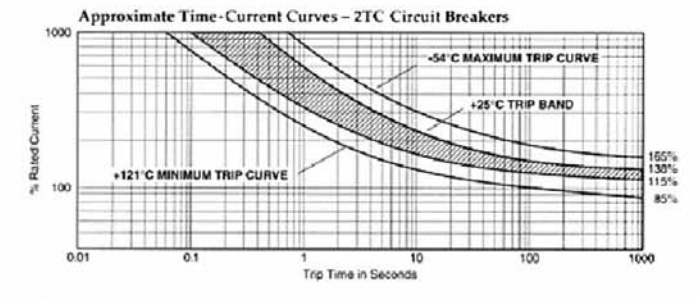
Circuit breakers! They stare at you from panels at your knees, overhead, behind you or perhaps on the console between you and your crewmate. Occasionally, they trip. Just what do these humble yet hardworking devices do, what does it mean when they pop and, just as importantly, what do they not do?

CIRCUIT BREAKERS probably don't get the attention they deserve. However, several recent high-profile aircraft disasters have reminded us that assumptions, misunderstandings or neglect of critical components, even small ones, like circuit breakers, can have tragic consequences. The problem is even more acute as aircraft become increasingly dependent on highly integrated electronic systems for navigation, stability and control. Fly-by-wire aircraft are obviously totally dependent on electricity for safe operations.

Aircraft circuit breakers are designed to interrupt the flow of electrical current when specific conditions are reached. Those conditions of time and current, generate heat. Circuit breakers are designed to trip (open the circuit) before this heat damages either wiring or connectors. A specification might be for a breaker to trip under a massive short jolt (e.g. 10 times the rated load of the circuit-breaker for between .5 to 1.4 seconds) or a longer, less intense overload (e.g. twice the rated amperage for 3-130 seconds, depending on the type of circuit breaker). If the designed overload conditions are not exceeded, the circuit breaker will not trip. Some breakers are temperature sensitive and will trip earlier when warm than cold (opposite page).

This highlights one of the limitations of circuit breaker design. The very tolerances that must be built into a circuit breaker to prevent nuisance tripping, such the high transient current that flows when a motor or component is started, means some glitches may not trip the breaker. Ticking faults and arc-tracking are examples. Ticking faults occur when tiny bolts of electricity intermittently arc from exposed wire conductor. On wires covered with aromatic polyimide wrap, installed in many aircraft built since 1970, this can burn the thin insulation, converting it into carbon, which is an excellent conductor - a nasty case of the insulator turning into the conductor! This can in turn lead to very

An Aviation Circuit Breaker
Picture courtesy of Texas Instruments



Typical Trip Curve
Courtesy of Texas Instruments

short bursts (micro-seconds) of violent arcing where localized temperatures can reach extremely hot temperatures (well in excess of 1,000°C) capable of igniting nearby flammable material. Nevertheless, short, violent bursts of arc tracking will not necessarily trip breakers, which are comparatively slow-acting devices. Special arc fault circuit interruption devices, still a few years away from widespread use in aviation, are needed to deal this type of situation. If your aircraft has aromatic polyimide wire, there are very good reasons not to be in a rush to reset any tripped circuit breaker. The results could be catastrophic.

Circuit breakers are not intended to protect the electrical equipment, which may have its own built-in protection or mitigation system, but the wiring and connectors, which would otherwise have no such protection. Aging, vibration, excessive bending, improper installation, heat, moisture, friction, wind blast, chemicals such as de-icing fluid, toilet fluid, hydraulic fluid, oil and fuel can damage the insulation on the wire, if not the conductor itself and any connectors. In addition to disabling the circuit and any associated component, this could also create a fire hazard, possibly in an area where it could be impossible to use extinguishers and that could easily threaten the safety of the flight. With any in-flight fire, especially one in an inaccessible location or close to critical components, an immediate landing becomes a very high priority. Because such an option may not always be readily available (e.g. in mountainous, arctic or oceanic areas) adequate circuit protection and a good knowledge of what it can and cannot do, is essential.

Circuit breakers, are thermal-mechanical in nature. Bimetallic elements, with one metal expanding more under heat than the other, pop the breaker open. This also enables them to be reset, albeit only after they have cooled down. However, there are good reasons why it MAY NOT BE ADVISABLE to do so, as we will soon see.

On many light aircraft, the circuit breakers are mounted along the bottom of the instrument panel. Many are flush fit and cannot be manually tripped or pulled. On larger aircraft, they are usually grouped in panels placed around the cockpit in locations were they would not be displacing vital instruments, switches or controls, and most can be manually tripped or pulled. Having them within sight and reach, although a necessity is both a blessing and a curse. A blessing because they can be seen and, IF NEED BE reset. A curse, because it is tempting to use them for a purpose they were never intended (i.e. as a switch) and to reset them when they should not be reset.

The electro-mechanical construction of a circuit breaker was not designed for use as a switch, and using it for this purpose causes premature

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wear and the risk of failure. When a circuit breaker fails, it will take down a system, which may be needed for the safe operation of the aircraft; or it will leave on line a circuit that should be de-energized. Both alternatives are unattractive, and both are capable of inflicting catastrophic consequences.

It is wise to think twice before resetting any circuit breaker in flight. It is telling you something is wrong - that there has been a serious electrical event. This danger signal must be interpreted with extreme caution. The old rule of thumb to automatically allow one reset is not prudent. Safety-conscious airlines are now telling their crews not to reset any breakers unless they are essential to safety and then to do so only once. Wherever possible, this should be done only after consulting the relevant resources (e.g. the Quick Reference Handbook, the MEL, Aircraft Flight Manual, Company Operations Manual, and/or maintenance.) This approach might suggest that the reset be delayed until the service is needed. There is no need to reset a landing gear circuit breaker that trips after take off until one is committed to landing.

Unless your organization already has a comprehensive policy on circuit breakers, it is time that Flight Ops and Engineering/Maintenance develop one. Even if you have one, don't assume that everyone is aware of it, understands it and is using it. Better to be surprised by finding out now that they are not than to learn about it after a tragic event. Being at altitude with a deteriorating situation on your hands is no time to develop a good policy. In the meantime, logging any circuit breaker anomalies gives maintenance a much more accurate picture of the nature of the problem.

Circuit breakers: a willing friend, ready to save you from harm's way, provided you understand and respect their limitations.

Mike Murphy, former ATPL pilot and ex-TC executive, now chair of the Air Passenger Safety Group, thanks Mark Van Berkel at Transport Canada Aircraft Services for his insights into this important topic, Texas Instruments (Klixon Circuit Breakers) for permission to use the above graphics, and a group of his former colleagues for vigorous peer review of this article.

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