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There are two Categories of Voltage Transformers:

Unearthed VT (UVT) and Earthed VT (EVT)

The Unearthed VT(UVT)

UVT are used for Symmetrical Secondary functions as described below, it can be connected to ANY network, is economically viable and has a low (or no) primary or secondary neutral displacement (Inversion) and can supply auxiliary power (Continuous and/or Short Duration (SD).

Continuous Processes:

- AVR
- Tap Changing
- Contactor Holding
- Battery and other Standing and continuous loads-operations

Short Duration Power

- Contactor Closing
- Spring-charging
- Solenoid Closing and/or Synchronising

Protections (<1VA):

- Symmetrical protection secondary functions of accuracy classes for Directional Overcurrent,
- Over-voltage
- Motor control
- Under/Over Frequency
- and Reverse Power

NB! Not for Under-voltage or directional earth-fault protections or protection classes as per table 12 of IEC60044-2 or table V1 of BS7625.

NB! Only to measurement classes of accuracy as per table 11 of IEC60044-2 or table V of BS7625.

The HV connection internationally specified markings are A &/or B &/or C and the voltage transformers coils are connected only to the lines (phases) of the system. The Earth connection is only on the frame, earth screens & core and not connected to the Primary windings which are fully/uniformly insulated above earth.

NB!: There is no electrical continuity between line phases and earth, only between line phases.



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In HV system's exceeding 52Um an Earthed Voltage Transformer is generally the only available option as the Unearthed (Uniformly insulated) VT is not a viable option due to the insulation requirements.

Configuration of an Unearthed Voltage Transformer (UVT):

i/: 3PhUVT: 3 PhaseYy(n)0, 3 Limb core and 3 HV Fully/Uniformly Insulated coils in one enclosure, each HV coil end line is connected to Terminals A & B & C, the other ends of each HV coil is connected to an internal Fully/Uniformly Insulated HV star point. The 3PhUVT must comply with BS7729:1994 and has a Rated Voltage Factor 1.2 of table 1 of BS7625:1993.

The voltage range of operation is 80%>120% for line connected symmetrical measurement and symmetrical protection secondary functions of accuracy classes as per table 11 of IEC60044-2 or table V of BS7625.

The core configuration is 1-3 coil limb core. The secondary neutral has little or no neutral displacement (due to the 3 limb core flux balance) and has no relationship to the system (HV) neutral. Since 3 Phases enter one enclosure 3-HV fuses are a necessity.

The secondary winding is normally safety earthed on b phase or n neutral terminals.

ii/: 3PhUVT: 3 Phases Vv0-into one enclosure or 2-1PhUVT enclosure as per iii/ below, the arrangement consists of 2 HV Fully/Uniformly Insulated coils each with separate core, all HV coil ends line connected (A-B, B-C), no VT HV star point and no relationship to the system (HV) neutral.

Each 1PHUVT of the 3PhVVT arrangement must comply with IEC60044-2 or BS7625:1993 and has a Rated Voltage Factor 1.2 of table 2 of IEC60044-2 or table 1 of BS7625:1993.

The voltage range of operation is 80%>120% for line connected symmetrical measurement and symmetrical protection secondary functions of accuracy classes as per table 11 of IEC60044-2 or table V of BS7625.

HV winding is in an open VEE connection.

The core configuration is 2-one coil limb cores.

No secondary neutral connection is available.

Since 3 Phases enter one enclosure 3-HV fuses are a necessity.



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The secondary winding is normally safety earthed on b phase terminal.

iii/: 1PhUVT: 2 Phases into one enclosure, 1 core and one HV Fully/Uniformly Insulated coil both HV coil ends line connected(A:B or B:C or A:C), no VT HV star point and no relationship to the system (HV) neutral.

The 1PHUVT must comply with IEC60044-2 or BS7625:1993.

Each 1PHUVT of the 3PhVVT arrangement must comply with IEC60044-2 or BS7625:1993 and has a Rated Voltage Factor 1.2 of table 2 of IEC60044-2 or table 1 of BS7625:1993.

The core configuration is 1-one coil limb core.

No secondary neutral connection is available.

Since 2 Phases enter one enclosure 2-HV fuses are a necessity.

The secondary winding is normally safety earthed on one phase terminal.



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The Earthed VT (EVT):

The Earthed VT (EVT): for Unsymmetrical or a combination of Unsymmetrical and symmetrical secondary functions.

The Rated Voltage Factor is determined by the system earthing conditions & protection and the primary coil connections are between Line and Earth (NB! Earth is not necessarily the system neutral point).

Configuration of an Earthed Voltage Transformer (EVT):

iii/: 3x1PhEVT: 3 Phase(Yeyn0) with 3 separate cores each with 1 Coil limb. Each Primary coil is graded Insulated, one HV coil end line phase connected, the other HV coil end connected to earth in one enclosure. The Earthed (graded) HV primary is for phase to earth connected secondary protection functions.

Not suitable for integrating into phase segregated (limited earth fault current) arrangements as 3 phases enter one enclosure.

Each 1PhEVT of the 3x1PhEVT must comply with IEC60044-2 or BS7625:1993 and must have a Rated Voltage Factor, dependent on system earthing conditions, selected from table 2 of IEC60044-2 or table 1 of BS7625:1993.

The voltage range of operation is 5%>150%(or 190%) for line to neutral connected unsymmetrical protection secondary functions of protection classes as per table 12 of IEC60044-2 or table V1 of BS7625 and for line connected symmetrical measurement at a voltage range of operation of 80%>120% for symmetrical protection secondary functions of accuracy classes as per table 11 of IEC60044-2 or table V of BS7625.

The core configuration is 3-one coil limb cores. The secondary neutral connection is available for connection to unsymmetrical secondary functions of protection (not Measurement symmetrical Functions). Since 3 Phases enter one enclosure 3-HV fuses are a necessity.

The secondary winding is normally safety earthed on b phase or n neutral terminals.

iv/: **3PhEVT (5 Limb core):** 3 Phase(Yeyn0) 1x5 Limb core, 3 coil limbs & 2 additional auxiliary half limbs. Each Primary coil is graded Insulated, one HV coil end line phase connected, the other HV coil end connected to earth in one enclosure. The Earthed (graded) HV primary is for phase to earth connected secondary protection functions.

Not suitable for integrating into phase segregated (limited earth fault current) arrangements as 3 phases enter one enclosure.



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Each 1PhEVT of the 3PhEVT must comply with BS7729:1994 and must have a Rated Voltage Factor, dependent on system earthing conditions, selected from table 2 of IEC60044-2 or table 1 of BS7625:1993.

The voltage range of operation is 5%>150%(or 190%) for line to neutral connected unsymmetrical protection secondary functions of protection classes as per table 12 of IEC60044-2 or table V1 of BS7625 and for line connected symmetrical measurement at a voltage range of operation of 80%>120% for symmetrical protection secondary functions of accuracy classes as per table 11 of IEC60044-2 or table V of BS7625.

The core configuration is 1x5 Limb core, 3 coil limbs & 2 additional auxiliary half limbs cores.

The secondary neutral connection is available for connection to unsymmetrical secondary functions of protection (not Measurement symmetrical Functions). Since 3 Phases enter one enclosure 3-HV fuses are a necessity.

The secondary winding is normally safety earthed on b phase or n neutral terminals.

v/: **1PhEVT:** 1 Phase-1 core 1 coil limb. The Primary coil is graded Insulated, one HV coil end line phase connected, the other HV coil end connected to earth in one enclosure. The Earthed (graded) HV primary is suitable for a voltage range of 5%>RVF(150% for1.5/30s or 190%(Sqrt3*1.1for 1.9/30s or8H)) mainly for phase to neutral connected secondary functions. Suitable for integrating into phase segregated (limited earth fault current) arrangements.

IMPORTANT EVT DATA:

There are 3 internationally recognised and specific voltage factor ratings(RVF) of EVT's, a fourth rating of **RVF2.1 continuous** has been introduced in ZA, it has not been defined in any definite terms at all, from hearsay RVF2.1/c is an extension of RVF1.9/8h and requires better magnetic properties for ferro-resonance withstand. When specifying an EVT it is important to specify a protection class (3P or 6P), without this requirement the voltage factor is not tested or confirmed and the magnetic properties could be compromised.

It is unfortunately and commonly perceived that if a 5limb core is specified all VT aspects have been covered and the VT is fit for any duty. Nothing is further from the truth a 5limb VT must have an earthed HV winding star point and suitable RVF and compared to other EVTs has a smaller winding area, lower insulation security and magnetic properties than the 3X1PhEVT and all the EVT requirements still apply.

• RVF 1.5/30s: For effectively connected system neutral earthing conditions with Earth Fault protection.



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New Zealand GST Reg. No 73-533-929 The VT primary winding neutral (RVF=1.5/30s) can have a moderate "inversion" displacement to the system neutral point in service as per **BS7625:1993 clause 4.23: "An** earthed neutral system in which the neutral is connected directly to earth or through a resistance or reactance of low enough value to reduce oscillations".

In service a 1.5/30s EVT cannot be damped sufficiently to completely reduce all the inversion unless the 1.5/30sEVT earth is directly connected to a close-by system NEUTRAL Point without involving an earth return path. This is the only system condition and VT connection where a 3Ph4W meter can be used with any accuracy for Precision or Tariff for 3Ph4W measurement.

Otherwise the 1.5/30s EVT is suitable for 3Ph4W protection, 3Ph3W measurement and indication duties when the EVT is within a zone of earth fault protection.

• RVF 1.9/30s: Non-effectively connected system neutral earthing (Resonant system earthing) conditions with Earth Fault protection

In non-effectively earthing system conditions as per 1.9/30s, the EVT primary winding earth will probably have a moderate to large oscillation "inversion" displacement to the system neutral point which is an "unsafe condition" as the core may overheat due to saturation and cause insulation failure.

In service this 1.9/30s EVT cannot be sufficiently damped to completely reduce all the inversion and should be used mainly for protection duties, it is not recommended for precision or tariff measurement.

This 1.9/30s EVT is suitable for 3Ph4W protection, 3Ph3W statistical and indication duties in system conditions with a limiting earth fault current impedance between the system neutral point and earth and the EVT is within a zone of earth fault protection.

• RVF 1.9/8H: Isolated system earthing or non-effectively connected system neutral earthing (Resonant system earthing) conditions without Earth Fault protection

In isolated earthing system conditions the 1.9/8H EVT primary winding earth will probably have a large oscillation "inversion" displacement to the system neutral point which is an "**unsafe condition**" as the core may overheat due to saturation and cause insulation failure.

In service this 1.9/8H EVT cannot be sufficiently damped to completely reduce all the inversion, it is not recommended for precision, tariff or important statistical measurement.

This 1.9/8H EVT is suitable for 3Ph4W protection and indication duties on a system with no connection or a high impedance between the system neutral point and earth that limits the system earth fault current to very low current faults and/or when the EVT is not in a zone of any earth fault protection.



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New Zealand GST Reg. No 73-533-929 Ferroresonance and inversion Damping: See "MVT Inversion_doc" for further details.

Secondary links should not be removed on earthed VTs while in service.

The Earthed Voltage Transformer is primarily a protection voltage transformer and is not recommended for precision or tariff measurement, as in service it is probably subject to the abnormal condition of inversion if the system earth is other then directly connected to earth (solid-VF=1.5).

IE: An earthed neutral system in which the neutral is connected directly to earth or through a resistance or reactance of low enough value to reduce oscillations. BS7625:1993 clause 4.23.

The first and most important consideration in choosing a voltage transformer is to determine the type of secondary functions required:

UVT for Phase to Phase connected Secondary Functions in General use i.e. Line-Line (I-I) connected/3Ph3W:

Indicators: Volts, VA, Watts, VAR, Frequency, and Power Factor.

Meters: VAh, Wh, and VARh including Precision or Tariff measurement-3Ph3W.

NB! No 3Ph4W meter connections should be made from any type of instrument voltage Transformer unless an actual system neutral (Not an Earth path) connection is available on a solid earthed system arrangement with a RVF 1.5/30s EVT only.

EVT for Phase to Neutral connected Secondary Functions in General use:

Continuous Processes: System Controllers and Recorders, Inversion Damping Ballast: Distance Impedance, Under-voltage.

Residual Protection and processors (Broken Delta-Short Duration): Directional Earth fault Protection, Ferro Resonance Damping.

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SUMMARY

The Rated Voltage Factor is ascertained from Table 1 below and is dependent on whether a VT Primary N Connection to Earth is required by the Secondary functions, the system earth arrangement and the auto-earth fault protection of the zone in which the VT is connected.

In accordance with BS7625 the rated Voltage Factors are abbreviated as 1.5/30s, 1.9/30s and 1.9/8h respectively.

RVF	Rated time	Method of connecting the primary winding and system earthing conditions	Category Abbreviated RVF
1.2	Continuous	Between phase in any network. Between transformer star-point and earth in any network	UVT 1.2/c
1.2 1.5	Continuous 30s	Between phase and earth in an effectively earthed neutral system (Sub-clause 4.23a)	EVT 1.5/30 s
1.2 1.9	Continuous 30s	Between phase and earth in a non-effectively earthed neutral system (Sub-clause 4.23b) with automatic earth fault tripping	EVT 1.9/30s
1.2 1.9	Continuous 8 Hours	Between phase and earth in an isolated or resonant earthed neutral system without automatic earth fault tripping (Sub-clause 4.20)	EVT 1.9/8h

Table 1 Standard values of rated voltage factors as per BS7625:1993, IEC60044-2 and BS7729:1994

The VT is Unearthed (UVT) or Earthed (EVT) as per the primary winding connection and category above.

To prove Voltage Factors compliance:

The VF is only proved during the routine protection accuracy tests at 25% and 100% secondary burdens at a power factor of 0.8 lagging, at the rated voltage multiplied by the rated voltage factors (example 1.2 and 1.9) from the table above as per clause 31-BS7625:1993

The VF is only proved during the routine protection accuracy tests at 25% and 100% secondary burdens at a power factor of 0.8 lagging, at the rated voltage multiplied by the rated voltage factors (example 1.2 and 1.9) from the table above as per clause 31-BS7625:1993.

The Test bay voltage source and standard voltage transformers must not be in saturation during the above Voltage Factor accuracy test.

Limits of error and displacement on protection type VTs BS7625:1993

Table V1-Limits of Protection Voltage error and phase displacement

Class	Percentage	Phase displacement minutes	Phase displacement Centiradians
3P	3.0	120	3.5
6P	6.0	240	7.0