IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X
PP. 01-04
www.iosrjournals.org

Full Authority Digital Engine Control: Overall System, Function and its Application

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Abstract: *The transformation from conventional hydro mechanical control system to modern digital control represents a revolutionary change with new capabilities, easy operation and lesser workload. Full Authority Digital Engine Control (FADEC) is a system consisting of digital computer known as Electronic Control Unit (ECU) with auxiliary components for controlling aircraft engine and propeller. It is produced for both piston engines and jet engines. The term Full Authority indicates that there is no manual override available, thus placing full authority over operating features to the computer. This technology with a characteristic feature of single lever control runs the engine in optimal condition with less consumption of fuel by controlling power and adjusting amount of fuel injection during the process of combustion. The basic objective is to give optimum efficiency for given flight condition. It manages starting phase and further engine operation from idle to full throttle. This paper deals with overall FADEC system and the application of FADEC in Lycoming Engine, MPM 20 Engine, Marine Gas Turbine. Also the System On Chip Technology (SOC) in FADEC which contributes to cost reduction and weight reduction of system. The functionality of this system relating with engine performance and parameters is being discussed.*

Keywords - *Control system, ECU, Engine, FADEC, Sensors.*

I. INTRODUCTION

A full authority digital engine control is a system having electronic control unit and other secondary components for monitoring the engine performance. The system controls the ignition timing, fuel injection timing and fuel-air ratio mixture thus, an engine with FADEC doesn't need magnetos and there is no requirement for manual air-fuel mixture control. The basic components of FADEC are two Master Power Control Units (MP1 and MP2) two ECU's, Health Status Annunciator (HSA) and sensors for temperature and pressure of manifold, cylinder head temperature(CHT), exhaust gas temperature(EGT), speed and fuel pressure, low voltage and high voltage harness, throttle body and fuel injection system. HSA has five lights on its panel and gives information relating with FADEC's status. FADEC works by receiving inputs during flight conditions such as density of air, throttle position, engine temperature and pressure and other parameters. These data from sensor will go to ECU for processing and analysis. Then the operating parameters of engine such as fuel flow, position of stator vane and bleed valve along with others are estimated from this data and applied appropriately. It also controls engine starting and restarting, giving optimum engine efficiency for given conditions of flight. It not only provides efficient functioning of engine but allows programming for engine shortcomings and get engine's maintenance report .As the term Full Authority indicates there is no manual intervention available hence it can be programmed to take required measures automatically without interference of pilot. The functions of FADEC are engine control, safety and data logging. Through this system engine receives correct fuel amount per cylinder and ignition of spark plug at correct time by RPM, throttle setting, convenient pressure and temperature leading to fuel savings and smoother running of engine.

II. FADEC SYSTEM AND APPLICATION

Md Akhtar Khan et al. [1] carried out experimental study of FADEC on Lycoming Engine. In this paper, testing and validation of Lycoming 0-320-B engine equipped with FADEC is done and results are evaluated for the performance of engine. The overall architecture and working of the system has been presented. Each MPC has lower and upper portion. The lower portion has electronic circuit board containing two control channels each assigned to a single engine cylinder and upper portion has ignition coils. Each MPC containing two control channels, operate two engine cylinders. These channels get input from pilot through throttle control. Information from MPC is given to HSA and status of FADEC system is conveyed to pilot through HAS. The control channels use sensor's signal to estimate required fuel mixture and ignition timing for consecutive combustion process. The system is electrically powered and needs two independent sources of power supply.

DOI: 10.9790/1684-17010030104

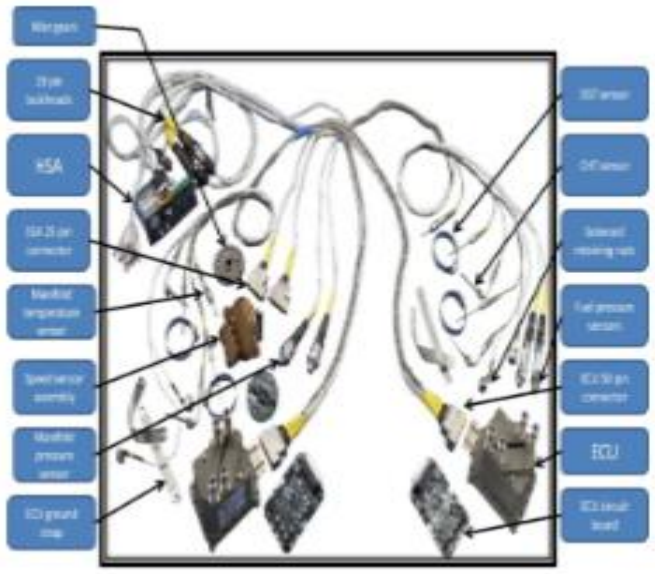

Fig.1. Parts of FADEC [1]

Through a conventional type ignition switch pilot controls enabling, starting and disabling of FADEC.The spark plugs of cylinder are fired twice per cycle, once on compression and on exhaust stroke. It schedules the timing of spark by two MPC units; spark timing is variable and set according to ignition advance. The solenoid actuated fuel injector supplies correct fuel amount to each cylinder by receiving data from control channels in MPC, depending on speed and position of engine. The test was conducted to study the effect of FADEC on this engine by observing fuel and oil quantity at start and after running the engine.The results obtained were as shown in Figure (b) and (c). Thus, we can infer that fuel and oil consumed were less. The engine was run at different RPMs and values of fuel consumption and thrust were recorded. Hence, increasing the efficiency and performance of the engine [1].

DATE	20/9/2013	**Fuel Qty. At START**	18	**Oil Level at START**	7.5 ltr	**Ignition Drop Check**
ENGINE TYPE	Lycoming O-320	**Fuel Qty. At STOP**	15	**Oil Level at STOP**	7.3 ltr	**BOTH**
ENGINE NO.	B-2B	**Fuel Consumed**	3	**Oil Consumed**	0.2 ltr	**LEFT**
START TIME	1625	**Propeller**	Catto 2 bladed	**Alternator No.**		**RIGHT**
STOP TIME	1640	**TEST DURATION**	00:15			

Fig.2. Engine Test record-1 [1]

Nikhil Kumar et al., through his paper highlighted the major functions of FADEC system which includes engine control, safety and diagnostics and data logging. The various engine functions like speed, pressure and temperature of manifold, power setting, etc. are controlled by advanced processors which collect data and establish required settings for optimum engine performance. These settings are ignition timing, proper fuel mixture. The system is equipped with diagnostic software which runs in background to monitor the health of system. Large number of data every second, held on flash memory chip is recorded by Powerlink system and is constantly evaluated for troubleshooting and engine diagnostics [2].

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Sl. No.	RPM (N)	MANIF OLD PR. (inch of Hg) P_m	FUE L PR. (psi) P_f	FUEL CONSUMP TION (Lt/Hr) V_f	THRUST (kgF) F
1.	730	11	6	1.4	13
2.	1200	14.7	6	4.2	45
3.	1500	17.4	6	6.6	65
4.	1700	20	5	9	85
5.	1900	22	5	10.8	100
6.	1950	23.1	5	12.8	107
7.	2000	23.4	5	13.2	116
8.	2100	24.5	5	14	120
9.	2200	25.1	5	15	130
10.	2285	25.9	5	15.8	138

Fig.3. Engine Test record-2 [1]

Rudolf Andoga et al. had designed and implemented a FADEC control system for experimental turbojet engine MPM 20. Manual control was one of the major drawbacks of turbojet engines and with the use of digital technology in it many advantages have been achieved like low mass of control system, high precision in regulating engine parameters, etc. FADEC had to deal with non-linearity, changing model structure and constants during operation of turbojet engine. FADEC with situational control methodology approach with gating neural network having situational frames and controller system to handle it was used [3].B Githanjali et al., presented their work for development of FADEC for aero-derivative marine gas turbine engine. By including the complicated controls, method for fault identification, improved actuator, sensor and fuel system design, FADEC offers important and economical benefits to engine control of marine propulsion system and has provided suitable control requirements of engine and fault withstanding features [4].S R Balakrishnan [6] discussed the bottom to top approach considering engine requirement and developing control system to required level. At starting gas turbine engines had electromechanical system then it switched to electronic system and then integration with electronic system followed by audit process and finally verification and validation [5]. Minling Zhu et al.,[6] signified the effects of System on Chip technology on FADEC system of aero engine and enlisted various benefits of this technology. High thrust-weight ratio and low specific fuel consumption are the aims of turbine engine performance and on the same hand cost and flexibility are important issue. There is problem of obsolescence of electronic components and hence reusable IPs and open system architecture can be adopted which leads to life-cycle cost reduction. FADEC needs data acquisition of every I/O channel interconnecting to sensor and actuator of all sub-systems, signal conditioning and processing. It can be achieved using one integrated chip and is able to take 80% tasks thus, electronic components are replaced by IPs offering less weight of the system. Also flexibility of the system can be obtained with the use of reconfigurable IPs and synthetic tools [6].

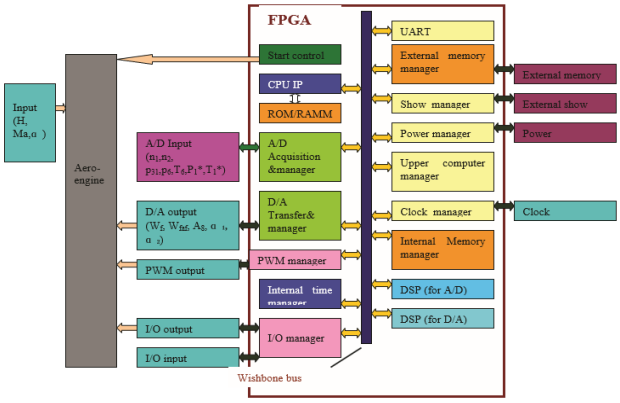

Fig.4.FADEC function on one integrated chip [6]

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Ganesan et al.[7] emphasized the need for proper control system. As air transportation is increasing, it has to satisfy safety and comfort criteria along with consideration of cost and optimal performance of engine. This led to the transition from conventional control system to today's modern Full Authority Digital Engine Control Systems].

III. CONCLUSION

Full Authority Digital Engine Control as a modern control system of engine proves to be a highly efficient system in terms of increasing engine performance along with engine diagnostics and monitoring of engine health.Implementation of FADEC in various engines as discussed offers multiple advantages with high precision in regulation of operating parameters of engine. Reprogrammable feature as per engine requirement and less need of monitoring the engine parameters by flight crews makes it a highly reliable system.

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