ELECTRIC DEMONSTRATION SYSTEMS OF THE GAS-TURBINE ENGINE FOR THE MORE ELECTRIC AIRCRAFT

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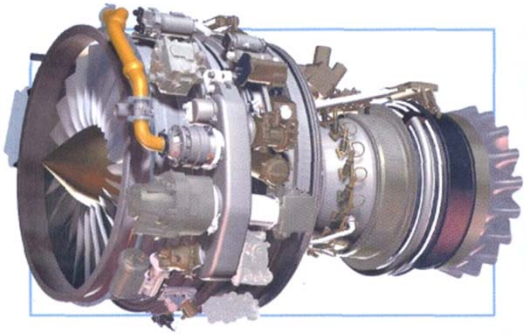
- CIAM activities on electric engine
- Demonstration system of electrically driven automatic control
- Demonstration system of oil supply system with electrically driven pumps

IMPORTANT AREAS OF ENGINE ELECTRIFICATION

- Engine working process
- Automatic control and fuel supply systems
- Oil system
- Starting system
- Electric power generation system
- Thrust generation system

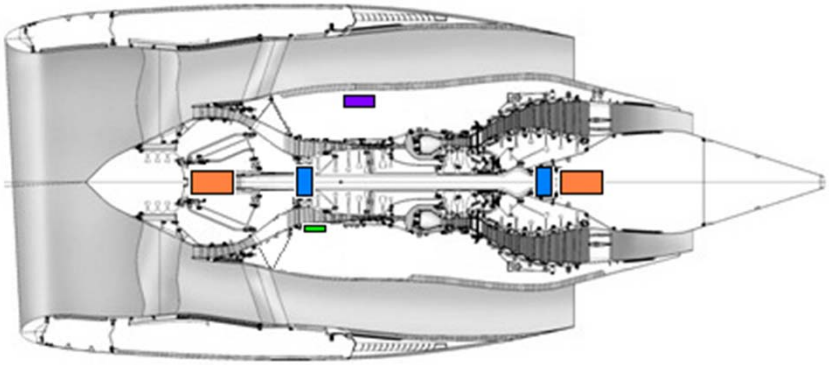
ELECTRIC ENGINE FOR THE MORE ELECTRIC AIRCRAFT

Current Technology Engine



- ***Gearbox***
- ***Power drives by fuel***
- ***Mechanical bearings with oil system***
- ***Air bleed for aircraft systems***

Electric Engine



- ***Without gearbox***
- ***Electric drives***
- ***Magnetic bearings (without oil system)***
- ***Without air bleed***
- ***Embedded starter/generator***

BASIC PROBLEMS OF ENGINE ELECTRIC DEVELOPMENT

- Optimization of air-gas channel for starter/generator arrangement
- Engine performance optimization at reduced air bleed
- Distributed control system with electric drives:
  - low weight electric-driven actuators
  - smart sensors and actuators
  - multistage centrifugal pumps with high efficiency
- Oil system with electrically driven pumps
- Magnetic bearings for rotors

CIAM ACTIVITIES ON ELECTRIC ENGINE

- Conception of electric engine
- Demonstration system of electrically driven automatic control
- Fuel system with electrically driven pumps
- Oil demonstration system with electrically driven pumps
- Engine test bed for testing of demonstration systems

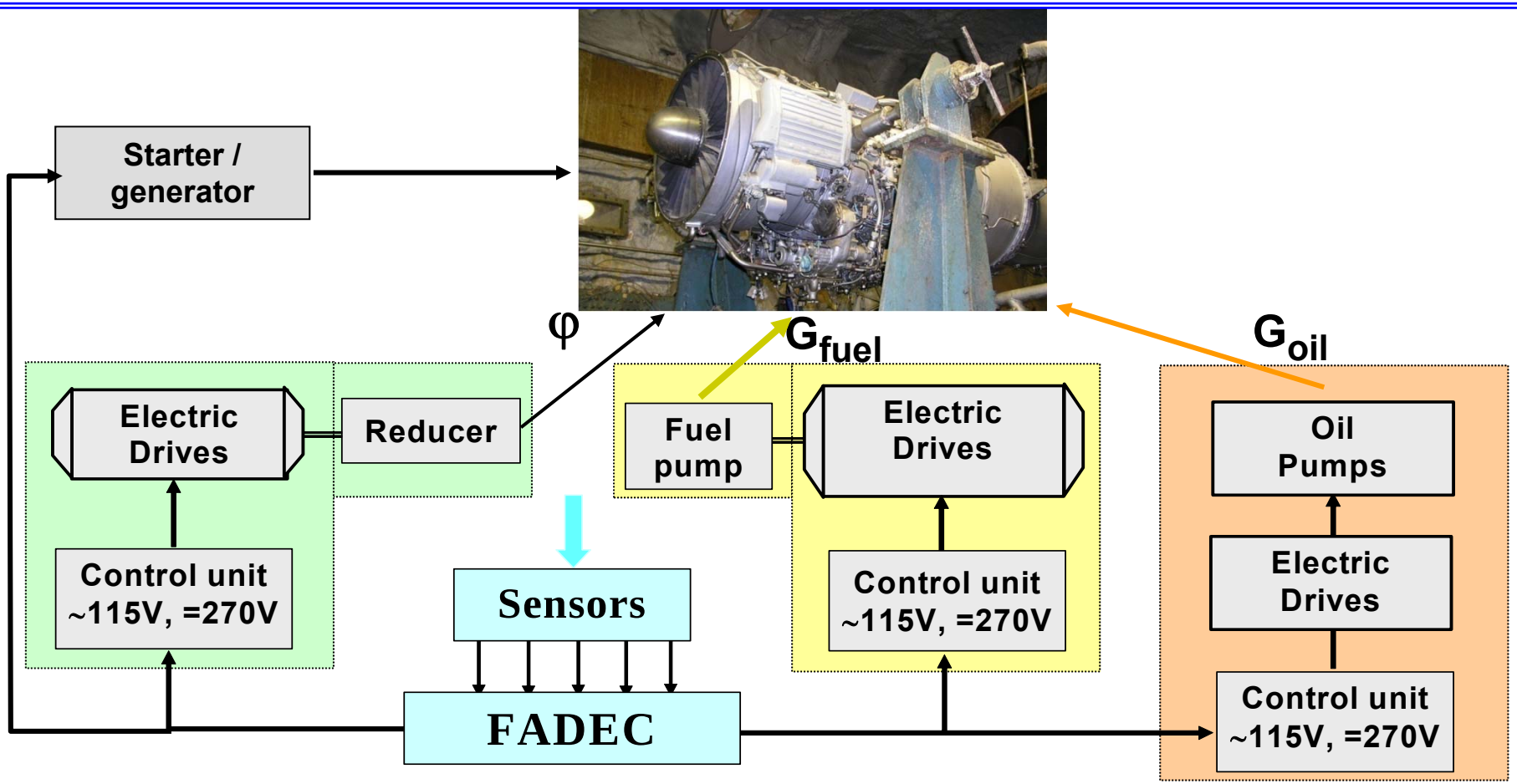
Engine-demonstrator
(n_2 = 17500rpm, T = 17kN)

Tests of automatic control system and oil system with electrically driven pumps

PURPOSES OF DEMOSTRATION SYSTEMS DEVELOPMENT

- Demonstration of electric technologies abilities
- Selection of actuators
- Development of a digital control system for electric drives
- Selection of control laws for electric drives management

DEMONSTRATION SYSTEM SCHEMATIC

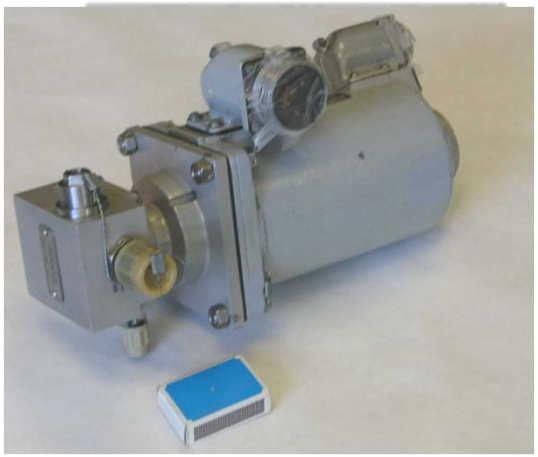


- Sensors: rpm (n_2, n_1), air pressure at the compressor exit(P_2), fuel flow (G_{fuel}), etc.
- control units of actuators (electric drives of the pump and compressor IGV)
- electromagnetic valves for control of air bleed

System affects fuel flow, IGV position and air bleed valves

ACCESSORIES

Electric drive of fuel pump

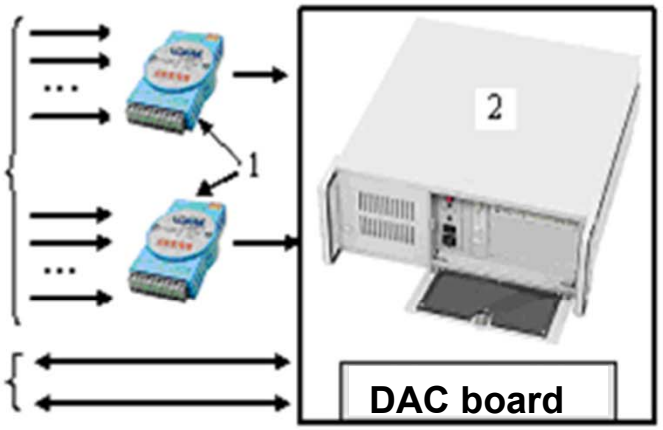


N	3 kW
N_{max}	12000 rpm
G_{Fmax}	1000 kg/h
P_{in}	3 – 5 bars
P_{max}	70 bars

IGV electric drive

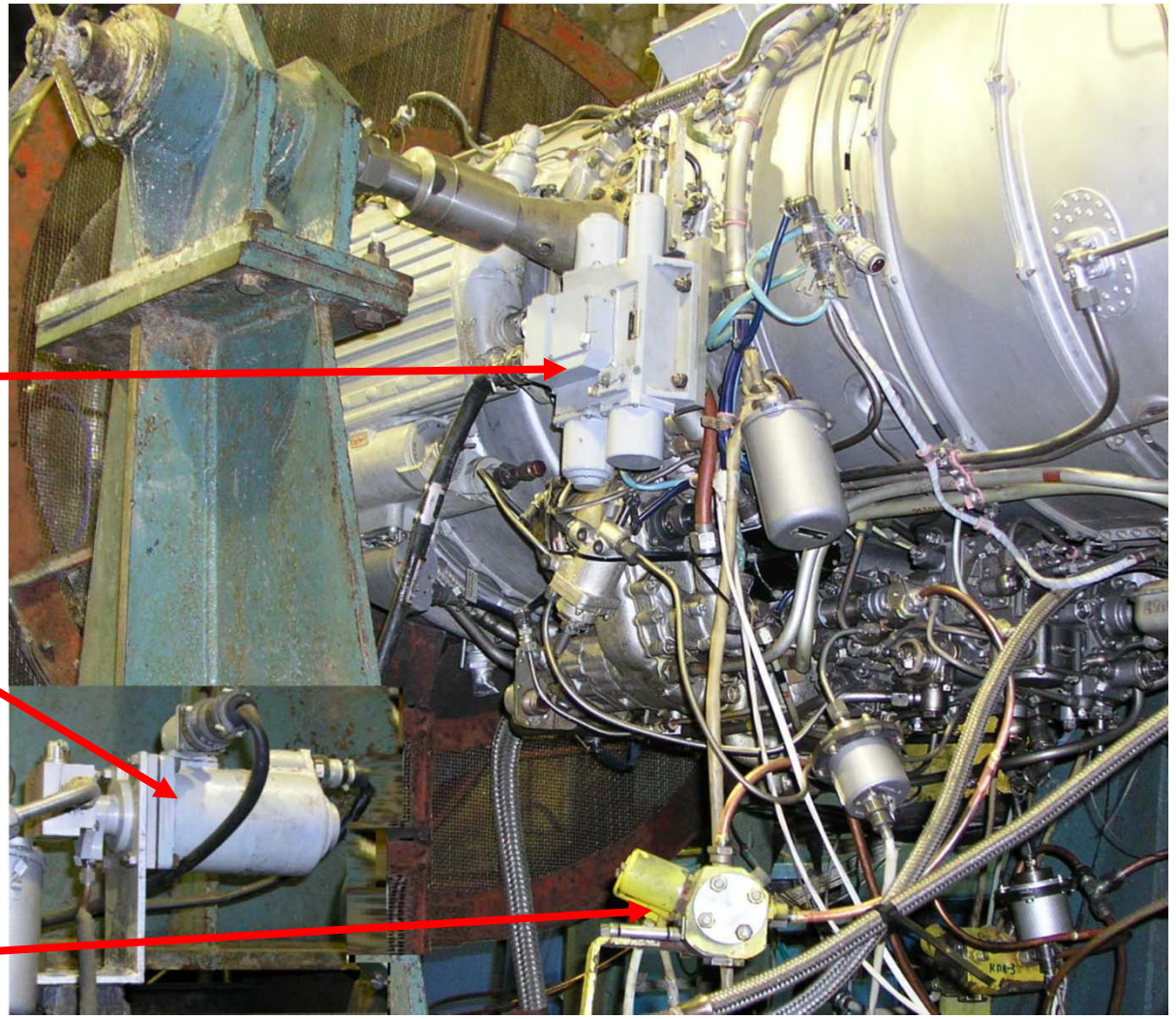
N	0.14 kW
N_{max}	12000 rpm
Force	100 kg
V_{max}	25 mm/s

Digital controller

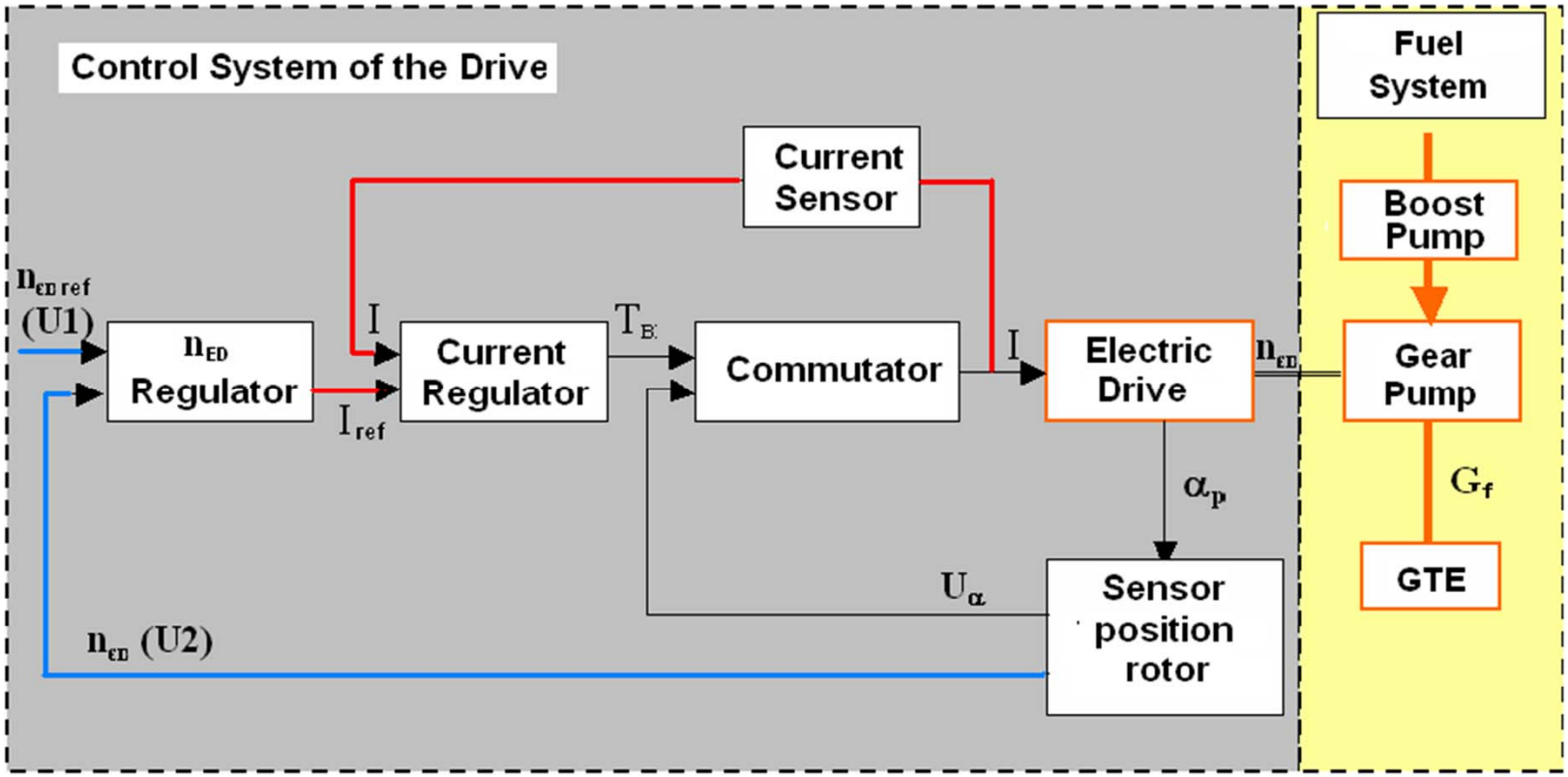


CPU speed	2.2 GHz
RAM	226 MB
CPU clock rate	33 ms
Number of input channels	10
Number of output channels	12

INSTALLATION OF UNITS ON THE ENGINE-DEMONSTRATOR



DRIVE CONTROL SYSTEM SCHEMATIC

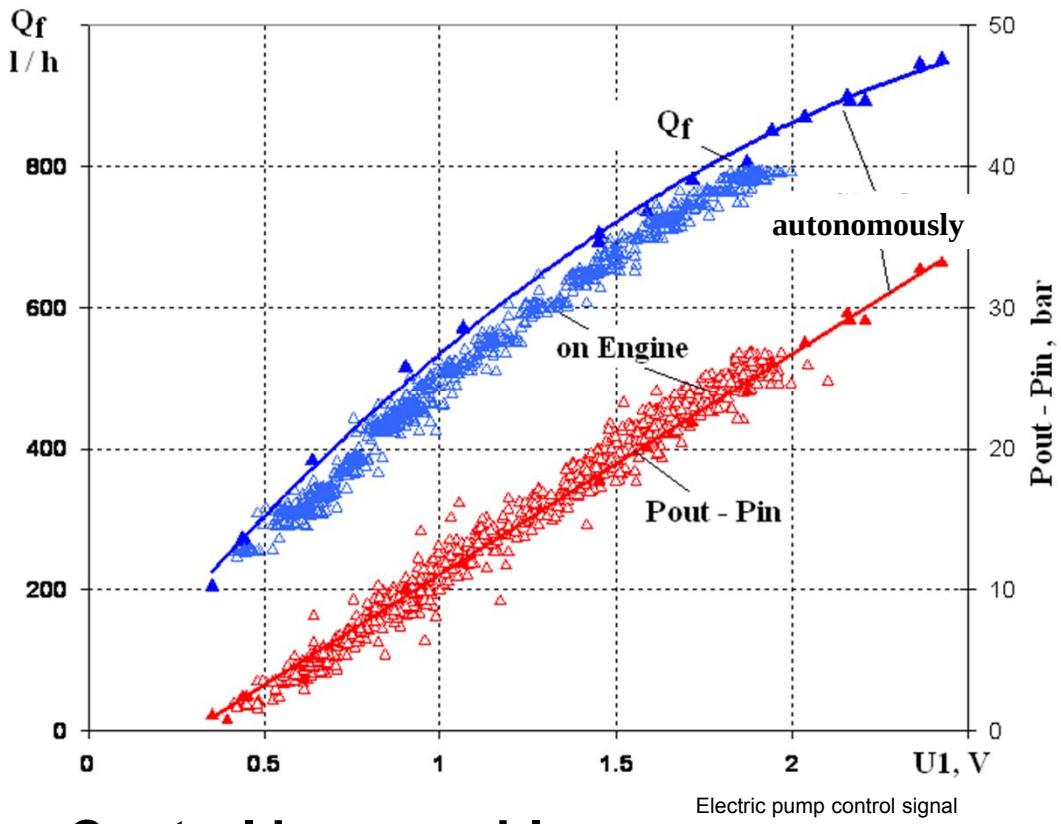


2 operating modes

- Control by rotational speed of electric motor rotor
- Control by torque on electric motor rotor

STATIC CHARACTERISTICS OF FUEL SYSTEM

Experimental fuel flow characteristic of fuel system



Electric pump control signal

- Control by rpm - blue
- Control by current (torque of electric motor shaft) – red

Installed electric drive system

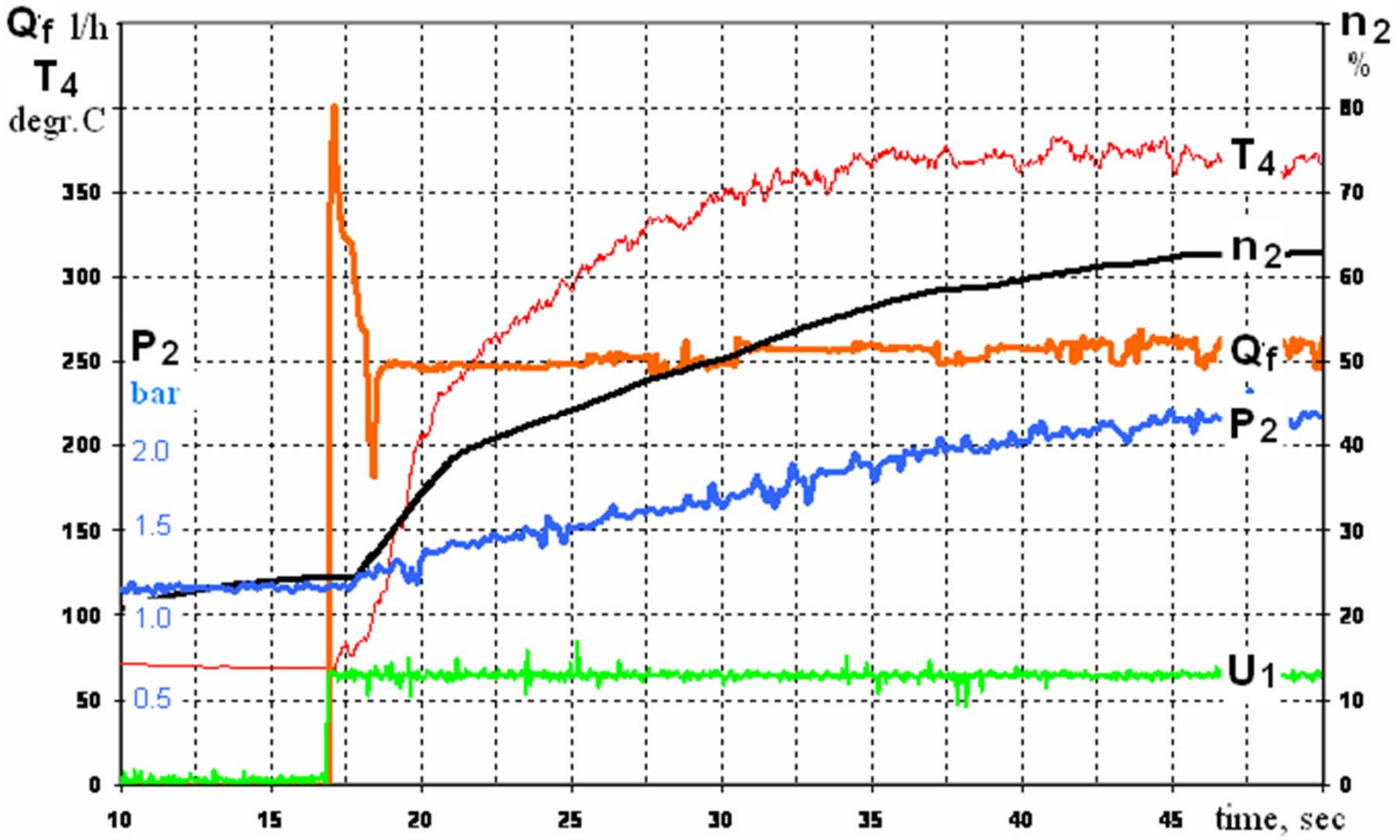
- At starting, acceleration, advanced acceleration, deceleration and stopping

Dynamic performance at control by rpm and by current are rather different

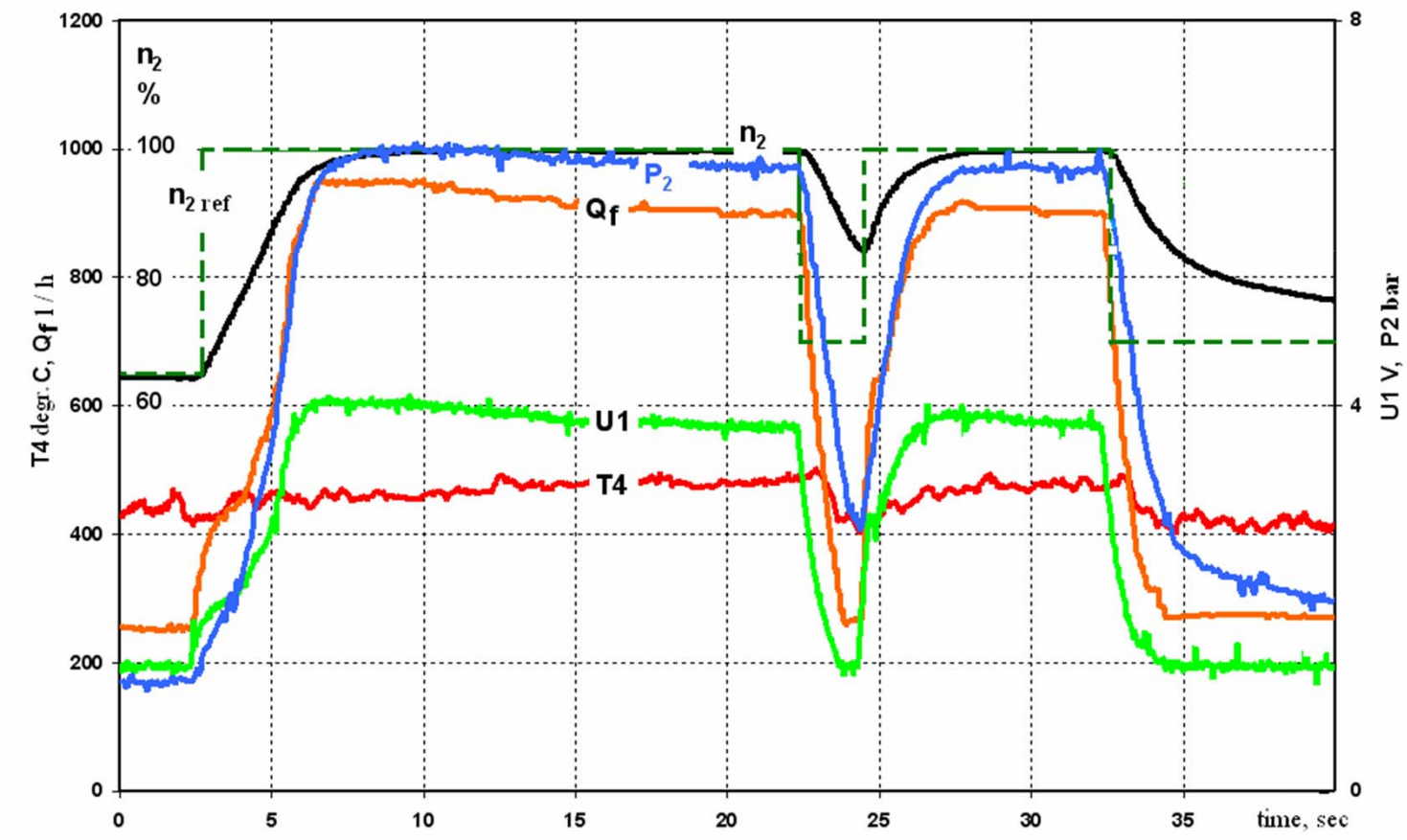
Transition time from MIN to MAX at control be rpm - 0.2s (2 times less than at control by current)

➢ **control by rpm is more preferable**

ENGINE STARTING



ENGINE ACCELERATION, ADVANCED ACCELERATION AND DECELERATION



n_2 - HPC rotational speed
Q_f – fuel flow
U1 - control signal to the pump electric drive
T4 – turbine exit temperature

MAIN RESULTS OF DEMONSTRATION SYSTEM TESTS

- Engine control is operable at steady and transient conditions (start, acceleration, advanced acceleration, deceleration, stopping)
- IGV electric drive:

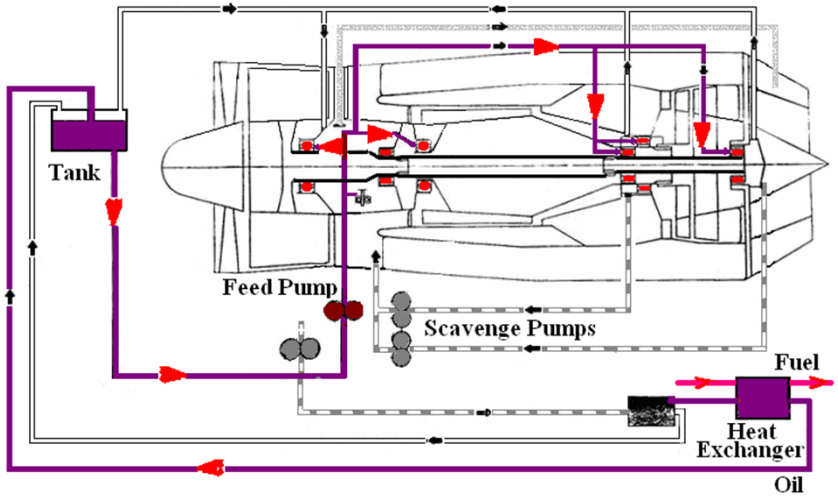
  transition time - 0.5 sec

- Electro - pneumatic bypass valve:

  opening / closing time - 0.2…0.3 sec

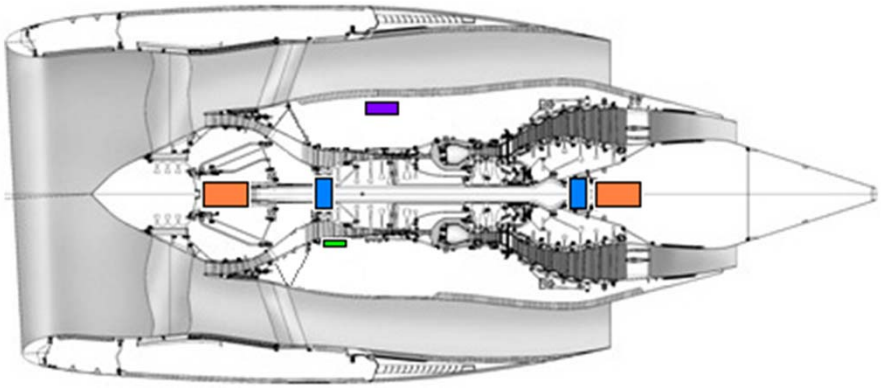
OIL DEMOSTRATION SYSTEM WITH ELECTRIC DRIVES

Current Technology Engine



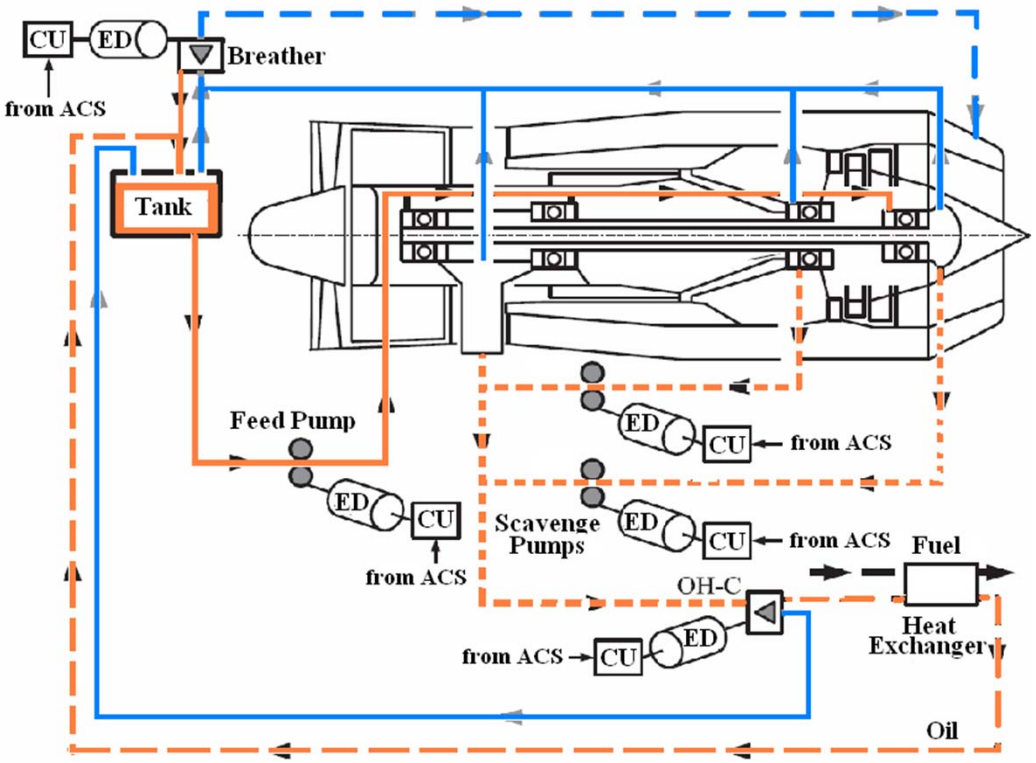
- *Oil pumps drive by HP rotor*
- *Breather drive by HP rotor*
- *System for oil heating at the engine start*

Electric Engine



- *Independent electric drive feed and scavenge pumps*
- *Electric drive for breather*
- *Electric drive for evacuation of oil from cavities*

OIL DEMONSTRATION SYSTEM WITH ELECTRICALLY DRIVEN PUMPS



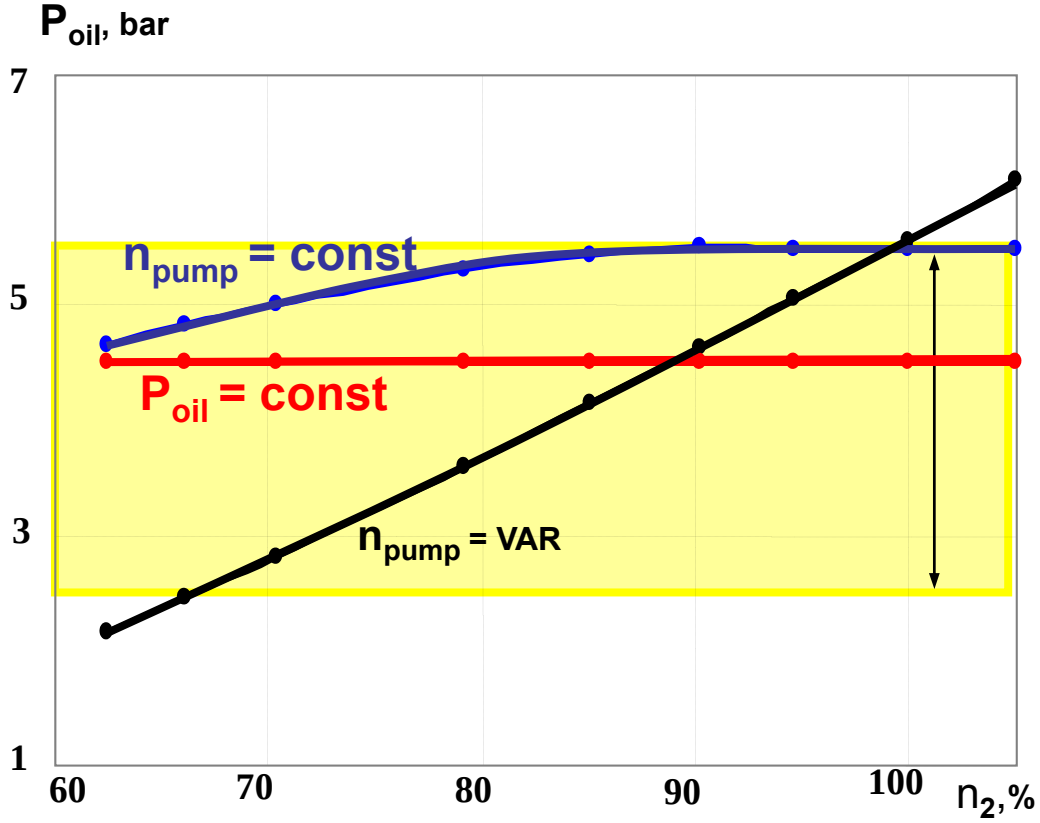
Principal feature of demonstration system

Each pump has its own electric drive

Efficiency:

- **Improvement of oiling quality (increase of life time)**
- **Decrease of fuel heating**
- **Weight reduction**
- **Engine starting improvement at low ambient temperature (t < -30°C)**

SELECTION OF CONTROL LAWS FOR ELECTRICALLY DRIVEN PUMPS OF OIL SYSTEM



Laws of oil supply

n_{pump} **= const** - constant rotation speed of the feed pump

P_{oil} **= const** – constant pressure behind the feed pump (with pressure controller)

n_{pump} **= var** - drive of pumps by gear box (conventional system)

1 and 2 laws - best performance relating to oil heating

➢ **Preferable law n_{pump} = const (without pressure controller)**

CONCLUSION

Demonstration systems

with electric drive units on the engine-demonstrator have shown an ability for development of More Electric Engine in the near future