


GEMS 2024 Workshop – SwRI San Antonio

Nidec Power- Kato Engineering

Harness the Heat: Generator Designs for Geothermal Power Generation


No. 1

We are the world's leading global manufacturer of electric motors and controls

1973	$16.5B	$26.8B
FOUNDED	FY2023 REVENUE*	MARKET CAPITALIZATION

*CONVERSION RATE OF 145¥ TO 1USD


If you drive a car, travel abroad, wash your clothes, watch a movie, use a camera or talk on a phone, you are using Nidec technology.

Mankato, MN (Kato Engineering)

- Focus on custom generators up to 25 MW
- Lower volume, higher customization
  - Increasing capacity - 100-150% output
- Dedicated Remanufacturing area

Lexington, TN (Leroy-Somer)

- Focus on industrial generators 800 kW – 4000 kW
- Medium Volume
  - Increasing Capacity - 150-200% output
- Dedicated Remanufacturing Area

Houma, LA & Houston, TX (Houma Armature Works)

- 50+ years of motor and generator service
- 24/7 on-call field service teams
- 25,000+ service trips complete
- 8,000+ motor, control and related products
- ISO 9001:2015 certified and EASA Accredited

Reynosa, Mexico (Leroy-Somer)

- Focus on industrial generators 25 kW – 2500 kW, + components for larger generators
- Higher Volume, lower customization
  - Increasing Capacity - 200% + output

Electric Power Generation – Americas (EPGA)

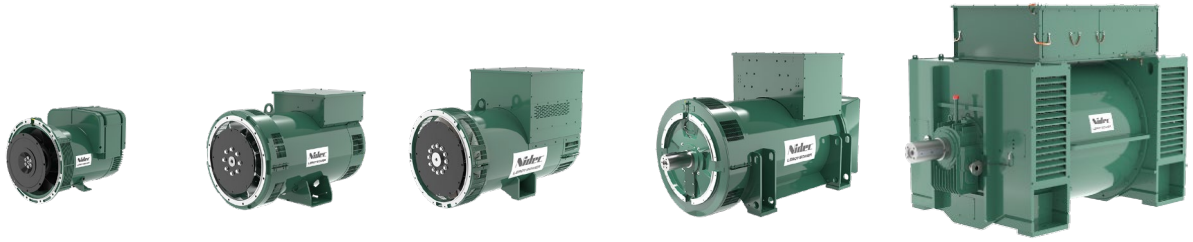
Nidec Power

Nidec Power - World Leader in Generators

- **Kato Engineering** brand renown for reliable, durable products, and is the generator of choice with high end user specifications
- **Leroy-Somer** brand recognition for critical backup power applications- known for product performance and quality
- Evolving product portfolio for low, medium and high voltage ranges up to 15 kV & 25 MW
- Compatibility with all prime movers- low, medium and high-speed Diesel and Gas engines, and Gas, Hydro, ORC, Steam, sCO2 and Wind turbines-to reach all segments of power generation

KATO ENGINEERING™

LEROY-SOMER™



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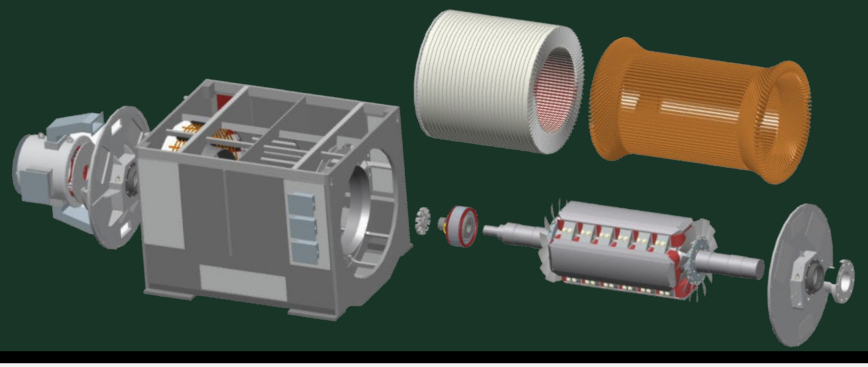
Kato Engineering Turbine Generators

Kato Engineering turbine generators are designed for efficiency and durability for use in demanding applications. They operate with extremely low vibration levels, can be sound-attenuated and require minimal maintenance.



Output Range: 1,000 – 25,000 KW
Voltage: 400V (up to 5200Amps) - 15,000 Volts
Speed: 1500 - 1800RPM
Power factor: 0.8 leading to 0.95 lagging
Frequency: 50/60hz
Enclosures: ODP, DIDO, WPI, WPII, TEWAC (CACW), TEAAC (CACA)
Insulation: Class H epoxy VPI insulation system
Excitation: Brushless Excitation with PMG
Standards/Compliance: NEMA, IEEE, IEC, API546, CE marking, CENELEC
Certifications Available: All marine agencies, USCG, CSA, UL, IECEx, ATEX, Hazardous locations
Quality Assessment: ABS, DNV, QAR, QAN, CSA, UL, ISO 9001

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AC Generator Principles & Components

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AC Generator Principles and Components

Generator Principles

Main Components

- Main Frame and Stator
- Rotor Shaft
- Excitation Circuit
- Bearings
- Insulation System
- Phase/Neutral Outlet Box(es), Auxiliary Boxes

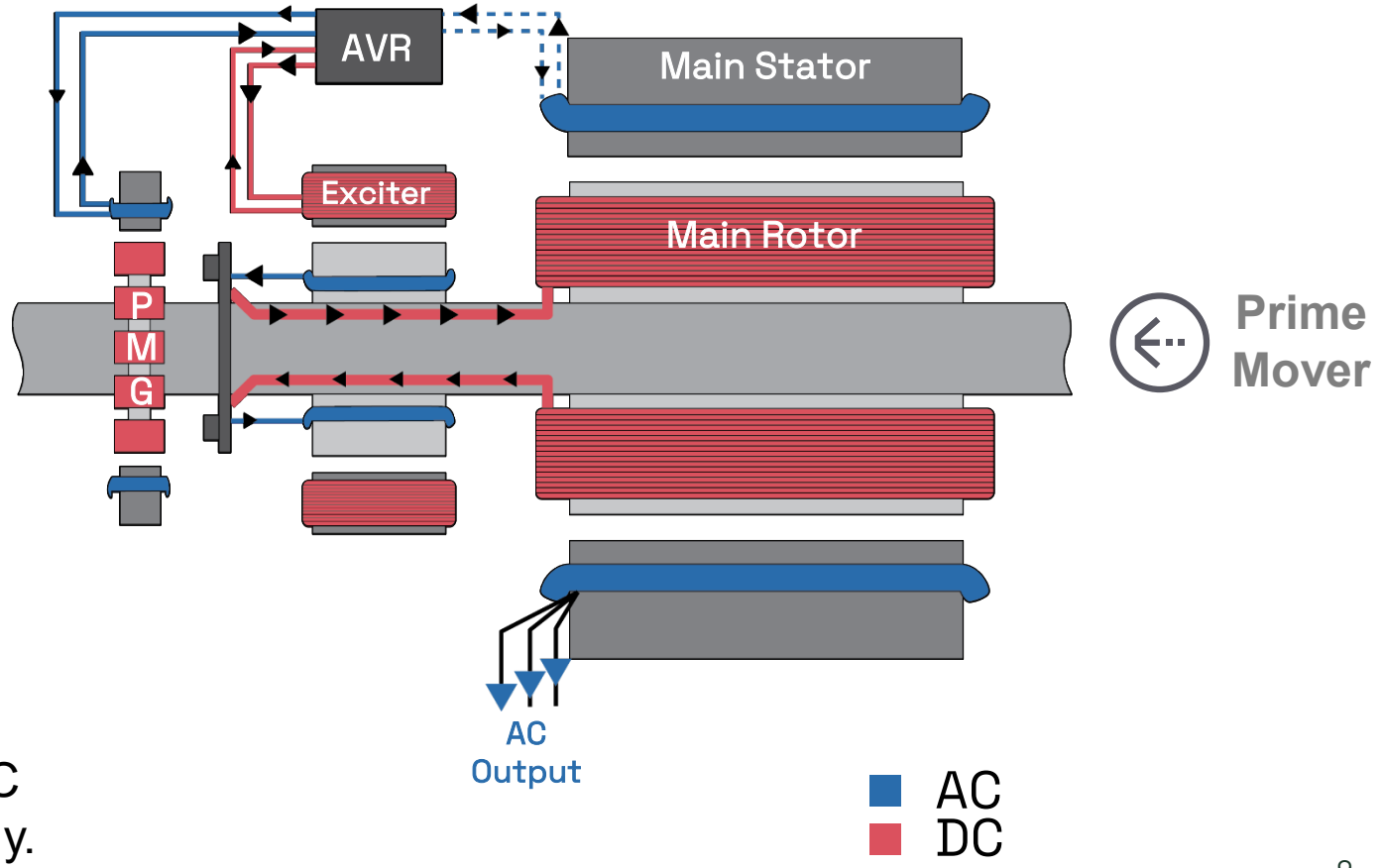
An AC generator is a machine that converts mechanical energy into electrical energy.

The mechanical energy is typically supplied by engines and turbines (“prime movers”).

The output is an alternating electrical power in the form of alternating voltage and current.

Generator Principles

- Prime mover rotates the generator shaft, and as the PMG (permanent magnet generator) rotor spins, the magnets produce AC voltage in the PMG stator.
- The Automatic Voltage Regulator (AVR) rectifies the AC voltage and applies the DC voltage to the exciter stator.
- A three-phase AC voltage appears at the exciter rotor and is rectified to DC by the rotating rectifier.
- The DC voltage appears in the main revolving rotor field and induces a higher AC three-phase voltage in the main stator.
- This AC voltage is sensed by the regulator, compared to a reference level, and output AC voltage is adjusted accordingly.



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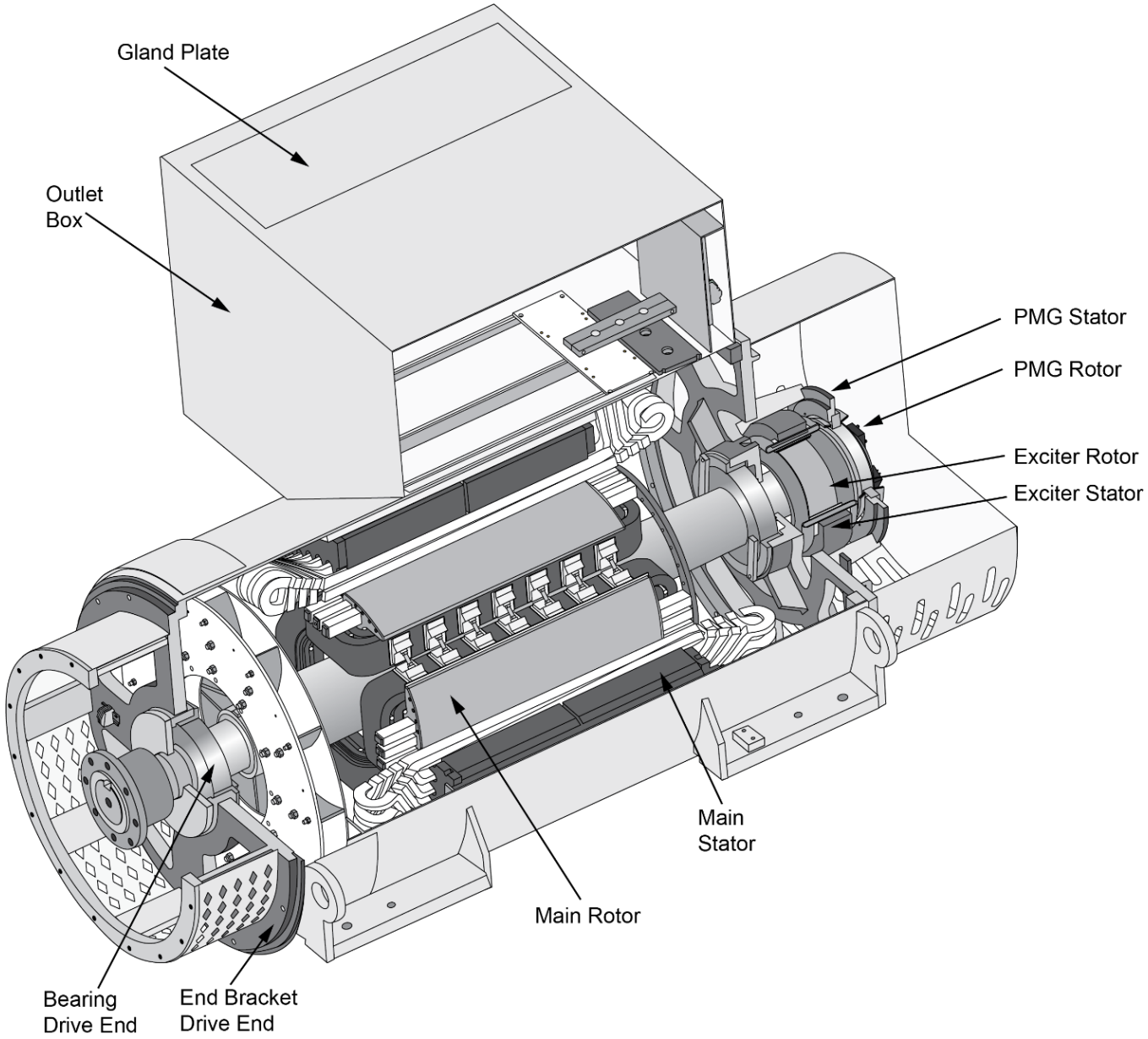
Generator Components

Standard AC Generator



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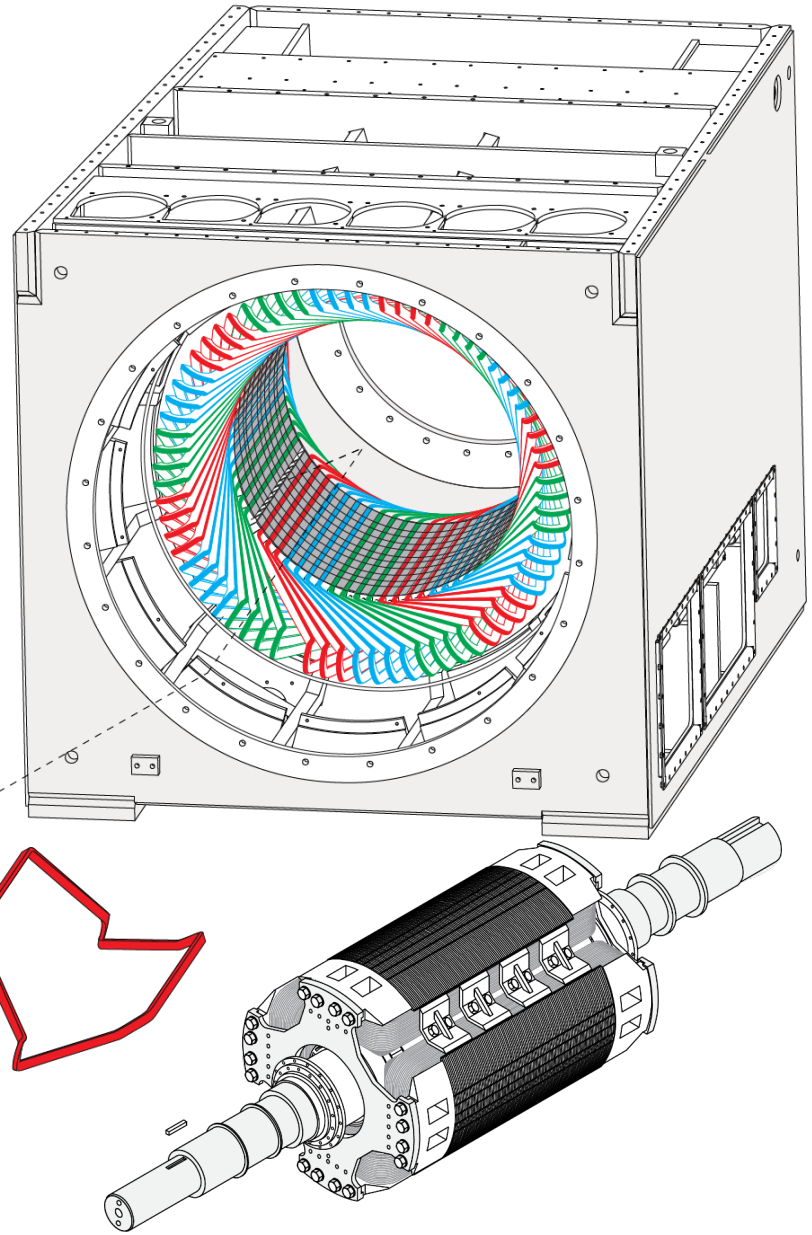
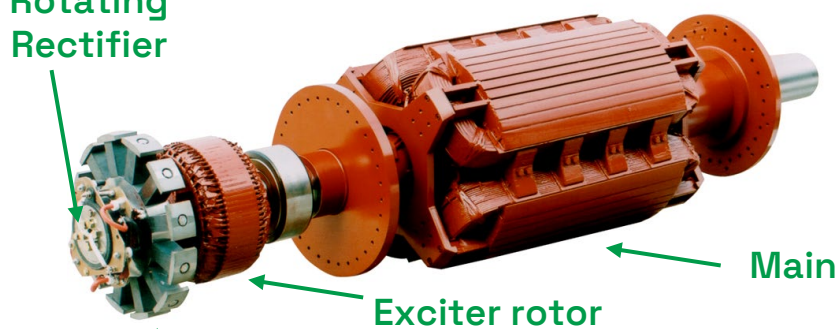
Main Stator and Rotor

- The main stator is a stationary steel core of stacked laminations shaped to hold the windings and is the main component carrying the current and **delivering the output power** to the equipment.

- The main rotor is a rotating electro-magnet comprised of poles having alternating-polarity creating the field that induces AC Voltage in the main stator windings.



Unwound stacked laminations Stator



4 Pole stacked laminations Rotor with windings

4 Pole Solid Rotor Shaft w/o windings

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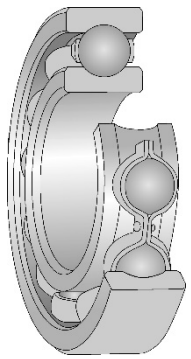
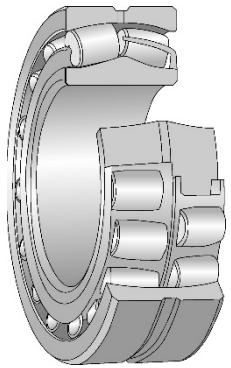
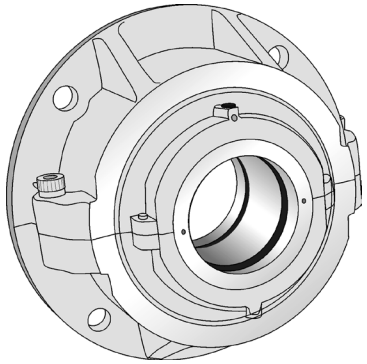
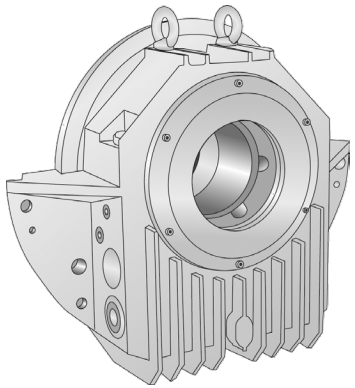
Bearings









	Deep Groove Ball	Spherical Roller	Split Roller	Split Sleeve (Journal)
Maintenance Cycle	~2000 hours	~200 hours	~200 hours	~8000 hours
Thrust	Capable	Capable		High capability
Lube	Grease	Grease	Oil	Oil
High Shock	Vulnerable	Vulnerable	Vulnerable	Capable
Removal	Must remove coupling	Must remove coupling	Easy/split	Easy/split
Bonus	Good for black start since no pre-lube required.	Spherical roller provides easy alignment.	Spherical seat provides easy alignment.	Available with integral insulation.

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Vacuum Pressure Impregnation (VPI)

- A polyester or epoxy resin is applied to windings.
- VPI provides mechanical strength, heat transfer, dielectric strength and environmental protection.
- After VPI, a bake cycle hardens the resin.

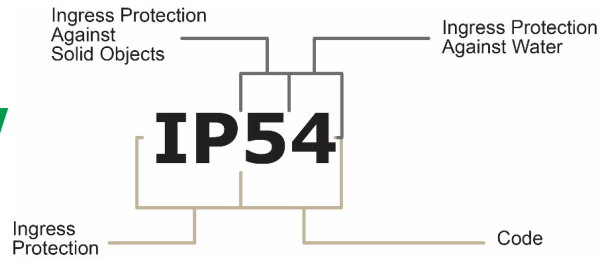
Generator Sizing

Power

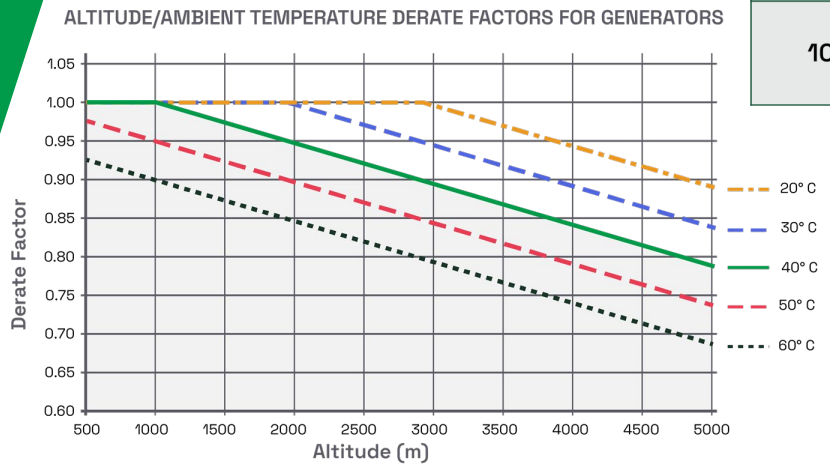
Generator Sizing

Baseline details that affect generator size:

- Power requirement kW_kVA
- Power Factor other than 0.8 … < equates to a larger, > equates to a smaller generator
- Enclosure Type and Cooling Method - IP2X is standard, higher IP ratings typically require larger generators due to reduced airflow, or closed-circuit cooling (TEWAC / CACW or TEAAC/CACA)
- Rotating Speed - Slower speed = larger machine required for same kW/kVA output
- Air Temperature seen by the generator if > 40° C or < -20° C
- Altitude > 1000 M
- Generator Winding Temperature Rise



Pole Count	RPM	Hz
4	1500	50
	1800	60
6	1000	50
	1200	60
8	750	50
	900	60
10	600	50
	720	60



H Insulation generator w/ Class B temp. rise would be larger than H insulation w/ Class F rise

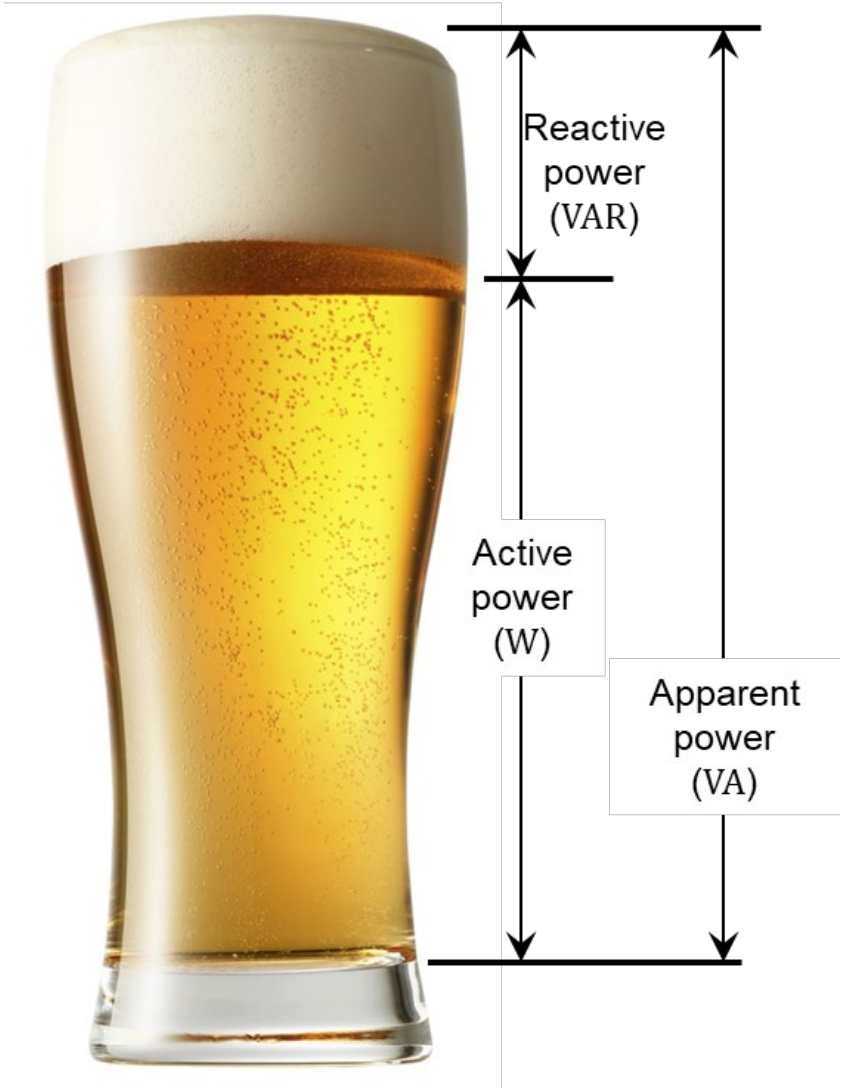
		Temperature Rise °C Class of Insulation System			
Part of Machine	Measurement Method	A	B	F	H
Armature Windings					
1. All kVA ratings	Resistance	60	80	105	125
2. 1563 kVA and less	Embedded detector	70	90	115	140
3. Over 1563 kVA					
Up to 7000 V	Embedded detector	65	85	110	135
Over 7000 V	Embedded detector	60	80	105	125
Field Windings	Resistance	65	80	105	125

A Power Analogy

- **Reactive Power (VAR)** is the froth that delays the delivery of the beer. It's the delay that occurs due to setting up alternating magnetic fields.

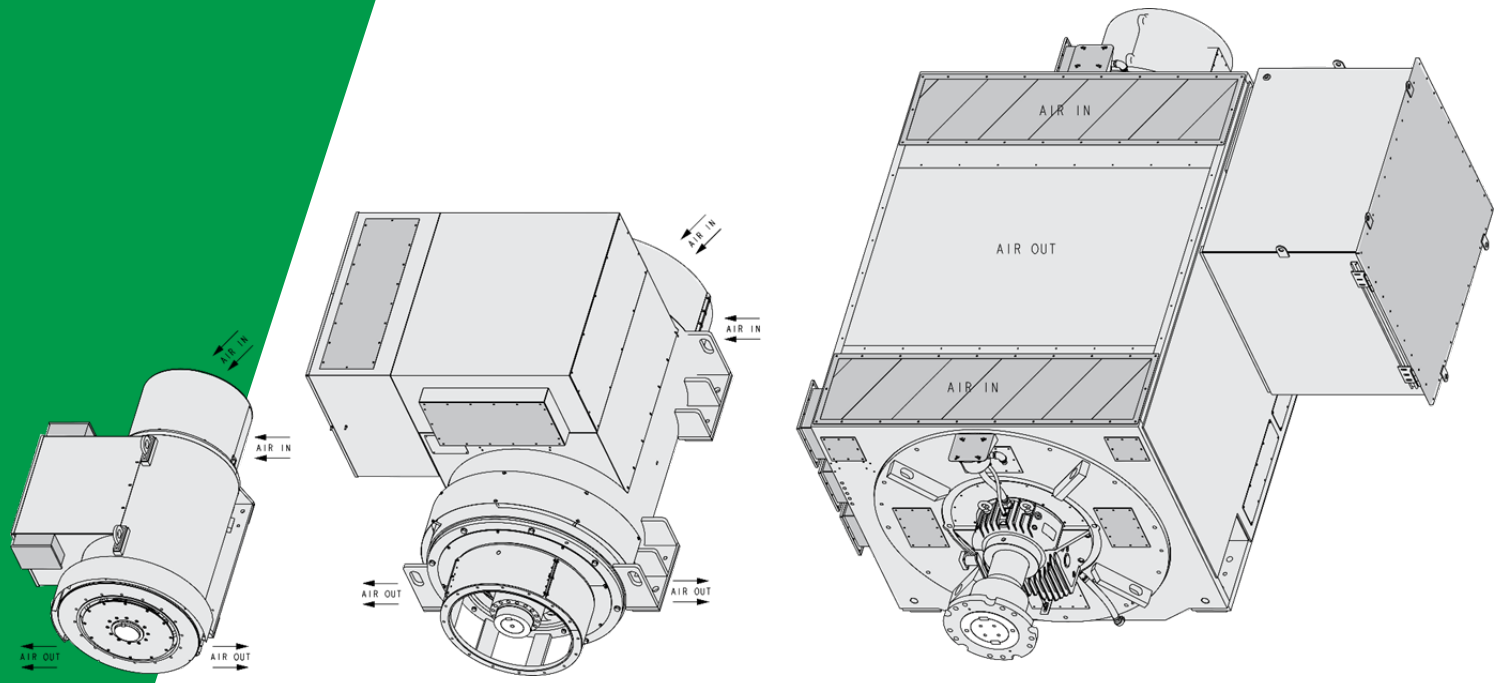
- **Active (real) Power (W)** is the beer that then flows into your mouth and quenches your thirst. It's the power flowing to the equipment.

- **Apparent Power (VA)** is everything in the glass: the froth and the beer. It's the sum total of reactive and active power.



ODP – Open Drip Proof

- Typically, the most optimized air flow design providing the highest power density
- Installed in customer enclosures or protected environments
- IP20, IP21*, IP22*, IP23* (* Depends on filtration and or customer air ducting to/from generator - DIDO)

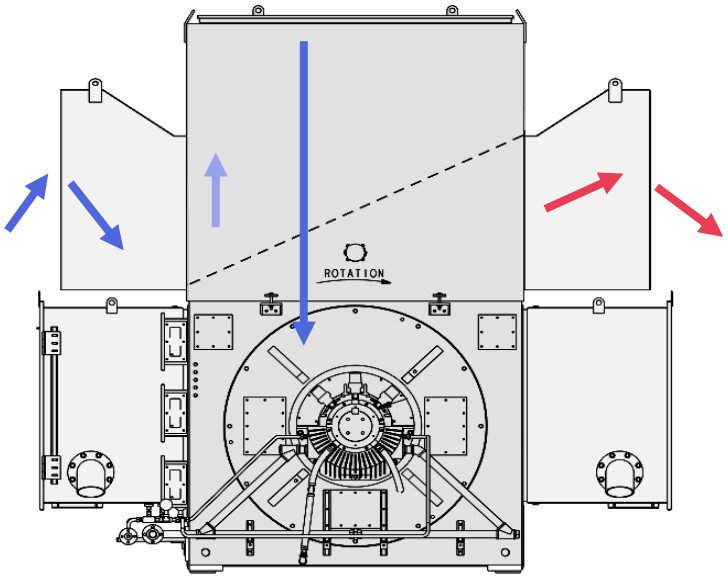


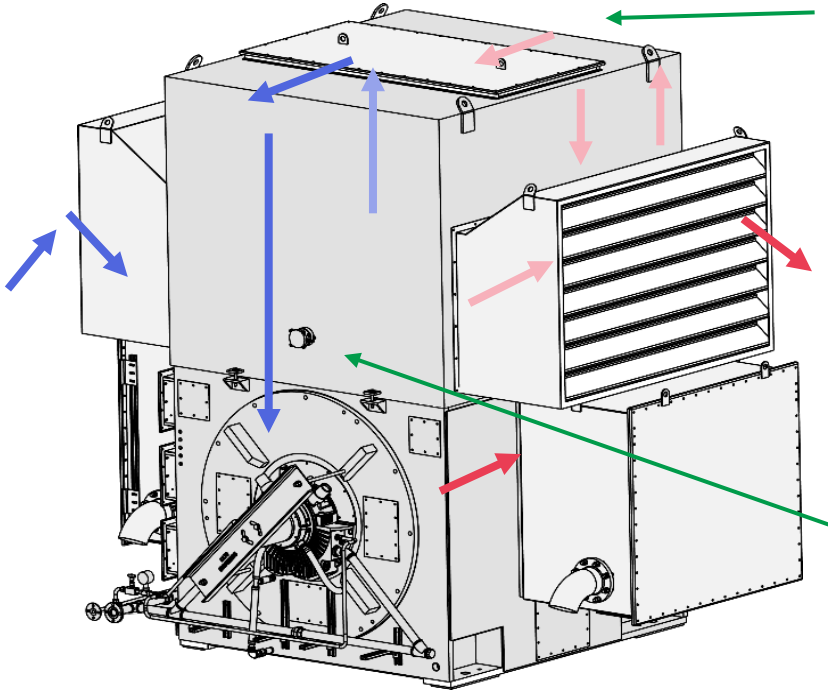
Weather Protected II – WPII

- Inlet Air: Three 90° direction changes causing particulate to get trapped at bends vs going into generator
- Inlet air temperature relatively unchanged with generator sizing similar to ODP, or oversized 5 – 10% depending on optional filters selections

Common requirements for Geothermal generator applications:

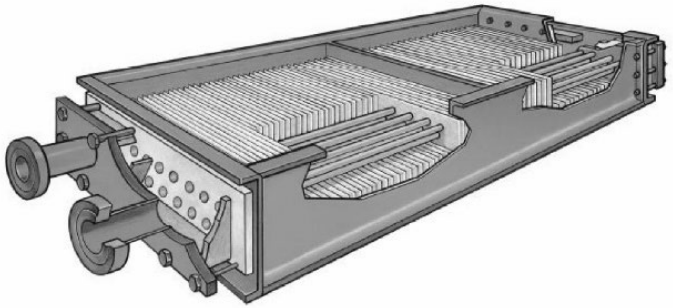
- 316 Stainless Steel replaceable / washable filters
- Air Differential Pressure Switch
- Cool and Warm Air temperature detection (RTDs)

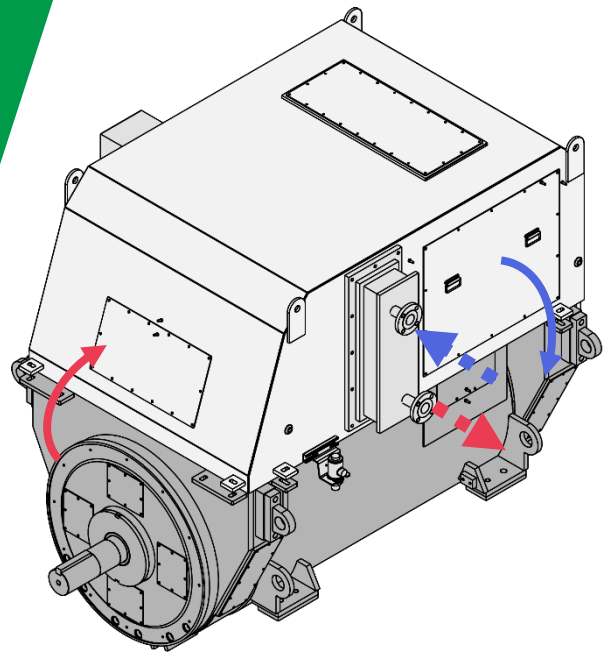




Totally Enclosed Water-to-Air Cooled – TEWAC (CACW)

- Two independent circuits; External cooling water and Internal generator air
- Typically, 25°C cooling water will provide 40°C air to generator (match ODP sizing). Warmer water = larger generator.
- Each design is specific to the application and cooler requirements
- Standard is single cooler with 90/10 CuNi tube & cooler materials for “wet” contact components
- IP44 – IP56 Enclosure Protection





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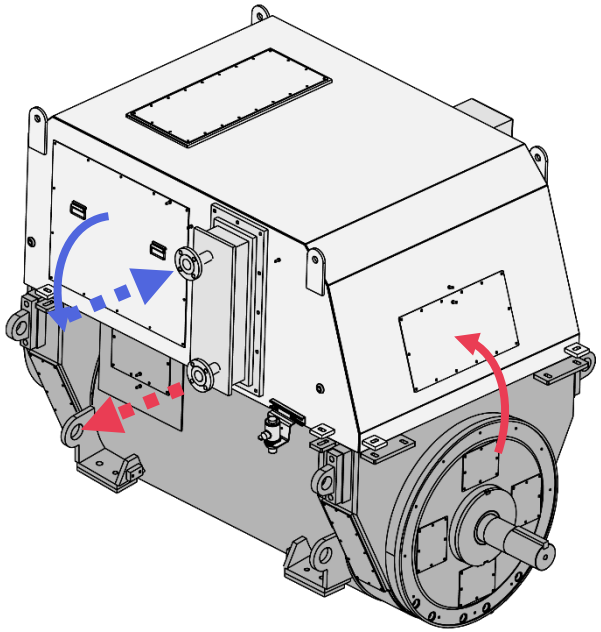
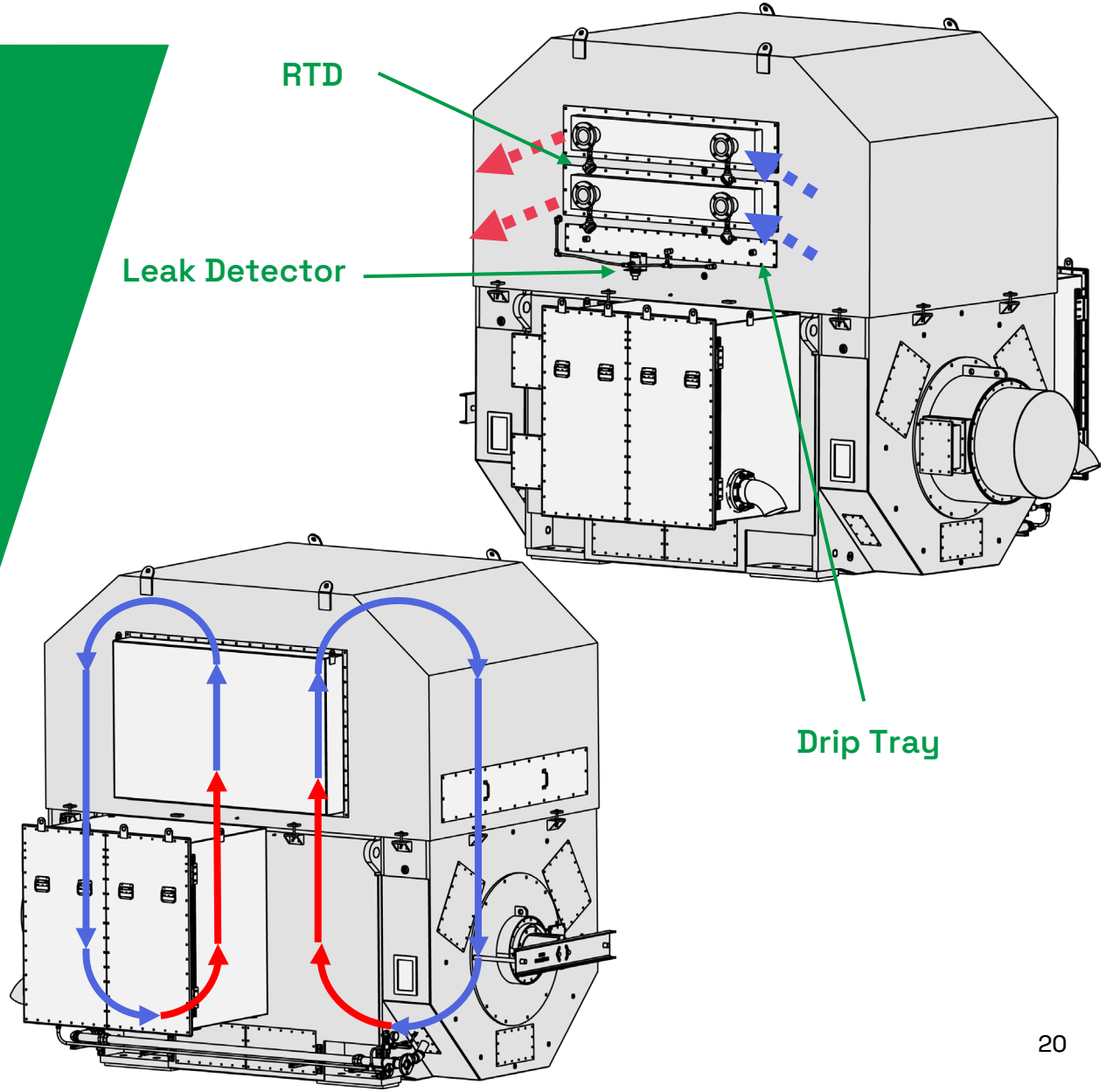


LHSFDE

Totally Enclosed Water-to-Air Cooled – TEWAC (CACW)

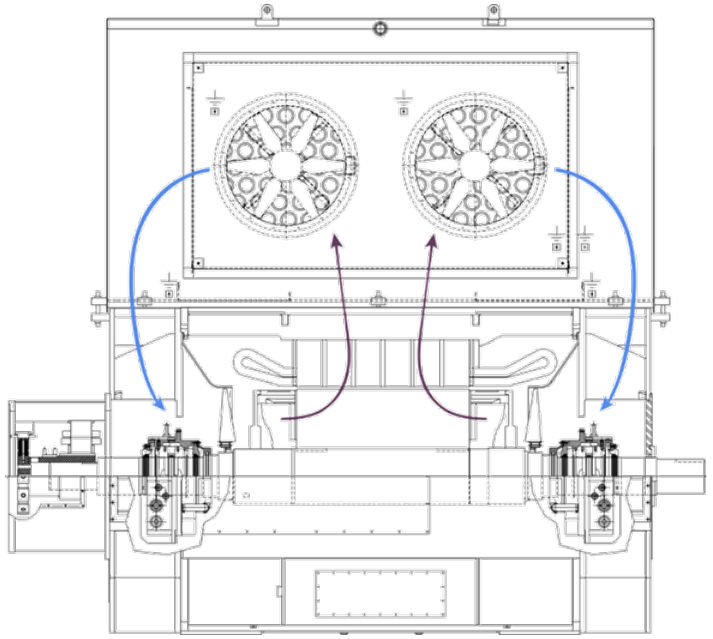
Common requirements for Geothermal generator applications:

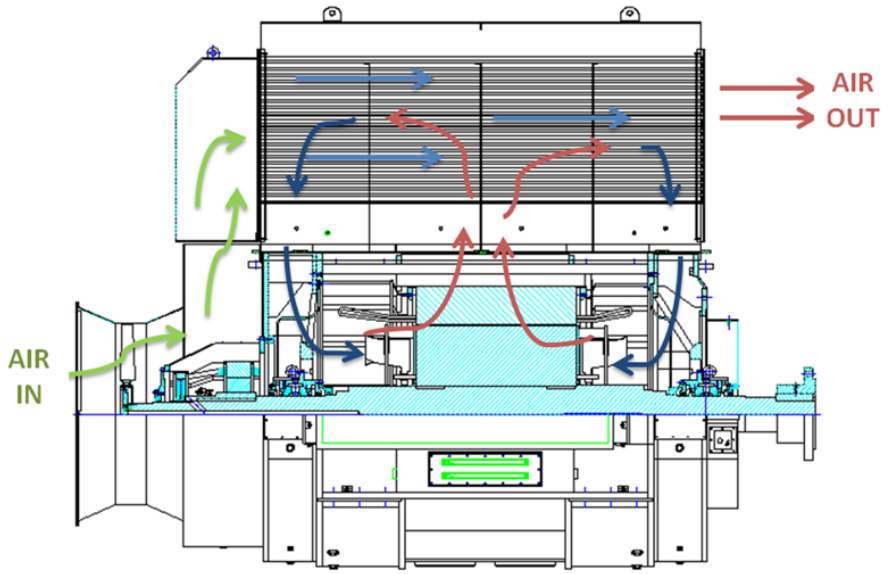
- 316 Stainless Steel tube & cooler materials for “wet” contact components
- Single cooler, but periodically double cooler to provide redundancy (range 50 – 100%) when one cooler is not operating
- Cool & Warm Air and Water temperature detection (RTDs)
- Leak Detector
- Drip Tray



Totally Enclosed Air-to-Air Cooled - TEAAC

- Two independent air circuits; External fresh air (motored blowers or shaft driven fan) and Internal generator air
- Typically, the internal generator inlet air temp will be ambient +20°C. Generator needs to be oversized 35-40% to equal an ODP rating.
- IP44 - IP56 Enclosure Protection

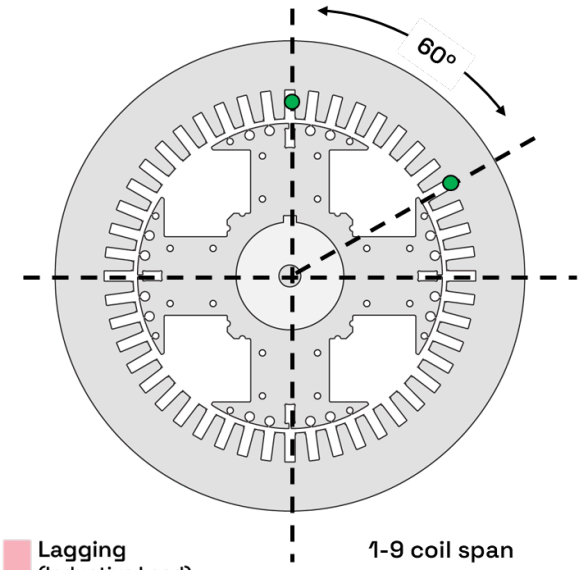


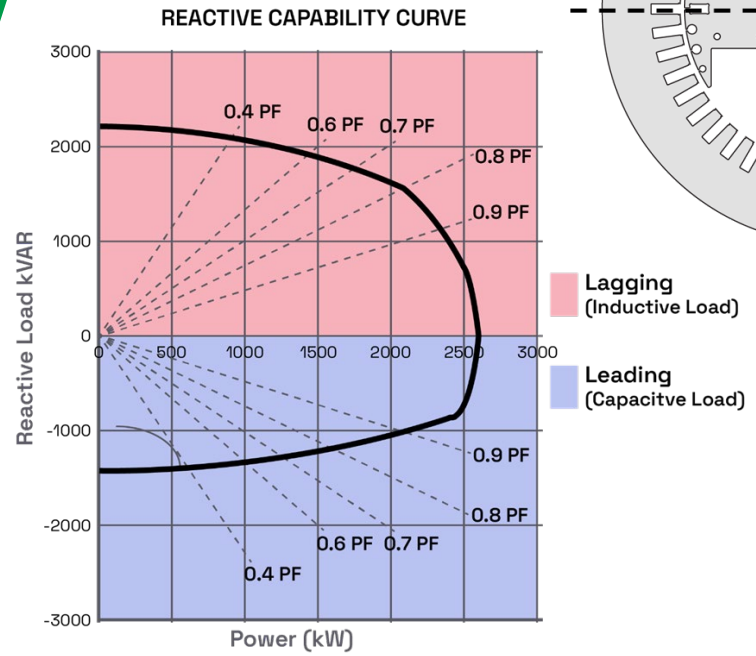


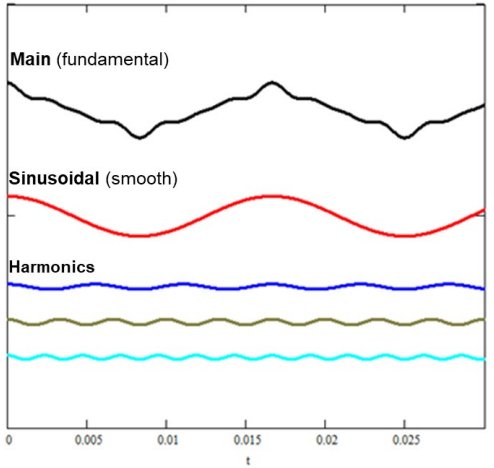
Generator Sizing

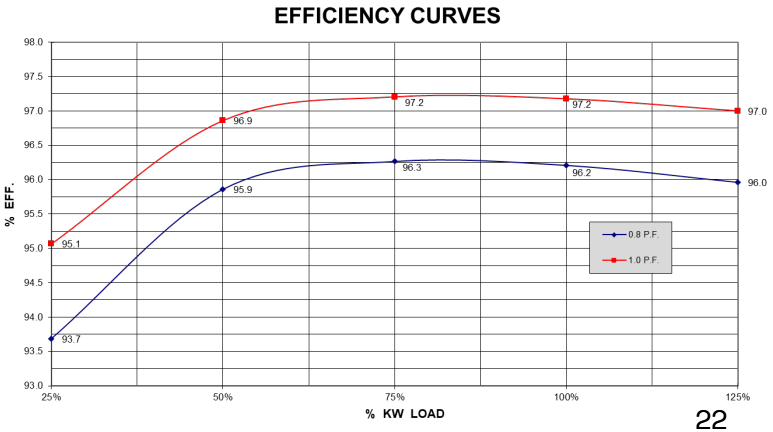
<u>Special requirements</u> that affect generator size (end user, agency, etc. specifications):

- Generator Winding Pitch - Optimum pitch designs can be smaller than 2/3rd pitch design
- Reactances (voltage dip and/or fault current limits)
- Motor starting or block loads with voltage dip limits
- Efficiency
- Overload capabilities (long duration overload)
- Excessive load unbalance (>20% delta between phases)
- High percentage of harmonic loads
- Grid Codes

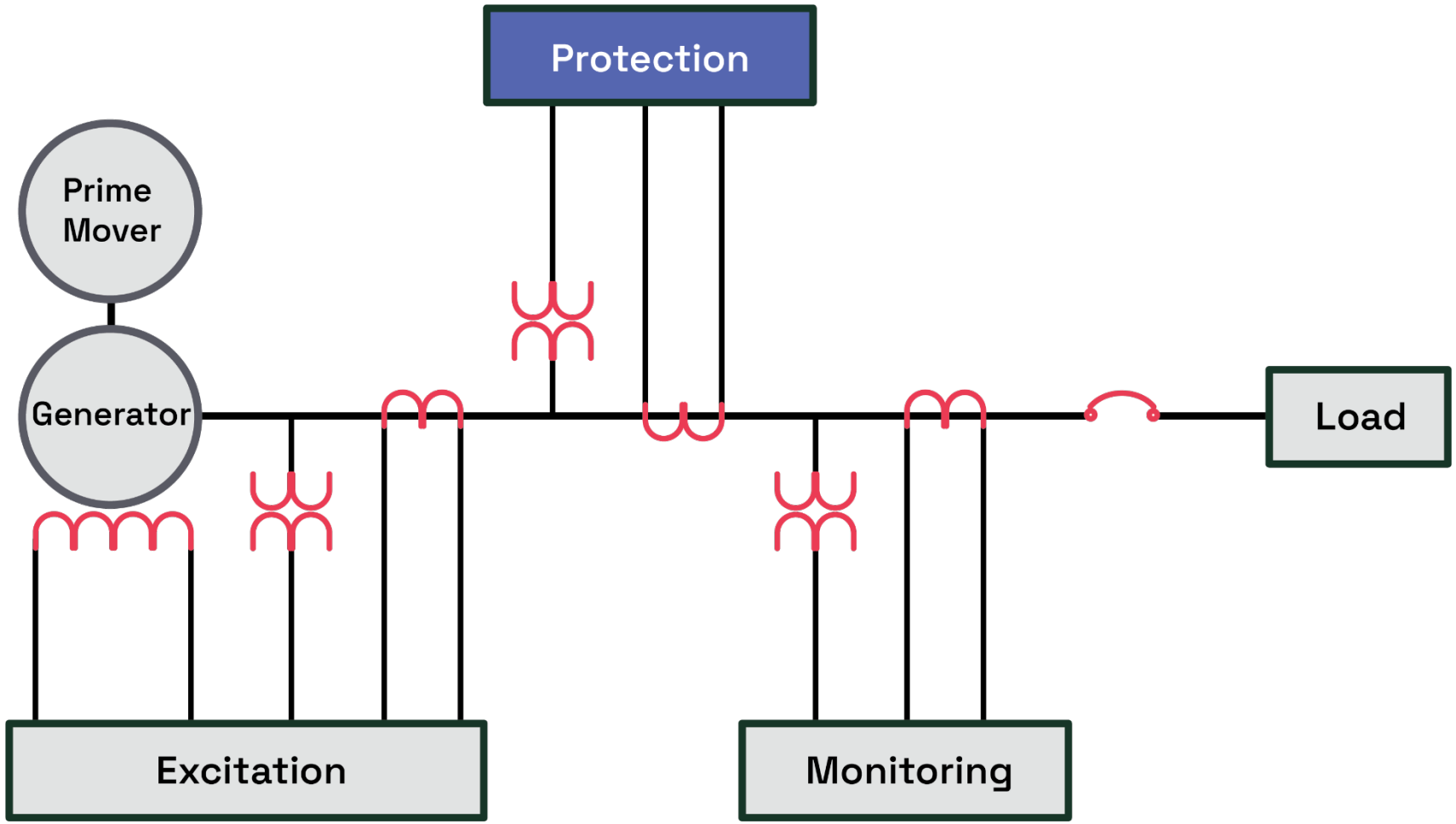






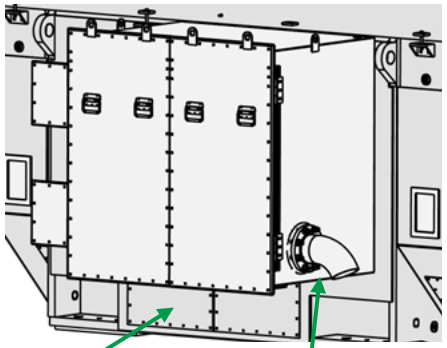


Protection devices commonly selected for Geothermal generators



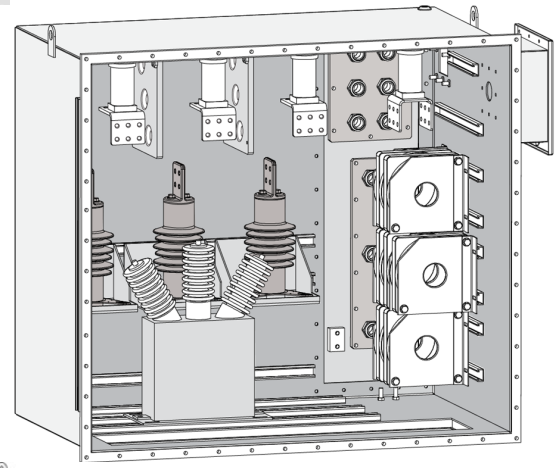
Protection devices commonly selected for Geothermal generators

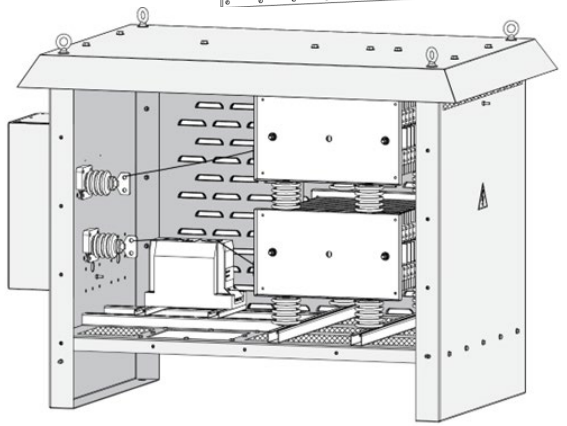
- **Space Heaters** to maintain temperature slightly > ambient air temperature to prevent condensation in generator frame, and main/neutral terminal box (may require thermostatic control)
- **Lightning / Surge Arrestors** for units exposed to direct lightning strikes
- **Surge Capacitors** for applications susceptible to line voltage surges
- **Pressure Relief Diaphragm** to provide a directional / safe release of pressure caused by a fault within a terminal box
- **Voltage Clamping / Limiting Module** for Hazardous and Zone II applications mounted with Current Transformers to protect in an open circuit event (high voltage)
- **Neutral Grounding Resistors** to limit ground fault currents to safe levels to help protect all electrical equipment in the power system
- **Corrosion Protection:** 316 Stainless Steel (small) and Magni 525 coating (large) external fasteners / hardware, Severe Environment Epoxy Paint



Frame Space Heater Access

Pressure Relief Diaphragm





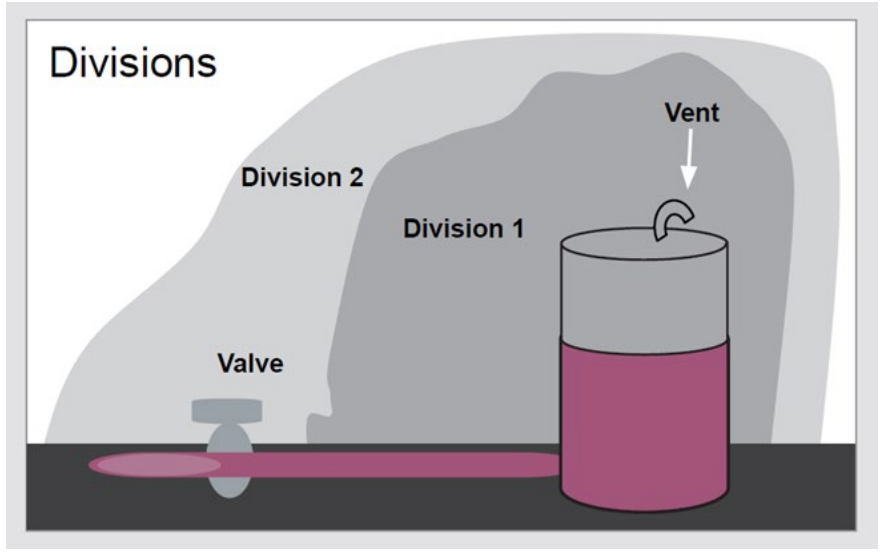
Hazardous Locations Geothermal Generators

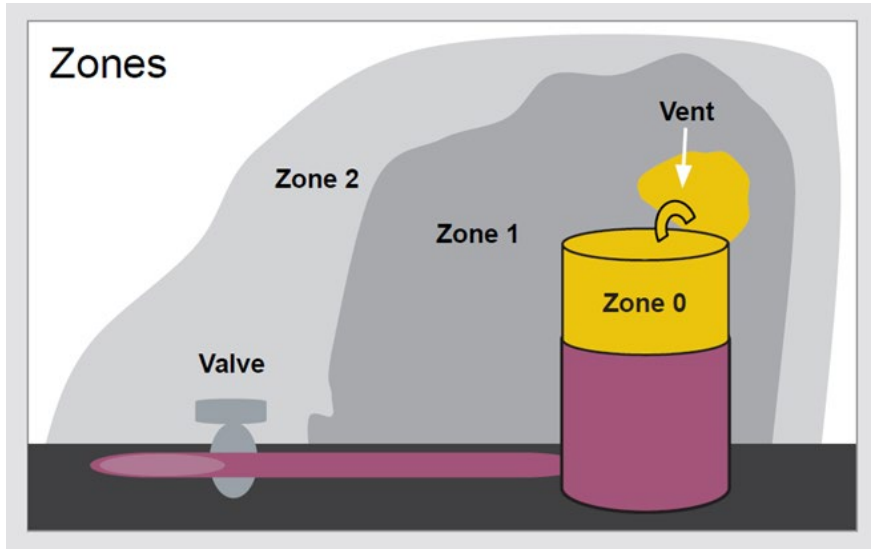
US / existing Canadian sites

- Class I - Those in which flammable vapors and gases may be present.
- Division 2: Explosive Atmosphere is abnormally present

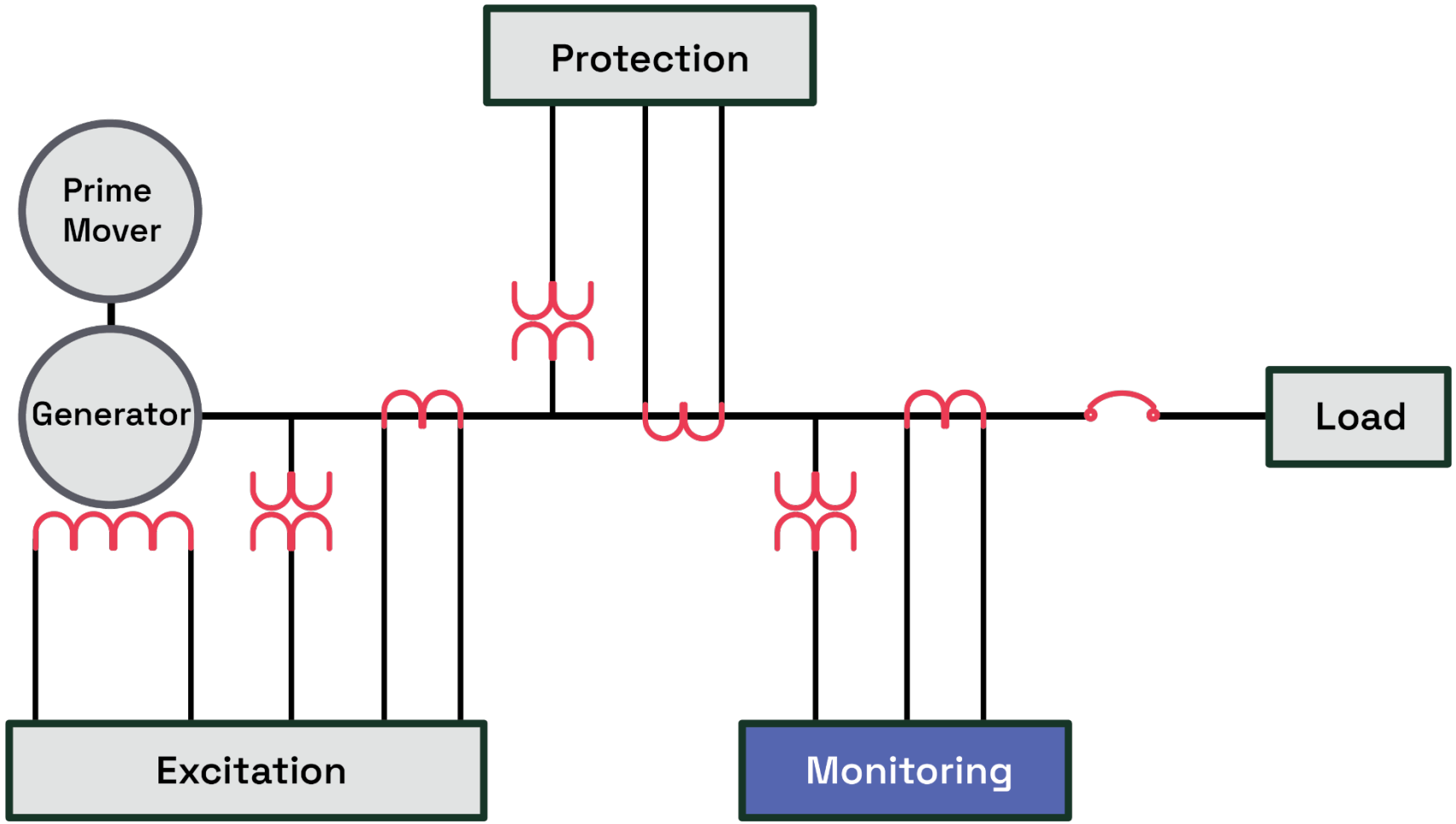
Outside US and existing Canadian sites

- Zone 2: Gaseous Hazard abnormally present



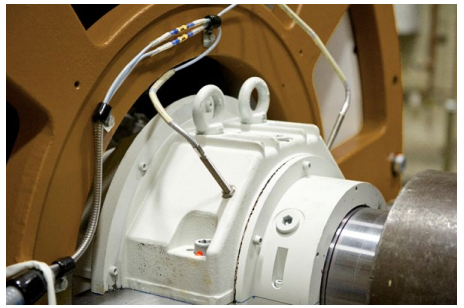


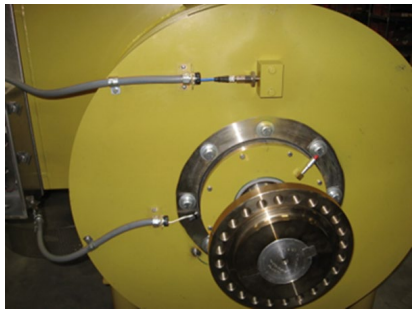
Monitoring devices commonly selected for Geothermal generators

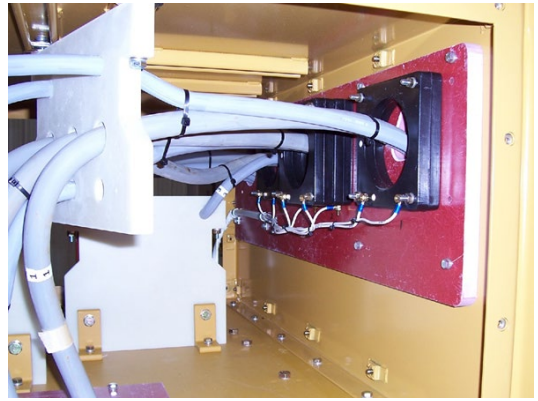


Monitoring devices commonly selected for Geothermal generators

- **Resistance Temperature Detectors (RTD)** embedded in main stator windings, bearing housings, and air & water in/out circuits
- **Proximity Probes and Proximitors** for shaft vibration
- **Key Phaser** for shaft location & speed
- **Velocity / Vibration Transducers** for bearing and or frame housing vibration
- **Current Transformers** for converting primary current to lower secondary current for Differential Fault, Metering, Paralleling, etc.
- **Potential (Voltage) Transformers** for converting primary voltage to a lower secondary voltage for measuring and protection







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