



AEROSPACE RECOMMENDED PRACTICE

ARP6538™

Issued

2018-05

Dynamic Modeling of Aerospace Systems (DyMAS)

RATIONALE

This document provides guidelines and suggested best practices for dynamic modeling of aerospace systems. Because, ostensibly, there are as many modeling methods as there are members of the aerospace community, this ARP attempts to provide a framework for standardized modeling practices that will facilitate fast, efficient, and more effective integration of models from numerous sources. The document begins with general guidelines applicable to models spanning all aerospace domains, and then gives focused examples for component models of aerospace electric power systems (EPS). The EPS component model guidelines are given in general terms, and can be easily translated into guidelines for models of other systems (e.g., thermal management, aerodynamic, actuation).

INTRODUCTION

The aerospace industry is facing some of its biggest challenges to date. Among these are range and endurance limitations, restricted flight envelopes caused by thermal constraints, increasing power demands, and power compatibility issues. Unlike in the past, these are too complex to solve by focusing solely on the component level. Rather, subsystem- or even air vehicle-level interaction is necessary to solve these issues. One of the tools that the aerospace community uses to solve these issues is modeling, simulation, analysis, and testing (MSAT). Presently, there are as many modeling methods as there are users. A set of modeling standards and guidelines are necessary in order to facilitate industry cooperation. This document, the Dynamic Modeling of Aerospace Systems (DyMAS) Aerospace Recommended Practice, will provide those standards and guidelines.

DyMAS draws on work done under the U.S. Air Force Research Laboratory (AFRL) Integrated Vehicle Energy Technology (INVENT) program [2-6]. The INVENT Modeling Requirements and Implementation Plan (MRIP) [7] provided much of the basis for the framework of this document. However, the scope and objective of the MRIP was to describe program requirements for the INVENT program. DyMAS' scope and objective, on the other hand, is to provide a framework for model interaction across the aerospace industry, including both civilian and military entities. Further, as DyMAS is an SAE AE-7 document, its scope is limited to the aircraft electric power systems (EPS).

SAE Technical Standards Board Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be revised, reaffirmed, stabilized, or cancelled. SAE invites your written comments and suggestions.

Copyright © 2018 SAE International

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of SAE.

TO PLACE A DOCUMENT ORDER:
Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
<http://www.sae.org>

SAE WEB ADDRESS:

Full document details: [SAE ARP6538](#)

SAE values your input. To provide feedback
on this Technical Report, please visit
<http://standards.sae.org/ARP6538>

Documents
Document Sharing Hub

TABLE OF CONTENTS

1.	SCOPE AND OBJECTIVE	4
1.1	Model Intended Use	4
2.	REFERENCES.....	4
2.1	Glossary	5
2.2	Definition of Terms	6
3.	DyMAS MSAT GUIDELINES	6
3.1	Generic Models	6
3.1.1	Functional Models	7
3.1.2	Behavioral Models.....	7
3.1.3	Real-Time Models	7
3.1.4	Signal Sign/Direction Convention	7
3.1.5	Model Documentation	8
3.1.6	Guidelines for Energy/Power Balance Ports.....	9
3.1.7	Model Configuration Management.....	10
4.	SUBSYSTEM MODELING.....	10
4.1	Electrical Power System	11
4.1.1	EPS Modeling and Engineering Goals.....	11
4.1.2	EPS Thermal Modeling	11
4.1.3	EPS Failure Modes	12
4.1.4	EPS Component Scaling/Sizing Parameters.....	12
4.1.5	EPS Schematic Layout	12
4.1.6	EPS Component Models.....	13
5.	CONCLUSIONS.....	34
6.	NOTES.....	34
6.1	Revision Indicator.....	34
Figure 1	Energy balance in DC-DC converter.....	9
Figure 2	Schematic layout of a typical MEA EPS system	13
Figure 3	Main ES/G thermal model block diagram	14
Figure 4	ES/G component model dynamic inputs and outputs.....	15
Figure 5	Exciter component model dynamic inputs and outputs	16
Figure 6	ICC component model dynamic inputs and outputs	17
Figure 7	ES/G controller component model dynamic inputs and outputs.....	19
Figure 8	EDU component model dynamic inputs and outputs.....	21
Figure 9	Battery component model dynamic inputs and outputs	22
Figure 10	BCCU component model dynamic inputs and outputs	24
Figure 11	EAU component model dynamic inputs and outputs	25
Figure 12	DC-DC voltage regulator component model dynamic inputs and outputs.....	27
Figure 13	DC-AC inverter	28
Figure 14	PMG component model dynamic inputs and outputs	29
Figure 15	AC-DC C/R.....	31
Figure 16	System load model dynamic inputs and outputs	32
Figure 17	Sensors and sensing component model dynamic inputs and outputs.....	33
Table 1	Main ES/G signals and recommended units.....	15
Table 2	Exciter signals and recommended units	16
Table 3	ICC signals and recommended units	18
Table 4	ES/G controller model states	19
Table 5	ES/G controller signals and recommended units.....	21
Table 6	EDU signals and recommended units.....	21

Table 7	ESD signals and recommended units.....	22
Table 8	BCCU model control states.....	23
Table 9	BCCU signals and recommended units	24
Table 10	EAU model control states.....	25
Table 11	EAU signals and recommended units.....	26
Table 12	DC-DC voltage regulator signals and recommended units.....	27
Table 13	DC-AC inverter signals and recommended units.....	28
Table 14	PMG signals and recommended units	30
Table 15	AC-DC C/R signals and recommended units.....	31
Table 16	System loads signals and recommended units	32
Table 17	Sensors signals and recommended units	34

1. SCOPE AND OBJECTIVE

The objective of this document is to provide a recommended practice for the development of aerospace EPS dynamic models so that models developed by different companies/industries/governments/etc. will have a basic level of compatibility and interconnectivity. This will be crucial as the aerospace industry looks to solve the challenges of the 21st century through integrated vehicle optimization.

This document focuses on model interfaces and their interconnection. Other than these boundary characteristics, this document does not attempt to describe or regulate the inner workings of individual component models.

AIR6326 defines the four-level paradigm for aircraft EPS MSAT studies. Of the four levels, Device Physical, Behavioral, Functional, and Architectural, only the first three are dynamic models. Further, the Device Physical level is too detailed and not intended to be interconnected to other EPS models. Thus, only the middle two levels – Behavioral and Functional – will be covered by this document. Real-time models are a fast subset contained within these two levels, and these will be addressed here as well.

Functional models capture EPS component performance over an entire flight or long portions of the flight. These models might include behavior of ground preparations, startup/warm up, taxi, takeoff/climb, cruise, and descent, for example. These models require lower fidelity than behavioral ones, and are intended to address overall system-level considerations. Real-time models are a subset of functional models that are typically used in hardware-in-the-loop (HIL) studies to establish relevant boundary conditions for hardware under test. They are dynamic models that must be as fast as or faster than real time at every time step; practically, this restricts real-time models to the functional level, although future increases in computational speed may one day make it possible to create real-time-capable behavioral models.

Behavioral models capture EPS component performance within considerably shorter time periods than functional models. They are generally used to investigate short-term (i.e., microsecond scale) transient behavior. Thus, they must simulate physical phenomena at much higher bandwidth (i.e., higher frequencies) than functional models. Consequently, they require a high level of fidelity and run much more slowly than functional models.

Since every model development team has its own set of goals, processes, and legacy codes, it is perhaps inappropriate and certainly infeasible to impose hard requirements for all models. Thus, rather than define a rigid framework that must be followed, this document provides a structured set of guidelines that, if followed, lay a foundation for the successful interconnection and integration of numerous disparate models.

1.1 Model Intended Use

Because aircraft EPS design is the goal, the intended use of the models described in this DyMAS is to perform detailed trade studies using dynamic and transient EPS-level models that both accurately predict EPS performance and illuminate the impacts of interconnected EPS components. Further, these models should be capable of supporting controls development and hardware testing. Thus, each model must accurately predict the transient behavior and dynamics of both the plant and closed-loop controllers (if applicable) contained in the component the model represents. Without this level of detail, a model will be incapable of achieving its intended use. The specific intended use each model establishes its necessary level of detail and structural requirements. Although it cannot be guaranteed, it is more likely than not that EPS models designed according to the DyMAS will be capable of integrated vehicle studies, which are increasingly necessary in order to design and realize modern aircraft.

2. REFERENCES

1. SAE AIR6326: Aircraft Electrical Power Systems. Modeling and Simulation. Definitions.
2. E. Walters, *et al*, "INVENT modeling, simulation, analysis, and optimization," in *Proc. AIAA Aerospace Sciences Meeting*, Orlando, USA, Jan. 2010, AIAA Tech. Paper 2010-287.
3. Zumberge, J., Wolff, J., McCarthy, K., O'Connell, T. et al., "Integrated Aircraft Electrical Power System Modeling and Simulation Analysis," SAE Technical Paper 2010-01-1804, 2010, <https://doi.org/10.4271/2010-01-1804>.
4. O'Connell, T., McCarthy, K., Yeu, R., Pigg, P. et al., "Software Tools for Efficient Model-Based Design of Energy Optimized Aircraft," SAE Int. J. Aerosp. 5(2):386-397, 2012, <https://doi.org/10.4271/2012-01-2176>.

5. O'Connell, T., McCarthy, K., Paquette, A., McCormick, D. et al., "Enhancements to Software Tools and Progress in Model-Based Design of EOA on the INVENT Program," SAE Technical Paper 2014-01-2118, 2014, <https://doi.org/10.4271/2014-01-2118>.
6. O'Connell, T., McCarthy, K., Paquette, A., McCormick, D. et al., "Model Validation Planning and Process on the INVENT Program," SAE Technical Paper 2014-01-2116, 2014, <https://doi.org/10.4271/2014-01-2116>.
7. Integrated Vehicle Energy Technology (INVENT) Modeling Requirements and Implementation Plan (MRIP) v.3.1, Rev. Mar. 2010.
8. J. A. Weimer, "Electric Power Technology for the More Electric Aircraft," in *Proc. 12th AIAA/IEEE Digital Avionics Sys. Conf. (DASC '93)*, Ft. Worth, TX, USA, Oct. 1993, DOI: 10.1109/DASC.1993.283509.
9. J. A. Weimer, "The Role of Electric Machines and Drives in the More Electric Aircraft", in *Proc. Int'l Elect. Machines & Drives Conf. (IEMDC '03)*, Madison, WI, USA, June 2003, DOI: 10.1109/IEMDC.2003.1211236.

2.1 Glossary

AFRL: Air Force Research Laboratory.

APTMS: Aircraft Power & Thermal Management System.

APU: Auxiliary Power Unit.

AVS: Air Vehicle System.

BCCU: Battery Charger Control Unit.

C/R: Converter/Regulator.

CCW: Counterclockwise.

CPL: Constant Power Load.

DyMAS: Dynamic Modeling of Aerospace Systems.

EAU: Electrical Accumulator Unit.

ECS: Environmental Control System.

EDU: Electrical Distribution Unit.

EMF: Electromotive Force.

EMI: Electromagnetic Interference.

EPS: Electrical Power System.

ES/G: Electric Starter/Generator.

ESD: Energy Storage Device.

ESL: Equivalent Series Inductance.

ESR: Equivalent Series Resistance.

FTMS: Fuel Thermal Management System.

HIL: Hardware-in-the-Loop.

ICC: Integrated Converter/Controller.

INVENT: Integrated Vehicle Energy Technology.

MDD: Model Design Document.

MDSD: Model Data Source Description.

MEA: More Electric Aircraft.

MRIP: Modeling Requirements Implementation Plan.

MSAT: Modeling, Simulation, Analysis and Testing.

MVaD: Model Validation Document.

MVeD: Model Verification Document.

PMG: Permanent Magnet Generator.

RTR: Run-Time Ratio.

SUM: Software User's Manual.

VMS: Vehicle Management System.

2.2 Definition of Terms

In addition to the Glossary given above, refer to AIR6326: *Aircraft Electrical Power Systems, Modeling and Simulation, Definitions* [1] for a detailed list with descriptions of several definitions and terms applicable to this document.

3. DYMAS MSAT GUIDELINES

Because the intent of the EPS models described in the document is to be compatible with other models, it is a reasonable objective to ensure that all of a model's code and/or structure be visible and accessible to the user. Of course, there are many cases where such visibility would compromise proprietary and/or national security interests, and in those cases the modeler should attempt to make the model as open as possible. All models, restricted and otherwise, will be the most useful if they follow a basic set of input/output and formatting standards in order to more easily integrate and function with other models. This section describes some of these generic modeling guidelines.

3.1 Generic Models

The model developer's primary goal is to achieve the fidelity detailed in this document while also following the suggested modeling practices. If the model run-times required to achieve the recommended fidelity are too long, the model developer might consider sacrificing fidelity in order to increase model run-time speed.

In this document the expression used to describe model run-time speed is the Run-Time-Ratio (RTR), which is defined as the ratio of real time to simulation time. For instance, if a model requires 10 seconds of real time to simulate one second of dynamics, the RTR is 10.

Recommended model RTRs are given in the sections below. These RTRs refer to those of unit/component models, and not to subsystems and/or systems of interconnected units/components. Those types of integrated models, which are not the focus of this document, will have larger RTRs.

In general, functional models are faster and have lower fidelity than behavioral models. Often, a single component, e.g., a DC-DC converter, may require models at multiple fidelity levels. An average-value functional model might be required for long simulations designed to predict energy efficiency whereas a detailed switch-level behavioral model would be used to predict switching losses and current ripple. The specifications in the following sections provide more detail and describe the level of fidelity that is required for each type of model.

3.1.1 Functional Models

Functional-level models are intended to predict low frequency (100 to 150 Hz bandwidth or less [1]) electrical performance and the associated losses, heat transfer, and temperatures, and could potentially be used to simulate an entire flight (i.e., tens of minutes to hours timescales). Because the time constants associated with these phenomena are relatively large, functional-level models likely will be capable of at least real-time average simulation speed.

The following is a list of guidelines for functional-level models:

- Model maximum RTR < 1 (i.e., it requires at most 1 second of computational time to simulate 1 second in the model).
- Physical effects modeled have no more than roughly 150 Hz bandwidth.
- The time range simulated can be up to several hours (i.e., thousands of seconds).
- Some nonlinearities can be included, as long as they do not slow down the model too much with respect to the target RTR.

3.1.2 Behavioral Models

If the bandwidths of all of the physical processes of interest in a component are less than 150 Hz, a single functional-level model will likely suffice. However, if there are processes of interest with bandwidths greater than 150 Hz, a behavioral-level model may be needed. Behavioral models can include nonlinear phenomena such as switching, fast dynamics that occur on the order of tens of microseconds. They can be used to examine power quality, peak and regenerative power, shorts and other failure modes, and any other EPS behavior that occurs on second or less time scales [1].

The following is a list of recommended guidelines for behavioral-level models:

- Model maximum RTR < 500 (i.e., it requires at most 500 seconds of computational time to simulate 1 second in the model). This is not a firm requirement, but RTRs larger than this make it very difficult to work with the model and/or achieve results in a reasonable amount of time.
- Physical effects modeled have up to roughly hundreds of kHz bandwidth.
- The time range simulated is expected to be up to roughly 10 seconds.
- Power electronic switching events can be included at this level.
- Nonlinearities can be included at this level.

3.1.3 Real-Time Models

Real-time models are often a subset of functional models; however, with the right computing platform, behavioral models can also achieve real-time performance. Real-time models are typically used in HIL studies to establish relevant boundary conditions for hardware under test. They are dynamic, and they must be as fast as or faster than real time at every time step. Thus, the bulleted list of guidelines for functional models applies to real-time models, with the additional requirement that real-time models must have RTR of 1 or less during each simulation time step.

3.1.4 Signal Sign/Direction Convention

To avoid misunderstandings and sign errors during system-level integration of EPS component models, standardized signal directions (i.e., sign conventions) are required. Signals to which this applies include, but are not limited to, electrical current, power flow, rotational position/velocity/torque, and heat flow. This DyMAS attempts to provide standard sign conventions for EPS directional variables most commonly encountered in EPS models. However, if other such variables are used and the sign convention is not specified here, the model developer should provide clear labels and/or instructions to the model integrator so that sign errors can be avoided.

The sign/direction convention adopted throughout this document is as follows:

- Current is defined as positive into a device (current for a machine will be negative in generating mode and positive in motoring mode).
- Power flow is defined as positive into a device (power for a machine will be negative in generating mode and positive in motoring mode).
- Rotational position and velocity and torque are defined as positive in the counterclockwise (CCW) direction. If torque and velocity are positive, the machine is in motoring mode, if one and only one is negative the machine is in generating mode.
- The CCW direction is defined by an observer viewing the front face of the rotating machine.
- Heat flow is defined as positive into a node. Thus, when a node has a higher temperature than the surrounding nodes, the numerical value of the heat flow into that node will be negative.

It is recommended that additional direction-specific signals be noted in the model documentation. Although the particular implementation within the model is up to the developer, it is necessary that *at the interconnection boundary* the signal sign/direction conventions are adhered to, for interconnected signals between distributed models, and for data logging purposes.

3.1.5 Model Documentation

This section defines the model documentation requirements. The standard documents are listed below, including the documents to be supplied by the model developer. Note that these are suggestions; the naming and arrangement of the model documentation can be tailored to the needs and desires of the model's users, provided all of the necessary information is included. Thus, various combinations of the documents listed below may be used, if it is convenient.

3.1.5.1 Model Design Document (MDD)

The Model Design Document (MDD) documents the design, features, limitations, capabilities, etc., of a model. The MDD also serves the purpose of a user's guide, with instructions for general usage of the model, and specific usage in various types of analyses. The MDD often includes a solver specification section that details what solver settings were used for verification and validation of the model.

3.1.5.2 Model Verification Document (MVeD)

The Model Verification Document (MVeD) provides a single location for all model verification plans, procedures and results. Formal releases of the model (i.e., model deliveries to the system integrator) should be accompanied by an MVeD update, with additional verification steps completed beyond the prior release. The MVeD is typically structured to show continuous improvement in the model confidence level with each model release.

3.1.5.3 Model Validation Document (MVaD)

The Model Validation Document (MVaD) provides a single location for all validation plans, procedures and results. Formal releases of the model (i.e., model deliveries to the system integrator) should be accompanied by an MVaD update, with additional validation steps completed beyond the prior release. The MVaD is typically structured to show continuous improvement in the model confidence level with each model release.

3.1.5.4 Model Data Source Description (MDSD)

The Model Data Source Description (MDSD) describes the data (e.g., lookup table parameters, equation coefficients, model constants, etc.) used in the model and their sources. This is useful to the system integrator to understand the model's parameters and how they were obtained. It also helps establish the model's pedigree, so that its users understand the physical system that the model represents.

3.1.5.5 Software User's Manual (SUM)

The MDD, MVeD, MVaD, and MDSD documents may be combined in a logical manner into fewer documents (or a single document), collectively referred to as a Software User's Manual (SUM). If a SUM is used in place of the MDD, MVeD, MVaD, and MDSD, it must contain all of the information expected in those as listed in their respective sections immediately above. A basic user's manual that does not include this level of detail is not sufficient and is not an acceptable replacement for the four documents above.

3.1.6 Guidelines for Energy/Power Balance Ports

A key verification test for models designed according to DyMAS recommendations is whether or not they conserve energy and power. To facilitate this, models might include a dedicated set of ports at the top level that describe the overall energy characteristics of the model. While not absolutely necessary for verification, including these ports makes verification checks by subsequent users much easier. As an added benefit, these ports can also be used to show energy flows between the models during simulation.

There are two types of verification ports recommended: energy balance ports and power balance ports. These will be described in the following sub-section.

3.1.6.1 Energy Balance Versus Power Balance

Energy balance requires that the difference between the energy flowing into and out of a model must equal the energy stored in the model. For example, 10 J of electrical energy flows into a DC-DC converter. Of this, 2 J is lost to inefficiencies and flows out of the model as heat and the other 8 J flows out as electrical energy. The difference between energy into and out of the converter is zero and no energy is stored in the converter. A graphical representation of this is shown in [Figure 1](#).

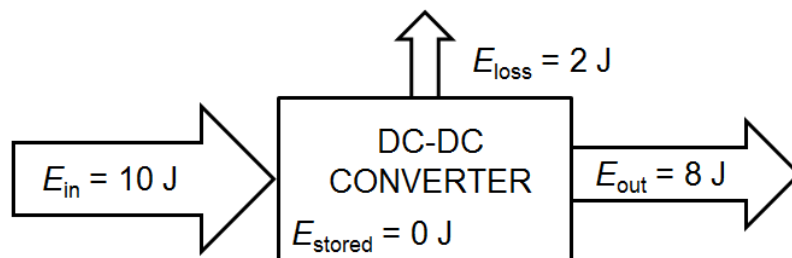


Figure 1 - Energy balance in DC-DC converter

As an energy balance check, this net energy calculation is the preferred method because it works under all conditions. However, sometimes it is intractable to identify and output all the energy storage items in a model. For situations where it is not anticipated that the component will store large amounts of energy (e.g., a resistor or a generator), the energy stored aspect of the balance can be ignored and the model can be checked for power balance only.

Checking for power balance may involve integrating the difference of the power in and power out to obtain the net energy of the model. If the net energy of a model is non-zero without having a method of energy storage defined, this is an indication of a problem in the model.

3.1.6.2 Power Balance Ports

Power balance model check ports should include the Power_in (W), the Power_out (W) and the integral of the difference Power_in – Power_out, Net_Energy (J). Power balance ports are a subset of energy balance ports and should only be used on models with small energy storage capabilities.

3.1.6.3 Energy Balance Ports

Energy balance model check ports should include Power_in (W), Energy_In (J), Power_out (W), Energy_out (J), Energy_Stored (J) and Energy_error (J). Energy_error should equal Energy_Stored – (Energy_in – Energy_out).

3.1.7 Model Configuration Management

It is important to track the model development through version control. As such, it is strongly recommended that the model developer utilize a defined version control process, whether it is manual or an automated tool such as Subversion, Git, or ClearCase.

Desired qualities of such a version control system are as follows:

- A fixed version number is associated with each model officially delivered to the system integrator. This version should be locked down and remain unaltered, and any updates to the model will result in a new version.
- Any figures, charts, or general post-processing documents that are officially submitted with the model must be capable of being regenerated by the original model that created the data. Therefore, for any test study conducted, a discrete folder with all files/parameters/models required to generate the study should be created and labeled appropriately.
- Any modeling code should include a comment box including such important information as follows:
 - o The version number of the model
 - o The date of the last update to the model (dd/mm/yyyy)
 - o The company and engineer who last updated the model
 - o Version of software package used (i.e., Matlab R2014a, etc.)
 - o Example Tag:

```
Model: AirCo_EPS_DcDcConverter_functional
Version: 01.00
Date: 15-Jan-2016
By: John.Doe@AirCo.com
Platform: Win10 MATLAB R2014a
```

- o Models should be labeled with a standardized naming convention, such as Company_Subsystem_Component (functional or behavioral). An example, using this format, would be: AirCo_EPS_DcDcConverter_functional.
- o When an official model release is generated (i.e., when a model “leaves” the version control system), it can be stored/delivered in a folder whose name includes the official version number generated by the version control software. This ensures that official model releases can be traced back to their original version in the version control software.

4. SUBSYSTEM MODELING

A significant challenge for any large aircraft development program is the creation of an integrated system simulation capable of addressing the engineering challenges through evaluation of subsystem interactions and system level optimization. This requires a large number of component models to be developed and constructed in a similar fashion such that they are easily interchangeable and can be interconnected quickly.

In this section, many of the most common EPS component models are described in order to provide general guidance on the level of fidelity and openness needed for successful interconnection with other EPS models. It is preferred that all components be modeled separately to allow for interchange of different component technologies for trade studies. However, there are some instances where multiple components can be integrated into a single model for convenience and functionality (e.g., AC electric machine and rectifier, AC electric machine and drive). In those cases, the combined model and the individual components should follow the guidelines of this document. Depending on the EPS architecture being designed and/or evaluated, the provided component model list may be incomplete, and the common component descriptions should be used as general templates for additional component models.

4.1 Electrical Power System

4.1.1 EPS Modeling and Engineering Goals

There are many uses for EPS models, but any good EPS model should accurately predict system behavior during the expected operating conditions. These may include:

- Normal operation with electric starter/generator (ES/G) power
- Emergency power modes including ES/G power, battery power, and auxiliary power
- Ground idle operation with external power source
- Ground/In-flight engine starting mode
- Transient behavior during power transfer modes

A common engineering goal is to optimize the EPS architecture in order to:

- Guarantee power system stability under any/all operating conditions
- Reduce/remove thermal impacts on the rest of the aircraft
- Reduce mechanical impacts on the engine
- Maximize system efficiency in order to minimize weight and cost

Engineering analyses that may be performed with EPS component models include, for example:

- Response to bus voltage transients and corresponding voltage regulation at different load levels
- Inrush current characteristics over a wide frequency range
- Current ripple analysis on individual load and generating components
- Electrical and thermal effects of highly dynamic load and source transients (e.g., short term high load and rate, regenerative load power, etc.)
- Thermal management system integration
- The impact of aircraft bay temperature on EPS performance
- The mechanical impact of the generator on the turbine engine (average and transient torque)
- Simulation of break and non-break power transfers, including contactor closing/opening delays if appropriate
- Analysis of protection mechanisms at component- and system-level
- Internal failure simulation, including short-duration power interruption and proper turn-on and turn-off procedures

4.1.2 EPS Thermal Modeling

Capturing component heat loss and appropriately accounting for associated temperature rise in coolants and surrounding bay areas will be integral in the thermal evaluation and optimization of aircraft platforms. As EPS components are major contributors of heat to the Air Vehicle System (AVS), it is important to include appropriate thermal physics in EPS component models.