STADT STASCHO is a No Loss AC drive that supplies sinusoidal voltage and current to the electric motor and back to the main switchboard. This gives very low harmonic disturbances without using transformers or filters. LV and MV for high power models.

STADT STASCHO is specially developed for marine propulsion systems, where it is used together with controllable pitch propellers.

THE GUIDELINE TO ELECTRIC PROPULSION
**GUIDELINE TO EP:**

**CHOOSING THE RIGHT ELECTRIC PROPULSION SYSTEM**

Electric propulsion for ships is today a natural choice for a long list of ship types, for different reasons, such as fuel savings, emission reductions, ECA regulations, redundancy, noise, vibration, maintenance, space utilisation, the use of LNG–electric propulsion etc.

These systems can be designed in many ways, with the following main elements:

<table>
<thead>
<tr>
<th>Different prime movers:</th>
<th>HFO gensets (typically 3 to 6 in parallel)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MDO gensets</td>
</tr>
<tr>
<td></td>
<td>LNG gensets</td>
</tr>
<tr>
<td></td>
<td>Dual Fuel gensets</td>
</tr>
<tr>
<td></td>
<td>Trifuel – gensets</td>
</tr>
<tr>
<td></td>
<td>Rechargeable batteries and Fuel cells</td>
</tr>
<tr>
<td>Or:</td>
<td>A combination of any of these</td>
</tr>
</tbody>
</table>

| Switchboard MSB:        | Low voltage AC: 220 V to 690 V           |
|                        | Medium Voltage AC: 1000 V to 15 kV       |

| AC DRIVES for propulsion| PWM 6 pulse (very high THD – not applicable for EP solutions) |
|                        | LCI, Cyclo etc.                             |
|                        | * PWM 12 pulse, or LLC                      |
|                        | PWM 18 pulse                                |
|                        | PWM 24 pulse                                |
|                        | * AFE PWM– Active Front End                |
|                        | Perfect Harmony drives                      |
|                        | * SINE WAVE technology like STADT STASCHO  |

| PROPELLERS             | Electrically driven shaft lines, CPP or FP, plus tunnel thrusters. |
|                       | Azimuth thrusters with CPP or FP, electric motor inside the hull. |
|                       | Podedded thrusters with electric motor inside the pod, only in FP. |

**TO GET A WELL FUNCTIONING SHIP: ALL ELEMENTS MUST BE SUITABLE FOR THE PURPOSE. IN A ELECTRIC POWERED SHIP PROPULSION SYSTEM, THE MOST CRITICAL ELEMENTS WILL BE THE ELECTRIC AC DRIVE TECHNOLOGY, NOT SO MUCH THE PRIME MOVERS (NOR THE GEAR AND PROPELLERS) SINCE THEY HAVE HUGE REDUNDANCY ANYWAY – ARRANGED WITH 4 TO 6 IN PARALLEL, ENABLING THE SHIP TO SAIL EVEN WITH ONE OUT OF 6 IN OPERATION. THE ELECTRIC SYSTEM ON THE OTHER HAND COULD BECOME A CRITICAL ELEMENT IF THE TECHNOLOGY IS VULNERABLE. AN EVALUATION OF THE MOST COMMON ELECTRIC DRIVE SYSTEMS IS FOUND IN OUR ENCLOSED REPORT, BASED ON OUR 25 YEARS EXPERIENCE AS A LEADING MANUFACTURER OF THESE SYSTEMS.**

**Choosing the right propeller type** is also very important when it comes to overall propulsion reliability etc. We do not recommend azimuths or pods for instance, if they can be avoided.
Captain Ronny Muren at MS Sanco Spirit.  

STADT STASCHO, Full Diesel-Electric Propulsion

Ship type: Seismic Research Vessel, DNV class, AUTR DP-2  
Owner: Sanco Shipping AS – Charted by PGS since 2011  
Delivered: October 2009 (Sister vessel MS Sanco Star in 2008)

The Sanco Spirit has been a very successful ship for its owners and charters since it went into operation in 2009. The ship’s captain, Mr Ronny Muren, and the technical manager at Sanco Shipping – Mr Jon Asklestad both report that the STADT STASCHO No-Loss electric propulsion technology has proven itself to be extremely reliable over the years. The ship has not gone off-hire at any time, and the crew has maintained the system easily with a very limited need for support from STADT. Also PGS is appreciating the use of this ship.

The robust and highly efficient drive technology has given the ship a minimal fuel consumption at all relevant operation point, including DP, and transit.

The system is remarkable in its compact design, and the No-Loss drive technology enables the designers of the ship to avoid any liquid pipes for cooling or ventilation to be used in switchboard rooms where also the STADT drives are located. Big power transformers used by most other drive manufacturers are completely eliminated, as the EMC noise and harmonic distortion from the drives.

The patented drive system from STADT is unique in the way it optimizes the use of 3 different power technologies, in segregated redundant modules, PCC1, 2 and 3. The PCC 1 is the traditional frequency converter, while the PCC2 and 3 are independent power boosters for the inverter based on thyristors and bypass switching. DC capacitors are avoided since they may easily explode and lead to major injuries and fatal failures (ref DNV and MAIB reports). In the new STADT drives the energy goes AC-AC most of the time. One of the most important improvements found in this solution is that one possible failure in the drive will NOT stop the propellers operation. In this way the STADT technology solves many problems that is seen by other electric propulsion technologies on the market today.

The electric propulsion plant onboard is designed and deliver by STADT, similar to what was earlier delivered to the sister vessel Sanco Star on year earlier, operated by Georadar in Brazil.

Propulsion Drive:  
STADT STASCHO FCT HY 2.2 G1 V0  
2 x 2500 kW, 690 V  
Full Diesel-Electric Propulsion  

www.STADT.no
**Efficient - Reliable - Predictable - Sustainable are they?**

**ISSUES TO BE EVALUATED:**

<table>
<thead>
<tr>
<th></th>
<th>Make 1</th>
<th>Make 2</th>
<th>Make 3</th>
<th>Make 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>TECHNOLOGY IN AC DRIVE</td>
<td>STADT STASCHO</td>
<td>12 PULSE</td>
<td>AFE</td>
<td>Wartsila LLC</td>
</tr>
<tr>
<td>NR OF ELECTRIC ENERGY TRANSFORMATIONS</td>
<td>SINE WAVE</td>
<td>PWM</td>
<td>PWM</td>
<td>PWM</td>
</tr>
<tr>
<td>POWER TRAIN LOSSES</td>
<td>0</td>
<td>4</td>
<td>4 or 5</td>
<td>4</td>
</tr>
<tr>
<td>COOLING</td>
<td>NO , or negligible</td>
<td>6 %</td>
<td>6 %</td>
<td>6 %</td>
</tr>
<tr>
<td>POWER TRANSFORMER NEEDED</td>
<td>AIR is sufficient</td>
<td>WATER</td>
<td>WATER</td>
<td>WATER</td>
</tr>
<tr>
<td>REDUNDANT POWER UNITS</td>
<td>NO</td>
<td>YES</td>
<td>NO / YES</td>
<td>YES</td>
</tr>
<tr>
<td>HARMONIC DISTORTION THD</td>
<td>STANDARD</td>
<td>Special</td>
<td>Special</td>
<td>Special</td>
</tr>
<tr>
<td>ELECTROMAGNETIC INTERFERENCE</td>
<td>NO</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
</tr>
<tr>
<td>DEPENDING ON HARMONIC FILTERS HF</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>DESIGNED ECONOMIC LIFETIME</td>
<td>25 years +</td>
<td>10 years -</td>
<td>10 years -</td>
<td>10 years -</td>
</tr>
<tr>
<td>MAINTENANCE NEED</td>
<td>very low</td>
<td>regular need</td>
<td>regular need</td>
<td>regular need</td>
</tr>
<tr>
<td>ONBOARD CREW SKILL LEVEL</td>
<td>low skills / regular</td>
<td>special skills</td>
<td>special skills</td>
<td>special skills</td>
</tr>
<tr>
<td>MTBF Mean Time Between Failures</td>
<td>7 years</td>
<td>1 year</td>
<td>1 year</td>
<td>1 year</td>
</tr>
<tr>
<td>MTTR Mean Time To Repair</td>
<td>1 hour by crew</td>
<td>1 week + by manufacturer</td>
<td>1 week + by manufacturer</td>
<td>1 week + by manufacturer</td>
</tr>
<tr>
<td>SPARES GLOBALLY AVAILABLE</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>WEIGHT OF DRIVES AND TRAFO</td>
<td>100 x 14</td>
<td>x 6</td>
<td>x 4,5</td>
<td>x 11</td>
</tr>
<tr>
<td>SPACE OF DRIVES AND TRAFO</td>
<td>100 x 6</td>
<td>x 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOLTAGE selectable 220 V - 15 kV</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>POWER SCALABLE OVER BIG RANGE</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>REGENERATES POWER TO GRID</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>NR OF COMPONENTS- IN LINE</td>
<td>1 - the BP switch</td>
<td>80.000</td>
<td>150.000</td>
<td>80.000</td>
</tr>
<tr>
<td>DEPENDING ON CAPACITORS AC and DC</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>EXPLOSION RISK IN DRIVE, trafo and filters</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>PROPELLER PITCH CONFIGURATIONS</td>
<td>CPP</td>
<td>CPP/ FP</td>
<td>CPP/ FP</td>
<td>CPP/ FP</td>
</tr>
<tr>
<td>FINANCIAL RISK, SERVICE COST and OFF-HIRE</td>
<td>Very LOW</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
</tr>
</tbody>
</table>
EVALUATION COMMENTS:

* TECHNOLOGY IN THE AC MOTOR DRIVE: SINE Wave or PWM

The use of Sinus vs PWM (Pulse Width Modulation) control technology will lead to many consequences. The sine wave technology is free from electromagnetic noise, while the PWM is a powerful noise transmitter that can disturb all kinds of electric equipment on a ship. The PWM can also force current to flow through roller bearings in ac motors and gearboxes—with mechanical breakdown as a consequence. PWM drives needs special screened cables, while Sinus can work with unscreened power cables.

* Nr OF ELECTRIC ENERGY TRANSFORMATIONS IN POWER TRAIN:

Every transformation of energy creates power losses. Transformations based on rectifiers or PWM also creates noise, both acoustic and electromagnetic.

* POWER TRAIN LOSSES:

The losses are calculated from switchboard to the electric propulsion motor, through the drive system. Losses in alternators and electric motors comes in addition to these, and adds typically 6% extra, giving total electric losses of 12 – 14% in a typical PWM based system. The STADT system has totally 6% electric losses, giving an improvement of the ships efficiency by more than 6% compared to other EP systems based on PWM.

* COOLING: AIR or WATER

High losses and the use of power electronic in the inverters, normally force the designer of the Drive to use water cooling in their electronics. Such cooling system consist of pumps, filters, pipes, sensors, fittings, sealings, heat exchangers, special water (de-ionised in high power drives) etc. If the cooling system is interrupted, the propeller stops, or the drive unit explodes in the worst case.

Air cooled drive solution is a very good and uncomplicated solution that easily can be used if the losses are low, as in the STADT STASCHO No-Loss drives.

* TRANSFORMERS NEEDED? Yes or No.

Most of the drives used in electric propulsion systems on ships require big transformers in their systems. There are two reasons why they are introduced. A: to filter harmonic disturbances from the electric grid. And B: to adapt the voltage level to a suitable for the drive unit, the reason why also AFE may use transformers.

Such transformers are very big in size, they are very heavy, and they need cooling. They are of special design, so if they are failing - it will be a big challenge to replace them.

STADT STASCHO is a unique patented solution that do not need the transformer for any of the 2 mentioned reasons.
* REDUNDANT POWER UNITS IN AC DRIVE: Yes or No

Most AC drive on the market is made as one compact integrated unit consisting of rectifiers, DC capacitor banks, IGBT inverters, control boards and systems, water cooling items etc. In total up to 80,000 small and big components plays together in a complex way. If one of these components fails, the drive (and the propeller) will stop working. The STADT STASCHO on the other hand, is one of very few solutions on the market that offers redundant power units, in segregated cabinets that can be located in different physical locations. A single failure will not stop the propeller.

* DEPENDING ON HARMONIC FILTERS HF? Yes or No

Most of the electric propulsion technologies does generate harmonic distortion that needs filtering in special units consisting of inductors, capacitors etc.

It might look like just an other trivial unit that is supposed to work without any problems. But this unit failed catastrophically at the cruise ship RMS Queen Mary II in September 2010, resulting in a very dangerous situation for the ship (total blackout). Read the MAIB report on this accident on the next page. It illustrates the problem with Harmonic distortion very well.

The STADT STASCHO is one of very few, if any drive solution - that does not need this type of filter devices.

* EXPLOSION RISK IN DRIVE, trafoe and filters? Yes or No

Most of the PWM based drives on the market is working with high frequency IGBT transistor switching, with a DC capacitor bank as the power source. The switching requires low inductive power foils to be used, with a minimum of clearance over the busbars, approximately 1 mm at full voltage, and far less in the capacitor bank. High energy is stored in these circuitries - with a potential to generate an explosive type of failure if something is not working as it should. After such explosion, the complete drive has to be changed normally.

In the STADT STASCHO drives - the use of DC capacitors is avoided, and isolation between power live parts increased from 1 mm to more than 20 mm as a minimum in LV. This fact makes explosions in the drive not likely to happen.

* OTHER ISSUES: ask STADT

Many of the other issues highlighted in this evaluation can be commented further on. Please ask STADT for more information if needed.
FLYER TO THE SHIPPING INDUSTRY

RMS Queen Mary 2: The catastrophic failure of a capacitor and explosion in the aft harmonic filter room

At 0425 on 23 September 2010, as the passenger liner RMS Queen Mary 2 (QM2) was approaching Barcelona, a loud explosion was heard from the direction of the aft main switchboard (MSB) room. Within a few seconds, all four of the podded propulsion motors shut down. A few seconds later, the vessel suffered an electrical blackout. Thick black smoke was seen to be coming from the aft MSB room. Fortunately, the vessel was clear of navigational hazards and no one was injured.

By 0439, the crew had confirmed that the explosion had taken place in the aft harmonic filter\(^1\) (HF) which was situated in a compartment next to the aft MSB room. After establishing with thermal imaging cameras that there were no hot spots, they ventilated the area and isolated the aft HF and MSB from the rest of the 11000 volt electrical network. The crew were able to restore some electrical power supplies and, by 0523, QM2 was underway using two propulsion motors powered from the forward MSB. Subsequent inspection of the aft HF revealed that one of its capacitors (Figure 1) had failed catastrophically due to internal over-pressure and another had developed a severe bulge.

The vessel had a history of HF capacitor failures, at an average rate of one per year. Although the exact cause of the capacitor failures could not be determined, it was concluded that capacitor degradation was probably caused by a combination of transient high voltage spikes due to frequent switching operations and occasional network overvoltage fluctuations. The capacitor deterioration had not been detected, and because there were no internal fuses or pressure relief devices, it had continued until the capacitor casing failed catastrophically.

Although the aft HF circuit breaker disconnected the HF from the rest of the electrical network to isolate the electrical fault, the disruption was likely to have caused electrical instability in the electrical network which led to the loss of propulsion and blackout. The vessel’s alarm logs were found to contain early warnings about the impending failure approximately 36 minutes before the accident. However, as the vessel’s alarm systems regularly logged more than one alarm every minute, this information was not seen and could not be acted upon.

Current imbalance detection system

The only protection against catastrophic failure of the capacitors was a current imbalance detection system. It consisted of a current transformer (Figure 2a) which was connected to the capacitor circuit. Under normal conditions, little or no current should have flowed through the transformer. When a capacitor degraded, the current flow across the circuit became unbalanced and induced a current in the transformer’s secondary winding. The system was set to give an alarm when the imbalance reached 400mA and to trip at 800mA. After the accident, the transformer’s windings were found to have failed (Figure 2b). There had not been any alarms on this part of the system for several years and it was likely that the imbalance detection system had not worked for some time.

The ship is equipped with a GE Convertaem electric propulsion system.

---

1 Harmonic filter: Alternating current (AC) motors for electric propulsion operate on variable frequency and voltage. Thyristors used in the power converters result in voltage distortion. Passive harmonic filters mitigate the effects of excessive voltage distortion.
A Drive technology that combines RPM control with pitch control.

**SINUSOIDAL waveforms, not PWM**

Combines 5 control elements
- IGBT control (FC)
- thyristor control (T1)
- bypass switch (BP)
- multi speed motor
- pitch propeller control

- NO LOSS due to bypass switching, BP
- no need for transformers
- no EMC problems
- very low THD in main switchboard
- redundancy, T1 - T2, BP1-BP2, FC, H - M - L
- handles regenerative power
- compact design
- air cooled
- no acoustic switching noise
- no bearing currents
- easy cabling, unscreened
- reduced number of active components
- can operate on very low generator capacity
- low voltage and medium voltage models
- 3 RPM modes gives very high propeller efficiency

**Reliability**

Less components and bypass leads to a very rugged system, with very limited maintenance and long lifetime, 25 years +. Limited risk for undesirable stops and off-hire. The bypass switch (BP) is the most important power element in the STASCHO. The FC and T1 are used only for short periods of time, and will have an easy life and long lifetime. The redundant, segregated PCC 1, 2, 3 cabinets increases reliability to a even higher level.

**Models available:**

This model- FC SIN 3.1 G1 V3
is available from 100 kW to 20 MW
in voltages from 220 V up to 15 kV
STADT STASCHO AC Drive
No-Loss Sine Wave System

How it typically looks like:

No-Loss makes air cooling possible

Compact

How it is arranged electrically in one of the STADT STASCHO models:

Failsafe.

Minor temporary use of capacitors

How it is working in a propulsion system:

The electric energy is NOT transformed: it is AC–AC normally
Every transformation creates losses, THD and EMC.
STADT STASCHO creates no losses, no THD and no EMC.
12 pulse AC Drive – PWM frequency converter with transformer

How it typically looks like:

How it is arranged electrically:

How it is working in a propulsion system:

All electric energy is transformed 4 times: AC – AC – DC – PWM – AC
Every transformation creates losses, THD and EMC.
**AFE - Active Front End Drive, PWM**

How it typically looks like:

![ASE Rectifier](image)

High losses - Needs complex water cooling

How it is arranged electrically:

![Diagram](image)

How it is working in a propulsion system:

![Diagram](image)

All electric energy is transformed **4 or 5 times**: (AC) - AC – PWM – DC – PWM - AC

Every transformation creates losses, THD and EMC.

If 1 out of 150,000 components fail, the propeller will stop working. Explosion may easily be the result, as well. Extensive use of capacitors.
Technology comparison

Our 5. gen technology

STADT STASCHO

SINUS

NO TRAFO

AC

Competitors technology

12 Pulse Frequency Converter

PWM

DC

TRANSFORMER

EMC FILTER SPECIAL CABLE

Competitors technology

AFE Frequency Converter

PWM

DC

EMC FILTER SPECIAL CABLE

Huge differences:

- TRANSMISSION LOSSES
- ECONOMICAL LIFETIME
- MTBF, MTTR
- REDUNDANCY
- EMC, THD
- VOLUME, WEIGHT
- COMPLEXITY

- PWM RELATED ISSUES:
  - Electric and acoustic noise
  - Bearing currents
  - Voltage stress in motors, Cabling type
  - AC versus DC systems - Capacitors
  - PRICE, SERVICE COST
STADT STASCHO Propulsion

Some basic arrangements for full electric propulsion, based on diesel, LNG or dual fuel using CPP propellers. Many other options are available.

**Twin screw**
- 4 generators
- 4 electric motors + 2 small as option
- 2 twin input gearbox
- 2 main switchboards

**Triple screw**
- 4 generators
- 3 electric motors + small as option
- 2 main switchboard

**Twin screw (Azimuth)**
- 4 generators
- 2 electric motors
- 2 main switchboard
Some basic arrangements for full electric propulsion, based on diesel, LNG or dual fuel using CPP propellers. Many other options are available.

**Single screw**
- 3 generators
- 1 electric motor + small as option
- 1 main switchboard

**Single screw**
- 4 generators
- 2 electric motors
- 1 twin input gearbox
- 2 main switchboards

**Single screw**
- 3 generators
- 2 electric motors in tandem
- 1 main switchboard

**Double ended**
- 4 generators
- 2 electric motors
- 2 main switchboards

**Twin screw (Voith)**
- 4 generators
- 2 electric motors
- 2 main switchboards
STADT STASCHO Benefits

- **Electric losses** reduced by up to 55 %
- **Weight** reduction of 80 % vs AFE
- **Volume** reduction of 85 % vs AFE
- **THD and EMC** eliminated 100 %
- **Redundancy** built in to all items
- **Lifetime** improved from 10 to > 30 years
- **MTBF and MTTR** improved several folds
- **FUEL SAVINGS** – the best in class
STADT SHIP REFERENCES
With our 5th generation No Loss technology

MV “Nam Cheong” 16 Vessels
AHTSV NCA80E
ABS Class, RP, DP2
STADT STASCHO DRIVES
Fully integrated diesel electric propulsion system
Installed Power – 6000 kW

MV “Vestland” 2 Vessels
SSV – at Cemre for Vestland Offshore
BV Class, RP, DP1
STADT STASCHO DRIVES
Fully integrated diesel electric propulsion system
Installed Power – 4000 kW

MV “THOR” 4 Vessels
Seismic Support Vessel operated by PGS
DNV Class, RP, DP, ICE-1A
STADT STASCHO DRIVES
Fully integrated diesel electric propulsion system
Installed Power – 4000 kW

MV “Econuri”
Incheon Port Authority Guide ship
KR Class, RP
STADT STASCHO DRIVES
Fully integrated electric propulsion system
LNG- and diesel – electric operation, dual fuel
Installed Power – 1800 kW

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STADT SHIP REFERENCES
With our 5th generation No Loss technology

MV “Sanco Spirit”
Seismic Research Vessel operated by PGS
DNV Class, RP, DP2, ICE-C
STADT STASCHO DRIVES
Fully integrated diesel electric propulsion system
Installed Power – 6600 kW

MV “Sanco Star”
Seismic Research Vessel operated by Georadar
DNV Class, RP, DP2, ICE-C
STADT STASCHO DRIVES
Fully integrated diesel electric propulsion system
Installed Power – 5000 kW

MS “Meløyfjord”
Purse Seiner
NMD Class
STADT STASCHO DRIVES
Fully integrated diesel electric propulsion system
Installed Power – 1920 kW

MS “Voldnes” + MS “Stokke Senior” +
MS “Harto”
Purse Seiners
NMD Class
STADT STASCHO DRIVES
Fully integrated diesel electric propulsion system
Installed Power – 1947 kW

www.STADT.no
NOTES:
STADT ELECTRIC PROPULSION SYSTEM

Sustainability • Reliability • Partnership

www.STADT.no

STASCHO NO LOSS AC DRIVE

Emission Reduction • Fuel Savings

STLETH Features

• No Acoustic Noise • No EMI
• No Heat Emission • No Vibration
• No Harmonics • No Transformers

690 V up to 30 MW • 6600 V up to 80 MW • 11000 V up to 150 MW

The elimination of transformers - saves a lot of space, weight and losses

WINNER OF THE ENVIRONMENTAL AWARD

Annual Offshore Support Journal conference & awards

2014