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SGB-SMIT Group

Vibration Analysis of Dry-Type Transformer for Offshore Wind Applications

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Agenda

- Introduction – SGB SMIT GROUP
- Offshore Wind Energy and their Challenges
- Importance of DRY type (Cast Resin) Transformer and Challenges
- Need of Vibration Analysis and Stuctural Reliability of Transformer
- Vibration Analysis based on Specification
- Modal Analysis of Transformer
- Simulation and test result comparison for Natural Frequencies and Model validation
- Transient Analysis and Random Vibration Analysis
- Conclusion

INTRODUCTION

SGB-SMIT Group

- Pure play electrical transformer specialist from Europe – Headquarter in **Regensburg, Germany**
- Engineering, Designing, R&D, Production, Testing and Services
- One of the leading transformer suppliers in the world
- Oil & Dry type transformer technology
- Distribution, Power and Special type of transformers

1 STARKSTROM-GERÄTEBAU GMBH
Regensburg (Germany)

2 SÄCHSISCH-BAYERISCHE STARKSTROM-GERÄTEBAU GMBH
Neumark (Germany)

3 ROYAL SMIT TRANSFORMERS B.V.
Nijmegen (The Netherlands)

4 RETRASIB S.A.
Sibiu (Romania)

5 SGB CZECH TRAFO S.R.O.
Olomouc (Czech Republic)

6 BCV TECHNOLOGIES S.A.S.
Fontenay-le-Comte (France)

7 SGB-USA INC.
Tallmadge, OH (USA)

8 OTC SERVICES INC.
Louisville, OH (USA)

9 SGB-SMIT SALES INC.
Summerville, SC (USA)

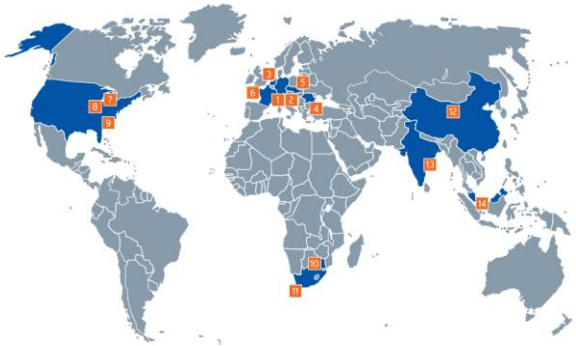
10 SGB-SMIT POWER MATLA (PTY) LTD.
Pretoria West (South Africa)

11 SGB-SMIT POWER MATLA (PTY) LTD.
Cape Town (South Africa)

12 SGB CHINA
Changzhou (P.R. China)

13 SGB TRANSFORMERS INDIA PVT. LTD.
Chennai (India)

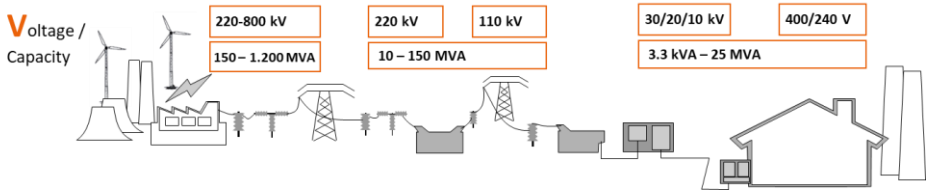
14 SGB MY SDN. BHD.
Nilai (Malaysia)



1913
HISTORY
... of steadily growing expertise

14
LOCATIONS
We are one of the world´s leading manufacturers of power transformers

3.200
EMPLOYEES
...are the key to our success, with an international team of highly talented and motivated people



Overview of Offshore Wind Energy and their challenges

Overview:

- Offshores wind turbines are installed **in bodies of water,** typically oceans or seas.
- Strategically located to take advantage of **strong, consistent winds, offering higher energy yields** compared to onshore sites.

Challenges:

- Subjected to **extreme weather** conditions such as high winds, saltwater exposure, and corrosive environments.
- These conditions pose significant challenges to the **reliability and durability** of equipment, including transformers.
- Necessitating **robust design and materials** to withstand such environments.

Transformer placed in Naccelle (Offshore Wind)*

*https://www.daelimtransformer.com/wind-transformer.html

Importance of Dry type Transformers and Challenges

- Dry-type transformers play a crucial role in offshore wind energy systems by facilitating the **transmission and distribution** of electricity generated by offshore wind turbines.
- Their robust construction and insulation properties make them well-suited to withstand the challenging environmental conditions.

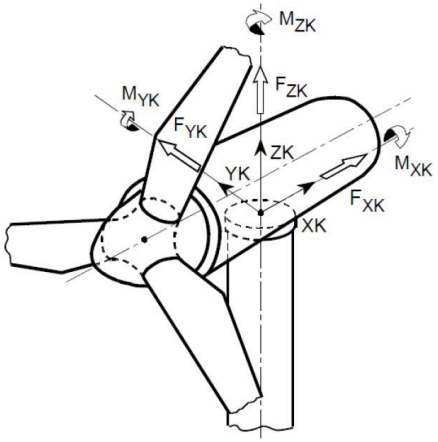
Challenges:

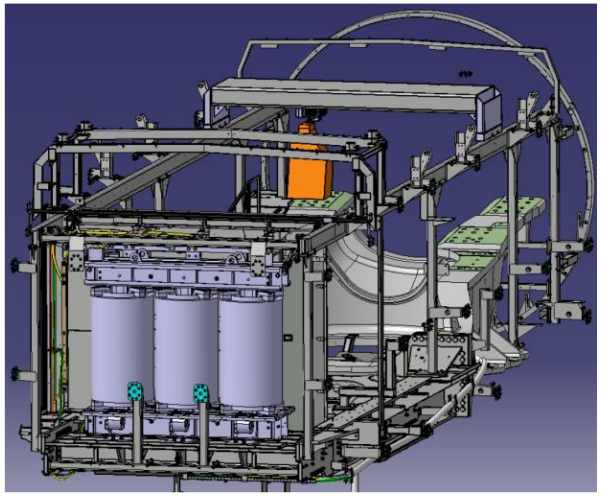
- **Vibrations** induced by wind, waves, and operational loads can **impact the structural integrity** also on transformers.
- Failures or malfunctions in transformers can result in significant economic losses, safety hazards, and disruptions to power supply.

Cast Resin (Dry type) Transformer

Need of Vibration Analysis for Structural Reliability of Transformer

- Vibration analysis plays a crucial role in optimizing the **performance and efficiency** of transformers.
- By **analysing vibration data and simulations**, we can identify inefficiencies, such as structural weakness and resonance, and implement corrective measures to improve overall performance**.**
- Optimizing performance through vibration analysis leads to **enhanced energy efficiency, reduced operational costs, and improved reliability** in offshore wind applications.

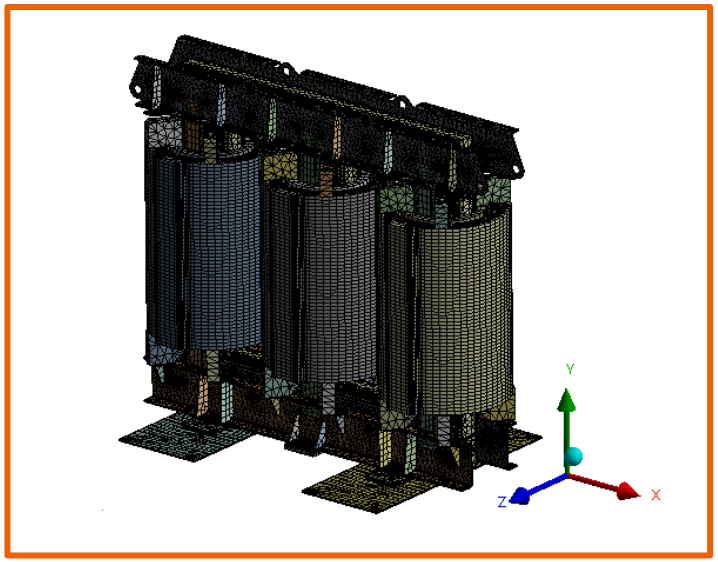




Reference nacelle and Location of Transformer in nacelle*

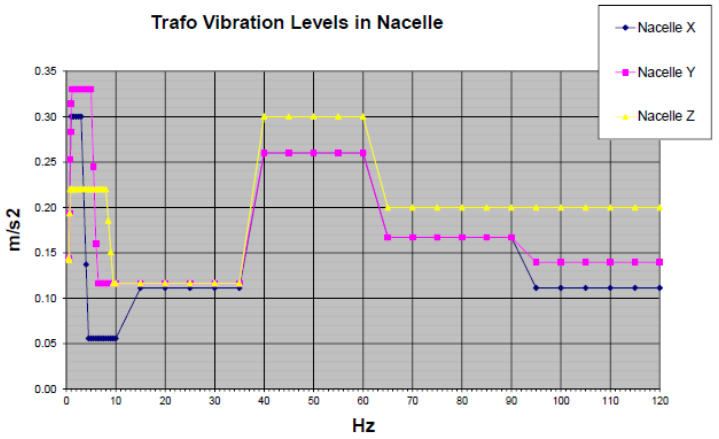
*SEDYC, s.r.o.

Vibration Analysis based on specification



Transformer Simulation Model (in Ansys)

- Vibration simulation can be done in FEA tool (Ansys), like **frequency analysis** (modal analysis) to identify the **Natural frequencies** / Eigenfrequencies to avoid resonance, which can be dangerous.
- **Random vibration analysis, transient analysis** also can be done(impact/shock analysis) based on customer specification according to international norms/standards*.
- Customer specified vibration profile is used in simulation model and at vibration test bench. Hence, simulation results can be validated as well.



Vibration Profile (Power Spectural Density -PSD Profile) based on IEC 62477-1-2012*

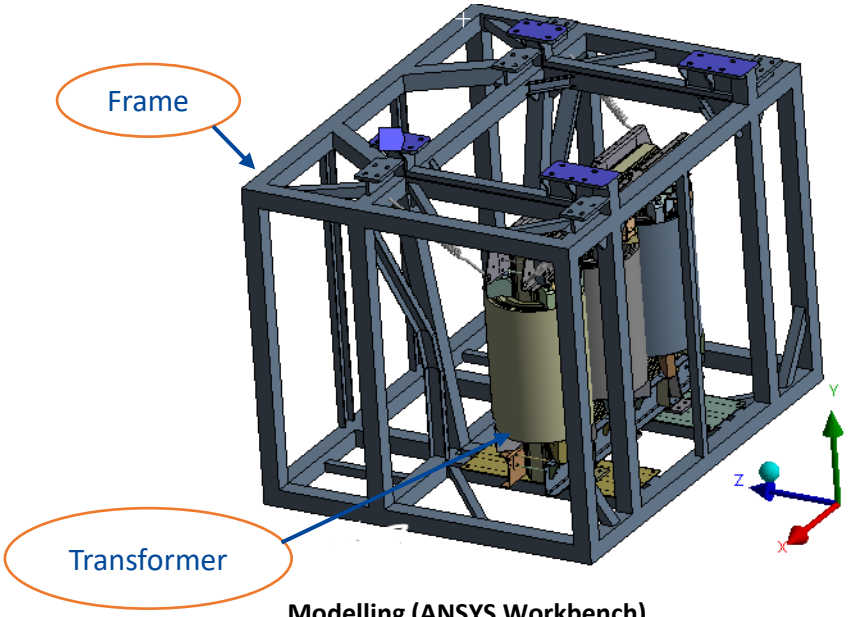
*IEC 62477-1-2012 -Safety requirements for power electronic converter systems and equipment - Part 1: General

Modal analysis of Transformer placed inside the Frame

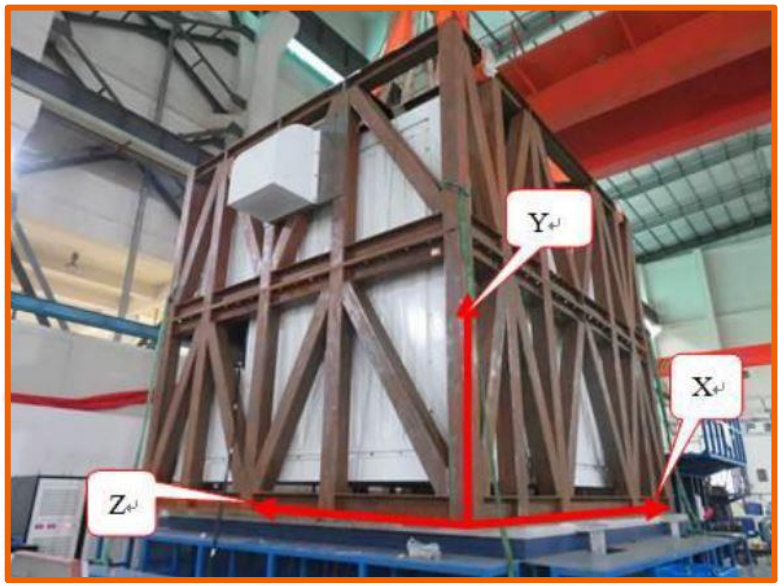
- Modal analysis is important **for identifying the natural frequencies** that are consequential.

Boundary Conditions:

- Modal Analysis of Transformer placed inside the frame with **bonded contact** at bottom of the transformer to the frame and **spring contact** from top of the transformer to frame with some spring stiffness.
- Further frictional contact (with coefficient of friction), rough contact, fixed support etc.



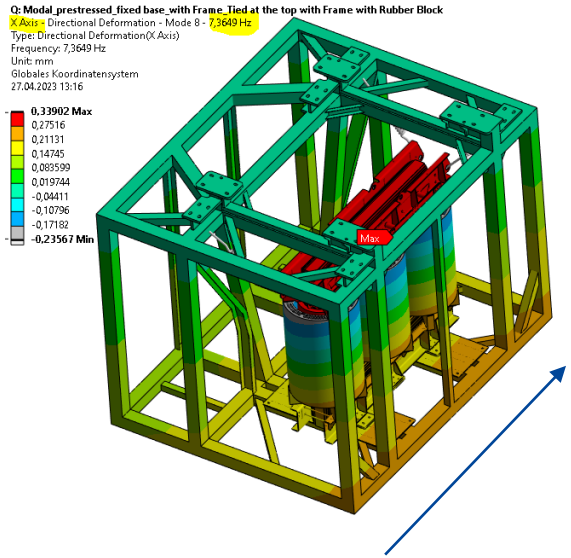
Modelling (ANSYS Workbench)



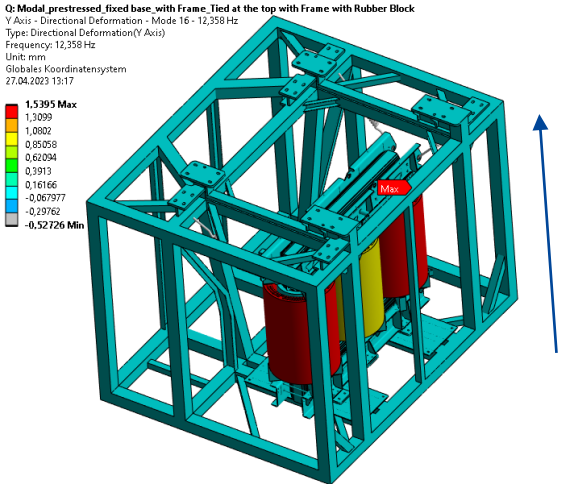
Vibration Test Setup (on Test Bench)

Result of modal analysis simulation, first and dominant modes

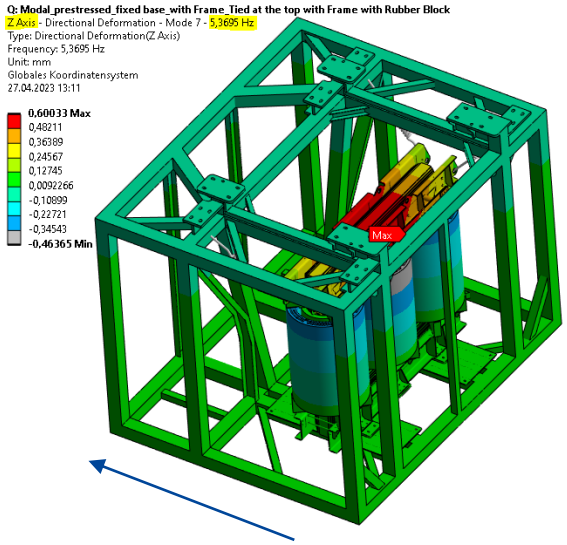
Natural Frequency mode at 7,36 Hz / x-direction



Natural Frequency mode at 12,35 Hz / y-direction



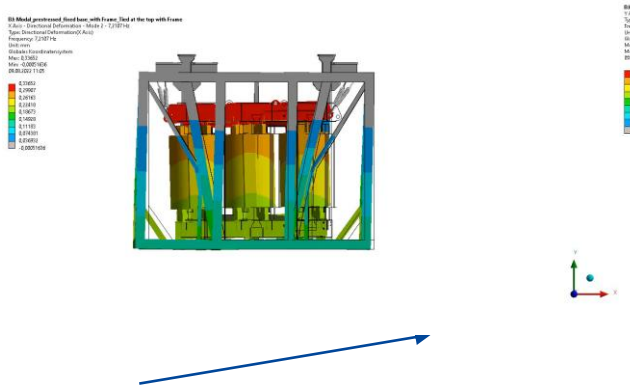
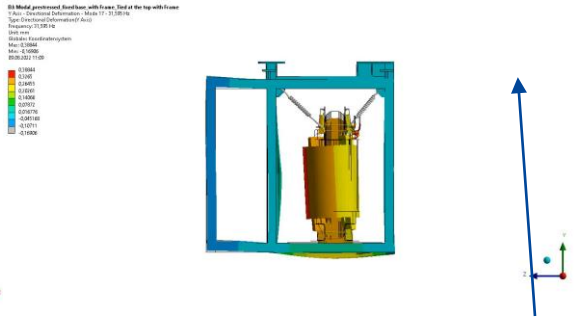
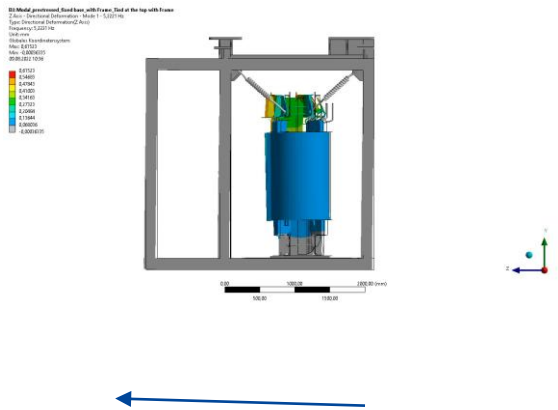
Natural Frequency mode at 5,36 Hz / z-direction



Vibration Simulation Results from Ansys

Direction	Frequency (Hz)
Z	5,36
X	7,36
Y	12,35

Result of modal analysis simulation, first and dominant modes

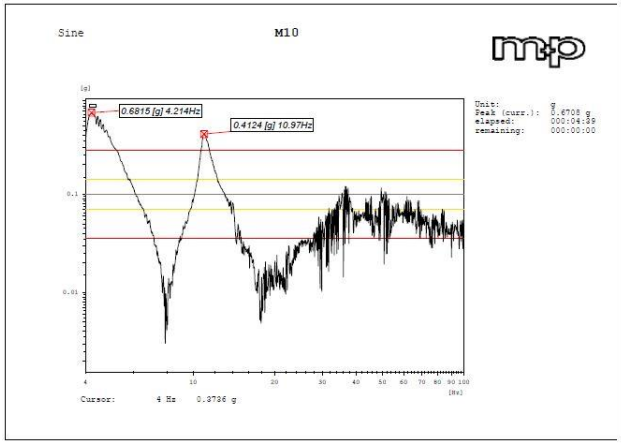
Natural Frequency mode at 7,36 Hz / x-direction (Transverse)	Natural Frequency mode at 12,35 Hz / y-direction (Vertical)	Natural Frequency mode at 5,36 Hz / z-direction (Longitudinal)
		

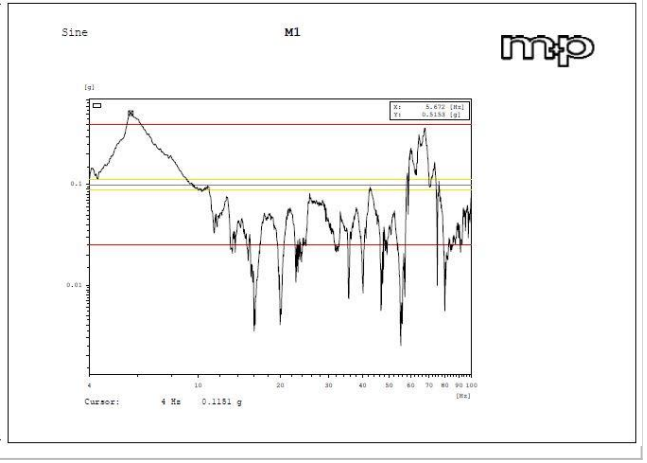
Vibration Simulation Results from FEA tool

Direction	Frequency (Hz)
Z	5,36
X	7,36
Y	12,35

Test results for Eigenfrequency/Natural Frequency

Natural Frequency x-direction	Natural Frequency y-direction	Natural Frequency z-direction





Vibration Test Results from Test bench

Direction	Frequency (Hz)
Z	5,65
X	10,97
Y	11,81

Result comparison and model validation

Direction	Frequency (Hz) (Test)	Frequency (Hz) (Simulation)
Z	~5,65	5,36
X	~10,97	7,36
Y	~11,81	12,35

Results comparison

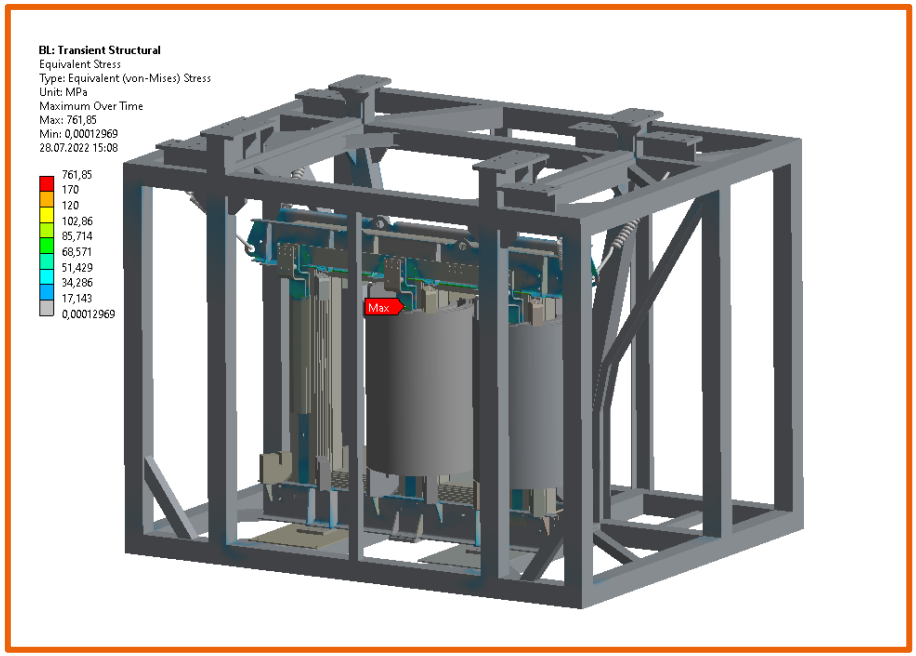
- Simulation results and test results quite align in all the directions.
- In X direction, simulation model was further adjusted particularly winding part, which is quite complicated to handle in FEA tool.
- Identification for actual damping ratio can be used in further simulation model.
- This verified simulations provide basis for the further simulations.

Transient analysis and Random Vibration Analysis

- After model validation and simulation model improvement, Random vibration simulations and Transient simulation can be carried out in FEA tool for further safety and design opimization according to norms/standards**.

Frequency (Hz)	Acceleration (g^2/Hz)	Acceleration spectral density (grms)
2	0,0027	0,51
100	0,0027	

Random Vibration Vibration Profile*



Transient simulation (ANSYS Workbench)

*Goldwind GW175-6.0 dry-type transformer vibration test procedure for wind turbine generator (WTG)

**IEC 62477-1-2012 -Safety requirements for power electronic converter systems and equipment - Part 1: General

Conclusion

- **Offshore wind energy** holds significant promise as a sustainable solution for meeting the increasing global energy needs.
- **Safety** is paramount in **transformer design** for offshore wind applications.
- **Vibration Analysis** is important for precise transformer design.
- **SGB-SMIT Group** has **capability** to do such vibration analysis and simulations.
- Transformer designs **undergo thorough evaluation** to ensure compliance with **international safety standards**.
- **Experimentally validated simulation results** ensure accuracy and reliability in predicting natural frequencies.

SGB-SMIT Group

Thank you

Questions & Comments ?