

Practical Experiences in Developing and Using a Wind Turbine Model based on IEC 61400-27-1



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Expert User of DIGSILENT PowerFactory for Power Systems Studies



1. Introduction

2. IEC standard 61400-27-1

3. Additional features and modifying of IEC model

- 3.1 Emulated Inertia
- 3.2 Delta Control

4. Simulation results

5. Conclusion

1. INTRODUCTION



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1. INTRODUCTION

- Wind turbine models were developed for MIGRATE project (Massive Integration of Power Electronic Devices)¹
 - Dynamic simulations of large grids with high share of power electronics
- Dynamic RMS models of type 3 (DFIG) and type 4 (fully rated converter) wind turbines needed
- Requirement: models based on IEC standard 61400-27-1
- Standard lacks certain important features e.g. Emulated Inertia, Delta Control, ...
 - IEC models had to be modified and extended
- Models were developed with DlgSILENT PowerFactory

¹ For more information see: <https://www.h2020-migrate.eu/>

2. IEC STANDARD 61400-27-1



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2. IEC STANDARD 61400-27-1

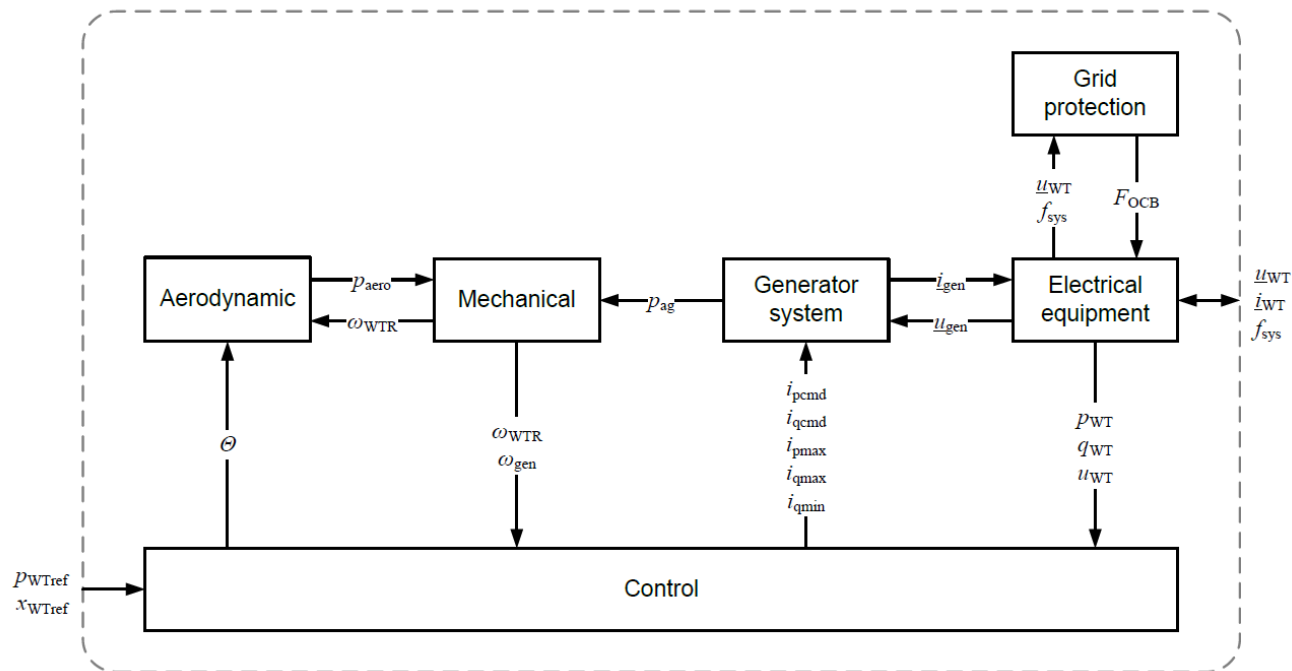
- Published in 2015
- **PURPOSE**
introduction of generic wind turbine models which can be used in stability studies and dynamic simulations
- **ADVANTAGE**
less need for manufacturer models with high level of detail and large amount of input data
- By changing parameters every type of wind turbine can be modeled



2. IEC STANDARD 61400-27-1

Modular structure of type 3 (DFIG) IEC model

- Used for type 3 and 4 in this project
- Type 4 IEC model was not suited for modifying and expansion



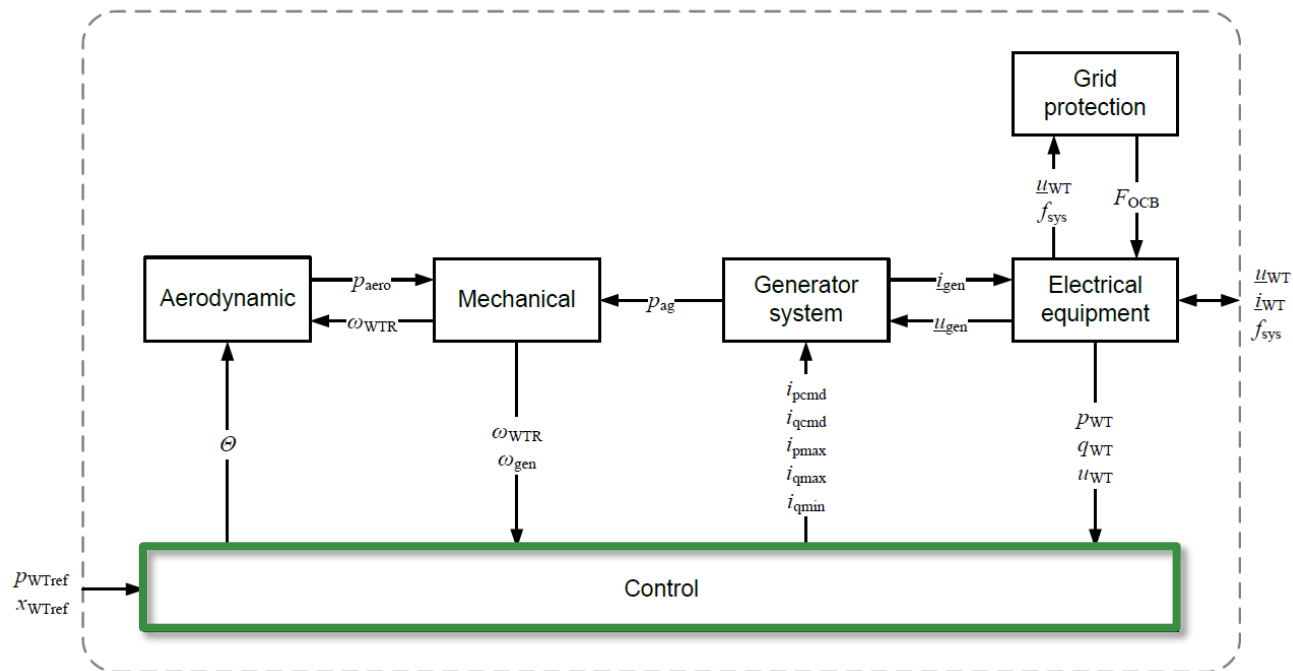
Source: IEC standard 61400-27-1



2. IEC STANDARD 61400-27-1

Control

- Main part of the model including:
- P Control, Q Control, Pitch Angle Control, Limits



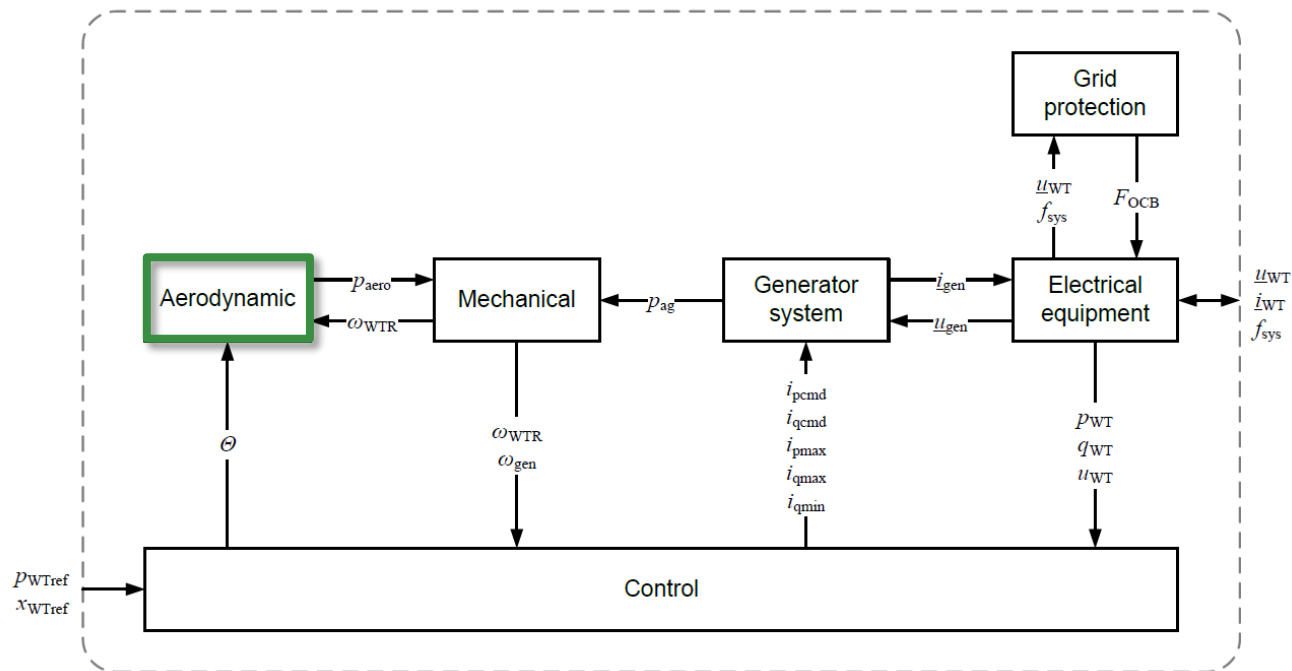
Source: IEC standard 61400-27-1



2. IEC STANDARD 61400-27-1

Aerodynamic model

- Simplified calculation of available power depending on pitch angle and rotor speed
- Linearized calculation assuming constant wind speed



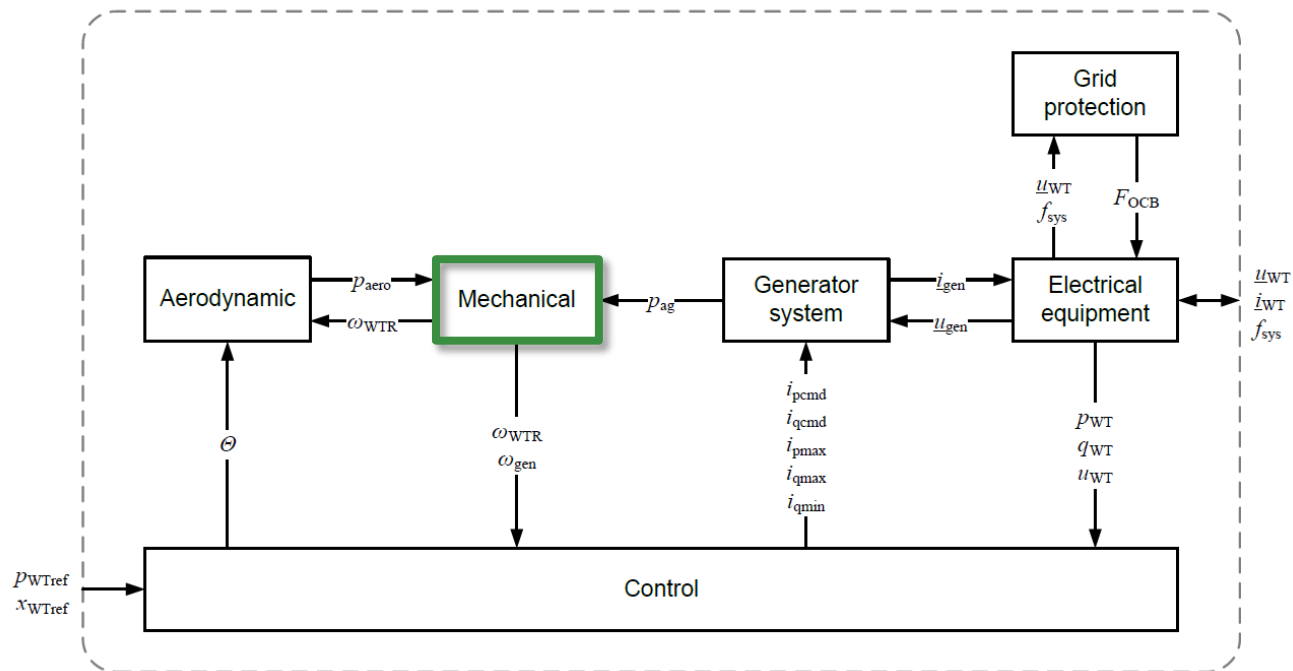
Source: IEC standard 61400-27-1



2. IEC STANDARD 61400-27-1

Mechanical Model

- Two mass oscillator consisting of generator and turbine



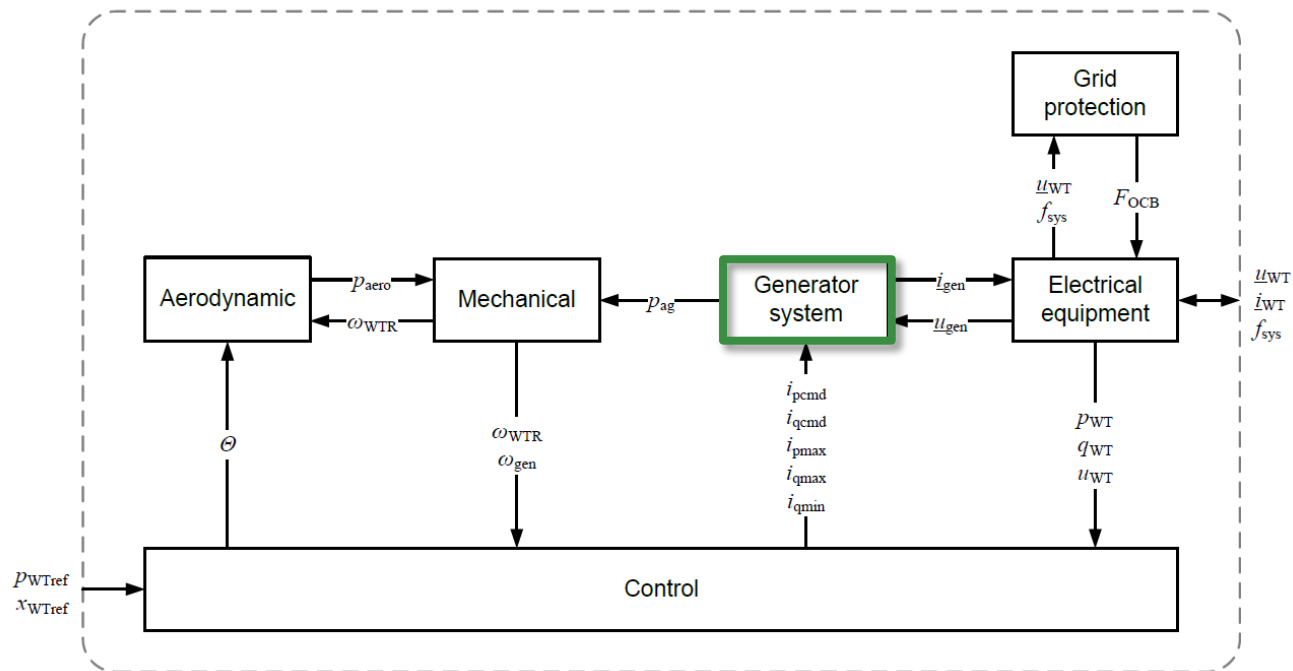
Source: IEC standard 61400-27-1



2. IEC STANDARD 61400-27-1

Generator System

- Simplified representation of the electrical part of generator and converter



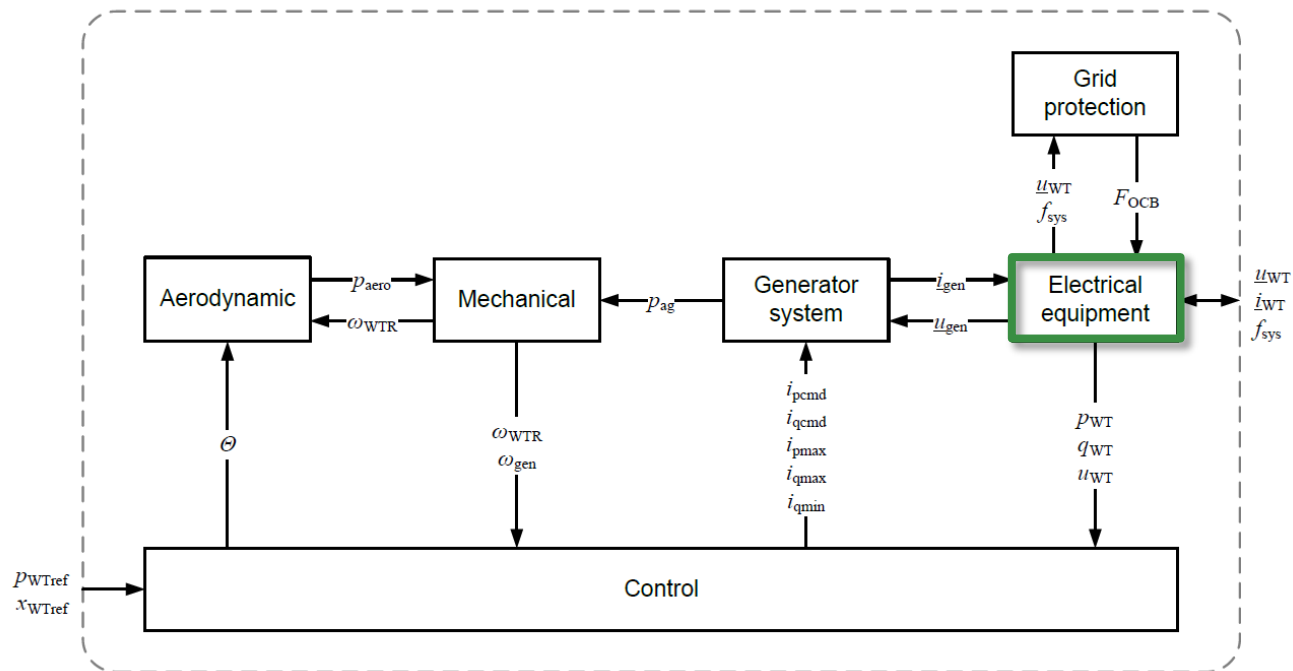
Source: IEC standard 61400-27-1



2. IEC STANDARD 61400-27-1

Electrical equipment

- Transformer
- Breakers



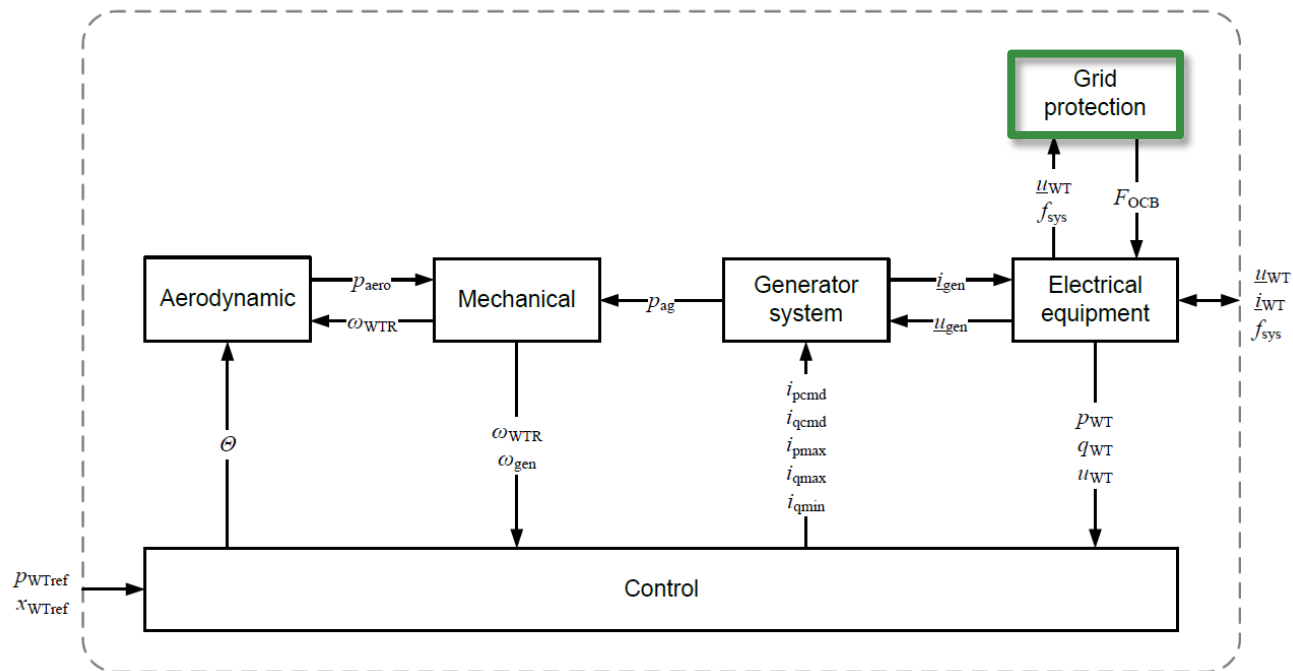
Source: IEC standard 61400-27-1



2. IEC STANDARD 61400-27-1

Grid protection

- Triggers protection depending on frequency and voltage



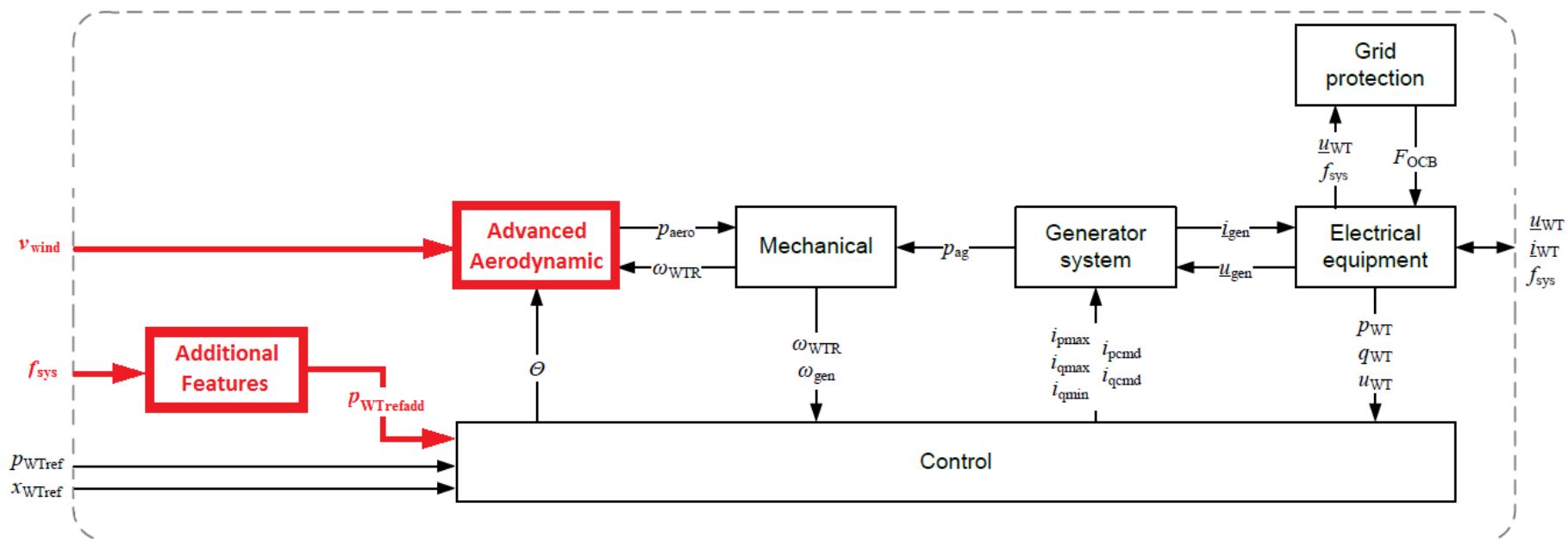
Source: IEC standard 61400-27-1



2. IEC STANDARD 61400-27-1

Modular structure of expanded model

- More detailed aerodynamic model with wind speed as input and Cp-curves
- Additional features (Emulated Inertia, Delta Control, Active Power Reduction with Overfrequency, ...) adapting the active power depending on the frequency
- Implemented based on publicly available literature



3. ADDITIONAL FEATURES AND MODIFYING OF IEC MODEL



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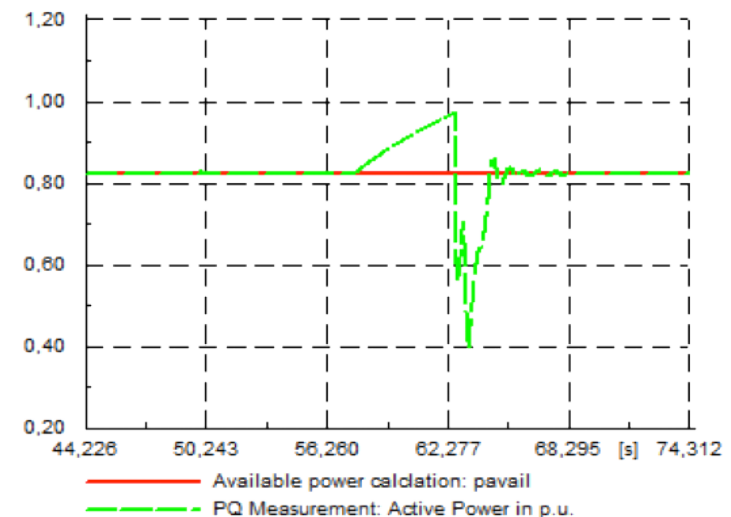
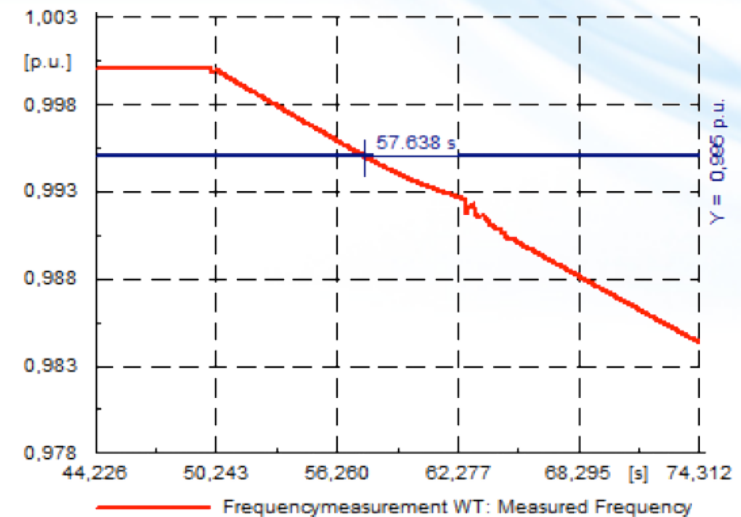
3. ADDITIONAL FEATURES AND MODIFYING OF IEC MODEL



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Emulated Inertia

- Additional power gets released, when frequency falls below a certain threshold
- Even when there is no more power available
- In this case power gets drawn from rotating mass of the rotor
- Speed decreases, suboptimal operating point
- After maximal allowed time Emulated Inertia stops
- WT returns to optimal operation point

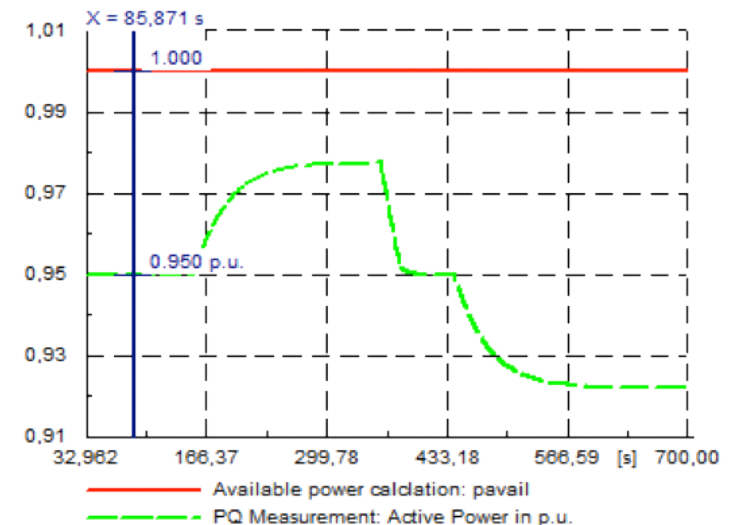
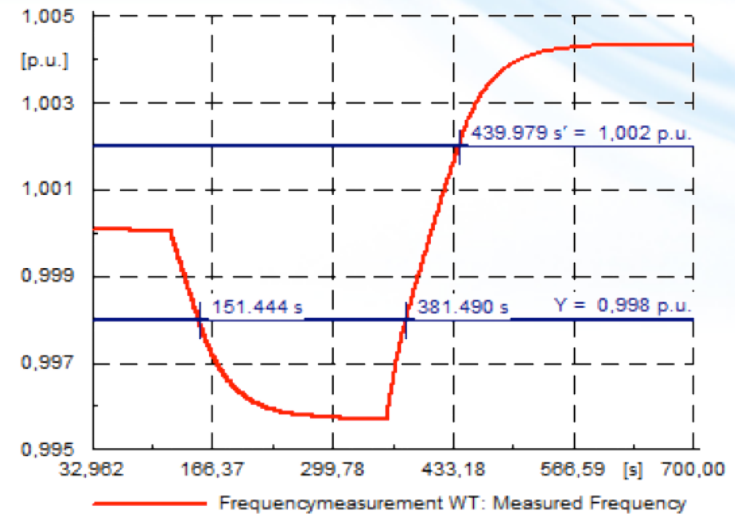


3. ADDITIONAL FEATURES AND MODIFYING OF IEC MODEL



Delta Control

- WT runs constantly below maximal available power, e.g. 5%
 - Can react to frequency deviations in both directions
- Available power gets calculated by measuring the wind speed
- If frequency exceeds a certain deadband, output power gets increased or decreased respectively
- Drawback: energy gets lost in steady state operation



4. SIMULATION RESULTS



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4. SIMULATION RESULTS

- Models were compared to manufacturer models by applying reference value steps and symmetrical short circuits according to IEC standard 61400-21
- Generic models were parametrized with IEC parameters delivered by manufacturers
- Additional features were deactivated
 - Type 3 model was equivalent to type 3 IEC model
 - Type 4 model was equivalent to type 3 IEC model with type 4 generator system

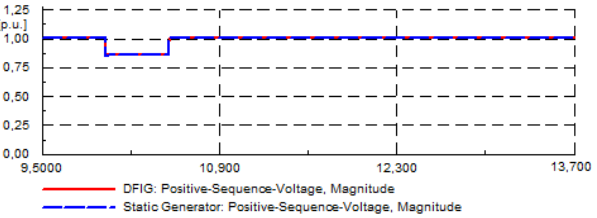
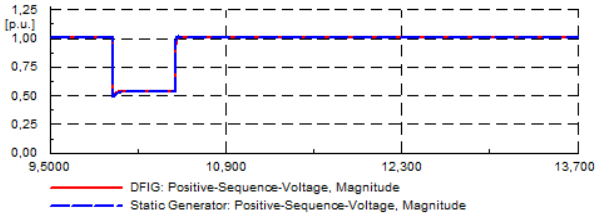
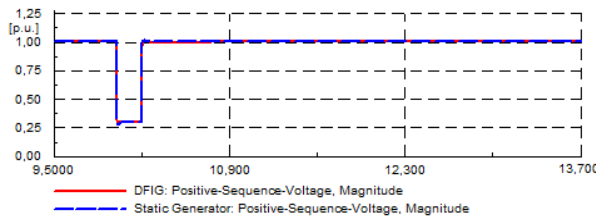
4. SIMULATION RESULTS



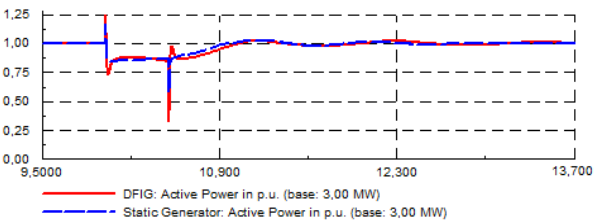
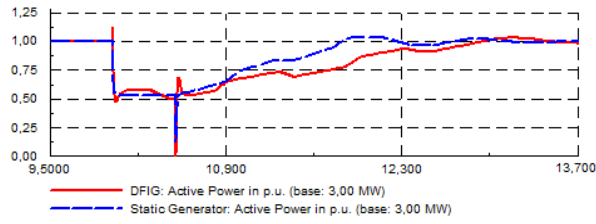
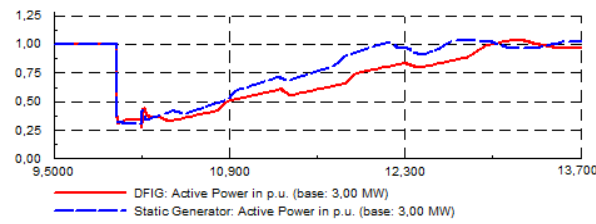
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Type 3, FRT simulations

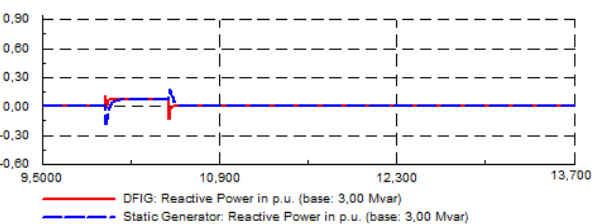
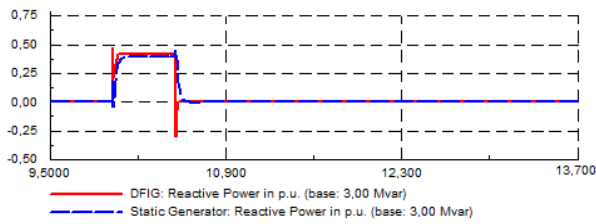
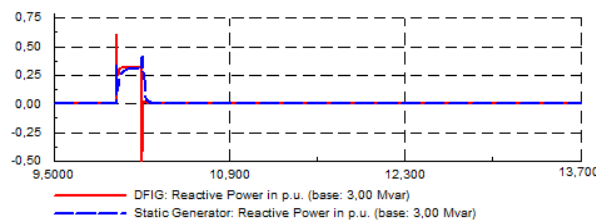
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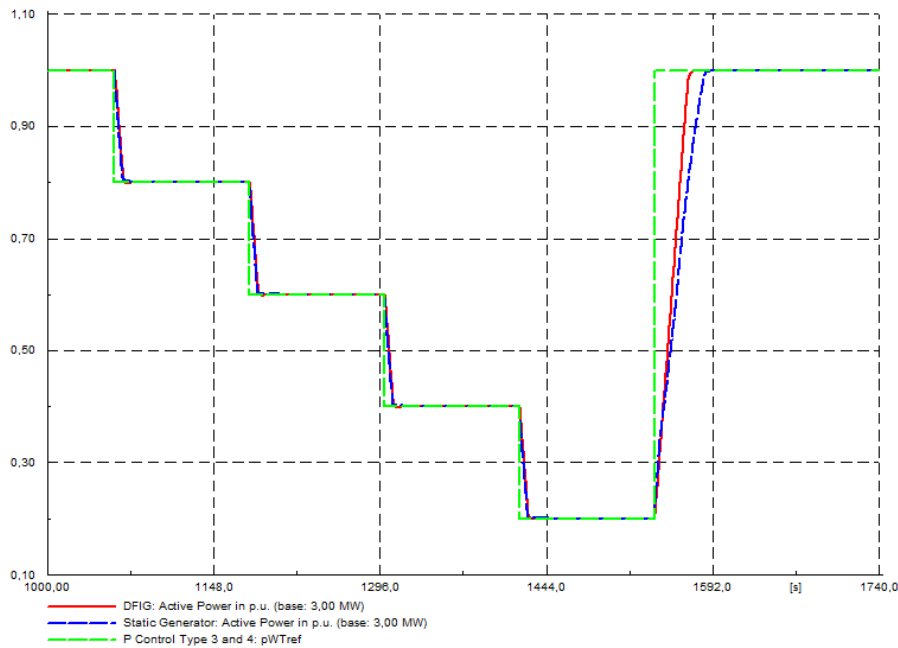
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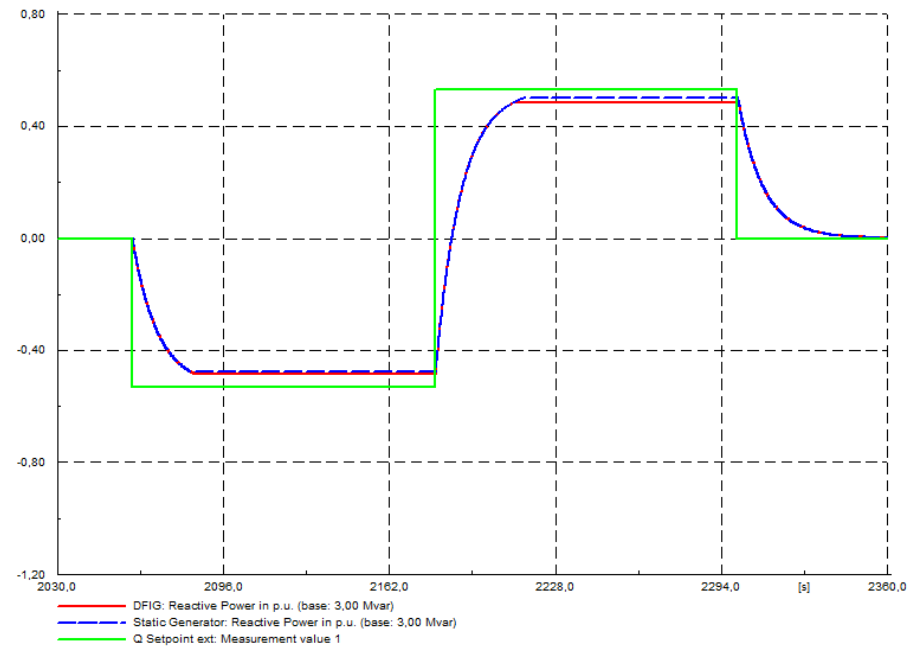
— Manufacturer model
- - - Generic model

4. SIMULATION RESULTS

Type 3, reference value steps



Active Power



Reactive Power

- Manufacturer model
- - - Generic model
- Reference value

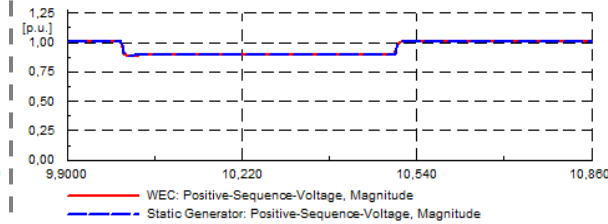
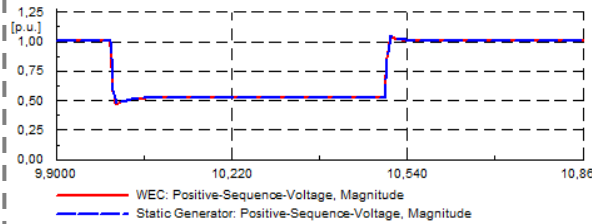
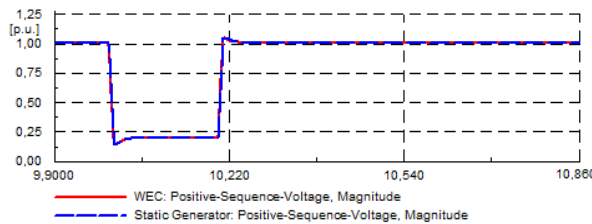
4. SIMULATION RESULTS



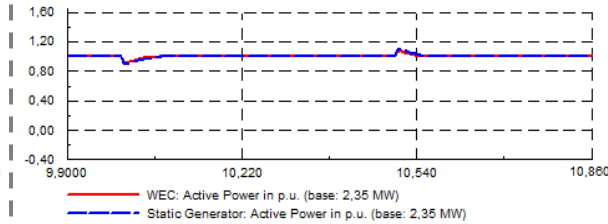
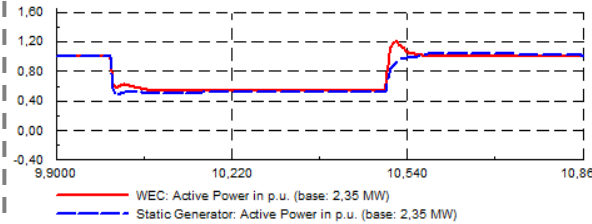
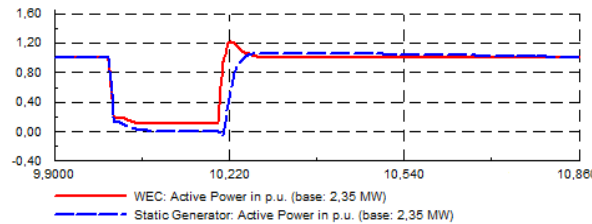
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Type 4, FRT simulations

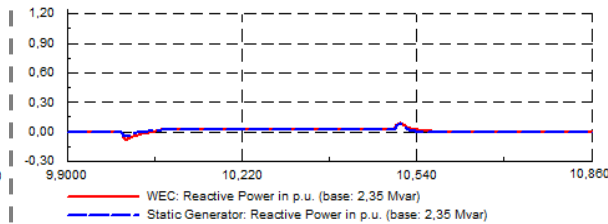
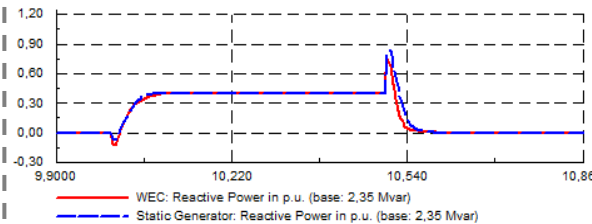
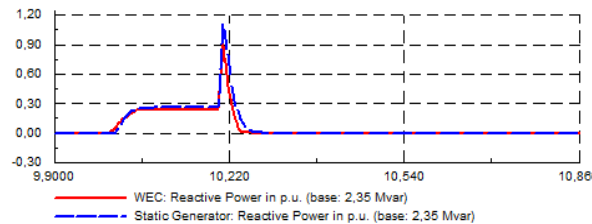
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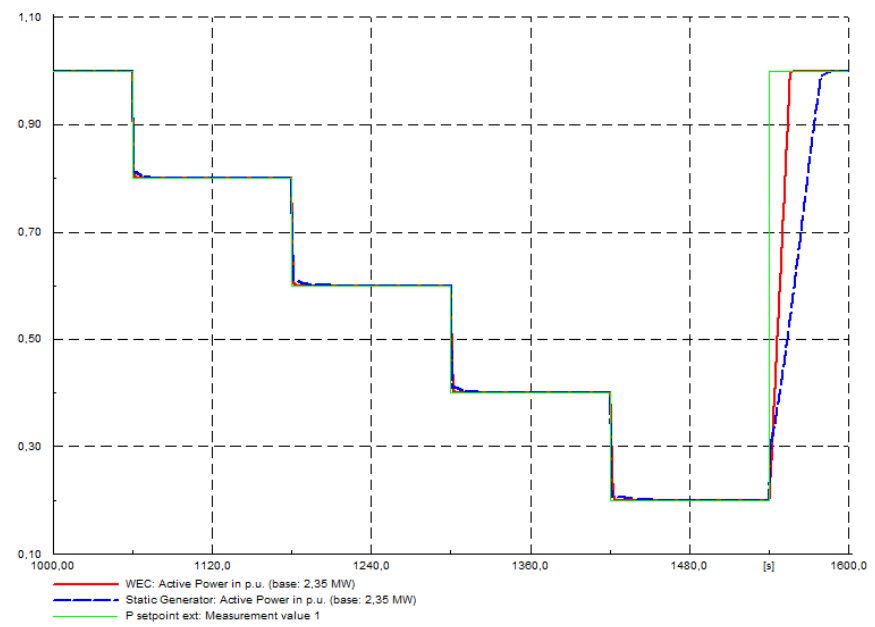


— Manufacturer model
- - - Generic model

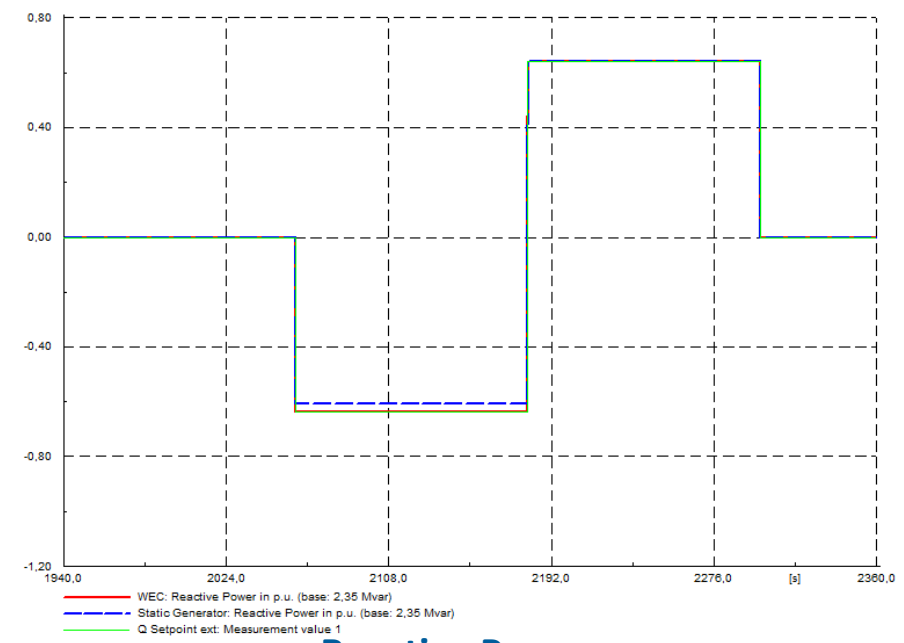


4. SIMULATION RESULTS

Type 4, reference value steps



Active Power



Reactive Power

- Manufacturer model
- - - Generic model
- Reference value

5. CONCLUSION



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5. CONCLUSION

- It has been shown, that IEC models can be modified or expanded
- The functionality of the additional features was shown
- When parametrized correctly, the generic models show similar behavior to manufacturer models

THANK YOU FOR YOUR ATTENTION!



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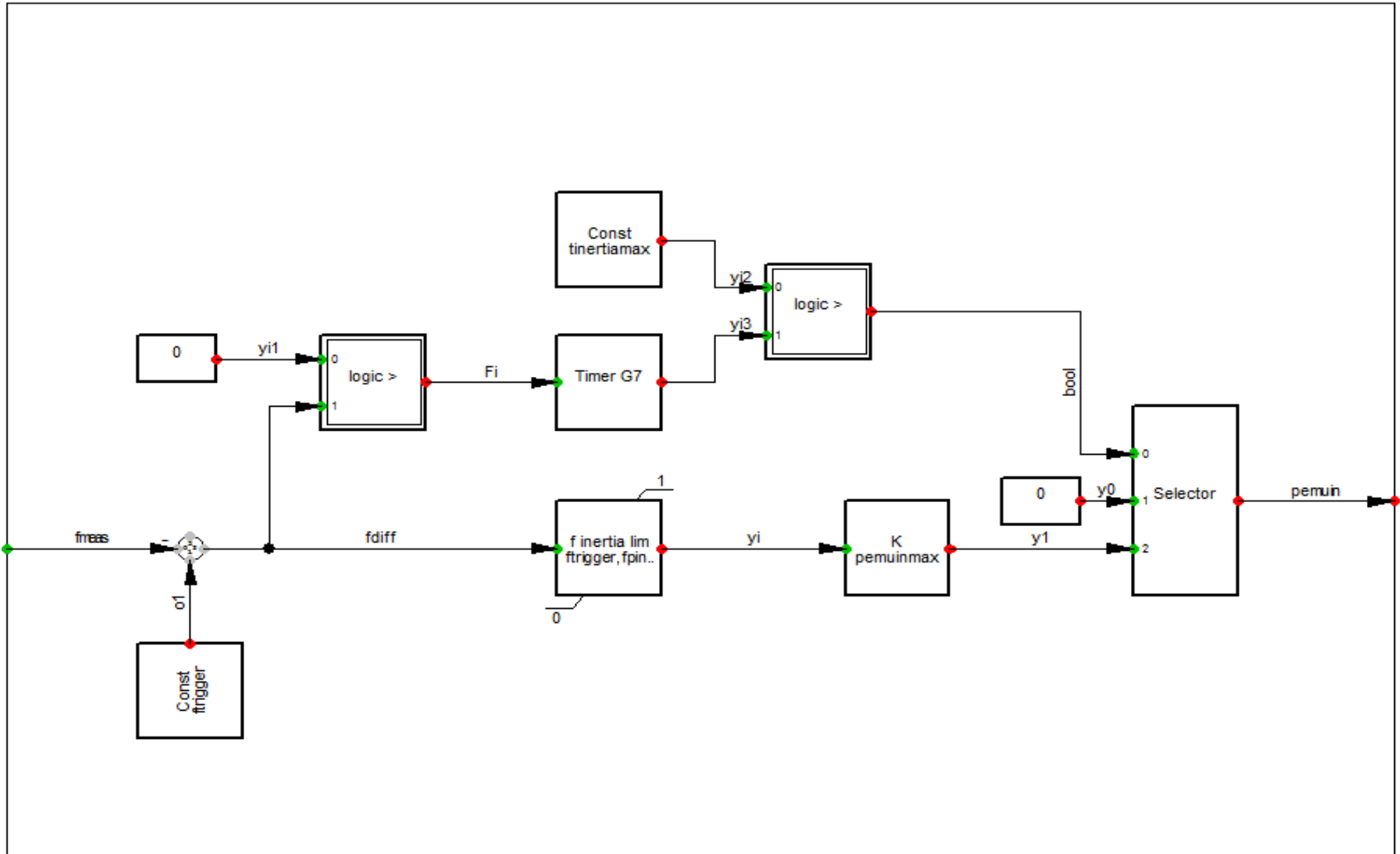
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EMULATED INERTIA



DELTA CONTROL



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