



## **Control**

# **Fuel Consumption and Emission Predictions Applications to a DP-FPSO Concept**

**Albert Aalbers**

*Marin*

*October 17-18, 2006*

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**MARIN**

## Challenging wind and waves

Linking hydrodynamic research to the maritime industry



MTS DP Conference  
17/18 October 2006

# Fuel consumption and emission predictions: Application to a DP–FPSO concept

A.B. Aalbers  
MARIN

## — What is this paper about?

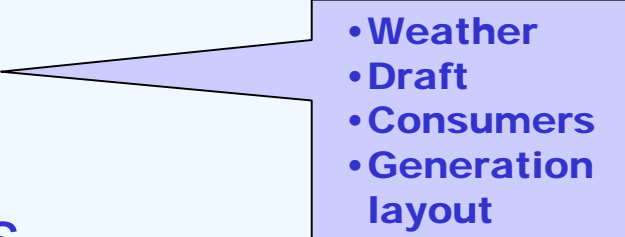
- Method to predict fuel consumption and emissions from offshore (DP) operations
- Application example:
  - Passively moored FPSO and a DP-FPSO concept
  - Area of operation: the Gulf of Mexico.



## Method to quantify fuel use and emissions

### Objective:

- A prediction method
- Greenhouse gas and major polluting emissions: CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>x</sub>, HC and CO
- Variation of design and operational parameters as well as off-design conditions, such as partial loading of generators.

- 
- Weather
  - Draft
  - Consumers
  - Generation layout

## Method

### Elements:

- DP time domain simulations
- Dynamic simulation of the energy systems, taking into account the thruster characteristics.

DP Master (MARIN):  
DP time domain  
simulation

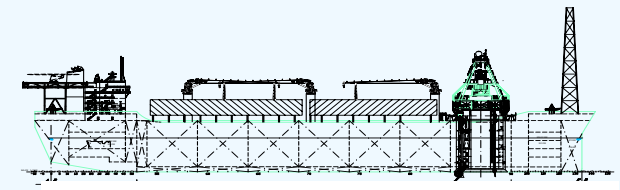
GES (TNO):  
"Geintegreerde  
Energie  
Systemen"

(Integrated Energy Systems)

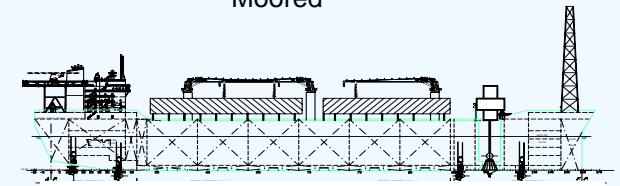


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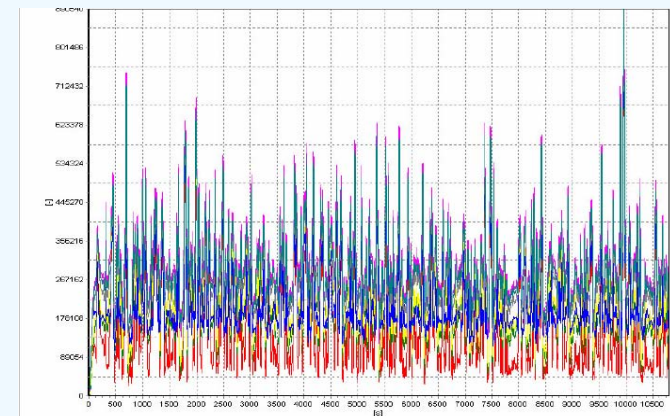
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  - Full and ballast loading condition
  - Thruster action (delivered thrust)
  - Design concept for GoM
  
- Output:
  - Time traces of delivered thrust
  - For range of conditions



Moored



DP



A horizontal banner image showing a blue ocean with white-capped waves under a clear sky.

## — Integrated Energy Systems (GES simulations)

Fuel consumption

Emissions (CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>x</sub>, HC and CO)

From "energy flow simulation"

- Input:
  - Power generation arrangement
  - DP system: delivered thrust per unit
  - Other consumers
  - Operating aspects
- Output:
  - 3 hrs average consumption and emission data

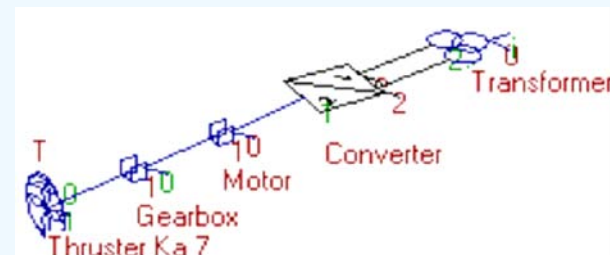
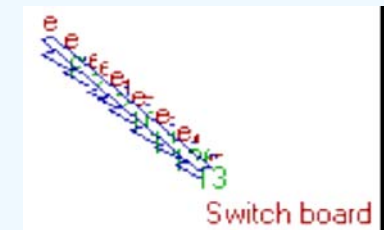
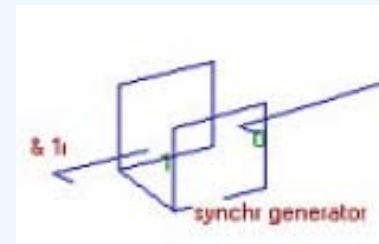
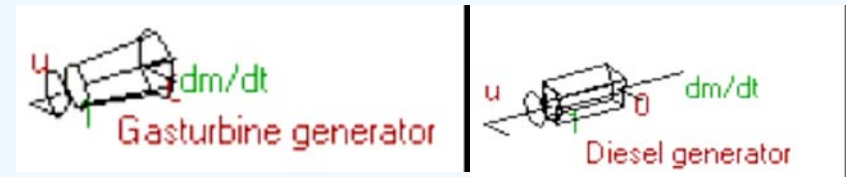


# Integrated Energy Systems

## Elements in Power arrangement

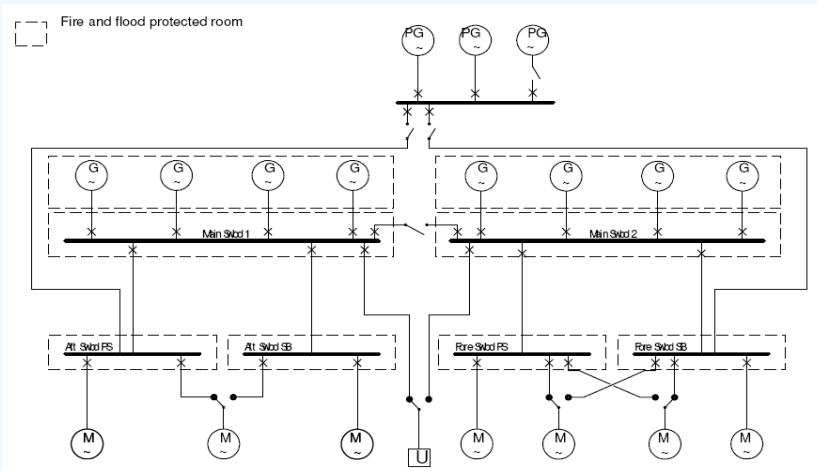
(selectable from dB):

- Engines
  - Gas turbine
  - Diesel
- Electric generators
- Switchboards
- Azimuthing thrusters

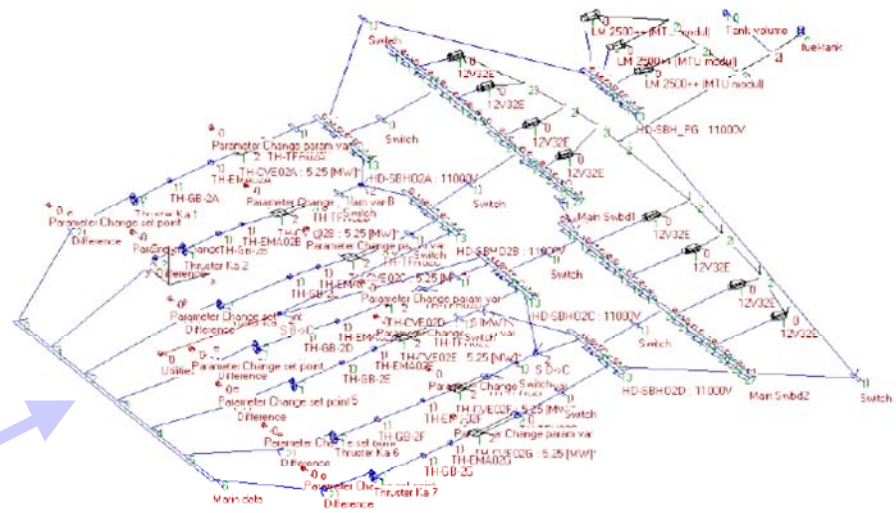
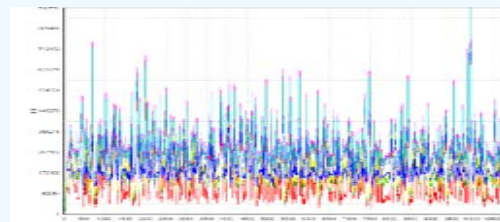




# Arrangement



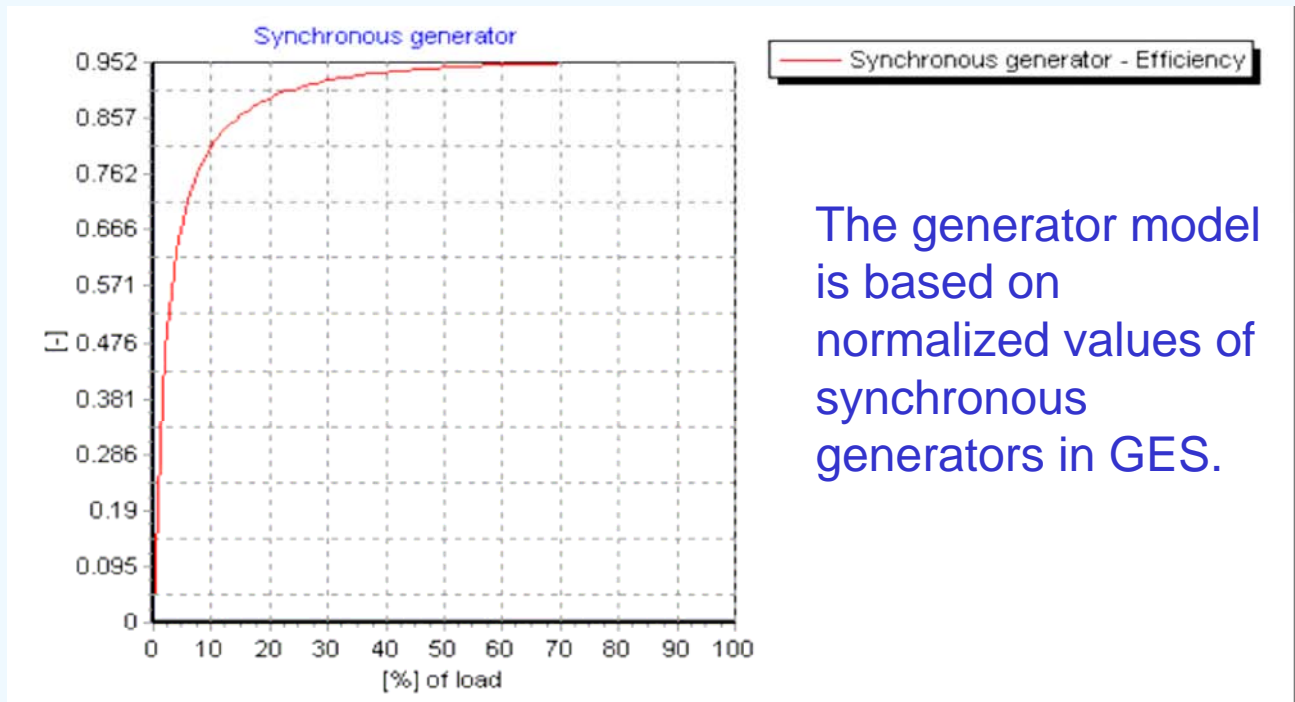
Key-One Line  
DP Class 2



GES representation



## — Efficiency of elements: for example a Generator





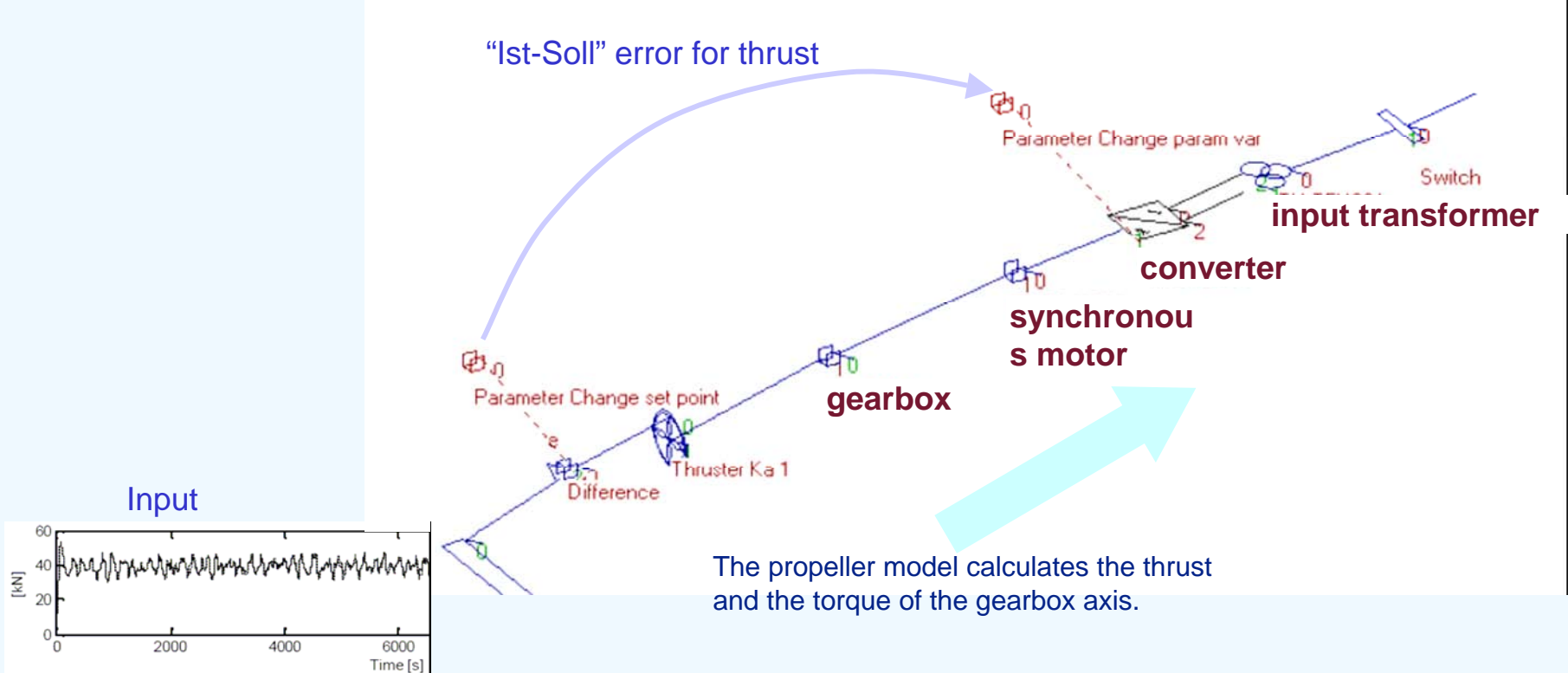
## Main consumers on FPSO

Service:	kW	Production:	kW
Ballast	50	Production Systems:	50,000
Control & communication	140		
Lighting/Accommodation	360		
Navigation	5		
Services	1,000		
Ventilation & A/C	1,100		

DP system	kW
Variable load:	1,000 to 31,000

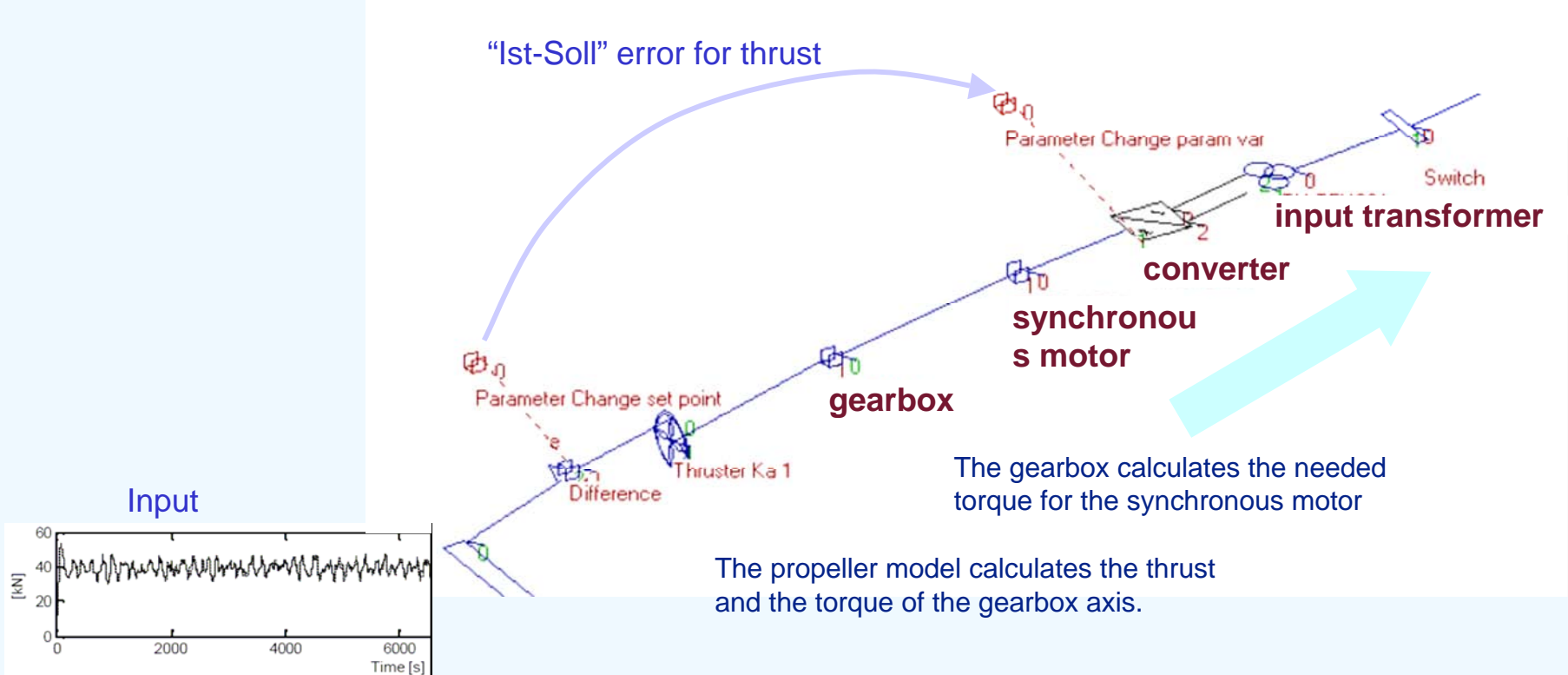


# The actual connection between DP and Energy Simulations



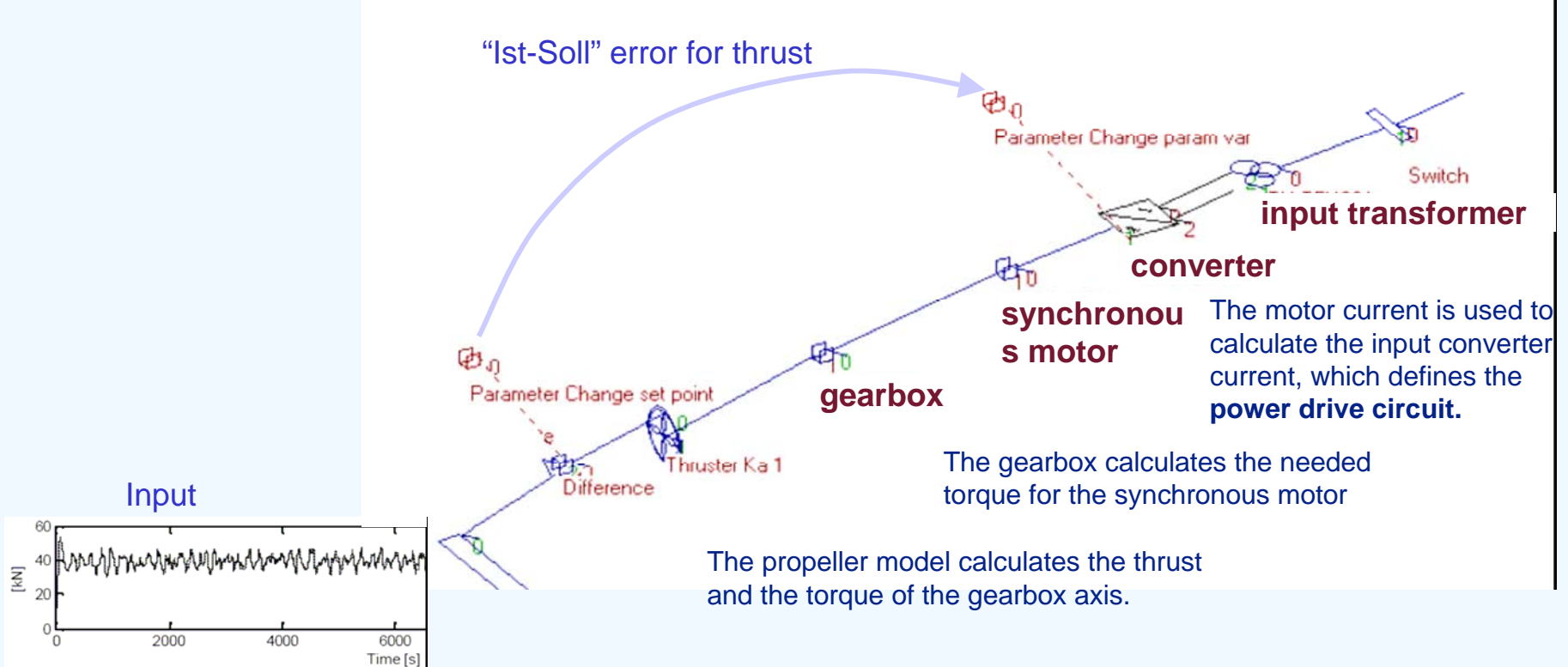


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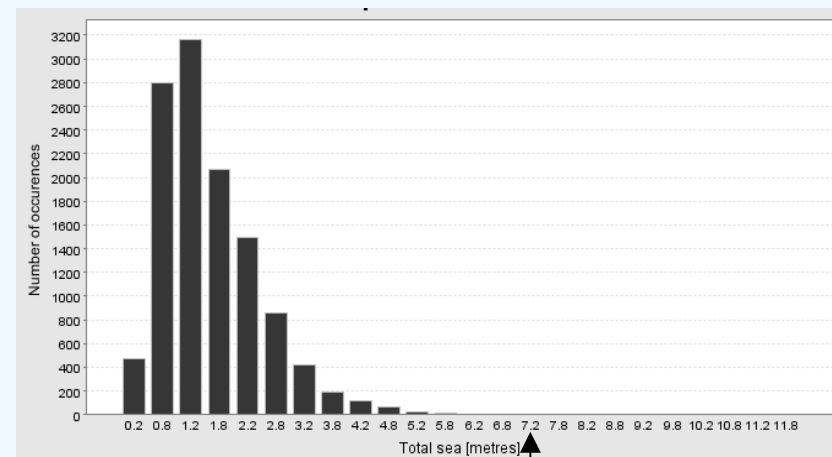
## — Power drive circuit

- The complete control circuit is based on power interaction between the components
- For each time step the load balance is calculated.
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- For every step the fuel flow is calculated.
  - The total amount of fuel is found by integration (“Tank volume”)
  - Present application: It is assumed that power demand can be delivered (sufficient generators running)



## — Integrate results over operational year

- GoM Climate
- Assume 50-50 loaded and ballasted draft
- In high seas the production can be stopped and gas turbine power will be available as back-up



FPSO:  
 Limit production:  $H_s=7.3$  m ,  $T_p=12.4$  s,  $V_c=0.73$  m/s,  $V_w=33$  m/s



# Results

DP FPSO

Fuel and emissions Review table	HFO t/year	CO2 t/year	SO2 t/year	NOx t/year	HC t/year	CO t/year
Loaded	7016.3	20868.1	561.3	659.2	32.7	79.4
Ballast	6845.1	20357.0	547.6	646.5	32.1	78.3
Annual Avg.	6930.7	20612.5	554.4	652.8	32.4	78.8

*Fuel and emission from diesel electric system (DP FPSO)*

Moored FPSO

Fuel consumption Ship Systems	HFO [t/year]	CO2 [t/year]	SO2 [t/year]	NOx [t/year]	HC [t/year]	CO [t/year]
2.5 MW Continuous	6428.4	18485.1	497.4	598.2	29.8	73.5

*Basic ship system consumptions and emissions (moored FPSO)*

Processing  
for both

Review Process Plant Gas Turbines 2*25MW	MDO equiv. [t/year]	CO2 [t/year]	SO2 [t/year]	NOx [t/year]	HC [t/year]	CO [t/year]
30MW load	24737.2	77994.7	1484.0	1040.7	60.2	65.5

*Fuel and emission from Production Gas Power plant*

## Results

- Loaded DP FPSO consumes slightly more power than ballasted
- The DP system requires about 7% extra fuel compared to the moored FPSO concept (total for the ship), while it is 1.5% if the power for production is also considered
- Diesel engines produce relatively much CO, HC and nitrous oxides (NO<sub>x</sub>) compared to gas turbine systems



## — Discussion of the results

### Two assumptions play a role:

- The selection of a GoM climate, which is generally mild and thus requires relatively little DP effort.
- The limitation to 8 diesel generators of 5 MW: in high seas the production can be stopped and gas turbine power will be available as back-up.

These assumptions are linked to each other, because the really severe storms in the GoM are related to hurricane passage, in which the vessel has to be stand-by for disconnection anyway.



## — Conclusions

- 1. DP simulations can be combined with energy flow simulations to evaluate emissions and fuel consumption of DP vessels*
- 2. The method allows to optimize the use of generators and consumers.*

Thank you for your attention



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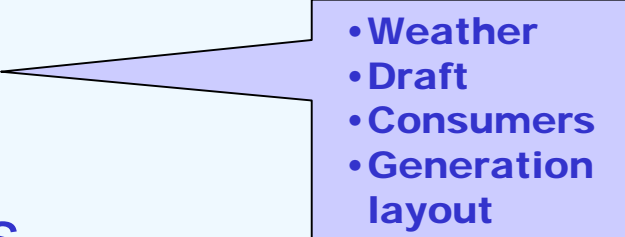
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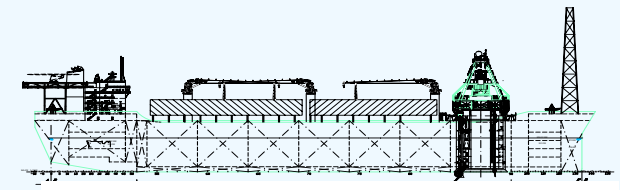
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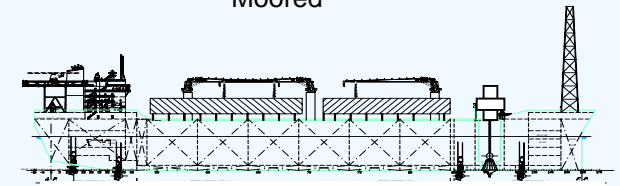


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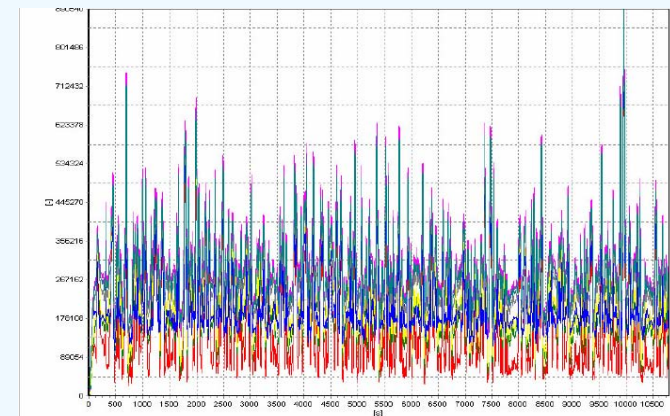
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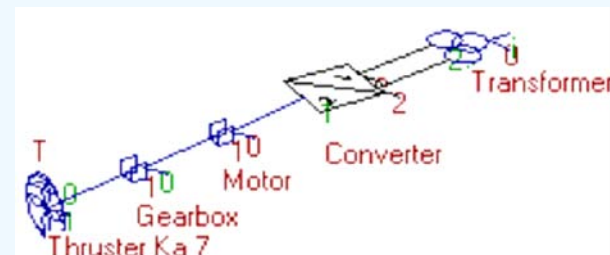
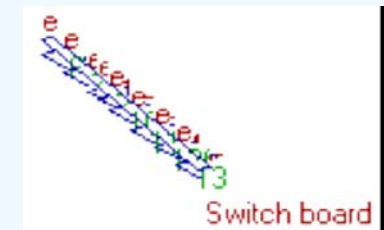
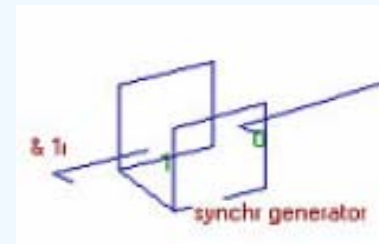
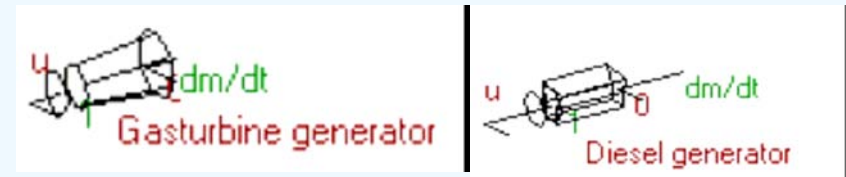


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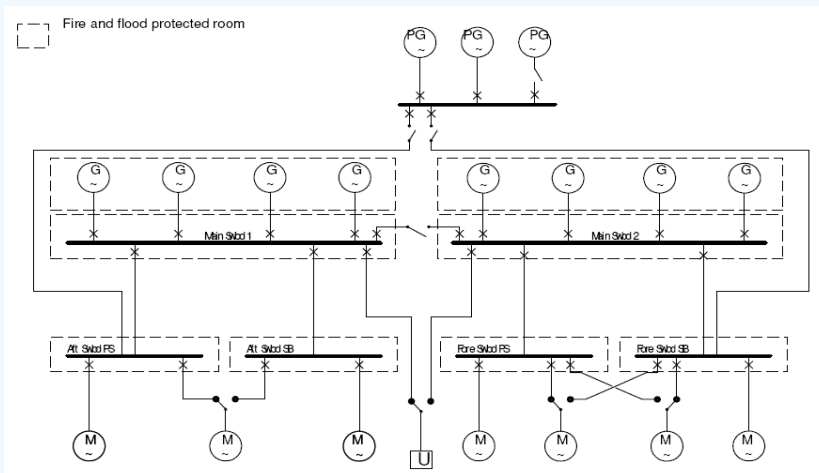
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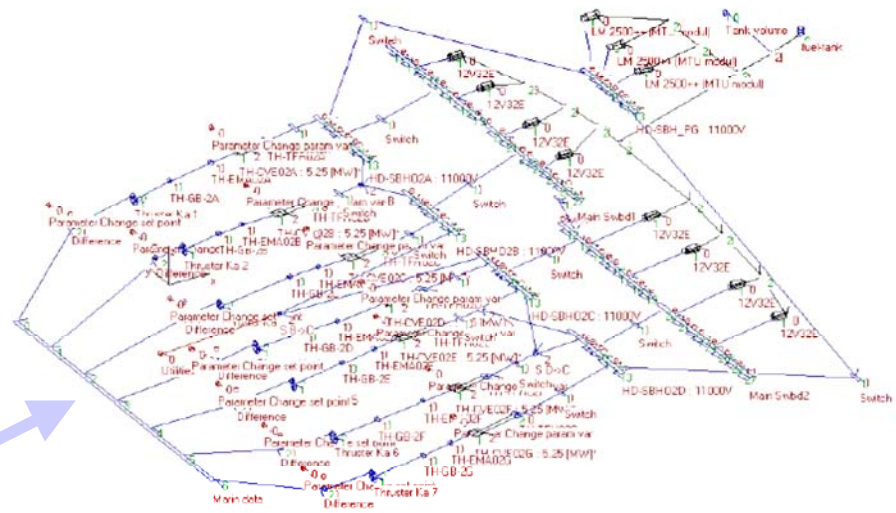
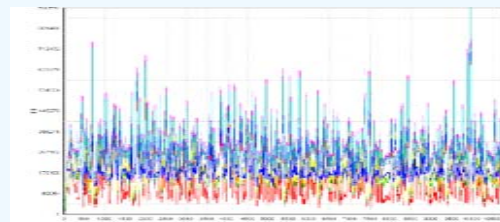




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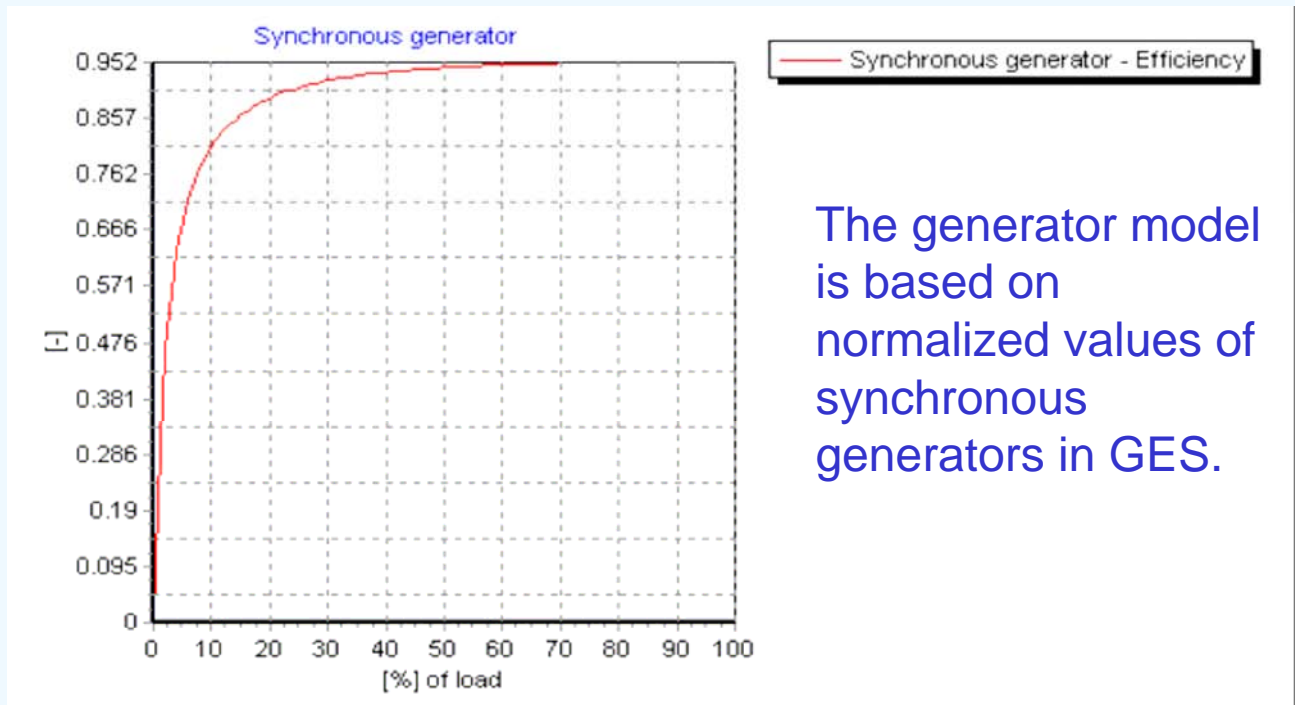
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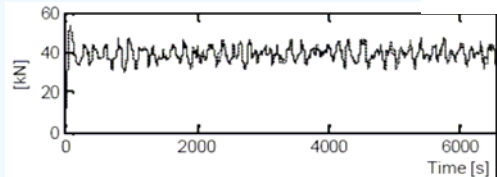
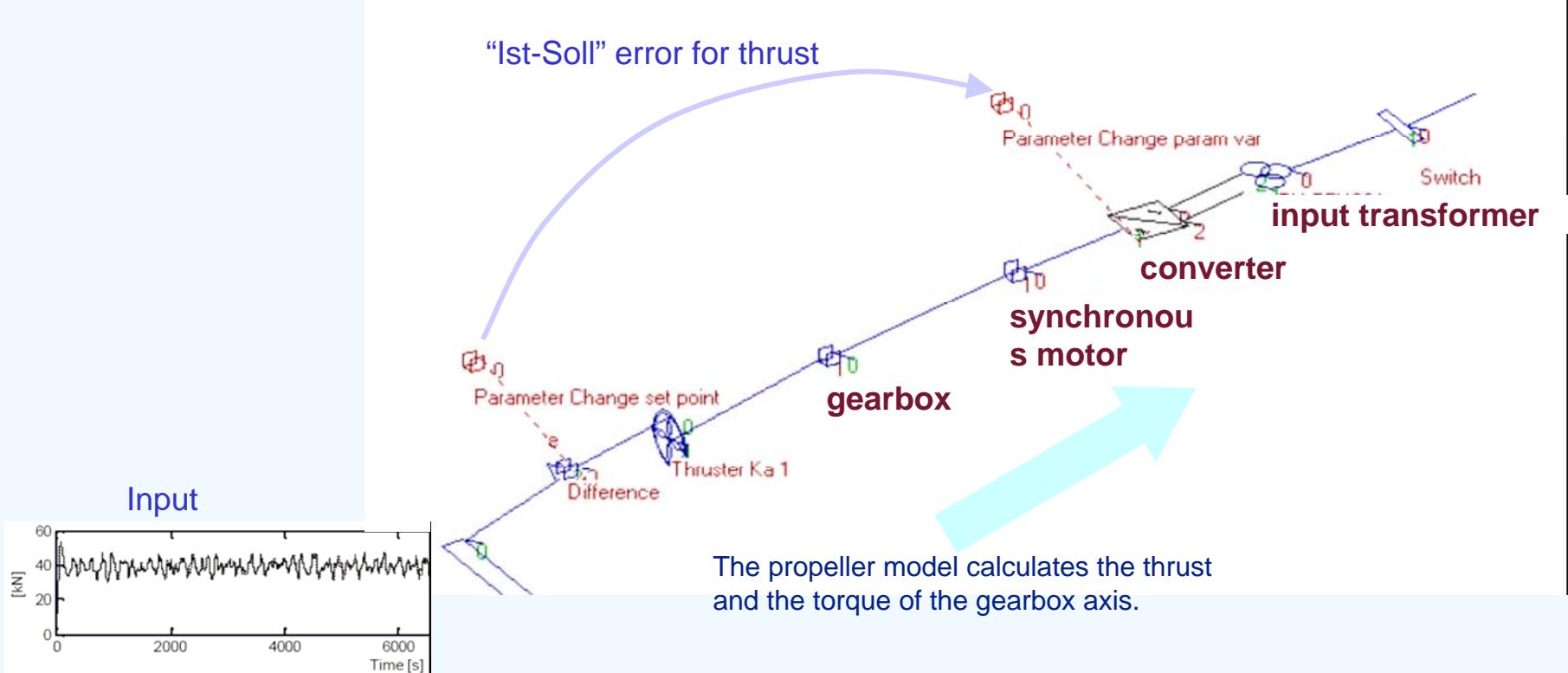
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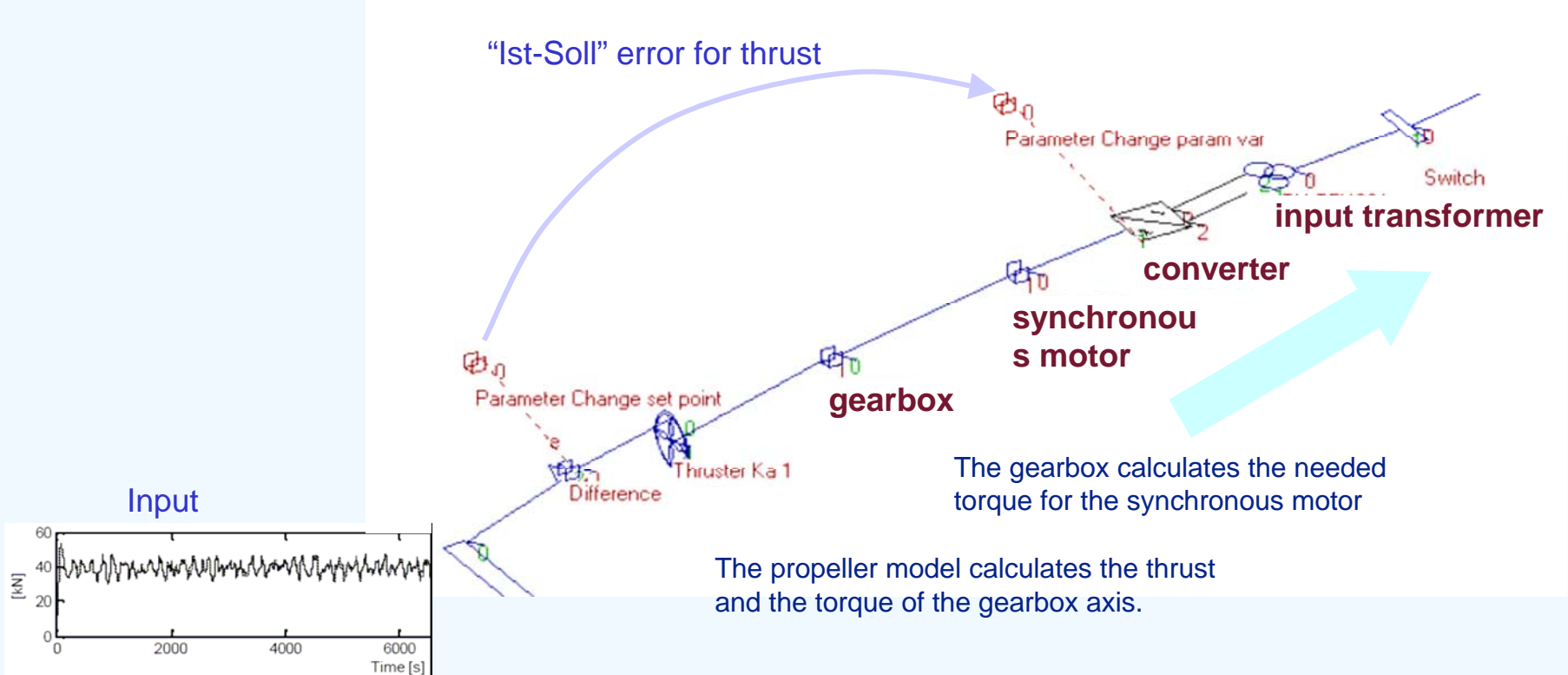


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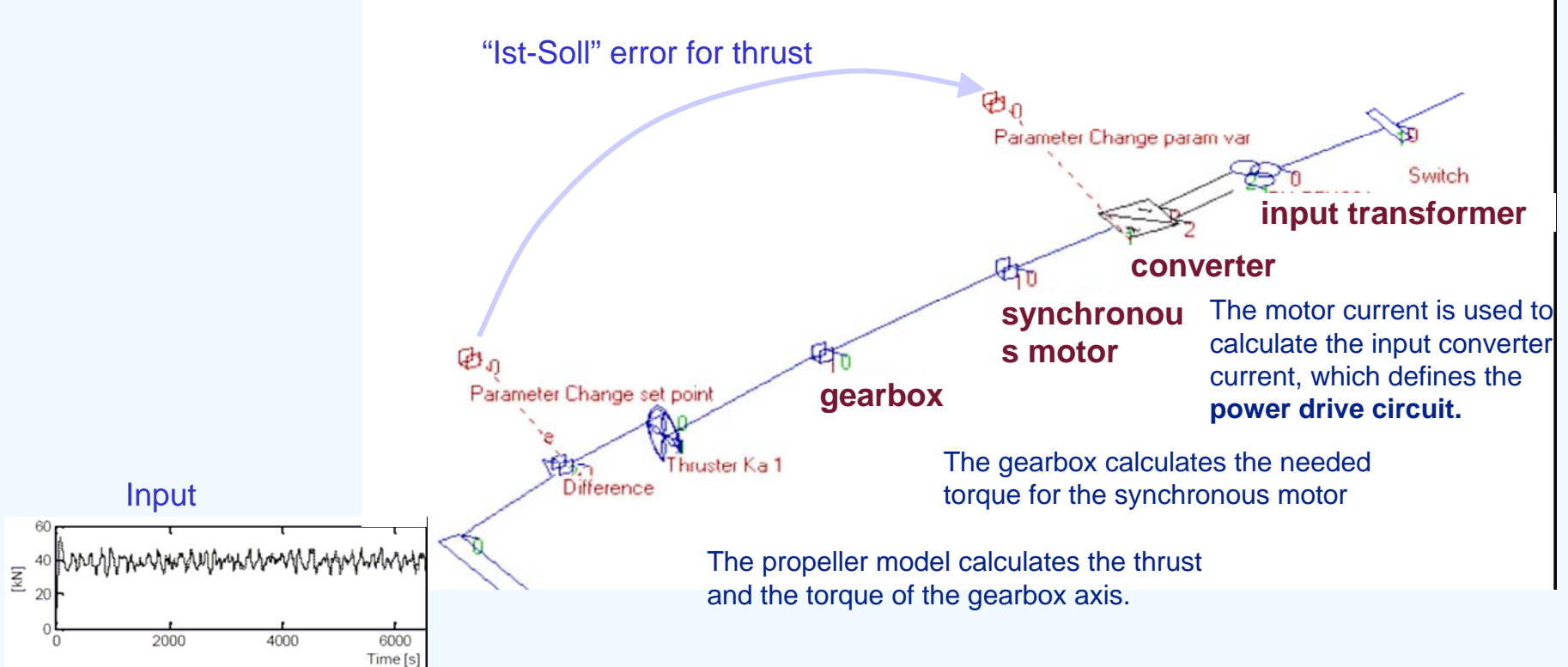


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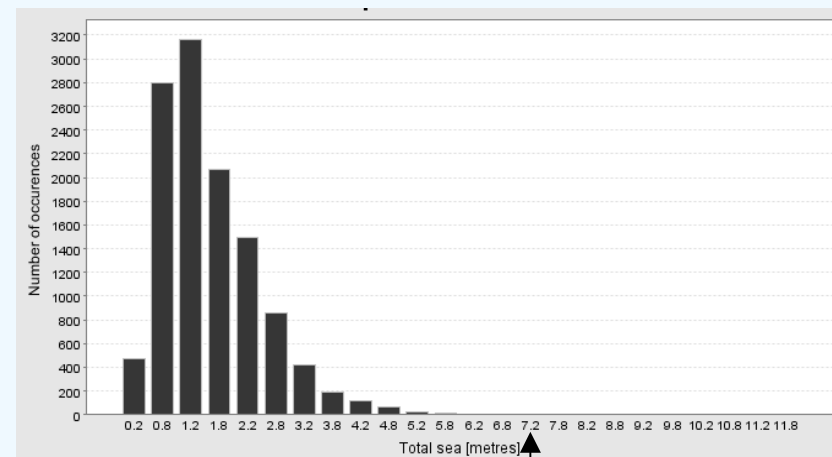
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