

WP 16 – Wind Turbine Black Start Validation Cosimulation – PHiL Testbench

By Alejandra Fabian

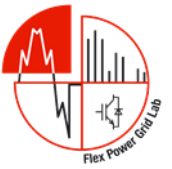
August 15th, 2019



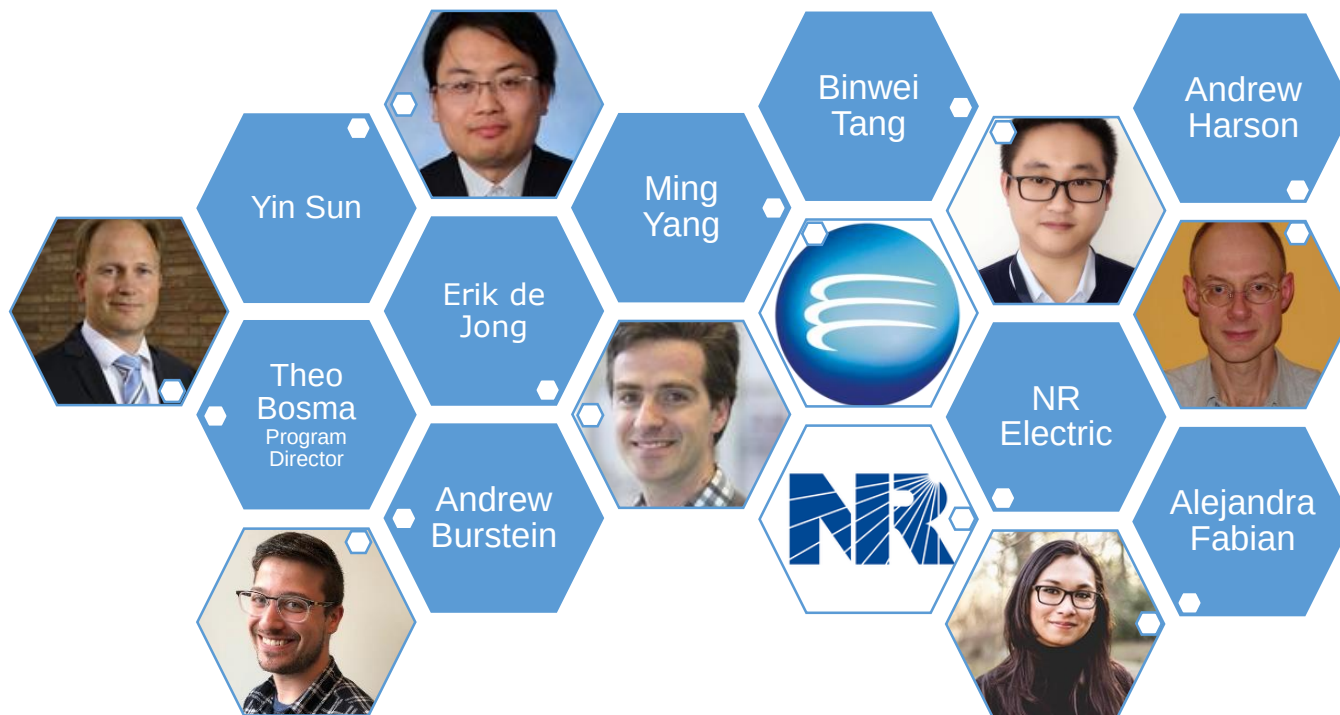
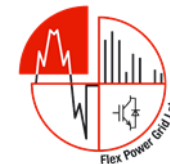
© PROMOTiON – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Content

- The team
- Motivation
- Study case
- Testbench concept (PHiL)
- Setup
- Results
 - Soft start DLC 1-3: 12 m/s test case
 - Hard start Fixed Speed – Failed
 - Hard start Fixed Speed – Success
 - Hard start LVRT
- Summary of results



The Team



Black start



- **More wind in the grid.**
- **TSO's looking into procuring black start services from wind power plants.**
- **Wind power plant operators can get flexibility for self-sustaining in case of prolonged outages.**
- **Black start using pitch control will have a strong coupling between the mechanical and electrical dynamics.**



Study Case Topology

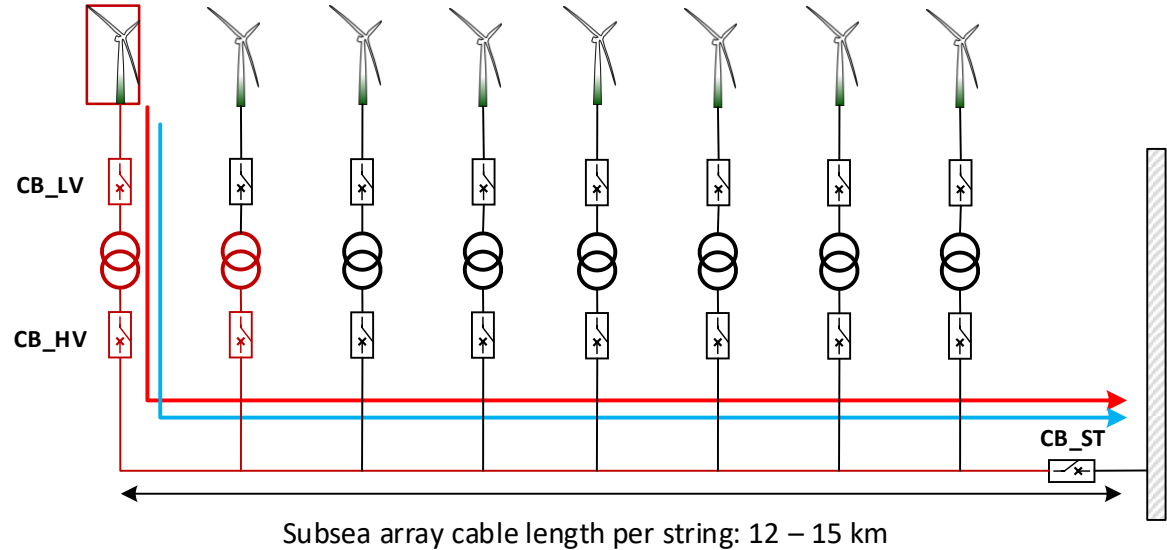


Soft Start

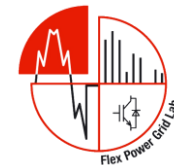
CB_LV and CB_HV closed before energization

Hard Start

CB_LV closed, CB_HV open before energization.
CB_HV will switch in after voltage is built by the WT.



Test cases



Energization strategy	Test Case Name	Conditions
Soft energization	- DLC1-2: 5m/s, with load - DLC1-2: 12m/s, with load - DLC1-3: 12m/s, with load - DLC1-4: 7m/s, with load - DLC2-3: 12m/s, with load	All cases are run with Bladed cosimulation
Hard energization	- DLC1-2: 12m/s, No load, LVRT Strategy - No cosimulation, fixed PMSG speed.	

Wind Conditions Specified by IEC 61400-1 Design Load Cases

- DLC 1.2 – Power production with Normal Turbulence Model (NTM)
- DLC 1.3 – Power production with Extreme Turbulence Model (ETM)
- DLC 1.4 – Extreme Coherent gust with Direction change (ECD)
- DLC 2.3 – Extreme Operating Gust (EOG).

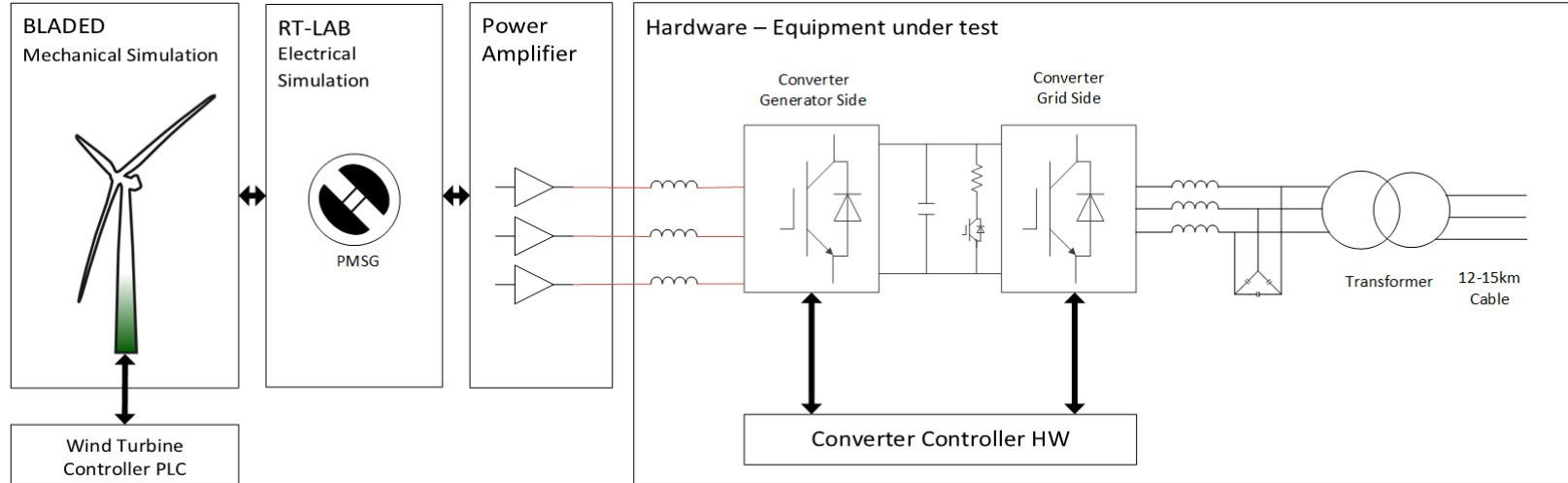


Wind Turbine Black Start Validation Cosimulation – PHiL Testbench

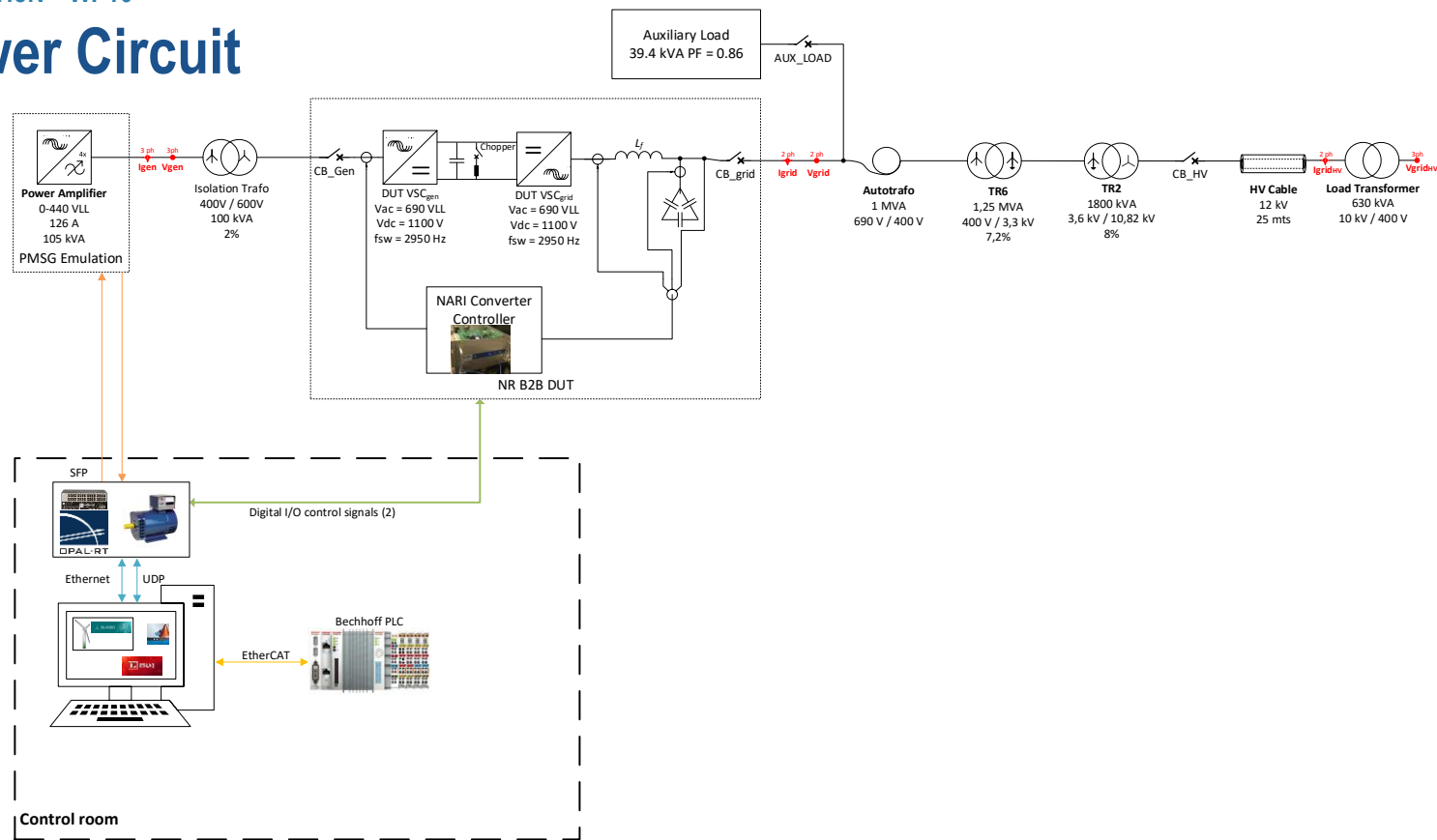


© PROMOTiON – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Cosimulation – PHiL Testbench Concept



Power Circuit

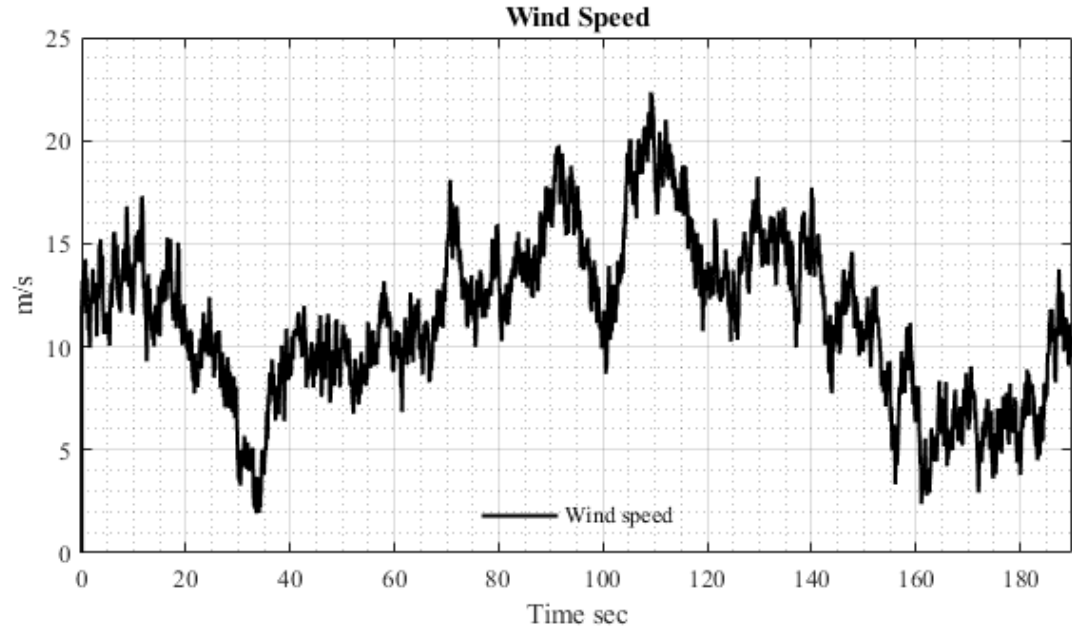


Soft Start

DLC 1-3: 12 m/s, Nominal wind with extreme turbulence

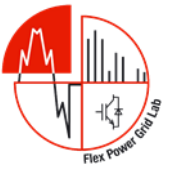


1. Start sequence
2. Blades pitch in
3. Generator speed increases
4. Airgap torque
5. Generator
6. Grid Side
7. Load Transformer

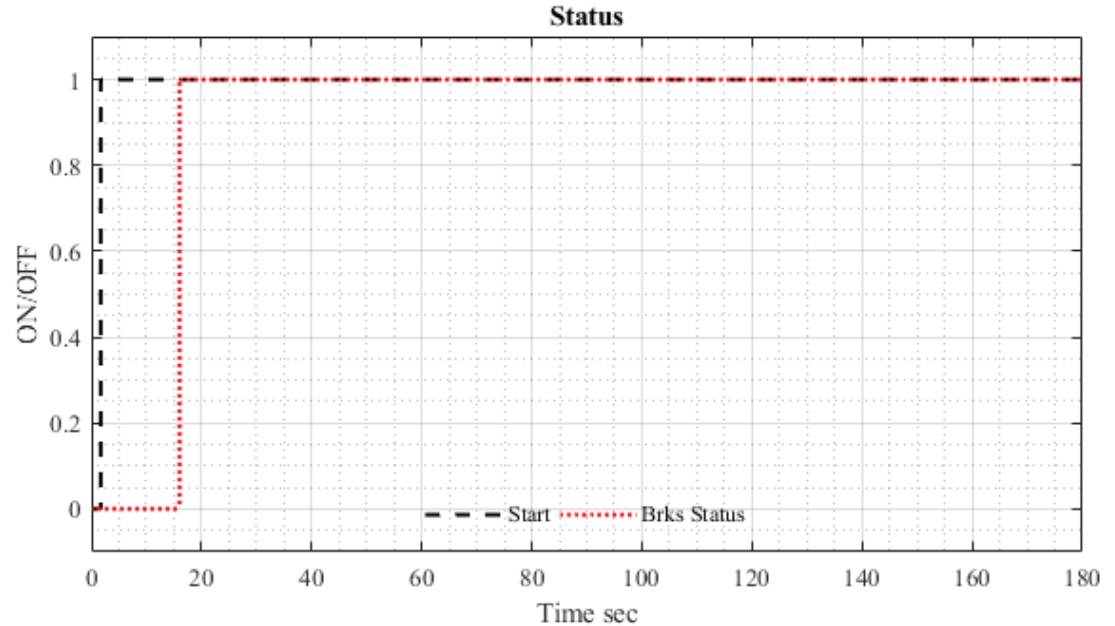


Soft Start

DLC 1-3: 12 m/s, Nominal wind with extreme turbulence

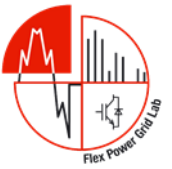


1. Start sequence
2. Blades pitch in
3. Generator speed increases
4. Airgap torque
5. Generator
6. Grid Side
7. Load Transformer

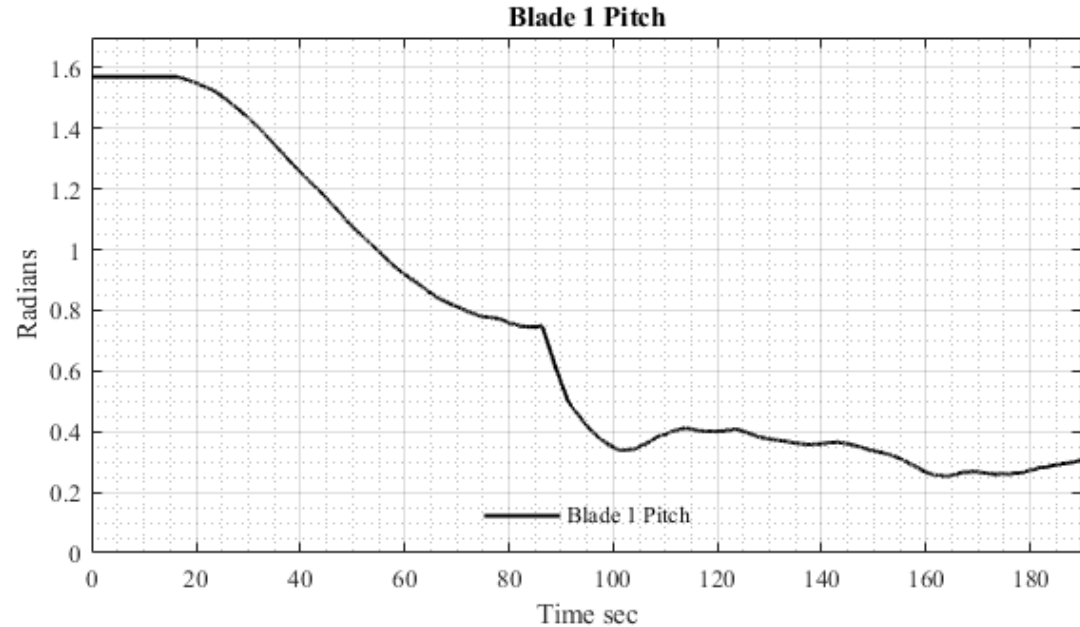


Soft Start

DLC 1-3: 12 m/s, Nominal wind with extreme turbulence

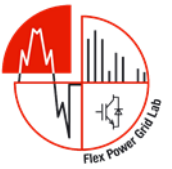


1. Start sequence
2. Blades pitch in
3. Generator speed increases
4. Airgap torque
5. Generator
6. Grid Side
7. Load Transformer

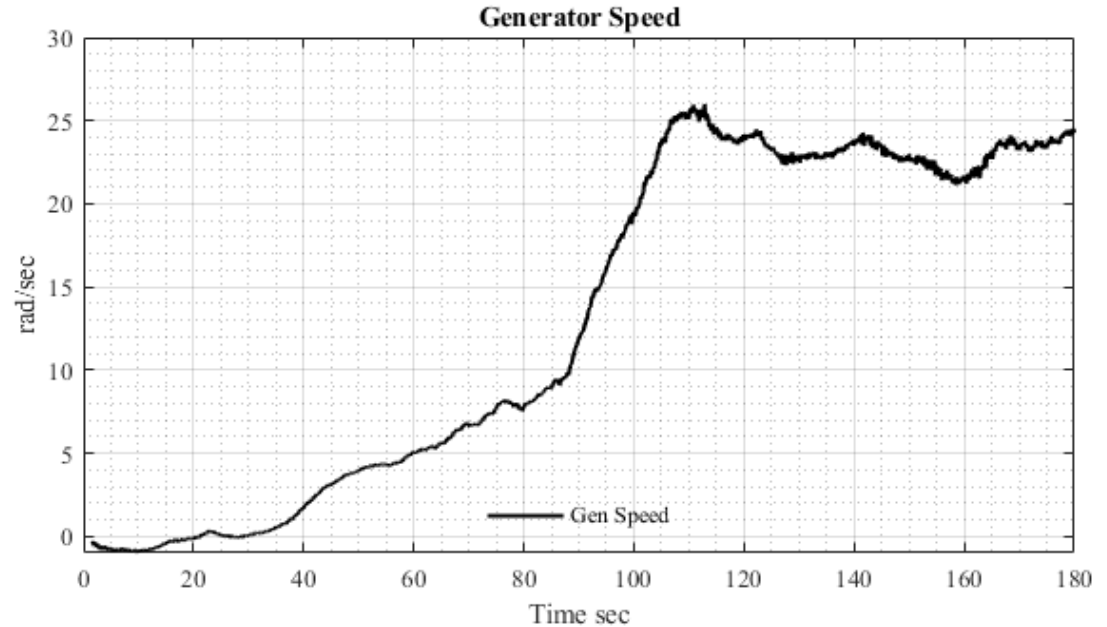


Soft Start

DLC 1-3: 12 m/s, Nominal wind with extreme turbulence

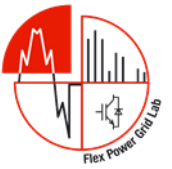


1. Start sequence
2. Blades pitch in
3. Generator speed increases
4. Airgap torque
5. Generator
6. Grid Side
7. Load Transformer

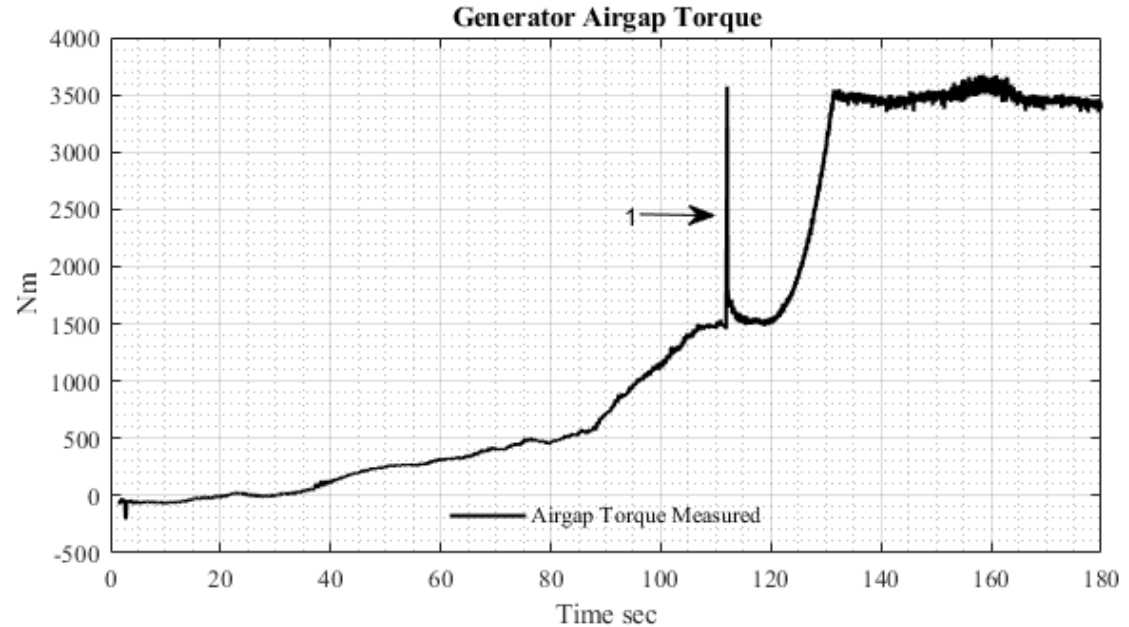


Soft Start

DLC 1-3: 12 m/s, Nominal wind with extreme turbulence



1. Start sequence
2. Blades pitch in
3. Generator speed increases
4. Airgap torque
5. Generator
6. Grid Side
7. Load Transformer

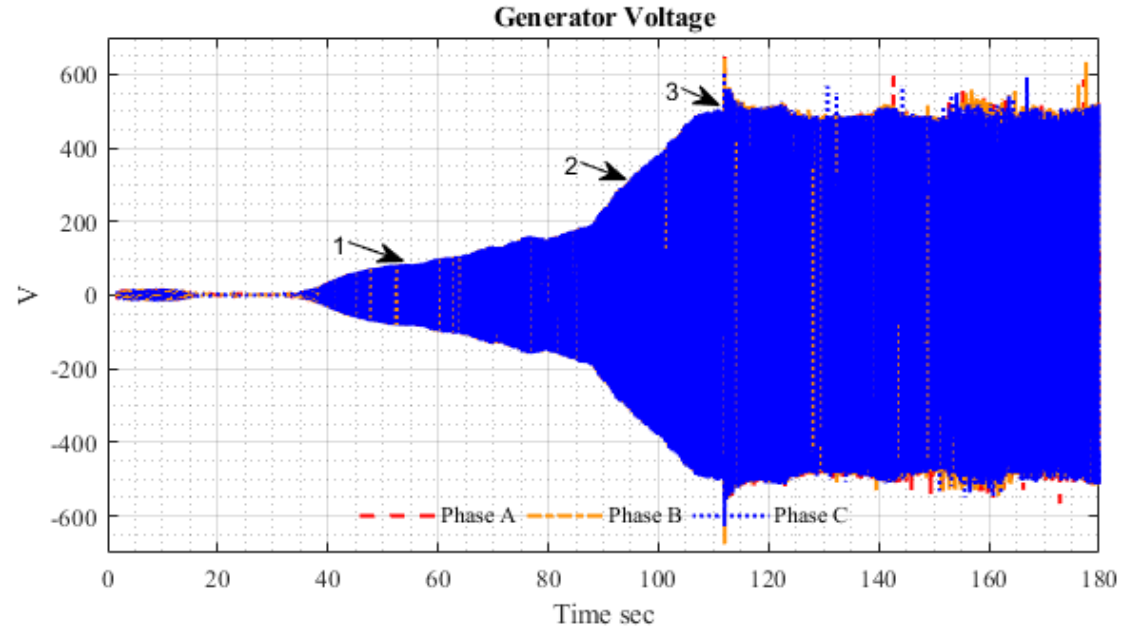


Soft Start

DLC 1-3: 12 m/s, Nominal wind with extreme turbulence

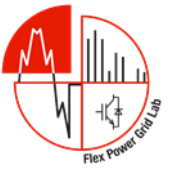


1. Start sequence
2. Blades pitch in
3. Generator speed increases
4. Airgap torque
5. Generator
6. Grid Side
7. Load Transformer

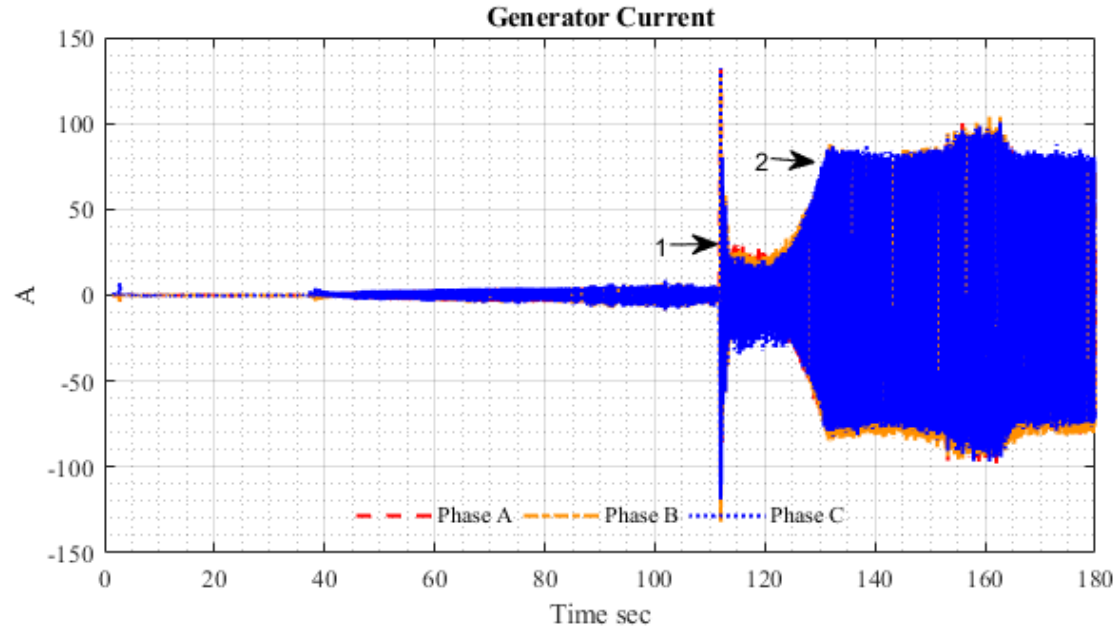


Soft Start

DLC 1-3: 12 m/s, Nominal wind with extreme turbulence



1. Start sequence
2. Blades pitch in
3. Generator speed increases
4. Airgap torque
5. Generator
6. Grid Side
7. Load Transformer

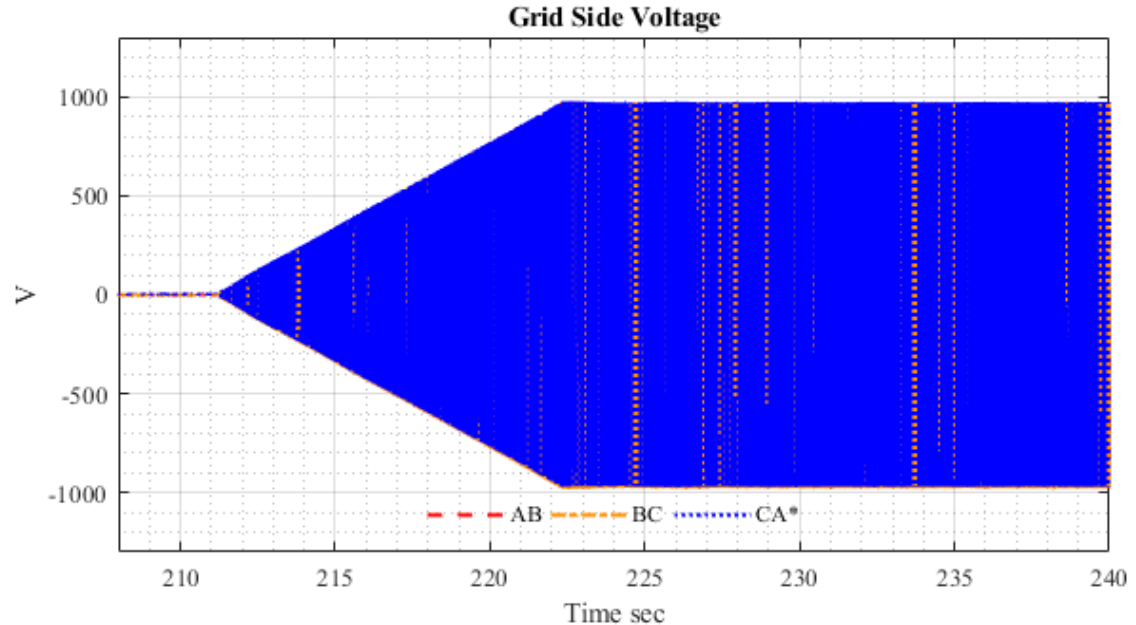


Soft Start

DLC 1-3: 12 m/s, Nominal wind with extreme turbulence

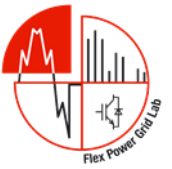


1. Start sequence
2. Blades pitch in
3. Generator speed increases
4. Airgap torque
5. Generator
6. Grid Side
7. Load Transformer

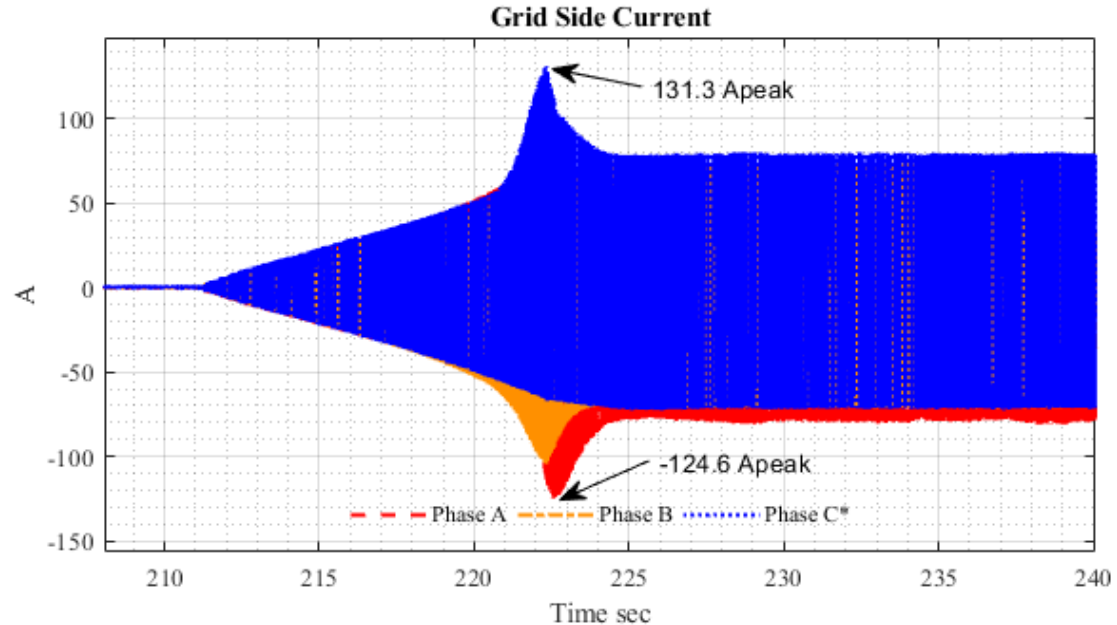


Soft Start

DLC 1-3: 12 m/s, Nominal wind with extreme turbulence



1. Start sequence
2. Blades pitch in
3. Generator speed increases
4. Airgap torque
5. Generator
6. Grid Side
7. Load Transformer

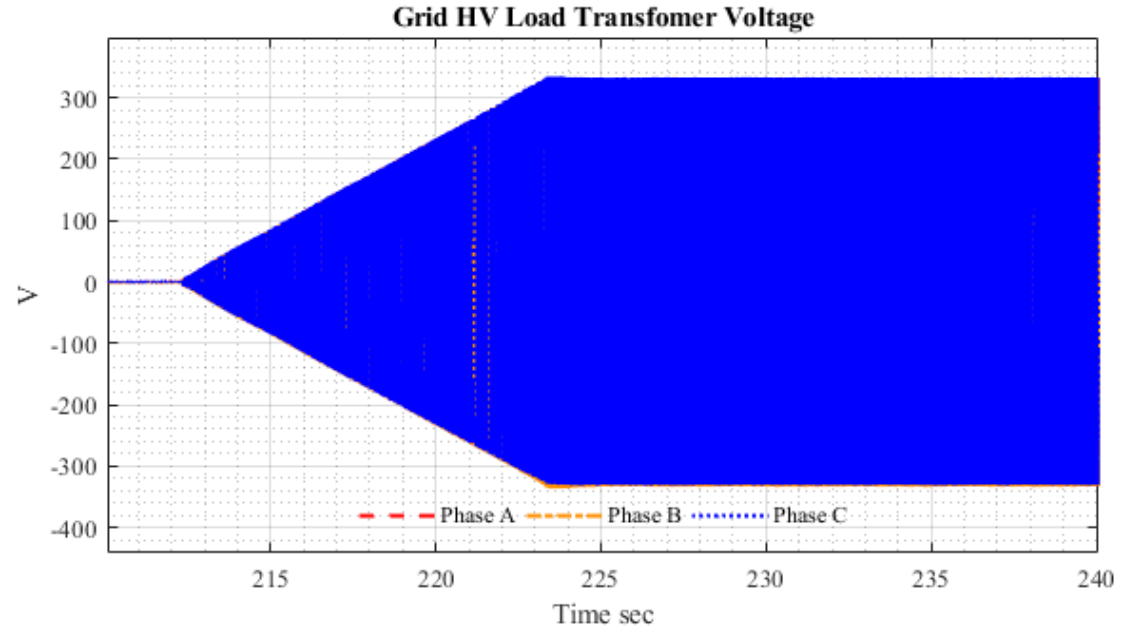


Soft Start

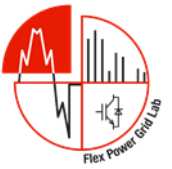
DLC 1-3: 12 m/s, Nominal wind with extreme turbulence



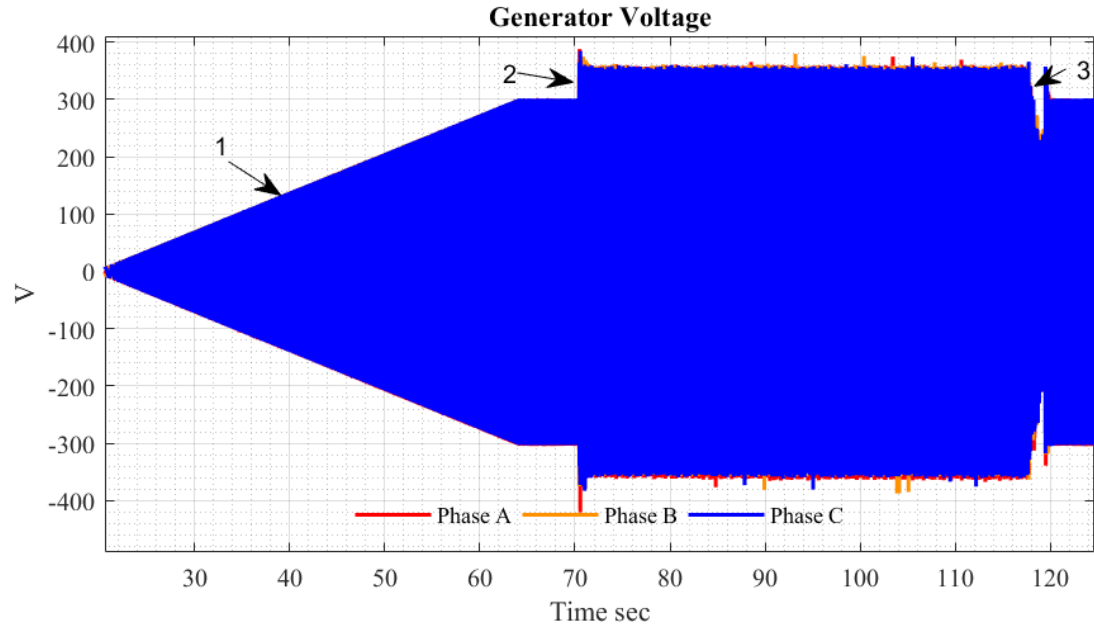
1. Start sequence
2. Blades pitch in
3. Generator speed increases
4. Airgap torque
5. Generator
6. Grid Side
7. Load Transformer



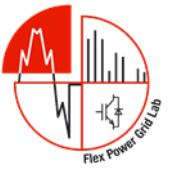
Hard Start - Fixed Speed PMSG Failed ☹️



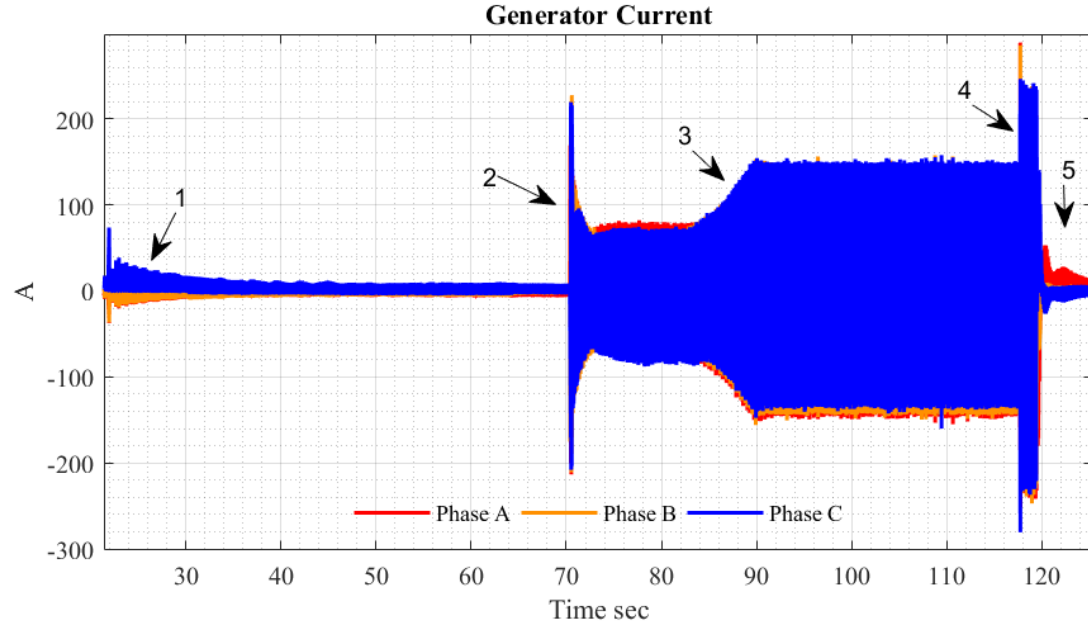
1. Manual start sequence
2. Generator
3. Grid Side
4. Load Transformer



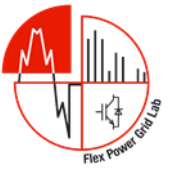
Hard Start - Fixed Speed PMSG Failed ☹️



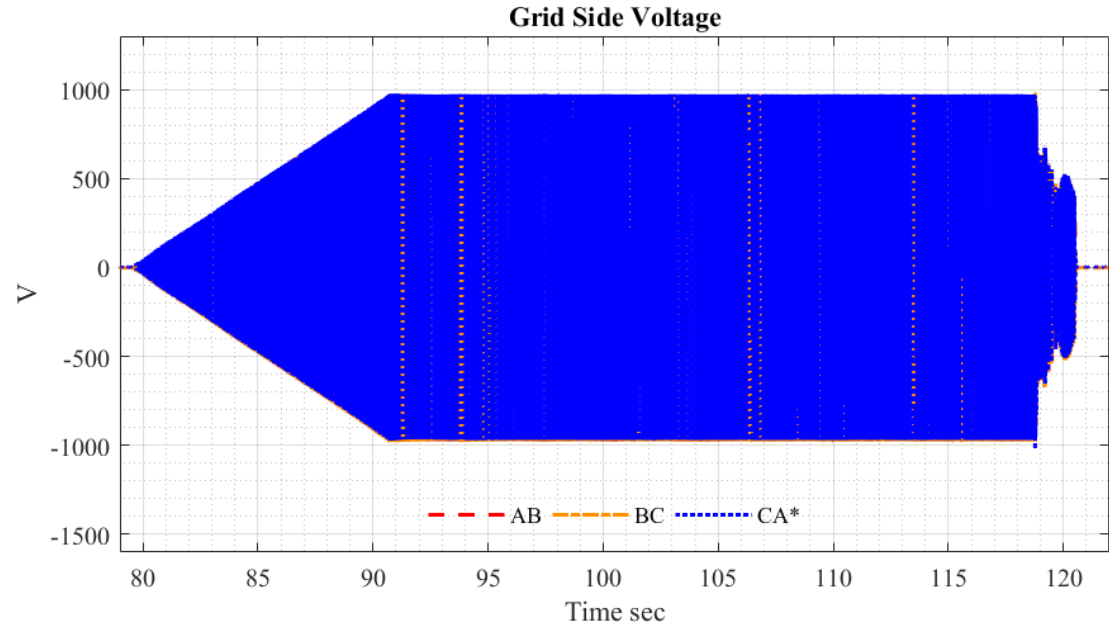
1. Manual start sequence
2. Generator
3. Grid Side
4. Load Transformer



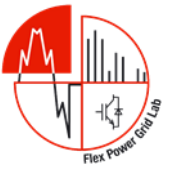
Hard Start - Fixed Speed PMSG Failed ☹️



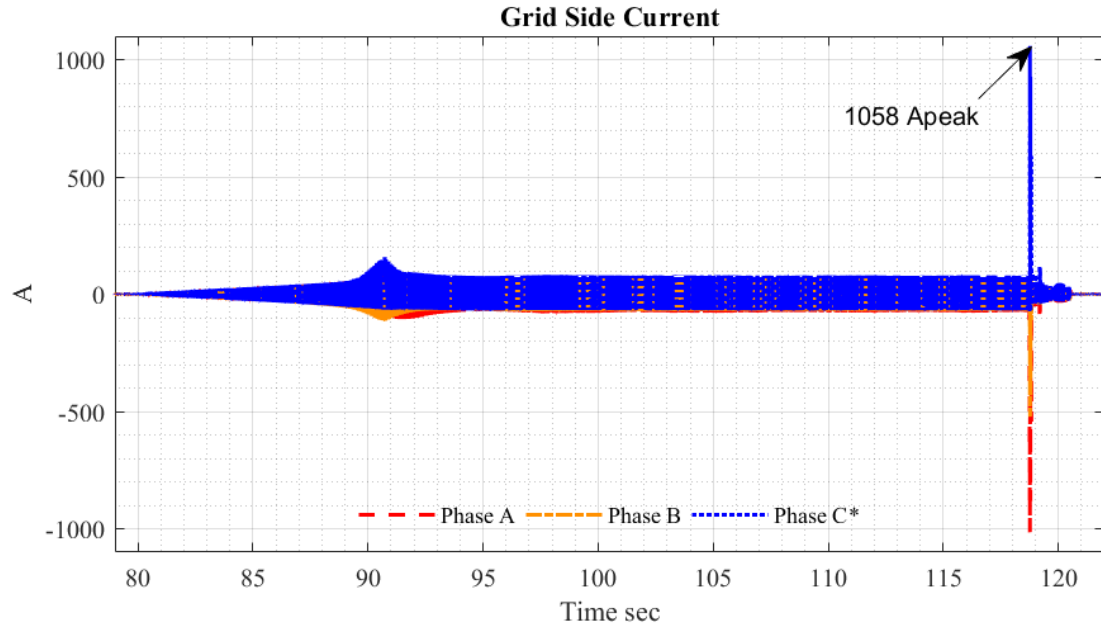
1. Manual start sequence
2. Generator
3. Grid Side
4. Load Transformer



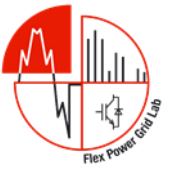
Hard Start - Fixed Speed PMSG Failed ☹️



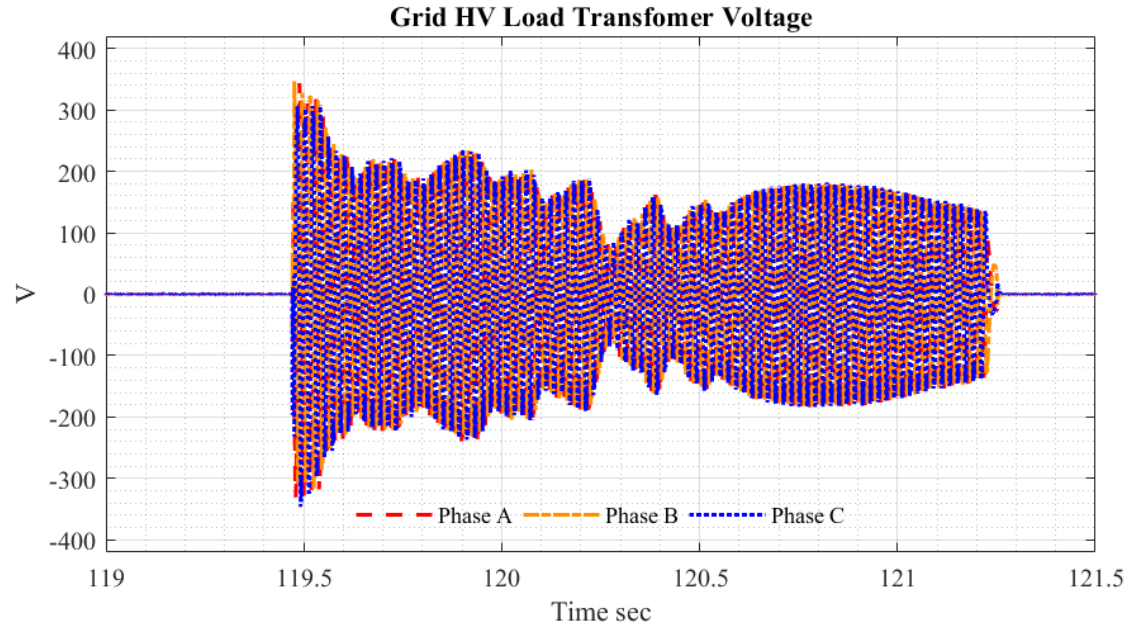
1. Manual start sequence
2. Generator
3. Grid Side
4. Load Transformer



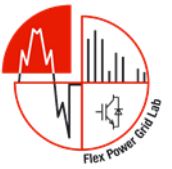
Hard Start - Fixed Speed PMSG Failed ☹️



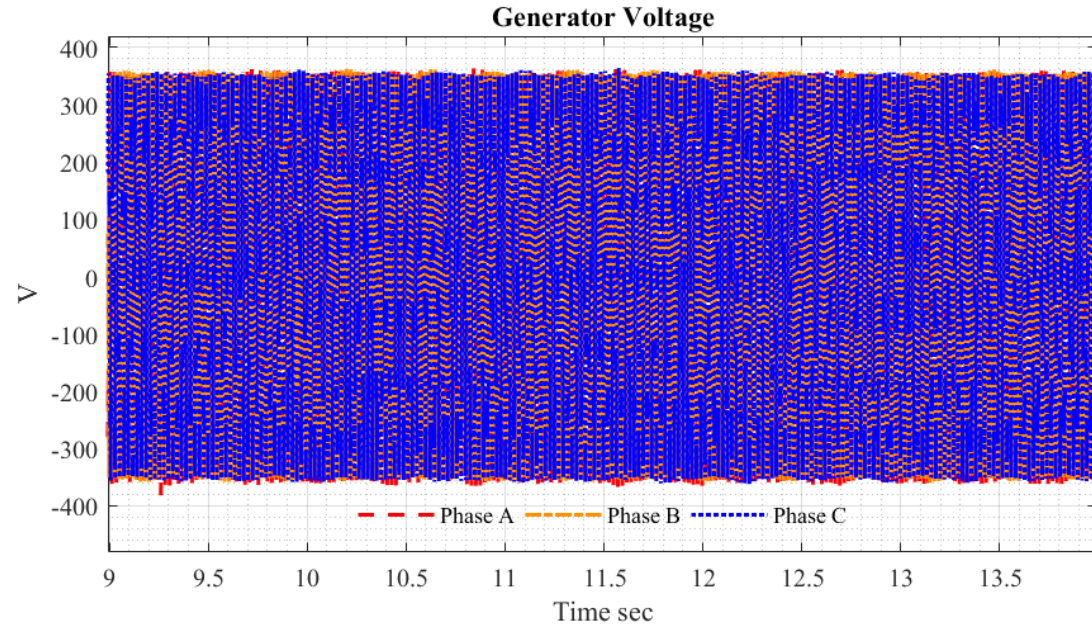
1. Manual start sequence
2. Generator
3. Grid Side
4. Load Transformer



Hard Start - Fixed Speed PMSG Success 😊



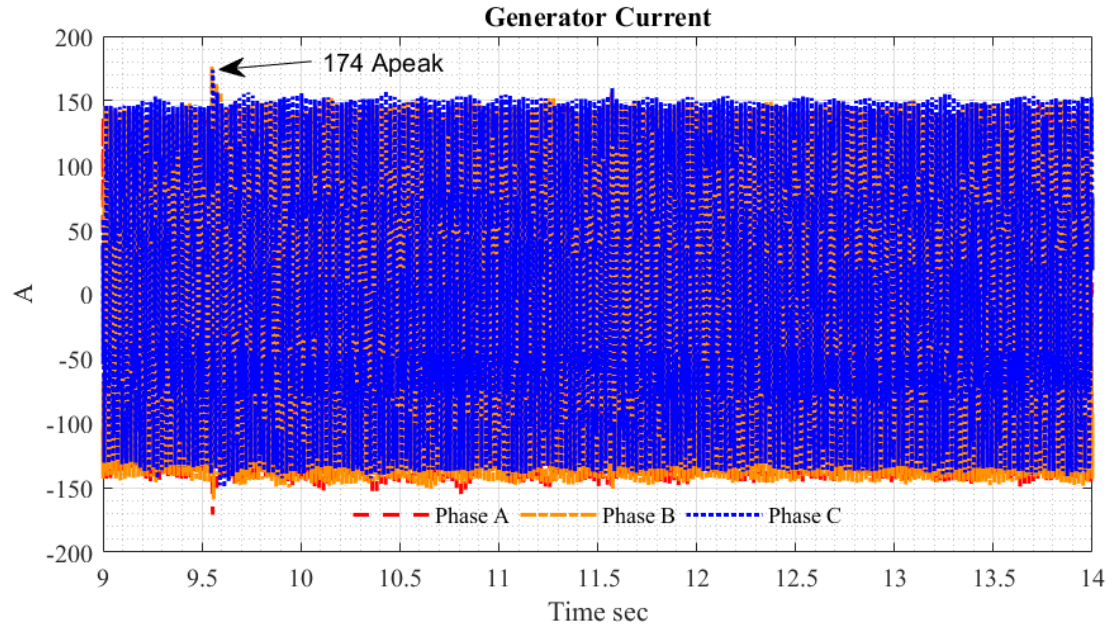
1. Manual start sequence
2. Generator
3. Grid Side
4. Load Transformer



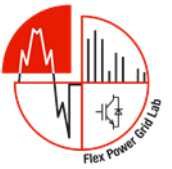
Hard Start - Fixed Speed PMSG Success 😊



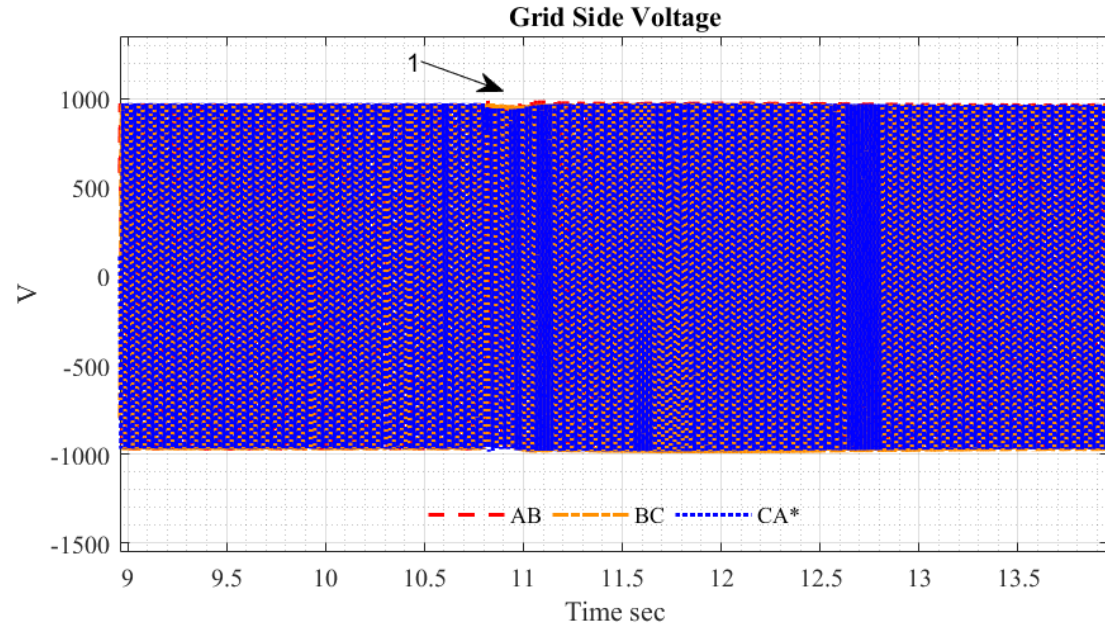
1. Manual start sequence
2. Generator
3. Grid Side
4. Load Transformer



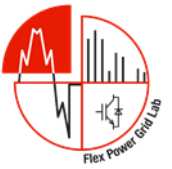
Hard Start - Fixed Speed PMSG Success 😊



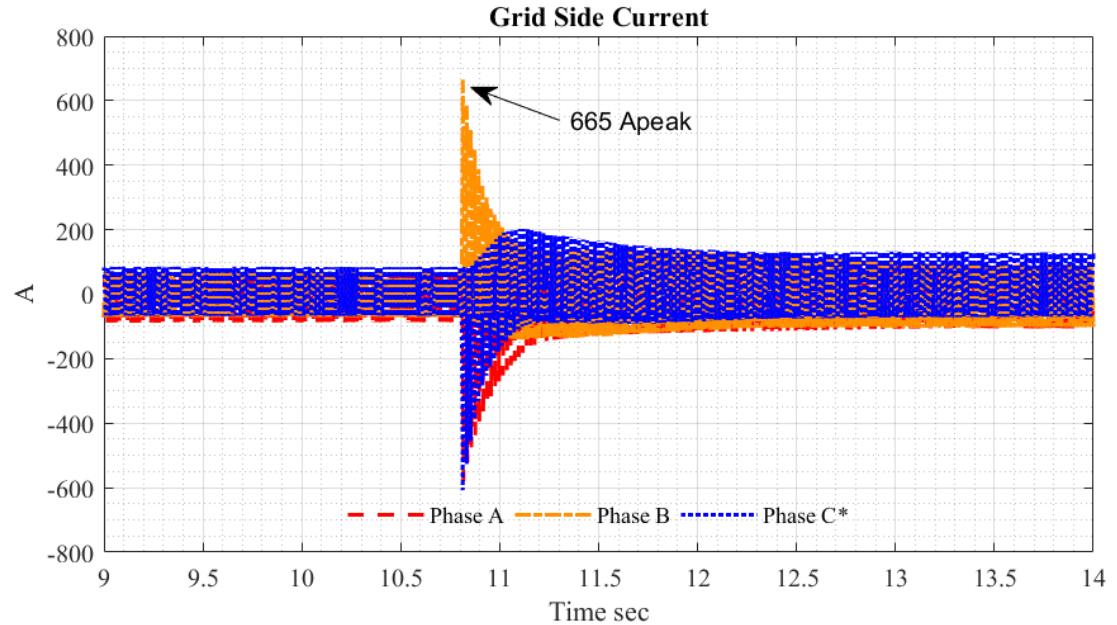
1. Manual start sequence
2. Generator
3. Grid Side
4. Load Transformer



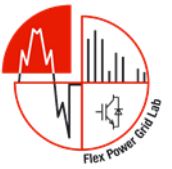
Hard Start - Fixed Speed PMSG Success 😊



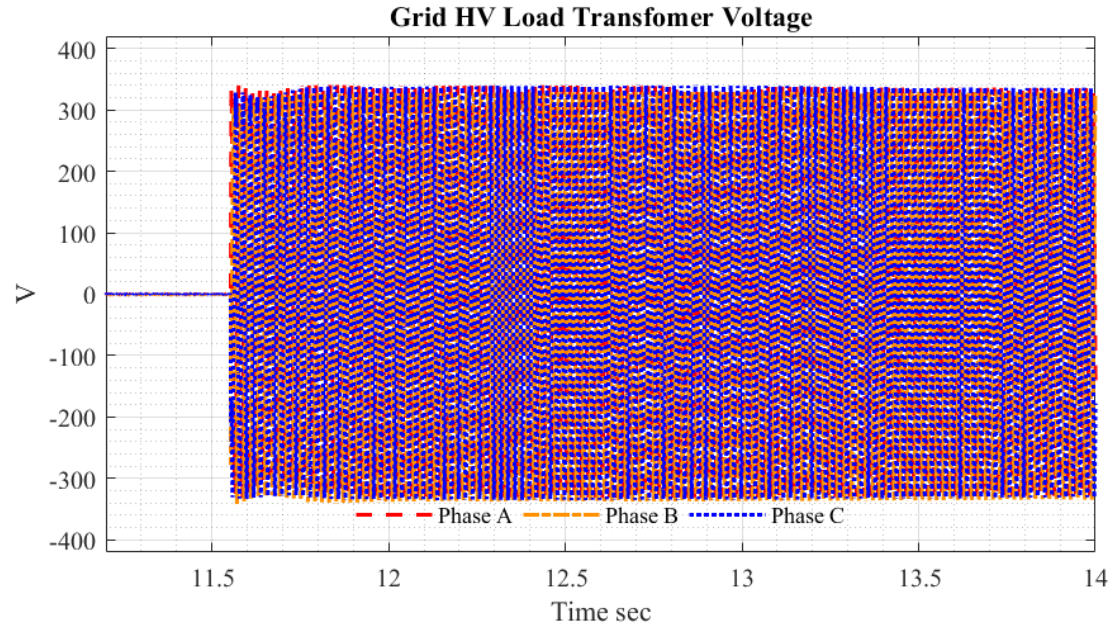
1. Manual start sequence
2. Generator
3. Grid Side
4. Load Transformer



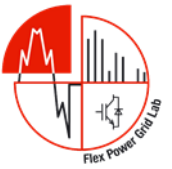
Hard Start - Fixed Speed PMSG Success 😊



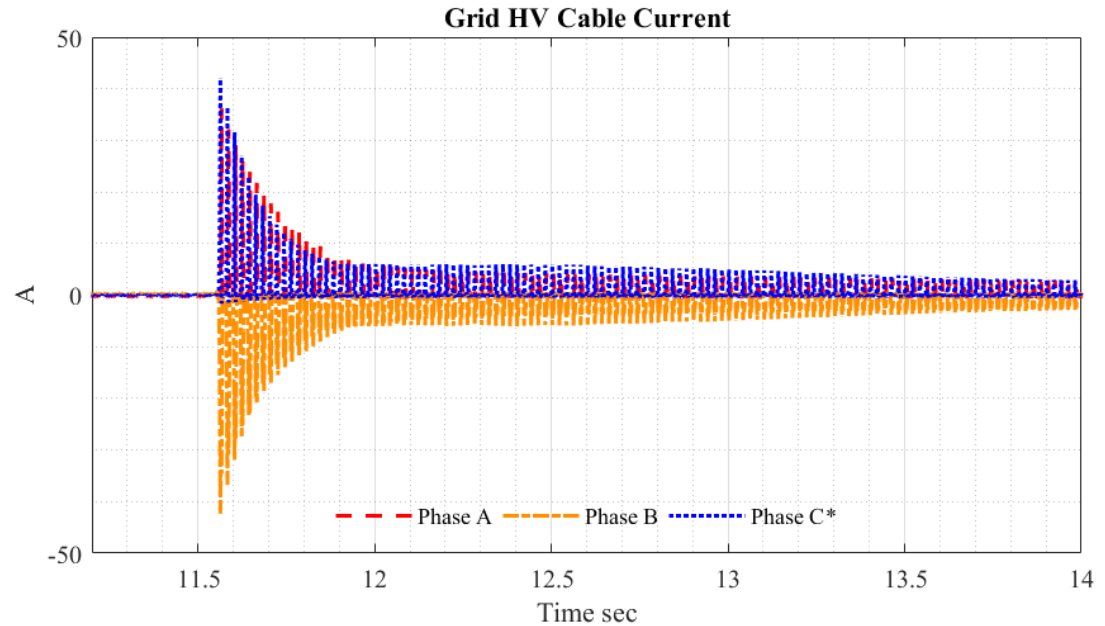
1. Manual start sequence
2. Generator
3. Grid Side
4. Load Transformer



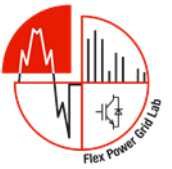
Hard Start - Fixed Speed PMSG Success 😊



1. Manual start sequence
2. Generator
3. Grid Side
4. Load Transformer



Summary of results



- Soft start **all** tested cases were successful.
- Hard start is possible, but control of voltage in the generator will be crucial to be successful. The success of this approach was not consistent due to the variable current transient during energization of the transformer.

DISCLAIMER & PARTNERS

COPYRIGHT

PROMOTiON – Progress on Meshed HVDC Offshore Transmission Networks
MAIL info@promotion-offshore.net WEB www.promotion-offshore.net

The opinions in this presentation are those of the author and do not commit in any way the European Commission

PROJECT COORDINATOR

DNV GL Netherlands B.V.
Utrechtseweg 310, 6812 AR Arnhem, The Netherlands
Tel +31 26 3 56 9111
Web www.dnvgl.com/energy

CONTACT

DNV GL Team for WP16
Alejandra.Fabian@dnvgl.com
Andrew.Burstein@dnvgl.com
Andrew.Harson@dnvgl.com
Erik.deJong@dnvgl.com
Yin.Sun@dnvgl.com
Yongtao.Yang@dnvgl.com

PARTNERS

DNV GL Netherlands B.V., ABB AB, KU Leuven, KTH Royal Institute of Technology, EirGrid plc, SuperGrid Institute, Deutsche WindGuard GmbH, Mitsubishi Electric Europe B.V., Affärsverket Svenska kraftnät, Alstom Grid UK Ltd (Trading as GE Grid Solutions), University of Aberdeen, Réseau de Transport d'Électricité, Technische Universiteit Delft, Statoil ASA, TenneT TSO B.V., Stiftung OFFSHORE-WINDENERGIE, Siemens AG, Danmarks Tekniske Universitet, Rheinisch-Westfälische Technische Hochschule Aachen, Universitat Politècnica de València, SCiBreak AB, Forschungsgemeinschaft für Elektrische Anlagen und Stromwirtschaft e.V., Ørsted Wind Power A/S, The Carbon Trust, Tractebel Engineering S.A., European University Institute, Iberdrola Renovables Energía, S.A., European Association of the Electricity Transmission & Distribution Equipment and Services Industry, University of Strathclyde, ADWEN Offshore, S.L., Prysmian, Rijksuniversiteit Groningen, MHI Vestas Offshore Wind AS, Energinet.dk, Scottish Hydro Electric Transmission plc, SCiBreak AB

