



BIFACIAL DUAL GLASS MONOCRYSTALLINE MODULE

PRODUCT: TSM-NEG19RC.20

PRODUCT RANGE: 565-590W

590W

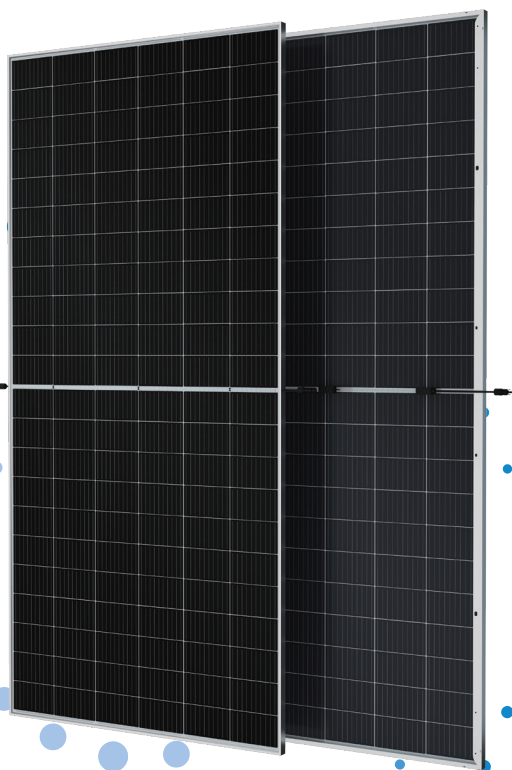
MAXIMUM POWER OUTPUT

0~+5W

POSITIVE POWER TOLERANCE

21.8%

MAXIMUM EFFICIENCY



High customer value

- Lower LCOE (Levelized Cost Of Energy), reduced BOS (Balance of System) cost, shorter payback time
- Lowest guaranteed first year and annual degradation;
- Designed for compatibility with existing mainstream system components
- Higher return on Investment



High power up to 590W

- Up to 21.8% module efficiency with high density interconnect technology
- Multi-busbar technology for better light trapping effect, lower series resistance and improved current collection



High reliability

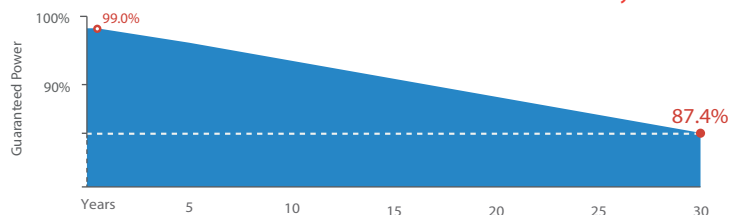
- Minimized micro-cracks with innovative non-destructive cutting technology
- Ensured PID resistance through cell process and module material control
- Resistant to harsh environments such as salt, ammonia, sand, high temperature and high humidity areas
- Mechanical performance up to 5400 Pa positive load and 2400 Pa negative load



High energy yield

- Excellent IAM (Incident Angle Modifier) and low irradiation performance, validated by 3rd party certifications
- The unique design provides optimized energy production under inter-row shading conditions
- Lower temperature coefficient (-0.30%) and operating temperature
- Up to 30% additional power gain from back side depending on albedo

Trina Solar's Vertex Bifacial Dual Glass Performance Warranty



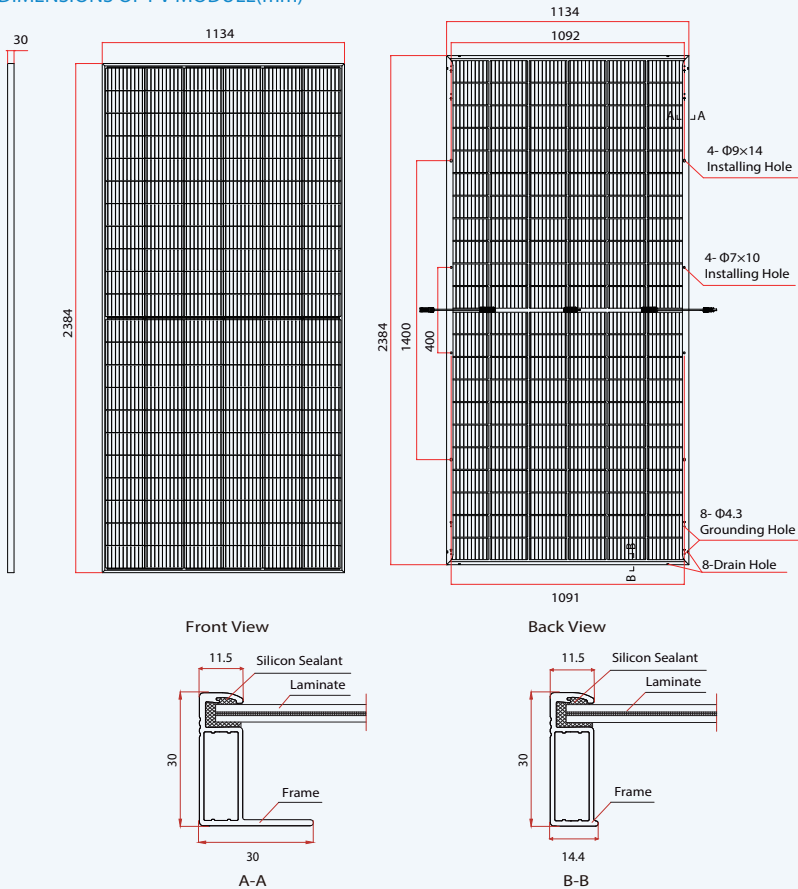
Comprehensive Products and System Certificates



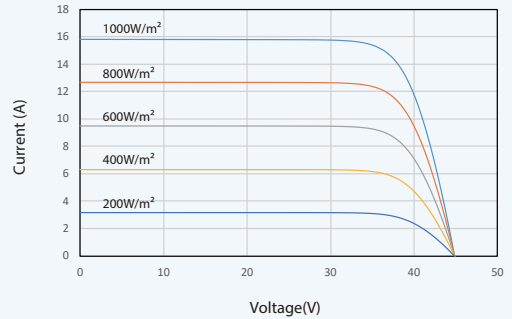
IEC61215/IEC61730/IEC61701/IEC62716/UL61730
 ISO 9001: Quality Management System
 ISO 14001: Environmental Management System
 ISO14064: Greenhouse Gases Emissions Verification
 ISO45001: Occupational Health and Safety Management System



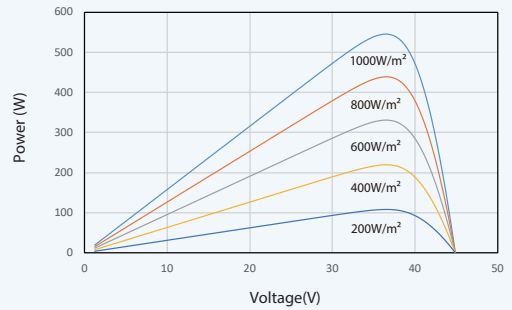
DIMENSIONS OF PV MODULE(mm)



I-V CURVES OF PV MODULE(580 W)



P-V CURVES OF PV MODULE(580 W)



ELECTRICAL DATA (STC)

Peak Power Watts-P _{MAX} (Wp)*	565	570	575	580	585	590
Power Tolerance-P _{MAX} (W)	0 ~ +5					
Maximum Power Voltage-V _{MPP} (V)	38.4	38.6	39.0	39.2	39.5	39.7
Maximum Power Current-I _{MPP} (A)	14.72	14.75	14.77	14.79	14.82	14.85
Open Circuit Voltage-V _{OC} (V)	46.2	46.5	46.9	47.2	47.5	47.8
Short Circuit Current-I _{SC} (A)	15.59	15.62	15.64	15.66	15.69	15.73
Module Efficiency η _m (%)	20.9	21.1	21.3	21.5	21.6	21.8

STC: Irradiance 1000W/m², Cell Temperature 25°C, Air Mass AM1.5. *Measuring tolerance: ±3%.

Electrical characteristics with different power bin (reference to 10% Irradiance ratio)

Total Equivalent power -P _{MAX} (Wp)	610	616	621	626	632	637
Maximum Power Voltage-V _{MPP} (V)	38.4	38.6	39.0	39.2	39.5	39.7
Maximum Power Current-I _{MPP} (A)	15.90	15.93	15.95	15.97	16.01	16.04
Open Circuit Voltage-V _{OC} (V)	46.2	46.5	46.9	47.2	47.5	47.8
Short Circuit Current-I _{SC} (A)	16.84	16.87	16.89	16.92	16.95	16.98
Irradiance ratio (rear/front)	10%					

Power Bifaciality: 80±5%.

ELECTRICAL DATA (NOCT)

Maximum Power-P _{MAX} (Wp)	431	434	439	442	446	449
Maximum Power Voltage-V _{MPP} (V)	43.8	44.1	44.5	44.7	45.0	45.3
Maximum Power Current-I _{MPP} (A)	12.56	12.59	12.60	12.63	12.66	12.69
Open Circuit Voltage-V _{OC} (V)	36.0	36.2	36.6	36.8	37.0	37.2
Short Circuit Current-I _{SC} (A)	11.95	11.97	11.99	12.02	12.04	12.07

NOCT: Irradiance at 800W/m², Ambient Temperature 20°C, Wind Speed 1m/s.

MECHANICAL DATA

Solar Cells	Monocrystalline
No. of cells	110 cells
Module Dimensions	2384×1134×30 mm (93.86×44.65×1.18 inches)
Weight	33.4 kg (73.63 lb)
Front Glass	2.0 mm (0.08 inches), High Transmission, AR Coated Heat Strengthened Glass
Encapsulant material	EVA/POE
Back Glass	2.0 mm (0.08 inches), Heat Strengthened Glass (White Grid Glass)
Frame	30mm(1.18 inches) Anodized Aluminium Alloy
J-Box	IP 68 rated
Cables	Photovoltaic Technology Cable 4.0mm ² (0.006 inches ²), Portrait: 350/280 mm(13.78/11.02 inches) Length can be customized
Connector	MC4 EVO2 / TS4*

*Please refer to regional datasheet for specified connector.

TEMPERATURE RATINGS

NOCT (Nominal Operating Cell Temperature)	43°C (±2°C)
Temperature Coefficient of P _{MAX}	- 0.30%/°C
Temperature Coefficient of V _{OC}	- 0.25%/°C
Temperature Coefficient of I _{SC}	0.04%/°C

MAXIMUM RATINGS

Operational Temperature	-40~+85°C
Maximum System Voltage	1500V DC (IEC)
	1500V DC (UL)
Max Series Fuse Rating	30A

WARRANTY

12 year Product Workmanship Warranty
30 year Power Warranty
1% first year degradation
0.40% Annual Power Attenuation

(Please refer to product warranty for details)

PACKAGING CONFIGURATION

Modules per box: 36 pieces
Modules per 40' container: 720 pieces



Fixed-Tilt Ground Mount Solution | GM-2

When EPCs and project developers across the USA need dependable, low-maintenance ground mount racking, they turn to RBI Solar. As a single-source provider, we take responsibility for the Design, Engineering, Manufacturing, and Installation of PV mounting solutions. When you choose RBI Solar for your next ground mount, you're choosing peace of mind that your project is in the hands of the most trusted solar racking team in the industry.

Why choose RBI Solar?

- Professional Engineers licensed in all 50 states
- Quick response & efficient communication
- National installation capabilities
- Our in-house team members are an extension of your staff
- 85+ years manufacturing experience
- Complete turn-key process, reduction in your vendor coordination
- Company owned post driving equipment
- National project management capabilities with roaming site service personnel
- More time to focus on your business





GM-2 Solution Features

Foundation and racking design	Site wind speeds 170+ mph and ground snow loads 90+ psf
Signed and sealed drawings	Available in all 50 states
Proprietary on-site testing	Pull testing & corrosion testing - no geotechnical report required
Pre-assembled parts	Reduction in installation time
Variable slope	Accommodates slopes up to 30% (with topographic site map)
20-yr standard warranty	Proven rack reliability and bankability
G115 minimum galvanized coating	Exceeds ASTM and UL standards for 30% extended life
Driven posts	Cost-effective cee channel or I-beam post options available
Up to 24' long post driving	Ability to address challenging soils or elevate array structure
Module configurations	Portrait, landscape (all module types)
Raised purlins	Integrated bonding and grounding to UL 2703
Corrosion class	System available for all corrosion classes
Wire management and electrical	Integrated wire management solution and inverter mounting

Contact us at info@rbisolar.com or (513) 242-2051

DESIGN • ENGINEERING • MANUFACTURING • INSTALLATION

6715 Steger Drive, Cincinnati, OH 45237 | 513-242-2051 | info@rbisolar.com | www.rbisolar.com



SUNNY CENTRAL

2660 UP-US / 2800 UP-US / 2930 UP-US / 3060 UP-US



Efficient

- Up to 4 inverters can be transported in one standard shipping container
- Overdimensioning up to 150% is possible
- Full power at ambient temperatures of up to 35°C

Robust

- Intelligent air cooling system OptiCool for efficient cooling
- Suitable for outdoor use in all climatic ambient conditions worldwide

Flexible

- Conforms to all known grid requirements worldwide
- Q on demand
- Available as a single device or turnkey solution, including Medium Voltage Power Station

Easy to Use

- Improved DC connection area
- Connection area for customer equipment
- Integrated voltage support for internal and external loads

SUNNY CENTRAL

2660 UP-US / 2800 UP-US / 2930 UP-US / 3060 UP-US

The new Sunny Central: more power per cubic meter

With an output of up to 3060 kVA and system voltages of 1500 V DC, the SMA central inverter allows for more efficient system design and a reduction in specific costs for PV power plants. A separate voltage supply and additional space are available for the installation of customer equipment. True 1500 V technology and the intelligent cooling system OptiCool ensure smooth operation even in extreme ambient temperature as well as a long service life of 25 years.

SUNNY CENTRAL 2660 UP-US / 2800 UP-US

Technical data*	SC 2660 UP-US	SC 2800 UP-US
Input (DC)		
MPP voltage range V_{DC} (at 35 °C / at 50 °C)	880 to 1325 V / 1100 V	921 to 1325 V / 1100 V
Min. input voltage $V_{DC, min}$ / Start voltage $V_{DC, Start}$	849 V / 1030 V	891 V / 1071 V
Max. input voltage $V_{DC, max}$	1500 V	
Max. input current $I_{DC, max}$ / with DC coupling	3200 A / 4800 A	
Max. short-circuit current $I_{DC, sc}$	6400 A	
Number of DC inputs	24 double pole fused (32 single pole fused)	
Number of DC inputs with optional DC coupling of battery	18 double pole fused (36 single pole fused) for PV, 6 double pole fused for batteries	
Max. number of DC cables per DC input (for each polarity)	2 x 800 kcmil, 2 x 400 mm ²	
Integrated zone monitoring	○	
Available PV fuse sizes (per input)	200 A, 250 A, 315 A, 350 A, 400 A, 450 A, 500 A	
Available DC-DC converter fuse size (per input)	750 A	
Output (AC)		
Nominal AC power at $\cos \phi = 1$ (at 35 °C / at 50 °C)	2667 kVA / 2400 kVA	2800 kVA / 2520 kVA
Nominal AC power at $\cos \phi = 0.8$ (at 35 °C / at 50 °C)	2134 kW / 1920 kW	2240 kW / 2016 kW
Nominal AC current $I_{AC, nom}$ (at 35 °C / at 50 °C)	2566 A / 2309 A	
Max. total harmonic distortion	< 3% at nominal power	
Nominal AC voltage / nominal AC voltage range ^{1) 8)}	600 V / 480 V to 720 V	630 V / 504 V to 756 V
AC power frequency / range	50 Hz / 47 Hz to 53 Hz 60 Hz / 57 Hz to 63 Hz	
Min. short-circuit ratio at the AC terminals ⁹⁾	> 2	
Power factor at rated power / displacement power factor adjustable ^{8) 10)}	1 / 0.8 overexcited to 0.8 underexcited	
Efficiency		
Max. efficiency ²⁾ / European efficiency ²⁾ / CEC efficiency ³⁾	98.7%* / 98.6%* / 98.5%*	98.7%* / 98.6%* / 98.5%*
Protective Devices		
Input-side disconnection point	DC load break switch	
Output-side disconnection point	AC circuit breaker	
DC overvoltage protection	Surge arrester, type I	
AC overvoltage protection (optional)	Surge arrester, class I	
Lightning protection (according to IEC 62305-1)	Lightning Protection Level III	
Ground-fault monitoring / remote ground-fault monitoring	○ / ○	
Insulation monitoring	○	
Degree of protection	NEMA 3R	
General Data		
Dimensions (W / H / D)	2815 / 2318 / 1588 mm (110.8 / 91.3 / 62.5 inch)	
Weight	< 3400 kg / < 7500 lb	
Self-consumption (max. ⁴⁾ / partial load ⁵⁾ / average ⁶⁾	< 8100 W / < 1800 W / < 2000 W	
Self-consumption (standby)	< 370 W	
Internal auxiliary power supply	○ Integrated 8.4 kVA transformer	
Operating temperature range ⁸⁾	-25 °C to 60 °C / -13 °F to 140 °F	
Noise emission ⁷⁾	67.0 dB(A)*	
Temperature range (standby)	-40 °C to 60 °C / -40 °F to 140 °F	
Temperature range (storage)	-40 °C to 70 °C / -40 °F to 158 °F	
Max. permissible value for relative humidity (condensing / non-condensing)	95% to 100% (2 month/year) / 0% to 95%	
Maximum operating altitude above MSL ⁸⁾ 1000 m / 2000 m	● / ○ (earlier temperature-dependent derating)	
Fresh air consumption	6500 m ³ /h	
Features		
DC connection	Terminal lug on each input (without fuse)	
AC connection	With busbar system (three busbars, one per line conductor)	
Communication	Ethernet, Modbus Master, Modbus Slave	
Communication with SMA string monitor (transmission medium)	Modbus TCP / Ethernet (FO MM, Cat-5)	
Enclosure / roof color	RAL 9016 / RAL 7004	
Supply transformer for external loads	○ (2.5 kVA)	
Standards and directives complied with	UL 62109-1, UL 1741 (Chapter 31, CDR 61), UL 1741-SA, UL 1998, IEEE 1547, MIL-STD-810G	
EMC standards	FCC Part 15 Class A	
Quality standards and directives complied with	VDI/VDE 2862 page 2, DIN EN ISO 9001	
● Standard features ○ Optional * preliminary		

1) At nominal AC voltage, nominal AC power decreases in the same proportion

2) Efficiency measured without internal power supply

3) Efficiency measured with internal power supply

4) Self-consumption at rated operation

5) Self-consumption at < 75% P_n at 25 °C

6) Self-consumption averaged out from 5% to 100% P_n at 25 °C

7) Sound pressure level at a distance of 10 m

8) Values apply only to inverters. Permissible values for SMA MV solutions from SMA can be found in the corresponding data sheets.

9) A short-circuit ratio of < 2 requires a special approval from SMA

10) Depending on the DC voltage

SUNNY CENTRAL 2930 UP-US / 3060 UP-US

Technical data*	SC 2930 UP-US	SC 3060 UP-US
Input (DC)		
MPP voltage range V_{DC} (at 35 °C / at 50 °C)	962 to 1325 V / 1100 V	1003 to 1325 V / 1100 V
Min. input voltage $V_{DC, min}$ / Start voltage $V_{DC, Start}$	934 V / 1112 V	976 V / 1153 V
Max. input voltage $V_{DC, max}$	1500 V	
Max. input current $I_{DC, max}$ / with DC coupling	3200 A / 4800 A	
Max. short-circuit current $I_{DC, sc}$	6400 A	
Number of DC inputs	24 double pole fused (32 single pole fused)	
Number of DC inputs with optional DC coupling of battery	18 double pole fused (36 single pole fused) for PV, 6 double pole fused for batteries	
Max. number of DC cables per DC input (for each polarity)	2 x 800 kcmil, 2 x 400 mm ²	
Integrated zone monitoring	○	
Available PV fuse sizes (per input)	200 A, 250 A, 315 A, 350 A, 400 A, 450 A, 500 A	
Available DC-DC converter fuse size (per input)	750 A	
Output (AC)		
Nominal AC power at $\cos \phi = 1$ (at 35 °C / at 50 °C)	2933 kVA / 2640 kVA	3067 kVA / 2760 kVA
Nominal AC power at $\cos \phi = 0.8$ (at 35 °C / at 50 °C)	2346 kW / 2112 kW	2454 kW / 2208 kW
Nominal AC current $I_{AC, nom}$ (at 35 °C / at 50 °C)	2566 A / 2309 A	
Max. total harmonic distortion	< 3% at nominal power	
Nominal AC voltage / nominal AC voltage range ^{1) 8)}	660 V / 528 V to 759 V	690 V / 552 V to 759 V
AC power frequency / range	50 Hz / 47 Hz to 53 Hz 60 Hz / 57 Hz to 63 Hz	
Min. short-circuit ratio at the AC terminals ⁹⁾	> 2	
Power factor at rated power / displacement power factor adjustable ^{8) 10)}	1 / 0.8 overexcited to 0.8 underexcited	
Efficiency		
Max. efficiency ²⁾ / European efficiency ²⁾ / CEC efficiency ³⁾	98.7%* / 98.6%* / 98.5%*	98.7%* / 98.6%* / 98.5%*
Protective Devices		
Input-side disconnection point	DC load break switch	
Output-side disconnection point	AC circuit breaker	
DC overvoltage protection	Surge arrester, type I	
AC overvoltage protection (optional)	Surge arrester, class I	
Lightning protection (according to IEC 62305-1)	Lightning Protection Level III	
Ground-fault monitoring / remote ground-fault monitoring	○ / ○	
Insulation monitoring	○	
Degree of protection	NEMA 3R	
General Data		
Dimensions (W / H / D)	2815 / 2318 / 1588 mm (110.8 / 91.3 / 62.5 inch)	
Weight	< 3400 kg / < 7500 lb	
Self-consumption (max. ⁴⁾ / partial load ⁵⁾ / average ⁶⁾	< 8100 W / < 1800 W / < 2000 W	
Self-consumption (standby)	< 370 W	
Internal auxiliary power supply	○ Integrated 8.4 kVA transformer	
Operating temperature range ⁸⁾	-25 °C to 60 °C / -13 °F to 140 °F	
Noise emission ⁷⁾	67.0 dB(A)*	
Temperature range (standby)	-40 °C to 60 °C / -40 °F to 140 °F	
Temperature range (storage)	-40 °C to 70 °C / -40 °F to 158 °F	
Max. permissible value for relative humidity (condensing / non-condensing)	95% to 100% (2 month/year) / 0% to 95%	
Maximum operating altitude above MSL ⁸⁾ 1000 m / 2000 m	● / ○ (earlier temperature-dependent derating)	
Fresh air consumption	6500 m ³ /h	
Features		
DC connection	Terminal lug on each input (without fuse)	
AC connection	With busbar system (three busbars, one per line conductor)	
Communication	Ethernet, Modbus Master, Modbus Slave	
Communication with SMA string monitor (transmission medium)	Modbus TCP / Ethernet (FO MM, Cat-5)	
Enclosure / roof color	RAL 9016 / RAL 7004	
Supply transformer for external loads	○ (2.5 kVA)	
Standards and directives complied with	UL 62109-1, UL 1741 (Chapter 31, CDR 6I), UL 1741-SA, UL 1998 IEEE 1547, MIL-STD-810G	
EMC standards	FCC Part 15 Class A	
Quality standards and directives complied with	VDI/VDE 2862 page 2, DIN EN ISO 9001	
● Standard features ○ Optional * preliminary		

1) At nominal AC voltage, nominal AC power decreases in the same proportion

2) Efficiency measured without internal power supply

3) Efficiency measured with internal power supply

4) Self-consumption at rated operation

5) Self-consumption at < 75% P_n at 25 °C

6) Self-consumption averaged out from 5% to 100% P_n at 25 °C

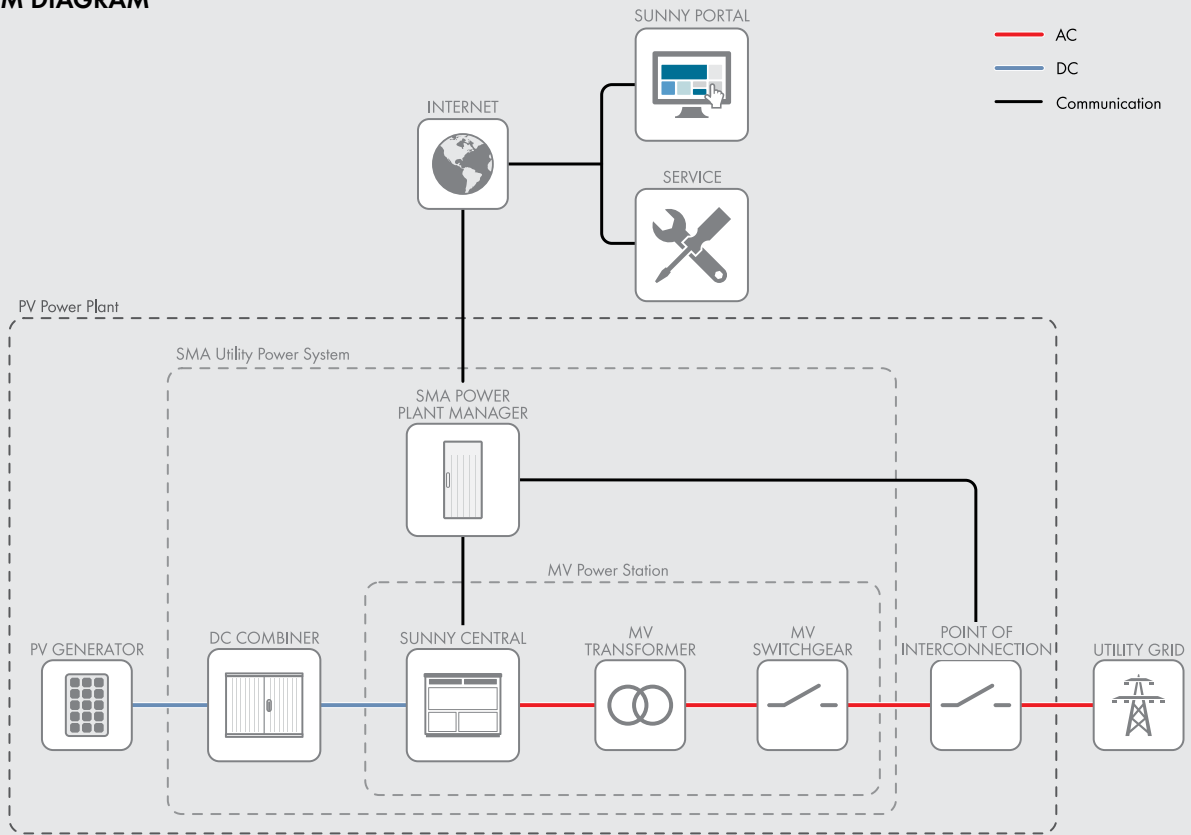
7) Sound pressure level at a distance of 10 m

8) Values apply only to inverters. Permissible values for SMA MV solutions from SMA can be found in the corresponding data sheets.

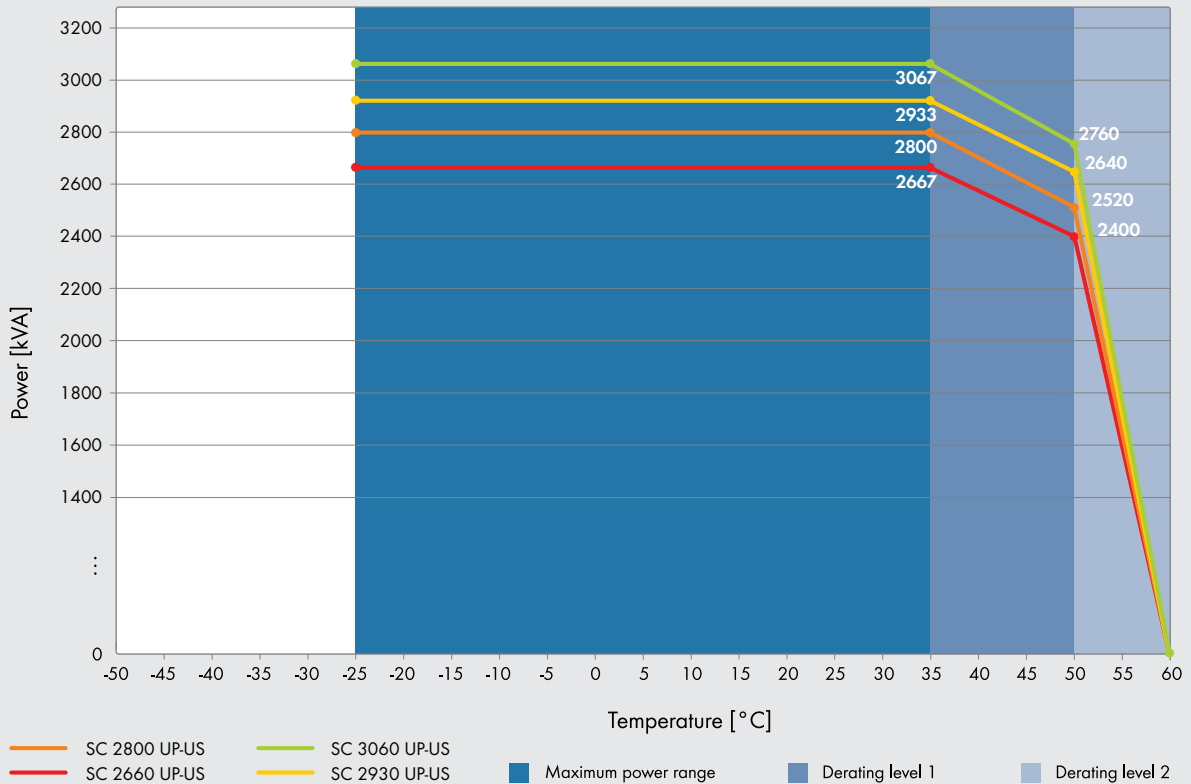
9) A short-circuit ratio of < 2 requires a special approval from SMA

10) Depending on the DC voltage

SYSTEM DIAGRAM



TEMPERATURE BEHAVIOR (at 1000 m)



SC2-3XXUPUSDS-en-17 All products and services described and all technical data are subject to change, even for reasons of country-specific deviations, at any time without notice. SMA assumes no liability for typographical or other errors. For current information, please see www.SMA.Solar.com.

RELIABLE TRANSFORMERS

for Renewable Energy



GSU PAD MOUNT TRANSFORMERS



VIRGINIA TRANSFORMER CORP

Corporate Office: 220 Glade View Drive, Roanoke, VA 24012 Ph: 540.345.9892

GSU TRANSFORMERS

IT'S IN THE DESIGN! – IT'S WHAT'S INSIDE THAT COUNTS

THE PROBLEM:

- SOLID STATE CONVERTER/INVERTERS IN TYPE 3 AND 4 TURBINES PRODUCE CURRENT AND VOLTAGE HARMONICS
- 5-LEGGED AND WOUND CORE DESIGN S MOST SUSEPTABLE TO HARMONICS AND GASSING
- THESE HARMONICS CAUSE LOCALIZED HEATING IN THE CORE AND COIL – LEADING TO GASSING AND ACCELERATED INSULATION AGING
 - GASSING ----- LOSS OF LIFE
 - DEGASSING ----- LOSS OF REVENUE
- DESIGN CONSTRUCTION - 3 - LEGGED CORE, RECTIFIER TYPE DESIGN MITIGATES HEATING, GASSING, AND PARTIAL DISCHARGE
- CORE FLUX DENSITY DESIGNS MINIMIZE HARMONICS AND HOT SPOTS
- ELECTROSTATIC SHIELDS – PREVENT CAPACITIVELY (COUPLED TRANSFER OF HIGH FREQUENCY HARMONICS FROM ONE WINDING TO ANOTHER)

THE SOLUTION:

- 30 YEARS EXPERIENCE IN RECTIFIER TRANSFORMER DESIGN
- RECTIFIER DUTY DESIGN MITIGATES HARMONIC HEATING AND GASSING
- 3 - LEGGED DESIGN OVERCOMES GASSING
- ELECTROSTATIC SHIELDS PREVENT COUPLED TRANSFER OF HARMONICS IN WINDING
- 3 YEAR WARRANTY, INCLUDING GASSING

RELIABLE GSU TRANSFORMER FOR RELIABLE POWER





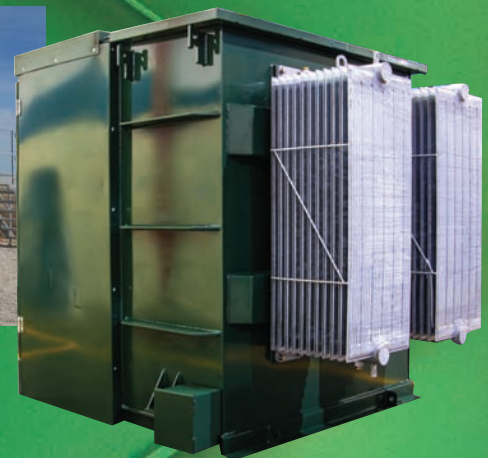
VIRGINIA TRANSFORMER CORP

VALUE - TECHNOLOGY - CONSTRUCTION



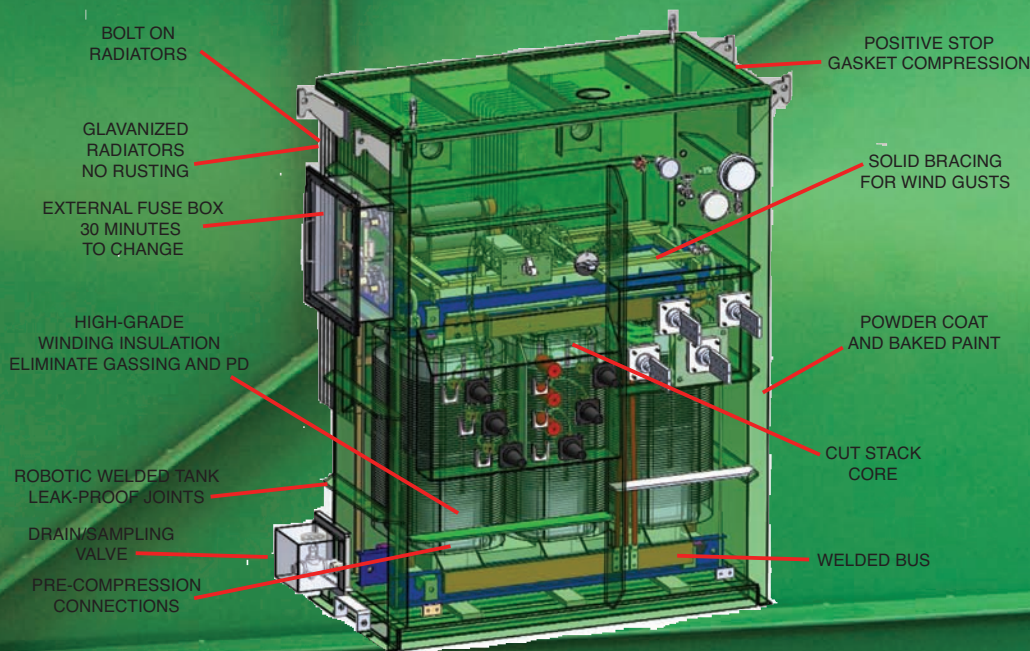
RELIABILITY BUILT THROUGH INNOVATIVE TECHNOLOGY

- INSULATION DESIGN; NO HOT SPOTS
- PRECOMPRESSION CONNECTORS - NO ARCING
- CLAMPED COILS - NO SHORT CIRCUIT FAILURES
- AUTOMATED CORE CUTTING - NO BURRS
- PLC CONTROLLED WINDINGS - NO LOOSE COILS
- EXTERNAL WEAK LINK FUSE BOX - NO DOWNTIME OR OIL CONTAMINATION
- GALVANIZED RADIATORS - NO RUST - NO OIL LEAKS
- ROBOTIC WELDING - NO JOINT LEAKS



25 YEAR LIFE PROTECTED BY PATENTS

IT'S WHAT'S INSIDE THAT COUNTS





Do Not Operate When Trapped

LOAD BREAK SWITCH



H1A



H1B



H2A



H2B

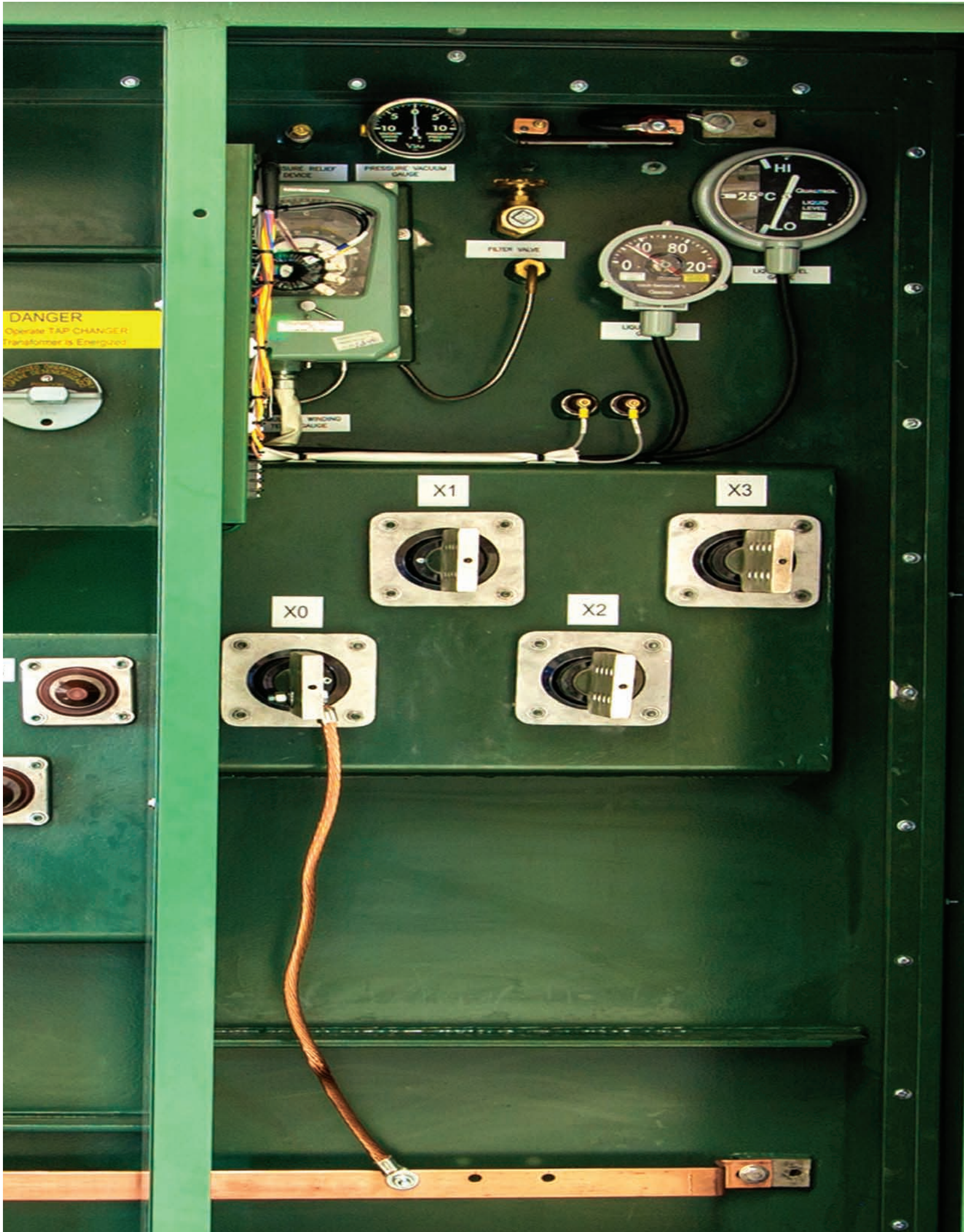


H3A



H3B







VIRGINIA TRANSFORMER CORP

STANDARD FEATURES

- PAD MOUNT LOOP FEED DEAD FRONT
- 1000 KVA – 3500 KVA
- 15 KV – 34.5 KV
- ALUMINUM WINDING
- EFFICIENCY: >99.3%
- BIL HV 150 - 200KV, LV 30 - 45 KV
- DELTA / GROUNDED WYE
- TEMPERATURE RISE 65° C
- FLUID - MINERAL OIL
- VOLTAGE ADJUSTMENT +5% TO -5% IN 2.5% STEPS
- GAUGES - PRV, PRESSURE/VACUUM LEVEL, TEMP.
- PAINT - POWDER COAT BAKED EPOXY
- MUNSELL GREEN (OTHER COLORS AVAILABLE)
- WEATHER PROOF GASKETS IN RETAINED GROOVES
- 3 YEAR WARRANTY, INCLUDING GASSING
- RADIATORS: GALVANIZED, BOLT-ON /
FIELD REPLACEABLE
- ELECTROSTATIC SHIELDING
- STAINLESS STEEL DOOR HINGES
- PADLOCKING AND PENTA HEAD BOLT,
3 POINT LATCHING
- 1" OIL DRAIN VALVE
- NEMA SST GROUND PADS
- POINT LIFTING
- JACKING BOSSES
- PRV, PRESSURE/VACUUM LEVEL, TEMP.

OPTIONAL FEATURES

- PAD MOUNT RADIAL FEED - DEAD FRONT, LIVE FRONT
- > 3500 KVA
- COPPER WINDINGS
- EXTREME LOW LOSS (LL/NLL) DESIGNS AVAILABLE
- WYE/WYE
- TEMPERATURE RISE 55° C/65° C
- * FLUID: FR3 / ENVIROTEMP / LUMINOL
- PAINT: CHOICE OF COLORS
- EXTERNAL MOUNTED WEAK LINK FUSE BOX
- RAD VALVES
- CIRCUIT BREAKERS
- EXTERNAL DRAIN VALVE
- CSA, IEC, UL

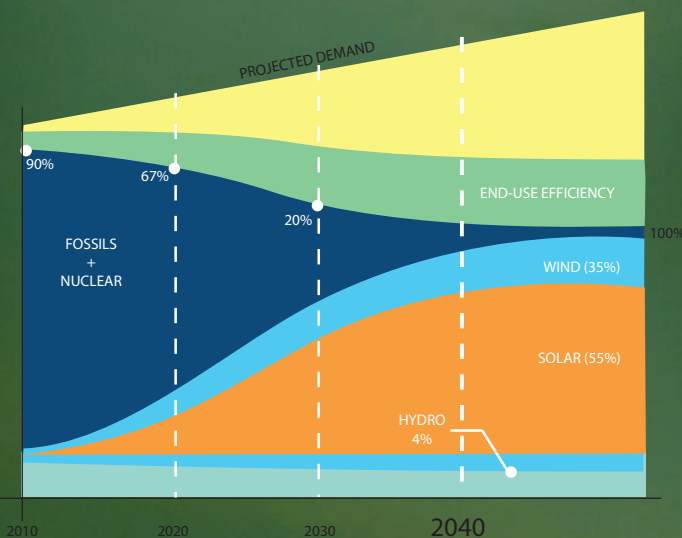
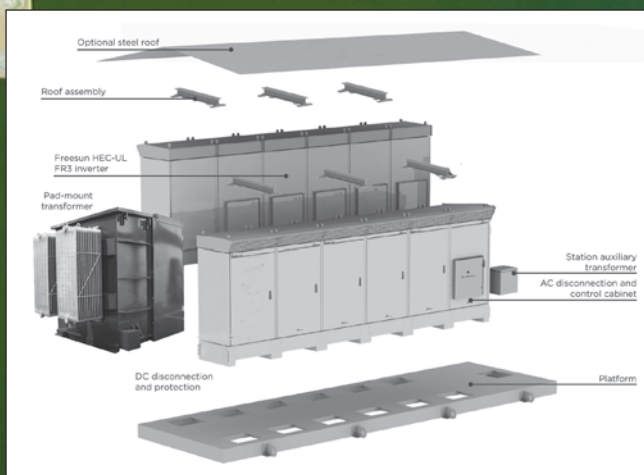


A 25 YEAR LIFE TRANSFORMER

SOLAR UTILITY – SCALE TRANSFORMERS

WILL YOUR TRANSFORMER STILL BE WORKING AFTER 25 YEARS?

- STAND - ALONE OR E-HOUSE INSTALLATIONS
- LIQUID GSU PAD MOUNTS – LONG LIFE INSTALLATIONS
- LIQUID OR DRY TYPE FOR E-HOUSE INSTALLATIONS AVAILABLE





VIRGINIA TRANSFORMER CORP

Virginia Transformer is a leader in custom power transformers engineered precisely for your application and optimized for performance and long life.

Corporate Office & Roanoke Facility

220 Glade View Drive
Roanoke, VA 24012

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VTC Pocatello, ID

3770 Poleline Rd.
Bldg. #37
Pocatello, ID 83201

☎ 208.238.0720
✉ 208.238.1678

VTC Chihuahua, MX

Complejo Industrial Chihuahua,
Ave. Homero #3307
Chihuahua, Mexico

☎ 52.614.483.0000
✉ 52.614.481.4900

VTC Delhi, India Office

Engineering Procurement

Field Service – Installation | Maintenance | Spare Parts

From three locations in North America

1-800-882-3944

24/7/365

www.vatransformer.com

For Sales assistance please contact our Corporate Sales Office 540.345.9892 or
e-mail sales@vatransformer.com

Visit www.vatransformer.com to find contact information for local sales representative



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PHOENIX FENCE

EDMONTON

12816-156 STREET T5V 1E9
 PHONE: (780) 447-1919
 FAX: (780) 447-2512
 TOLL FREE: 1-800-661-9847
 E-MAIL: phoenix@phoenixfence.ca

CALGARY

6204-2nd STREET S.E. T2H 1J4
 PHONE: (403) 259-5155
 FAX: (403) 259-2262
 TOLL FREE: 1-888-220-2525
 E-MAIL: calgary@phoenixfence.ca

WEBSITE: www.phoenixfence.ca

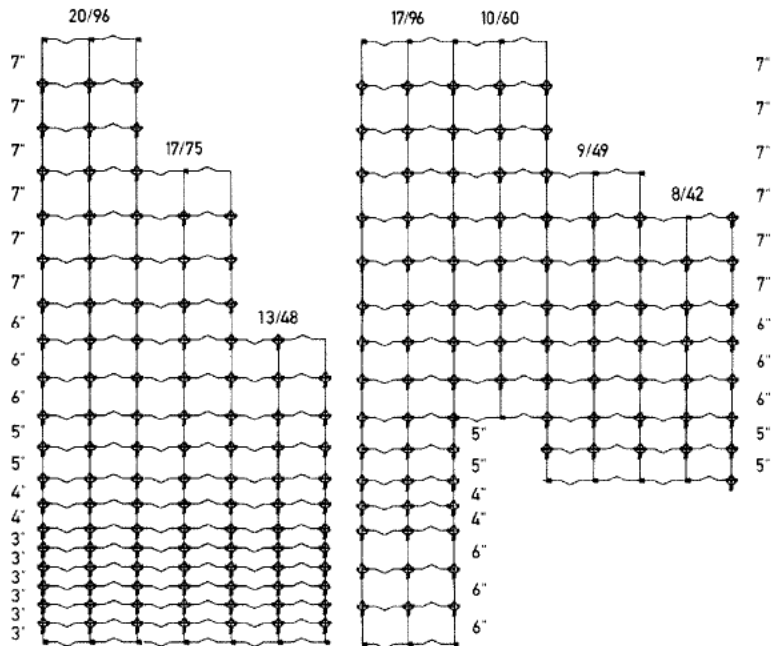
Fixed Knot Fence Specifications

Wire	Gauge	Tensile Strength	Breaking Load	Galvanization
Line Wires	12 1/2 ga.	Hi-Tensile 179K-210K	1350 lbs – 1584 lbs	.85 oz.-1.4oz. per sq.ft.
Stay Wires	12 1/2 ga.	Med-Tensile 125K-145K	943 lbs – 1094 lbs	.85 oz.-1.4oz. per sq.ft.
Knot Wires	13 ga.	Low Tensile 72K-95K	438 lbs – 580 lbs	.85 oz.-1.4oz. per sq.ft.

Wire Type	Length	Weight
20/96/6	330'	386 lbs
20/96/6	500'	585 lbs
20/96/12	330'	276 lbs
20/96/12	660'	552 lbs
17/96/6	330'	346 lbs
17/96/6	500'	525 lbs
17/96/12	330'	247 lbs
17/75/6	330'	318 lbs
17/75/12	330'	229 lbs
10/60/6	330'	205 lbs
10/60/12	660'	293 lbs
9/49/12	660'	256 lbs
13/48/6	330'	220 lbs
8/42/12	660'	220 lbs

Order Nomenclature:

The first number indicates the number of horizontal wires, while the second number indicates the height of the fence. The last number is the distance between vertical stays.
 Eg. 20/96/12 is a roll with 20 horizontal wires, is 96" high, with vertical stays 12" apart



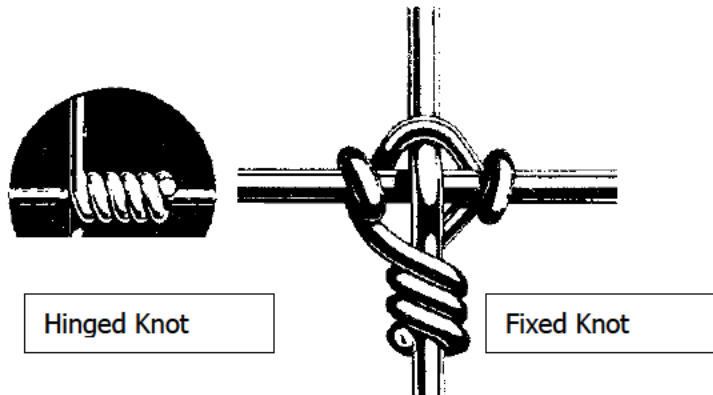
FIXED-KNOT fencing is designed

specifically for wildlife and is not a domestic livestock fence being used as a wildlife fence. Here is the ultimate in fencing for all animals, large or small, wild or domestic. FIXED-KNOT, a North American product, gives excellent control for animal containment, exclusion and protection from predators.

FIXED-KNOT Hi-Tensile fencing is the best of its kind. Exceeding Class 3 galvanizing assures three times the life over conventional hinge joint fencing. The combination of Hi-Tensile wire (which provides three times the strength of conventional 12 1/2 ga. Wire) and fixed knot vertical stays allow fence installation using 20' post centers.

FIXED-KNOT vs. Hinge lock

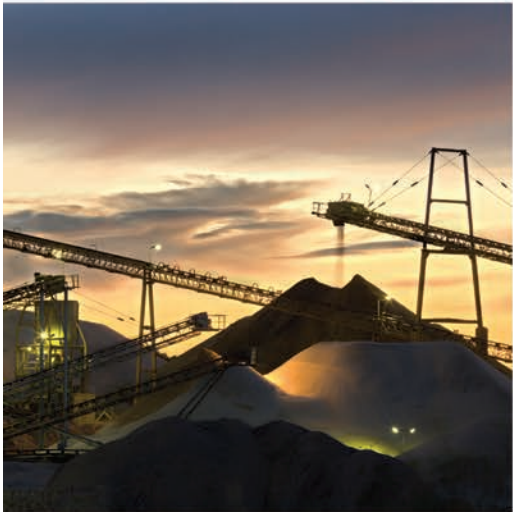
Fixed lock (game fence) has continuous horizontal (line) and vertical (stay) wires, and the wires are fastened together using a fixed lock knot. Hinge lock (farm fence) has continuous horizontal (line) wires and vertical wires that are wrapped between the line wires using a hinge lock. The fixed knot is considerably stronger



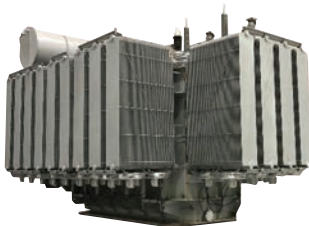


VIRGINIA TRANSFORMER

Precisely Your Power Solution



VIRGINIA - GEORGIA TRANSFORMER
ONE SOURCE-ONE COMMITMENT



Liquid Filled Transformers
Load Tap Changing Transformers
Three-Phase Voltage Regulators

Liquid-Filled Transformers for Precisely Your Application



Full Range of Liquid-Filled Transformers

Virginia Transformer manufactures a full range of liquid-filled transformers from 500 kVA to 1,400 MVA up to 500 kV class, from 45° C rise to 65° C rise.



OLTC transformer, available up to 500 MVA



On-Load Tap Changing (OLTC) Transformers

Tap Changer Types: Virginia Transformer offers resistive-type OLTC or reactive-vacuum-type systems. We will custom engineer your transformer with the OLTC switch connected on the high- or low-voltage winding according to your specifications.



Virginia Transformer Three-Phase Voltage Regulators up to 50 MVA throughput and 69 kV

Three-Phase Voltage Regulators

Virginia Transformer voltage regulators are used in distribution applications throughout North America to maintain voltage over transmission lines.

Virginia Transformer Liquid-Filled Transformers: Powering Industrial, Commercial, and Utility Operations Throughout North America

Engineered and Custom Built to Your Precise Requirements

Our expert sales team helps you specify your individual transformer requirements. Our engineering and manufacturing staff transforms your specifications into a unique, top quality, efficient, and long-life solution for your application. Virginia Transformer will customize units for special requirements. Common options and accessories are available for system protection, reliability and hassle-free maintenance.

Virginia Transformer brings more than 50 years of transformer engineering experience to each new assignment. We have amassed an archive of more than 15,000 designs and test data, serving as an exclusive resource for the development of new solutions...perhaps yours.



Virginia Transformer liquid-filled transformers are integral to industrial, commercial, and utility operations, but don't let that limit your thinking. We build custom units for specialty segments such as mining, transit, oil & gas, marine, government, data centers, storage facilities, and export markets. Think about your precise requirements. We do.



Circular Coil Windings for Short-Circuit Stability

Virginia Transformer uses disc and/or helical winding types for both HV and IV windings, using either copper or aluminum conductors, as specified. Windings are made in temperature- and pressure-controlled environments. We typically provide circular coils, which are more stable than rectangular coils and can better withstand short-circuit forces.

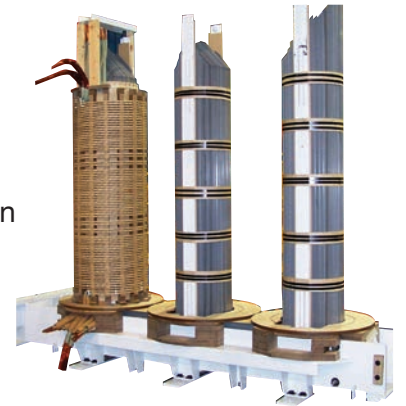
Rectangular coils tend to become circular when exposed to strong short-circuit conditions; this transformation can lead to internal damage.



Core-Stacking Configurations to Optimize Cost, losses, and Sound levels

Virginia Transformer engineers select from a variety of core-lamination materials based on your specifications that are made from high-grade, grain-oriented silicon steel to optimize cost, losses, and sound levels.

Virginia Transformer uses mitered-joint and/or step-lap core construction with an appropriate grade of cold-rolled, grain-oriented silicon steel laminations for optimum efficiency and



Choice of Oil Preservation Systems

Virginia Transformer offers three types of oil preservation systems based on your specification for liquid-filled transformers: sealed tanks, conservators and automatic (nitrogen) positive-pressure systems.

Conservator tanks are custom designed primarily for environments with extreme variations in ambient temperatures, most often in severe cold and winter climates.



VCM (Virginia Control Module) Transforms Control and Management

Monitor your transformer's performance remotely with wired (Modbus, DNP3 and Fiber) or wireless connection VCMs from Virginia Transformer. The VCM is a proprietary PLC-based monitoring and diagnostic module to track and record topoil temperature, winding temperature indicator, gas pressure, rate-of-rise pressure, and liquid level. The device sends real-time, solid-state contact outputs, and data to supervisory controls. VCM analyzes and detects abnormal conditions and provides data for trend analysis and historical review.

VCM Transformer Monitoring and Diagnostic Module connects through the internet remotely for a real-time view of transformer conditions.



Equipped For Heightened Performance

Virginia Transformer Standard Features

Range – 500 kVA to 1,400 MVA up to 500 kV class
Loading – Designed to deliver rated current and MVA in all tap positions

Service – Outdoor or indoor

Basic Impulse Level (BIL) – Per ANSI standard / CSA standard - or per spec

Impedance – ANSI standard/CSA standard - or per spec

Coils – Aluminum or copper conductor, circular construction, utilizing helical or continuous disc design
Cooling Fluid – Type II mineral oil or less-flammable oils including biodegradable fluids

Fluid Preservation System – Sealed tank, conservator with bladder, nitrogen preservation

Cooling Radiators – Panel type, galvanized standard
Gauges and Accessories – Liquid-temperature gauge, liquid-level gauge, vacuum-pressure gauge, drain valves, filter press connections (top and bottom), automatic pressure relief device, control wiring for indoor/outdoor

Paint – ANSI 61/70 epoxy, polyurethane, high-performance paint on sandblasted surface; special colors available

Nameplate – Stainless steel, engraved

Bushings – Cover or side-mounted in air chambers

Removable manhole covers

Provisions on base for skidding

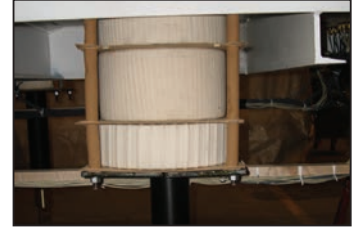
Radiator Mounted Fans



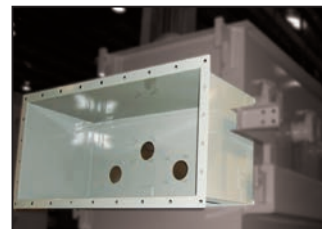
Potential Transformer



CT's (Bushing mounted internally)



Throat for Non-Segregated Bus



Dual Voltage Switch



Nitrogen Preservation System



Control Cabinet



LTC Controls



Custom Options

- Nitrogen supply for oil preservation
- Reconnectable windings
- Non-standard impedance
- High-performance paint in your choice of color
- Demountable radiators with isolation valves
- Stainless steel radiators
- Air terminal throats and chambers
- Explosion-proof control box
- Sloped or dome top cover
- Multi-stage fan cooling for increased MVA
- Thermally upgraded insulation system 120° C
- Customer-specific controls and relays
- Stainless-steel junction box
- Less-flammable fluids – natural and synthetic ester
- Low-temperature oils – Isuminol
- Control wiring – rigid, or flexible conduits

FIVE (5) MANUFACTURING PLANTS IN NORTH AMERICA

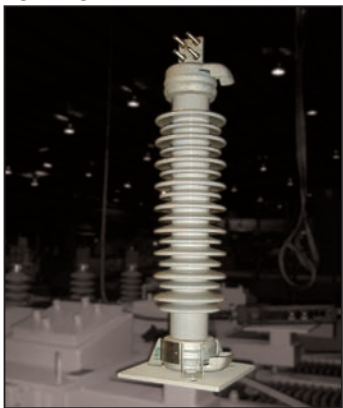
Load Tap Changer



Liquid Level Gauge



Lightning Arrestors



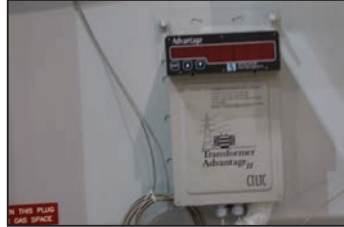
Side Mounted LV Bushings



HV Bushings & Arrestors (Shipped demounted)

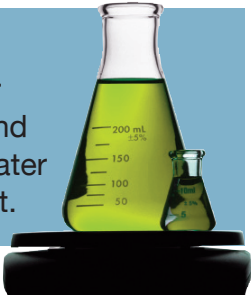


Electronic Temperature Monitor



Fluid Choices

Virginia Transformer uses natural and synthetic esters to lower the risk of fire or explosion in equipment located indoors or near buildings or hazards. Natural and synthetic esters are less-flammable transformer fluids that provide an even greater flash/fire point and are biodegradable to lessen the impact on the environment.



Engineered for Your Precise Requirements



Sophisticated AutoCAD® design systems drive down costs and optimize performance

Custom engineering is our calling card at Virginia Transformer. We provide more than a dozen transformer types for industrial, commercial and utility operations plus variations for mining, cement, marine, export, transit, oil & gas, government facilities and data center specialties. Our engineering strength extends to every discipline of transformer design including electrical, mechanical, thermal and materials engineering.

The design and engineering process at Virginia Transformer is ISO-9001-2015 Certified and delivers quality assured transformers for customer applications demanding performance, efficiency and long-life at the lowest possible cost.



Controlled Manufacturing Environments

- Virginia Transformer is in the leader of transformer manufacturing processes and technology. We produce the world's finest liquid-filled transformers in controlled environments at our five plants in North America.



Test Proof

Virginia Transformer performs complete, in-house production testing per ANSI C57.12.90 and customer specifications as applicable, including:

- Ratio
- Resistance Measurement
- Impedance & Load loss
- Induced Potential
- Polarity & Phase Relation
- Excitation Current & No-load loss
- Applied Potential

Other testing facilities are available including

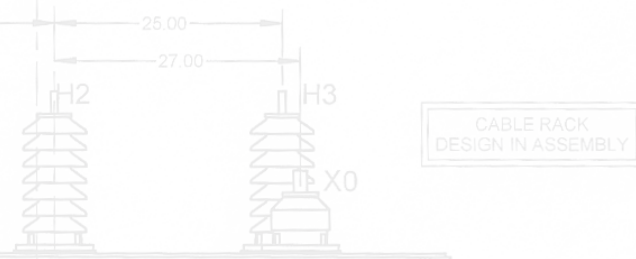
- Power Factor*
- Lightning Impulse Test*
- Switching Surge
- Sweep Frequency Response Analysis (SFRA)
- Sound level Measurement
- Partial Discharge*
- Front of Wave
- Temperature Rise Test
- Short-Circuit Test (Outside lab)
- Thermal Imaging during Temperature Rise Test

* Becomes routine test for Class II Power Transformers



Shortest Industry Lead Times

Linked design, engineering, and manufacturing systems help us produce and deliver custom-built transformers with the industry's shortest turnaround times for both drawing submittals and production.

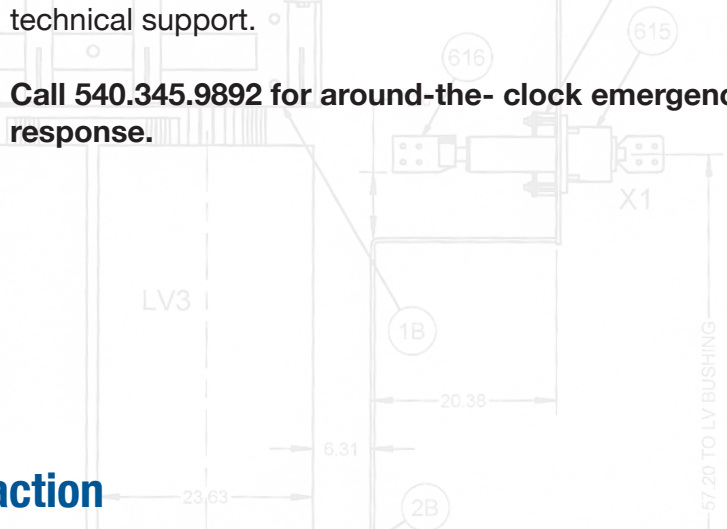


Field Service for Installation and Maintenance



We offer complete installation and maintenance support for transformers produced in our facilities, including assembly, oil filling, pre-commissioning testing, repair services, replacement parts, oil handling, hot-oil processing and testing services, periodic inspection, and technical support.

Call 540.345.9892 for around-the-clock emergency response.



Commitment to Customer Satisfaction

Each transformer is installed under the watchful eye of our Customer Service Center. They will know the status of your transformer project at every stage of production from start to finish. You will have your own single point of contact for contracts and logistics. You will be kept informed and up to date. Your total satisfaction is both our goal and commitment.

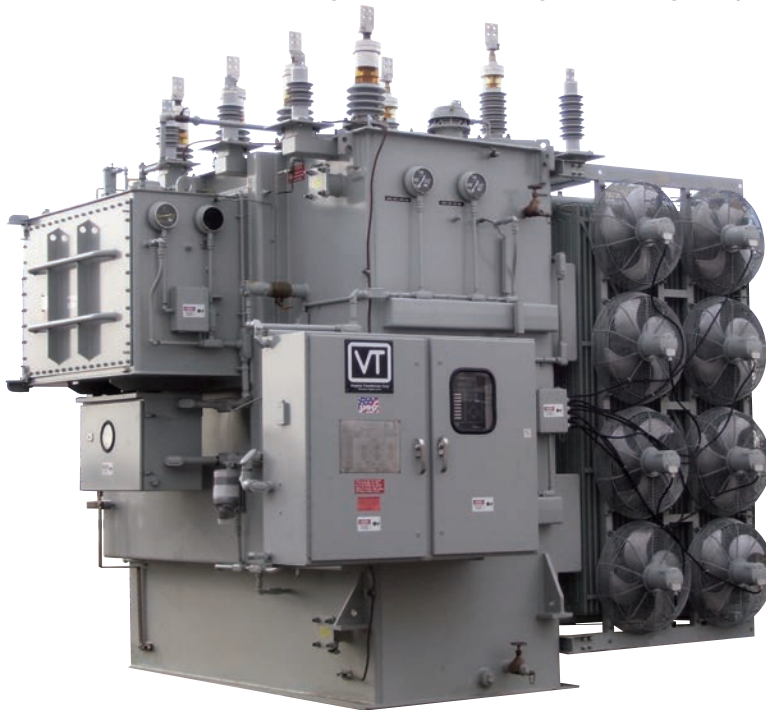


Virginia Transformer On-Load Tap Changer (OLTC) Solutions

Individualized Solutions for Precisely the Transformer You Need

Virginia Transformer designs OITC transformers for your specific application. Resistive-type or reactive-vacuum-type systems are available. You can configure your transformer with the OLTC connected on the high-or low-voltage winding, depending on your application.

A tap range of +/- 10 percent in 5/8 percent increments is typical, but increased adjustment ranges and incremental steps are available, as directed by your requirements.



Control System Alternatives to Fit Your Operations

Virginia Transformer offers local or remote, automatic or manual control systems for single or multiple (parallel) applications. Line monitoring, time delays, supervisory control and interfaces are available as required.

OLTC Transformers available from 500 kVA to 1400 MVA in liquid filled units up to 500 kV class.

Additional options are available for this application, including remote indication of tap position via selsyn, current-loop analog output, digital position indicator, multi-contact position indicator, and more.

Long Life and Reliability Means You Keep the Power On

Virginia Transformer utilizes coil-winding designs and bracing to maximize short-circuit strength. The core and coil designs are also optimized to the customer's loss evaluation profile. Hot spots are calculated to ensure the transformer runs at a consistent and appropriate temperature, with additional cutting-edge equipment available to monitor transformer health.

Transform Your LTC into an Intelligent Transformer

With the available VICM, your LTC transformer will talk to you. VICM provides alarm contacts for the 16L, 16R, Nominal and Off Tap positions and operational counter information on its PIC screen and on your PC screen via remote or direct access. Electronic contacts replace mechanical switches common in other devices for greater reliability and lower cost.

Isolation view of VLCM with accessible PLC.
Direct or remote access to data with optional wired connection (wireless network).

VLCM installs neatly inside the LTC motor cabinet.



Voltage Regulators

Three-phase voltage regulators are used in distribution and transmission applications to maintain steady voltages. The voltage ratio of a regulator is nearly one to one as its basic design differs from that of an OITC transformer, in that it is wound as an auto-transformer.

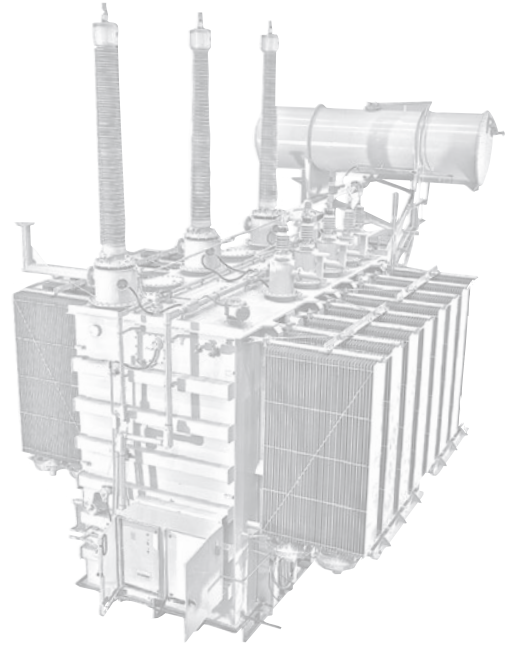
Many critical applications require a more controlled voltage delivered at the load terminals. Three-phase voltage regulators can perform this duty by employing a load tap changer, which is operated by sensing the load voltage. Our designs utilize the Reinhausen RMVII tap changer. Normally, about +/-10percent voltage is required to be corrected and therefore employing an auto-transformer configuration would result in ten times the through-put power for the same sized transformer.



Transformer Facts

Dimensions and weights are typical and should not be used for design purposes. For exact dimensions and weights, contact factory. Smaller or matching dimensions may be possible.

TYPICAL DIMENSIONS														
15 and 35 kV Classes, Two-winding, Copper					46 and 69 kV Classes, Two-winding, Copper, Circular					115 kV Class				
KVA	H"	W"	D"	Wt. Lbs.	KVA	H"	W"	D"	Wt. Lbs.	KVA	H"	W"	D"	Wt. Lbs.
500	57	43	55	7,600	1500	120	84	78	15,600	5000	80	145	124	53,000
750	59	46	62	9,500	2000	125	88	84	19,000	7000	185	147	138	65,000
1000	64	49	64	10,700	2500	125	90	88	22,200	10000	189	160	141	72,000
1500	73	53	64	14,000	3750	130	96	94	28,500	12000	190	170	150	80,000
2000	76	53	80	16,000	5000	130	100	98	34,200	15000	195	170	160	85,000
2500	79	55	108	19,000	7500	135	106	106	44,200	20000	196	180	165	107,000
3750	82	61	110	24,100	10000	135	112	112	54,000	25000	210	195	180	130,000
5000	89	78	109	32,300	12000	140	115	115	60,500	36000	210	220	200	160,000
7500	93	86	114	39,300	15000	140	120	122	70,000	50000	240	260	220	200,000
10000	110	94	117	46,100	20000	165	140	160	90,000	-	-	-	-	-
12000	118	97	118	54,200	25000	180	160	180	105,000	-	-	-	-	-
15000	124	103	124	63,000	33000	192	220	190	140,000	-	-	-	-	-

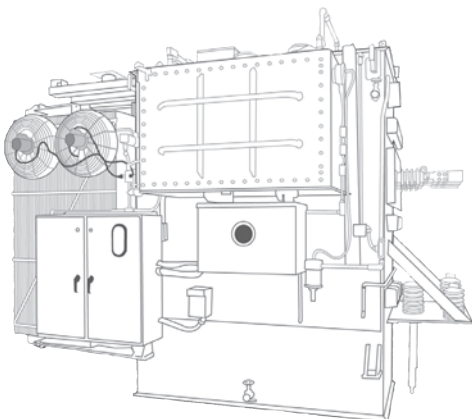


TYPICAL DIMENSIONS														
138 kV Class					161 kV Class					230 kV Class				
KVA	H"	W"	D"	Wt. Lbs.	KVA	H"	W"	D"	Wt. Lbs.	KVA	H"	W"	D"	Wt. Lbs.
7500	195	155	140	70,000	10000	215	156	175	100,000	15000	250	240	180	123,000
10000	202	160	150	80,000	-	-	-	-	-	20000	-	-	-	-
12000	209	165	160	87,500	15000	230	180	175	119,000	25000	250	280	195	175,000
15000	213	170	180	100,000	25000	240	210	200	160,000	37500	290	290	200	220,000
20000	220	180	190	120,000	-	-	-	-	-	40000	302	310	240	235,000
25000	220	200	200	135,000	36000	256	230	220	175,000	50000	298	300	230	250,000
36000	225	220	205	165,000	50000	260	280	235	225,000	-	-	-	-	-
50000	248	270	225	215,000	-	-	-	-	-	-	-	-	-	-

AUDIBLE SOUND LEVELS

kVA	Sound Level (dBA)
700	57
1000	58
1500	60
2000	61
2500	62
3000	63
4000	64
5000	65
6000	66
7500	67
10000	68
12500	69
15000	70
20000	71
25000	72
30000	73
40000	74
50000	75

BIL AND PERCENT IMPEDANCE VOLTAGES AT SELF-COOLED (ONAN) RATING



High Voltage BIL (kV)	Without LTC	With LTC
≤110	5.5	-
150	6.5	7.0
200	7.0	7.5
250	7.5	8.0
350	8.0	8.5
450	8.5	9.0
550	9.0	9.5
650	9.5	10.0
750	10.0	10.5

Above 15000 kVA consult factory. Data are based on OA rating for oil-immersed power transformers are per NEMA TR-1 standard.

COMPARISON OF PROPERTIES OF LESS-FLAMMABLE FLUIDS

		Mineral Type II	Luminol Bi	Beta -51	FR-3	Silicone
Dielectric	Dielectric Strength kV	30	44	40	45	35
	Dielectric Constant	2.2	2.2	2.1	3.2	2.7
	25 °C	>0.05	<0.0001	0.05	0.08	0.01
	100 °C	>0.30	0.0001	0.1	0.59	0.9
Physical	Specific Gravity 25° C	0.91	0.835	0.87	0.92	0.96
	Interfacial Tension 25° C (dynes/em) Neutralization	40	48	38	24	31
	Total Acid Number (mgKOH/gram)	0.4	<0.01	0.01	0.02	0.01
Thermal Viscosity	0 °C	76	48	195	190	90
	40 °C	12	9.0	108	34	38
	100 °C	3.0	2.4	12	88	16
Thermal	Flash Point °C	145	>160	284	316	300
	Fire Point °C	173		308	360	370
	Pour Point °C	-40	<-40	-24	-21	-55

DIELECTRIC INSULATION LEVELS FOR CLASS II POWER TRANSFORMERS

LOW FREQUENCY TEST LEVELS						
Nominal System Voltage (kV)	Basic lightning impulse insulation level (BIL) (kV crest)	Chopped wave level (kV crest)	Switching impulse level (BSL) (kV crest)	Induced-voltage test (phase to ground)		Applied voltage test level (kV rms)
				One hour level (kV rms)	Enhancement level (kV rms)	
115	350	385	280	105	120	140
	450	495	375	105	120	185
	550	605	460	105	120	230
138	450	495	375	125	145	185
	550	605	460	125	145	230
	650	715	540	125	145	275
161	550	605	460	145	170	230
	650	715	540	145	170	275
	750	825	620	145	170	325
230	650	715	540	210	240	275
	750	825	620	210	240	325
	825	905	685	210	240	360
	900	990	745	210	240	395

IEEE Std C57.12.00-2006

IEEE STANDARD FOR STANDARD GENERAL REQUIREMENTS FOR LIQUID-IMMERSED DISTRIBUTION, POWER, AND REGULATING TRANSFORMERS

DIELECTRIC INSULATION LEVELS FOR DISTRIBUTION TRANSFORMERS AND CLASS I POWER TRANSFORMERS

Application	Basic lightning impulse insulation level (BIL) (kV crest)	Chopped-wave impulse levels		Induced-voltage test		Low-frequency test level (kV rms)
		Minimum voltage (kV crest)	Minimum time to flashover (μs)	Minimum voltage (kV crest)	Specific time to sparkover (μs)	
	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Distribution	30	36	1.0	---	---	10
	45	54	1.5	---	---	15
	60	69	1.5	---	---	19
	75	88	1.6	---	---	26
	95	110	1.8	---	---	34
	125	145	2.25	---	---	40
	150	175	3.0	---	---	50
	200	230	3.0	---	---	70
Power	250	290	3.0	---	---	95
	350	400	3.0	---	---	140
	45	50	1.5	---	---	10
	60	66	1.5	---	---	15
	75	83	1.5	---	---	19
	95	105	1.8	165	0.5	26
	110	120	2.0	195	0.5	34
	150	165	3.0	260	0.5	50
	200	220	3.0	345	0.5	70
	250	275	3.0	435	0.5	95
350	385	3.0	580	0.58	140	

Applicable Standards

- ANSI – American National Standards Institute
- IEC – International Electrical Commission
- IEEE – Institute of Electrical and Electronic Engineers
- CSA – Canadian Standards Association
- C57.12.00 – Standard General Requirements for Liquid-Immersed Distribution, Power and Regulating Transformers
- C57.12.90 – Standard Test Code for Liquid-Immersed Distribution, Power and Regulating Transformers and Guide for Short Circuit Testing of Distribution and Power Transformers
- C57.93 – Guide for installation of Liquid-Immersed Power Transformers
- C57.98 – Guide for Transformer Impulse Tests
- C57.100 – Standard Test Procedure for Thermal Evaluation of Oil-Immersed Distribution Transformers

Ever Expanding Markets and Applications



Utility Power Generation

<ul style="list-style-type: none"> Substations Voltage Regulator Auto-Transformer Grounding Transformer Sub Transmission Bi-Directional 	<ul style="list-style-type: none"> Generator Step Up (GSU) Unit Auxiliary Transformer (UAT) Station Service Transformer (SST) Excitation Generator Start Up 	<ul style="list-style-type: none"> Reserve Auxiliary Transformer Solar & Wind Power Geo Thermal Bio-Mass
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Virginia Transformer maintains professional relationships with engineering consulting firms and keeps a large archive of engineering solutions complete with Utility customer profiles to facilitate your specification and purchasing process.

Industrial Applications

<ul style="list-style-type: none"> Rectifier Duty Paper & Cement Mills Steel Mills Motor Start Fan, Pump, & Compressor Operation Data Centers Bitcoin Mining EV Charging Stations 	<ul style="list-style-type: none"> Hoists Mining Drive Isolation (AC, DC) Chemical Plants/Ethanol Oil & Gas: Refineries, Pipelines, Storage, etc. 	<ul style="list-style-type: none"> Zig-Zag Transformers Special Fluid Transformers – Natural and Synthetic Ester Fluids Chemical/Hazardous Environment – Class I, Division II, Group C & D Coastal Environment/Offshore
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Commercial/Institutional

Hospitals, Universities, Hotels, Offices, Airports, Unit Substations

Transit & Large Drive Switch Gear Match Up for

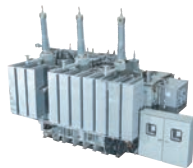
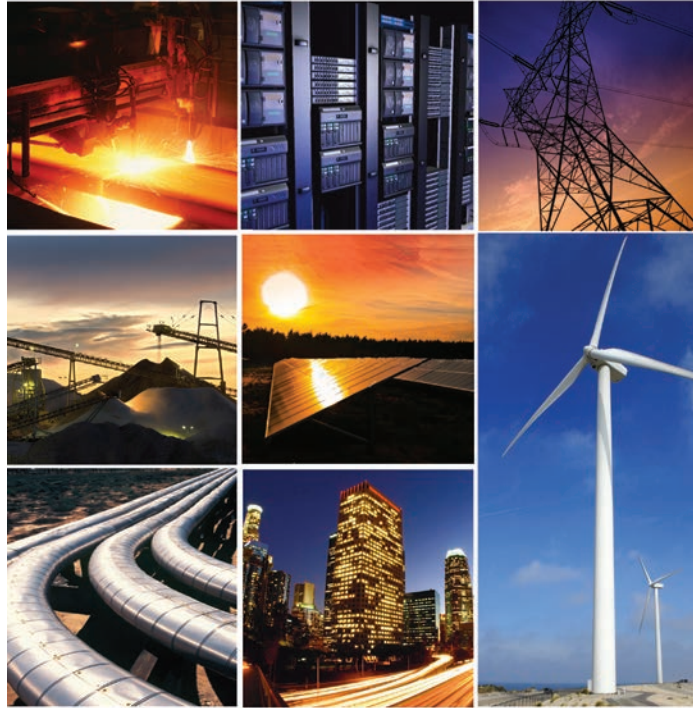
<ul style="list-style-type: none"> Extra Heavy Duty Traction (RI9) ANSI Circuit 25, 26, 25 & 26, 31, 41 Up to 5000 kW Rectifier Up to 20,000 HP, AC, DC Liquid Filled - 55° C or 65° C Rise Dry Type – 80° C, 115° C, 150° C Rise 	<ul style="list-style-type: none"> General Electric Cutler-Hammer Siemens Square D Others
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Transformer Noise

Lokesh Solanki
VTC Engineering Department

Introduction:

- **What is sound?**

Sound is an air pressure disturbance that human ear can ‘hear’. Speech produces sound and disturbances produced by practically everything that moves. the frequency of the sound wave is perceived as pitch and amplitude is perceived as loudness.

When the sound is unwanted, it becomes “Noise”. Transformers in operation emit noise, the magnitude of noise increases with its size in MVA and its voltage class.

Sound level for transformers is specified in NEMA TR1.

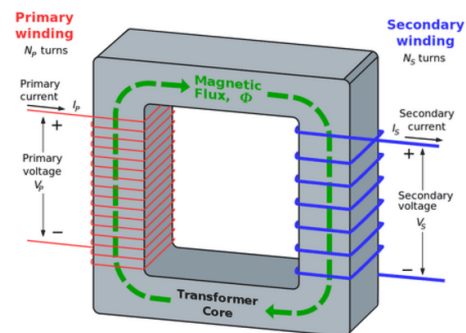
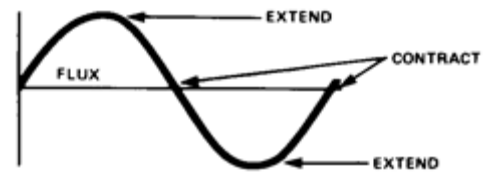
- **How it is produced?**

Transformer core noise is caused by a phenomenon called magnetostriction. In very simple terms this means that if a piece of magnetic sheet steel is magnetized it will extend itself. A transformer is magnetically excited by an alternating voltage and current so it becomes extended and contracted twice during a full cycle of magnetization. The frequency is 2X of the frequency of the voltage.

A transformer core is made from many thin sheets of special electrical steel. It is made this way to reduce losses due to circulating eddy currents, and the consequent heating effect. If the extensions and contractions described above are taking place in various directions depend upon the clamping of the laminations, each sheet can nonuniformly behave over its length and width. This ‘writhing’ and twisting motion produces harmonics of the fundamental frequency up to the 16th harmonic. These extensions are a few micro inches dimensionally, however, sufficient to cause a vibration as noise. This is the core noise.

Apart from the core noise, transformer windings contract and expand with the current. The frequency of winding noise is that of the current. The noise generated by core and winding is transmitted to the tank wall via the mechanical structure and through the oil. The magnetic shields, if used, will also vibrate with the magnetic flux and create noise.

During operation, transformer generate heat which is dissipated by radiators, fans are used to enhance cooling. The fan motor and blades, causing additional noise. The fan noise is added to transformer noise and total noise of transformer during operation increased.



- **What is the significance of sound to the quality and reliability of transformer?**

The transformer noise is mainly due to vibration in the core laminations due to magnetostriction. As we all know vibration is not good for any device. The effect of vibration in transformer is as bad as of any rotating equipment. More noise means more vibration and more vibration means more abrasion of transformer insulation. Vibration also cause looseness in hardware. Insulation

abrasion will lead to coil failure and loose hardware leads to increased vibration and increased insulation abrasion, and loosening of electrical connections.

How to mitigate transformer Noise?

- In order to mitigate transformer noise, it is essential to know the amount of noise generated by transformer. With wide range of transformer design and number of transformer tested designed and tested for noise level, VTC/GTC has developed an empirical formula to estimate noise level generated by transformer during operation.

$$\text{Transformer Noise} = K_1 \lg W + K_2 B + K_3 \text{ [dB]} \quad \dots\dots\dots (1)$$

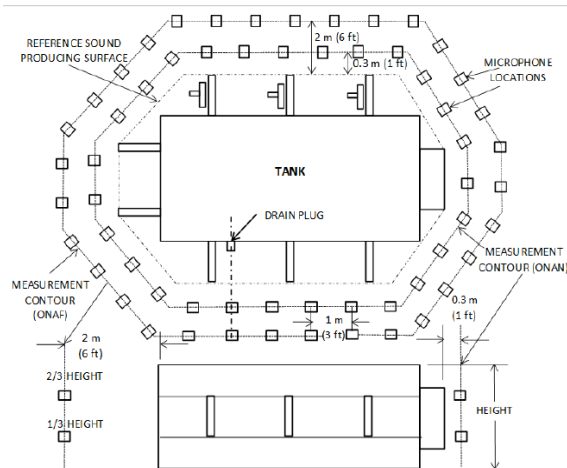
Where, W = Core weight, B = Flux Density and K_1, K_2, K_3 = coefficients and constants

These can be evaluated with large amount of data and then used to predict the noise from a transformer.

Using various design considerations as explained below the overall transformer noise is reduced at design stage.

- Reduction of noise from Core:
 - a. No-load sound level of core mainly depends on Magnetostriction and magnetic forces. The magnitude of Magnetostriction could be reduced by lowering flux density. The studies show that reducing induction by 0.1 Tesla flux density, noise of transformer's core reduces by 3 - 4 dB. Flux density is inversely proportional to the core weight, means the weight and cost of the transformer increases. This method, while the easiest, is the most costly method.
 - b. Grade of CRGO laminations, which is used for making the core, should have properties such as low loss, high permeability and low noise generation from core. When applying high B and laser scribed laminations, it is possible to reduce transformer's noise for approximately 3 dB.
 - c. Core construction is also important to reduce noise generated by core. Study shows that step-lap lap core construction reduces the noise of the magnetic core for up to 6 dB. At lower inductions with step-lap even greater noise reduction can be achieved.
 - d. Well-designed clamping and tightening structure and techniques for the core yokes and legs can reduce the noise due to reduced magnetostriction and reduced interlaminar 'chatter'. Controlling the 3 dimensional 'undulation' of the core assembly will also reduce the harmonics.
 - e. The vibration of transformer core sheets is the main source of noise generation in transformer. Tightening the core and reducing gaps in the corners will help to reduce core noise. Core laminations are tightened with glass tape (stage B epoxy) banding. This tightens the core uniformly when it is heated and leads to very strong and uniform tightening of core steel. Use of non metallic bolts for tightening of core yokes will provide additional tightening of the core lamination which helps core to produces less amount of noise.
 - f. Bottom yoke of core and core legs after stacking, are coated with varnish or wood glue to reduce vibration of the sheet edges.
 - g. The peaks in angles overhanging of laminations (horns) are cut off, since they are free and vibrate due to the magnetic flux. Alternatively, they can be covered with a putty to keep them from vibrating.
- Reduction of noise from Winding
 - a. Specific winding's noise reduction is achieved by increasing the conductor's size, or increasing the transformer's impedance. This however will increase the amount of copper in the cost of the transformer.
 - b. For large power transformers special kind of transposed conductors for making windings are being made in order to reduce losses in the windings and winding's noise reduction.

- c. Tightness of winding during manufacturing process, and pressing these axially during drying stage, at certain pressure will reduce the ‘accordion’ effect during operation.
 - d. Moreover, on magnetic circuit assembly after drying process assure winding compression. A tightly compress winding will help to reduce winding noise.
- Reduction of Noise Transfer to the Tank
 - a. Avoid mechanical connection between core and coil assembly and tank surfaces to eliminate structure borne noise transmission. No direct connection to tank base or tank wall. Use vibration damping arrangement between all connection points between core and coil assembly and tank walls bottom and top.
 - b. Use of wall sound barriers to reduce oil borne noise. Oil barriers and cushion padding may also help insulate transformer noise and prevent it from spreading.
 - c. The distance from the noise producing surfaces to the tank wall can be adjusted for the fundamental noise frequency to ‘reflect’ most of the sound pressure from the tank wall and ‘dissipate’ the sound energy in the oil.
 - Reduction of Fan Noise
 - a. Fan’s noise reduction is achieved with fewer numbers of rotor’s revolutions per minute of the fan, but at the same time it reduces the cooling capacity, thus the commonly used fans are with greater number or with larger diameter of blades, in order to compensate the reduced cooling capacity.
 - b. Reduction of fan’s noise can be achieved through balancing the rotating masses, quality of bearing and stable structure for securing the fan to the tank or the radiator for cooling.
 - c. Fan structure borne noise can be reduced by providing vibration dampening material in mounting arrangement between fan to the tank wall.
 - d. The location of fans on transformer also affects the overall noise of the transformer. Use multiple radiator banks and fan bank. Multiple radiator banks will help to increase overall sound producing surface and hence measurement contour for ONAN & ONAF testing. Multiple fan banks will help to reduce overall fan born noise to keep FA sound low.

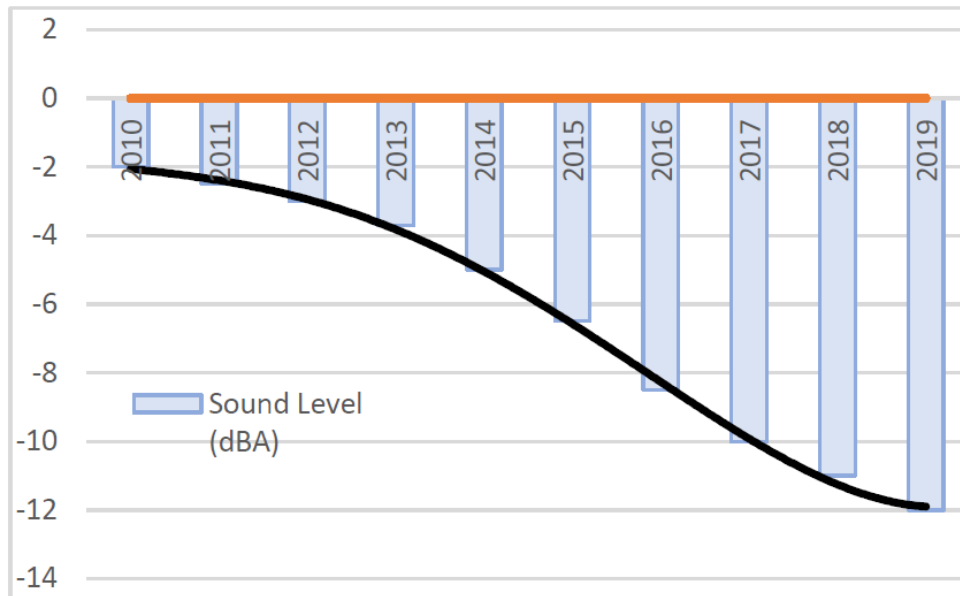


- Reduction of Overall External transformer Noise
 - a. While installing transformers at customer site, use external vibration dampeners along with flexible connections and mounting methods. This prevents metal contact between the mounting surface and the unit, to reduce noise transmission.

- b. Noise reduction by sound screens or sound walls would be next best option for sound attenuation. The sound barrier will help reduce the noise in surroundings and reduce sound travel.

VTC/GTC Achievement in transformer sound reduction

- VTC/GTC achieved 12dB sound reduction to NEMA TR-1 requirement by rigid mechanical design of core and coil, reduced vibration from coil by geometry and material and dampening of vibration emitted from core and coil assembly, reducing transmission of vibration and noise from transformer inside to outside. The graph below shows VTC/GTC achievement of transformer noise reduction compared to NEMA TR-1 –2013 a standard describing transformer sound level requirement. *



Year of Mfg.	Description	Measured Sound, dBA		NEMA Rating, dBA		Difference - ONAN	Difference- ONAF
		ONAN	ONAF2	ONAN	ONAF2		
2014	22.5/30/37.5MVA, 350kV BIL, 69kV	52.7	58.11	71	74	18.3	15.89
2014	22.5/30/37.5MVA, 350kV BIL, 138kV	52.83	57.82	71	74	18.17	16.18
2014	22.5/30/37.5MVA, 350kV BIL, 69kV	53.23	59.2	71	74	17.77	14.8
2015	18/21.6/24/26.8/30/33.6M VA, 450kV BIL, 115 KV	59	63.5	73	75	14	11.5
2016	11.2/14MVA, 250 Kv BIL, 69KV	56	58	69	70	13	12

* **Disclaimer:** The transformer noise reduction depends on design, material, performance, size and cost. This paper does not confirm all transformer manufactured by VTC / GTC will have reduced sound as standard function. The noise level performance shown above are the jobs designed to achieve specific noise reduction.

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