ELECTRICAL SYSTEMS

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Almost all aircraft electrical systems have one thing in common. Usually they all have a battery that will last at least 1/2 hour and run one communication radio and one set of navigation radios. This is usually designed in so that if everything else shoots craps a pilot can still get down in bad weather or night.

Often things do go wrong electrically and the airplane will lose some systems all the way to loss of the aircraft.

Types of failures that can occur:

1. over or under voltage.
2. over or under frequency
3. over or under excitation
4. dead shorts
5. wire chaffing
6. sneak circuits
7. insulation fires and flashovers
8. generator speed control problems and surging
9. generator failure
10. transfer relay /load shed chattering
11. load sharing faults in multiple generator aircraft
12. transformer /rectifier failures
13. Fuse failure
14. Circuit breaker popping.
15. E.M.I.

Electrical systems of airplanes need electricity of a good quality and quantity to power sophisticated radio, navigation and weapons systems. Alternate current systems are usually 115 + or - 5 volts 400 cycle + or minus - 8, systems with generator excitation specified. So faults of varieties 1 to 3 are about the quality and quantity of electricity provided to and sensed at a load bus from a generator. The D.C system is usually 28 volt.

A dead short is simply a load carrying power supply wire or bus going to ground creating a severe short circuit and thereby pulling unlimited amps causing failures within the system.

Suppose I short out a hair dryer at home. This does little harm to Austin Texas electricity. Suppose a crane gets into a power transmission line at the power plant. This causes havoc. Similarly there are severe shorts in an airplane and there are routine shorts as well.

Wire chaffing is a potential problem in airplanes. Take an F-16 that has 11 miles of wire bundles in its tiny airframe. Sharp screws, sharp edges, small radius turns, maintenance procedures, and flight vibrations may all cause unwanted chaffing. The fact bundles will chaff is known, when they will fail is not. Chaffing may cause interruption to a single system, failure of that system, short circuits and sometimes wire bundle fires.

Sneak Circuits. This is a very rare occurrence that was expected to be designed out. It is where an electrical signal designed to be transmitted solely in one set of circuits' sneaks to an adjacent circuit or by the proximity of one circuit to another, affects the adjacent circuit deleteriously.

Insulation Fires and Flash over There are generally three varieties of aviation acceptable wire insulation. It is a polymer rated at 150 degrees C and Kapton rated at 200 degrees C, and an irradiated Polymer with additives rated at 200 degrees C. All of these wires are supposed to not sustain burning absent a heat source. The temperature rating means that it is supposed to keep all its properties intact and insulate at the elevated temperature for at least 10,000 hours of usage. The wires have been tested in excess of 300 degrees for 7 hours with no ill effect. Aircraft wiring in airliners is supposed to last 50,000 hours. Remember that most aircraft parts are no where near the 200 degree C, which is about 392 degrees F. However all these wires under stress will exhibit phenomena known as flashover. An investigator will recognize it instantly for so long as he can find it in the remains of the wreckage. It is usually seen in airplanes that land safely and in the laboratory.

Generators Speed control. Generators are run by either fan belts or more likely from Constant Speed Drive mechanisms. This C.S.D. operates like the old Buick fluid drive automatic transmissions in cars of the 1950 era. When a C.S.D. gets low on fluid or the fluid is contaminated or when the fighter airplane pulls g's with a low C.S.D.s. fluid it drags. Generator speed is not held constant and the **system surges and fluctuates**. This can cause components that need good electricity to protect themselves by dropping of the line. If it is serious the entire generator may be taken off the line by its own protective devices thereby un-powering many subsystems.

Generator Failures: Generator failures are caused by many things. Often it is the failure of a carbon block within the generator case. Regardless when a generator self destructs all electrical capability is lost from that generator. Partial failure is unlikely although it is possible to only lose one phase of a three phase generator. If this occurs the generator will be tripped off the line and the net result is the same as total generator loss.

Transfer Relay Failures or Chattering Transfer Relay failures and auto shed failures occur when a switch designed to automatically switch positions because of a change in electrical availability fails to do its designed job. For instance in the old A model F-16 airplane when a main generator becomes unusable a series of 5 transfer relays are supposed too work automatically. The main relay is supposed to remove the first generator and install the backup generator. The others simply turns off 4 unneeded (non Essential) busses. Failures of these to perform will either deprive the airplane of a backup generator or keep busses on line that should have been turned of. Sometimes these auto shed devices can't seem to decide what they are supposed to do and they chatter. This is aviation description for switching back and forth. The failure and type of failure is easily recognized if the part can be recovered.

Load Sharing Faults Whenever a multiple generator airplane is attached to a common load buss, then each generator should supply the same amount of electricity. This is called sharing the load. Sometimes a single generator will provide errant amounts of electricity. When this occurs it forces the others to adjust. The generators end up fighting one another until the system decides to separate the generators to power their own designated busses. Sometimes when the disconnect has occurred the generators settle down and work satisfactorily separated.

Transformer Rectifier Faults (TR) FAULTS . These devices are devoid of moving parts and usually are flawless for the life of the airplane. The transformer simply changes 115 volt electricity into 28 volt electricity. The rectifier changes or straightens out the alternate current into direct current. Each such device is designed to carry a maximum load. Occasionally you will get an overload over heat failure and occasionally you will see a dead short across the device.

Fuse Failures are as a result of overheat and melting. A fuse is designed to carry so much amperage for a period of time. Once this limit is reached the circuit melts and the fuse is blown. When this occurs the electrical circuit can not be reinstated without changing the fuse. These are very easy for an investigator to detect.

CIRCUIT BREAKERS pop when to much current is passed through them. They may be re set by crewmember input.

E.M.I. Some electrical systems can be interfered with or operated by external interferences by Electronic Impulses. Electronic Flight control systems, Electronic fuel control conditions, CRT and other displays can all be affected. This is an area of great concern and, the investigations of this suspected interference is in its infancy.

INVESTIGATION FOR ELECTRICAL FAILURES

Electrical system is sophisticated and usually has back up systems or redundancy for safety. A typical system might consist of two engines, two generators, and the back up battery. Either generator is capable of powering all the aircrafts essential electrical equipment. When working properly both generators will be tied to a common electrical bus so they can share the load.

When both generators are working they share the load and produce enough power to satisfy all needs (essential and non essential electrical equipment.) Each generator will attach to a common bus and this buss will in turn power the primary AC essential bus this primary bus supplies AC power to a secondary AC non essential bus through the transfer relay (an auto shed device)(failure of one generator will be sensed and the transfer relay will turn off non essential).

Additionally the primary AC essential bus will provide power to a T/R that will transform the electricity down to 28 volt and rectify it to DC. This DC electricity powers the primary DC essential electrical bus. It also provides DC electricity through another transfer relay (auto shed device) to the DC secondary non essential bus. Electricity from the essential DC bus is used to power the Battery charger and the hot battery bus.

When one generator fails the non essential busses are turned off by the transfer relays. When both generators fail the battery supplies 1/2 hour to the hot battery bus that has only a radio and one simple set of standby flight instruments.

Depending on design there are variants of this basic concept. For instance the B-737 has an additional generator called the auxiliary power unit that can be started and it will replace the loss of either generator. The F-16 has an instant on automatic starting Emergency power unit that senses the loss of the single generator (old models- new have two generators) and it will power all essential electrical systems within 2 seconds.

The B727 has three generators, aground only A.P.U. and a thirty minute battery.
Whenever a generator failure occurs, numerous individual components will be denied electrical power, and several warning and status lights will be illuminated.

Remember that some devices on an airplane require very good and constant quality of electricity to work properly. Examples are in your home, your personal computer that has surge devices that protect the machine and the hard drive from errant electricity. Your T.V. needs good electricity or else the picture will go bananas. New housing codes require surge to short protectors around certain appliances so they will turn off before electrocuting the user fatally. Not critical are the lights which will work dimmer or brighter before a failure.

Varieties of equipments in airplanes that require very good quality and quantity of electricity are: Inertial Navigation Devices, Flight Management Computers, Electronic flight controls, A.D.I.s', heads up displays, computers and gyro platforms.

These devices when they sense bad electricity disconnect themselves through protective devices, some internal, some with solenoid switches (powered on-spring loaded off) some with fuses, and some with circuit breakers. All other equipments although not as sensitive are provided overload protection through fuses and circuit breakers. You have these in your own home. The circuit breaker is reset able whereas the burned out fuse must be replaced.

When an electric problem is suspected the investigator is faced with a monstrous problem. It is difficult enough in an intact aircraft. It is very difficult in a badly destroyed aircraft, and it is nearly impossible when one has been crashed and badly burned. The impossible takes a little longer!

The investigator must be very logical and thorough in this attempt to audit the electrical system. He must get a copy of the correct electrical diagrams and schematics for the airplane.

This is paramount for the next step is to determine what buss powers each and every component. Once this is learned then the investigator must determine the ratings and type of protective device (fuse, circuit breaker, solenoid, internal device) that protects the components. Then the investigator should determine where the components, busses, fuses and circuit breakers were located within the aircraft. He should determine the wire bundles routing and make up.

Next he begins his audit by finding as much of the entire electrical system as he can recover.

1. Circuit breaker panels should be inventoried and condition of breakers recorded. These breakers should be systematically identified as to which component they were designed to protect. Popped breakers should be analyzed since they may be crash damage not electrical fault.

2. Fuses should be treated in similar manner to determine if they had melted as a result of overload.

3. Light bulb analysis should be conducted to ascertain that electricity was available to components that would be expected to be on. (AIRCRAFT NAVIGATION LIGHTS AND ROTATING BEACONS are on day and night) Cockpit lighting at night. Instrument panel lighting at night. Map lights at night. Passenger lights at night.

4. Light bulb analysis of component status lights and failure and warning lights should be conducted and inventoried.

5. Electrically powered components should be inventoried for operation. These devices only fail for lack of power or material component failure, or switch position.

6. Switch positions should be inventoried to electric components to help ascertain off or on condition. The investigator must be aware of wreck damage.

7. Electrical busses, transformer/rectifiers and Transfer Relays should be examined for status, operation, and short circuiting, arcing or overheat indications.

8. Constant speed drives should be checked for fluid, condition and whether it had been disconnected.

9. The generators should be examined for rotation and condition .Sometimes the can be bench checked. They can be dismantled for indication of pre existing failure.

10. Wire bundles should be examined for flashover fire, overheated areas or obvious chaffing.

Any investigator who has read this will say “Sure you do" very sarcastically since severe wrecks are never amenable to such a complete inventory and audit. The point is that you attempt the discipline with what is available to you. The truth is that you will almost never get 100% reconstruction. The point is that you don't always need it to draw valid conclusions.

I always put a complete schematic on the wall of a conference room. Often a hotel room wall near the accident sight. As each piece of new data is captured, I place it on the charts. Soon patterns begin to become discernible as to the status of the electrical system. The failure of multiple devices on a singular buss suggests a buss failure. Failure of all critical items on a bus with lights still available suggests that the buss was not getting good quality and quantity electricity and the components could not work while pumps and lights still worked.

An electrical engineer familiar with aviation electrical system design and a metallurgist is helpful in this inventory.

Knowing the electrical system design, layout and function is a must before any determination of value can be made.

A haphazard approach to the investigation of the electrical system will produce haphazard results and conclusions. The military does an excellent job in this respect. In my opinion the N.T. S. B. investigations range from good to non existent.

If an investigator completes a comprehensive investigation he will have determined everything that wasn't working, and from this he is more able to determine what failed and why. If he is extremely lucky, during this inventory, he will find tangible evidence of the actual failure, not just the results of the failure.