

# Modeling of a Warship's Electrical Power Generation and Propulsion System

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# UK Ministry of Defence

- Defence Procurement Agency (DPA)
  - Specify and procure the ships
- Commander in Chief Fleet (Fleet)
  - Operate the Ships
- Defence Logistics Organisation (DLO)
  - Maintain and support the Ships
- Simulation supports all phases of activity, DLO leads this.
- UK MoD is adopting Electric Power and Propulsion - The Electric Ship Programme

# Why UK MoD adopting the Electric Ship?

- Reduced LCC (Life Cycle Cost)
- Flexibility - operational and layout
- Fight-Through/Ride-Through Capability
- Reduced Acoustic and Infra-Red Signatures
- Compliant with emerging environmental legislation
- Compatibility with future weapons

# Type 45 – HMS Daring



Simulation being used to predict performance and even for acceptance

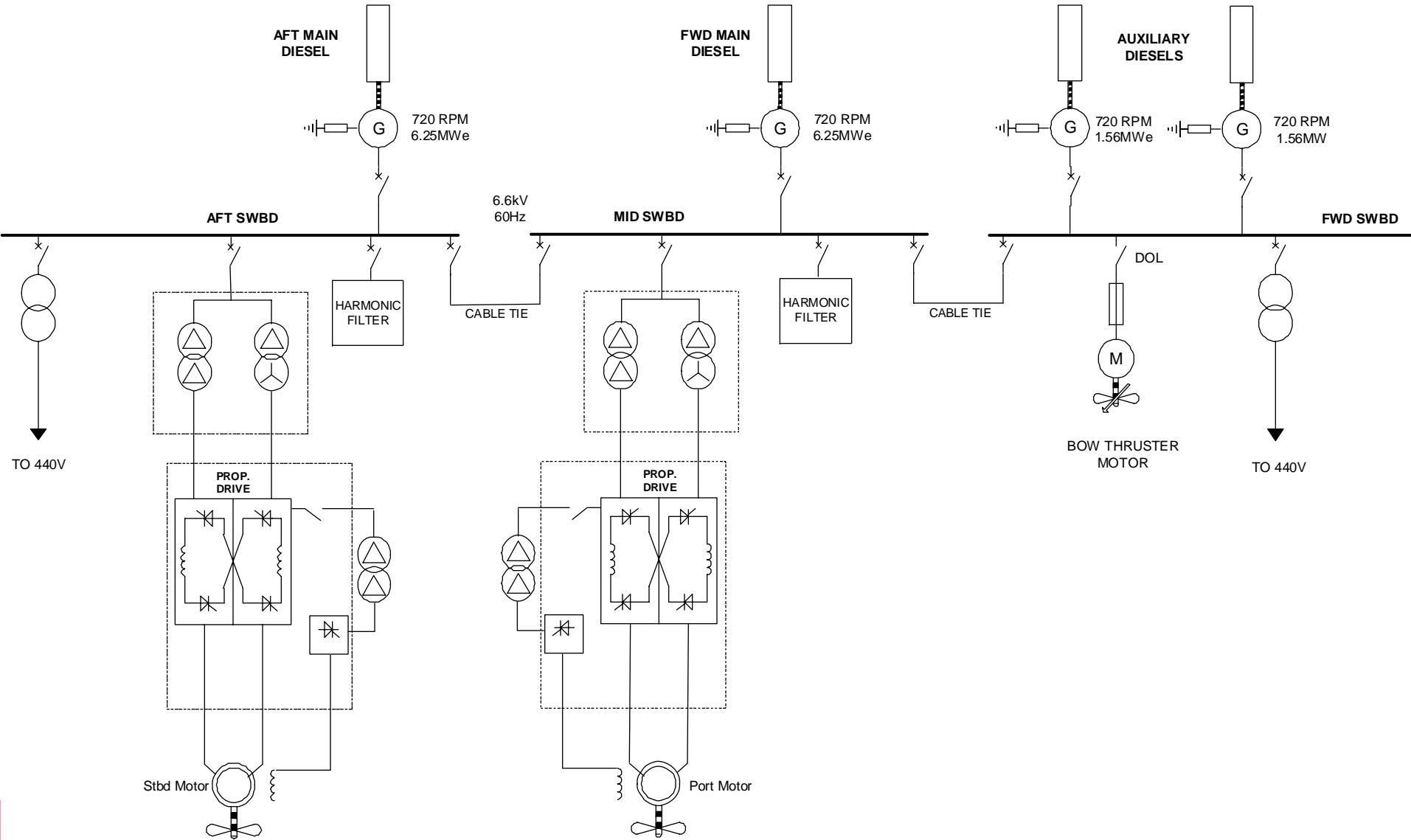
# Type 23 – HMS Argyll



# LPD – HMS Albion



Extensive simulation being used to predict the performance and manage issues



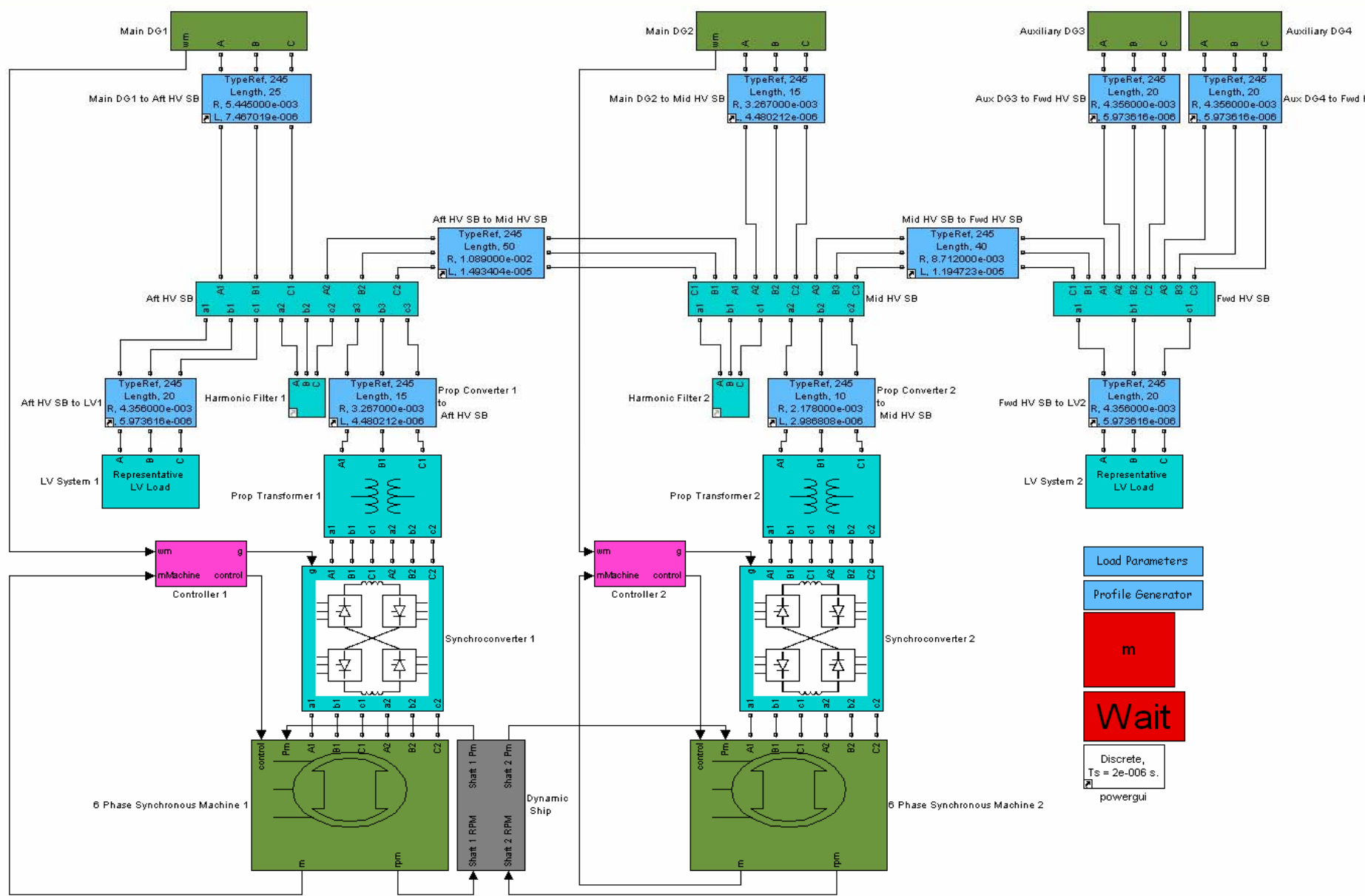
# Scope of Naval Vessel Simulation LPD

- Develop a model of a power / propulsion system
  - Generation (prime movers, alternators and control)
  - Distribution (cables, filters)
  - Propulsion (drive, PM, propeller and ship)
- System Objectives
  - Dynamics associated with Platform motion
  - Voltage and frequency transient stability
  - Harmonics, including during transient events
  - Behaviour in extreme conditions
  - Interaction with PMS
- These system objectives define the system model



# Component Oriented Approach

- Each entity within the model corresponds to an entity within the system.
- Structure of model reflects the structure of the system
  - Better advertises its purpose
  - Facilitates decomposition of development effort
  - More likely to support component re-use
  - Scales to large models involving multi-disciplinary teams
- Define interfaces between components
  - Compatible with contractual boundaries
  - Permits further development in parallel
- Define the characteristics the component must have
  - Based on system objectives



# Model, Parameter and Results Management

Major challenge:

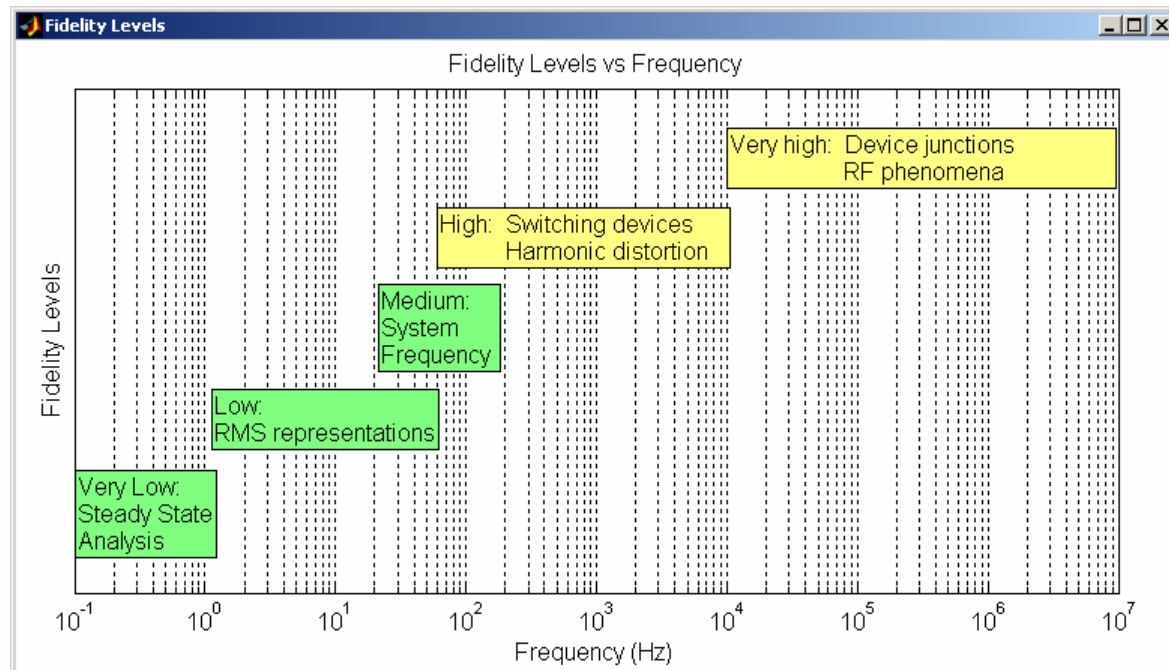
Parameters, scenarios, report generation, traceability

<i>Component</i>	<i>Parameters</i>	<i>Measurements</i>	<i>Blocks</i>	<i>States</i>
Prime movers	64	41	465	33
Converter	7	66	783	26
Propulsion motor	7	36	469	8
Ship / shaft	10	8	81	2

# Scope of the System Model

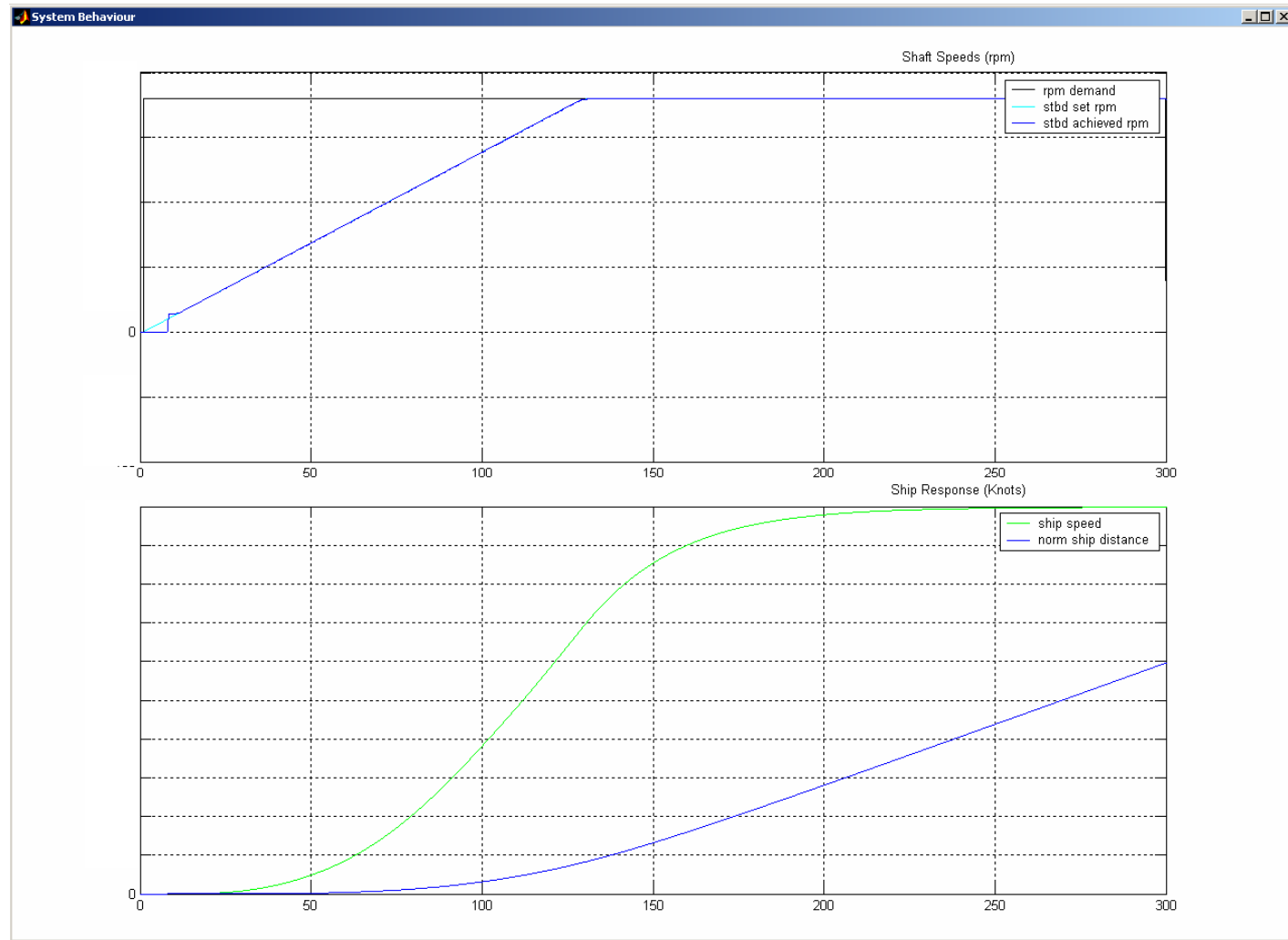
Each system objective suggests a feature of the system model and a timescale of analysis:

- Platform motion (Acceleration, Manoeuvring, Crash Stop)
  - Shaft/propeller/hull model
- Voltage and frequency response (Stability)
  - Prime movers & generators with appropriate governors and AVR
- Harmonics (THD)
  - Power electronics



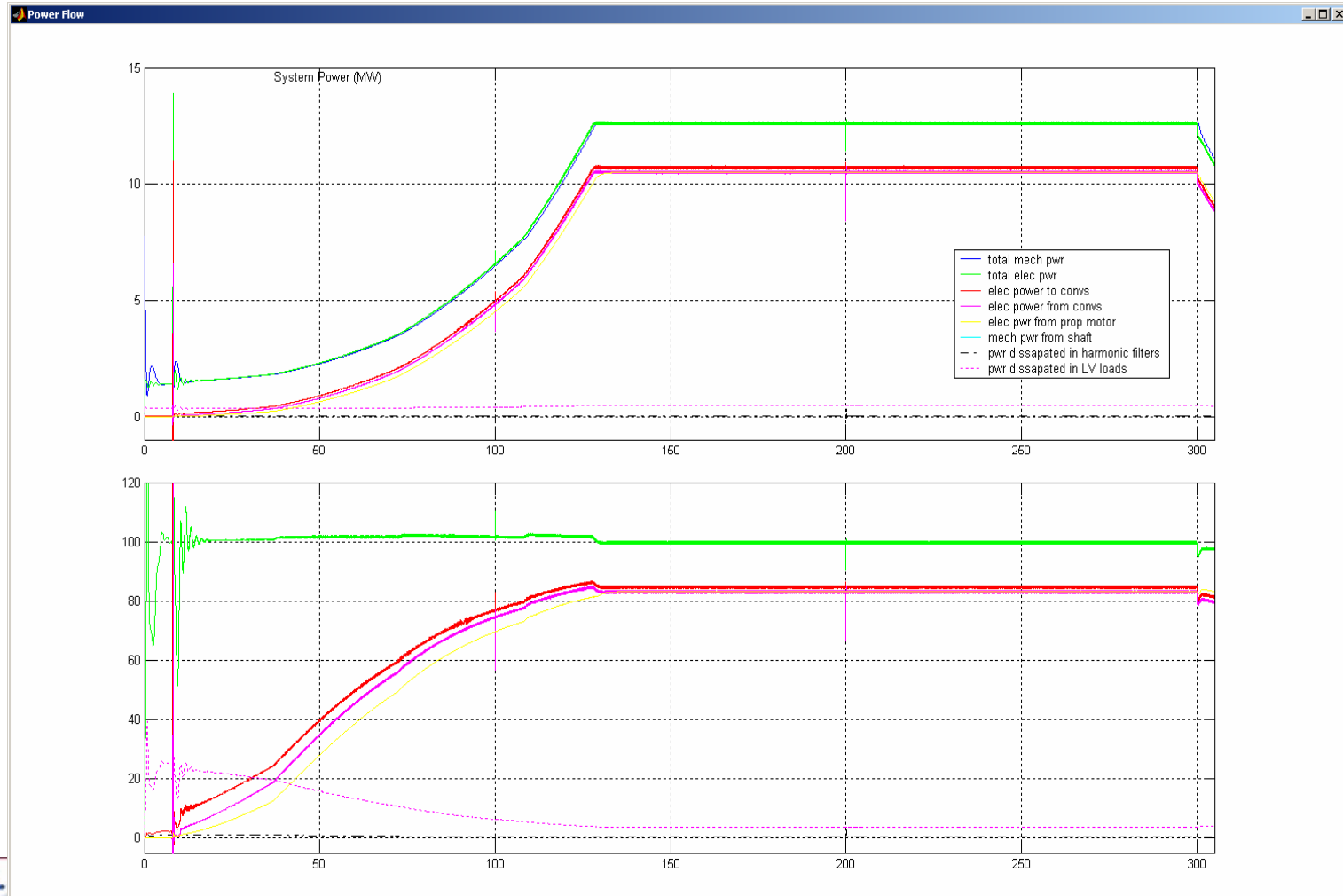
# Results: Platform motion

- Shaft Speed
- Ship Speed
- **Minutes**



# Results: Voltage and frequency response

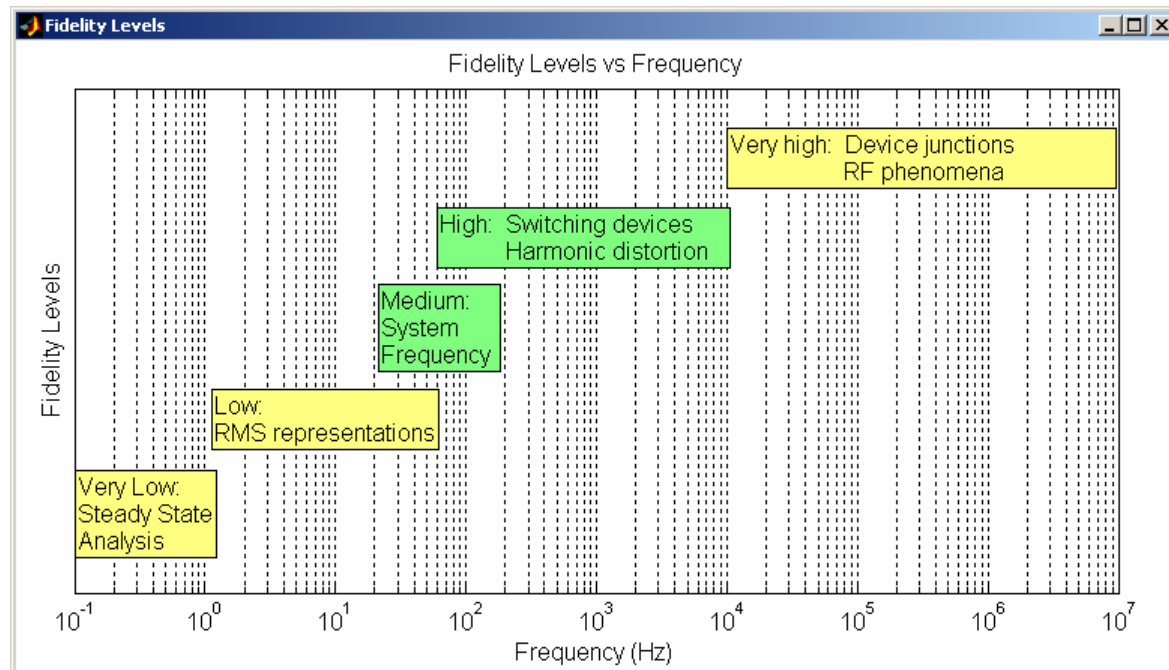
- Absolute Power
- Relative Power
- **Seconds**



# Scope of the System Model

Each system objective suggests a feature of the system model and a timescale of analysis:

- Platform motion (Acceleration, Manoeuvring, Crash Stop)
  - Shaft/propeller/hull model
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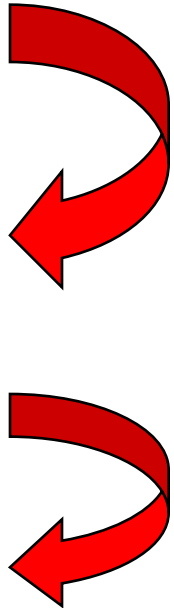
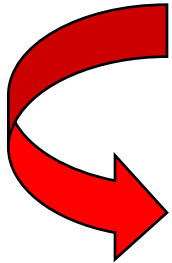
## Example: Harmonics

System Objective: “The system model should permit measurements of THD during transient events.”

The variable speed propulsion drive component model must generate representative harmonic distortion.

Explicit device-level model of Electrical Drive required.

Model: power electronic devices, switching logic



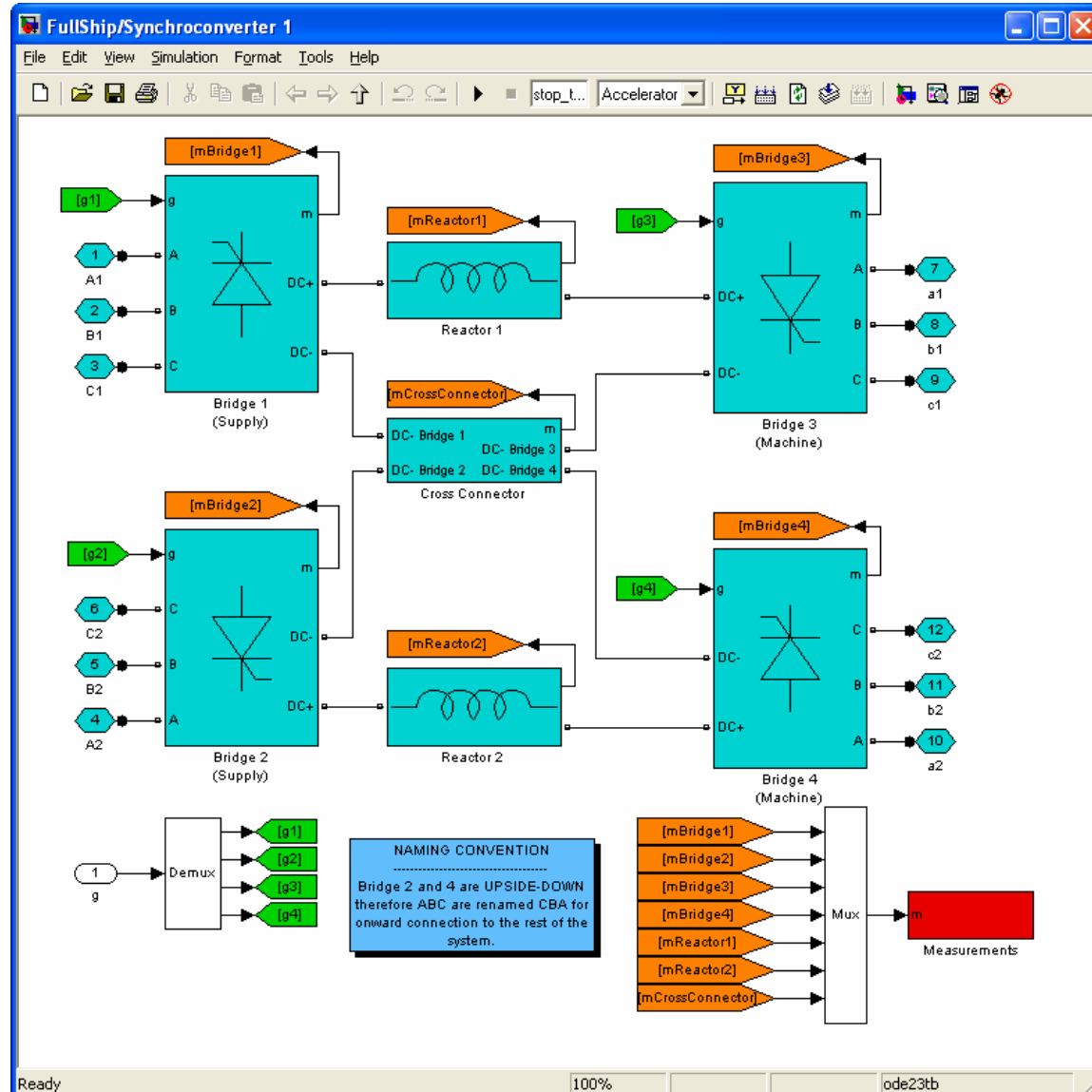
Therefore:

- Development Process = Decomposition Process
- The developer must map the system objectives onto the model



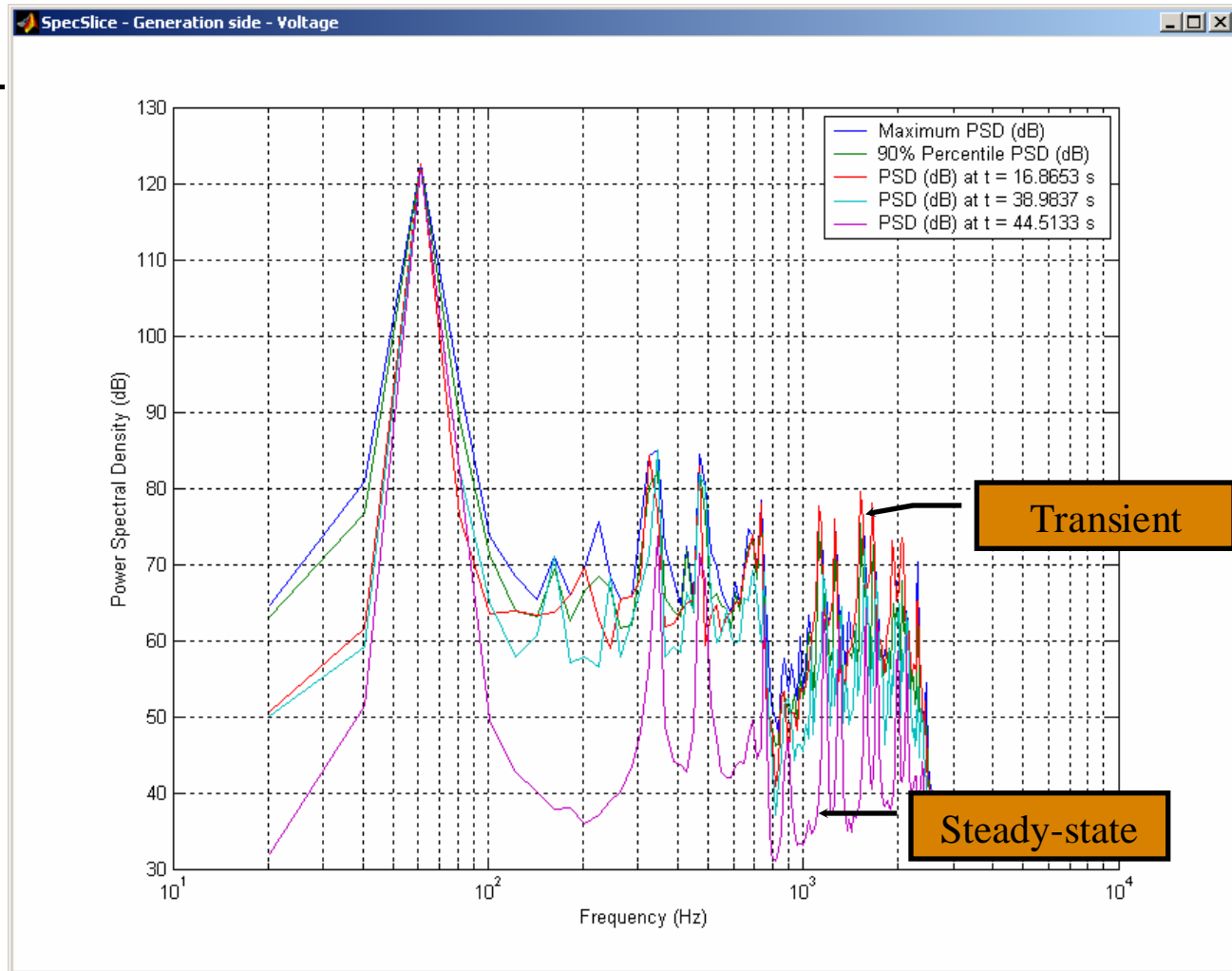
# Propulsion Converter

- Natural Hierarchy
  - Each component has further sub-components
  - A component oriented approach for component development
- Such decomposition of components was applied to the entire system



# Results: Harmonics

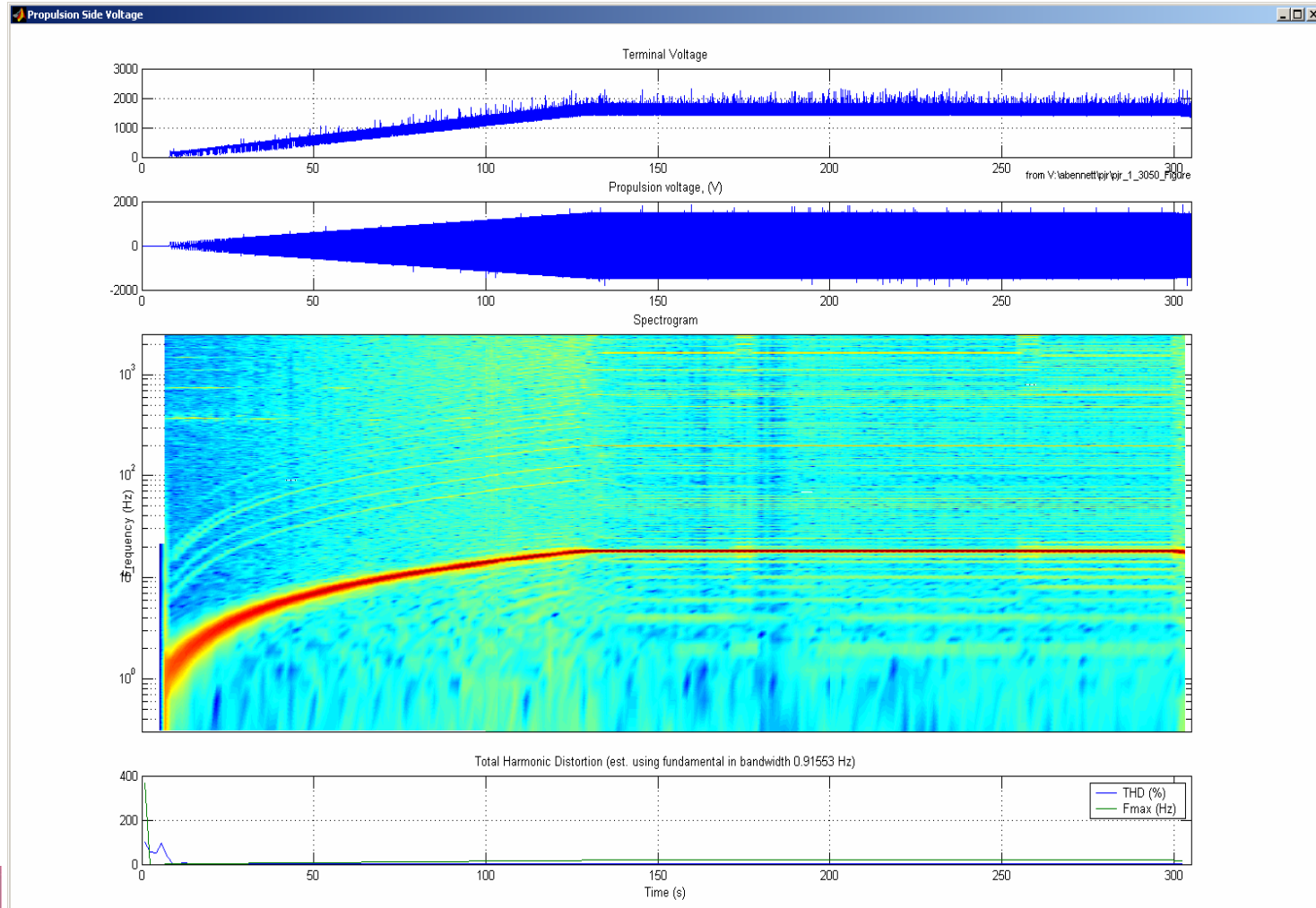
- Harmonics at steady-state vs. transient
- Milliseconds**



# Results: Propulsion Harmonics

Propulsion:

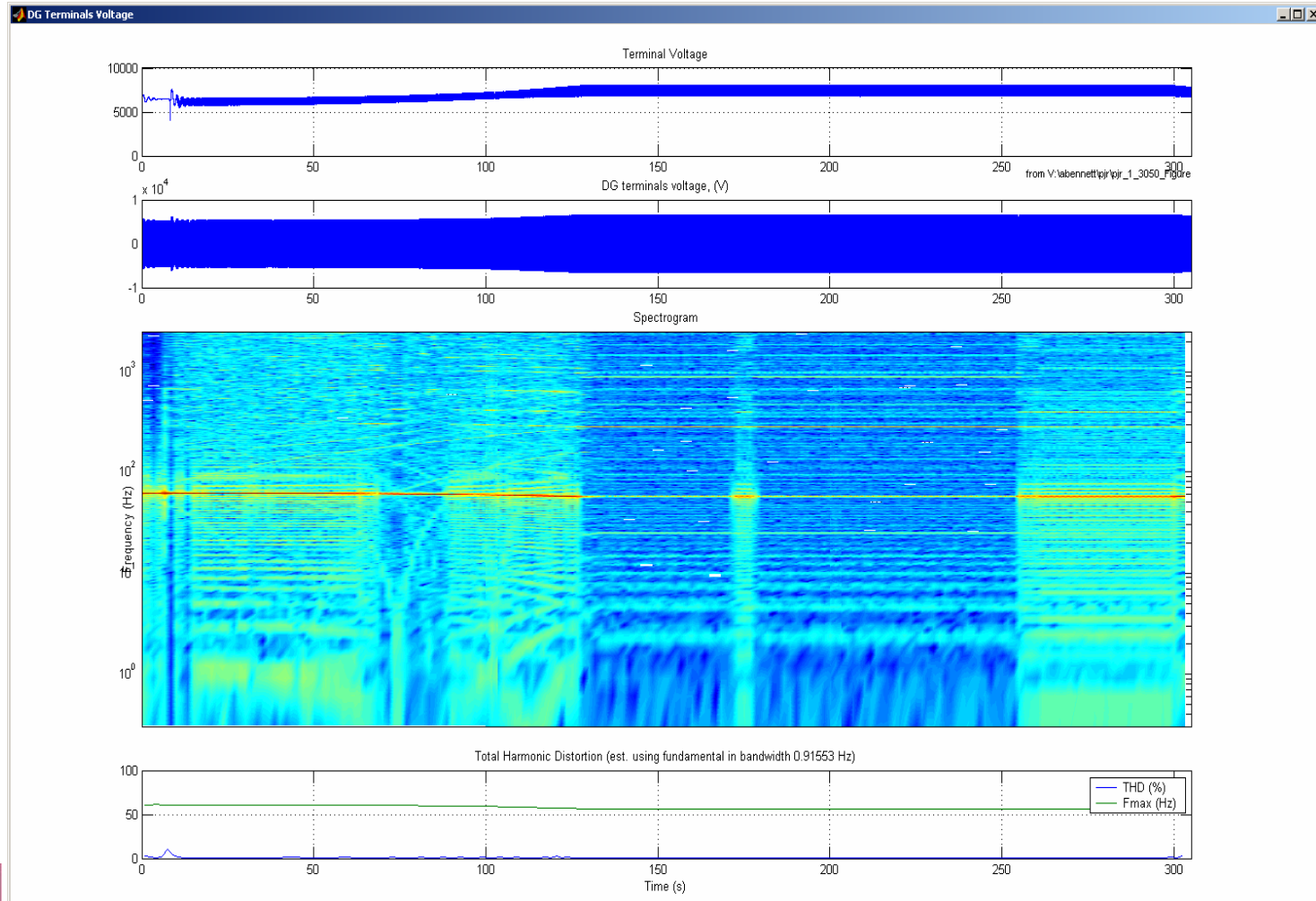
- Terminal Voltage
- Spectrogram
- THD
- **Milliseconds**



# Results: AC Network Harmonics

Generation:

- Terminal Voltage
- Spectrogram
- THD
- **Milliseconds**



## Results: Summary

- Timescales of order minutes
  - Time from rest to full ahead
  - Time to crash stop
- Timescales of order seconds
  - Voltage / frequency transient stability
- Timescales of order milliseconds
  - Harmonic content as a function of operating point
  - Harmonic content during transient events
  
- Can exercise the model against requirements
  - Manoeuvring requirement
  - Transient stability and Quality of Power Supply
  - DefStan / MilStan and Lloyds / ABS

# Challenges

- Standard approach to modeling
  - Agree standards for model interfaces
  - Agree standards for model quality and acceptance
  - UK DefStan in preparation
- Technical challenges
  - Increasing complexity of systems
  - Execution time for complex models
    - Distributed simulation (cluster of PCs)
- Possible further expansion
  - Stability margins
  - EMC/EMI and noise/vibration prediction
  - Future weapons and launching interface

# Summary

- Large-scale high fidelity system modeling
  - Feasible, over wide range of timescales of interest
    - Platform motion
    - Voltage and frequency response
    - Harmonics
  - Exercise the model against relevant standards / requirements
  - Results inform both
    - new design
    - in-service support
- UK MoD use Simulink/SimPowerSystems as the package for Marine Systems Modeling
- Provides commonality with other navies

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## Questions