Technical Description B-09-109T

Static Inverter for variable speed, permanently excited synchronous generators

Alteration Review

Document Number-	Issue and Alteration Type [1])		Comments	Author
B-09-109T	1.0	A	First Issue	Wimmer

Changes between this document and the previous version are marked in light green for easier verification.

[1]) A: Alteration due to faulty documentation or improvement of the documentation

B: Alteration maintaining full or upward compatibility

C: Alteration limiting or excluding compatibility

Content

1 Executive Summary

This Technical Description B-09-109T describes a Static Inverter that provides a constant voltage and frequency three-phase output generated from a permanently excitated synchronous generator running in variable speed mode. The described Static Inverter was designed and is manufactured by the company SMA Railway Technology GmbH of Kassel, Germany.

The Static Inverter is designed for commercial applications and is available in different power classes currently between 5 kVA and 125 kVA. The unit described in this document is designed for 44 kVA / 40 kW and comes with an optional battery charger. The technical description is also generally valid for the other power ranges (except for the technical data given). All systems are available as off-grid solutions (powering loads without any connection to the public utility) or as grid-feeding systems. Off-grid solutions are available for fixed installations as well as mobile applications (such as on board of rolling stock).

All Static Inverters are custom-tailored products and can be easily adjusted to meet specific requirements. We hope that the proposed solution is interesting and we are looking forward to getting the chance to introduce our solutions and services personally. In case of any questions or further requests we are available anytime.

2 System Description

The Static Inverter has been designed as compact unit specifically for the application in variable speed generator sets. Due to the modular approach of the device the needs of other applications can be easily fulfilled.

The Static Inverter consists of an input converter stage that sets up a controlled internal DC link. The output three-phase inverter is connected onto this DC links and generates a constant voltage and frequency either for the supply of directly connected loads (off-grid application) or in order to feed a current into the public utility (grid-tied application). Further output modules (e.g. a battery charger) can be connected onto the internal DC link if requested.

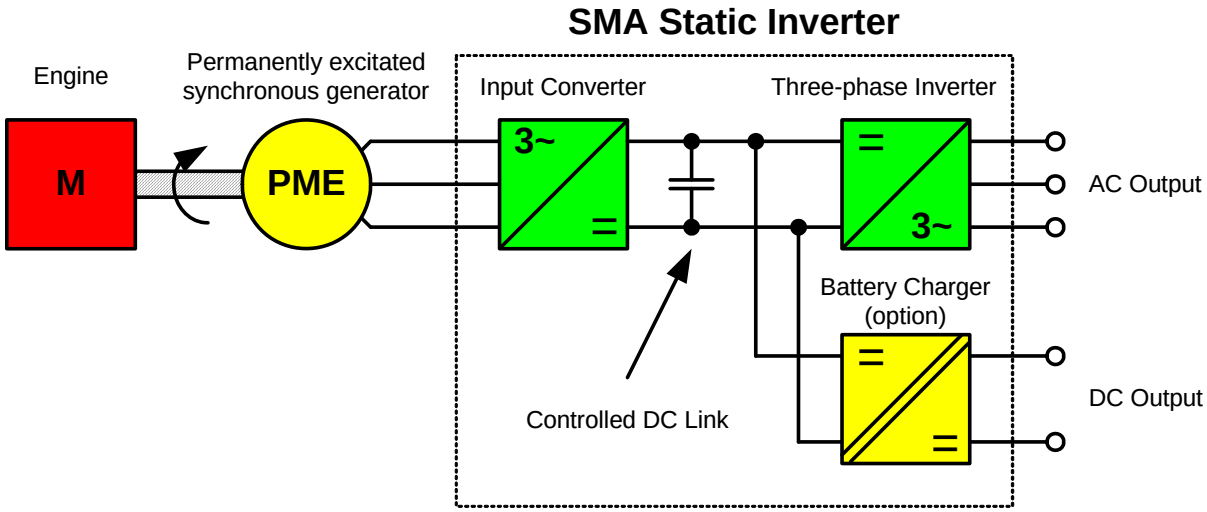

Figure 1: Static Inverter for variable speed generators

The input converter is designed as non-isolating controlled rectifier working as boost converter. As a consequence the rectified output voltage of the generator as to be at or below 850 V DC at maximum engine speed and no load. We suggest to design the generator in a way, that at maximum engine speed and no load a rectified DC voltage of 825 V DC appears. Ideally the generator provides a trapezoidal output voltage in order to minimize the generator voltage variation between no load and full load conditions. Sinusoidal generator voltages generator frequencies of up to 1 kHz are supported.

While the output three-phase inverter comes with all necessary sine wave and EMI-filters in order to fulfil the demands of the connected loads respectively the public grid, the input converter can either use the leakage inductance of the feeding perma-

nently excitated synchronous generator or can be optionally equipped with separated input coils.

The generator can be manufactured in star or delta connection of the windings. However, a star connection of the windings with an available middle point is necessary in off-grid applications if single-phase loads have to be supplied. The Static Inverter supports generators in delta and star connection and the later with and without middle point.

The input converter is designed for a constant input current. Therefore the maximum active output power is only available at full engine speed. The available active power decreases linearly with the decreasing engine speed. However, the full output current remains available over the complete engine speed (reactive power only).

The Static Converter is designed for liquid and air-cooling. Low power units are available for natural air-cooling while high power units require forced cooling.

Figure 2: 44 kVA / 40 kW Static Inverter as complete, water-cooled unit (without sine wave filter coils) for a military application

Mechanically the Static Converter is available as kit containing all necessary parts for installation by the customer or as complete unit.

2.1 Input Converter

The input converter generates a controlled, electrically not separated DC link out of the input voltage. The output modules such as the three-phase inverter and optionally the battery charger are connected into this DC link.

The input converter is a controlled rectifier working as boost converter designed in state-of-the-art IGBT technology.

The input converter is controlled in a way that a constant DC link voltage is provided to the output modules. Due to medium-frequency pulsing of the IGBTs the necessary inductance of the input coils is comparably low.

The control of the input converter is highly dynamic and digital within a DSP (Digital Signal Processor) and designed as voltage control with underlayed input current control. The DC link is supplied with an almost ideal DC current resulting in triangular phase currents drawn from the generator. A power factor correction is not supported. Details on the necessary inductances and the currents generated are available on request.

The operational control is realized by a second microprocessor that monitors the DSP and specifies parameters. This microprocessor operates all external interfaces available in form of digital and/or analogue input and output ports and as computer interfaces (e.g. RS232).

An important task of the microprocessor for the operational control of the input converter is the storing of process values, events, interferences and failures in a non-volatile memory.

All components of the input converter, except of the input choke, are positioned together in compact power stage either available as module for integration or already mounted into a complete unit.

2.2 Three-phase Inverter

The three-phase inverter generates a controlled, three-phase AC voltage of constant amplitude and frequency out of the DC link.

If the generator features an accessible middle point the three-phase inverter can directly provide a neutral wire that can be connected to protective ground. Single-

phase loads up to a total unbalance defined by the generator can be powered without the need for any additional transformer.

The extremely overload-proof power unit of the inverter is realized in state-of-the-art IGBT technology. The medium pulse frequency reduces weight and installation size of the integrated sine wave filter to a minimum.

The inverter is controlled by a DSP (Digital Signal Processor) with integrated operational control. The DSP controls highly dynamically the output voltage and current of the inverter, monitors all measurement signals, generates process values and produces the control signals for the IGBTs. Another function of the DSP is the operational control and the detection of process values, events, interferences and failures together with date and time of occurrence.

All components of the three-phase inverter, except of the sinewave filter choke, are positioned together in compact power stage either available as module for integration or already mounted into a complete unit.

2.3 Battery Charger (Option)

The battery charger generates a controlled, galvanically separated DC voltage out of the DC link.

The proven power unit of the battery charger is realized in state-of-the-art IGBT technology. The use of medium switching frequencies reduces the size and weight of the transformer and filter chokes to a minimum.

All components of the battery charger are positioned together in compact power stage either available as module for integration or already mounted into a complete unit.

For the purpose of a careful battery charging, charging procedures adequate for all relevant battery types can be realized due to the integrated microprocessor control. An output voltage control with underlayed output current limiting control is realized. Additional battery current limiting controls or a battery temperature compensation are optionally available. Even battery monitoring function such as state of charge (SoC) or state of health (SoH) detection can be integrated on request.

3 Technical Data

3.1 General Technical Data

All technical data apply to a complete unit. Details on individual power stages are available on request. Data below is for a 44 kVA / 40 kW unit of off-grid application, intended for application on board of rolling stock and to be understood as an example.

Dimensions:	approx. 1,000 x 500 x 450 (width x depth x height; mm), incl. heat sink, drain valves, fasteners for the Static Inverter without sinewave filter chokes, as example for an air-cooled system
	approx. 350 x 250 x 150 (width x depth x height; mm), for the sinewave filter chokes
	drawings or other dimensions are available on request
Weight:	approx. 100 kg (complete system, but without sinewave filter chokes)
	approx. 50 kg for the sinewave filter chokes only
Protection Degree:	IP 54 for the Static Inverter
	IP00 for the sinewave filter chokes for installation in a ventilated compartment with IP 21 to the outside world
Internal Supply:	directly from input voltage or optionally from a back-up battery
Efficiency:	approx. 92 % at full engine speed and nominal load
Insulation Coordination:	according to EN 50124-1
Ambient Temperature:	-40 °C < Tamb. < 85 °C for storage (no operation)
	-25 °C < Tamb. < 45 °C for operation, degraded mode at higher ambient temperatures available

Height:	< 1,000 m above sea level,
Air Humidity:	according to EN 60721-3-5, class 5K2
Cooling System:	water-cooling for Static Inverter using the cooling system of the generator, forced air ventilation for the sinewave filter coils, other cooling systems are available on request
Shock and Vibration:	according to EN 61373, for underframe installation (Category 1, Class B)
EMC:	according to EN 50121-3-2
Discharge Time:	at < 60 V within 5 minutes
Life Time:	20 years

3.2 Input

Nominal Input Voltage:	825 V DC (rectified input voltage measured at internal DC link at full engine speed and no load)
Maximum Input Voltage:	850 V DC (rectified input voltage measured at internal DC link at full engine speed and no load)
Maximum Input Frequency:	1 kHz
Maximum Input Current:	125 A (RMS, per phase)
Input Voltage Waveform:	trapezoidal or sinusoidal with superimposed full PWM (details available on request)
Input Current Waveform:	triangular (details available on request)
Generator Winding:	delta or star, with and without middle point

3.3 Three-phase AC Output

Galvanic Isolation:	no
Nominal Output Voltage:	3 x 400 V AC (+/- 5 %, steady-state), other output voltages are available on request
N Conductor:	available if provided by generator, load tolerance defined by generator
Nominal Output Frequency:	50 Hz (+/-1 %) steady-state), other output frequencies are available on request
Output Voltage Ripple:	< 50 V (peak - peak, measured phase-to-phase, referring to switching frequency)
THD:	< 5 % at ohmic load and nominal power
Sine Wave Filter:	integrated with du/dt < 10 V / µs at ohmic load and nominal power
Nominal Power:	44 kVA / 40 kW permanently
Nominal Output Current:	64 A (RMS per phase)
Maximum Output Current:	100 A (RMS per phase) for up to 2 s 150 A (peak value per phase) for up to 10 ms output current limitation control to start-up large motorized loads available on request
Maximum Output Power:	50 kW for up to 2 s (if supported by engine and generator)
Repeat Rates for Overload:	once every 60 s at maximum
Output:	open- and short-circuit proof

3.4 Interfaces

Galvanic Isolation:	yes
Diagnosis Interface:	RS232, other interface types available on request
Diagnosis Software:	included in delivery
Digital Inputs:	3 potential-free digital inputs for e.g. 24 V DC available and assignable with function project specifically
Digital Outputs:	3 potential-free digital outputs for e.g. 24 V DC available and assignable with function project specifically, loadable with a maximum of 200 mA with adequate overvoltage protection