



REAP CARE

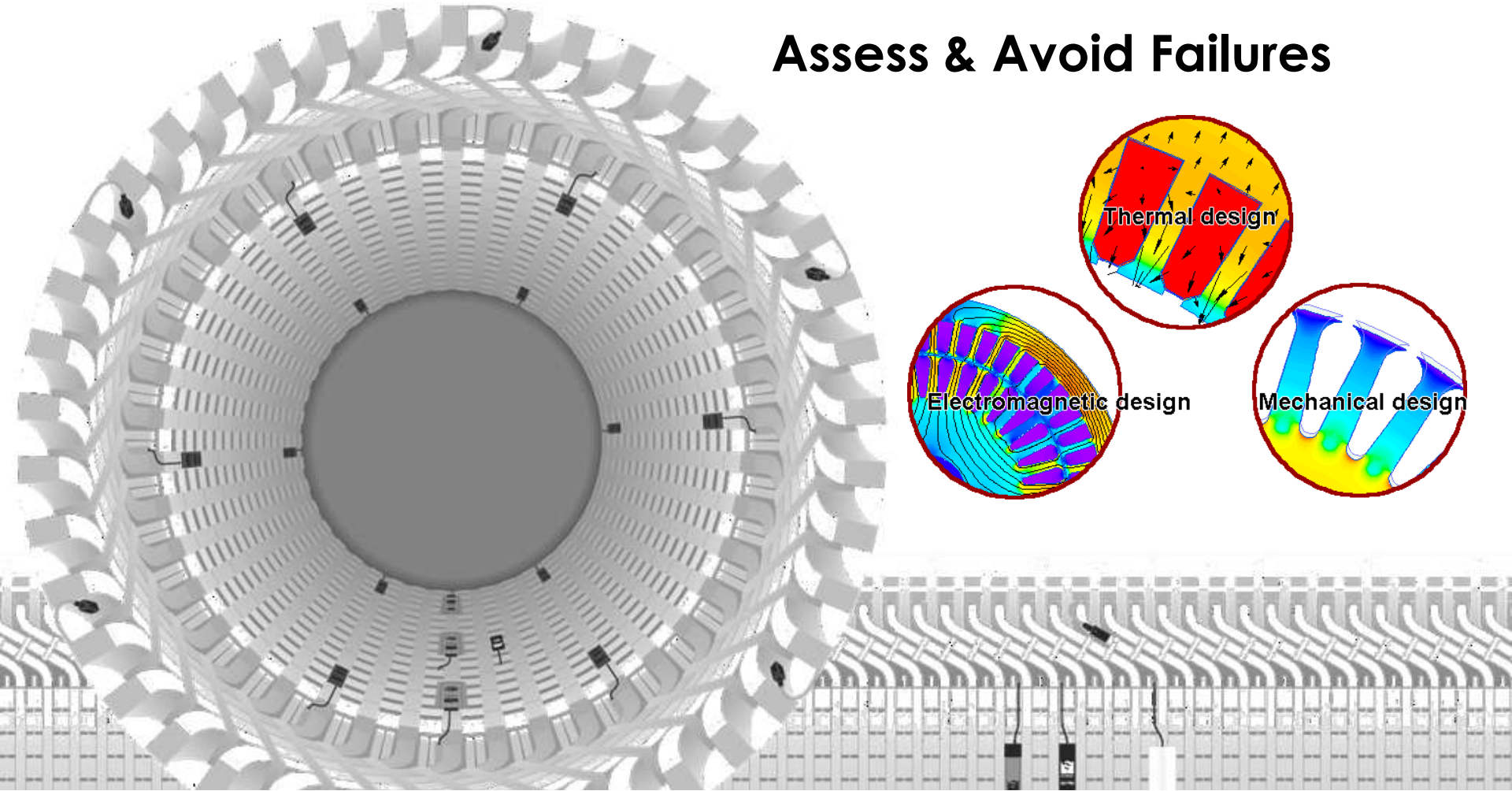


ROTATING ELECTRICAL ASSET PROGNOSTIC CARE

Longevity approach



Assess & Avoid Failures



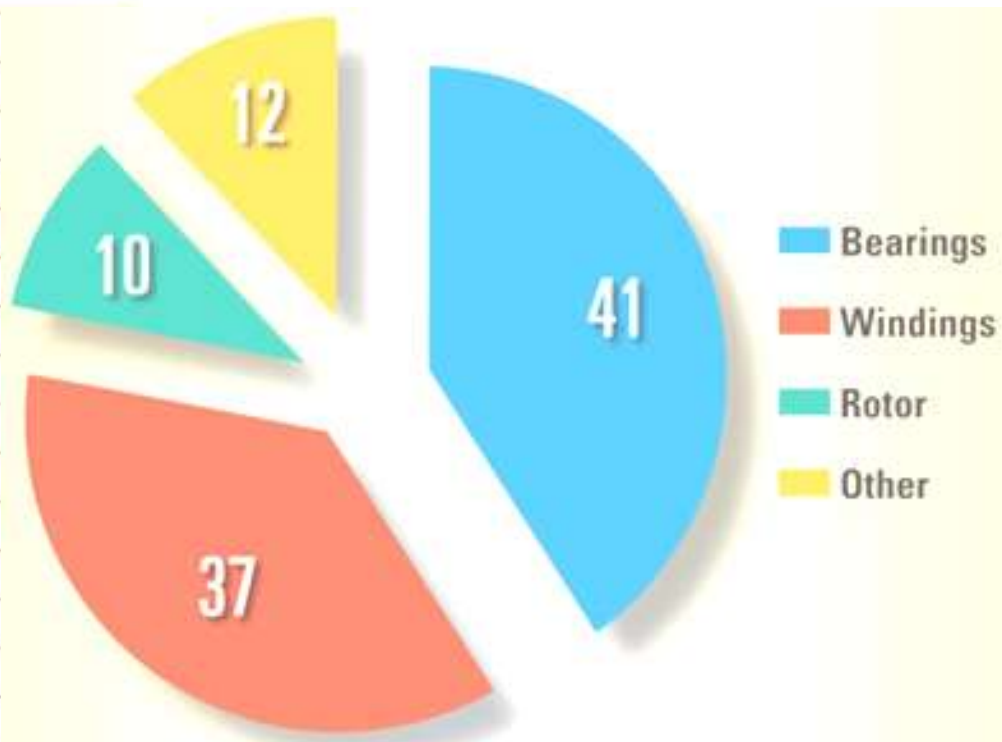
ROTATING **E**LECTRICAL **A**SSET **P**ROGNOSTIC CARE

Failure Statistics



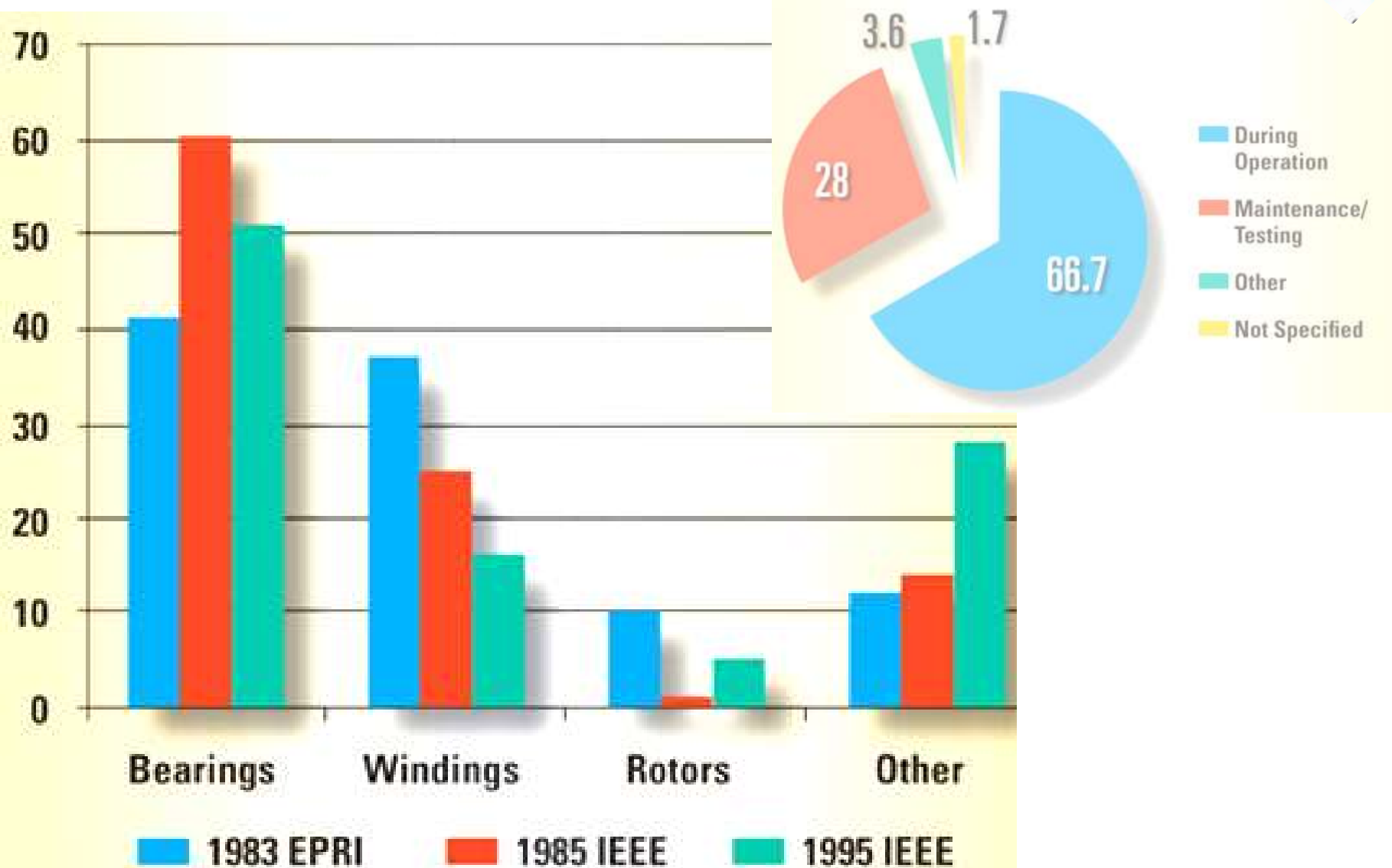
Table I. 1983 EPRI Study Motor-Failure Modes [1]

Failure Mode	Number of Motors	Percent of Total (%)
Other – Unspecified	313	35.9
Insulation to Ground	161	18.5
Sleeve Bearing	85	9.7
Ball Bearing	43	4.9
Thrust Bearing Vertical	41	4.7
Oil Leakage	36	4.1
Turn Insulation (Short)	32	3.7
Rotor Bar Failure	31	3.5
Roller Bearing	20	2.3
Bearing Seal	20	2.3
Loose Blocking	16	1.8
Rotor Shaft	13	1.5
Oil System	12	1.4
Stator Slot Wedges	11	1.3
Loose Iron	9	1.0
Stator Frame	7	0.8
Line Cable	6	0.8
Coil Connection	5	0.6
Balance Weights	5	0.6
Accessories	4	0.5
Thrust Bearing Horizontal	2	0.2

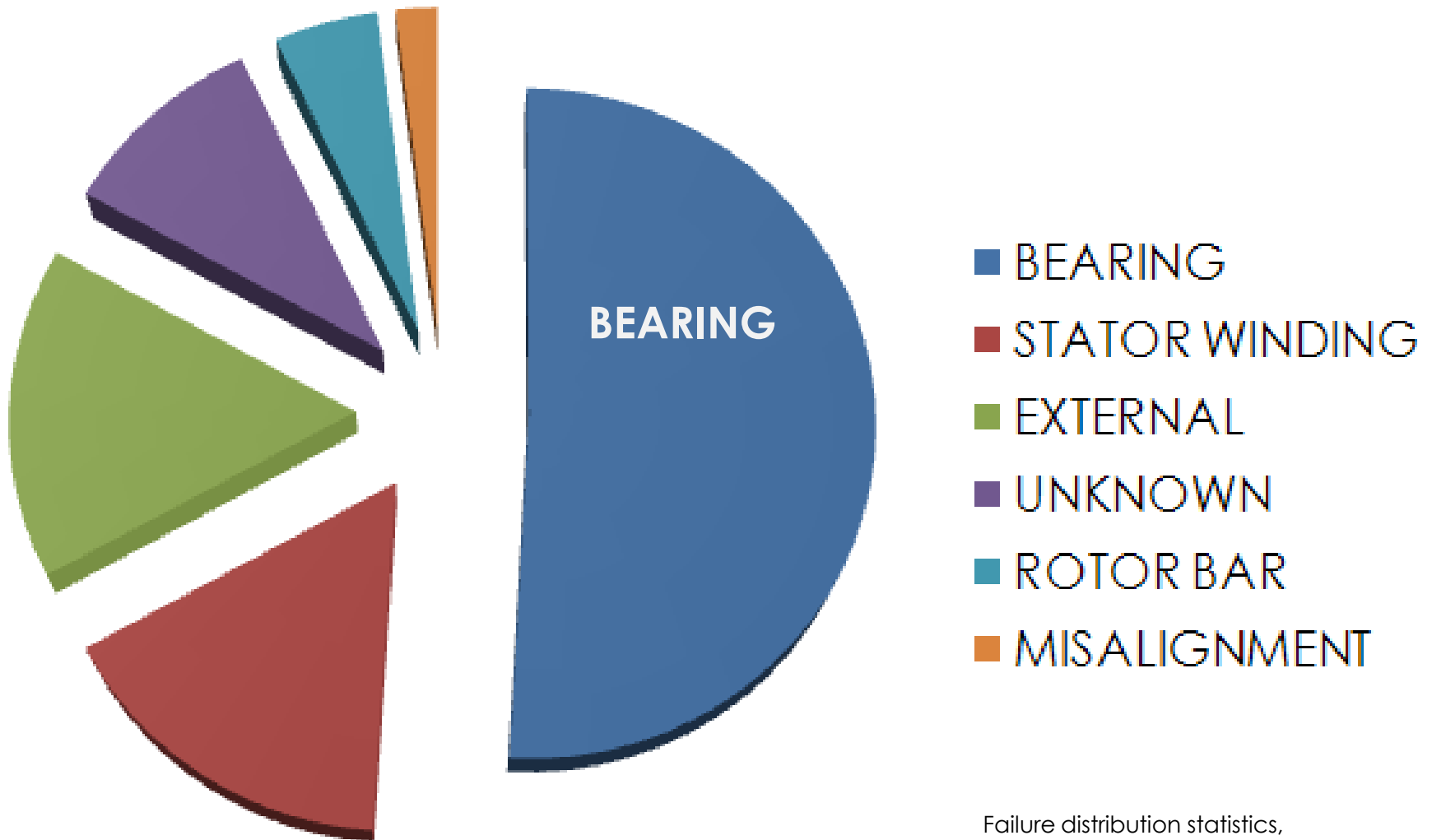


g. 1. 1983 EPRI Study motor-failure rates [1]

Failure Statistics ...

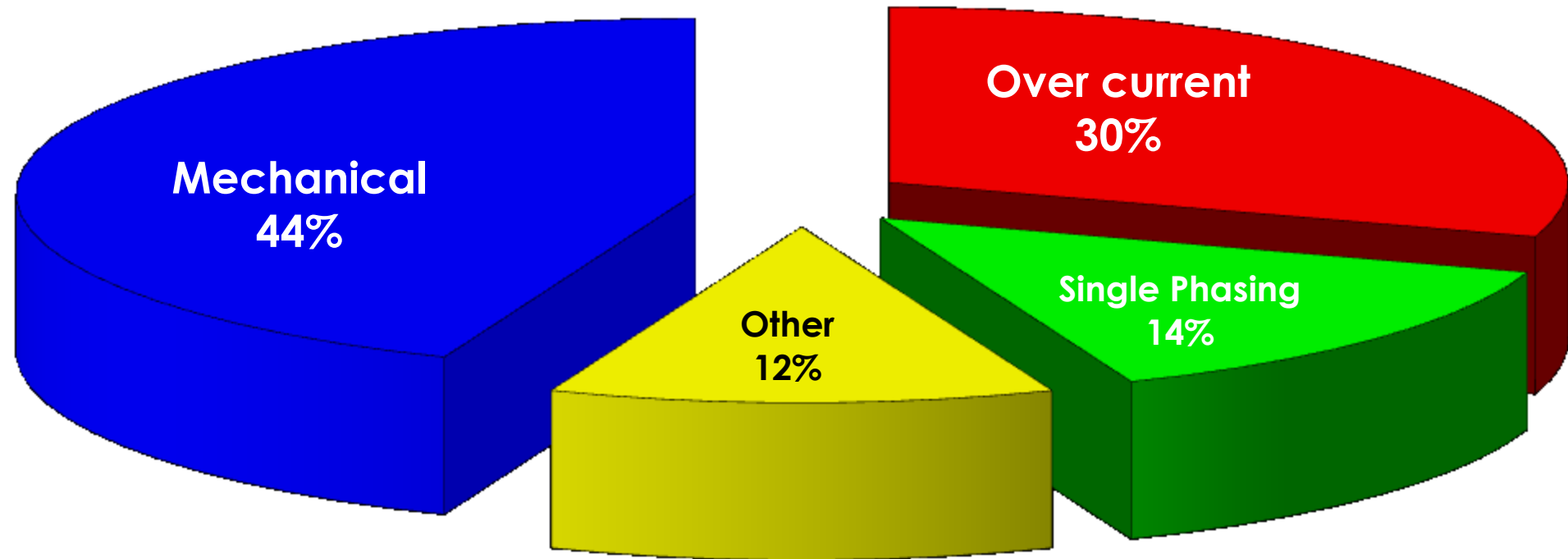


Failure Statistics ...



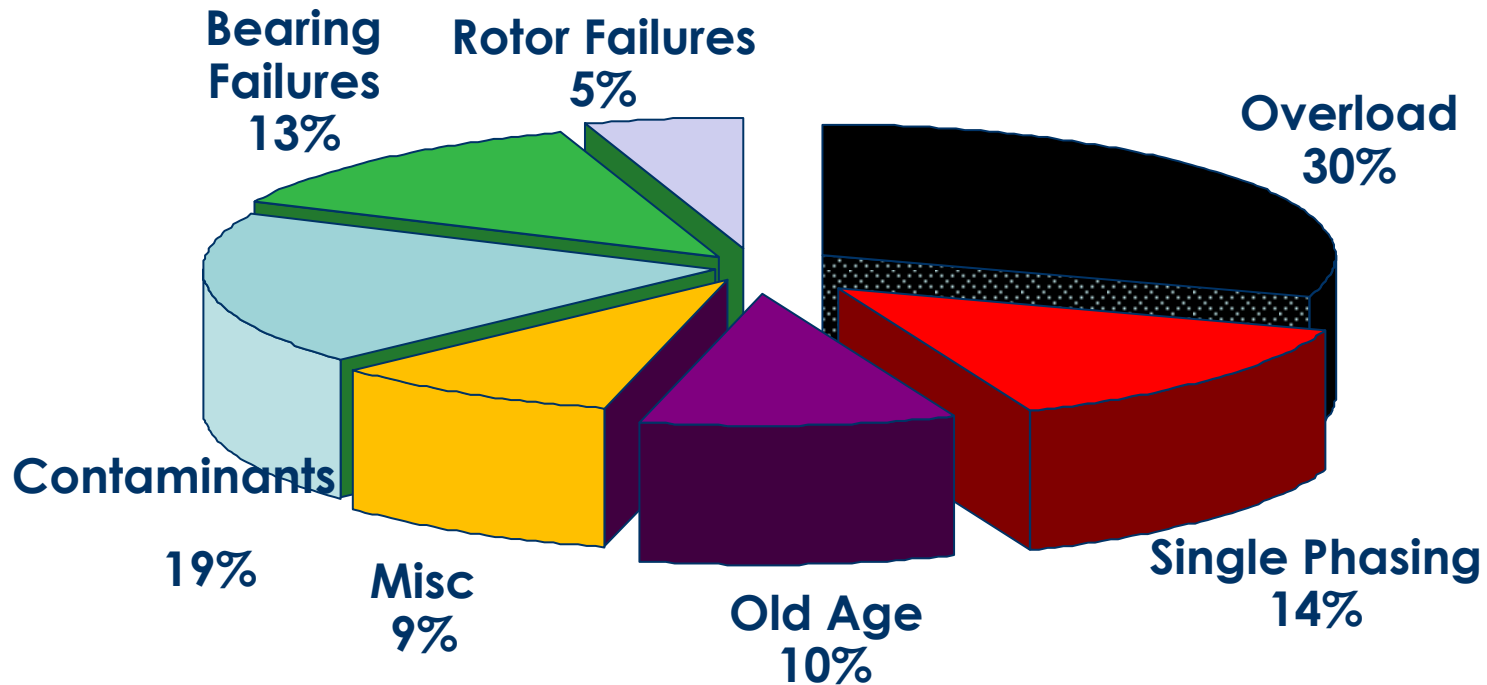
Failure distribution statistics,
Source: IEEE Petro-Chemical Paper PCIC-94-01
No details on root cause analysis of failure.

Failure Statistics ...



*** Based on 9,000 failure events researched by the Electric Motor Manual which was written by Robert Lawrie in conjunction with the staff at Electric Construction and Maintenance Magazine.**

Failure Statistics ...



*** Based on 9,000 failure events researched by the Electric Motor Manual which was written by Robert Lawrie in conjunction with the staff at Electric Construction and Maintenance Magazine.**

Failure Statistics ...



Generator Vibration (displacement $>125\mu\text{m}$):

- End-winding 82.1%
- Stator core 10.7%
- Phase (Circuit / Parallel / Connection Rings) 39.3%
- Phase drop (phase rings with bushings) 21.4%

Cause of excessive vibration

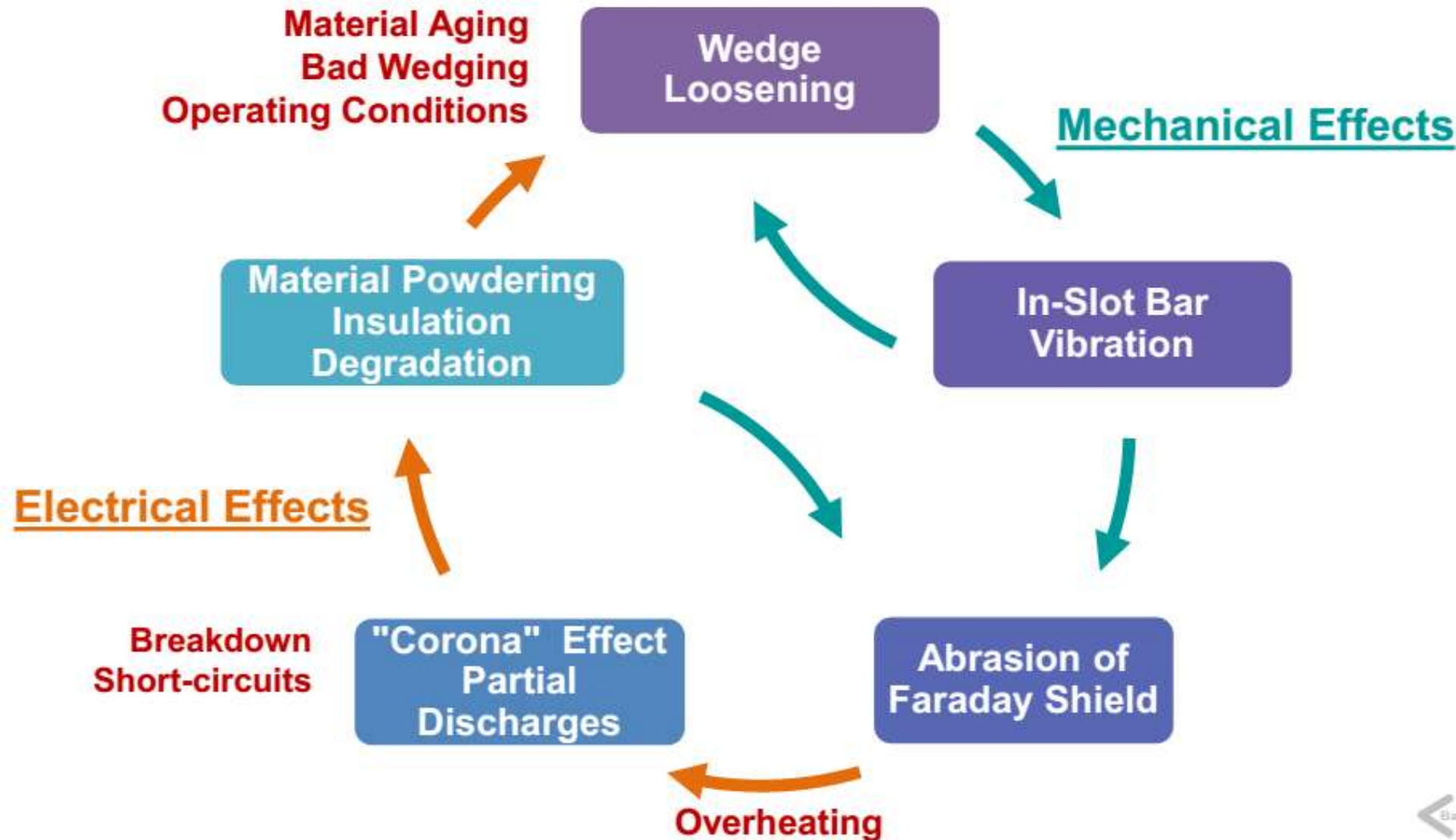
- Design 57.7%
- Assembly/workmanship 19.2%
- Unusual operation 3.8%
- Improper repair 7.7%



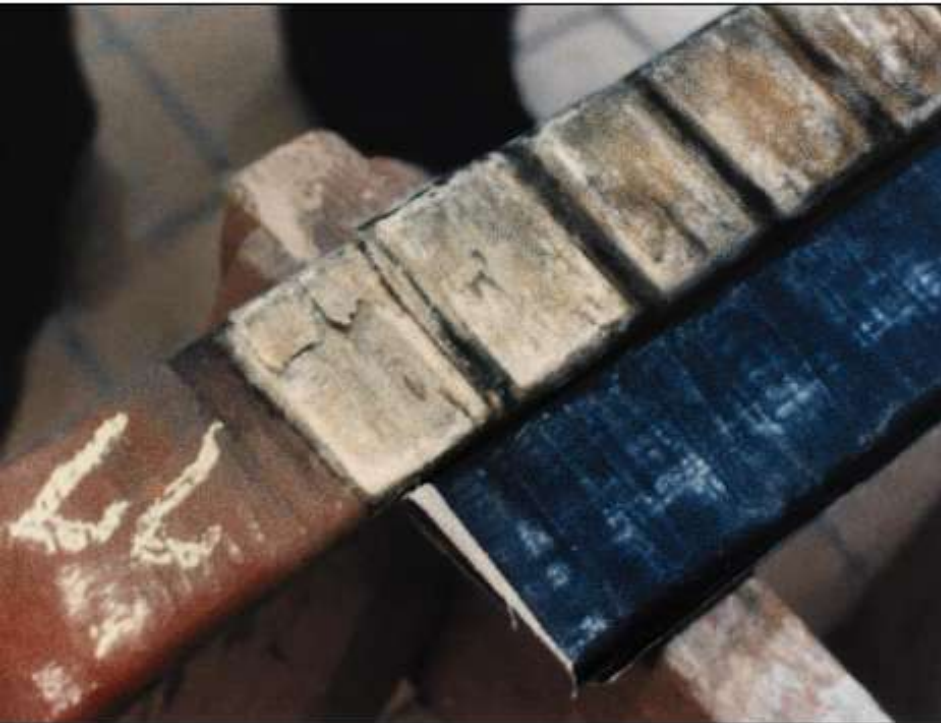
Stator Winding integrity : stator winding replacement, stator core restacking and rewedging



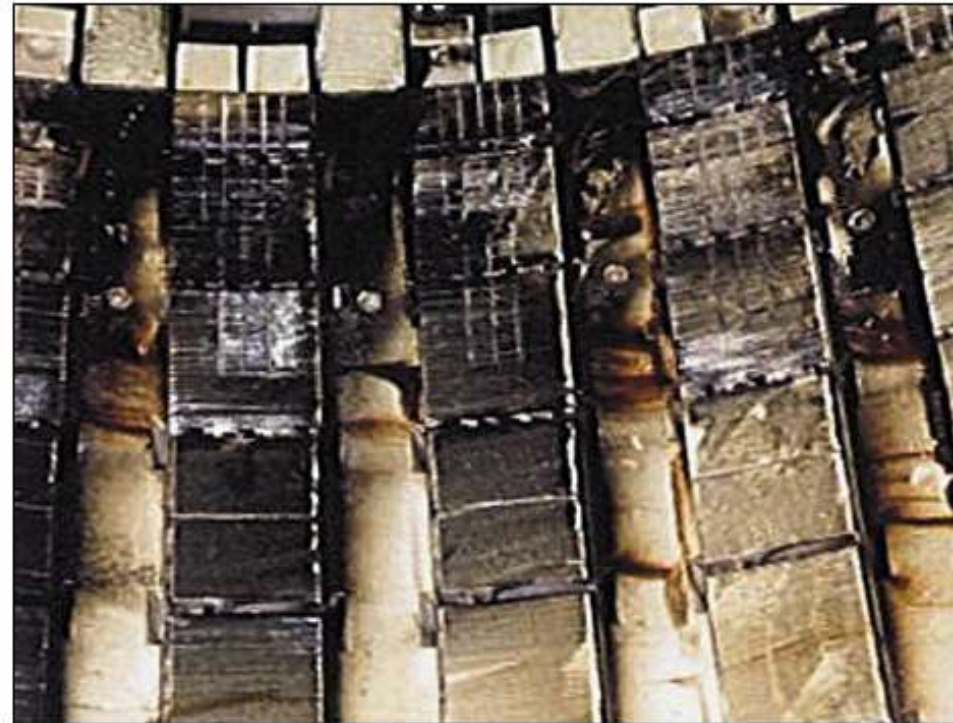
Stator Failures



Stator Failures



**Abrasion on bar insulation
from in-slot vibration against
stator laminations**



**Deposit of oil mist on stator core
contributing to bar vibration**

Stator Failures



Poor manufacture / De-lamination



Thermal Cycling



Discharges During HV Test



Stator Failures

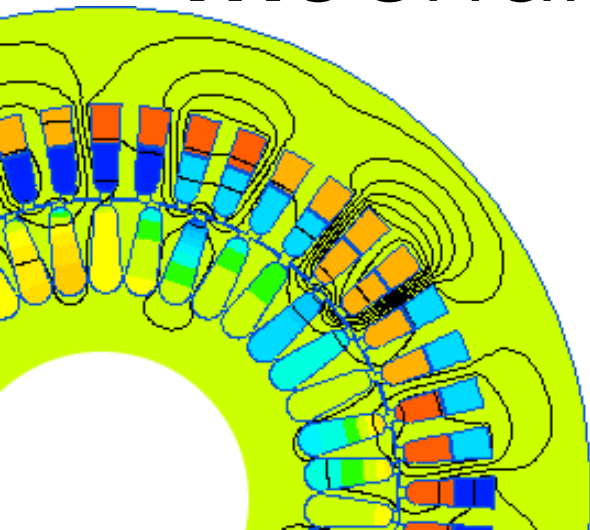
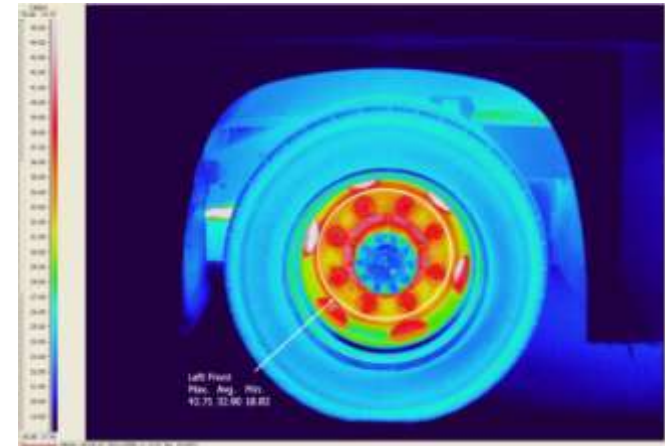


- Failures due to windings' insulation failure caused by various factors such as electrical, thermal, environmental and mechanical stress factors.
- mechanically induced defects attributes to Loose wedges, erosion due to bar vibration etc. Accelerated degradation process.
- Discharge between phases due to cracks / low spacing
- Contamination of end windings.
- Others: internal voids, insulation ageing, delamination.
- Electrical partial discharges

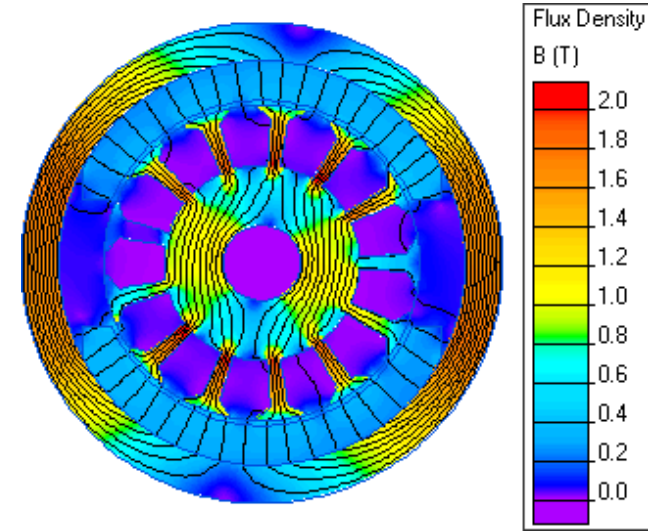


Stress

- **T**emperature
- **E**lectrical
- **A**mbient
- **M**echanical



online
offline



Stress ...



THERMAL STRESS

Thermal Aging
Voltage variation
Cyclic loading
Restricted Ventilation
Ambient

AMBIENT STRESS

Moisture / Humidity
Corrosive Chemical
Abrasion
Damage parts
Rodents & Insects

ELECTRICAL STRESS

Dielectric Aging Tracking /
Corona / Partial Discharge
Harmonic Distortion
Voltage Spikes / Transients
Voltage / Phase imbalance

MECHANICAL STRESS

Stator Coil Movement
Rotor Damages / Rubbing
Torsional load variation
Vibration / 2 x LF Air gap
Improper lubrication

 online

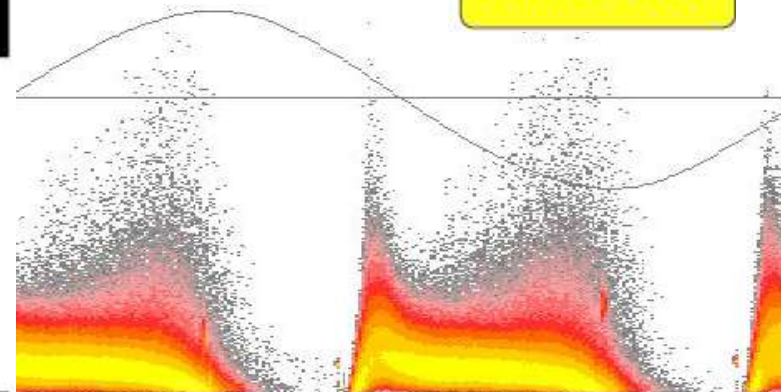
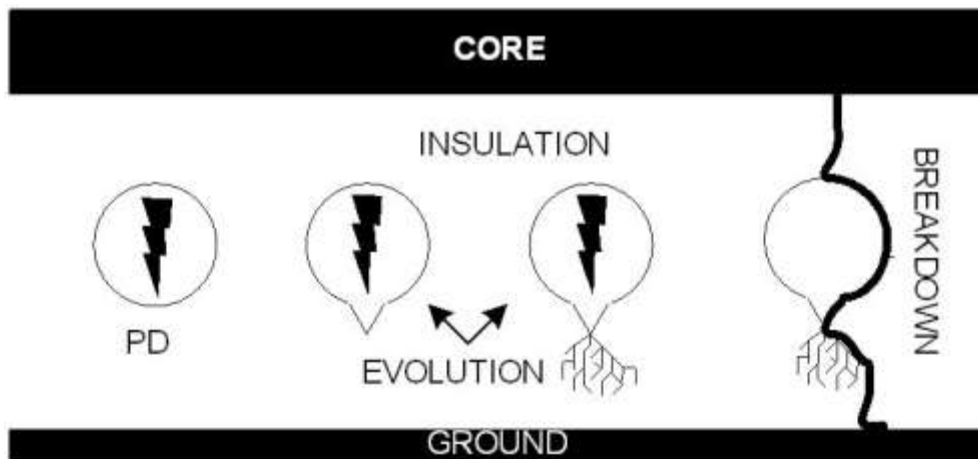
 offline

Assess Stator Insulation

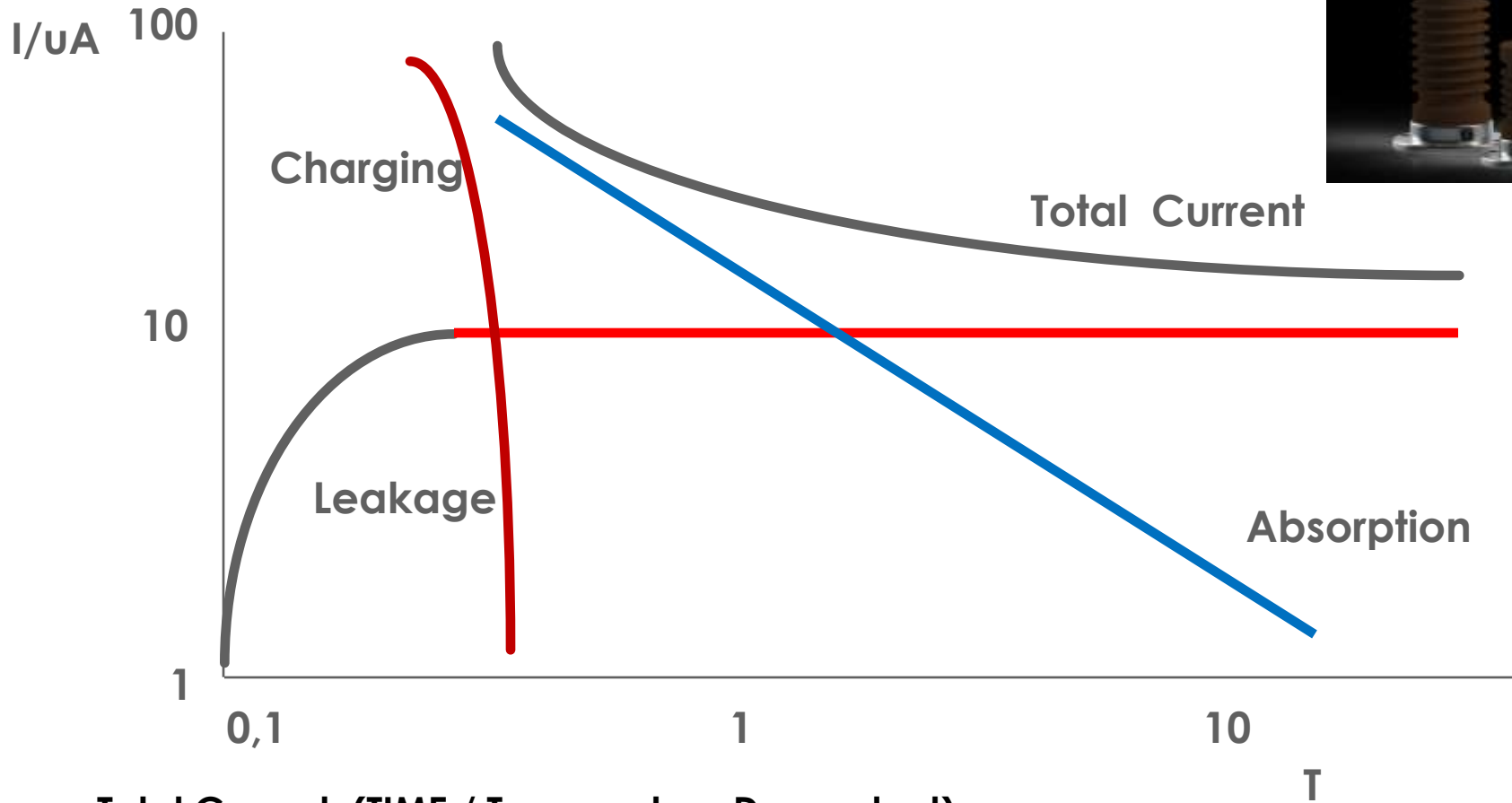


- Capacitance deterioration
- Insulation Resistor (IR)
- Polarization Index (P.I.)
- Di-electric Loss Factor : Tangent Delta
- Partial Discharges (PD)

offline

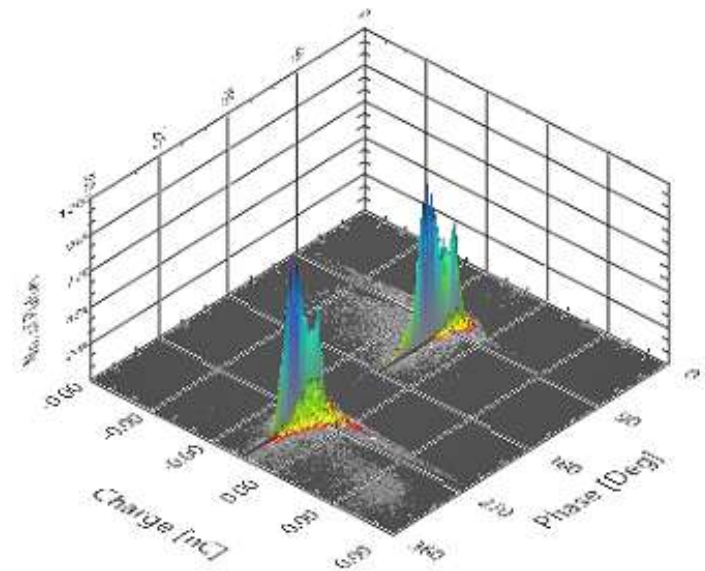
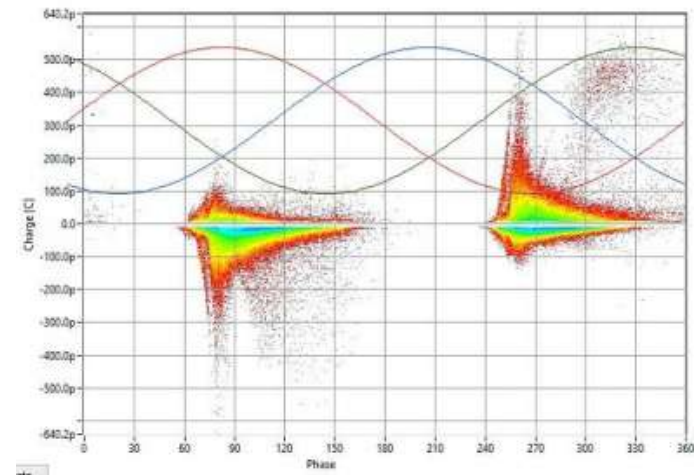
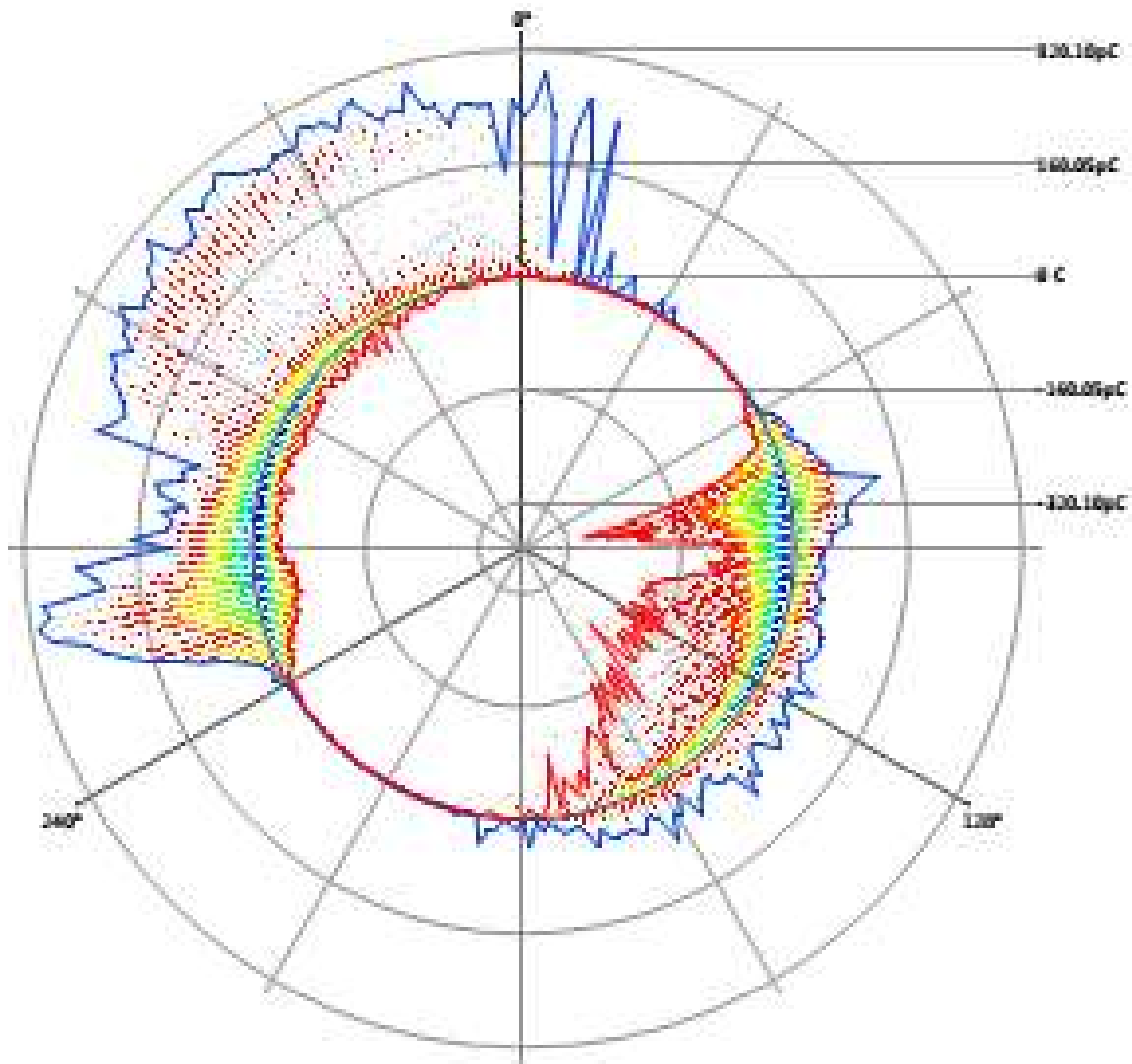


Assess Stator Insulation ...



Total Current (TIME / Temperature Dependent) =
Capacitive Current Charging + Absorption Current - Polarisation + Leakage Current

Partial Discharge Study

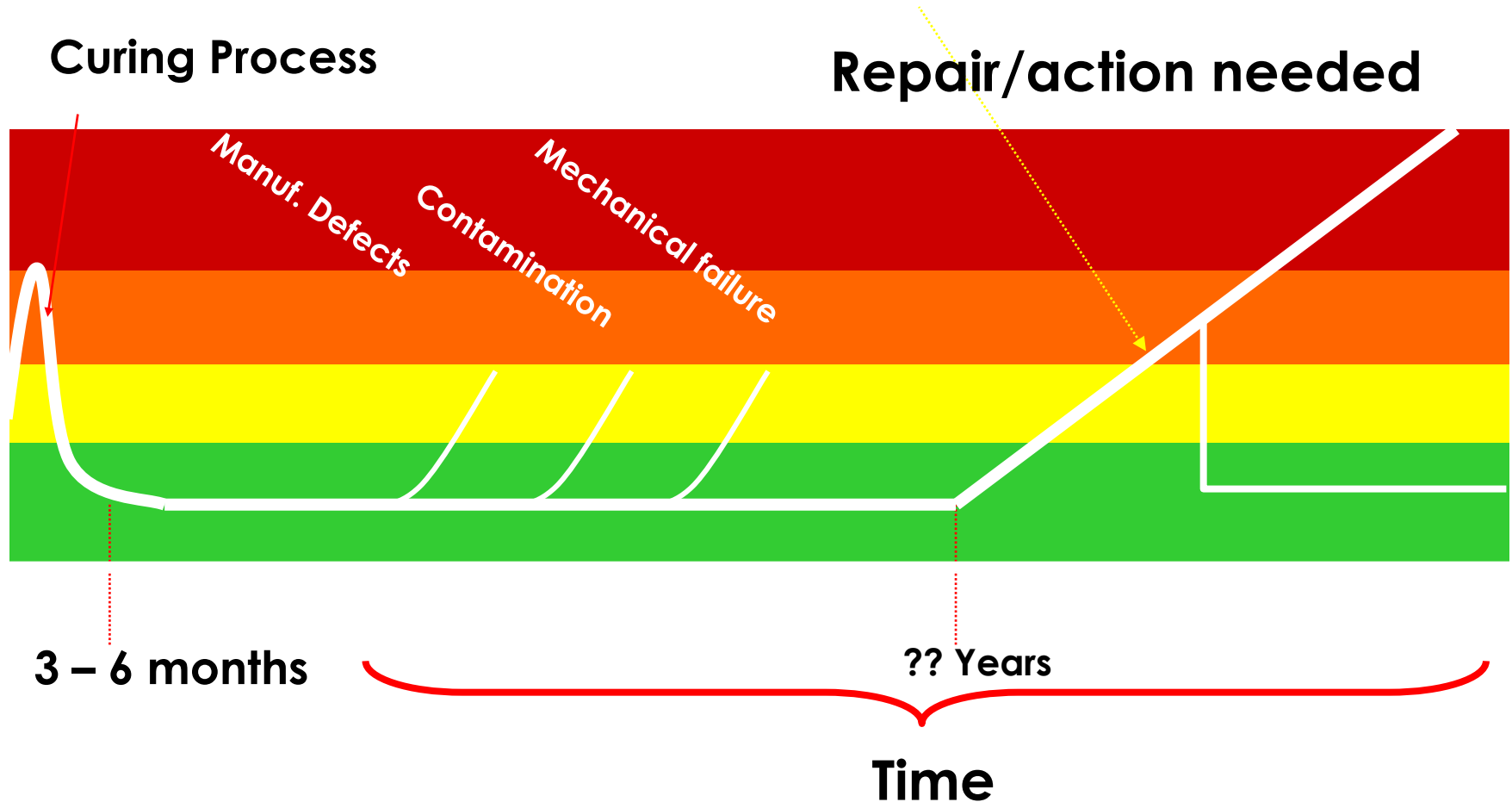


Partial Discharge Phenomena



- Loose wedges/bar vibration/slot discharges
- cracked and broken conductors
- end winding surface contamination
- damage / corrosion of the corona suppression unit
- connection ring external discharge due to vibration
- inter-phase discharge
- insulation degradation
- collector ring, brush sparking
- faults in generator high voltage accessories

Partial Discharge Trending

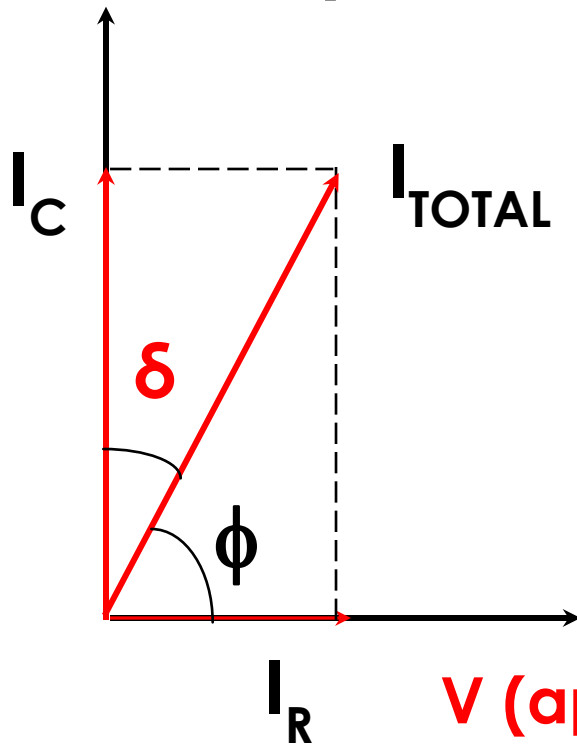


* Inter-turn fault can be identified online ESA – negative sequence current / Impedance imbalance

Loss factor (Tangent delta)



I (capacitive)



- Tan Delta is the ratio of in-phase (resistive) current to the 90-degree (capacitive) current
- Tan Delta equals Dissipation Factor

$$\text{Tan } \delta = \frac{I_{\text{Resistive}}}{I_{\text{Capacitive}}}$$

$$\text{Power Factor } \Phi = \frac{I_{\text{Resistive}}}{I_{\text{TOTAL}}}$$



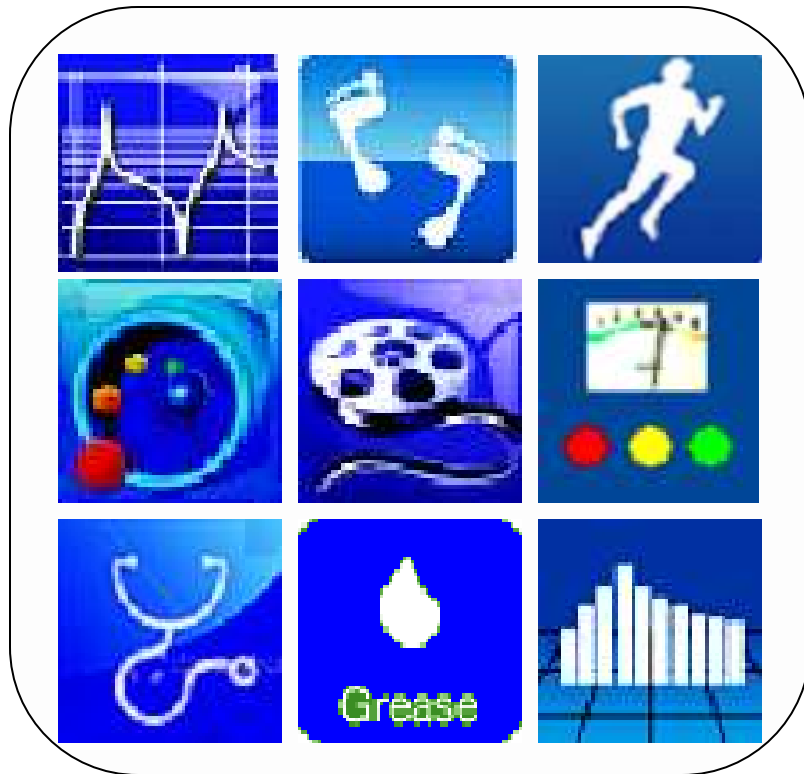
Options

- **REPAIR / REWIND**
- **REPLACE**
- **REVITALISE / REFURBISH**
- **RELIABILITY (LONGEVITY by PROGNOSTICS)**
Residual Life Assessment / Failure Prediction
Analyse Insulation Dielectric properties,
mitigate the risk of catastrophic failure and
extend periods between outages

REAP Solutions

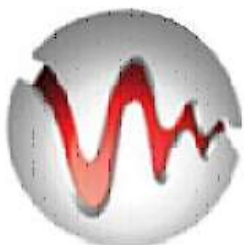


REAP Solutions



ROTATING ELECTRICAL MACHINES

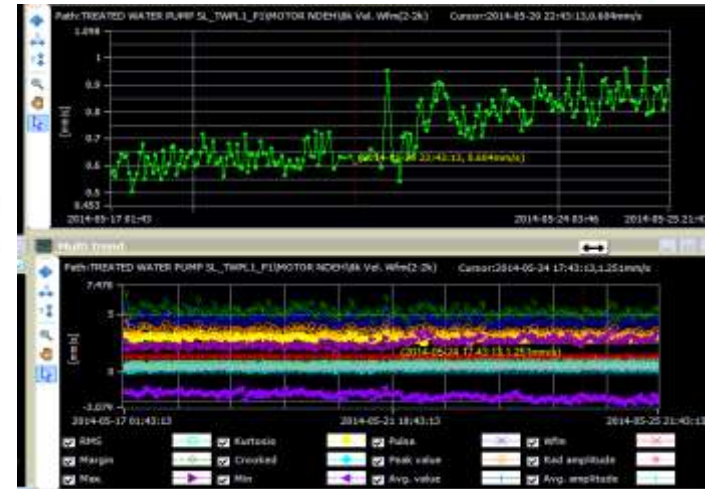
- Vibration
- Noise / Sound
- Ultrasonic
- Current / Flux
- Pressure, Flow, Load....



VADDIT PRO 2124 XT
MACHINERY DIAGNOSTIC SYSTEM



REAP Solutions .. Wired / Wireless Vibration Alert System



CRITICAL ASSET CARE - CAC 21NX



USER GUIDE



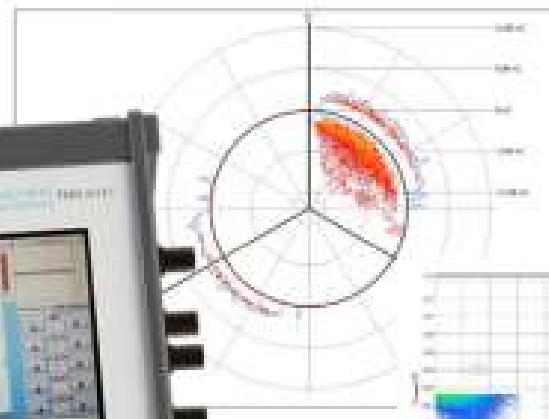
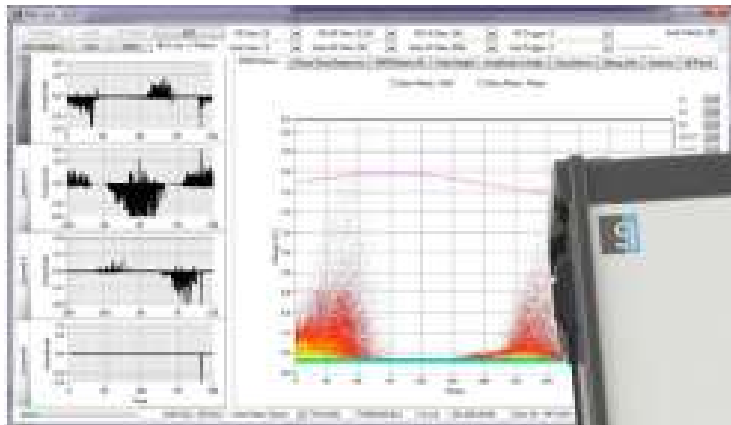
VABBIT^{PRO} CAC 21NX

REAP Solutions .. assess Insulation



offline

- Capacitance
- Winding Insulation Resistor (IR)
- Polarization Index / Current charging
- Di-electric Loss Factor : Tangent Delta
- **Partial Discharge (PD)** with Voltage source



Know more !

