ELECTRONIC CONTROL SYSTEM

INTRODUCTION

The engine electronic control system has two identical FADECs. The FADEC provides complete control of the engine without hydromechanical backup.

DESCRIPTION

Either FADEC is capable of controlling the engine. One FADEC will control the engine and the other FADEC will operate in a standby mode. Control of the engine will be transferred from the controlling FADEC to the standby FADEC if the controlling FADEC fails.

Each FADEC receives input data from aircraft equipment:

- The air data computer provides aircraft operating data.
- The throttle lever resolver provides the pilot's Throttle Lever Angle (TLA).
- Cockpit discretes provide cockpit switch positions.
- Aircraft discretes provide aircraft switch positions.

The FADECs are identified in the system by jumpers in the connecting cables. These jumpers identify each FADEC as A or B and a left or right engine.

The FADECs have two sources of electrical power. The aircraft supplies 28 V DC, which is used during the initial engine start or when the engines are not operating. Once the engines is running, the engine Permanent Magnet Alternator (PMA) provides power for the FADECs.

FADEC A and FADEC B communicate with each other through the cross channel data link. This allows them to share engine sensor data. They also are hardwired to each other for three discrete signals.

The FADECs in each engine nacelle also communicate with the FADECs in the other engine nacelle through a data bus. This is used for thrust reverser coordination and automatic takeoff thrust control in the event of engine failure during take-off.

Each FADEC has a dedicated set of sensors for engine operating data. These sensors provide:

- N1P: primary N1 RPM from primary fan speed sensor.
- N1S: secondary N1 RPM from secondary fan speed sensor.
- N2P: primary N2 RPM from HP rotor speed pickup on accessory gearbox.
- P2.5: compressor inlet pressure from pressure sensor on front frame.
- T2.5: compressor inlet temperature from sensor on front frame.
- ITT: interstage turbine temperature from LP turbine thermocouples.
- CVG feedback: variable vane position from LVDT in hydraulic actuator.
- P0 sensors (static pressure sensor): backup static pressure to the FADEC′s.

The figure ″FADEC′s/SET OF SENSORS-ON THE ENGINE - COMPONENT LOCATIONS″ shows all the sensors on the engine.

The figure ″P0 SENSORS - COMPONENT LOCATIONS″ shows the location of the sensors in the aircraft tail.

The FADEC′s compare the P0, static pressure, supplied by the P0 sensors and Pamb, ambient pressure, supplied by the ADC′s. If any difference between these two signals occurs, the FADEC′s trigger a fault bit. The message ″PALT X P0 DIFF FAULT″ appear on the CMC (versions 6 and 7).

The messages ″ND-ENG1/2 P0 SYS″ appear on the CMC (version 9), when there is a dual P0 sensor failure 1 or a dual P0 sensor failure 2.

The controlling FADEC will control the following devices:

EFFECTIVITY: ALL

N1 REVERSIONARY MODE

In case of N1 total fault (in both FADECs), the FADEC reverts to N1 reversionary mode (or ″total loss of N1″ reversionary mode).

In this reversionary mode, the FADEC synthesizes N1 (N1 SYN) as a function of N2 and ambient conditions. The N1 SYN is then used in the normal control loop on N1 REQUEST, in the selected thrust rating mode.

This mode is evident to the pilot due to the absence of N1 indication in the EICAS.

THRUST/N1 TARGET CALCULATION

The FADEC calculates the maximum available engine thrust for a given thrust rating mode, airspeed/ambient conditions and air bleed configuration. Such a maximum thrust corresponds to the N1 TARGET, provided to the EICAS and indicated in a digital display and as a cyan bug on the N1 analog indicator arc.

N1 TARGET corresponds to the N1/thrust predicted by the engine CPCP provided by the engine manufacturer, considering same airspeed/ambient/installation conditions.

When TLA is set at the THRUST SET position the FADEC controls the engine at N1TARGET.

There are several sources of ambient/airspeed data to be used in the N1TARGET calculation logic: ADC1, ADC2 (ADC1 is completely segregated from ADC2), engine sensors (used as reference - in case of disagreement between ADC1 and ADC2 - and as backup), takeoff data entered by the pilot and default values.

In normal mode (that is, with no ADC faults) the following data are used as primary reference for N1TARGET calculation.

NOTE: When there is any detected problem (disagreement between ADC1 and ADC2, out-of-range faults, etc.) with the primary reference data, the ADC data fault accommodation logic is applicable.

ALTITUDE AND AIRSPEED REFERENCE FOR N1 TARGET CALCULATION

- In T/O-1, ALT T/O-1 and CON modes:
  - Eng #1: PALT1 and MN1 from ADC1.
  - Eng #2: PALT2 and MN2 from ADC2.
- In CLB and CRZ modes:
  - For both engines: PALT1 and MN1 from ADC 1.

    NOTE: In case a x-check difference fault is detected between ADC 1 and ADC 2 data the each engine begins to use its own ADC data.
    In case of an ADC data failure, refer to ADC data fault accommodation logic.

TEMPERATURE REFERENCE FOR N1TARGET CALCULATION

Regarding temperature reference, N1TARGET calculation is performed by the FADECs in two steps:

- TARGET N1C (corrected fan speed): which corresponds to the maximum available thrust. It is correct based on sqrt (theta). Theta means the quocient between the total temperature and the ISA temperature at sea level, in Rankine.
  TARGET N1C is calculated based on ambient conditions and the thrust rating mode.
- N1TARGET (mechanical fan speed): it is calculated by uncorrecting TARGET N1C. TARGET N1C is uncorrect based on a given temperature which may or may not be the same one used to calculate it (TARGET N1C).

EFFECTIVITY: ALL

Following are the several temperature references for TARGET N1C calculation and uncorrection:

- TATTOT: synthesized total air temperature based on the adjusted TOTEMP.

  NOTE: In order to calculate TATTOT, the static TOTEMP value is decremented at a rate of 1°C/500 ft (continuously updated) up to 1,700 ft ATOA (in order to approximately reflect the atmospheric static temperature lapse rate).
  In addition, the MN effect is accounted for.
  The PALT and MN values are not frozen during all this sequence. The FADEC keeps on reading and updating the PALT and MN values to compute the TATTOT.

- TATSYN: synthesized total air temperature based on last good TAT recorded at touchdown.

  NOTE: At aircraft touchdown, during landing, the FADECs record the existing TAT, which is used to calculate TATSYN, during 30 seconds, if the aircraft remains on the ground, or up to 1,700 ft ATOA, in case of a touch-an-go maneuver.
  This logic is provided due to the following reasons:

  - TAT is not accurate on the ground, at low airspeed.
  - To avoid the need to transition directly from TAT to engine sensor (T2SYN) at touchdown.
  - To have a better temperature reference in case of a touch-an-go maneuver.

- TAT 1 (from ADC 1).
- TAT 2 (from ADC 2).
- T2SYN: synthesized total air temperature at the fan inlet, based on engine sensor T2.5 and N1.

The FADEC selects the primary temperature reference data for TARGET N1C calculation and uncorrection according to the following logic:

- All Engines Operating condition (AEO)
  The temperature reference, refer to the primary reference for TARGET N1C calculation and uncorrection.
  In case the primary reference is not available or is declared faulty, it is replaced according to the ADC data fault accommodation logic described in the section FADEC inputs selection and fault accommodation.
  Following are the main features of this logic:

  - For AEO condition, the temperature reference for TARGET N1C calculation is always the same as the one used for uncorrection.
  - For T/O-1, ALT T/O-1 and CON modes, each engine uses its own ADC data as primary reference (engine #1 uses ADC1 data, and engine #2 uses ADC2 data).
  - For CLB and CRZ modes, both engines use primarily ADC1 data in order to provide N1 synchronization. In case of disagreement between ADC1 and ADC2 data, each engine begins to use its own ADC data (see section FADEC inputs selection and fault accommodation).

- One Engine Inoperative condition (OEI)
  The temperature reference defined in the figure refer to the primary reference for TARGET N1C calculation and uncorrection.
  In case the primary reference is not available or is declared faulty, it is replaced according to the ADC data fault accommodation logic described in the section FADEC inputs selection and fault accommodation.
  Following are the main features of this logic: skip - in OEI condition, there is a logic to recover the predicted/expected engine

thrust during takeoff, by using the actual temperature (TAT1 or TAT2) 2 seconds after lift-off (when TAT1 and TAT2 are accurate) to uncorrect the TARGET N1C.

- This logic is very helpful when the actual air temperature is different than the predicted one (based on standard lapse rate).
- TAT1 or TAT2 is used only in case it provides more thrust than by using TOTEMP.
- This logic is used only below ISA + 15^{o}C (engine thermodynamic kink point), because above this kink point there may be no engine ITT margin to try to recover thrust.

The figure ″ELECTRONIC CONTROL SYSTEM - ENGINE INDICATION LOCATIONS″ shows the MFD and EICAS engine indication.