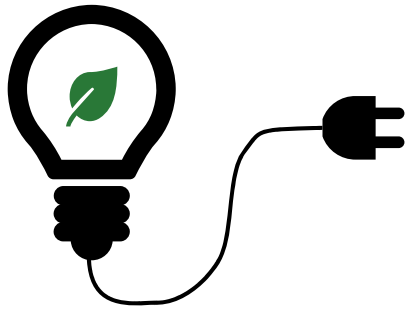




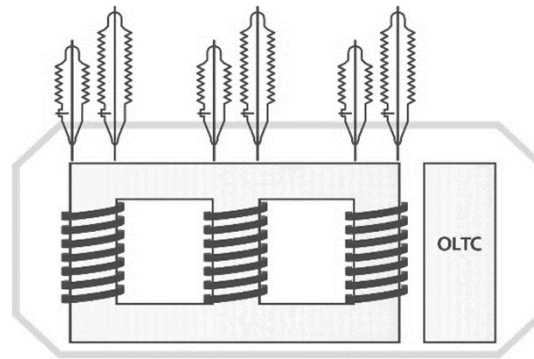
Hochspannungssymposium 2022

Automatisierte Qualitätsprüfung und Interpretation von SFRA-Daten
mittels künstliche Intelligenz

► Motivation

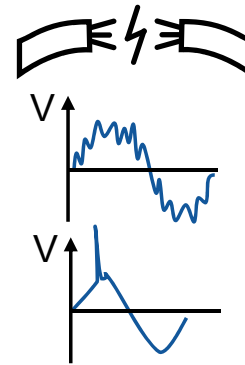


Anteil der erneuerbaren Energien hat sich mehr als verdoppelt (2004-2019) [1]



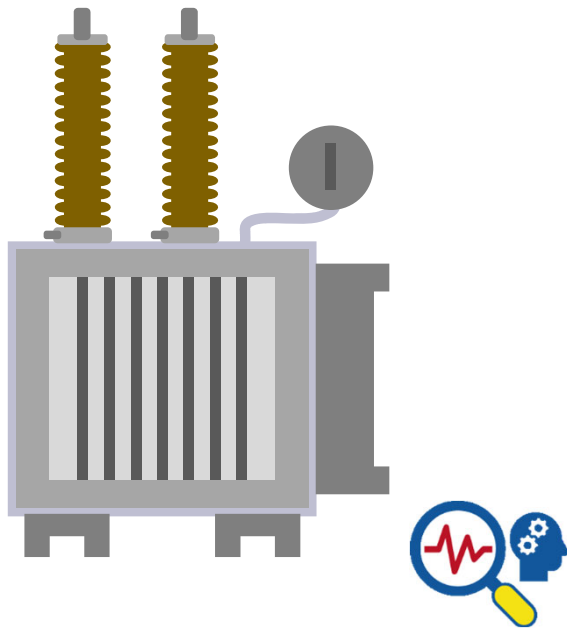
Steigendes Risiko von gefährlichen Effekten wie:

- Kurzschlüsse
- Oberschwingungen
- Transiente Spannungen



Verlängerung des Lebenszyklus von Leistungstransformatoren

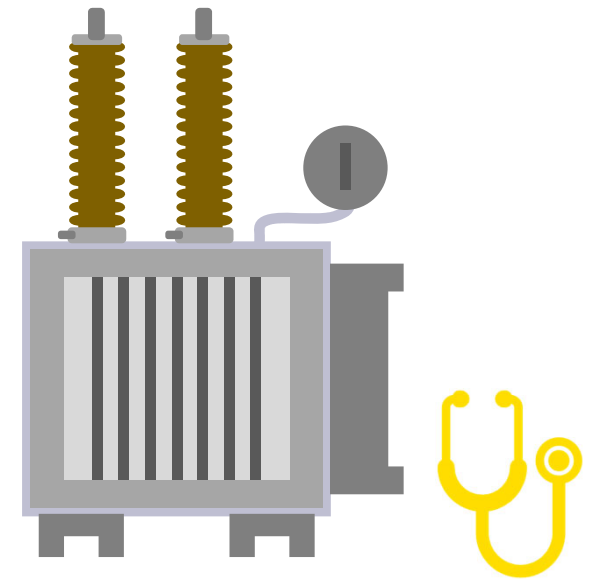
► Motivation



Online Daten
(Monitoring, Betriebsdaten)



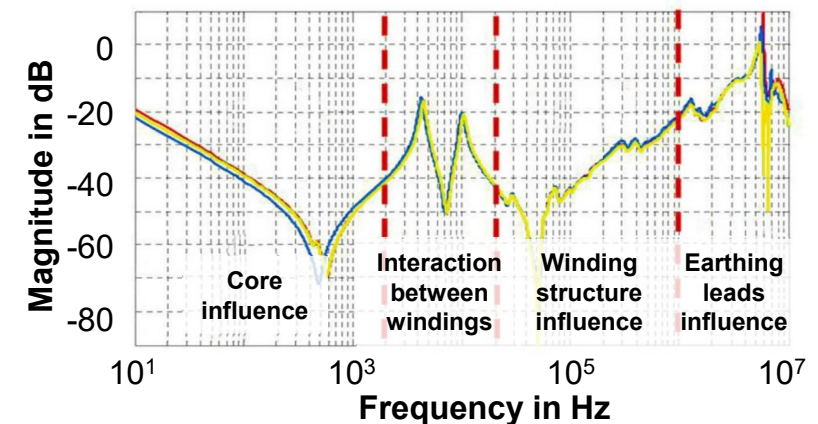
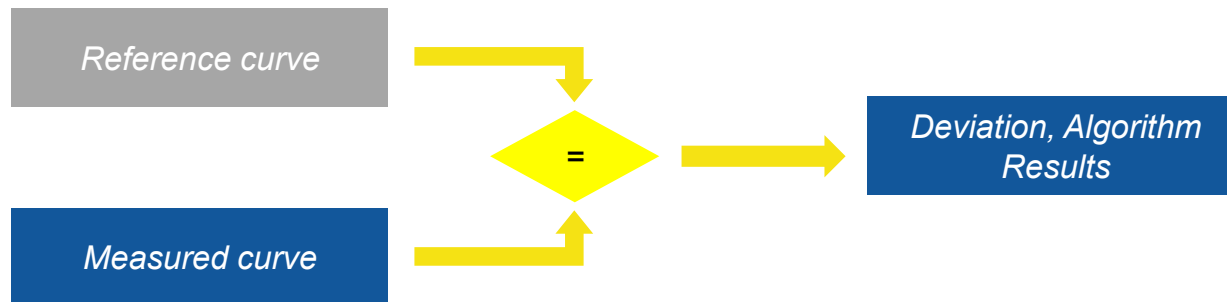
A2.49



Offline Daten
(Diagnostische Messungen)

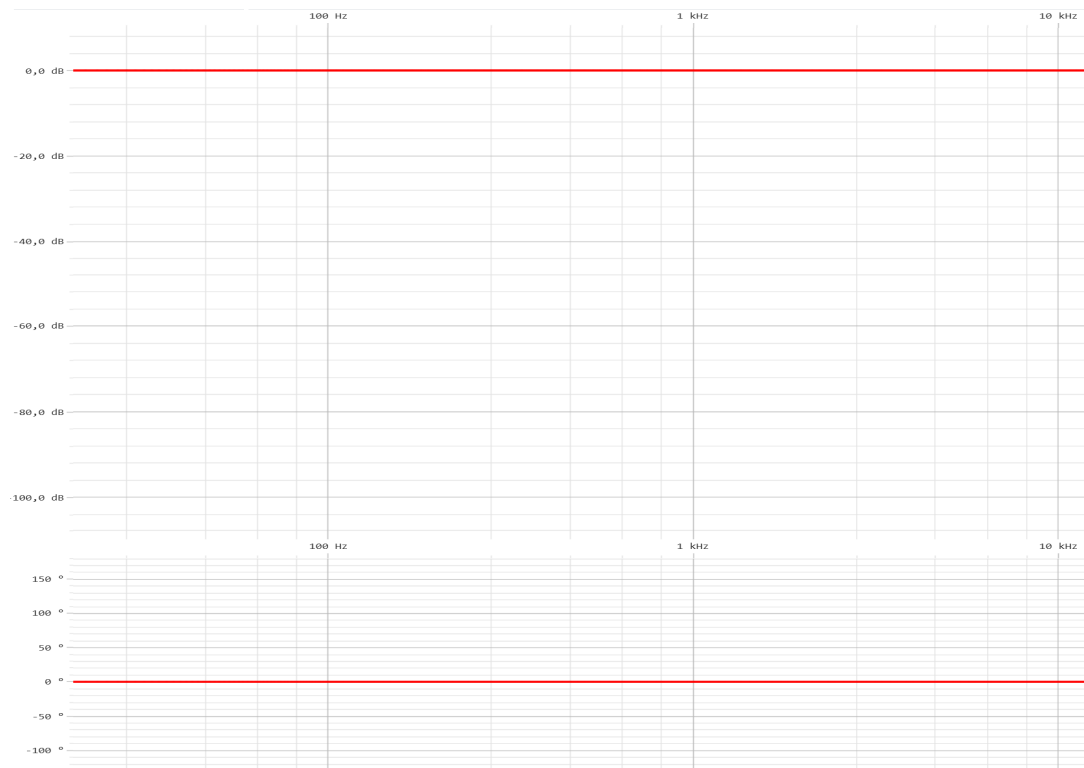
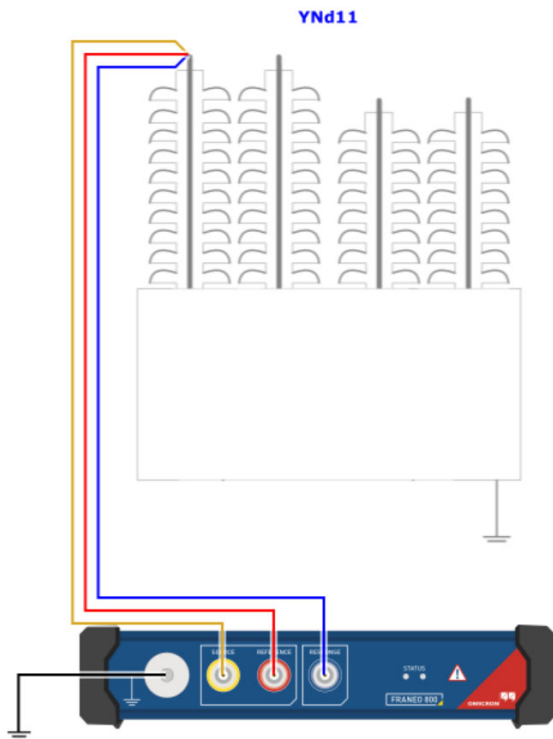
Die SFRA Messmethode

- ▶ Messung von elektrischen Übertragungsfunktionen über einen großen Frequenzbereich
- ▶ Weltweit bewährte Methode für Messungen im Frequenzbereich
- ▶ Bewertung des Transformatorenzustands (mechanische Integrität/elektrischer Zustand) durch Vergleich der SFRA-Ergebnisse mit Referenzergebnissen



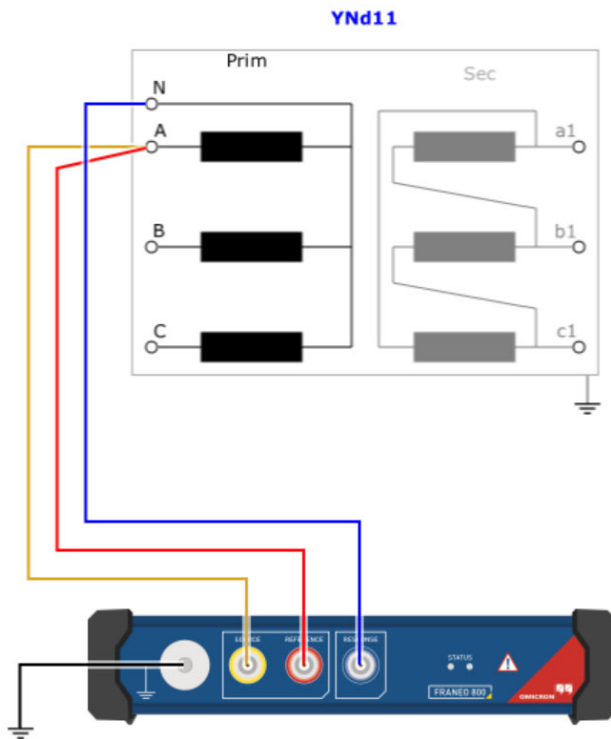
Die verschiedenen SFRA Messungen und deren Muster

Kalibrierung (Zero-Check)



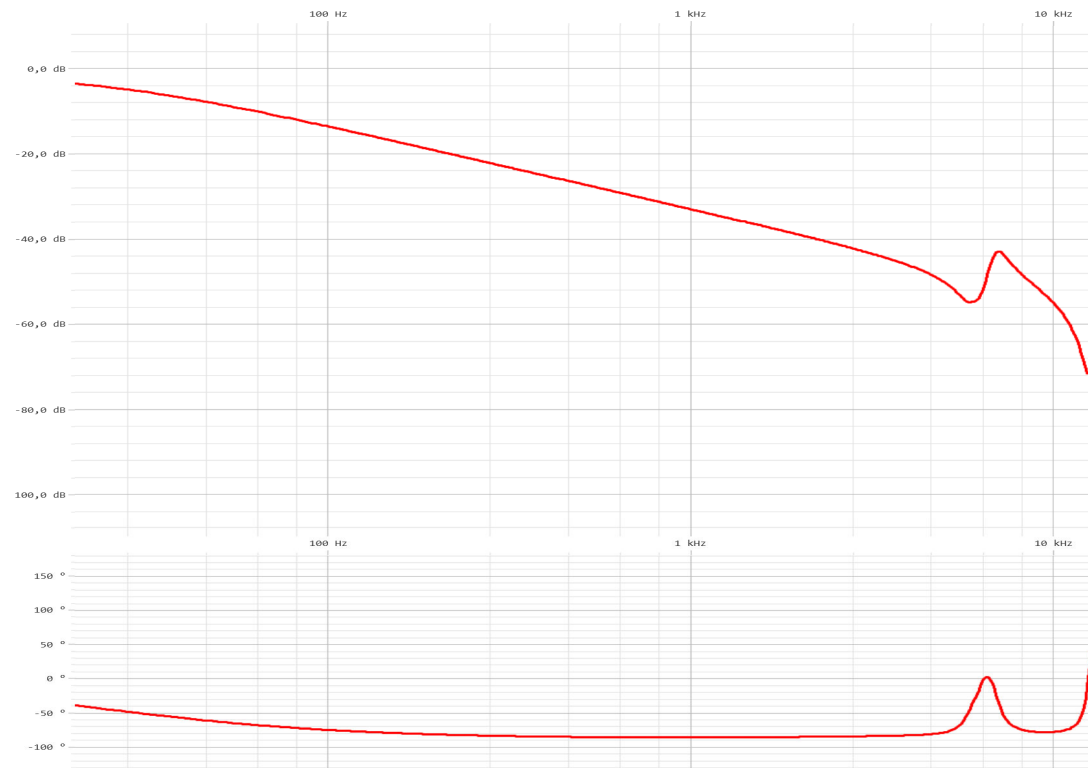
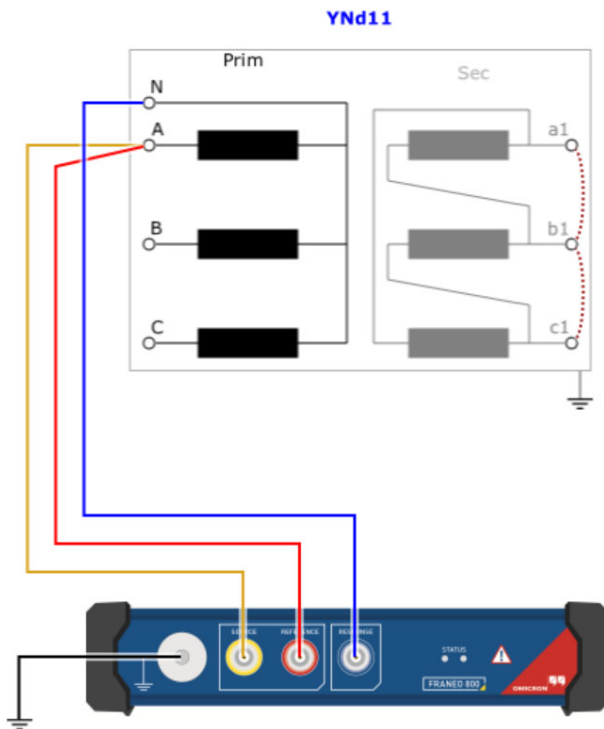
Die verschiedenen SFRA Messungen und deren Muster

End-to-end open circuit



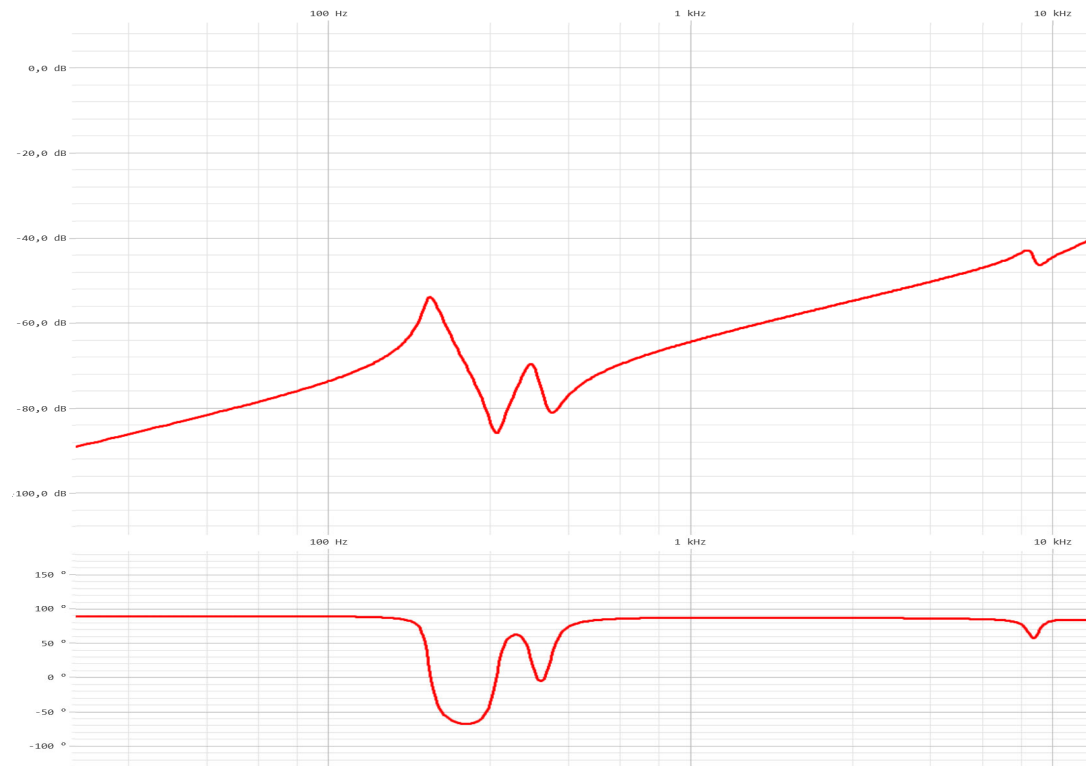
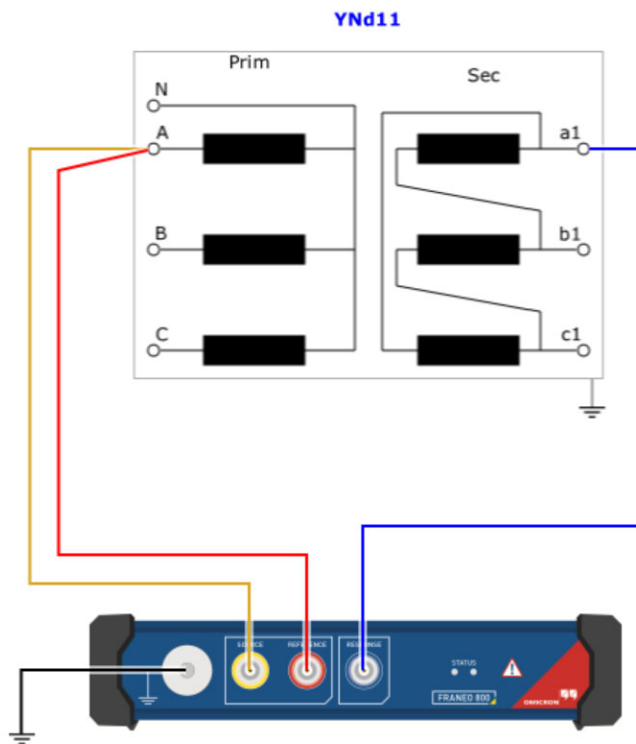
Die verschiedenen SFRA Messungen und deren Muster

End-to-end short circuit



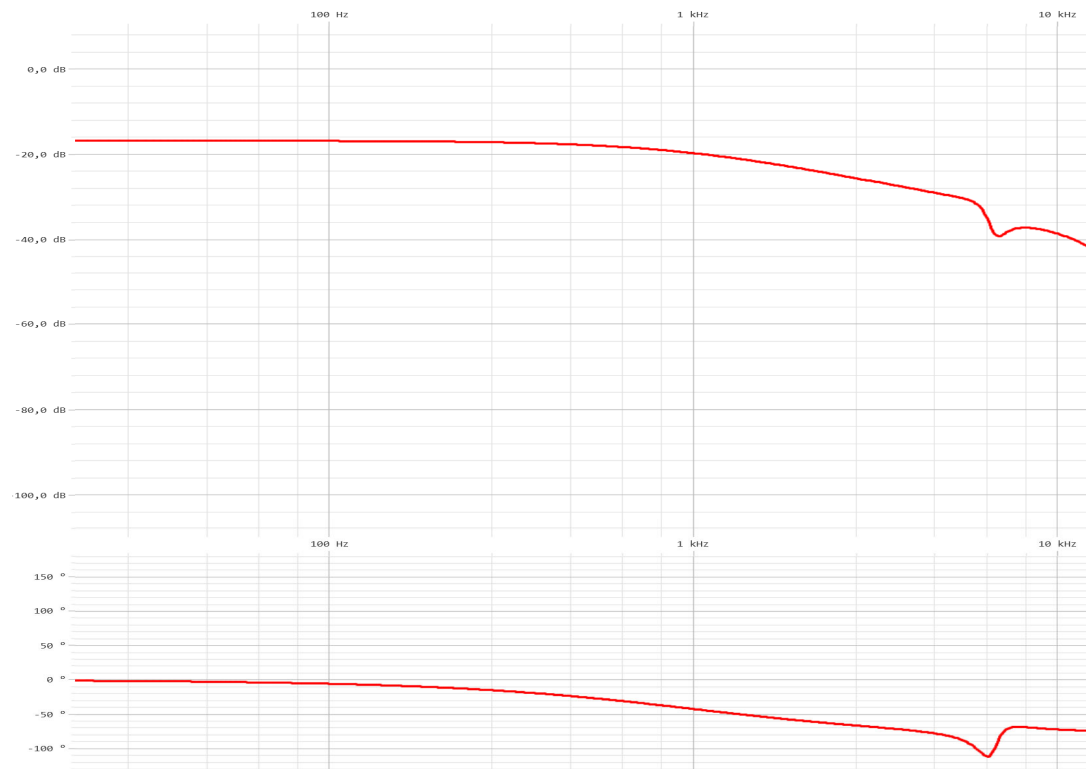
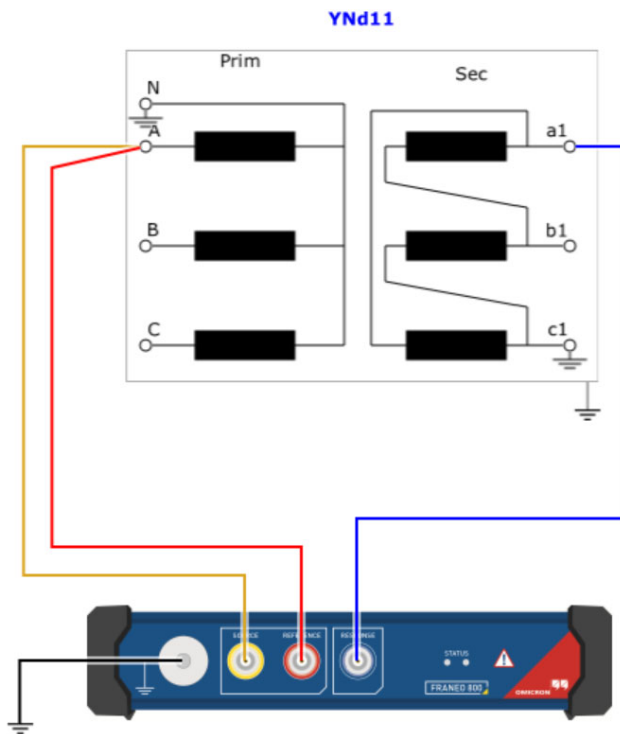
Die verschiedenen SFRA Messungen und deren Muster

Capacitive interwinding



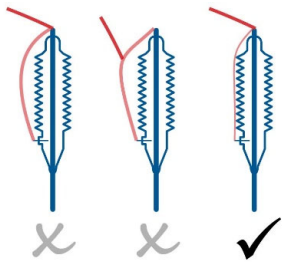
Die verschiedenen SFRA Messungen und deren Muster

► Inductive interwinding

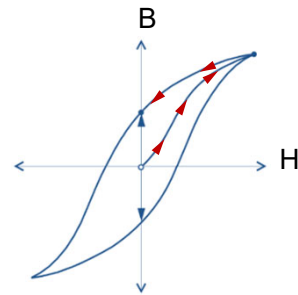


► Faktoren welche die SFRA Messung beeinflussen

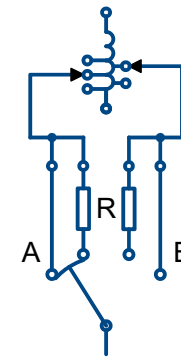
Anschlussfehler



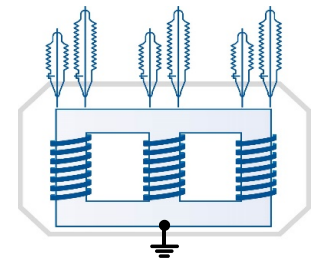
Restmagnetismus



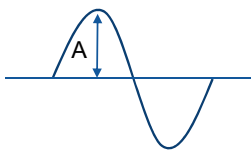
Stufenschalterposition



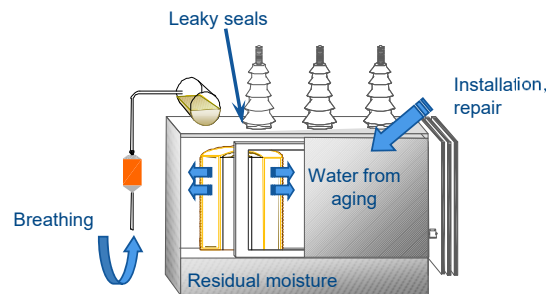
Kern Erde



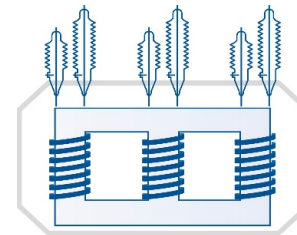
Einspeisespannung



Temperatur und Luftfeuchtigkeit



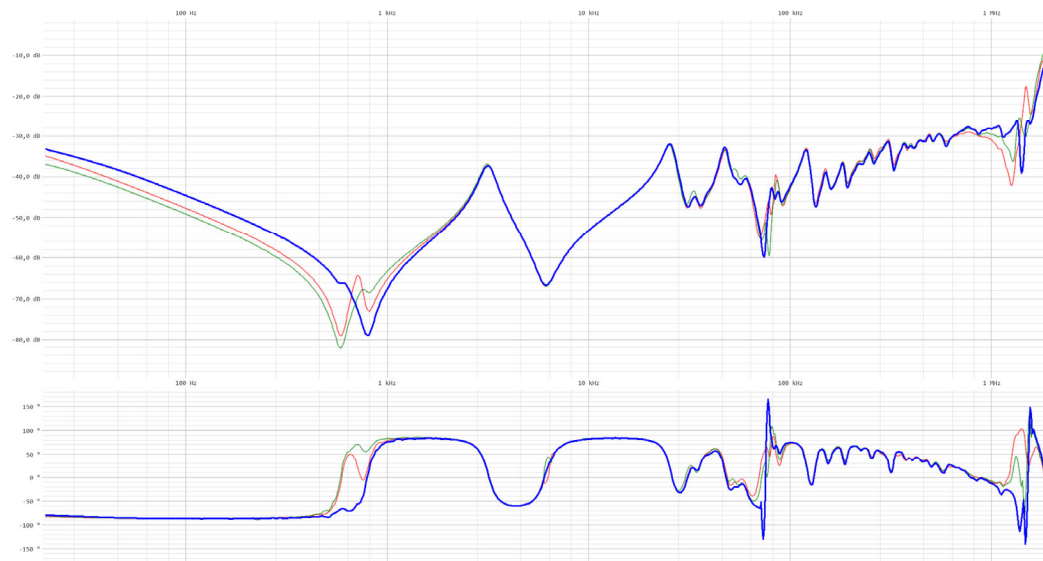
Einspeiserichtung



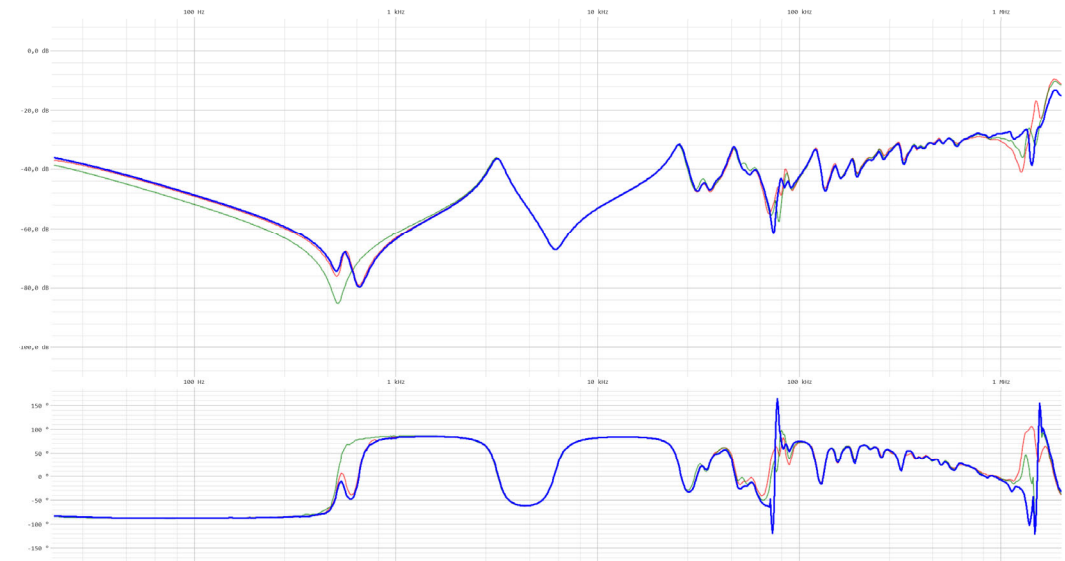
A2.53

Auswirkung von Restmagnetismus

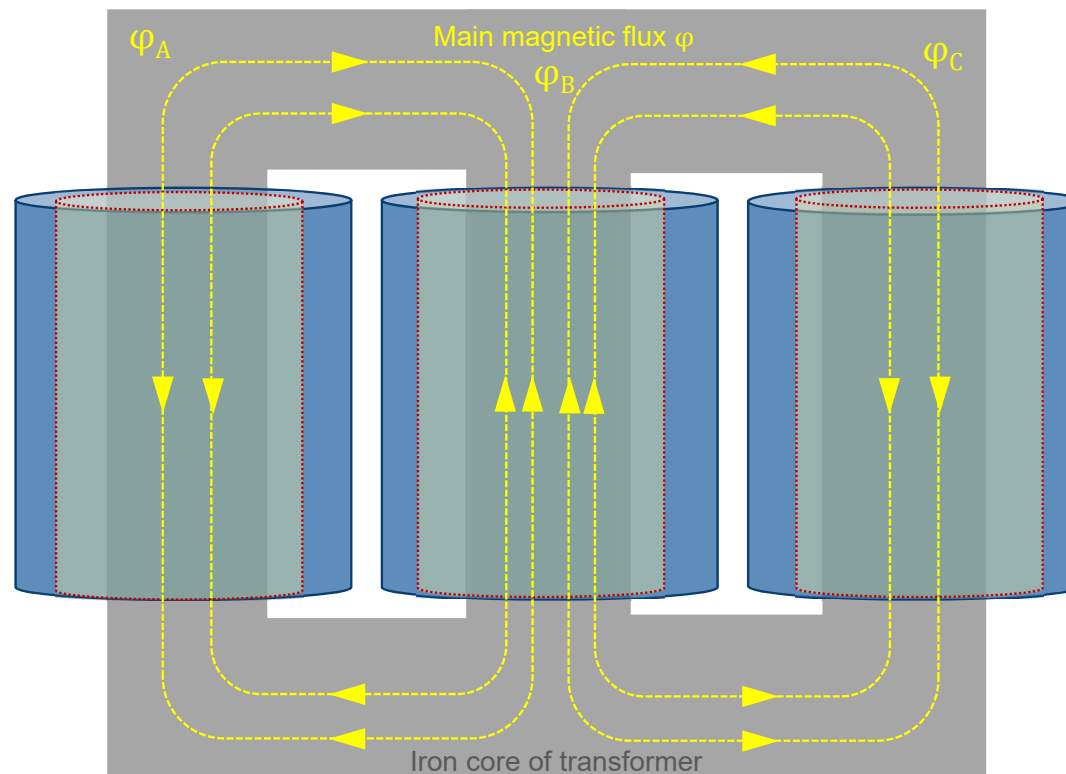
Nach dem Wicklungswiderstandstest



Nach der Entmagnetisierung

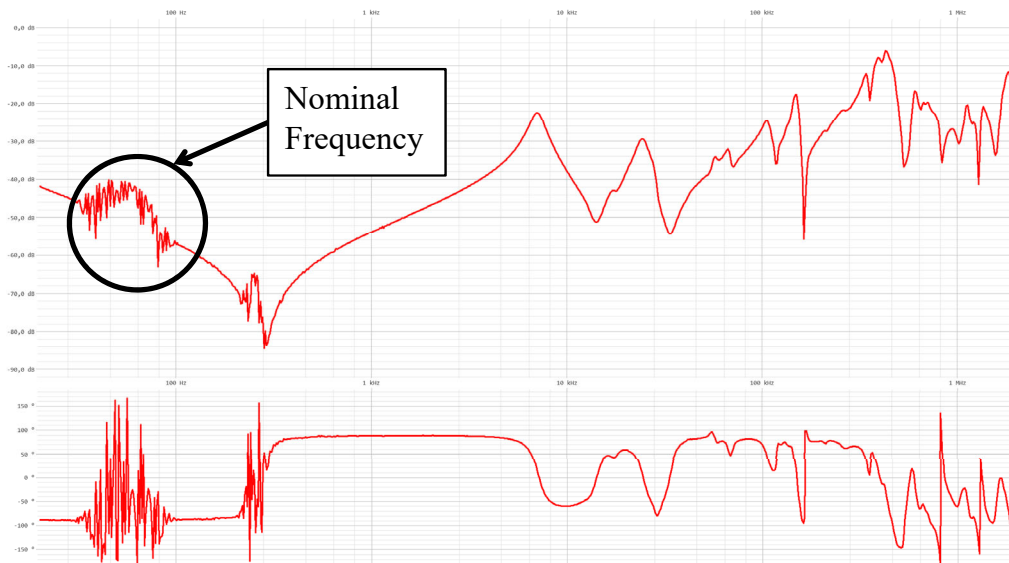


Leistungstransformator mit drei Schenkeln

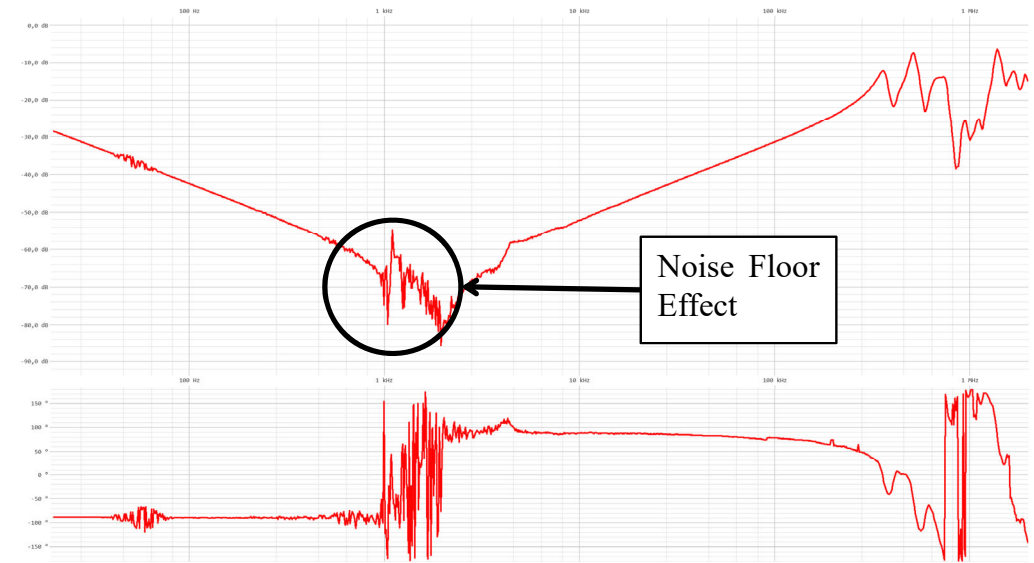


Auswirkung externer Faktoren

Auswirkung von externen Interferenzen

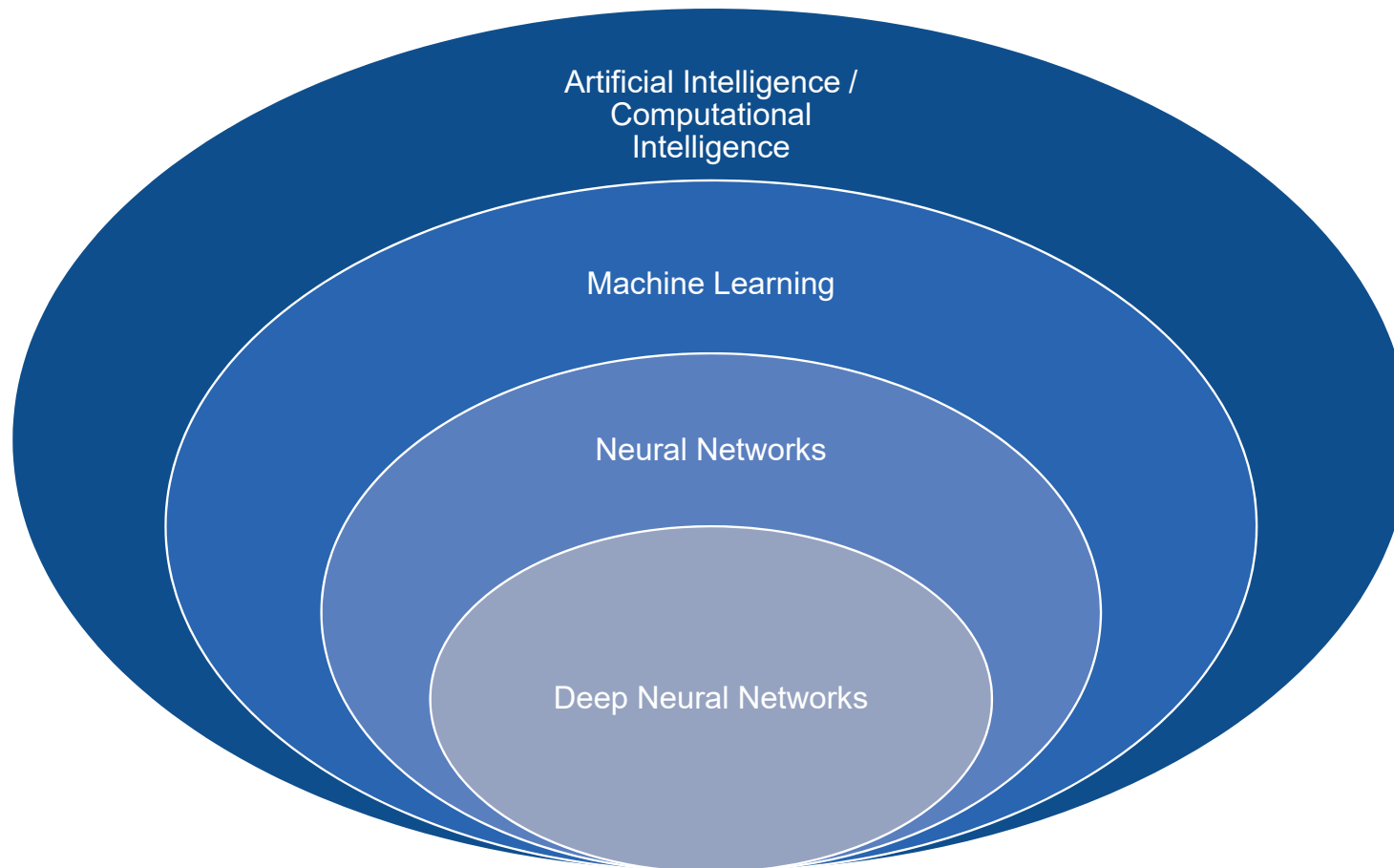


Auswirkung eines unzureichenden Dynamikbereichs

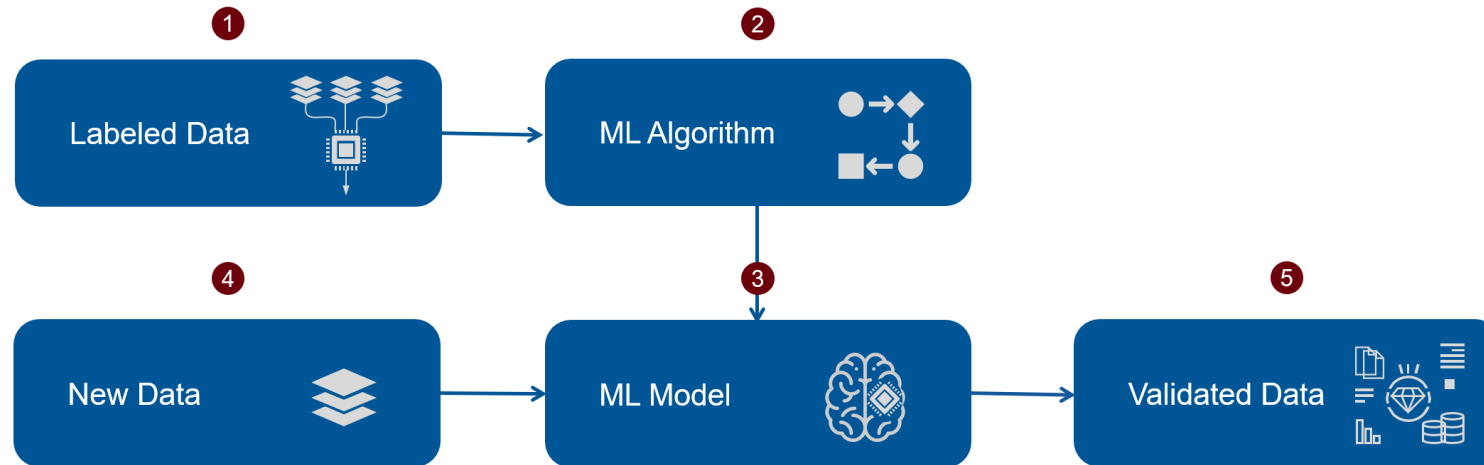


Die klassischen AI Schichten

14



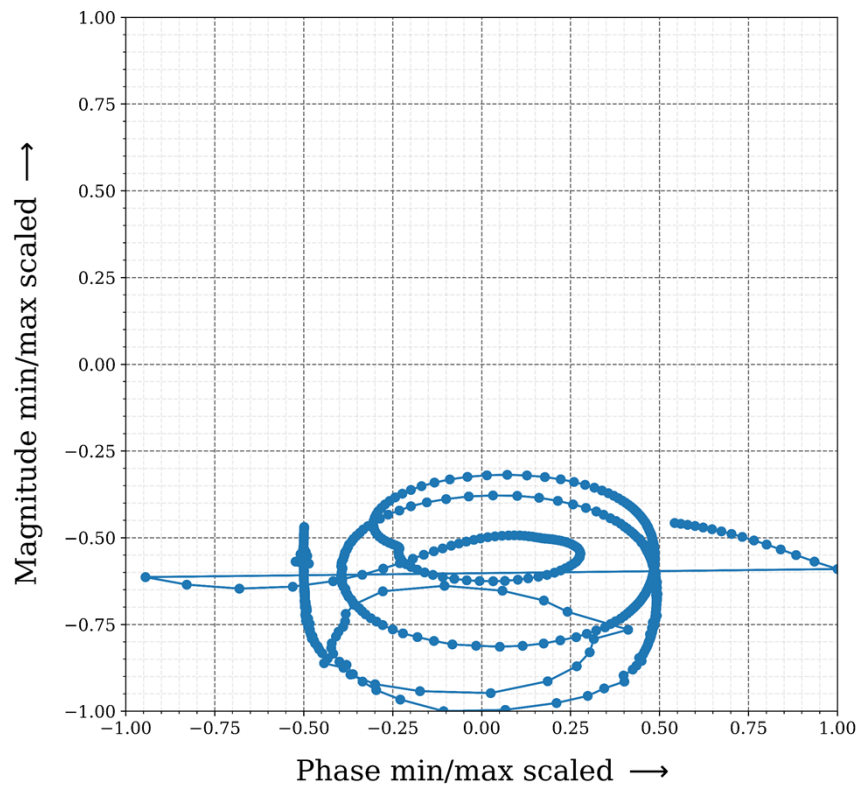
► Supervised Machine Learning Prozess



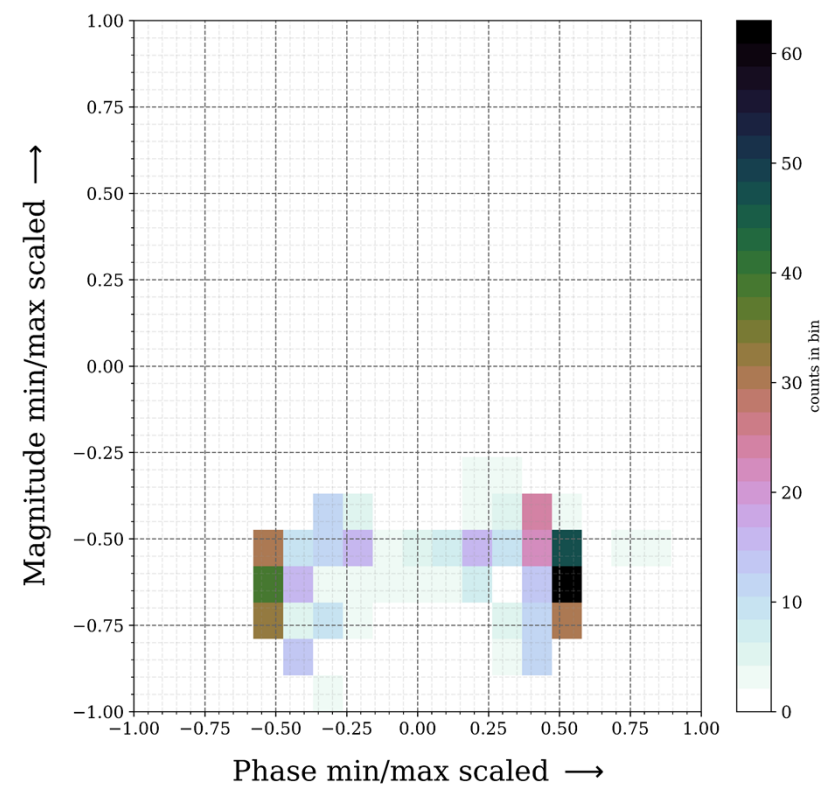
- Pattern (**Unknown**, **Zero-Check**, **End-to-End open circuit** , **End-to-End short circuit**, **capacitive Interwinding**, **inductive Interwinding**)
- Klassifizierungsmetriken für die Messqualität
 - **Pass** (gute qualität)
 - **Investigate** (ausreichend, muss überprüft werden)
 - **Error** (nicht verwendbar)

► SFRA Mustererkennung: End-to-end open circuit

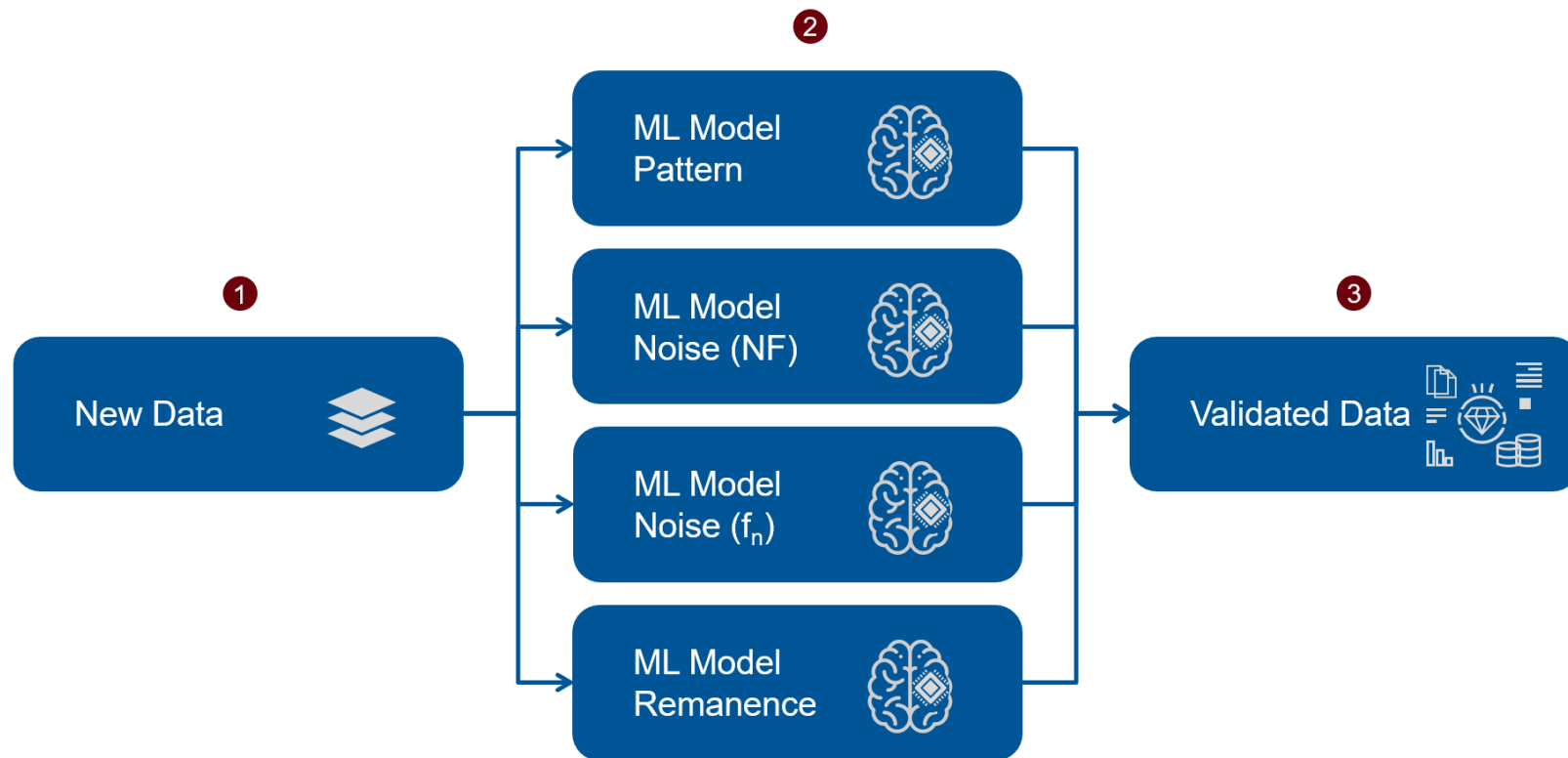
Nicholas Plot – Min/Max skaliert



Nicholas Plot Histogramm – Min/Max skaliert



► SFRA Daten-Validierungsworkflow



► Modellresultat – externe Faktoren

Power Frequency/Harmonic Noise Prediction

True Label			
	OK	Investigate	Error
	OK	Investigate	Error
	Predicted Label		
OK	100%	0%	0%
Investigate	0%	100%	0%
Error	0%	0%	100%

Dynamic Range/Noise Floor Prediction

True Label			
	OK	Investigate	Error
	OK	Investigate	Error
	Predicted Label		
OK	100%	0%	0%
Investigate	0%	100%	0%
Error	0%	0%	100%

► Modellresultat – Transformator Zustand und Muster

Remanence Prediction

True Label	OK	86%	6,9%	6,9%
	Investigate	6,5%	87%	6,5%
	Error	0%	1,3%	87%
		OK	Investigate	Error
Predicted Label				

Patrern Prediction

True Label	Unknown	86%	4,7%	3,1 %	4,7%	0%	1,6%	
	Calibration	1,8%	100%	0%	0%	0%	0%	
	End-To-End Open	0%	0%	100%	0%	0%	0%	
	End-To-End Short Circuit	0%	1,6%	1,6%	97%	0%	0%	
	Capacitive Interwinding	0%	0%	3,1%	0%	95%	1,6%	
	Inductive Interwinding	0%	0%	0%	0%	0%	100%	
		Unknown	Calibration	End Open Circuit	End-To- End Short Circuit	End-To- ng Interwindi	Capacitive ng Interwindi	Inductive Interwindi
Predicted Label								



Vielen Dank für Ihre Aufmerksamkeit!

Emotions are energy. Our energy moves.



► Quellenverzeichnis

- [1] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable_energy_statistics#Share_of_renewable_energy_more_than_doubled_between_2004_and_2019, Zugriff 2022-04-04 11:15