Standalone Air Conditioning Power System

Schaffler can provide standalone air conditioner inverter system for under frame mounting or on-board mounting. The DCformer and inverters can be supplied in separate enclosures to suit the rail car or locomotive.

Air Conditioning Power System is a prime example of the advancement in power electronics for rail applications. As technology has improved, the use of higher switching frequencies and IGBT components has facilitated size and weight savings. Early versions of this power system were almost 200 kg. The current under frame model shown above weighs only 60kg.

Another factor is the reliability of this equipment. Previous models required forced ventilation. The current model is self-ventilated. This means it has no external fans and is completely enclosed so the electronic components are protected from dirt and dust. Since this model has no external fans it does not require maintenance other than outside heatsink cleaning from time to time.

Standards

<table>
<thead>
<tr>
<th>Standards</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 50155</td>
<td>Electronic equipment used on rolling stock</td>
</tr>
<tr>
<td>IEC 1287-1</td>
<td>Power converters installed on boarding rolling stock</td>
</tr>
<tr>
<td>EN 50121-3-1</td>
<td>Electromagnetic Compatibility</td>
</tr>
<tr>
<td>EN 50121-3-2</td>
<td>Electromagnetic Compatibility</td>
</tr>
<tr>
<td>IEC 61000-4-3</td>
<td>EMC standard</td>
</tr>
<tr>
<td>IEC 61373</td>
<td>Railway application rolling stock equipment: Shock and vibration testing</td>
</tr>
<tr>
<td>BR/0/112-12</td>
<td>British Rail Standard for transients and surges</td>
</tr>
<tr>
<td>AS 3080</td>
<td>Wiring regulations</td>
</tr>
</tbody>
</table>

Other Schaffler products are:

- Intelligent battery chargers powered from 750 Vdc or 380/400 Vac 3-phase galvancically isolated – 100 to 300 amp
- Single phase inverters 74 or 110 Vdc to 240 Vac, 4, 9 and 14 kW galvancically isolated intended for air conditioning
- Three phase inverters 600 or 750 Vdc to 380/400 Vac 9, 18, 22 and 30 kW galvancically isolated
- Three phase inverters 74 or 110 Vdc to 380/400 Vac 9, 14 kW galvancically isolated intended for air conditioning
- Three phase inverters 600 or 750 Vdc to 380/400 Vac 30 kW in phase-lock-loop to create a common 3-phase bus galvancically isolated
- DCformers (dc:dc converters) in 9 kW modules paralleled up to 120 kW galvancically isolated
- Three phase inverters, liquid cooled 30 kW to 120 kW
- Cycloverter – single phase to 3-phase at unity power factor for EMUs operating off ac overhead supplies, 15 kV and 25 kV
- Headlight controllers

Work is done on a refrigerant substance collecting energy from the evaporator section (the cool area) and exhausting it into the condenser section (the warm area). The compressor (4) forces the refrigerant into the condenser section (1). The high pressure heats the refrigerant above the ambient temperature in the condenser so as it condenses heat energy is released to the air. The refrigerant then passes through an expansion valve (2) into the low pressure evaporator section (3). This causes another state change as the refrigerant evaporates into a cold gas and it is thus able to extract heat from the ambient air in the evaporator section (3).

To cool the air inside a train, the inside air is passed through the evaporator section. At the same time, the heat extracted from the inside air is exhausted to outside air via the condenser section.

It is quite normal that the electrical energy spent driving these loads is only a fraction of the heat energy transferred between the two sections. Hence, air conditioners are often described as being more than 100% efficient.

MULTIPLE INVERTER SYSTEMS

A multiple inverter system uses individual inverters to supply 3-phase power to each motor load. The air conditioner control system sends a start or stop signal to each inverter as necessary to maintain the desired temperature.

The advantages of the individual inverter system design are:

- Motors are soft started
- Rated power is never exceeded
- The power converter is much smaller and lighter
- Motor speeds are individually controllable
- The system is more efficient
- The inverters provide individual motor protection
- No need for external contactors, overloads and phase loss protection
Because the motors are soft started, there is no inrush current. This means that the rated power is never exceeded and the front-end power converter can be smaller. The inverters operate off 650 V DC provided by power converters that accept the electrical system overhead ac catenary, 3rd rail or locomotive battery supply.

Variable frequency inverters facilitate speed control of the motors so the system can maintain temperature in a more efficient manner than simply turning motors on or off. The inverters are able to be programmed with the individual specifications of each motor and can detect when a motor has been overloaded or lost a phase. In this way the inverters also act as a motor protection device.

AIR CONDITIONER POWER SYSTEMS

**Input:**
- 110V DC, 74V DC, 110V DC locomotive battery voltage
- 600V Vdc or 750V Vdc 3rd rail or catenary
- 25 kV, 15 kV, 50 or 60 or 16 2⁄3 Hz catenary
- 380 Vac, 415 Vac or 440 Vac 3-phase auxiliary generator

**Output:**
- 380 Vac, 415 Vac or 440 Vac 3-phase variable frequency
- Optional 220 Vac or 240 Vac 1-phase for fans
- Optional 110 Vdc for fans
- Individual fan motor / compressor motor control

Air conditioners used on locomotives, EMUs and DMUs use two 3-phase inverters systems. One for the compressor plus the evaporator fan and one for the condenser fan. The inverter driving the compressor can be speed controlled and can operate above 50 or 60 Hz. In some installations the fans are driven from 1-phase ac or 110 Vdc.

**Inverter 3-phase output**

To comply with EMI standards, the output of all Schaffler 3-phase and 1-phase inverters are fitted with common mode and differential mode filters. Therefore the output is sinusoidal. It is not commonly known that motor failures are caused by PWM inverters that have no filtering. What occurs in the motors and cables is insulation failure and bearing failure. It usually takes 3 years for such failures to occur due to gradual insulation breakdown.

**POWER SOURCES IN RAIL APPLICATIONS**

Schaffler supply converters to cover most rail supplies. Rail supply variations are typically +25%, -30%. Schaffler converters are typically ⅓ of the size, ⅓ of the weight of competitive products and they are silent because of the high frequency of operation. Efficiency is of the order of 96%.

**600 Vdc and 750 Vdc 3rd Rail**

This supply varies from 400 Vdc to 950 Vdc depending on the conditions caused by accelerating and decelerating trains. Schaffler provide a galvanically isolated dc:dc converter (Dcformer) that provides a fixed 650 Vdc to the inverters controlling the air conditioning motors. The withstand for Schaffler 3rd rail systems is 1200 Vdc.

**74 Vdc and 110 Vdc**

Supplied from batteries on locomotives. Schaffler provide a galvanically isolated dc:dc converter (Dcformer) that provides a fixed 650 Vdc to the inverters for controlling the air conditioner motors.

**25 kV or 15 kV AC Catenary, 50, 60 or 16 2/3 Hz**

The Schaffler Cycloverter operates off the single phase supply on-board transformer reduced from the overhead catenary supply. The Cycloverter is an active front end inverter exhibiting unity power factor to the supply eliminating harmonic distortion to the supply. Schaffler never offer an uncontrolled rectifier off the single phase supply.

**ENCLOSURE VARIATIONS**

**Side-mounted Air conditioner Power System**

Smaller locomotives have side mounted air conditioners that can be removed by forklift for maintenance.

The air conditioner power system comprises a ‘Dcformer’ and two Inverters. The Dcformer converts the incoming 74V DC (nominal battery voltage) and produces a regulated 650V DC. This is then used by the inverters to generate 380 Vac, 415Vac or 440 Vac 3-phase at variable frequency.

In this system the supply fan (evaporator fan) is connected to one inverter. The compressor and condenser fan are connected to another inverter.

**Roof-mounted Air conditioner Power System**

Larger locomotives for both freight and passenger services have the air conditioner mounted in the roof above the single driver’s cab. As with other systems, the 74Vdc nominal battery voltage is converted and regulated to 650V dc. This is then used by inverters to generate 380 Vac, 415 Vac or 440 Vac 3-phase power for the motor loads at 50 or 60 Hz.

Naturally, the physical arrangement is quite different from the side-mounted systems, but the electrical schematic is virtually identical. The Dcformer and inverters are again contained within the air conditioner unit and are identified in the exploded view below.

**Underframe mounting of Power System**

The enclosure for underframe mounting is divided such that the input converter (Dcformer or Cycloverter) is fitted to the back heatsink and the inverters are fitted to the front door heatsink. The enclosure is IP66. All Schaffler products are supplied with military style plugs and mating cable plugs are provided.