Control

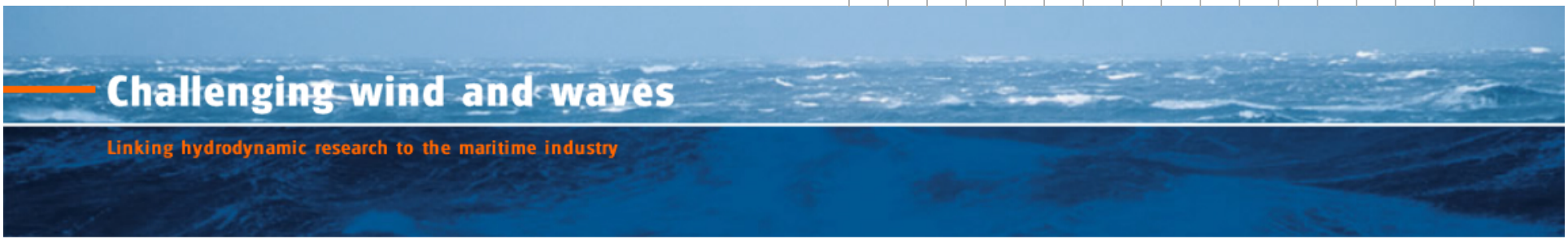
Fuel Consumption and Emission Predictions Applications to a DP-FPSO Concept

Albert Aalbers

Marin

October 17-18, 2006

Return to Session Directory



Dynamic Positioning Committee
Marine Technology Society

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_2, SO_2, NO_x, 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

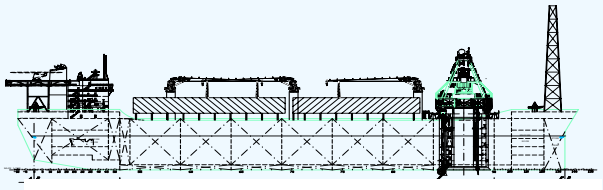
GES (TNO):

“Geintegreerde Energie Systemen”

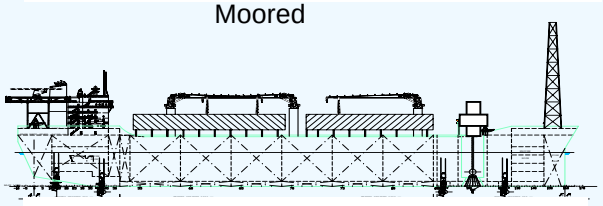
(Integrated Energy Systems)

DP time domain simulation

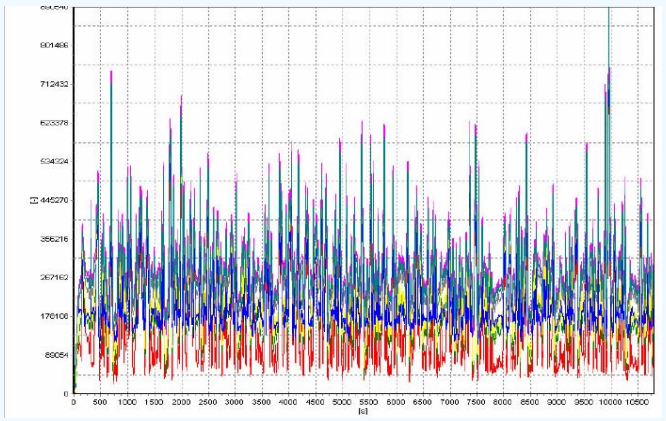
- DP-FPSO concept
  - Full and ballast loading condition
  - Thruster action (delivered thrust)
  - Design concept for GoM
- Output:
  - Time traces of delivered thrust
  - For range of conditions



Moored



DP



Integrated Energy Systems (GES simulations)

Fuel consumption

Emissions (CO_2, SO_2, NO_x, HC and CO)

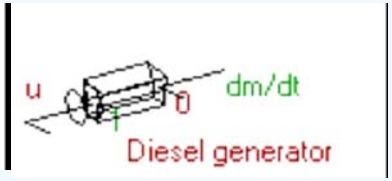
From “energy flow simulation”

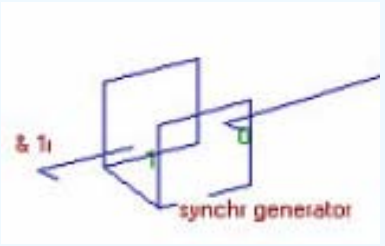
- Input:
  - Power generation arrangement
  - DP system: delivered thrust per unit
  - Other consumers
  - Operating aspects
- Output:
  - 3 hrs average consumption and emission data

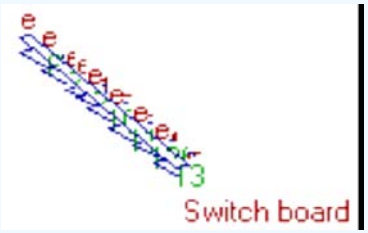
Integrated Energy Systems

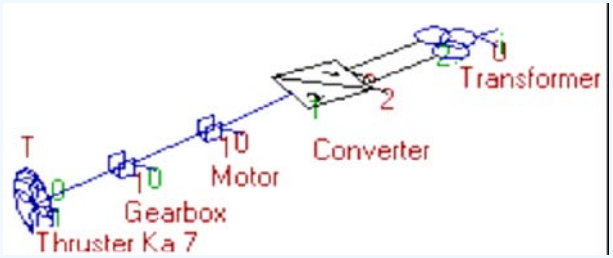
Elements in Power arrangement
(selectable from dB):

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

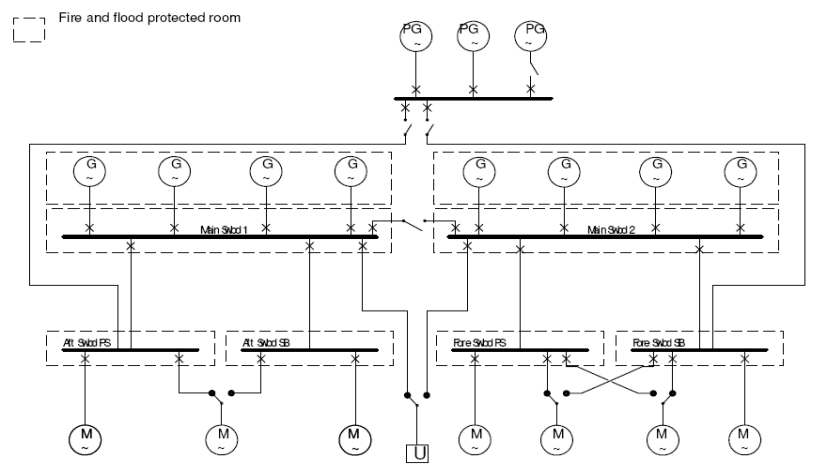




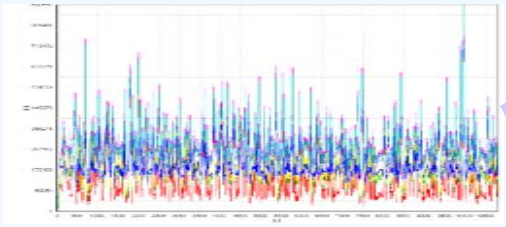


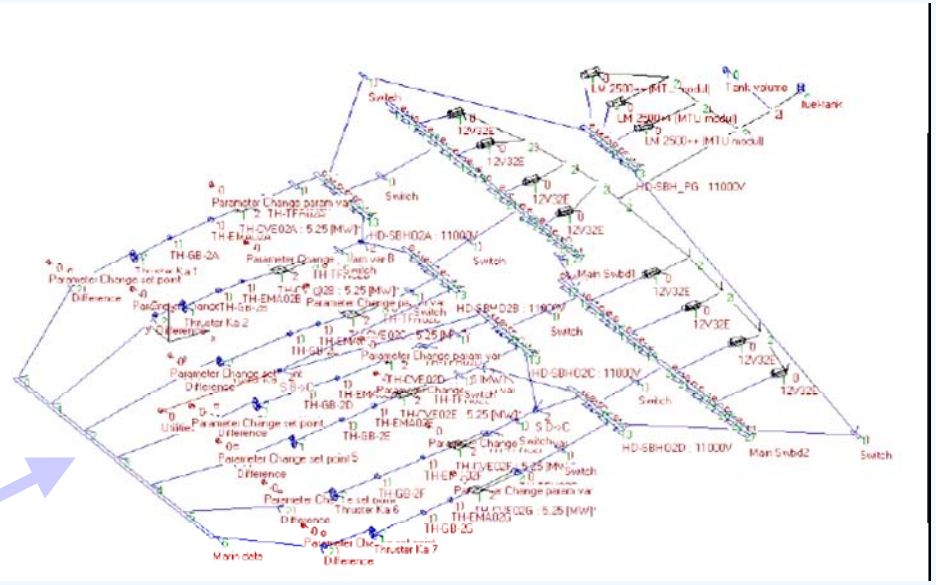


Arrangement



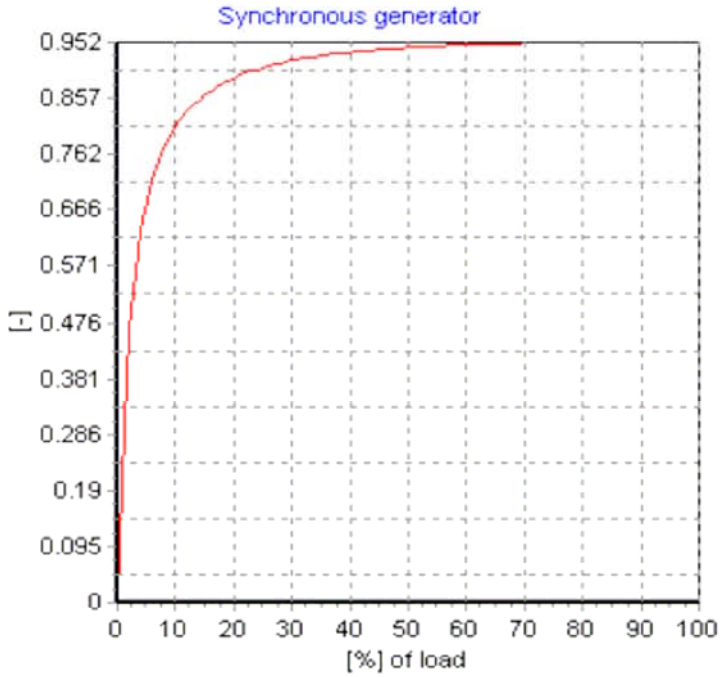
Key-One Line
DP Class 2

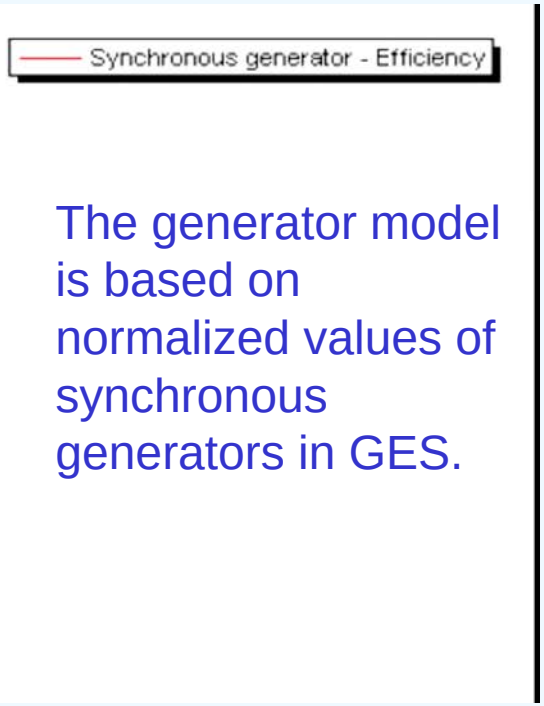




GES representation

Efficiency of elements: for example a Generator





The generator model is based on normalized values of synchronous generators in GES.

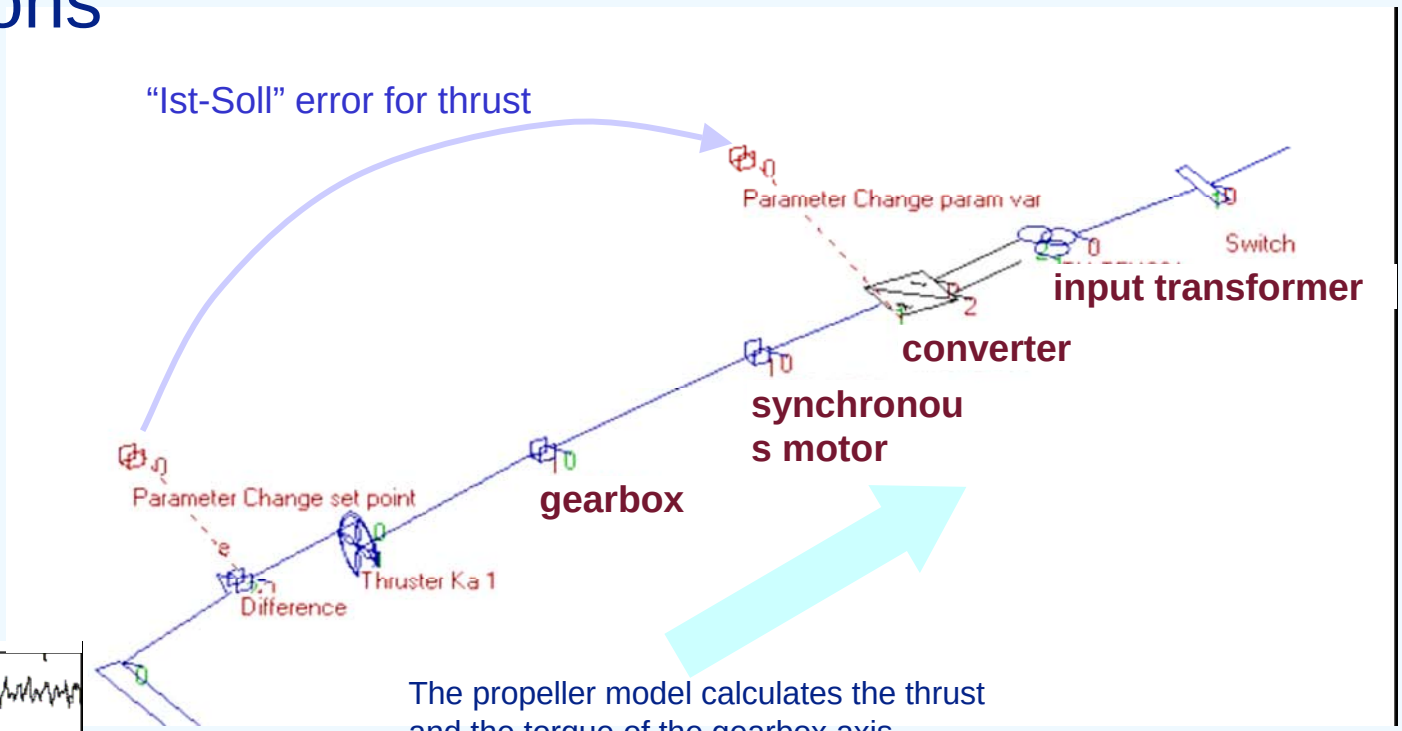
Main consumers on FPSO

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

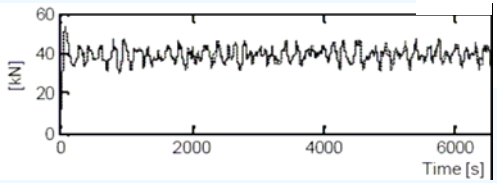
Production:	kW
Production Systems:	50,000

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

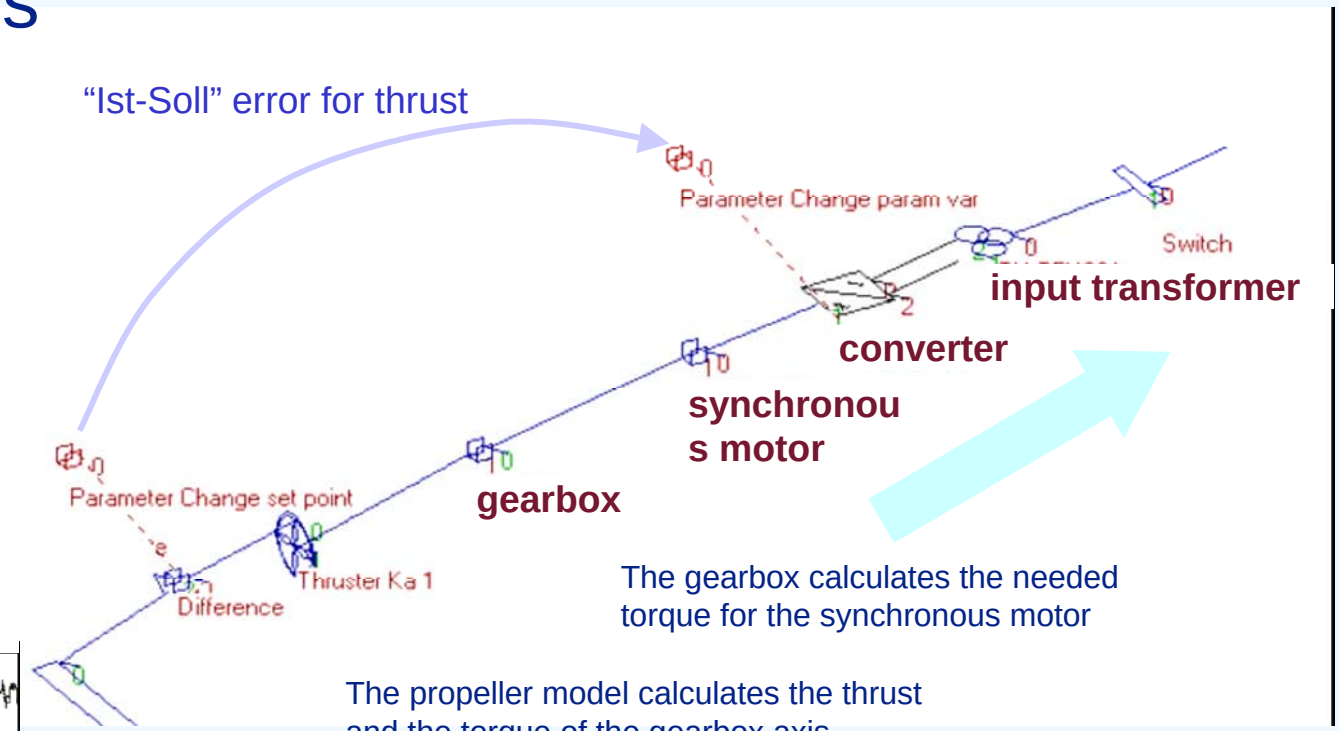
The actual connection between DP and Energy Simulations



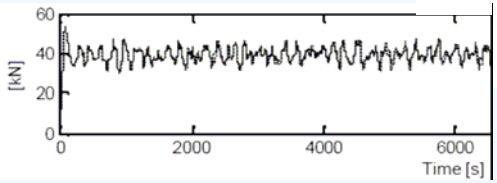
Input



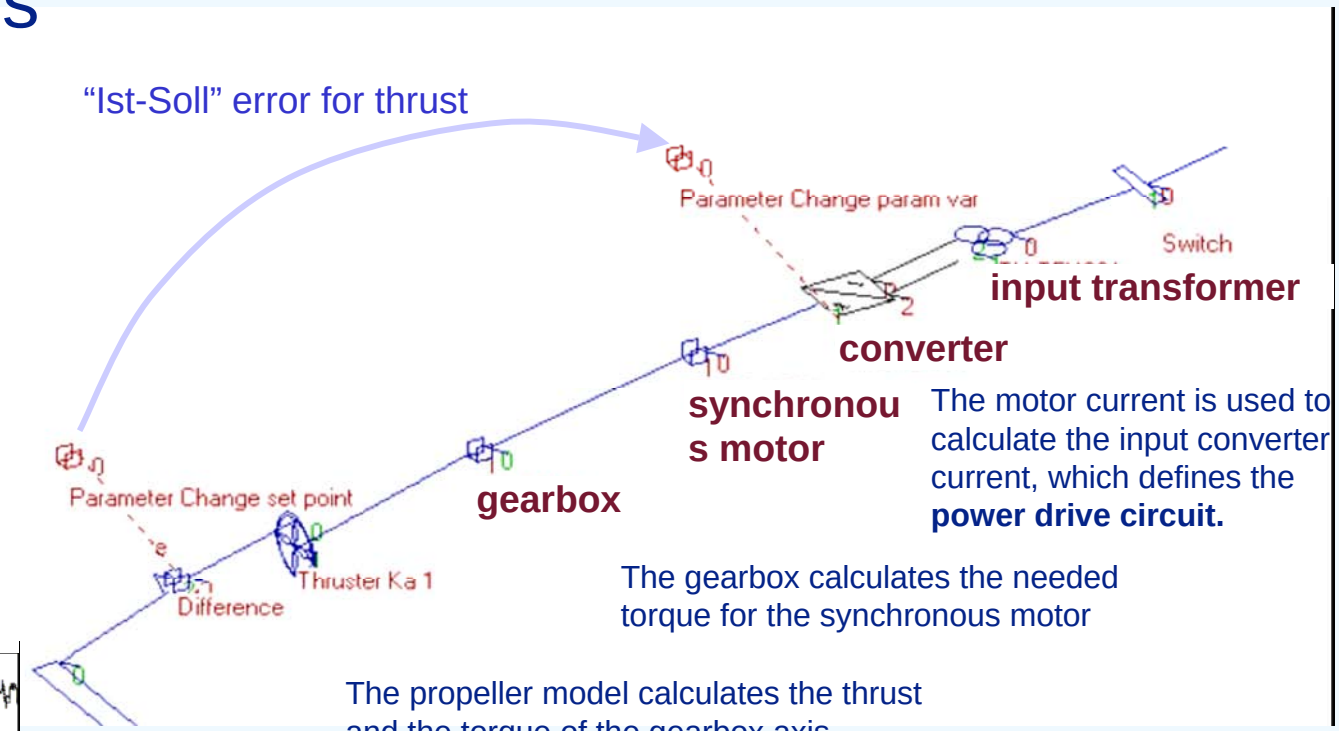
The actual connection between DP and Energy Simulations



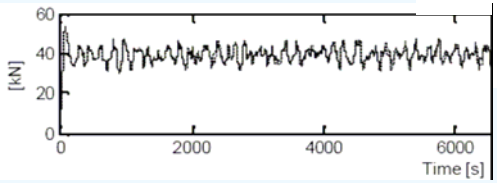
Input



The actual connection between DP and Energy Simulations



Input

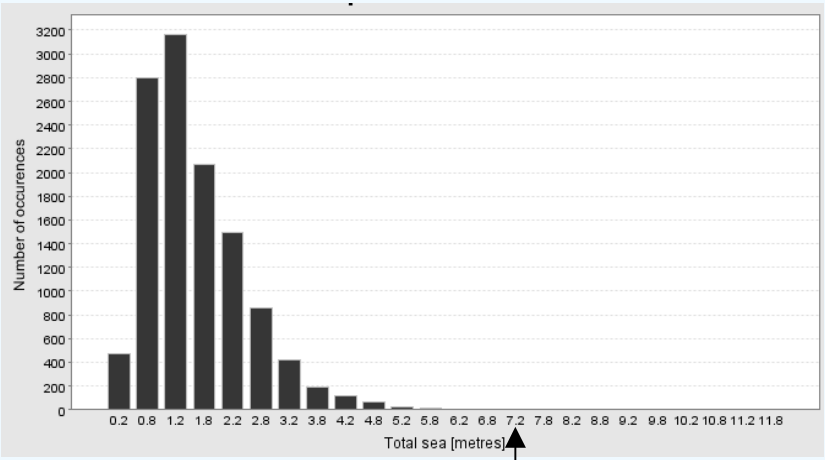


Power drive circuit

- The complete control circuit is based on power interaction between the components
- For each time step the load balance is calculated.
- This is done for all the components.
- 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: Hs=7.3 m , Tp=12.4 s, Vc=0.73 m/s, Vw=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_x) 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.

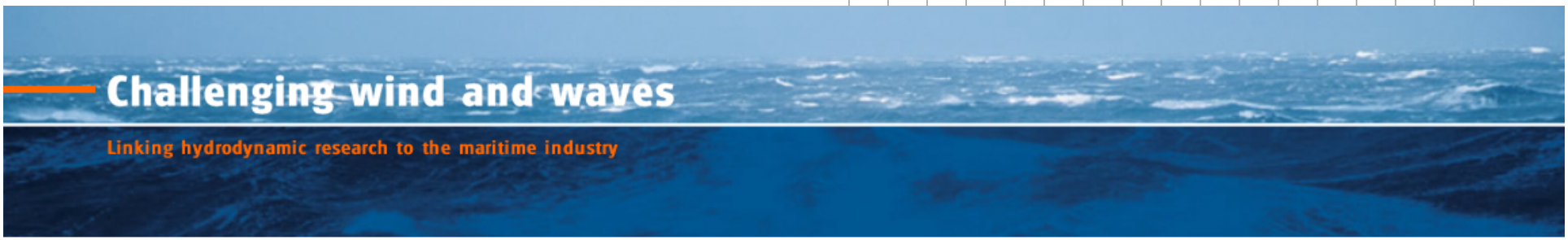
Conclusions

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

MTS DP Conference
17/18 October 2006

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



Dynamic Positioning Committee
Marine Technology Society

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_2, SO_2, NO_x, 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

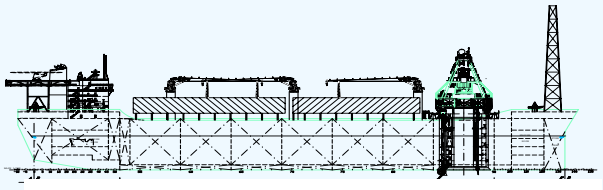
GES (TNO):

“Geintegreerde Energie Systemen”

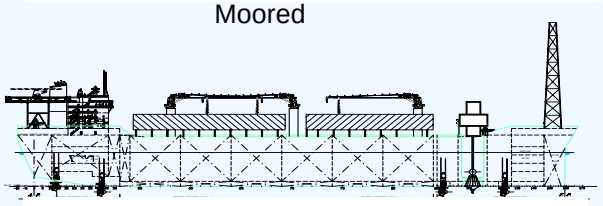
(Integrated Energy Systems)

DP time domain simulation

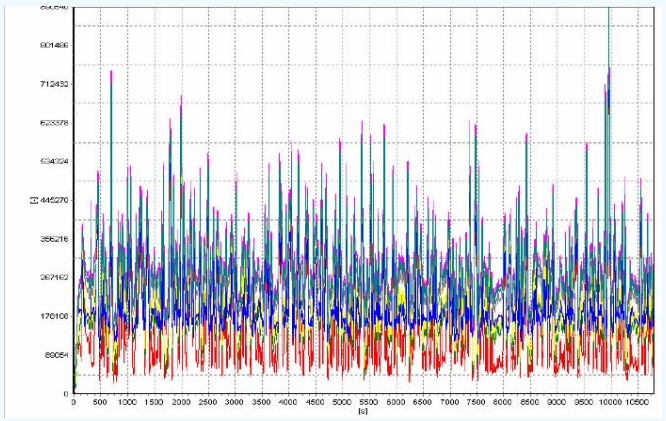
- DP-FPSO concept
  - Full and ballast loading condition
  - Thruster action (delivered thrust)
  - Design concept for GoM
- Output:
  - Time traces of delivered thrust
  - For range of conditions



Moored



DP



Integrated Energy Systems (GES simulations)

Fuel consumption

Emissions (CO_2, SO_2, NO_x, HC and CO)

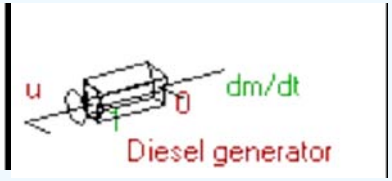
From “energy flow simulation”

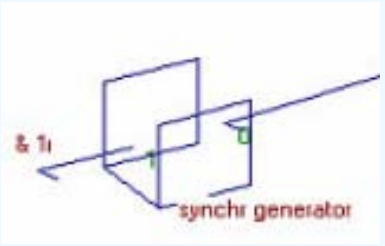
- Input:
  - Power generation arrangement
  - DP system: delivered thrust per unit
  - Other consumers
  - Operating aspects
- Output:
  - 3 hrs average consumption and emission data

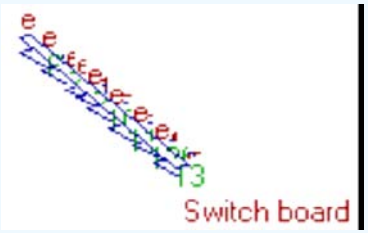
Integrated Energy Systems

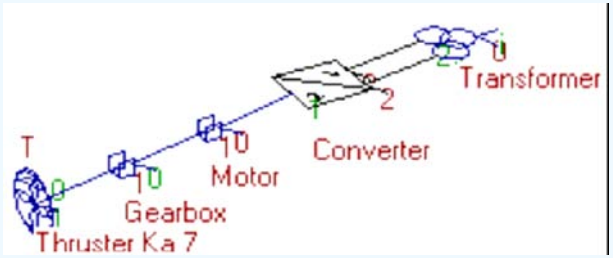
Elements in Power arrangement
(selectable from dB):

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

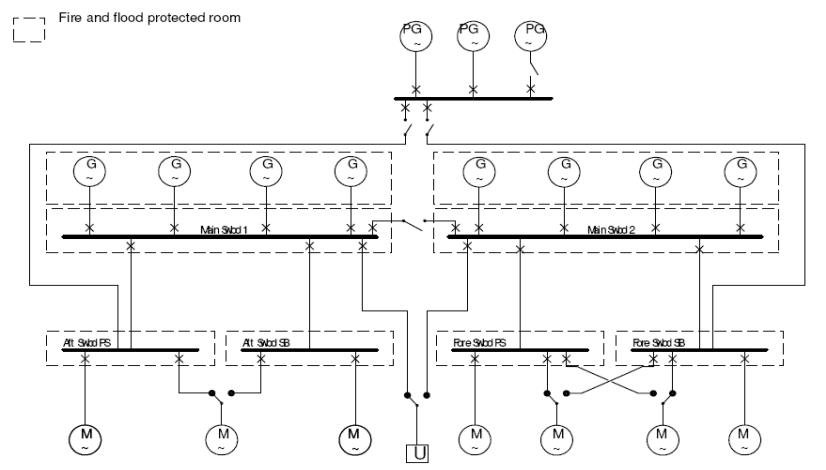




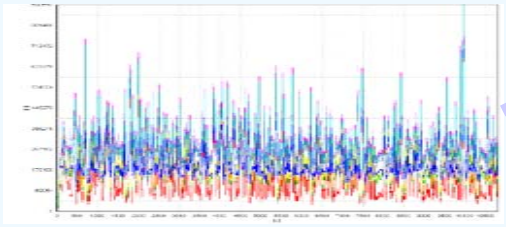


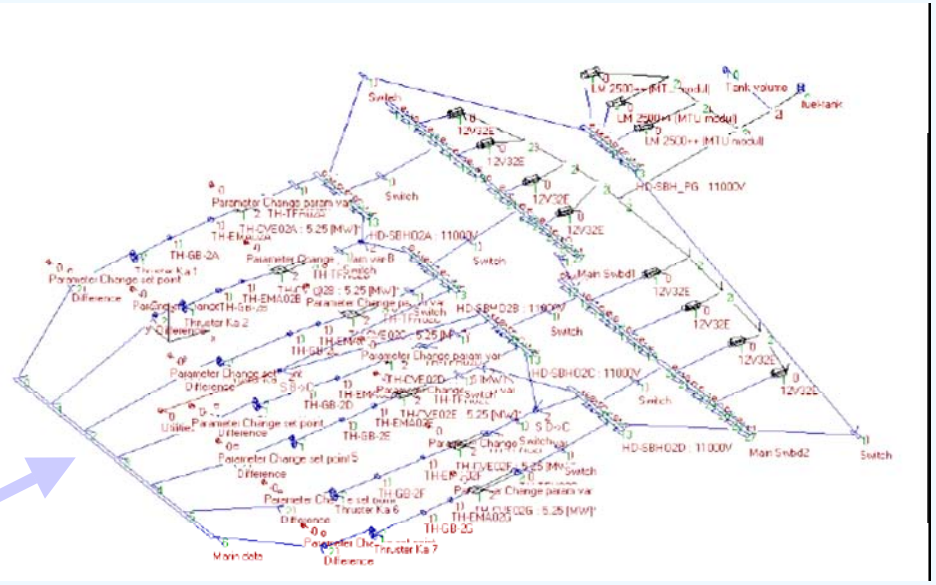


Arrangement



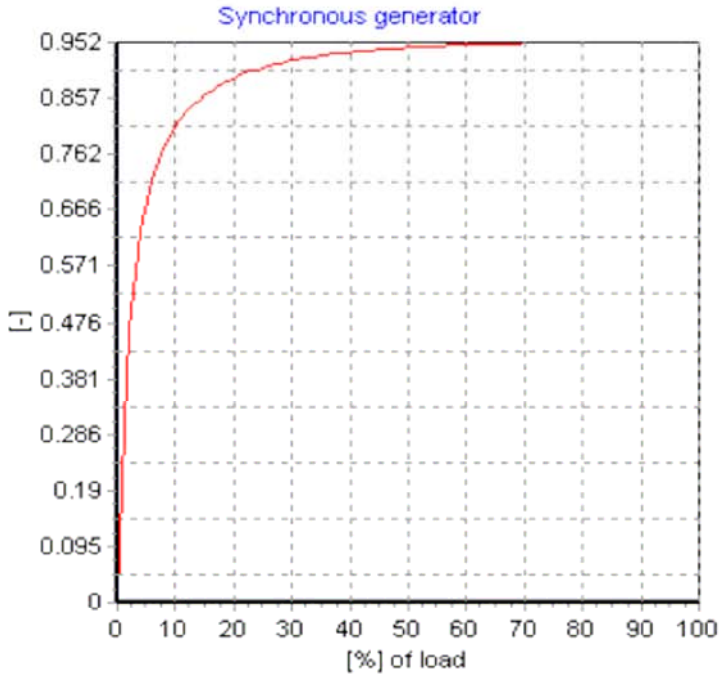
Key-One Line
DP Class 2

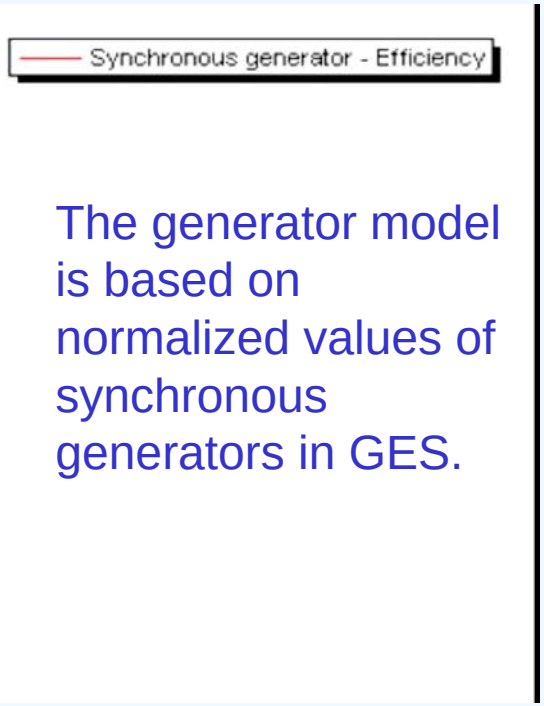




GES representation

Efficiency of elements: for example a Generator





The generator model is based on normalized values of synchronous generators in GES.

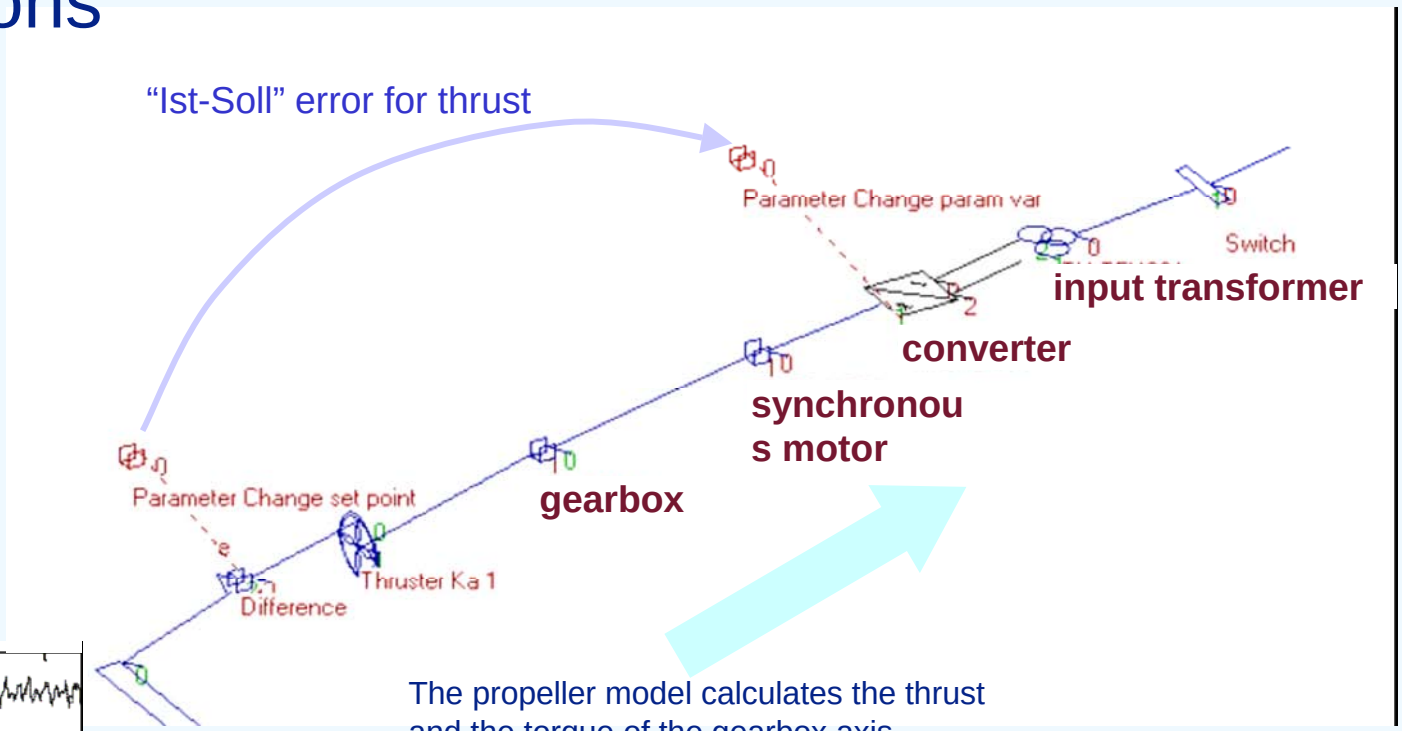
Main consumers on FPSO

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

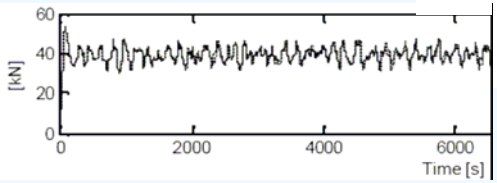
Production:	kW
Production Systems:	50,000

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

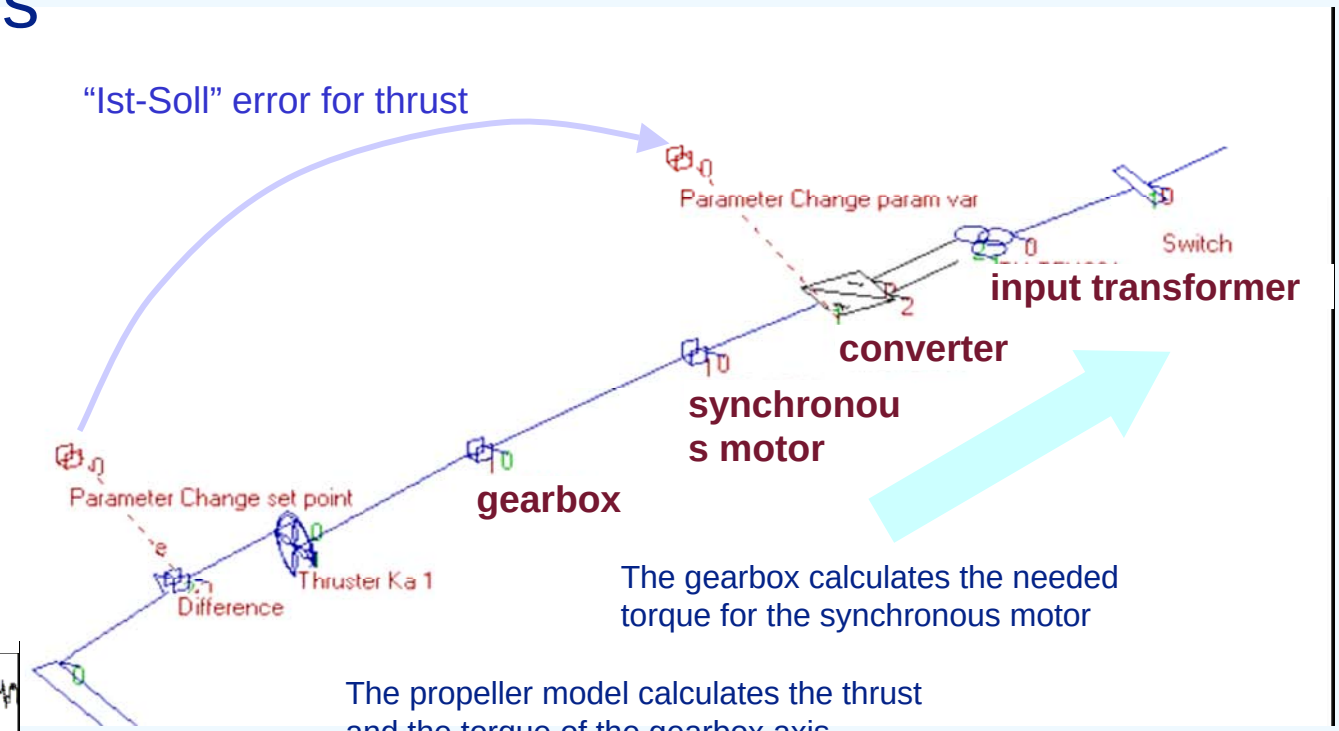
The actual connection between DP and Energy Simulations



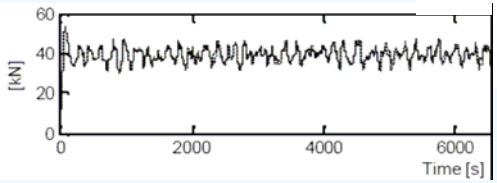
Input



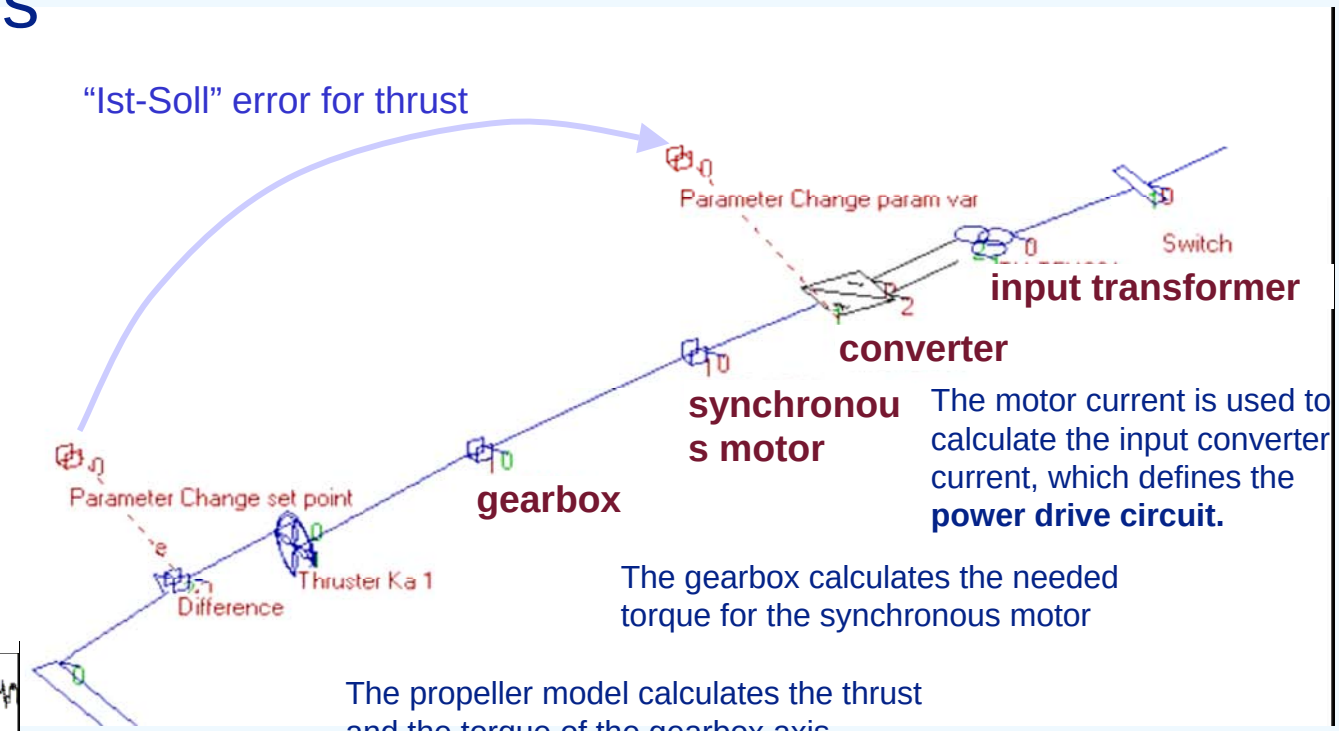
The actual connection between DP and Energy Simulations



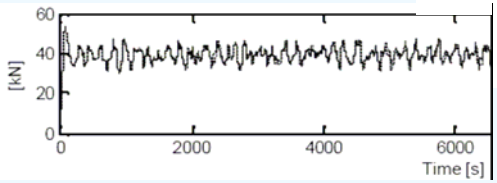
Input



The actual connection between DP and Energy Simulations



Input

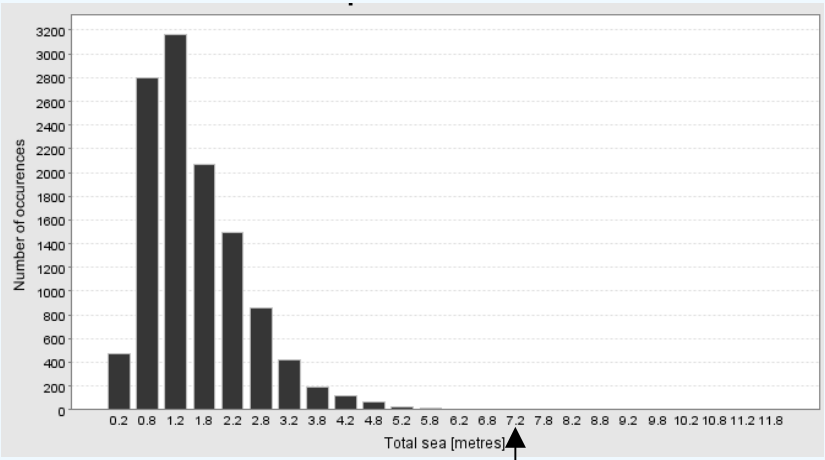


Power drive circuit

- The complete control circuit is based on power interaction between the components
- For each time step the load balance is calculated.
- This is done for all the components.
- 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: Hs=7.3 m , Tp=12.4 s, Vc=0.73 m/s, Vw=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_x) 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

MTS DP Conference
17/18 October 2006

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