TECH TIME

Helpful tips for the Avionics Technician

B Y   A L   I N G L E

This month we continue our study of electrical load analysis, a subset of *wiring systems*. As was explained previously, an electrical load determination is required when installing new equipment into an aircraft or when questions arise as to the state of an electrical system. Lacking clear guidance for the Repair Station, the FAA is studying the issue with the plan to provide this information in the near future. We must first define the common terms associated with electrical load analysis before we can implement procedures that are universally accepted. We therefore continue from the previous issue with definitions and standardization.

We will use as a guide the British Civil Aviation Authority's *Airworthiness Information Leaflet* titled *AIL/0194, Issue 1, 25 March 2004*. It may be found at www.caa.co.uk.

Definitions and Assumptions

Momentary or Intermittent Loads Certain devices, such as electrically operated valves which open and close in 3 seconds or less and do not constitute more than a 5% duty cycle (one opening/closure in one minute) are not included in the calculations.
Intermittent Loads Communications and/or navigation equipment that may have different current consumption depending upon operating mode (i.e. receive or transmit) must be considered.
Cyclic Loads. Heaters, pumps, etc., operating under a duty cycle must be considered.
Motor Load Demands are calculated for steady state operation and do not include starting inrush power. The overload ratings of the power sources should be shown to be adequate to provide motor starting inrush requirements.
Estimation of Load Current must include voltage drop between busbar and load.
Power Factor must be estimated for equipment, if unknown.

AC and DC Load Analysis – Tabulation of Values A typical "Load and Power Source Analysis" would identify the following details in tabular form**:**
Load at Circuit Breaker Ampere Loading for DC circuits; Watts, VA (Volt-Amps), PF (Power Factor) for AC Circuits.
Operating Time Usually expressed as a period of time (seconds/minutes) or may be continuous, as appropriate. If the "on" time of the equipment is the same or close to the average operating time of the aircraft, then it could be considered that the equipment is operating continuously for all flight phases.

In such cases, where suitable provision has been made to ensure that certain loads cannot operate simultaneously or where there is reason for assuming certain combinations of load will not occur, appropriate allowances may be made i.e. multiple communications transmitters.

Three ways in which the load data may be tabulated using a specified range for equipment operating times are as follows:
5 Second Analysis - All loads that last longer than 0.3 second are entered into this column.
5 Minute Analysis - All loads that last longer than 5 seconds are entered into this column.
Continuous Analysis - All loads that last longer than 5 minutes are entered into this column.

Alternatively, the equipment operating times could be expressed as follows:
Actual operating time of equipment, in minutes or seconds, or
Continuous operation.

Note: In piston aircraft with generator/alternator power sources, the latter method will be preferred as the lower margin of available power in many cases precludes the tabulated inflation of actual loads.

Condition of Aircraft Operation The number of categories may vary with the operation. For commercial aircraft, the following conditions of a flight could be considered: Ground Operation and Loading, Engine Start, Taxi, Take-Off and Climb, Cruise, and Landing. For helicopters and private aircraft, there may be more or fewer conditions.
Condition of the Power Source Normal, Abnormal (these conditions are specified, i.e. one generator inoperative, etc.), and Emergency.
Calculations The following calculations can be used to estimate total current, maximum demand, and average demand for each of the aircraft operating phases (Ground operation and loading, Engine Start, Taxi, Take-Off and Climb, Cruise and Landing):
Total Current (Amps) = Number of Units Operating Simultaneously x Current per Unit (Amps), or
Total Current (Amp-Min) = Number of Units Operating Simultaneously x Current per Unit (Amps) x Operating Time (Min).
Volt-amperes (VA or kVA) = Voltage x Current
Maximum Demand or Maximum Load (Amps) = Number of Units Operating Simultaneously x Current per Unit (Amps) or
Maximum Demand or Maximum Load (Volt-Amps, VA or kVA) = Number of Units Operating Simultaneously x Current per Unit (Amps) x Supply Voltage (Volts).

It is important to remember that AC loads with reactance are calculated using vector addition and not algebraic addition. (For those not familiar with this phenomenon, the vector addition of resistive and reactive components was explained and illustrated in the August 2004 edition of Tech Time. It is available for viewing on the AEA web site).

Power = Voltage x Current x Power Factor
where Power Factor is the angle Ø of lag or lead between the voltage and the current or
Power Factor = cos Ø

In a purely resistive circuit, the current and voltage are in phase with one another. Therefore, the cos of 0º being 1, the formula reduces to P = V x I.

Average Demand or Average Load (Amps) = Total Current (Amps-Minute) ÷ Duration of Ground or Flight Phase (minutes), or
Average Demand or Average Load (Volt-Amps, VA or reactive power) = Total Current (Amps-Minute) ÷ Duration of Ground or Flight Phase (minutes) x supply voltage (volts).

It can be assumed that at the start of each operating period (taxi, take-off, climb, etc.), all equipment that operates during that phase is considered to be "on", with intermittent loads gradually being switched "off".
Intermittent Loads For intermittent peak loads, root mean square (RMS) values of current should be calculated. Where the currents are continuous, the RMS and the average values will be the same., however, where several intermittent peak loads are spread out over time, the RMS calculation will be more accurate than the average.
Non-Ohmic or Constant Power Devices These are devices that consume a fixed amount of power and draw varying amounts of current at a specified voltage. One example is the static inverter. It produces a regulated AC voltage and the current drawn will vary with its input voltage. As the busbar voltage decreases, the input current consumption to the inverter goes up to compensate so that the total power consumed is the same. Conversely, a navigation light is resistive. As the input voltage increases, the current consumed (and illumination) increases and as the input voltage decreases, the current consumption (and illumination) decreases.

System Regulation The system voltage and frequency should be regulated to ensure reliable and continued safe operation of all essential equipment while operating under Normal and Emergency conditions. Voltage drops in cables and connectors should be taken into account.

The following definitions are provided for the following conditions:

28 VDC	Maximum	30.3 volts	**14 VDC**	Maximum	15.1 volts
System	Nominal	27.5 volts	**System**	Nominal	13.8 volts
	Minimum	22.0 volts		Minimum	11.0 volts
	Emergency	18.0 volts		Emergency	9.5 volts

Load Shedding Following the loss of a power source or sources it is considered that a 5 minute period will elapse prior to any manual load shedding by the flight crew, provided that the failure warning has clear and unambiguous attention-getting characteristics. However, any automatic load shedding can be assumed to take place immediately.

Emergency or Standby Power Operation Where standby power is provided by non-time limited sources such as Ram Air Turbine, Auxiliary Power Unit, or pneumatic or hydraulic motor, the emergency loads should be listed and evaluated such that the demand does not exceed emergency generator capacity.

Where batteries may be used to provide a time limited emergency supply for certain phases of flight i.e. landing, an analysis of battery capacity should be undertaken. This should be compared with the time necessary for the particular phase of flight where batteries may be used in lieu of non-time limited sources.

Calculation An accurate theoretical assessment of the battery performance requires a load analysis to be compiled and the discharge figures checked against the battery manufacturer's discharge curve and data sheets.

The capacity of a battery is: **Rate of Discharge (amps) x Time to discharge**

This is normally expressed in ampere-hours, but for a typical load analysis calculations are usually expressed in amp-mins (i.e. amp-hours x 60). The battery capacity is not a linear function but varies with the discharge rate. Consult with the battery manufacturer for the appropriate discharge curve. In the event they are not available, certain approximations and assumptions may be made for that type of battery composition.

All calculations are based on the one-hour rate. To standardize the definition of capacity, it may be assumed that the one-hour rate is 85% of the quoted five-hour rate.

Following the generator system failure and before the pilot has completed the load shedding drills the battery may be subjected to high discharge currents with a resultant loss of efficiency and capacity. To make allowance for such losses, the calculated power consumed during the pre-load shed period should be factored by an additional 20% if the average discharge current in amps is numerically more than twice the one-hour rating of the battery.

Therefore, unless otherwise agreed, for the purpose of this calculation, a battery capacity at normal ambient conditions, at the one-hour rate, with 80% of the nameplate rated capacity, and a 90% state of charge, may be assumed or **72% of nominal capacity at 20º C.** Likewise, at the five-hour rate, same conditions, **assume 61% of nominal capacity at 20º C.**

Next month we continue our study of Electrical Load Analysis.