«EMR of helicopter electrical power system for its management in different operating modes»

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Research program
- supported by the Direction Générale de l’Armement (French government defense agency)

- in partnership with: Eurocopter (an EADS company)

Cirtem (expert on power converters)

Study of Electrical Power System in a More Electrical Aircraft (helicopter)

Helicopter Electrical Power System = System for electrical production, conversion, distribution and storage aboard the aircraft

Aims:
- study a new electrical architecture
- evaluate an energy management strategy
- develop and test a full-scale prototype
1. Helicopter electrical architecture
   • Classic / more electrical architecture
   • Aims of more electrical architecture
   • Different operating modes
   • EMR : tool for model organization

2. Energetic Macroscopic Representation of an helicopter EPS
   • Devices : S/G, BAT, SCAP, DC buses
   • EMR of the whole EPS

3. Maximal Control Structure of an helicopter EPS
   • Devices : S/G, BAT, SCAP, DC buses
   • MCS of the whole EPS
   • Energy management of EPS

4. Simulation of helicopter EPS modelling with Matlab® Simulink
« Helicopter electrical architecture »
« EMR of helicopter Electrical Power System (EPS)»

- Classic Electrical Power System -

Classic AC architecture as helicopter EPS:

- AC bus: three-phase network
- DC bus connected to AC bus with Transformer Rectifier Unit (TRU)
- Independent starting system
- One energy source per bus (no source in parallel)
- Unidirectional power flows (sources and loads)

More electrical architecture as helicopter EPS:

- Two DC buses connected with a bidirectional chopper
- Starter/Generator system
  - S/G1 = APU
  - S/G2 = main S/G
- Generators and Energy Storage Systems (ESS) connected to the DC bus1 with converters
- Bidirectional power flows


Objectives:

- Warranty network stability and quality and the energy availability
- Reduce the embedded weight
- Meet the growing energetic requirements of the aircraft
- Optimize the global energetic efficiency

Methods:

- Control of bus voltages through the different sources in all operation modes
- Reduction of the filters
- Addition of Energy Storage Systems
- Management of the energy flows by balancing the energetic requirements of the loads between the different sources according to their characteristics (energy or power source, Energy Storage System or Starter/Generators, …)
« EMR of helicopter Electrical Power System (EPS) »

- Energy management in different operating modes -

Starting modes:

Degraded operation modes:
No source is always connected to the network
⇒ No source can set its voltage to the remaining system
⇒ All the sources must be considered as a current source
« Energetic Macroscopic Representation of an helicopter Electrical Power System »
- EMR of a Starter/Generator and its converter -

Starter/Generator and its converter:

\[ T_{turb1} = f(\Omega_{turb1}) \]

\[ T_{turb1} = \frac{T_{turb1}}{K_1} \quad \Omega_{turb1} = \frac{\Omega_{shaft1}}{K_1} \]

\[ \Omega_{shaft1} = \frac{1}{J_{tot1}} \int (T_{sm1} - T_{gear1} - f_{r1} \cdot \Omega_{shaft1}) \cdot dt \]

where: \( J_{tot1} = J_{T1} + \frac{J_{sm1}}{(1/K_1)^2} \)

\[ I_{sm1} = \frac{1}{L_{s1}} \int (E_{sm1} - V_{conv1} - R_{s1} \cdot I_{sm1}) \cdot dt \]

\[ E_{sm1} = K_e \cdot \Omega_{shaft1} \quad T_{sm1} = K_e \cdot I_{sm1} \]

\[ I_{bus_sm1} = m_{conv1} \cdot I_{sm1} \]

\[ V_{conv1} = m_{conv1} \cdot V_{bus1} \]

**Battery and its converter:**

\[ I_{bus\_BAT} = m_{chop1} \cdot I_{BAT} \]

\[ V_{chop1} = m_{chop1} \cdot V_{bus1} \]

where model parameters are dependent on SOC and temperature

\[ I_{BAT} = \frac{1}{L_{chop1}} \int (V_{BAT} - V_{chop1} - R_{chop1} \cdot I_{BAT}) \, dt \]

Supercapacitor pack and its converter:

\[ I_{bus\_SCAP} = m_{chop2} \cdot I_{SCAP} \]

\[ V_{chop2} = m_{chop2} \cdot V_{bus1} \]

\[ I_{SCAP} = \frac{1}{L_{chop2}} \int (V_{SCAP} - V_{chop2} - R_{chop2} \cdot I_{SCAP}) \, dt \]

where model parameters are dependent on voltage and temperature.


DC buses and the DC/DC converter:

\[ V_{bus2} = \frac{1}{C_1} \int (I_{dc2} - I_{bus2}) \cdot dt \]

\[ I_{dc2} = \frac{1}{L_{dcdc}} \int (V_{dc2} - V_{bus2} - R_{dcdc} \cdot I_{dc2}) \cdot dt \]

\[ I_{dc1} = m_{dcdc} \cdot I_{dc2} \]

\[ V_{dc2} = m_{dcdc} \cdot V_{bus1} \]

\[ V_{bus1} = \frac{1}{C_1} \int -I_c \cdot dt \]
« EMR of helicopter Electrical Power System (EPS) »

- Helicopter Electrical Power System -

« EMR of helicopter Electrical Power System (EPS) »

- EMR of the helicopter Electrical Power System -

EMR of the helicopter EPS:

« Maximal Control Structure of an helicopter Electrical Power System »
« EMR of helicopter Electrical Power System (EPS) »

- Maximal Control Structure of the helicopter EPS -

MCS of Starter/Generators:

![Diagram of Starter/Generators](image)

Starter mode: speed control

Generator mode: current control

« EMR of helicopter Electrical Power System (EPS) »

- Maximal Control Structure of the helicopter EPS -

MCS of Energy Storage Systems:

**Battery:**
- Current control

**Supercapacitor pack:**
- Current control

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« EMR of helicopter Electrical Power System (EPS)»

- Maximal Control Structure of the helicopter EPS -

MCS of buses:

Bus 1:
voltage control and association with current control loop of supercapacitor pack (source with the fastest time response)

Bus 2:
voltage control and association with a current control loop

Energy management of helicopter EPS:

« Simulation of helicopter EPS modelling with Matlab® Simulink »
Conclusion and outlooks:

- Characterization and modeling of the EPS devices
- Simulation of the helicopter EPS in different operating modes
- Tests in a full-scale prototype with energy management
- Comparison of model simulation results with experimental results
« BIOGRAPHIES AND REFERENCES »


« EMR of helicopter Electrical Power System (EPS) »

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