



Electro-Mechanical Differential System

„DS_{gen-set}“

The step into the future of advanced energy technologies!

POWER
FOR ENERGY

Agenda

SET Background

SET Capabilities

DS_{gen-set}

Prototype 3 MW

Measurements and Simulations

System performance relative to state-of-the-art concepts

Outlook 7 MW

Summary

SET Background

- 1986** ⇒ **Start Development of 600 kW WECs**
with variable speed & pitch control
- 1995** ⇒ **Foundation of WINDTEC**
Start development of 600 kW and 1.5 MW WECs
with double-fed induction generator and electrical
pitch-control system
- 2001** ⇒ **Start co-development Offshore, 5 MW, hybrid-type WEC**
with PMG-FSC technology
- 2003** ⇒ **Start technology-transfer to ASIA**
- 2005** ⇒ **Start engineering and field service activities in China**



**Commissioning of Floda
600 kW, Israel 1992**



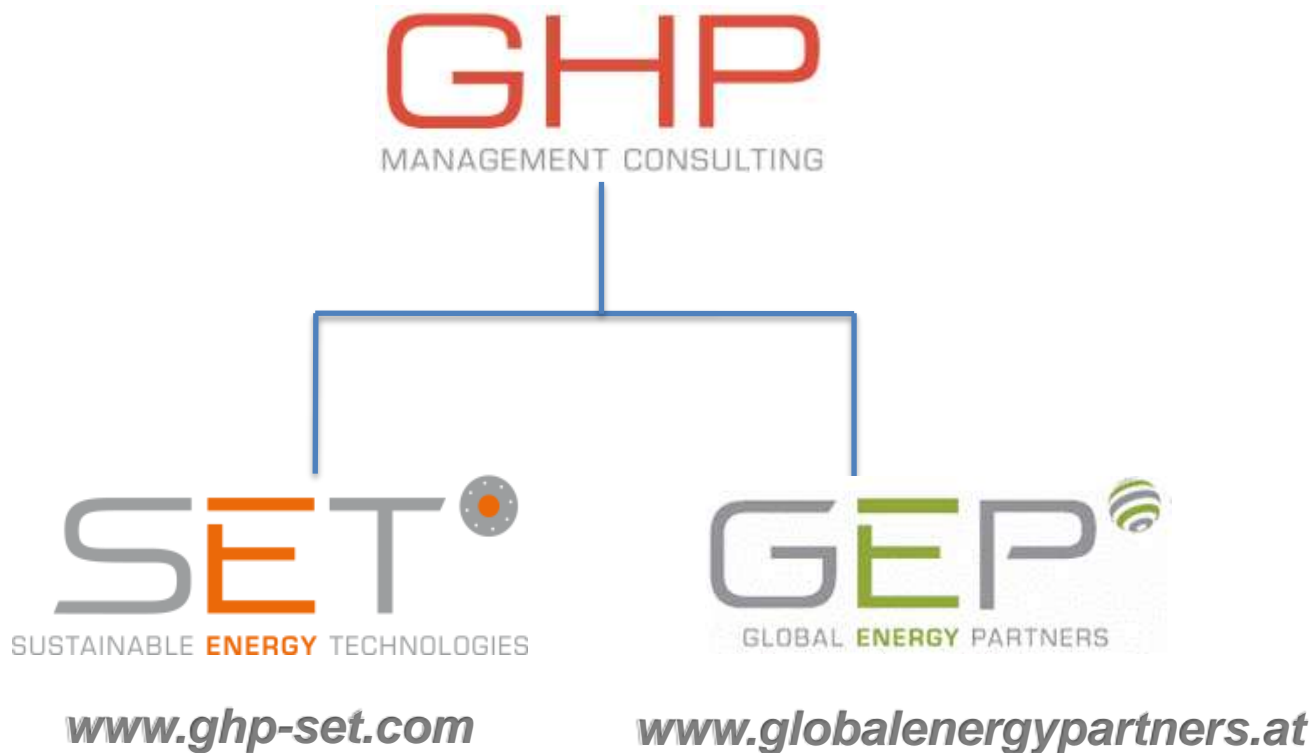
**Commissioning of
Multibrid 5 MW,
Germany 2004**

SET Background

- 2008 ⇒ Foundation of “SET Sustainable Energy Technologies GmbH”
- 2009 ⇒ Start development of advanced drive-train concepts
Differential Systems ($DS_{\text{gen-set}}$)
- 2011 ⇒ Successful test and qualification of a 3 MW **Differential System** ($DS_{\text{gen-set}}$)



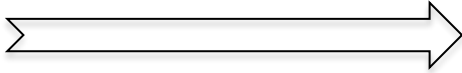
GHP Group Members - Renewable Energy

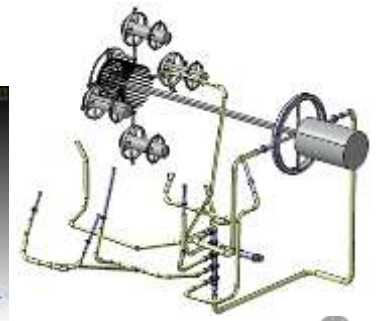
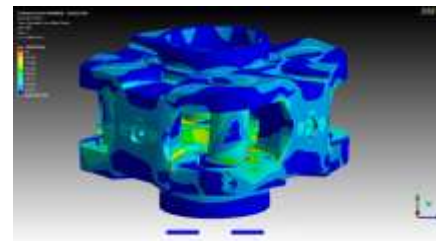
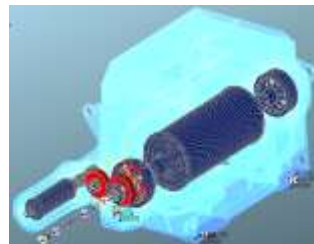


SET Capabilities

25 years of expert knowledge and comprehensive engineering capabilities enable us to provide a wide range of services:

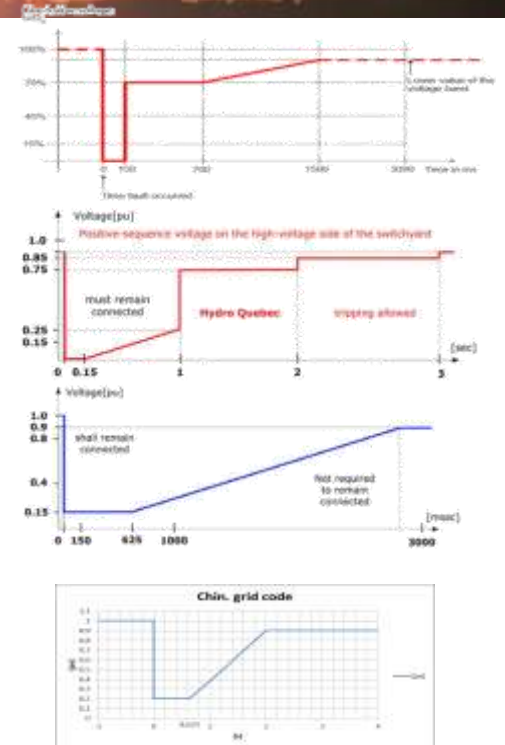
One stop shop: “from development through system integration”

- ❖ Concept analysis incl. grid integration
 - ❖ Product development 
 - ❖ Manufacturing
 - ❖ Assembly and commissioning
 - ❖ Full-scale tests before integration into the WEC
 - ❖ Service and training
- ✓ Gear & servo-drive development
 - ✓ FEM calculation
 - ✓ 3D Multi-Body-Simulation
 - ✓ Simulation of lubrication circuit
 - ✓ Generator interface development
 - ✓ Controller and software development

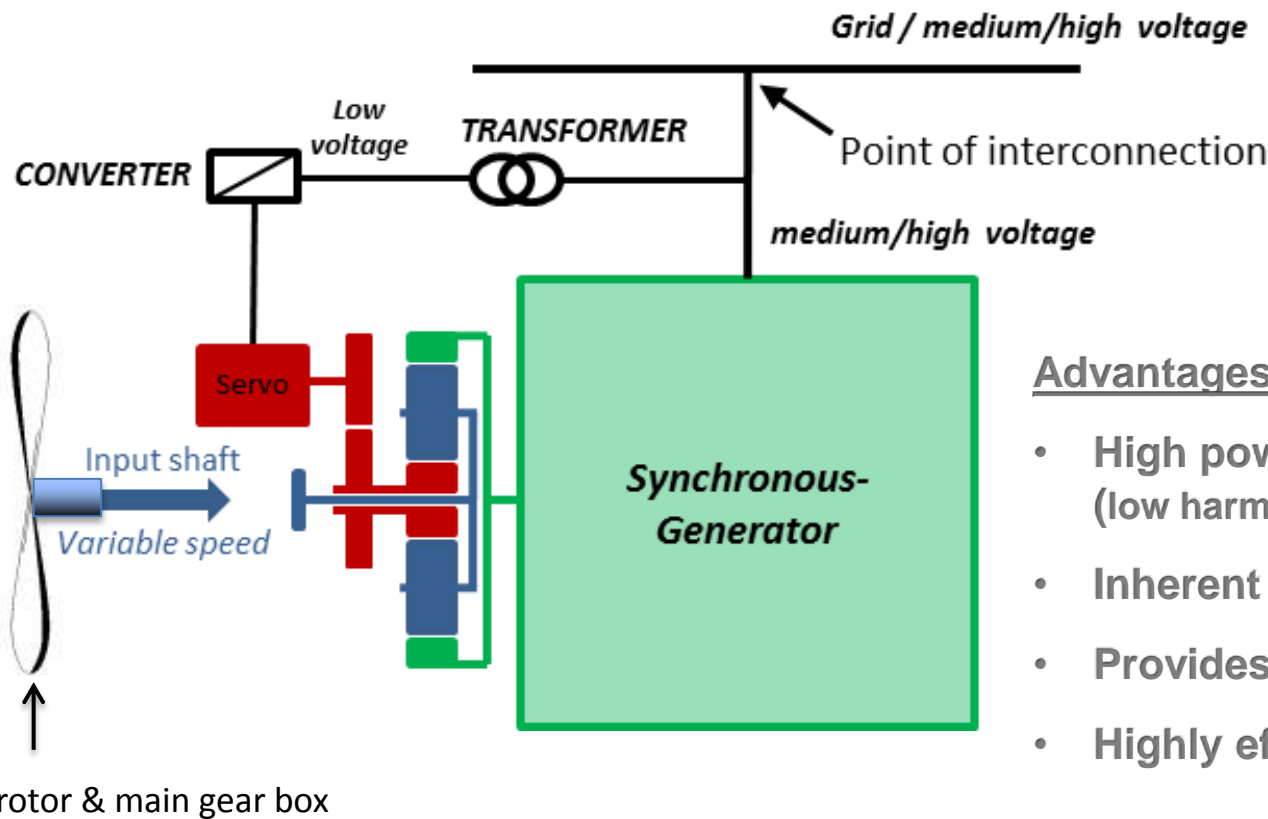


Challenges for an advanced WEC

- **Compatibility with all grid codes, e.g.**
 - Transmission code 2007 (Germany)
 - Hydro Quebec Grid-Code (Canada)
 - US-FERC Grid Code (USA)
 - China Grid Code (2011)
- LVRT capability during grid failures & generation of reactive current
- Ability of working under extreme climate conditions
- Reduction of weight and space (nacelle)
- Reduction of system costs
- Reduction of service and maintenance costs
- Increase of wind energy converter's annual energy yield -> better NPV



SET DS_{gen-set} Principle

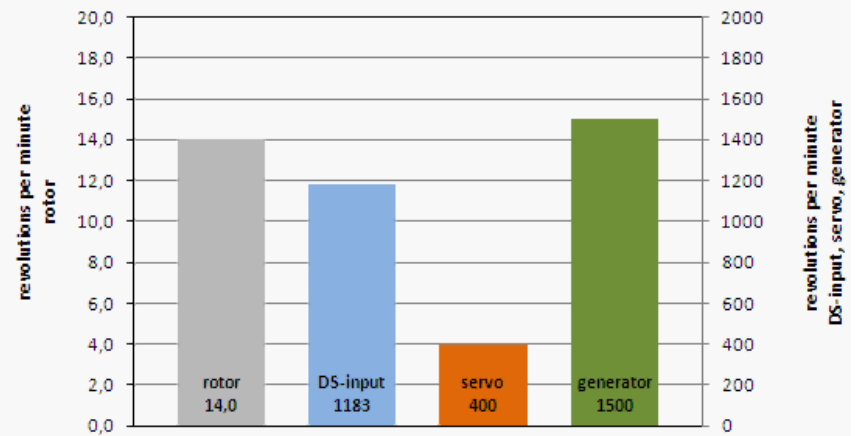
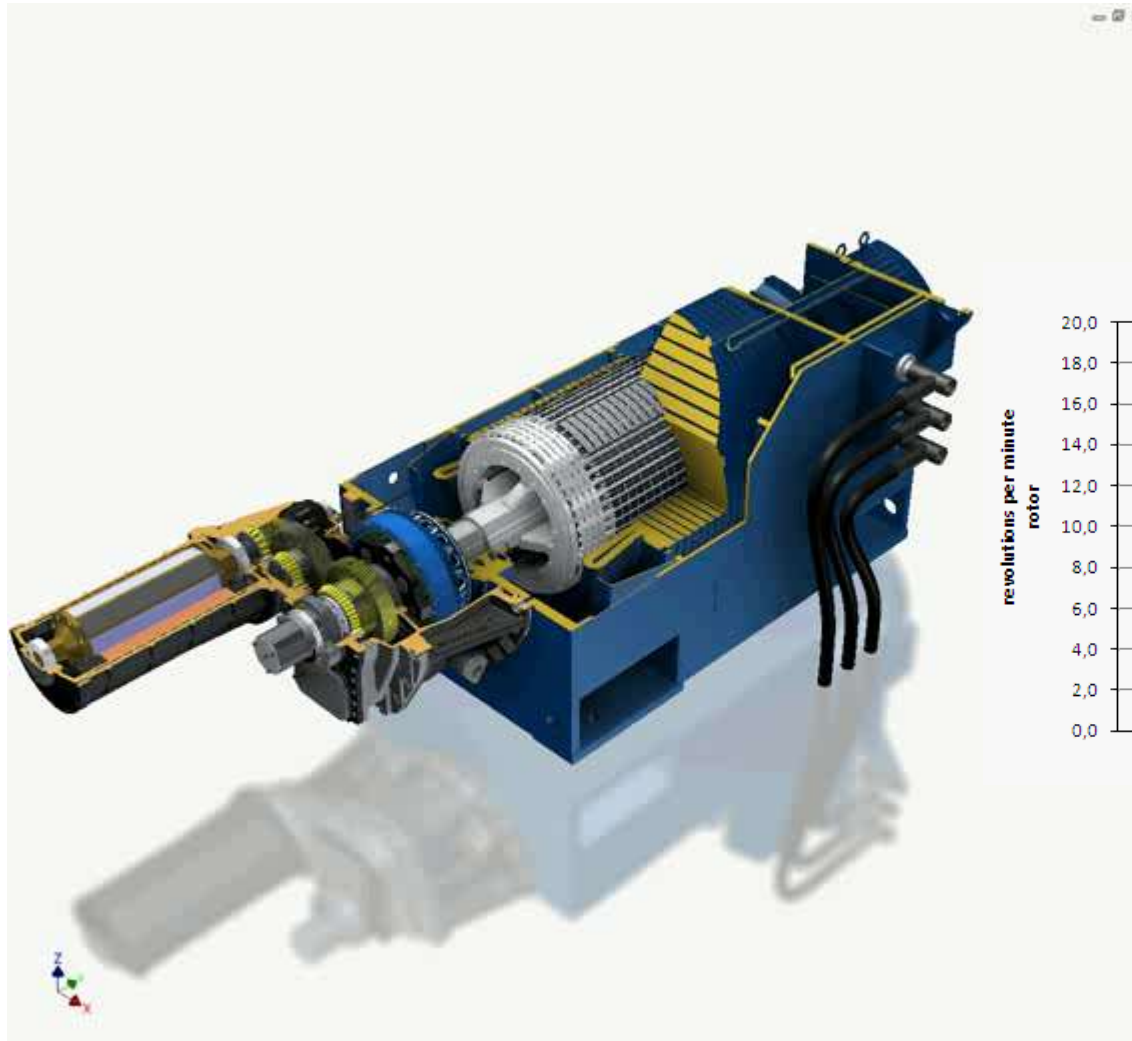


Advantages of Synchronous Generators:

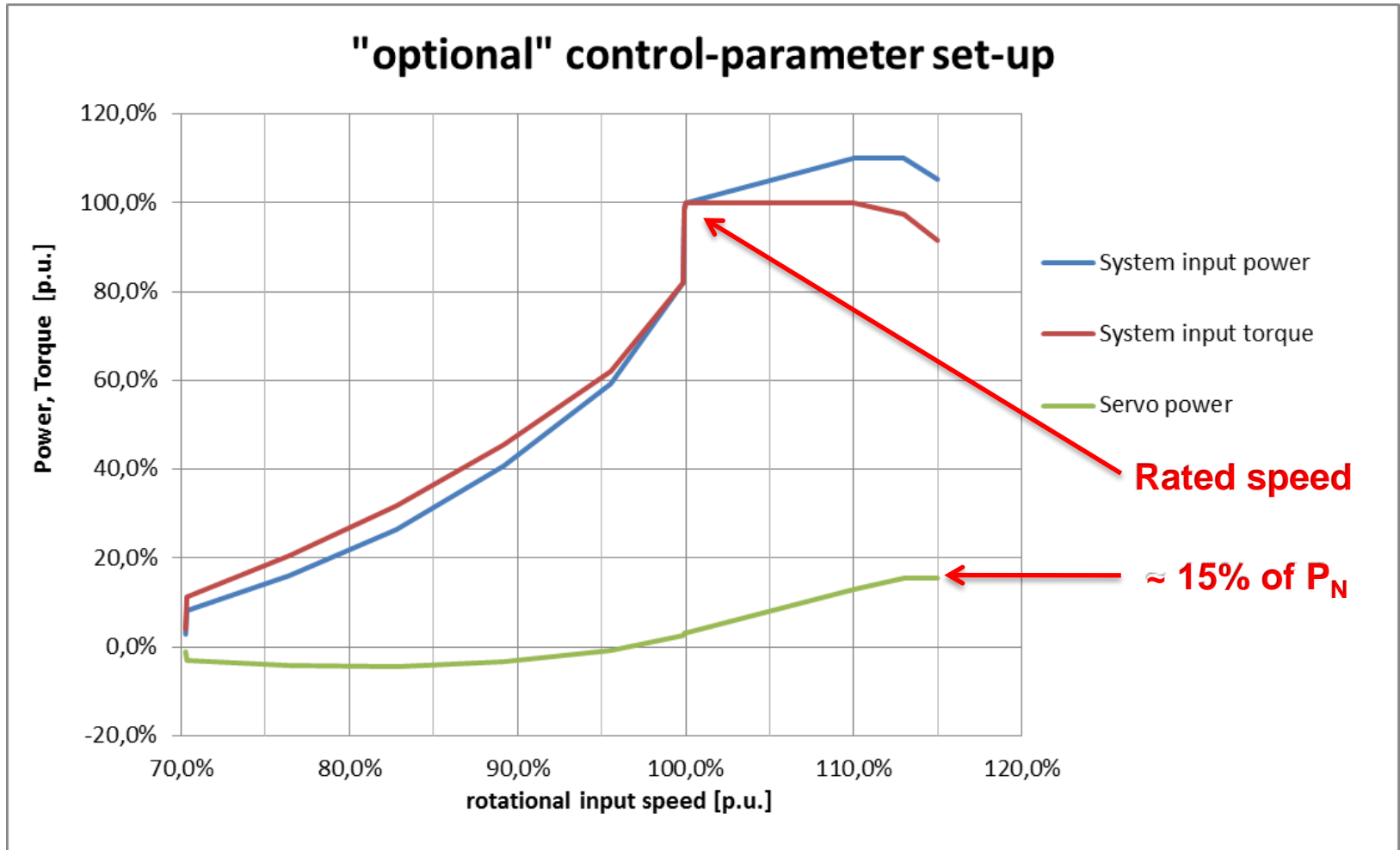
- High power quality (low harmonics & low flicker)
- Inherent LVRT characteristics
- Provides inertia to the grid
- Highly efficient / high-voltage grid connection

The better way of generating electricity!

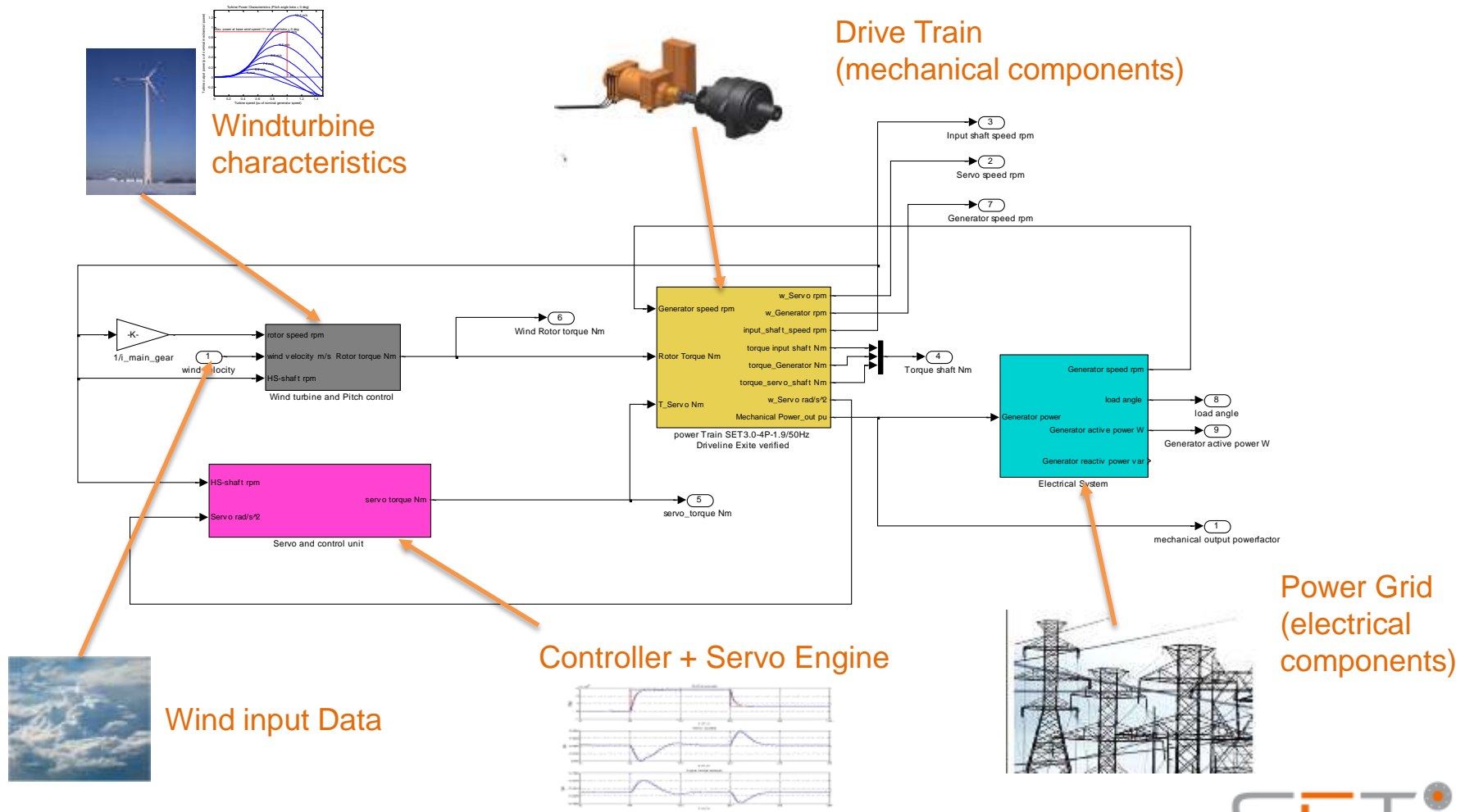
SET DS_{gen-set} / Principle



Optimal Speed Range and Power/Torque Characteristics



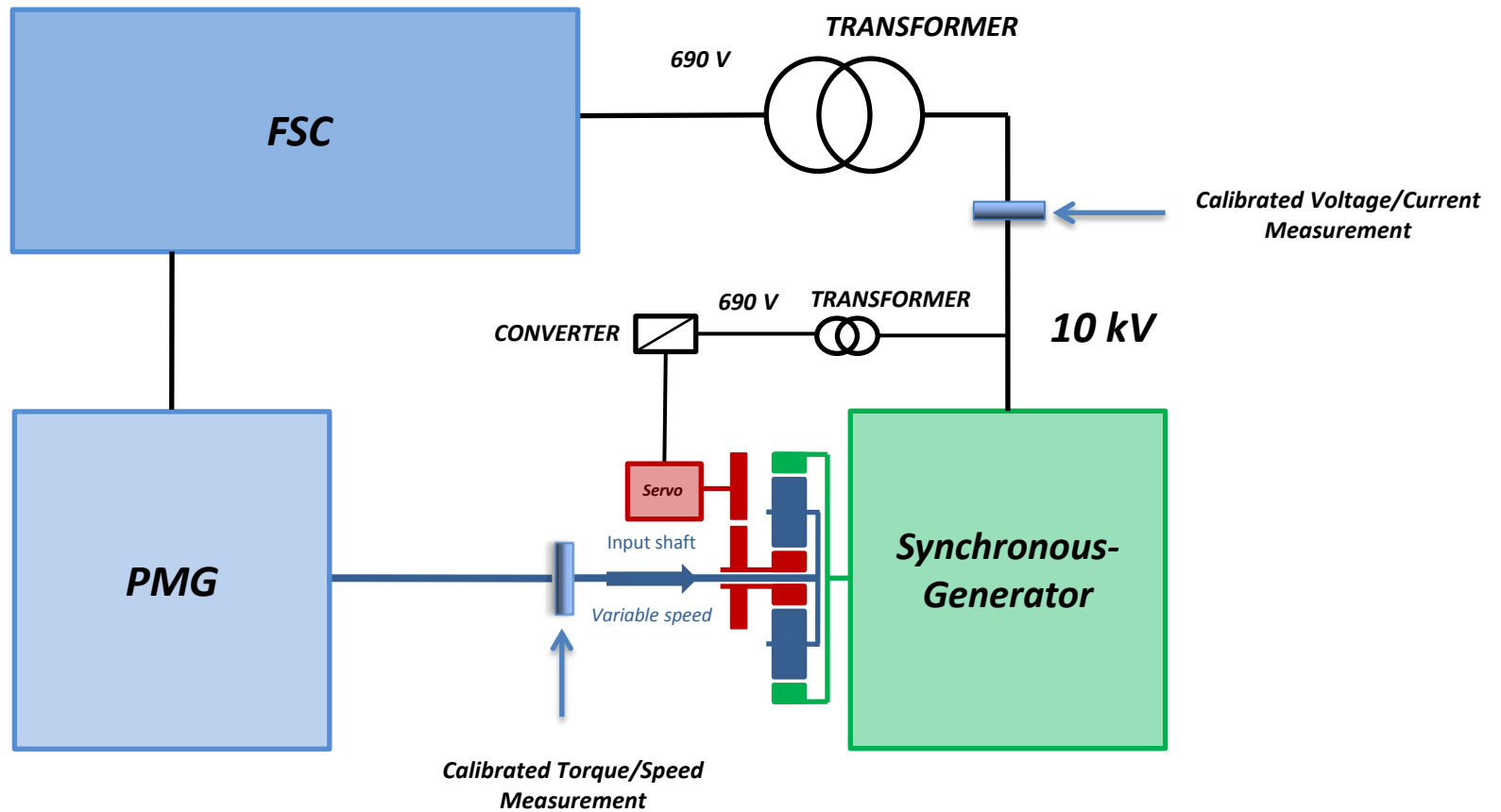
SET DS_{gen-set} / Simulation Model Topview



SET 3MW Prototyp at Test Bench

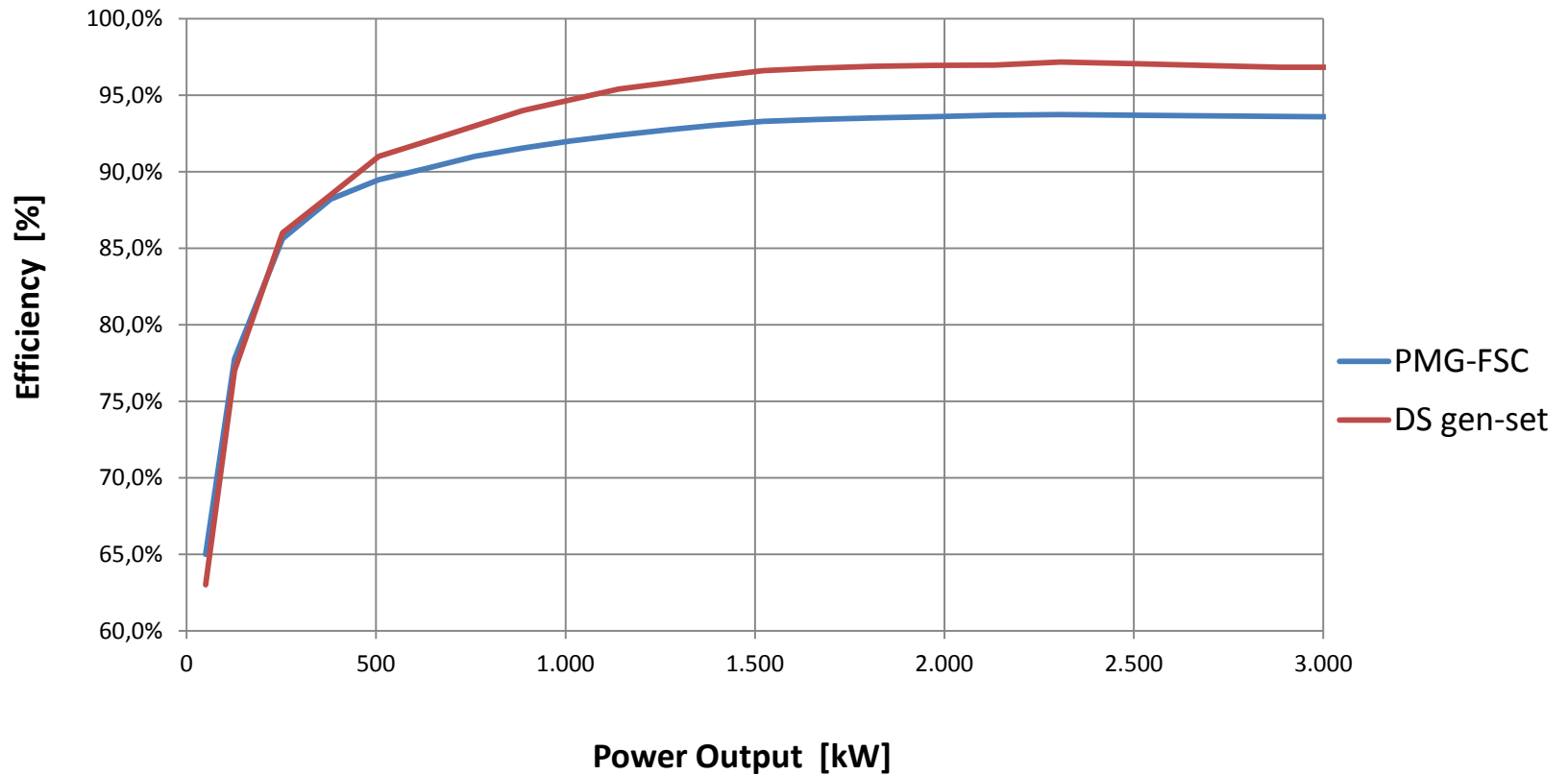


SET 3MW Test Bench Configuration

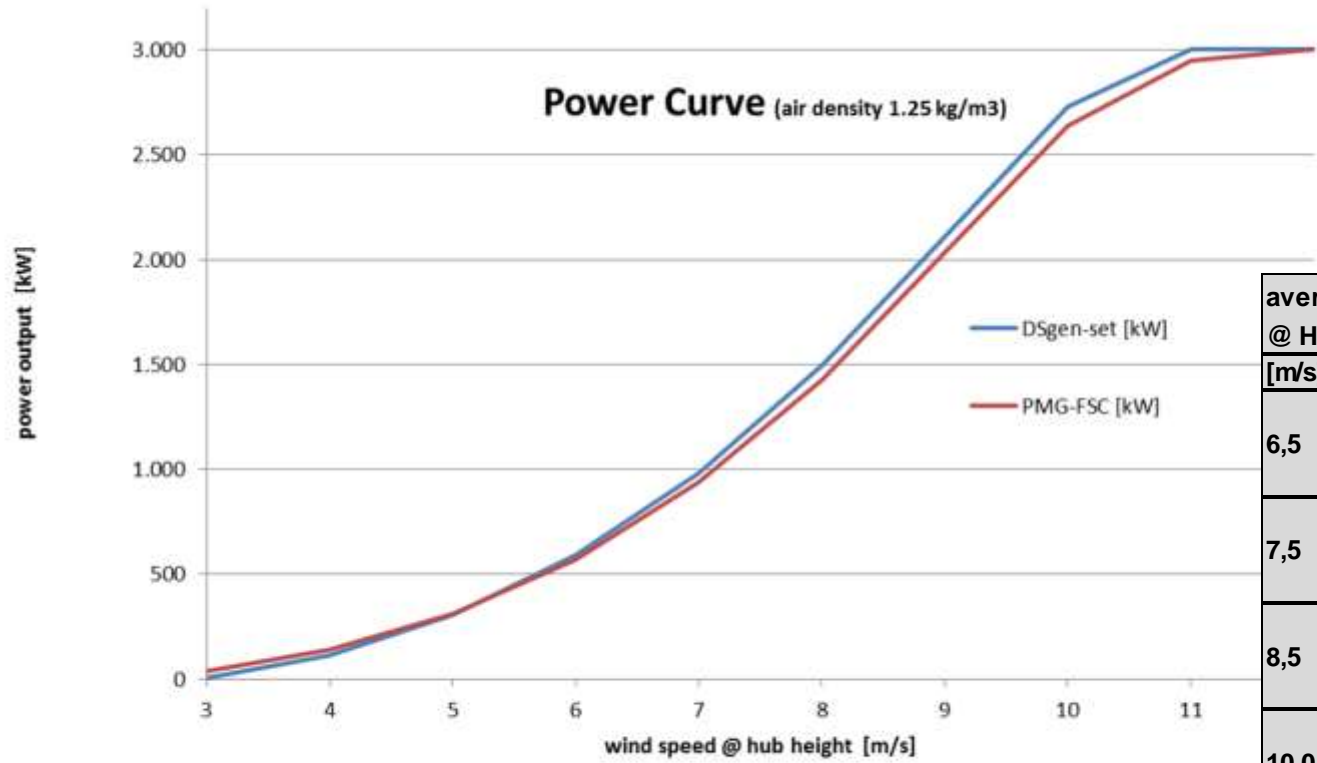


Test Results: Efficiency Comparison DS_{gen-set} vs. PMG-FSC

Efficiency Comparison: DS_{gen-set} vs. PMG-FSC

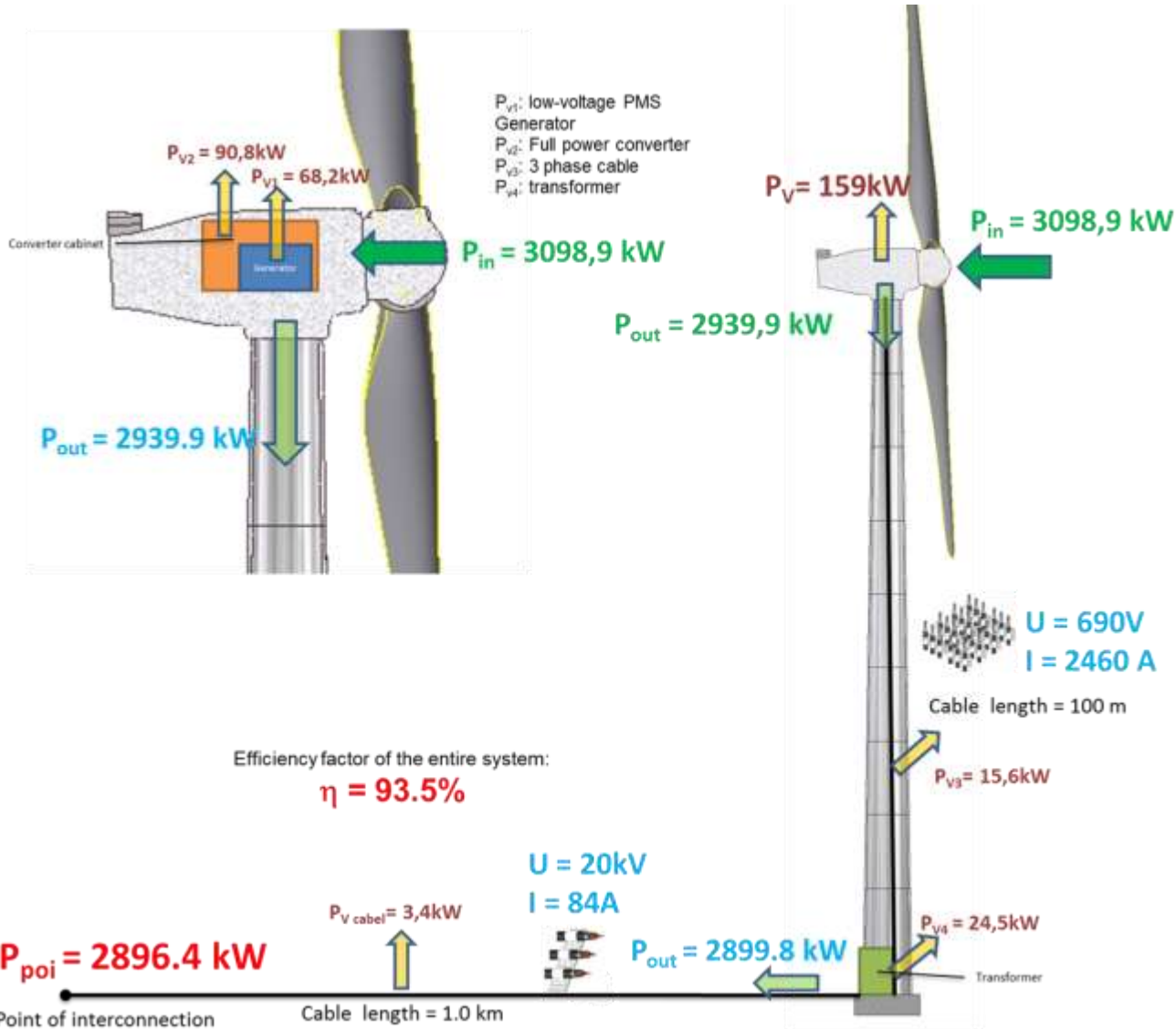


Resulting Power Curve DS_{gen-set} vs. PMG-FSC

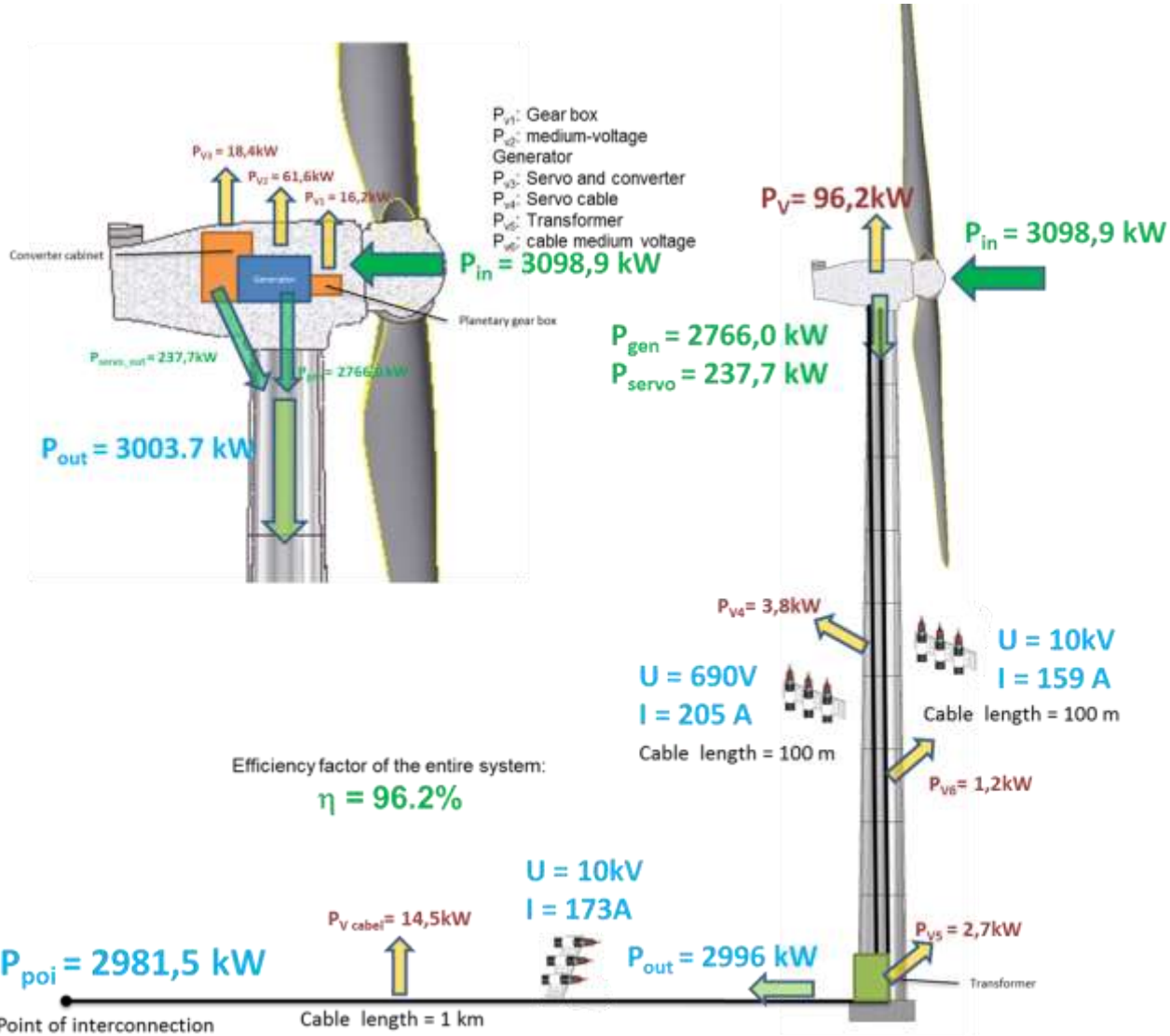


average wind speed @ HH; 1.25kg/m ³ [m/s]	DS _{gen-set} [MWh]	PMG-FSC (incl. Trafo) [MWh]
6,5	9.244.664	9.068.059 -1,9%
7,5	11.670.937	11.468.071 -1,7%
8,5	13.811.031	13.602.128 -1,5%
10,0	16.226.632	16.028.593 -1,2%

Efficiency PMG-FSC

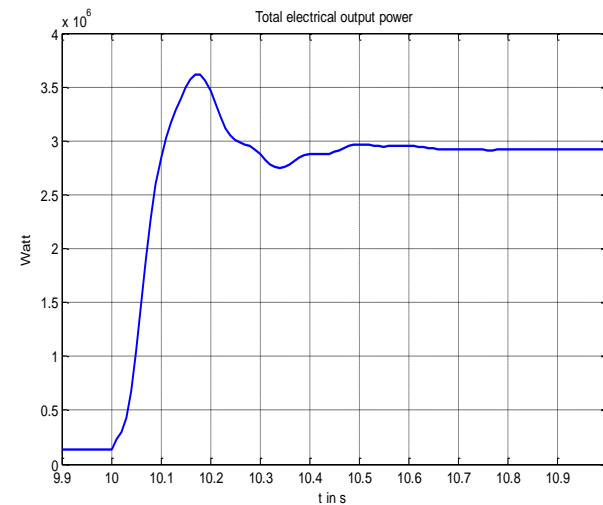
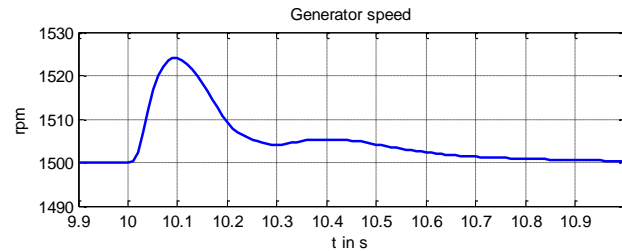
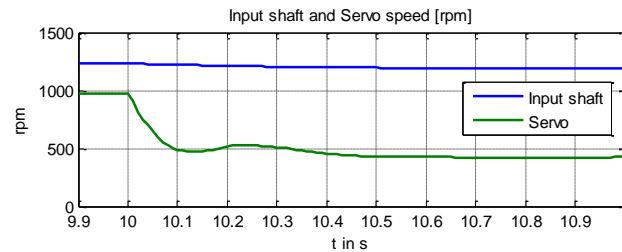
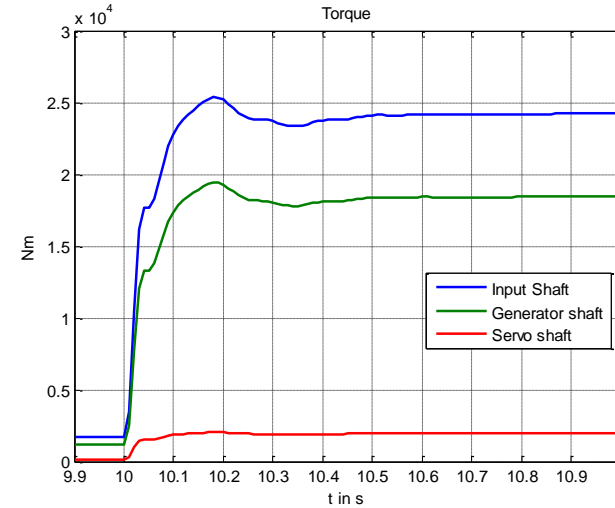
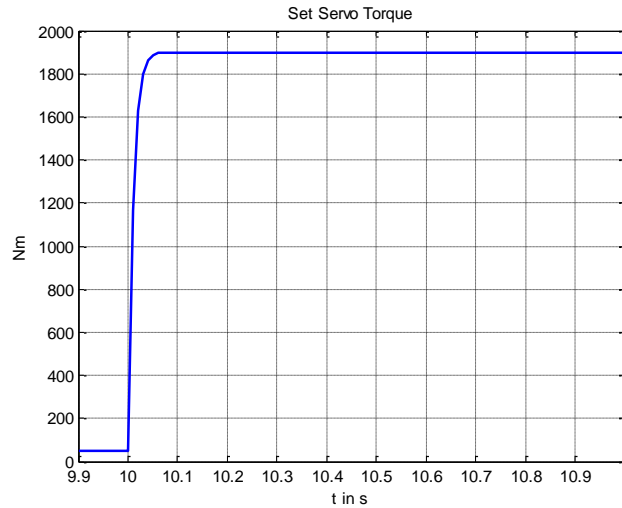


Efficiency DS_{gen-set}



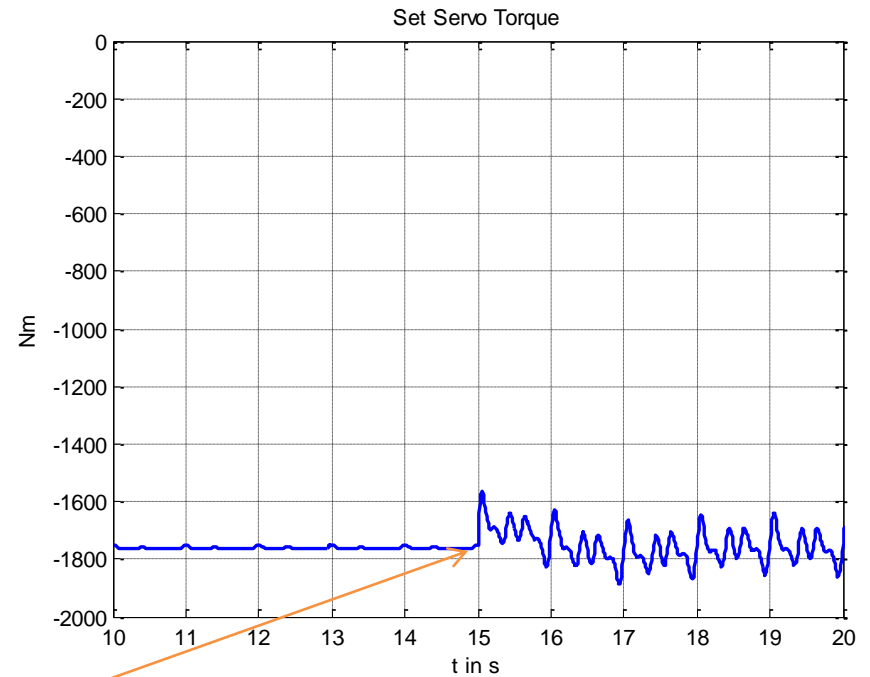
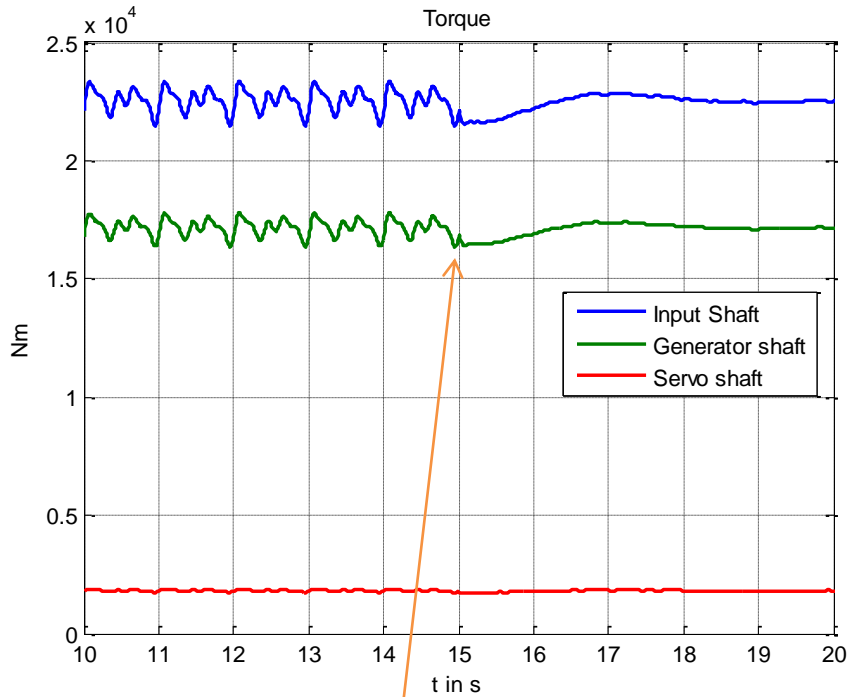
+ 2,85%

Test Results: Step response - servo torque



Resulting features: Drive train damping

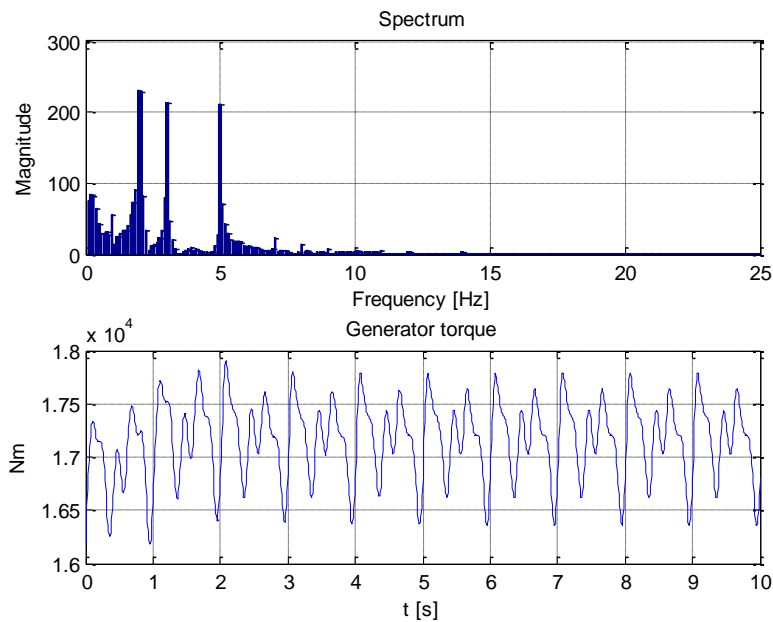
2 Hz, 3 Hz and 5 Hz oscillation @ rated output



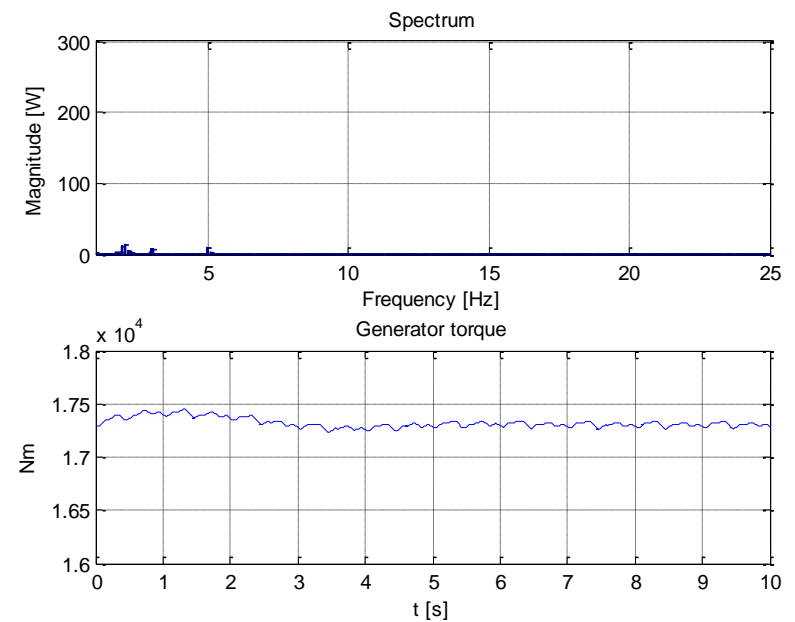
start damping

Effect of drive train damping on generator torque

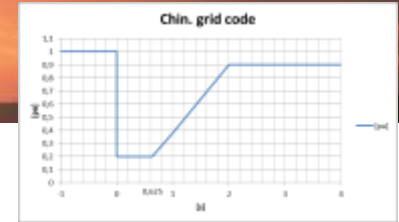
Without damping



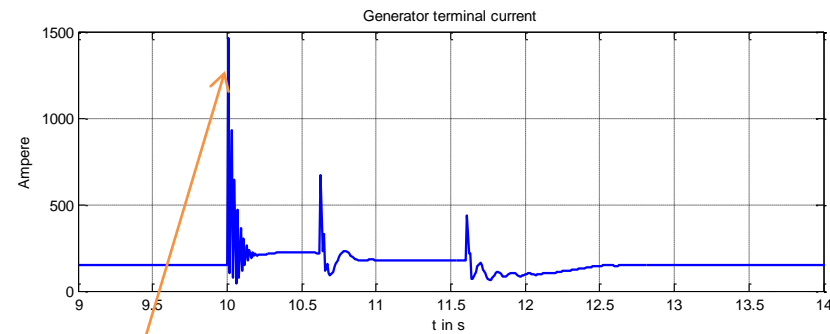
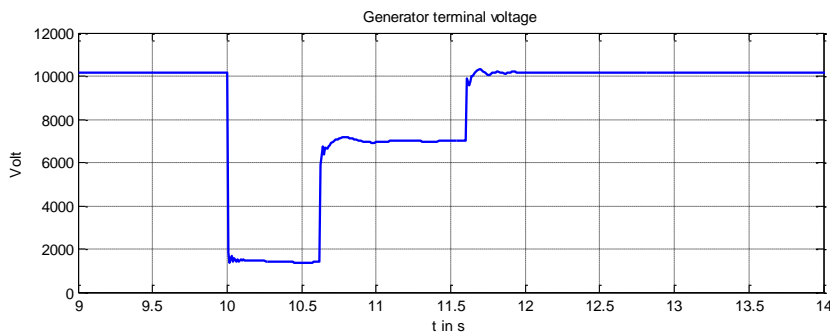
With damping



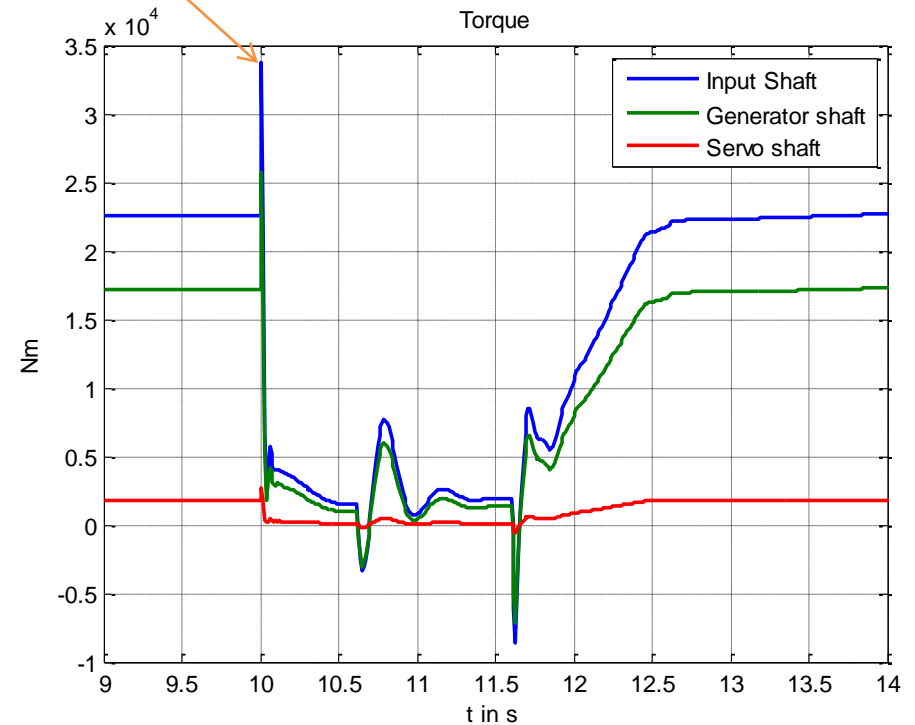
LVRT Simulation - based on Chinese grid code



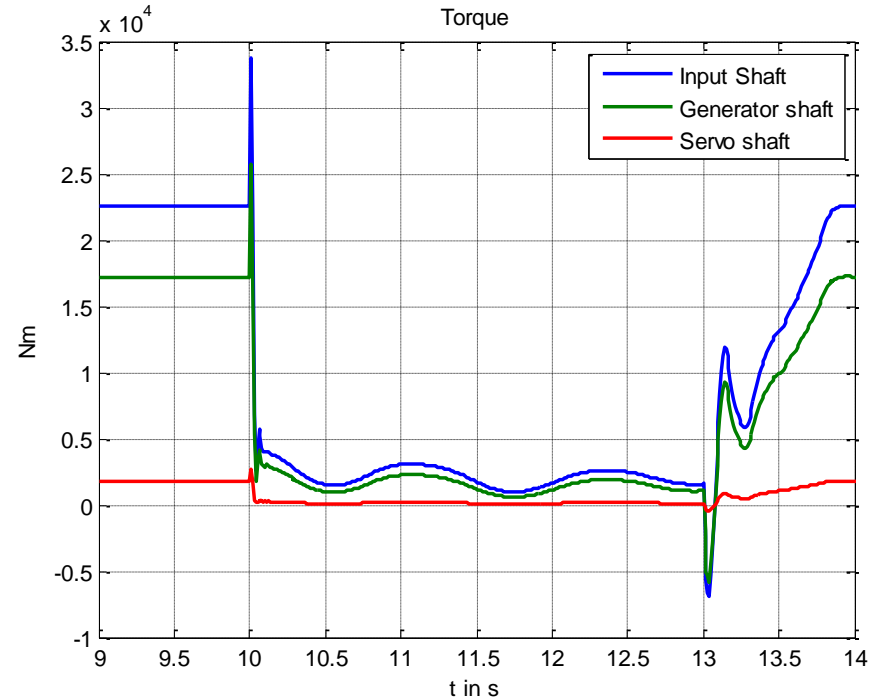
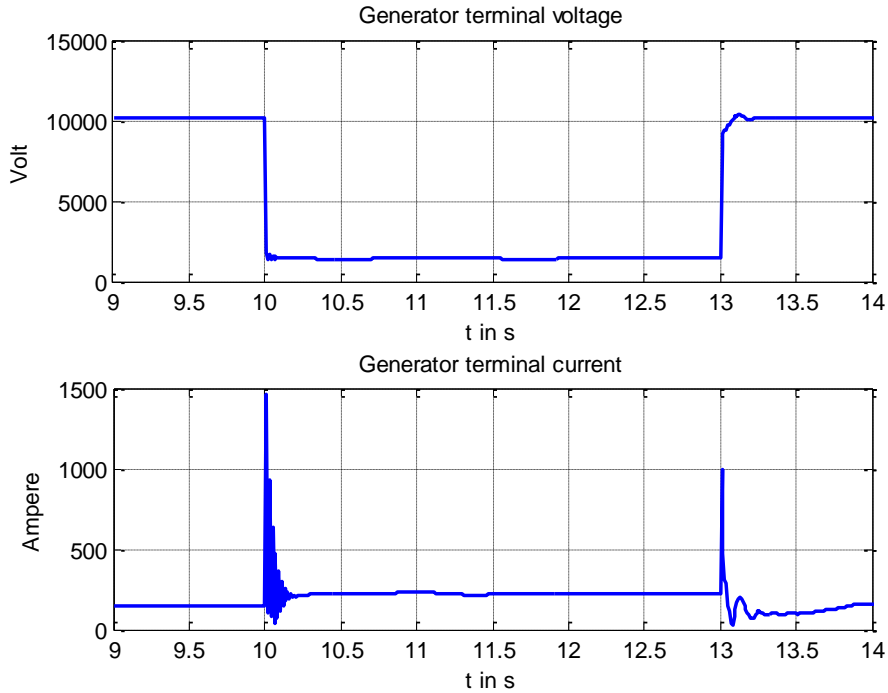
~1.4x rated torque [@ generator shaft]



~8x rated current



LVRT Simulation (3sec) - exceeding Chinese grid code



System performance relative to state-of-the-art concepts

Challenges:

- ✓ Reactive current during LVRT ("3-phase")
- ✓ LVRT capability in 1- and 2-phase grid faults
- ✓ Torque peaks during LVRT (relative to T_N)
- ✓ Compatibility with all grid codes
- ✓ Ability of working under extreme climate cond.
- ✓ Reduction of weight and space (nacelle)
- ✓ Reduction of service and maintenance costs
- ✓ Increase of WEC's annual energy yield (7,5 m/s)
- ✓ Reduction of system costs

	PMG-FSC	DFIG	Direct drive (gear less)	DS _{gen-set}
	≤ 1,2	≤ 1,2	≤ 1,2	≥ 8,0
	+	--	+	++
	≤ 1,5	≤ 3,0	≤ 1,5	≤ 1,5
	+	--	+	++
	+	+	+	+
	-	+	--	++
	+	+	++	++
	-2,0%	-1,0%	-1,0%	0,0%
	-	+	--	++

Benefit for our clients: Better Net Present Value (NPV)

3MW-WEC TC3

		DS _{gen-set}	PMC-FSC
prob. (7,5m/s)	Ej [MWh]	11.671	11.468
		1,74%	
Tariff [€/MWh]	€ 90,00		

		DS _{gen-set}	PMC-FSC
CAPEX 3 MW equipment acquisition	EUR	-€ 3.500.000,00	-€ 3.650.000,00
Economic lifetime	years	20	20
Required rate of return	%	7%	7%
Cash inflow / year	EUR	€ 1.050.396,39	1.032.126,39 €
Sum cash inflow / year	EUR	€ 1.050.396,39	1.032.126,39 €

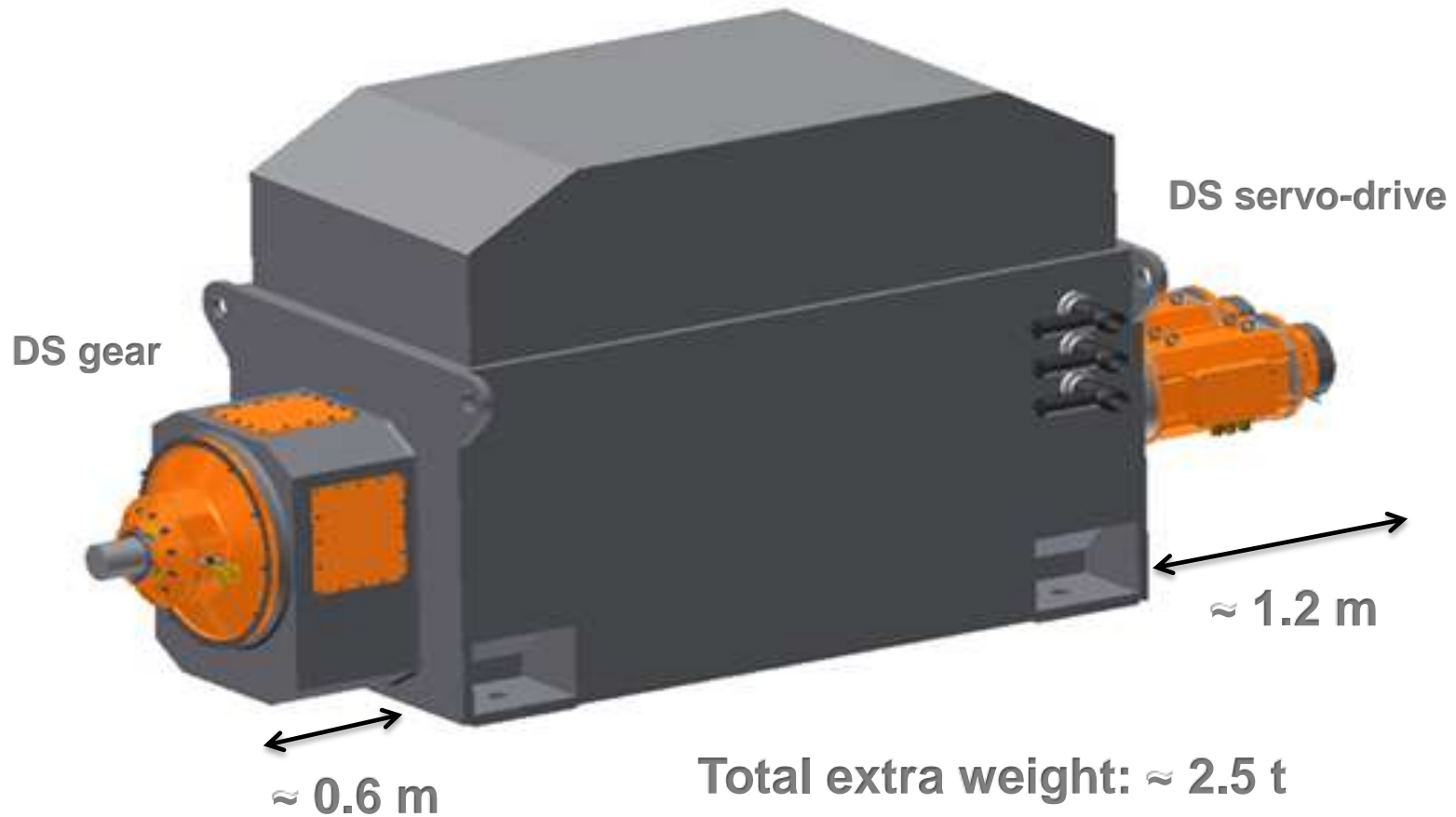
OPEX sum cash outflow / year	EUR	-€ 165.710,71	-€ 165.710,71
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Net Present Value	EUR	€ 5.872.372,66	€ 5.528.820,02
Net Present Value relative	%	5.85%	0%
Net Present Value absolute	EUR	€ 343.552,64	

~ 10% of CAPEX

Outlook 7.0 MW DS_{gen-set}

Air/water cooled, high-voltage synchronous generator



Summary:

SET's DS_{gen-set} guarantees:

- ✓ Compatibility with all grid codes - and more
 - ✓ Provides inertia to the grid (power system damping)
 - ✓ Improved efficiency
 - ✓ Reduction of weight and space
 - ✓ Reduction of system costs
 - ✓ Limitation of transient loads by torque control of servo drive
 - ✓ ~6% better NPV (equivalent to 10% of CAPEX)
 - ✓ Easily to be up-scaled to 7 MW – and more
 - ✓ Meets important targets of 12th five year plan
- **Electro-mechanical differential systems do combine the optimum of both worlds:**
- proved, utility-grade electricity generation
& power electronics**



Thank you for your attention!

Smart technology
for our **E**nvironment and
your benefi**T**