Netherlands Defense Academy
Ministry of Defense

[1]

Engine Dynamics of variable speed generators

EAAW 2025

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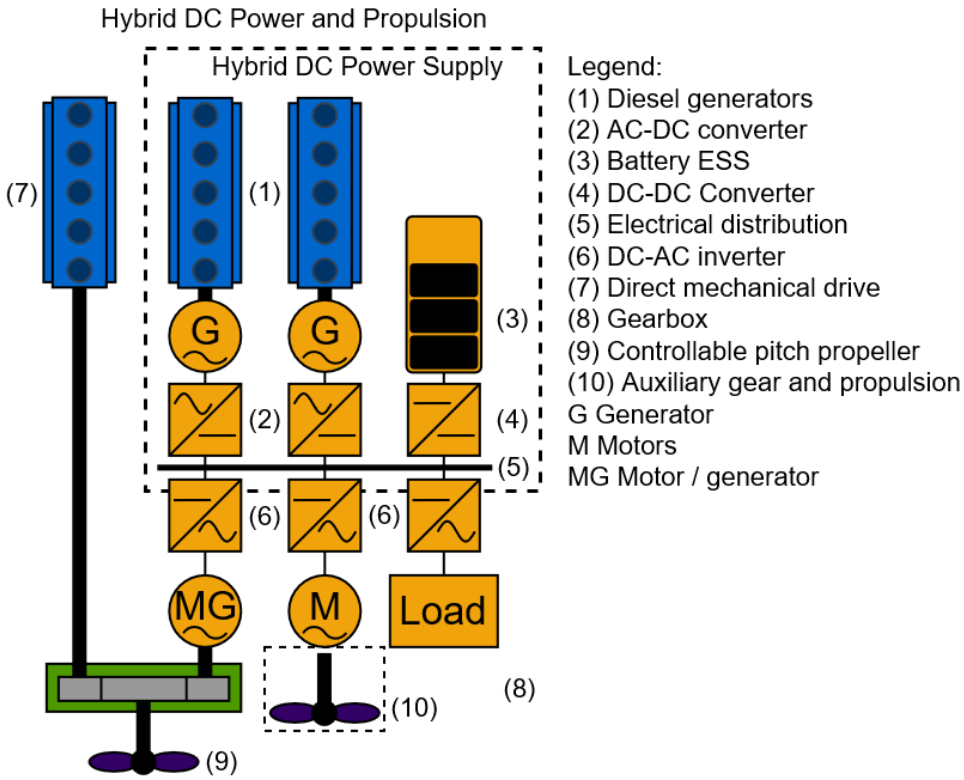
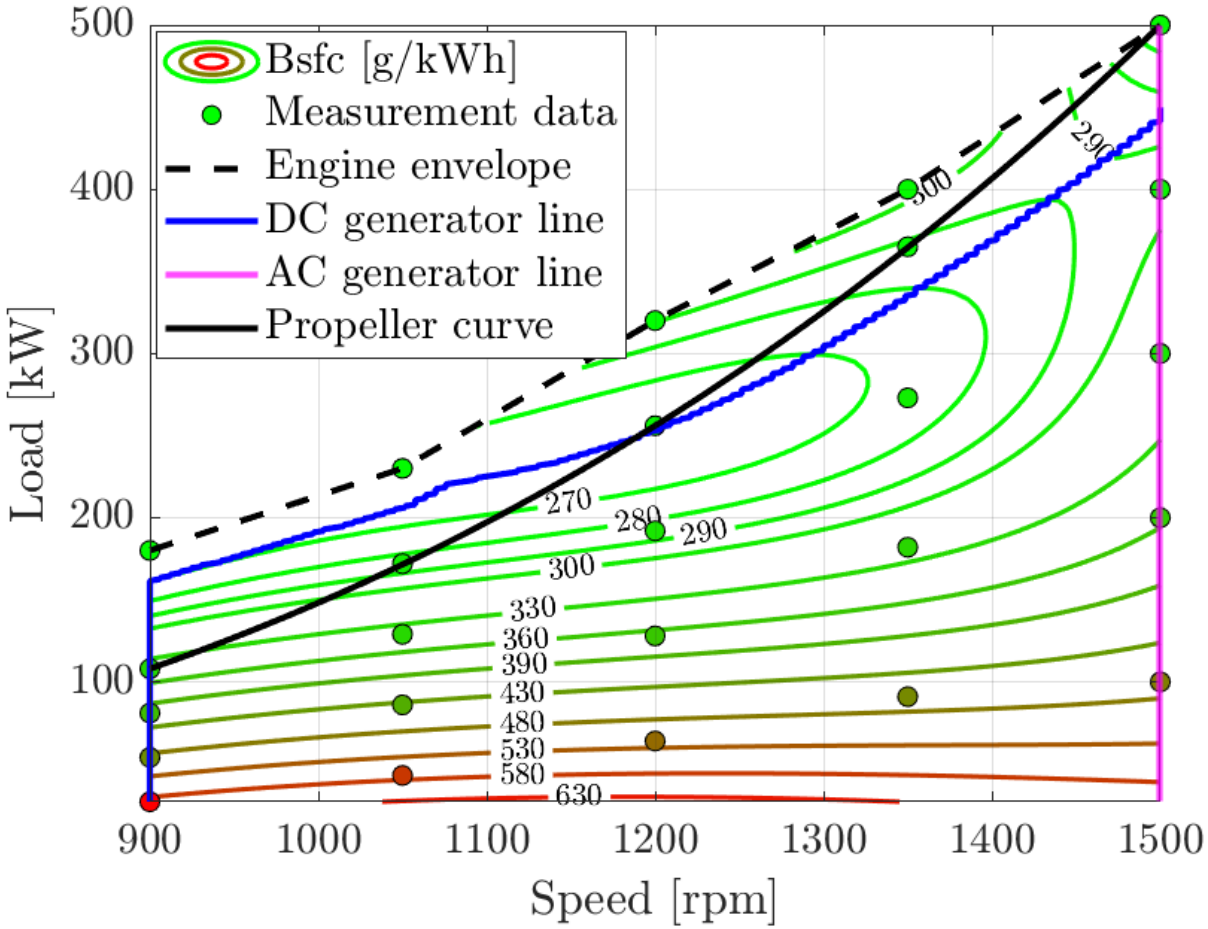
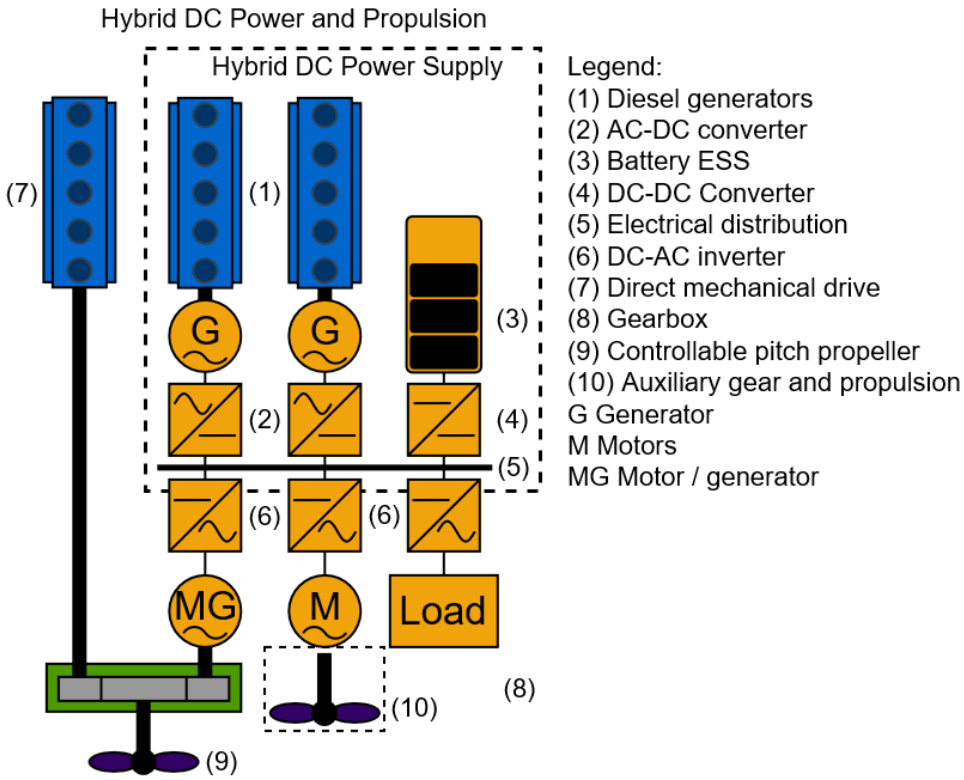

Hybrid DC Power and Propulsion
Hybrid DC Power Supply
(7)
(1)
G
G
(3)
(2)
(4)
(5)
(6)
(6)
MG
M
Load
(8)
(10)
(9)
Legend:
(1) Diesel generators
(2) AC-DC converter
(3) Battery ESS
(4) DC-DC Converter
(5) Electrical distribution
(6) DC-AC inverter
(7) Direct mechanical drive
(8) Gearbox
(9) Controllable pitch propeller
(10) Auxiliary gear and propulsion
G Generator
M Motors
MG Motor / generator

[3]


Bsfc [g/kWh]
Measurement data
Engine envelope
DC generator line
AC generator line
Propeller curve
290
300
270
280
290
300
330
360
390
430
480
530
580
630
500
400
300
200
100
Load [kW]
900
1000
1100
1200
1300
1400
1500
Speed [rpm]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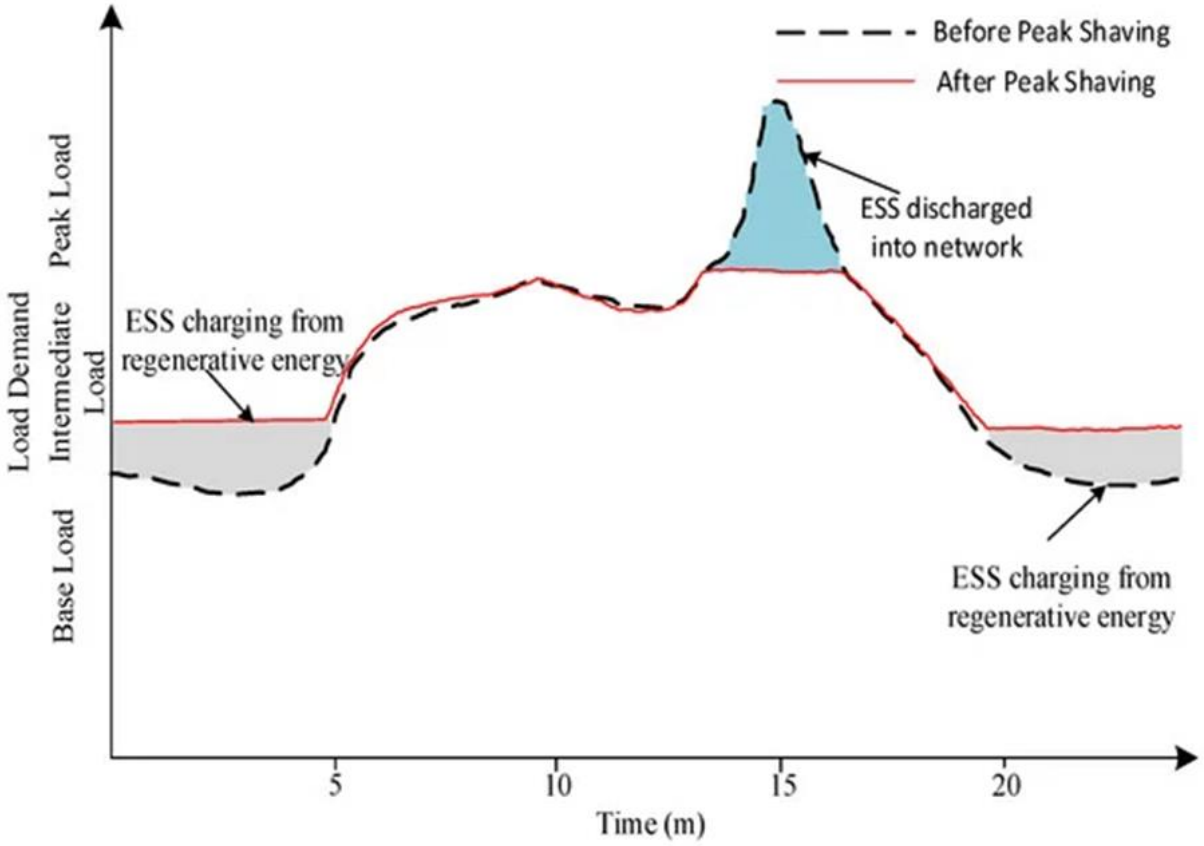
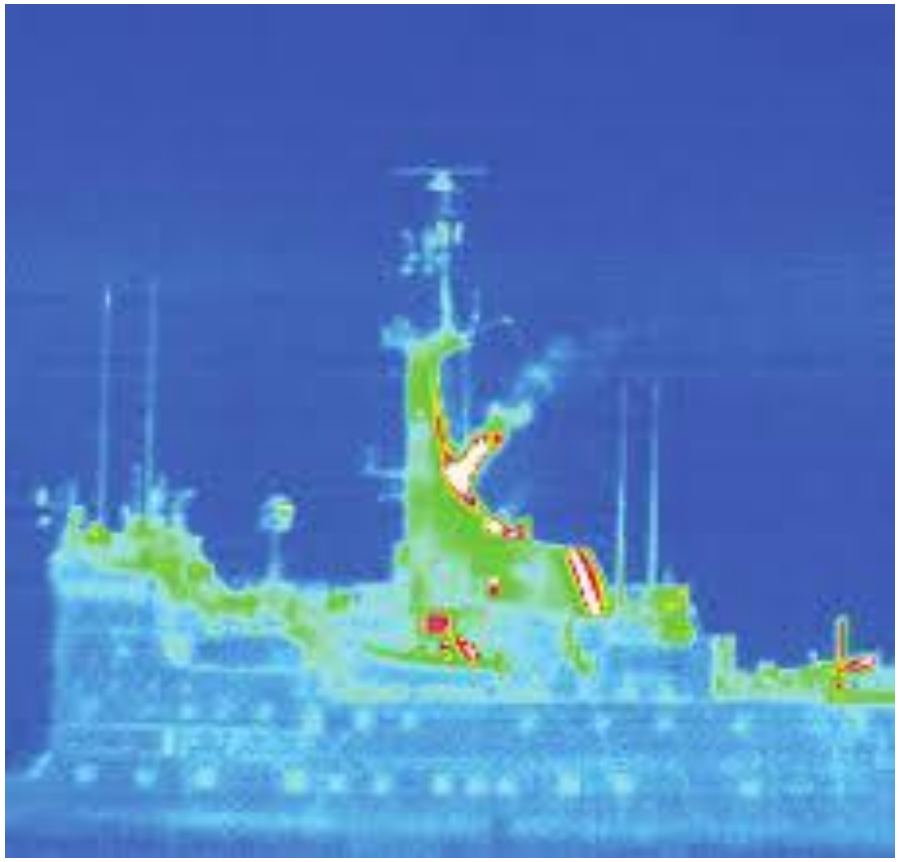

Before Peak Shaving
After Peak Shaving
ESS discharged into network
ESS charging from regenerative energy
ESS charging from regenerative energy
Load Demand
Peak Load
Intermediate Load
Base Load
5
10
15
20
Time (m)

[4]

[5]



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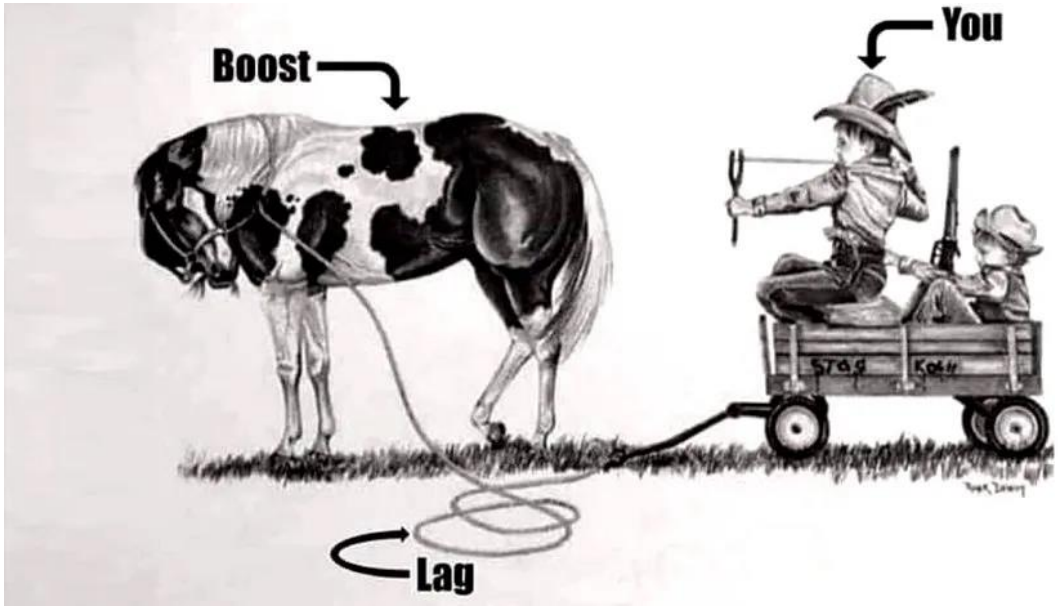
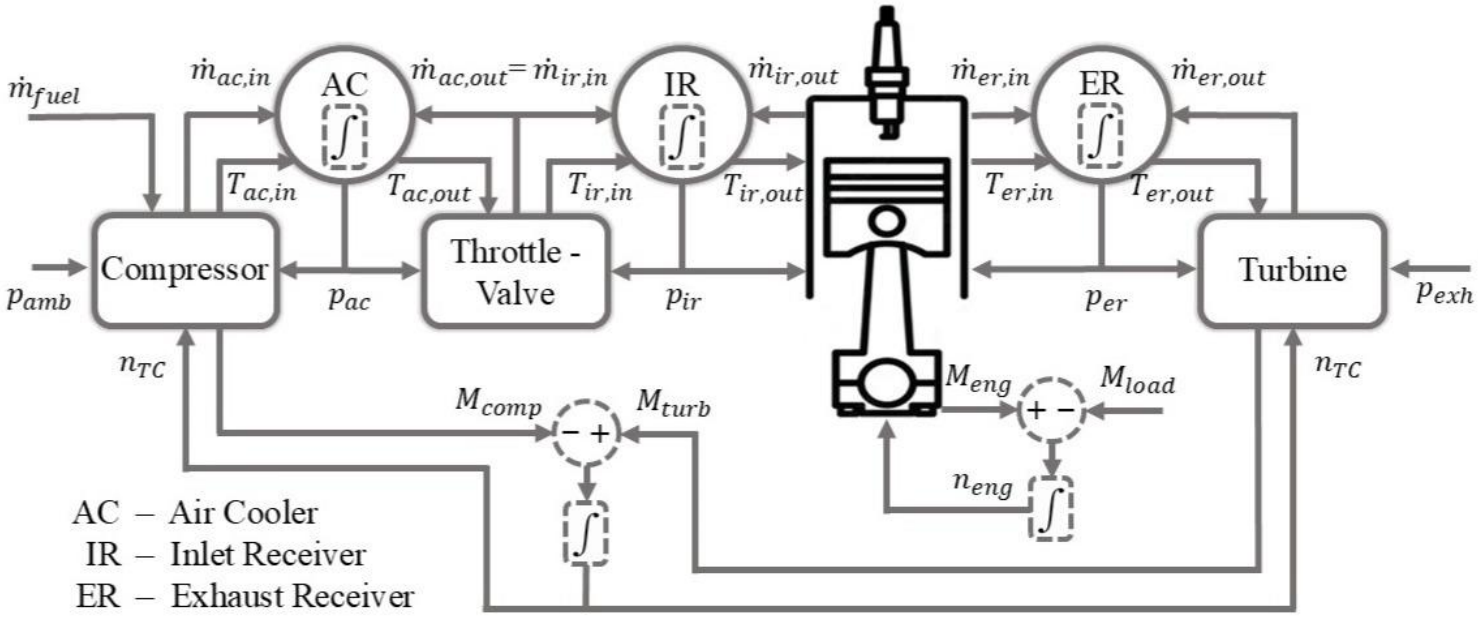


[7]

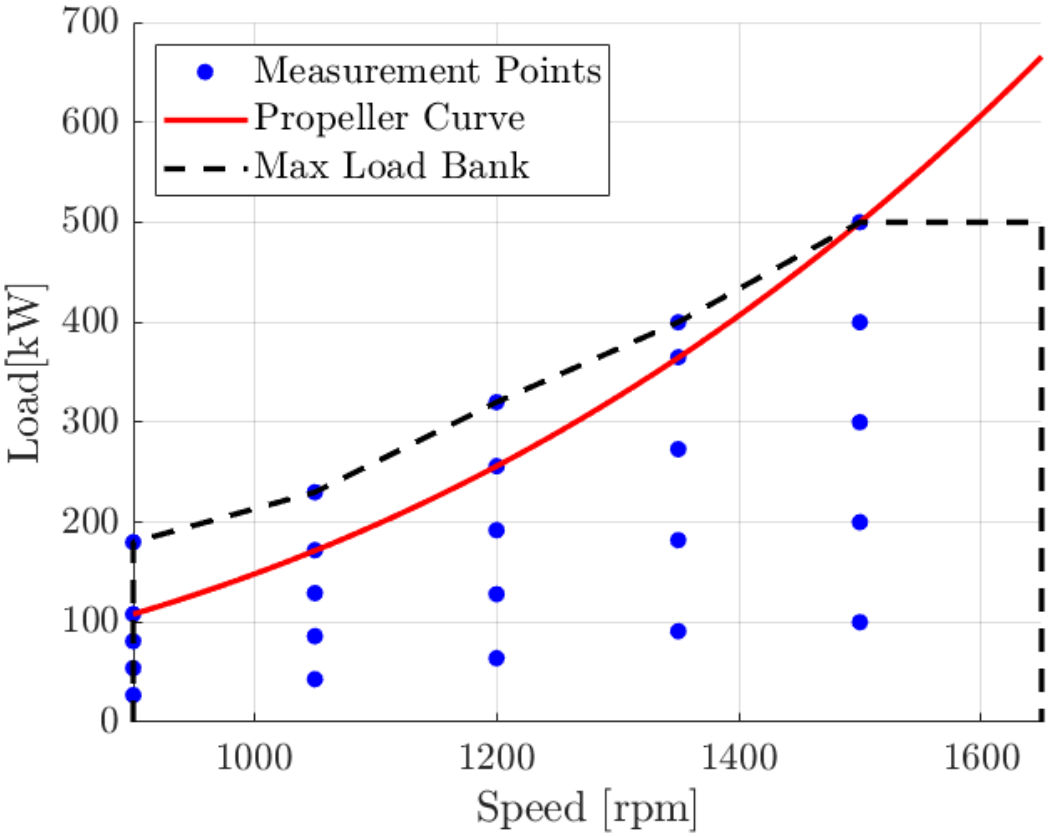
[8]

Block diagram of engine model

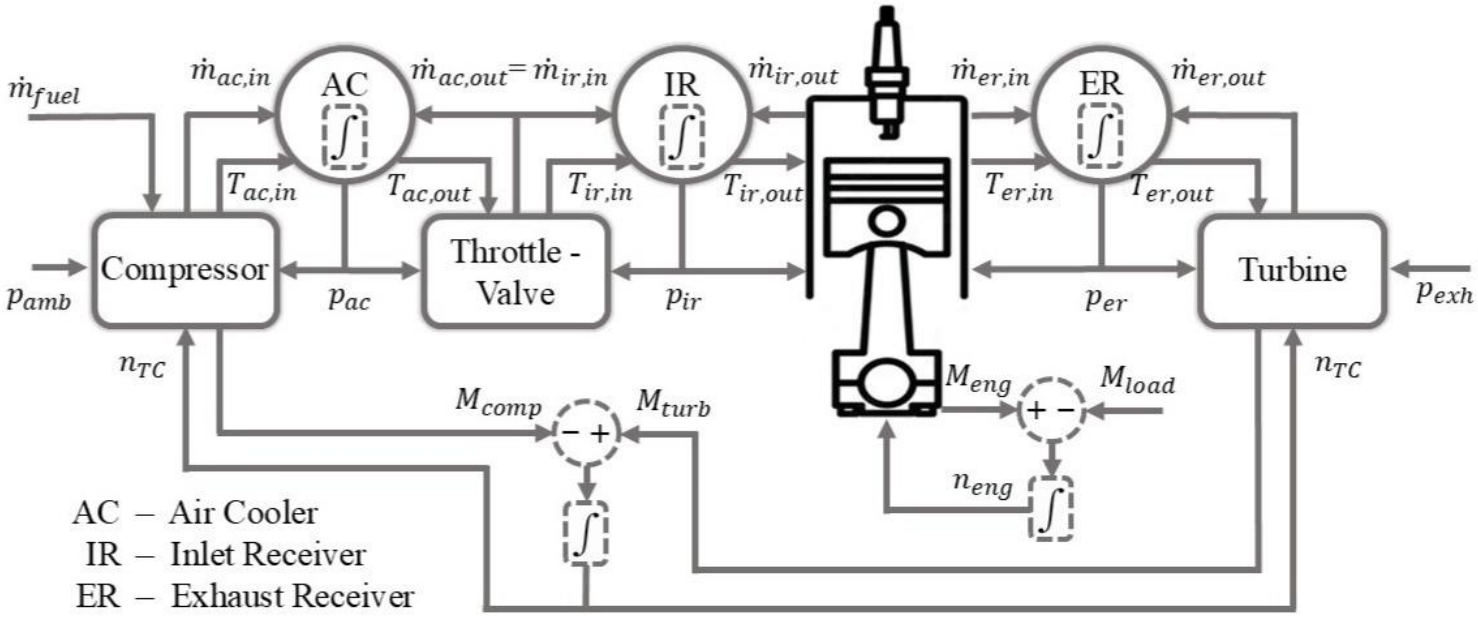


[8]

Measurement Grid



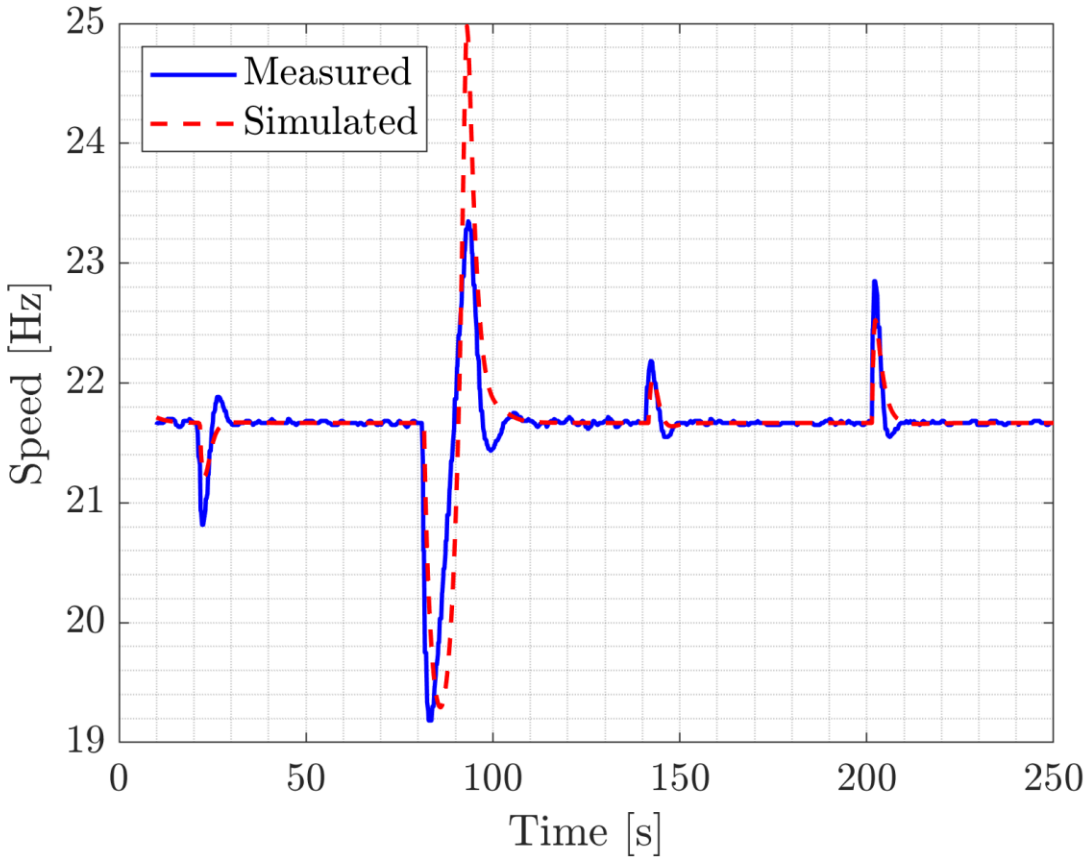
Block diagram of engine model



[8]

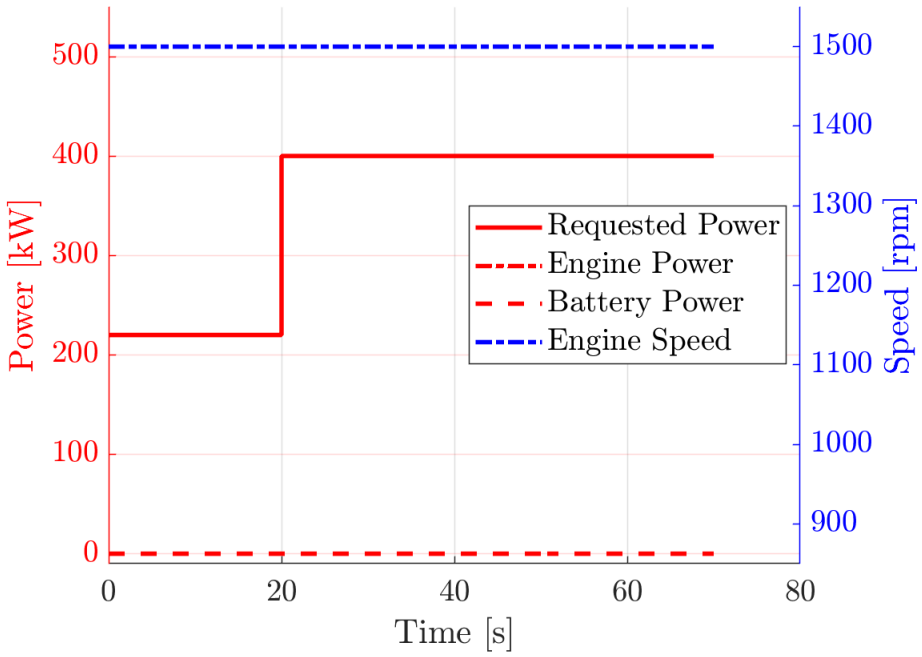
Validation of engine speed

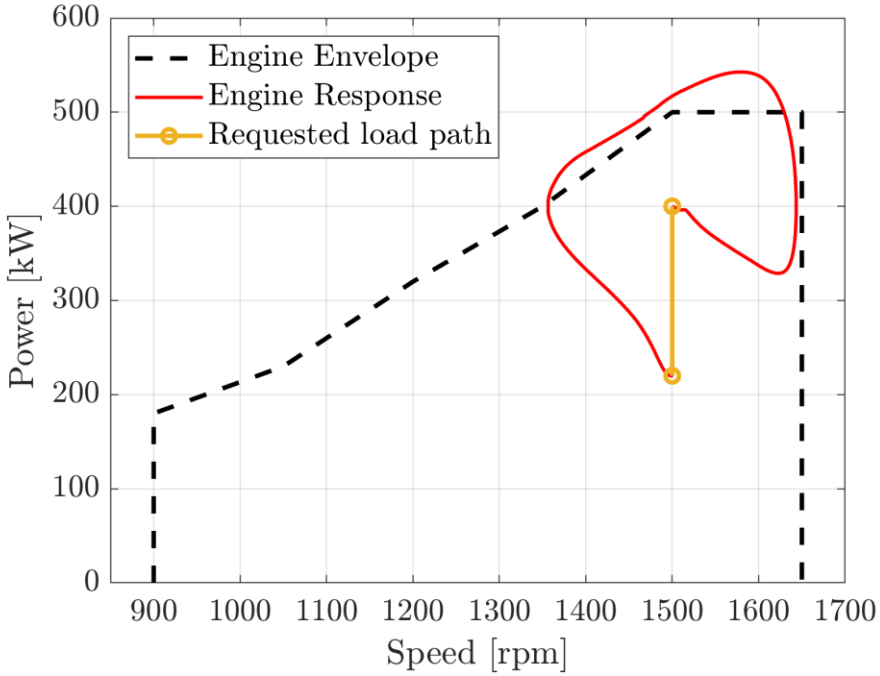
MAPE of 1.89 and PPMCC of 0.86 at dynamic segments



Reference AC Loadstep

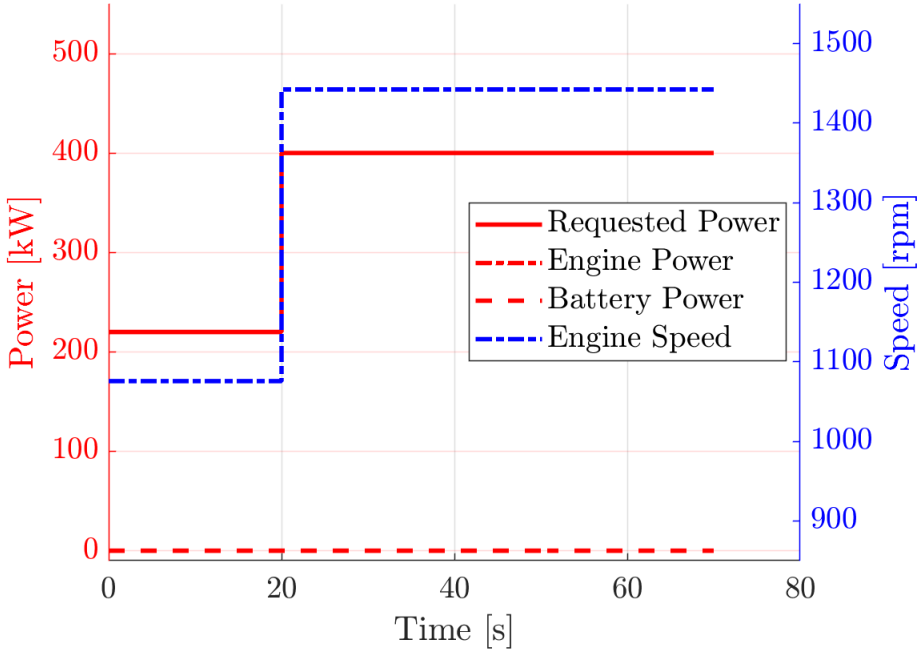
At max speed
Stabilizing time of 21s

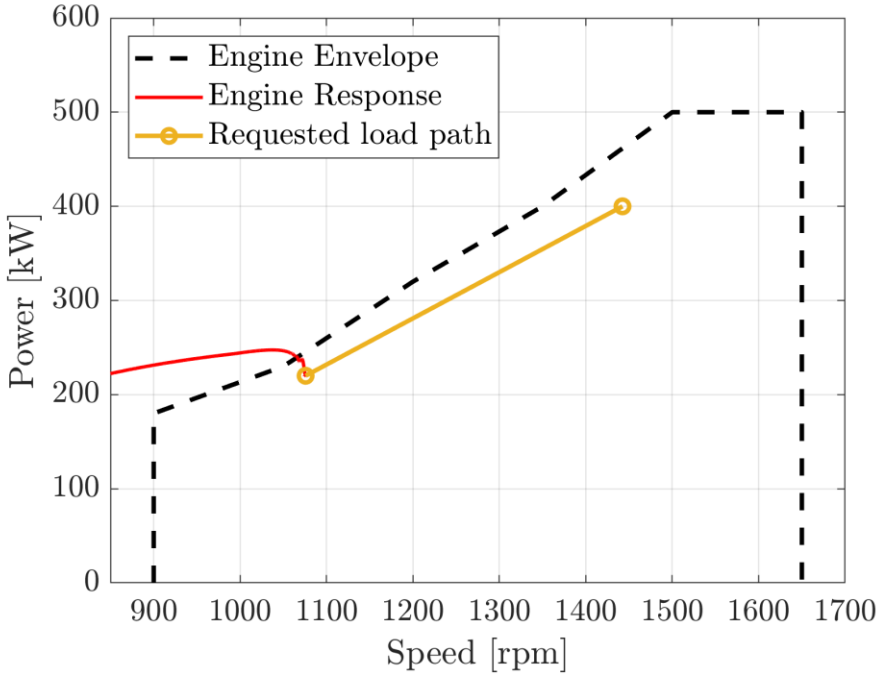




VSG Without ESS

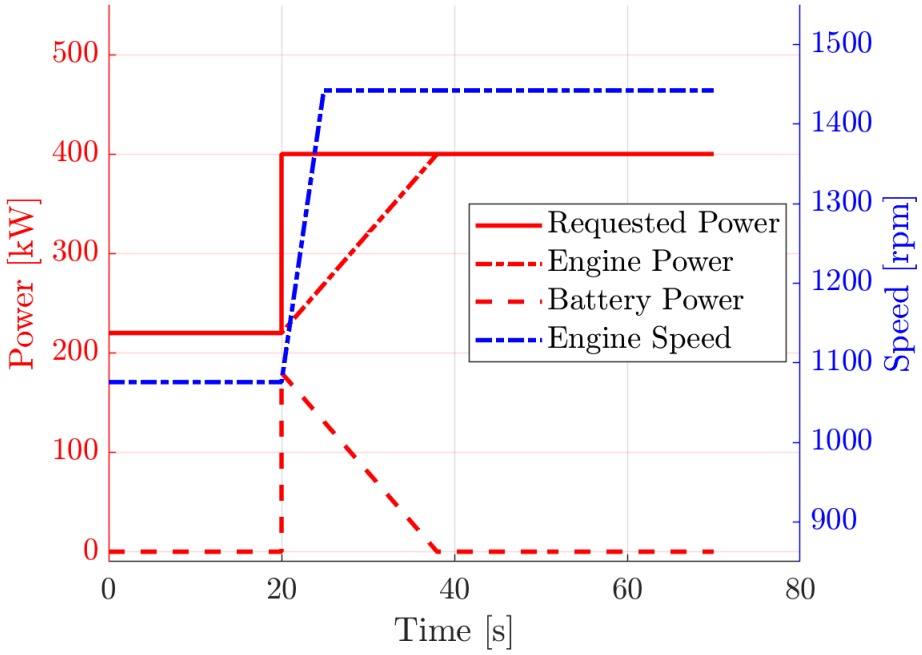
At optimum speed

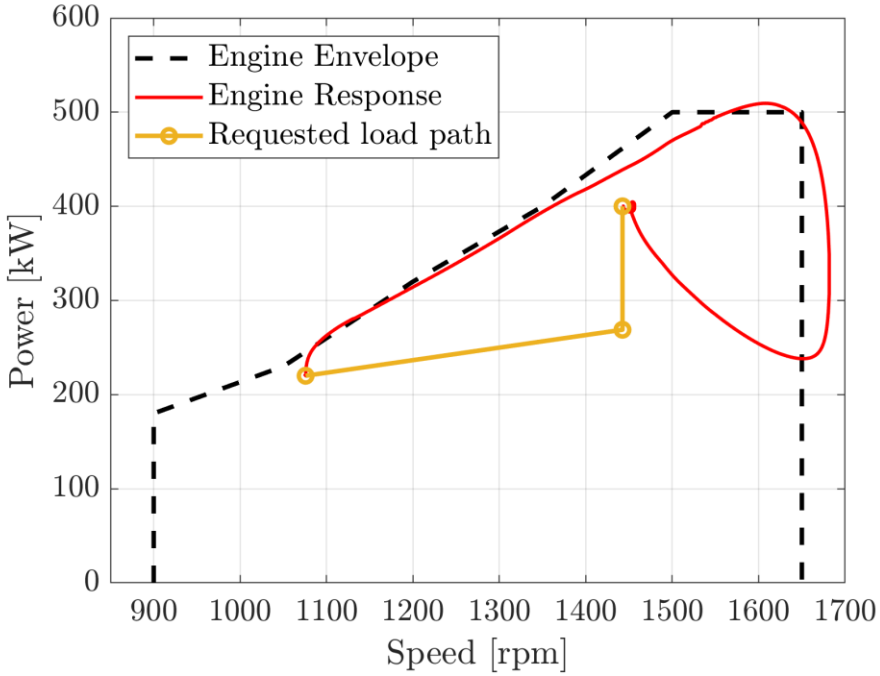




VSG Long Ramp

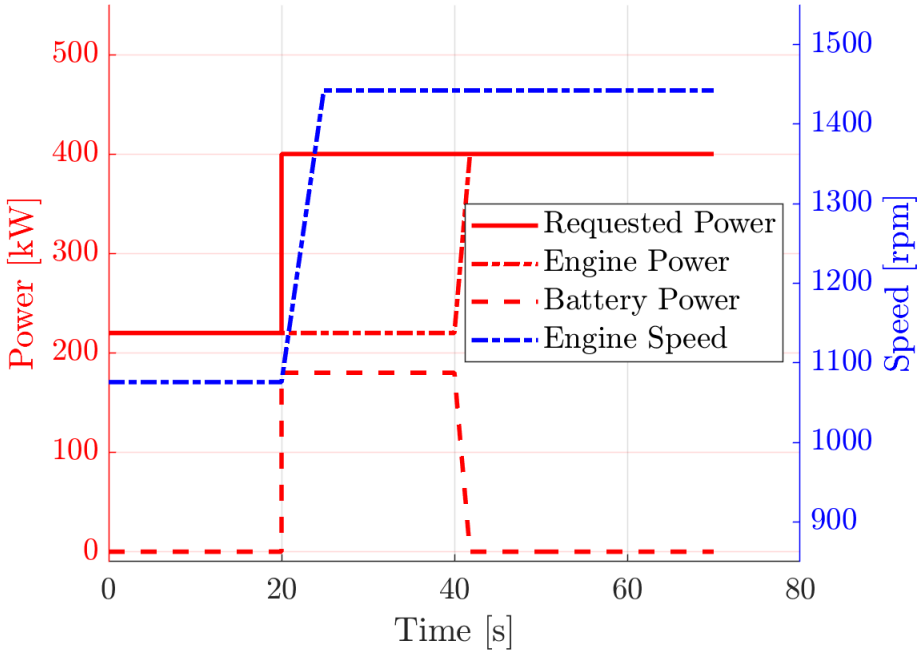
0 s delay, 75 RPM/s and 10 kW/s
Stabilizing time of 25s

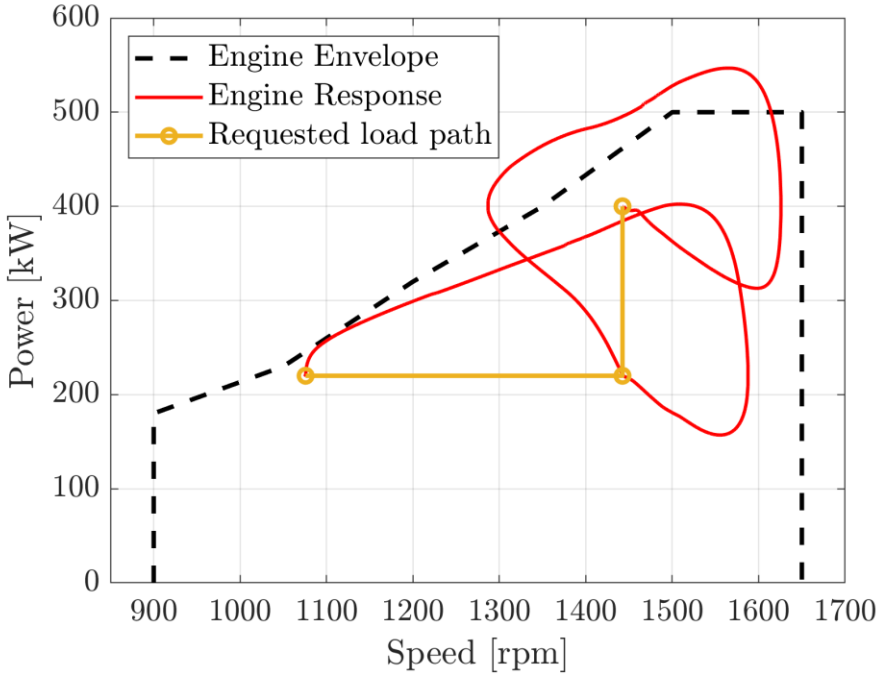




VSG Long Delay

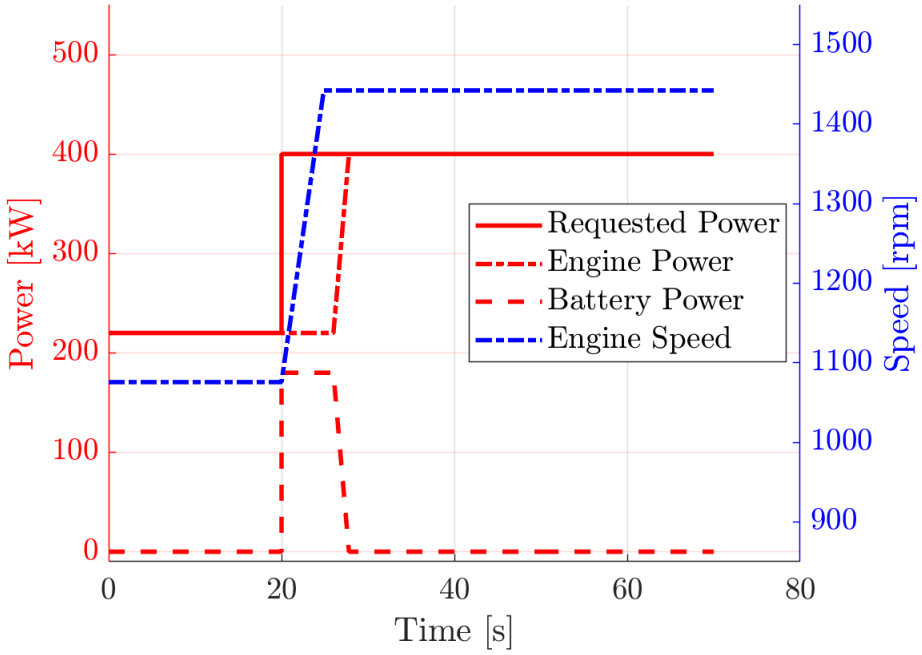
20 s delay, 75 RPM/s and 100 kW/s
Stabilizing time of 43s

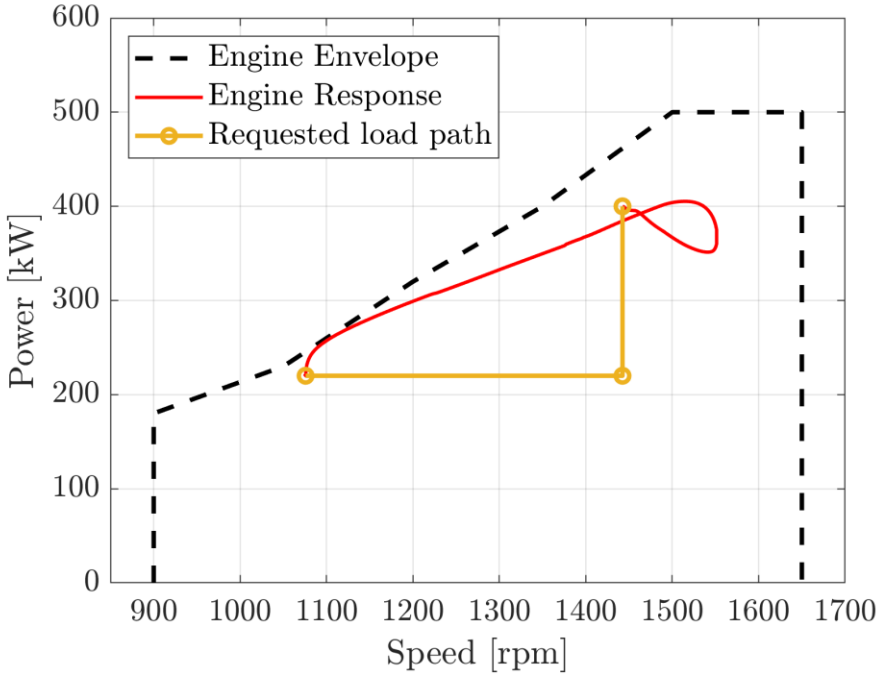




VSG Best Option

6 s delay, 75 RPM/s and 100 kW/s
Stabilizing time of 18s





Conclusions

- Engine dynamics crucial for variable speed control strategy
- Improvement on dynamic behaviour of VSG with ESS
- Better engine response on ramps than steps
- Only shown in limited number of scenarios

Beside:

- Working model with limited calibration data

Recommendations

- Increase speed before load
- Test full operating profile and dynamics in FAT
- More research
  - Diesel
  - More scenarios and generalised control strategy
  - Control stability evaluation

Refrences

[1] https://www.defensie.nl/actueel/nieuws/2023/04/03/nieuwe-anti-submarine-warfare-fregatten-vanaf-2029-in-de-vaart
[2] https://news.usni.org/2021/04/07/navy-installing-more-directed-energy-weapons-on-ddgs-conducting-land-based-laser-testing-this-year
[3] W. Roos, "Performance analysis of variable speed diesel generators in naval hybrid dc power supplyarchitectures," M.S. thesis, TU Delft, 2025
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[5]https://www.reddit.com/r/WarshipPorn/comments/11bsupk/1200x900_regular_reminder_that_the_aircraft/?tl=nl&rdt=33452
[6] https://www.davis-eng.com/docs/NavalIR_SM.pdf
[7] https://www.cartoq.com/what-is-turbo-lag/
[8] J. Vollbrandt, A. Coraddu, R. D. Geertsma, and D. Stapersma, "Predicting dynamic performance with mean value models," Concept of journal paper, 2025.

Thank you for your attention

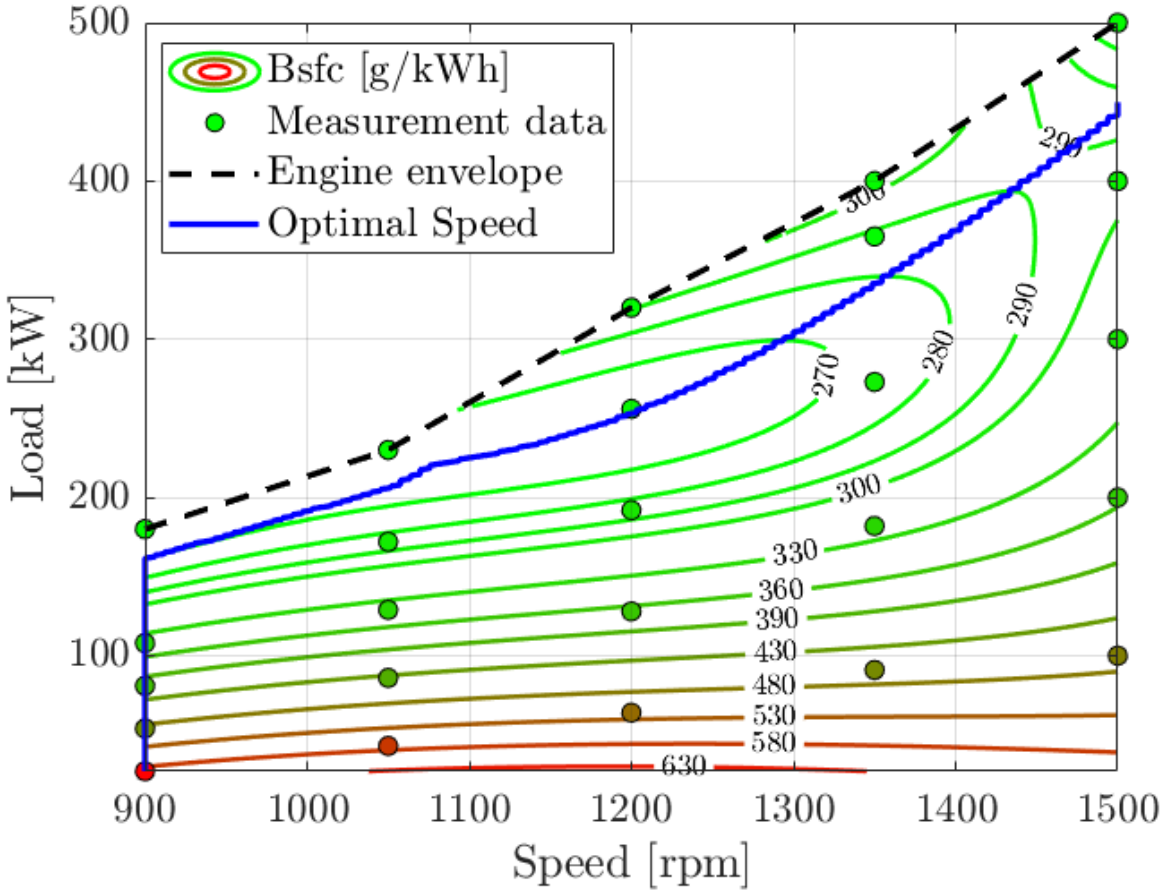
[8]

Fouten bij validatie profiel

Bij 1300 RPM

Variable	MAE	MAPE	PPMCC	MAE_ss	MAPE_ss	PPMCC_ss	MAE_dyn	MAPE_dyn	PPMCC_dyn
P_B [kW]	7.69	3.37	0.97	2.41	1.35	1.00	29.15	11.60	0.84
n_eng [rpm]	5.47	0.42	0.86	0.85	0.07	-0.31	24.26	1.89	0.86
Thr_pos [%]	3.52	7.00	0.95	2.78	5.91	0.98	6.52	11.38	0.95
n_TC [rpm]	1679.46	4.78	0.99	1347.82	4.20	1.00	3035.39	7.19	0.93
p_ac [kPa]	3.63	2.80	0.97	2.87	2.33	1.00	6.73	4.74	0.89
p_ir [kPa]	5.42	4.99	0.98	4.41	4.34	1.00	9.57	7.68	0.92
p_er [kPa]	2.77	2.13	0.98	2.46	1.96	1.00	3.99	2.80	0.94
eta_eng [%]	1.18	3.99	0.92	0.77	2.65	1.00	2.83	9.40	0.51
dm_in [kg/s]	0.04	8.23	0.94	0.03	6.17	1.00	0.08	16.68	0.72
m_f [kg/s]	0.00	3.39	0.98	0.00	2.49	1.00	0.00	7.09	0.92

BSFC plot


Bsfc [g/kWh]
Measurement data
Engine envelope
Optimal Speed
Load [kW]
Speed [rpm]
500
400
300
200
100
900
1000
1100
1200
1300
1400
1500
290
300
270
280
290
300
330
360
390
430
480
530
580
630