



Small wonder

Station service voltage transformers for small power requirements

MATHEW PAUL – An estimated 1.3 billion people worldwide have no access to electricity. In small communities, this is often due to the cost of installing a substation. ABB can now alleviate this situation with its microsubstation, a low-cost substation that exploits station service voltage transformers (SSVTs) to supply local power for a small capital outlay, with ease of design and low maintenance. SSVTs are single-phase power transformers in their simplest configuration: connected line-to-ground on the primary side and pedestal-mounted, they step down power from high voltage levels to medium or low voltage in one step. By avoiding two, or more, stepdowns, SSVTs can save on costs, improve efficiency and enhance reliability. SSVTs make it economical to supply power to locations that cannot justify the expense of a full-scale substation, such as oil and gas pumping stations, mining projects, cell phone towers and hospitals, to name but a few.



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An SSVT combines power and instrument transformer characteristics in a product with high reliability, low costs, simplicity and compactness that is ideal for small power applications. The SSVT's capabilities allow it – or an SSMV, which is an SSVT for medium-voltage (MV) levels – to meet the power requirements of a remote community or a substation with just a single unit. The SSVT has a small footprint and is easily configured by virtue of its single-phase design.

Construction

An SSVT or SSMV has a single-phase, shell-type construction and is connected between the primary line and ground, with

a grounded shield winding interposed between the high-voltage (HV) and low-voltage (LV) windings to protect the secondary from transient voltage surges. An SSVT or SSMV is, for the most part, built according to ANSI C57.13 [1] and IEC 61869-3 [2], and complies with C57.12.00 [3] and IEC 60076 [4] → 1. A

new standard – C57.13.8, IEEE Station Service Voltage Transformers – is being drafted that will incorporate the relevant parts of C57.12.00 and C57.13.

Protection

In the SSVT protection scheme, a current transformer (CT) on the HV neutral or ground connection will detect any line-to-ground fault on the secondary winding → 2.

A CT on the tank ground wire can detect a ground fault on the primary side. An optional, under-oil, sudden-pressure relay

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can also detect internal faults just as in a power transformer.

In the event of a fault on the primary side, the line protection can isolate the SSVT. Since the transmission line is a critical element, many utility customers want an isolating mechanism for the SSVT substation. At present, up to a 750 kV basic impulse level (BIL) HV dropout fuse protection is available to isolate a defec-

Title picture

ABB's SSVT provide a low-cost and simple way to draw power from a high-voltage line where the expense of a full-scale substation cannot be justified. Shown is an oil-filled SSVT.

The microsubstation is a low-cost substation that makes use of SSVTs to supply local power for a small capital outlay, with ease of design and low maintenance.

1 Comparison of ANSI standards

Class II power transformer	SSVT/SSMV instrument transformer
ANSI C57.12.00	ANSI C57.13
115 – 450 kV (550 kV optional) BIL	115 – 550 kV BIL
138 – 550 kV (650 kV optional) BIL	138 – 650 kV BIL
161 – 650 kV (750 kV optional) BIL	161 – 750 kV BIL
230 – 750 kV (825 kV optional) BIL	230 – 900 kV BIL
345 – 1050 kV (1,175 kV optional) BIL	345 – 1,300 kV BIL
Partial discharge: 500 pC	Partial discharge: 10 pC, partial discharge extinction voltage (PDEV) 135% of nominal voltage
Overvoltage factor: maximum continuous overvoltage (MCOV) 105%, maximum momentary overvoltage (MMOV) 110%	Overvoltage factor: MCOV 115%, MMOV 125%
	Shield winding

tive SSVT/SSMV from the transmission line → 3.

Above 750 kV, a single-phase circuit breaker can be used → 4. Gas-filled SSVTs can be offered with a built-in circuit breaker or isolator for added protection.

Fault level and overvoltage withstand capability

An SSVT/SSMV has about 5 to 10 percent impedance on its own base. By virtue of its small kVA frame size, secondary-side fault current is limited to a safe level. A fuse or miniature circuit breaker (MCB) can protect the SSVT from overload on the secondary side under normal operation. An MV circuit breaker could perform the same function in an SSMV. If the HV primary nominal voltage is rated at 230 kV, the full load current is 1.5 A at 200 kVA and the most severe fault on the secondary side would induce 30 A on the primary.

Environmental impact

By eliminating one or more intermediate transformers, no-load losses and copper losses are reduced, making the system more energy efficient. Further, the SSVT's oil volume is a fraction of that of a comparable power transformer, so the consequences of spillage are far less severe and refilling needs are reduced, as are fire protection and containment requirements. SSVTs are also virtually silent in operation – emitting only about 30 dBA

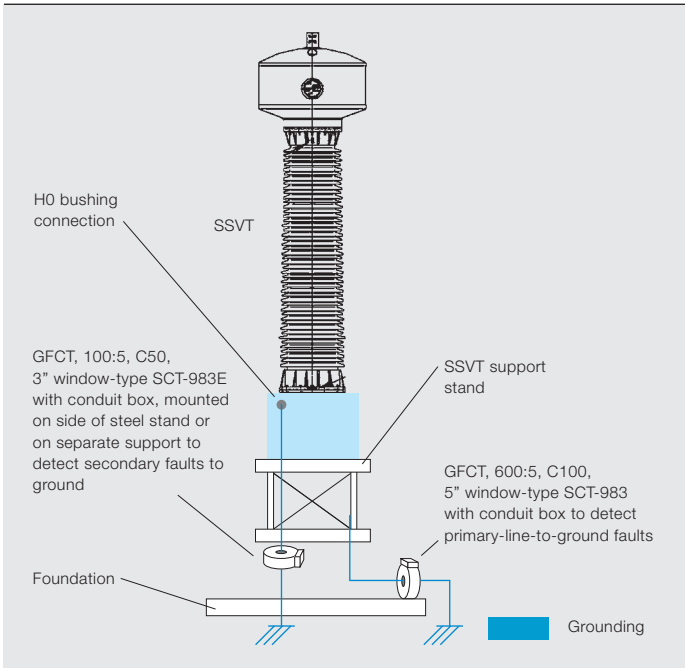
compared with 70 dBA for a large transformer.

Substation control power supply

Substations come in many sizes and have many purposes. In a distribution substation, power is stepped down from high voltage to medium voltage or from medium voltage to low voltage for powering a number of distribution feeders. A switching substation is for interconnecting HV power transformers in an HV grid or simply for connecting transmission lines that are at the same voltage level. Yet other substations are connected to often remote generating stations to evacuate power from them.

Whatever the type, all substations have metering and protection systems that run off an LV power supply – the so-called control power supply. For reliability, every substation requires two redundant control power supplies. Usually, the main transformer in the substation is the primary source of control power. However, a second power supply is needed – for a number of reasons. For example, in a generator substation, where the primary supply is often tapped off the generators themselves, the generators may stop for maintenance or may be mothballed for a long period, or, in a wind or solar plant, the energy source may wane.

2 SSVT protection



3 Oil-filled SSVT with dropout fuse



When there is no power generation, control power has to be drawn from the grid. There are several ways to do this: A large power transformer can be kept energized in order to supply the secondary control power – but this is very inefficient as the losses incurred are high compared with the load (to say nothing of the capital costs). Drawing power from a feeder connected to a local LV distribution network or from a standby generator is another option, but one that is expensive and prone to disruptions from external factors.

Substation designers may, from lack of choice, resort to using a distribution feeder from another location to get a redundant control power supply – an expensive undertaking that may be subject to quality and reliability concerns, and open to disruptive influences outside of the operator's control.

In some cases, the main HV transformer is equipped with a third winding to provide the control power supply. However, this is not an ideal solution as it limits the power transformer engineer's design scope. In most cases, it also complicates the design disproportionately, diminishes

the transformer's reliability, and adds cost in terms of losses and the larger oil tank and oil quantity required. Conductor and coil sizes have to be bigger, too. Another deficiency of using the tertiary is the requirement to keep the power transformer energized even if the secondary load is switched off.

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Another option that readily lends itself as a secondary source of control power supply is a standby generator. This option probably has the lowest initial costs, but the highest lifetime costs, compared with an SSVT or a power transformer. Generators using fuel introduce concerns relating to reliability, fire hazard and maintenance as well as environmental factors like noise pollution, fuel spill hazard, etc.

As an alternative to the approaches outlined above, an SSVT/SSMV can, in many cases, be used to provide the control



power supply – for a fraction of the cost and much more easily.

The microsubstation concept

Many communities around the world are denied electric power due to the cost of installing a substation. HV transmission lines may pass nearby, but cannot be tapped to power a water supply system, community center, a school or a primary health care facility. An SSVT or SSMV, though not a replacement for a full substation, can, however, expand the reach of electricity to these deprived communities → 5. When the quality of life in the area improves, power demand may grow enough to justify a large substation. At that time, the SSVT/SSMV can easily be relocated to another area.

The initial costs and total life-cycle costs of an SSVT make it an attractive proposition for applications like those just mentioned → 6 and inside cover.

Power transformers are not only costlier but also require extensive monitoring and maintenance to keep them running. For example, a power transformer's dielectric liquid will have to be replaced during its

lifetime, and a 230kV/100MVA power transformer may contain 25,000kg of oil compared with 2,000kg of oil in a 230 kV / 200 kVA SSVT.

Further, a substation using a single-phase SSVT or SSMV can be unmanned and very straightforward, with just an arrester, HV circuit breaker, isolator, earthing grid and LV distribution board – all in a single-phase configuration. This simple arrangement also reduces footprint.

Single-phase configuration also allows the SSVT/SSMV to be connected in a star or delta configuration on the secondary

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side. In a secondary three-phase delta configuration, two SSVT/SSMVs can provide a three-phase supply (open delta) at reduced capacity, providing even more flexibility than a three-phase power transformer → 7. Alternatively, one SSVT can be taken out of a three-phase system, in an emergency, to power up another location.

6 A 100 kVA / 220 kV SSVT installation costs around \$200,000 and takes 12 months to complete.



7 SSVTs in a three-phase arrangement



SSVT/SSMV units are significantly lighter and smaller than a power transformer – ideal for transportation to poorly accessible sites.

They can be used as a power source during the construction phase of the installation before being configured as a control power source for the operation phase.

Applications

Isolated load feeds are required by many applications such as oil and gas pumping stations, oil rigs, mining projects, cell phone towers, defense projects, hospitals, railroad substations and transmission tower lighting. SSVT/SSMVs can be designed to cope with the variety of environmental conditions met in these locations – such as high altitude, high/low ambient temperatures, seismic activity or high salt or dust contamination. They can supply power from 25 kVA to 333 kVA,

subject to certain limitations on voltage, at 50 Hz or 60 Hz. SSVT/SSMVs can be tested for seismic withstand capability by a shaker table test if required.

An SSMV, with an MV secondary, can send power to distant loads through an MV distribution feeder. The power can be stepped down at the load end using pole-mounted distribution transformers. This reduces the distribution losses and improves voltage regulation.

SSVTs can be offered with measurement windings so that they can serve a dual purpose. Also, SSVTs with higher kVA ratings are under development, which will make microsubstations even more attractive and enable even larger isolated applications and communities to benefit from the convenience of electricity delivered through the grid.

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- [2] *Instrument Transformers*, IEC 61869-3:2011.
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- [4] *Power Transformers*, IEC 60076, 2011.