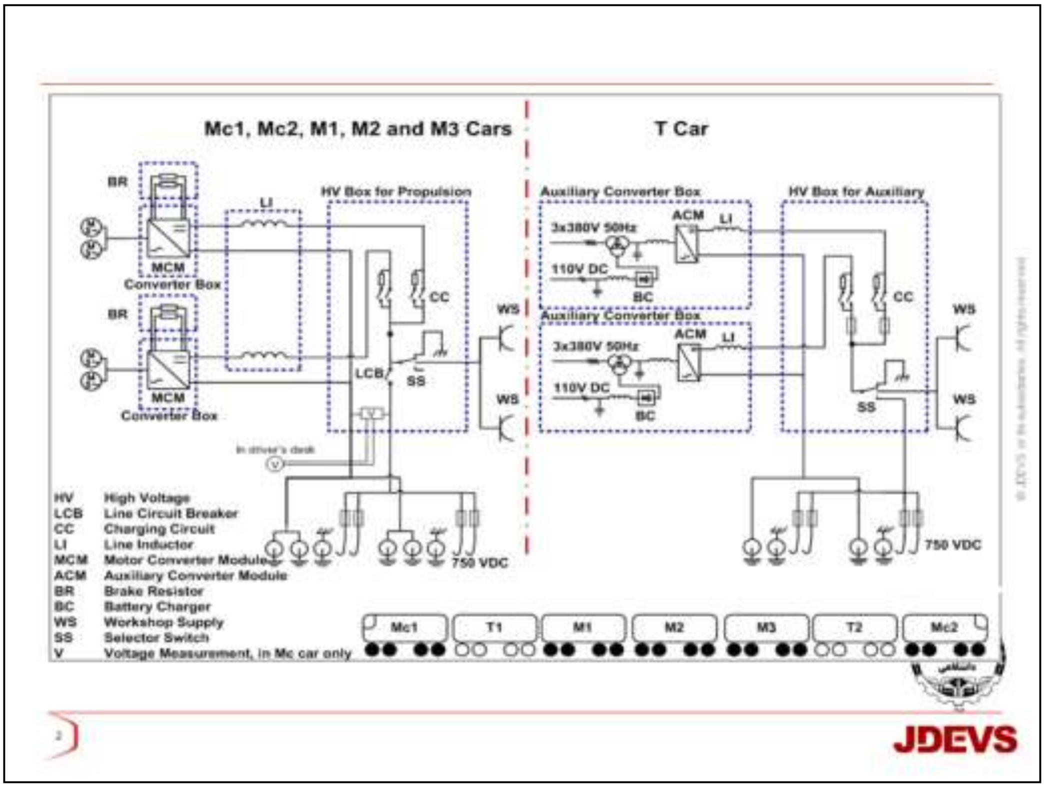
National Metro Train Project

Auxiliary Converter Module

JDEVS


Mc1, Mc2, M1, M2 and M3 Cars
T Car
BR
LI
HV Box for Propulsion
MCM
Converter Box
CC
LCB
SS
WS
In driver's desk
Auxiliary Converter Box
3x380V 50Hz
ACM
110V DC
BC
HV Box for Auxiliary
750 VDC
HV High Voltage
LCB Line Circuit Breaker
CC Charging Circuit
LI Line Inductor
MCM Motor Converter Module
ACM Auxiliary Converter Module
BR Brake Resistor
BC Battery Charger
WS Workshop Supply
SS Selector Switch
V Voltage Measurement, in Mc car only
Mc1
T1
M1
M2
M3
T2
Mc2
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ACM - Task

- **The ACM converts the line voltage to a 3-phase voltage and a battery charger voltage.**
  - The 3-phase current supplies the train's auxiliary systems.
  - The battery charger voltage charges the battery, supplies the control equipment, lighting and so on.
- **The auxiliary electric system comprises:**
  - Auxiliary Converter modules, ACM
  - Battery charger (included in ACM)
- **The auxiliary electric system produces:**
  - Auxiliary Converter modules, ACM
  - Battery charger (included in ACM)

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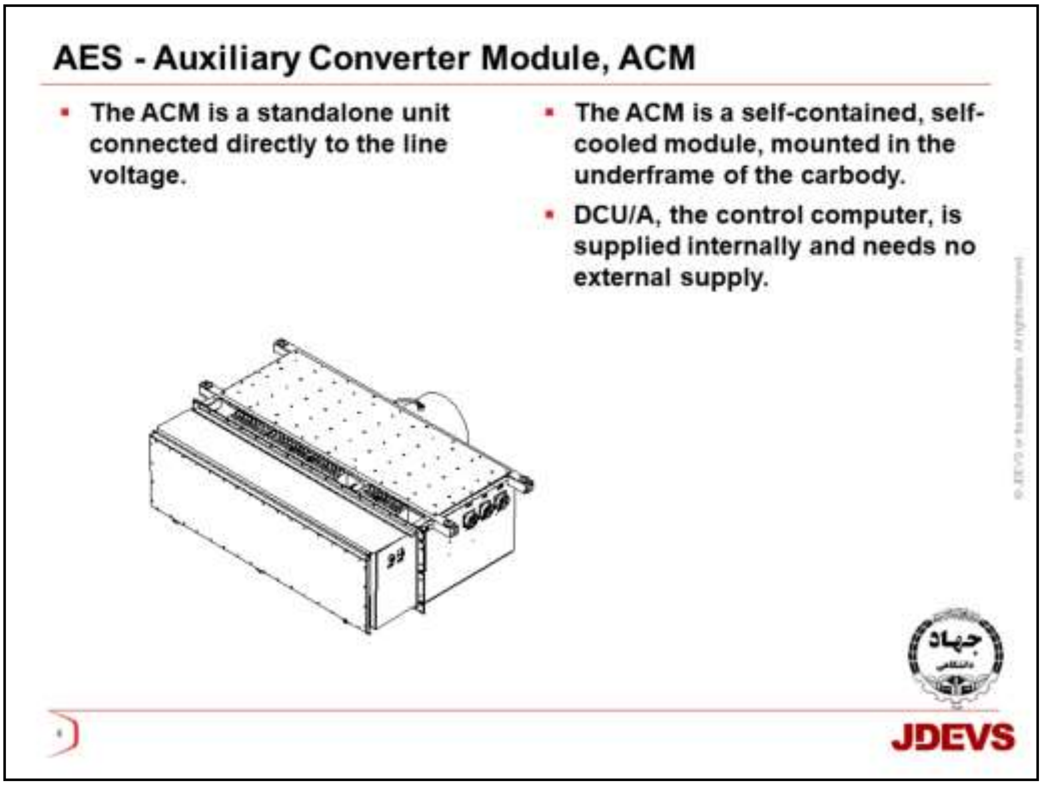
The ACM converts the DC link voltage (either from the line or from the LCM) to a three phase voltage and a battery charger voltage. The three phase voltage supplies the train's auxiliary systems, for example air conditioners, pumps, fans, air compressors and lighting. The battery charger voltage charges the battery and supplies the loads on the DC output control equipment. This equipment is supplied from the battery when the ACM is not in operation, for example due to over- or undervoltages or a breakdown of the ACM.

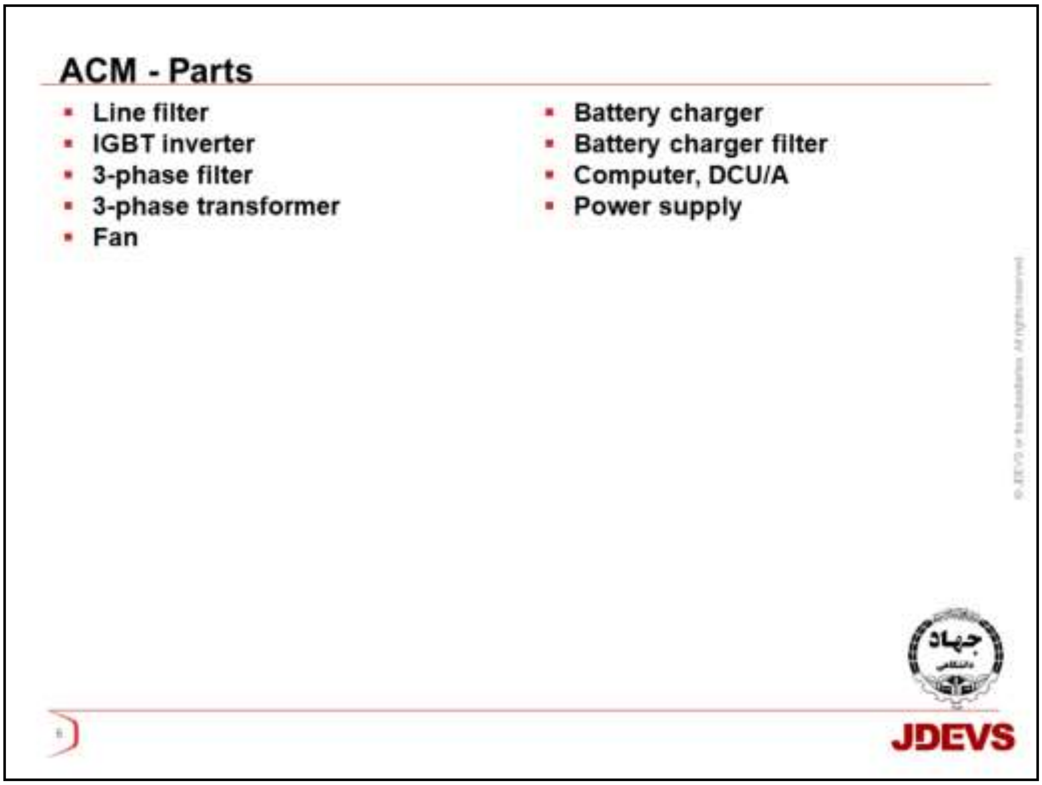
The rated output power is 45 kVA three phases and 10 kW battery power at nominal line voltage of 600-900 VDC. The output power is reduced at line voltage below 600 VDC. The converter will be blocked at line voltage below 525 VDC.



The ACM is a standalone unit connected directly to the DC-line via a main circuit breaker, a line inductor, a charging circuit and a line fuse. The ACM includes all the necessary control electronics. The control electronics are supplied from the battery system via the power supply.

Each ACM has a control computer, DCU/A, that communicates with the VCU. The DCU/A is supplied internally and needs no external supply. The converter starts when the input voltage is within limits. The ACC/I is supplied from the battery system or the high voltage system via the power supply unit.

The ACM is energized 8400 hours/year because the battery charger have to be activated to charge the batteries. The auxiliary electric loads are only activated when the train is in service, about 4850 hours/year.



Main parts of the ACM are:

The line filter that protect the IGBT inverter against transient overvoltages.

The **overvoltage protection** protects the line filter capacitor against harmful voltages.

The **IGBT-inverter** that creates the 3-phase voltage by its switching characteristics

The **3-phase filter** reduces the harmonics generated by the inverter.

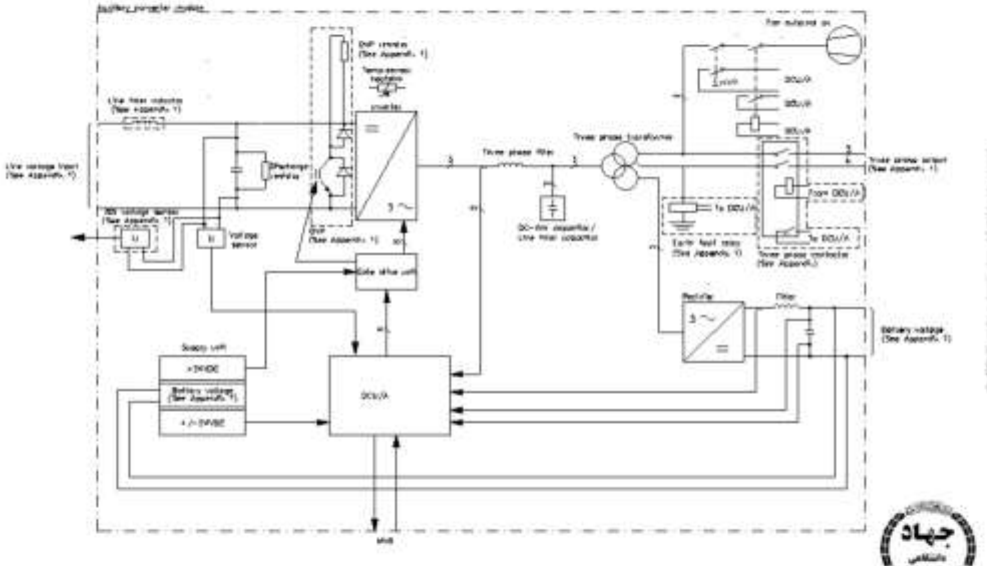
The **3-phase transformer** that isolates the auxiliary system from the high voltage system and the battery system from the auxiliary system.

The **blower** that provides forced cooling of the heat sink and back section components in the ACM.

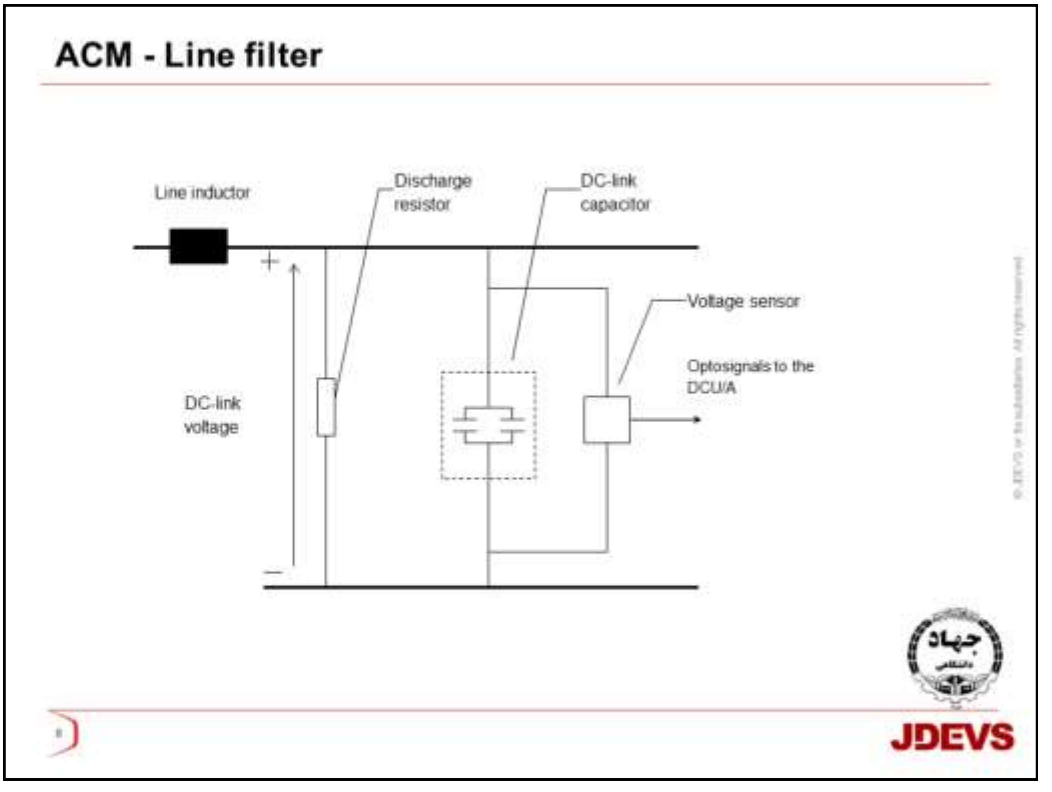
The **ACC/I** the ACM computer that controls the ACM

The **power supply unit** that converts the battery voltage to +5 V DC and 15 V DC for the ACC/I supply.

ACM Layout



Voltage sensor
Supply unit
Battery voltage (See Appendix 1)
DCU/A
Three phase transformer
Rectifier
Filter



The line filter capacitor and the line filter inductor forms the line filter which filter and stabilise the DC-link voltage and is sized with sufficient capacitance to keep the voltage ripple in DC-link within permitted limits and enable accurate converter control. Link filter featuring line filter capacitor, line filter inductor, discharge resistor and a voltage sensor. In the other direction, harmonics generated by the IGBT inverter are prevented from reaching the line.

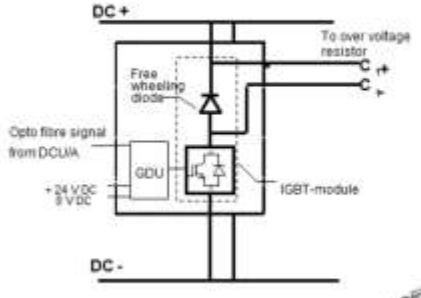
The **line filter inductor** together with the line filter capacitor gives a cut-off frequency for the line filter. This effectively prevents inverter generated harmonics from reaching the line.

The **line filter capacitor** handles transient overvoltages. The capacitor consists of two film capacitors connected in parallel, the two capacitors are housed in the same enclosure. The line filter capacitor also acts as an energy storage element stabilizing the LFC voltage to make accurate control of the IGBT inverter possible. The energy in the line filter capacitor is enough to handle short DC power interruptions.

The voltage across the DC-link is measured by a **voltage sensor**. The value is continuously supervised by the DCU/A computer. The signal is used in the inverter control algorithm and for protection.

ACM - Overvoltage protection

- Protects the line filter capacitors against harmful voltages.
- Consists of an IGBT-module and an over voltage resistor.



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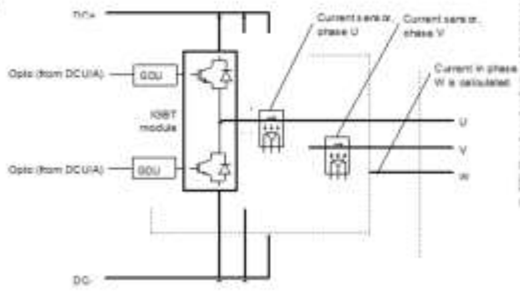
If the LFC voltage for some reason exceeds a specified level the **overvoltage protection** is activated. It consists of an overvoltage resistor in series with an IGBT. The IGBT-module consists two free-wheeling diodes, one for the IGBT and one for the resistor, which is neccessary due to their internal inductance.

The main purpose of the overvoltage protection is to protect the line filter capacitor against voltage transients. When the the voltage reach a specific limit the voltage over the line filter capacitor is measured and the IGBT is switched on and off. The energy is dissipated in the OVP-resistor and the DC-link voltage starts to drop. This overvoltage protection is dimensioned to handle an energy pulse as it occurs, for example, when the MCM which is connected in parallel is blocked at full load.

ACM - IGBT-inverter

- Is a 2-level 6-pulse bridge.
- Converts DC voltage to 3-phase AC voltage.
- Consists of three identical phase legs.
- Is controlled by the DCU/A using PWM.



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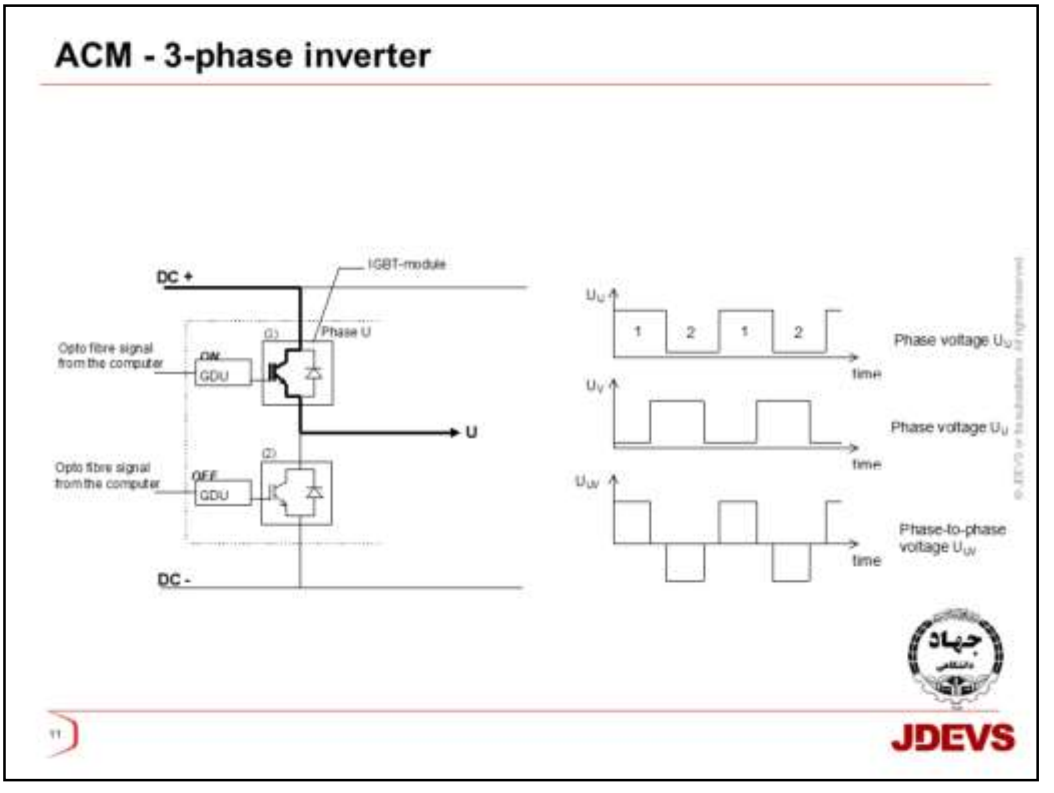
The inverter is a 2-level 6-pulse bridge which converts DC voltage to 3-phase AC voltage. It consists of three identical phase legs. The switching elements are high voltage IGBTs. The inverter is controlled by the DCU/A using a Space Vector Modulation (SVM) technique which is a well known PWM (Pulse Width Modulation) algorithm.

The **IGBTs** are housed in modules containing also the free-wheeling diodes. There are two IGBT modules in each phase leg giving a total of six IGBT modules in the inverter. The IGBT is switched on and off by the gate drive unit, feeding a voltage signal to the gate terminal. The switching of the IGBTs makes the voltage at the phase outputs (U, V and W) alternate between DC+ and DC-. This results in a controlled AC phase to phase voltage. The switching frequency is 900 Hz/phase leg. The control signals to the GDUs are transmitted through optical fibres directly from the DCU/A.



Phase Commutation When the upper IGBT in phase U (1) is switched ON and the lower IGBT (2) is switched OFF, the voltage output in phase U is equ-al to the DC-link voltage (DC+). When the U phase output is to be set low, an OFF order is being sent to the upper IGBT (1) and an ON order is sent to the lower (2). The phase current will be going through the free wheeling diode of the lower IGBT-module (2). The output voltage of phase U is now 0 V (DC-).

If the phase current is negative, the current during commutation become rever-sed; the current commutates from the lower IGBT (2) to the free wheeling dio-de of the upper IGBT-module(1).

In switching the IGBTs off and on, a pulse train is generated. The pulse train pattern creates the phase voltage output, UU. The simplest pattern is the square wave, also named HEX-pattern.

The pulse train in phase U starts with ON in the upper IGBT (1). When the up-per IGBT is switched OFF, the lower IGBT (2) is switched ON. The phase voltages of phases U and V are similar in shape but have a delay phase angle of 120 (or 240). The phase-to-phase voltage is the difference bet-ween the phase voltages in U, V and W.
This is how, in theory, the AC-current from the inverter is formed. When using square waves, the amplitude of the AC-voltage is determined by the DC-link voltage. To produce an AC-voltage with variable amplitude, Pulse Width Modulation is used. Using PWM, the

amplitude of the AC-voltage can be varied almost independently of the DC-link voltage.

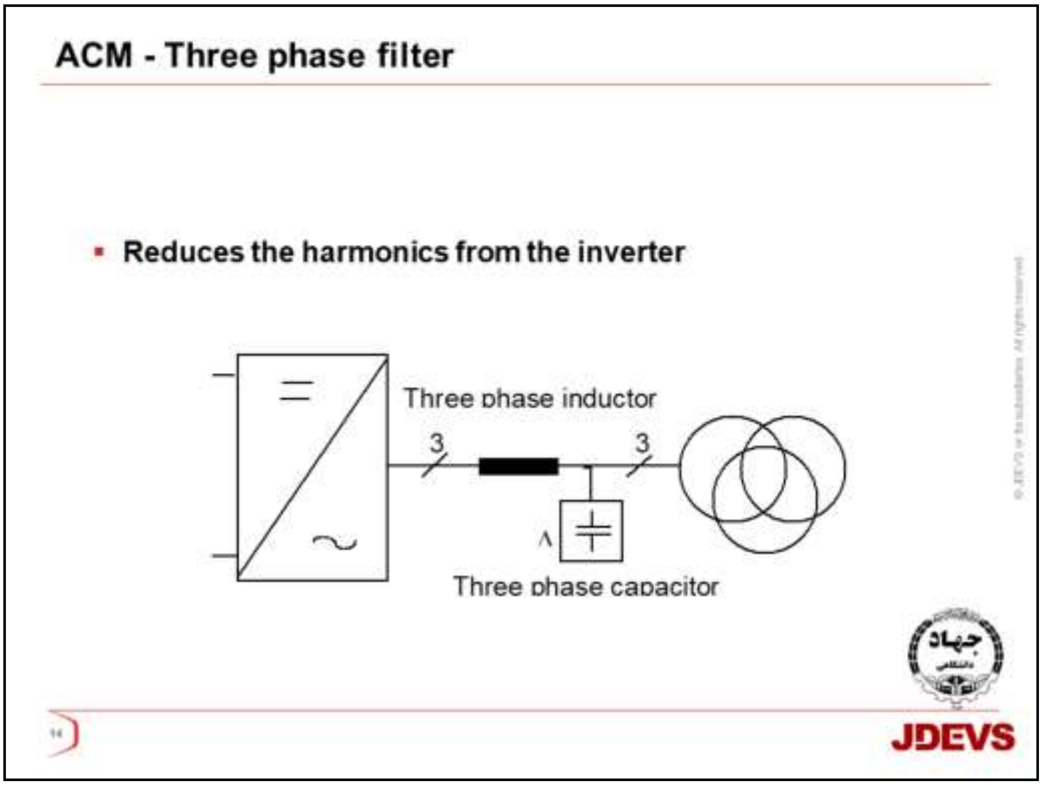
ACM - Gate drive unit, GDU

- One GDU per IGBT.
- Switches the IGBTs off and on at order from the DCU/A.
- Is supplied with +24 V from power supply.
- Equipped with 2 LEDs.

The **gate drive unit** switches the IGBTs off and on at order from the DCU/A. The gate drive units can also detect phase short circuits. There are two gate drive units per phase leg, one for each IGBT.

The gate drive units are powered with +24 V from the power supply. The switching orders from the DCU/A is transmitted via opto fibres. This way of transmitting information galvanically separates the high voltage system from the control system. The gate terminal on the gate drive unit is short circuit proof.

When the DCU/A detects a loss of +24 V power, the inverter is immediately blocked.



At the output of the IGBT inverter there is a **three phase filter** to reduce the harmonics generated by the inverter. The filter consists of a three phase inductor and a three phase capacitor.

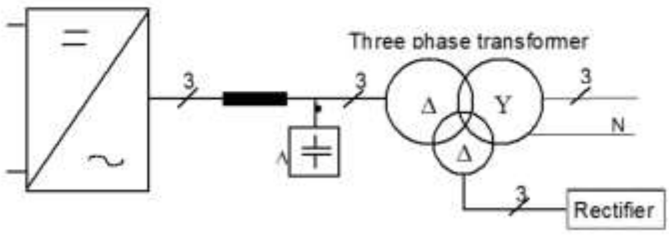
The filter is designed to give low distortion in the output voltage. Besides being part of the filter, the three phase capacitor also provides reactive power compensation for some of the reactive power consumed by the three phase transformer and load.

The **three phase inductor** consists of three single phase inductor units with 300 µH of inductance per unit. They are specially designed to handle high frequency current harmonics superimposed on the fundamental load current.

The **3-phase capacitor** is built up of three -connected capacitors enclosed in a steel container. The capacitance of each element is 169 µF.

ACM - Three phase transformer

- Isolates the auxiliary system from the high voltage system and the battery system from the auxiliary system.



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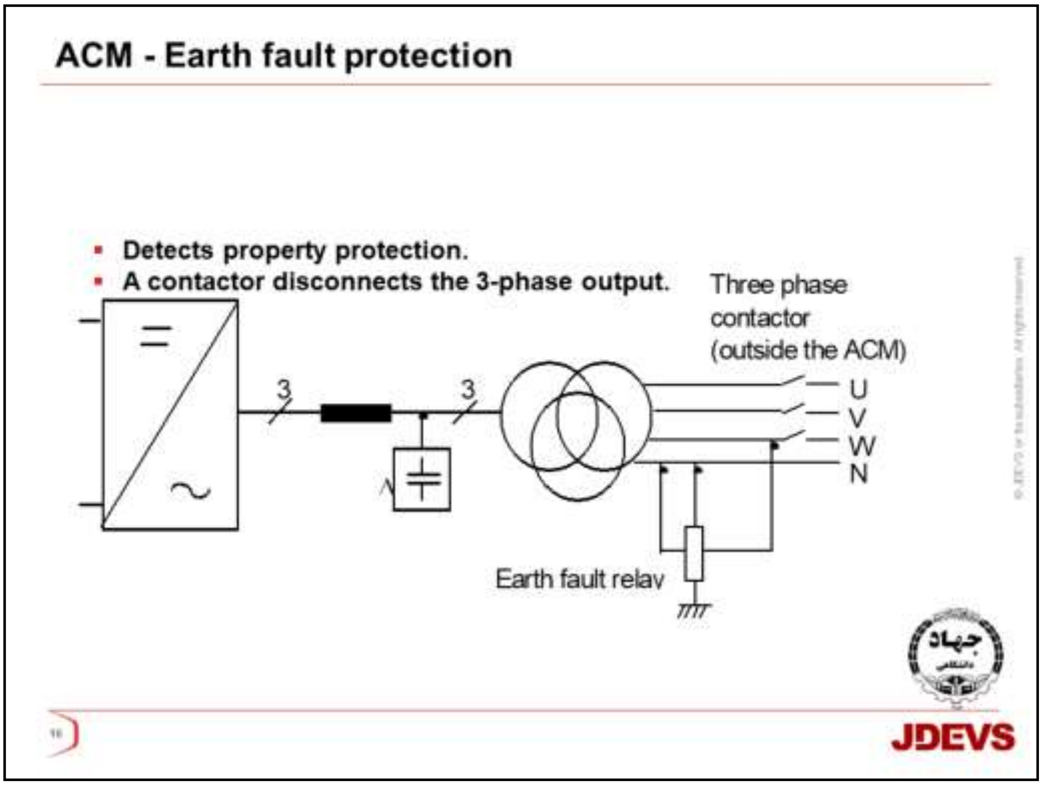
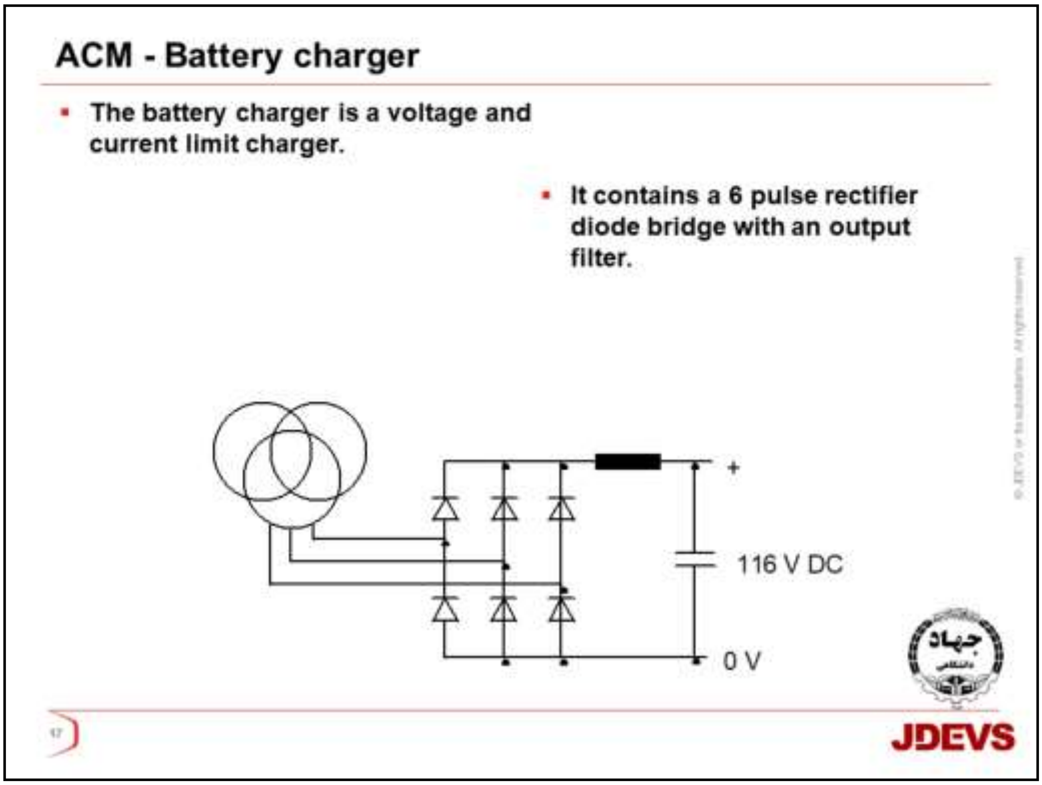
The transformer has three windings, one primary, one secondary for the three phase load and one secondary for the battery rectifier. The transformer isolates the auxiliary system from the high voltage system and the battery system from the auxiliary system. The voltage ratio of the transformer is 270/400/92 V at rated load.????



The earth fault protection consists of a resistance measuring relay connected to the neutralzero on the three phase system. The neutral, in the 3-phase system, is high ohmic connected to the earth. The relay is supplied from the phase voltage on the secondary side on the transformer.

The relay emits a DC voltage to the three phase system. If an earth fault occurs in a phase or in the neutralzero, a current runs through the relay. At higher currents than 230 mA the relay sends a earth fault signal to the DCU/A. It corresponds to an earth fault of 1 k.????

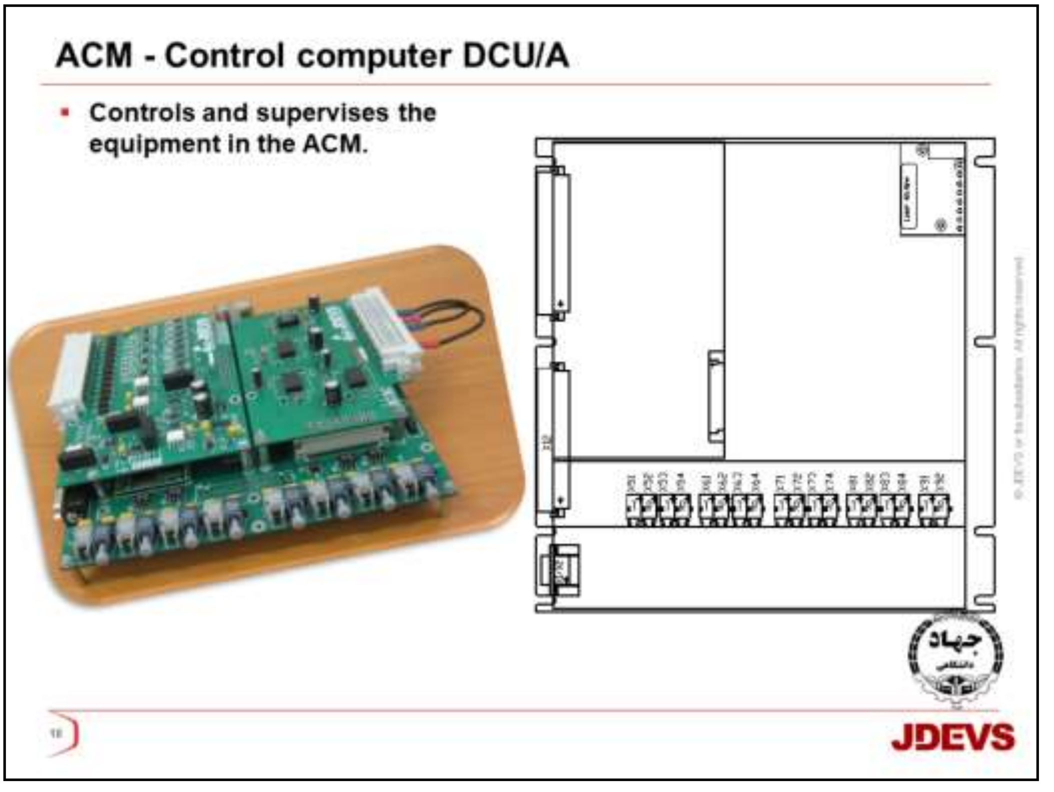
The earth fault protection detects property protection. If the current to earth is more than 300 mA???, the three phase system is disconnected from the ACM and the battery charging can continue. This is done with a three phase contactor on the secondary side 1 of the transformer. The three phase contactor is located outside the ACM and is used at short circuits, overvoltages etc. It also breaks the neutral phase.



The **battery charger** is a 6 pulse rectifier diode bridge with an output filter. The secondary winding of the transformer supplies the rectifier which connects to the output filter.

The battery charger is a voltage and current limit charger. That means the battery charger output voltage is constant up to the limit of the battery charger output current and drops to keeps the charger current constant.

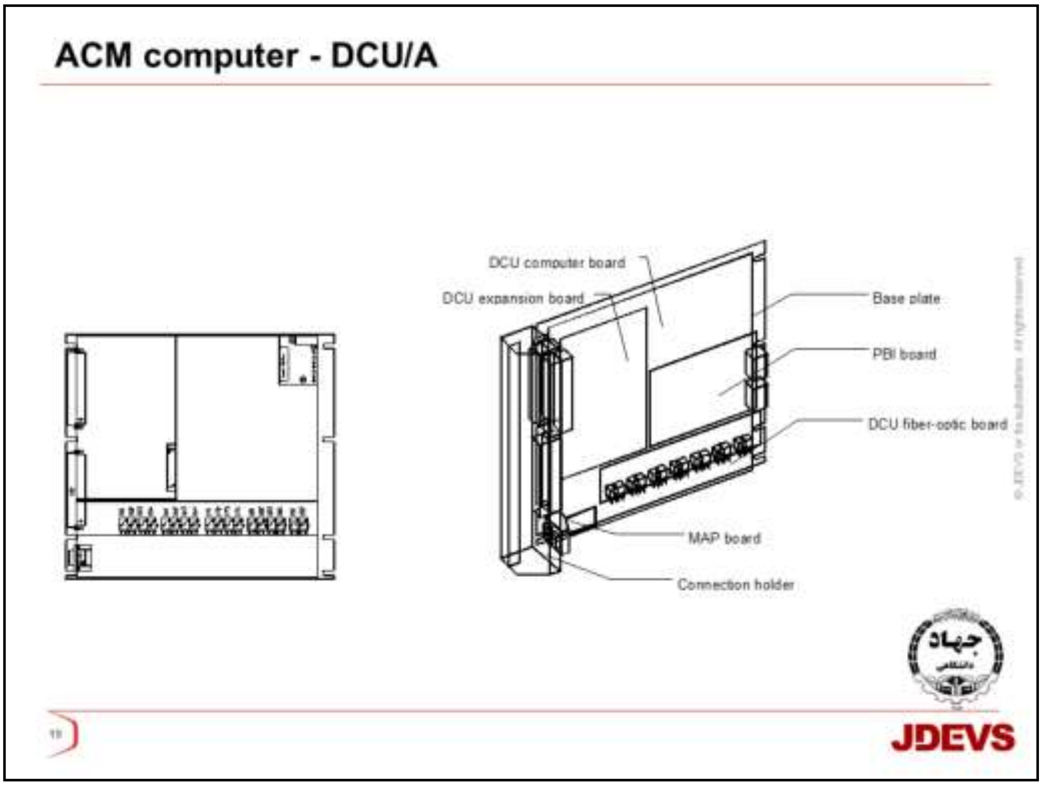
The **battery charger filter** attenuates the ripple appearing at the rectifier output.



The control computer, DCU/A, in the ACM is a distributed control computer. The objective with the DCU/A distributed control is to control and supervise the equipment in the ACM e.g. the converter, the voltage and current measurement, heatsink temperatures, fan contactor etc.

The computer communictas with the VCU via LAN.

Orders to and from the GDUs are transmitted by opto fibres. The opto connectors are mounted on a separate circuit board on the computer.



The MCM computer, DCU/M (Motor Converter Control for IGBT) supervises and controls most of the MCM functions.

The computer is a part of the distributed control system in the vehicle. Hence, the MCM is somewhat independent of external controls and operates with a minimum of input and output signal for the propulsion control. The computer is connected to the vehicle control unit via the LAN.

The DCU/M is both software and hardware. Most of the system controls are programmed in a Micro Processor (MCU) and a Digital Signal Processor (DSP). The MCU handles the slow controls and the external communications. The DSP handles fast software functions and the interface towards the programmable hardware.

The software is constructed out of functional blocks. Some important and time critical functions are implemented in the programmable hardware (FPGA, Field Programmable Gate Array).

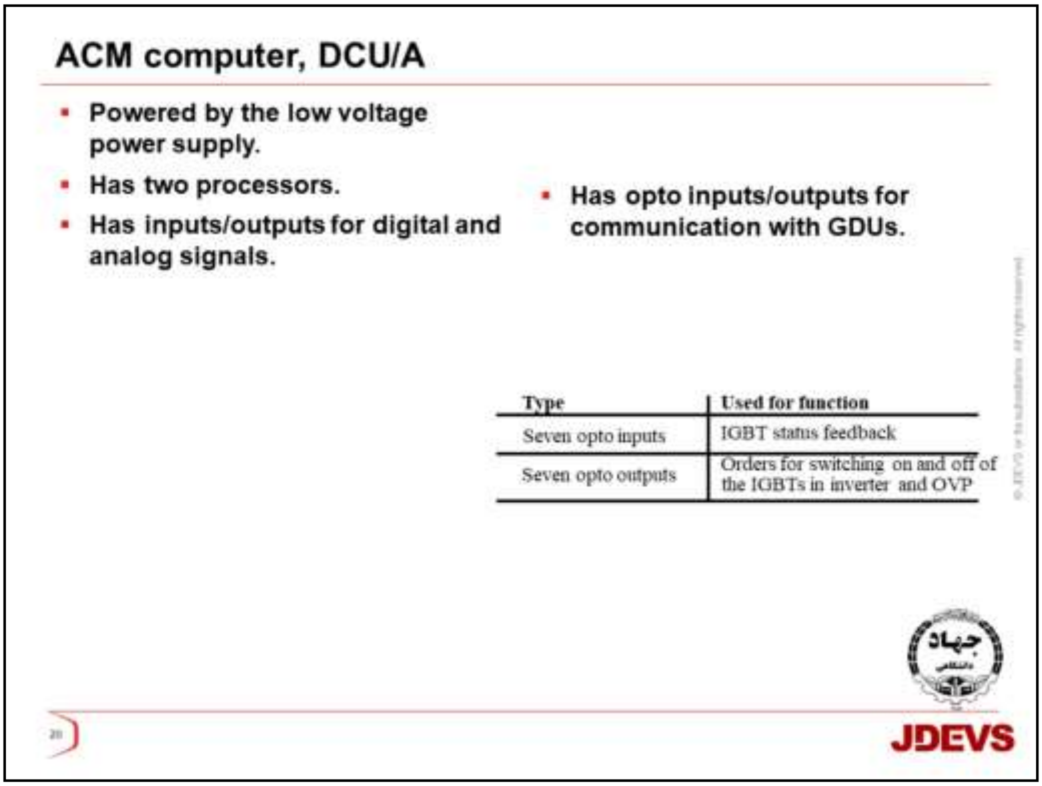
The control structure reduces size and weight of the computer, at the same time it makes the controls extremely flexible.

The DCU/M has sevenLEDs for status indications.

LED Label	Color	Note	Function	
POW	Green	Controlled by hardware	Power supply ok	OK
	Green	Controlled by MCU software	SW running	
ERR	Red	Controlled by MCU software	Fault	

WARN	Yellow	Controlled by MCU software	Warning

MVB activity / Receiving data (RS 232) / Transmitting data (RS 232) Yellow



The computer circuit board is powered by the +24 V DC from the low voltage power supply.

The DCU/L has two processors, where most of the system controls are programmed.

The MCM computer has a number of inputs and outputs for both digital and analog signals. These inputs and outputs are used for the MCM internal control and motor temperatures, speed measurements and ABS.

Mounted on the MCM computer there is a separate circuit board for the opto fibres. The opto fibres are used for communications with the GDUs and the voltage measu-ring board.

The MCM computer is equipped with six **Light Emitting Diodes** . Yellow are used for information, green are indicating OK and the red are used for fault indication**:**

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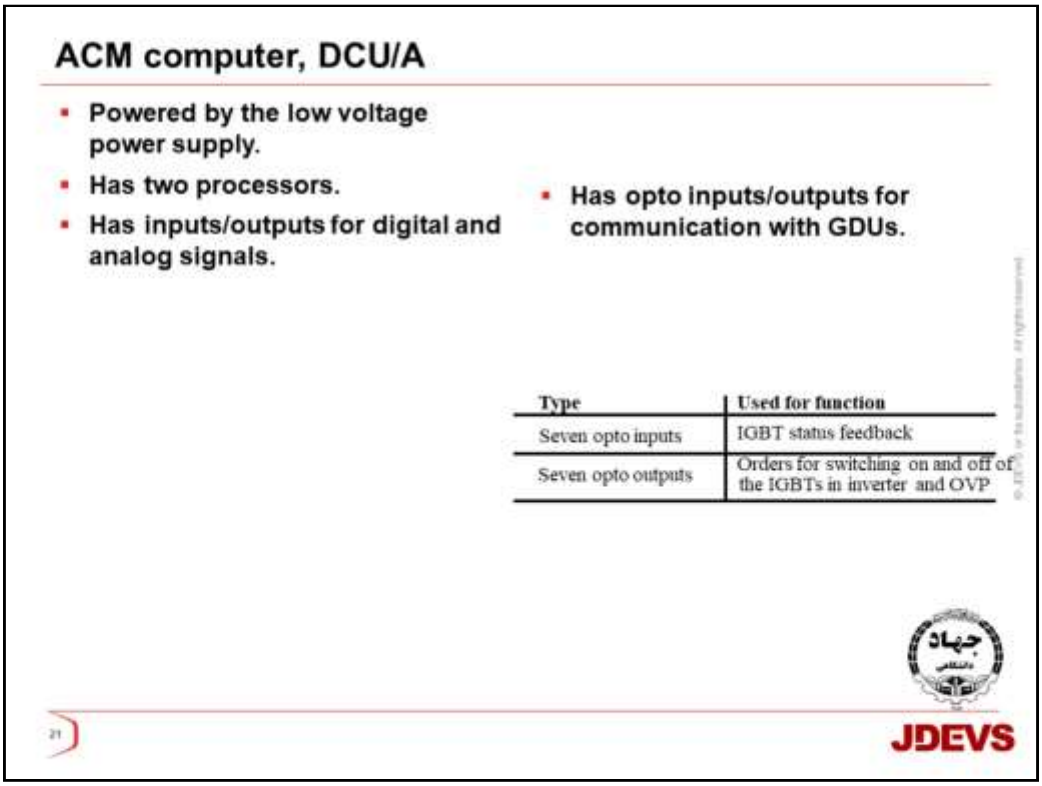
MVB activity

Receiving data (RS 232)

Transmitting data (RS 232) Yellow



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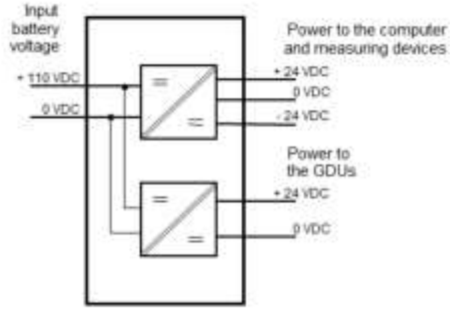
MVB activity

Receiving data (RS 232)

Transmitting data (RS 232) Yellow

ACM - Low voltage power supply

- Supplies 24 V DC to the DCU/A, the current measuring devices and the GDUs.
- Has a +110 V DC input from the vehicle battery voltage.



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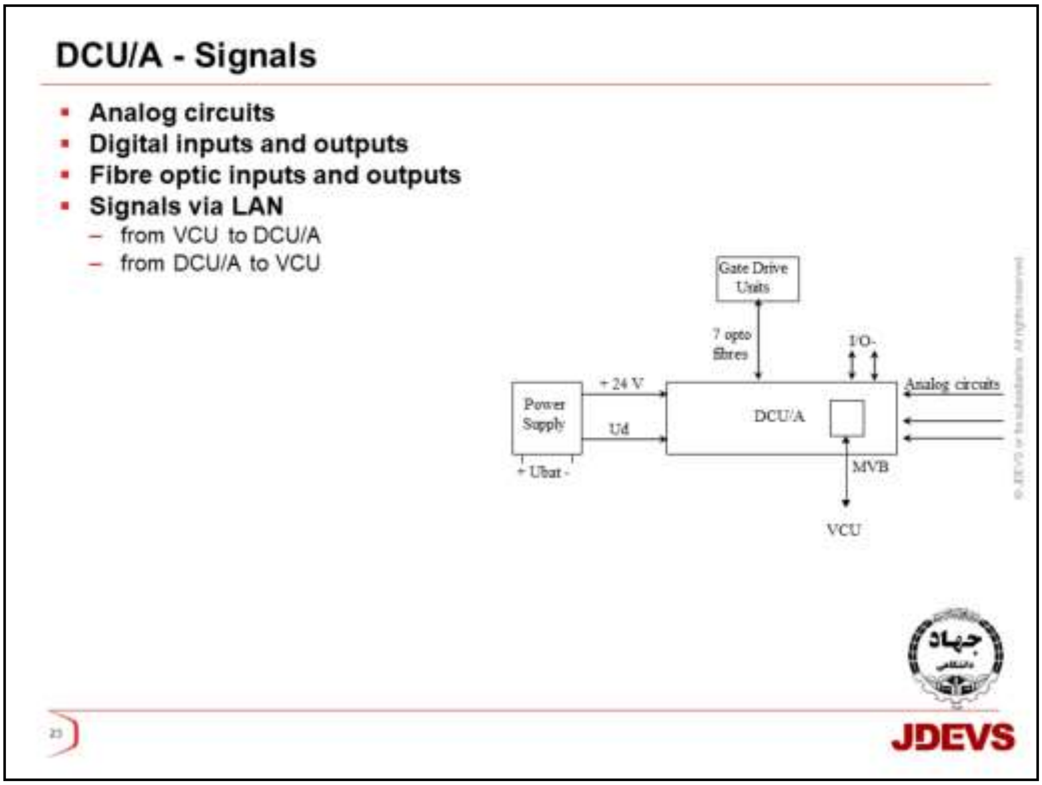
In the MCM there is a low voltage power supply to supply the MCM computer and the current measuring devices with 24 V DC. The power supply also supplies the Voltage Measuring Board (VMB) and the GDUs with +24 V DC.

The power supply has a +110 V DC input from the vehicle battery voltage. The input voltage is converted into the mentioned output voltages using a DC/DC-converter with galvanically separated inputs and outputs.



Input and Output

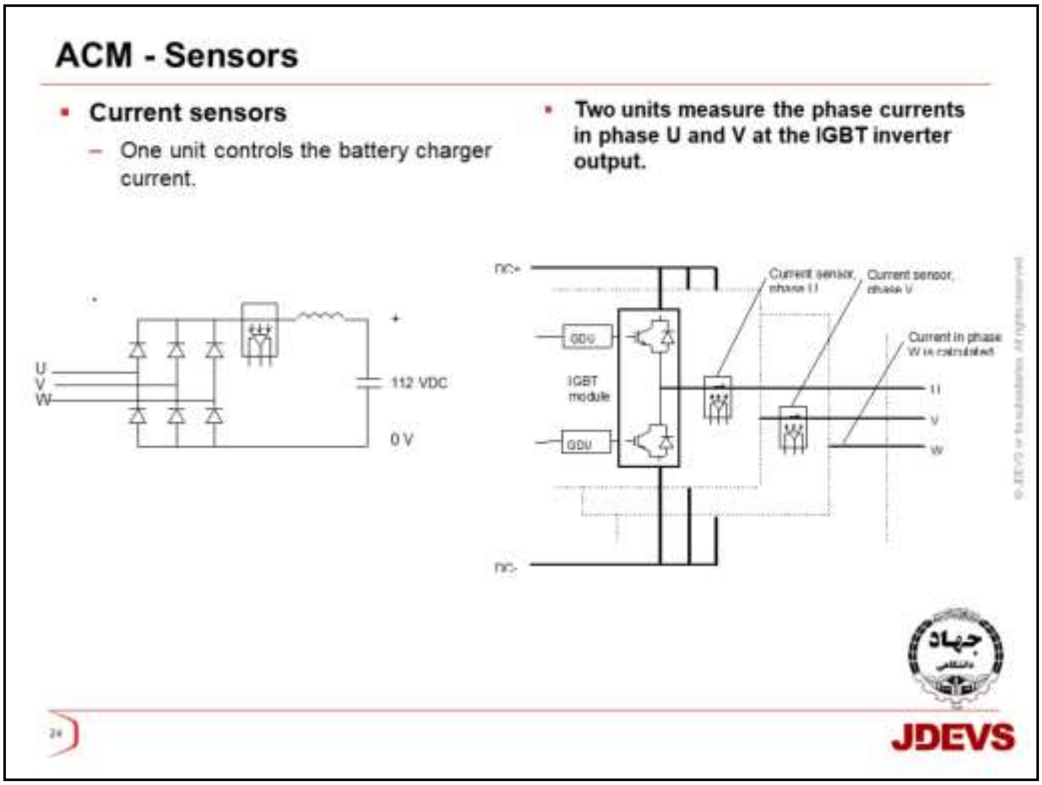
The control computer is provided with inputs and outputs in order to transmit digital and analog signals.

Fibre optic outputs

The optic interface board is mounted on the control computer. The electric signals convert to optic signals on this board. These signals is send to the gate drive unit. The optic fibers galvanic separate the control computer from the line voltage, which reduce the interference sensitivity.

The optic feedback signals from the gate drive units are used for checking status of the switching algorithm on IGBT.

Communication to the VCU is connected via the LAN coupler 12KM02 mounted on the DCU/A and the MVB.



There are three current sensors in the ACM. Two sensors measure the phase currents on the output side of the inverter. One sensor measures the battery charger current on the output side of the battery charger.

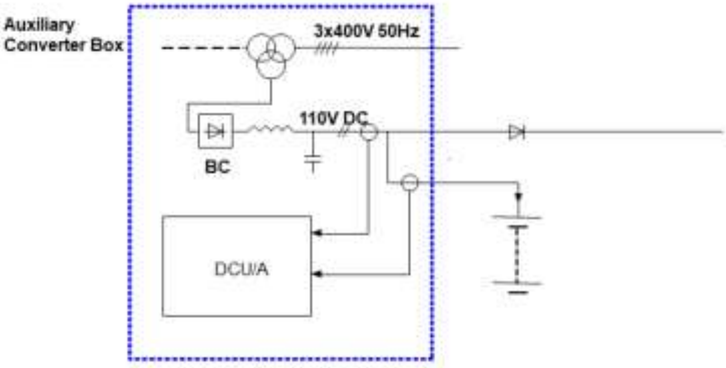
The phase current in phase U and V are measured with one current measuring device each. The current through the other phase W is continuously calculated in the DCU/A.

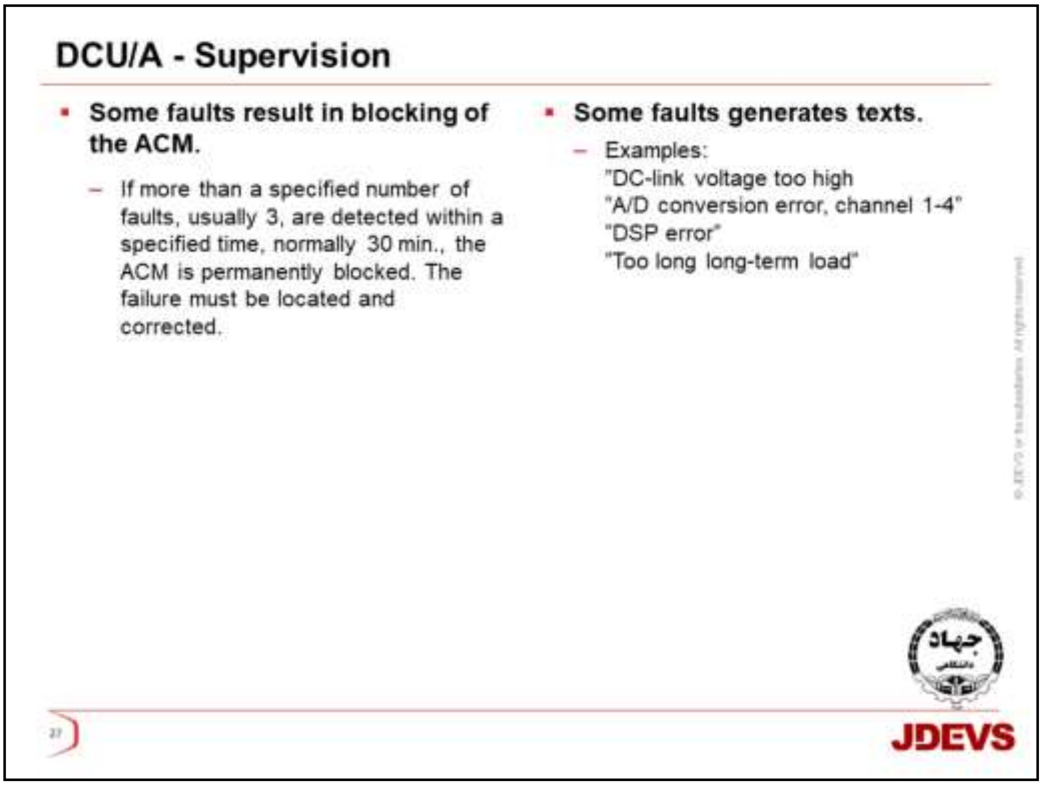
The phase currents are continuously monitored by the DCU/A. If a phase current exceeds the maximum allowed level, the power output is temporarily reduced. The battery charger current is controlled by one current measuring unit.

(The sensor hasve a ratio of 600 A/200 mA. The measuring range is ±600 A)

ACM - Sensors

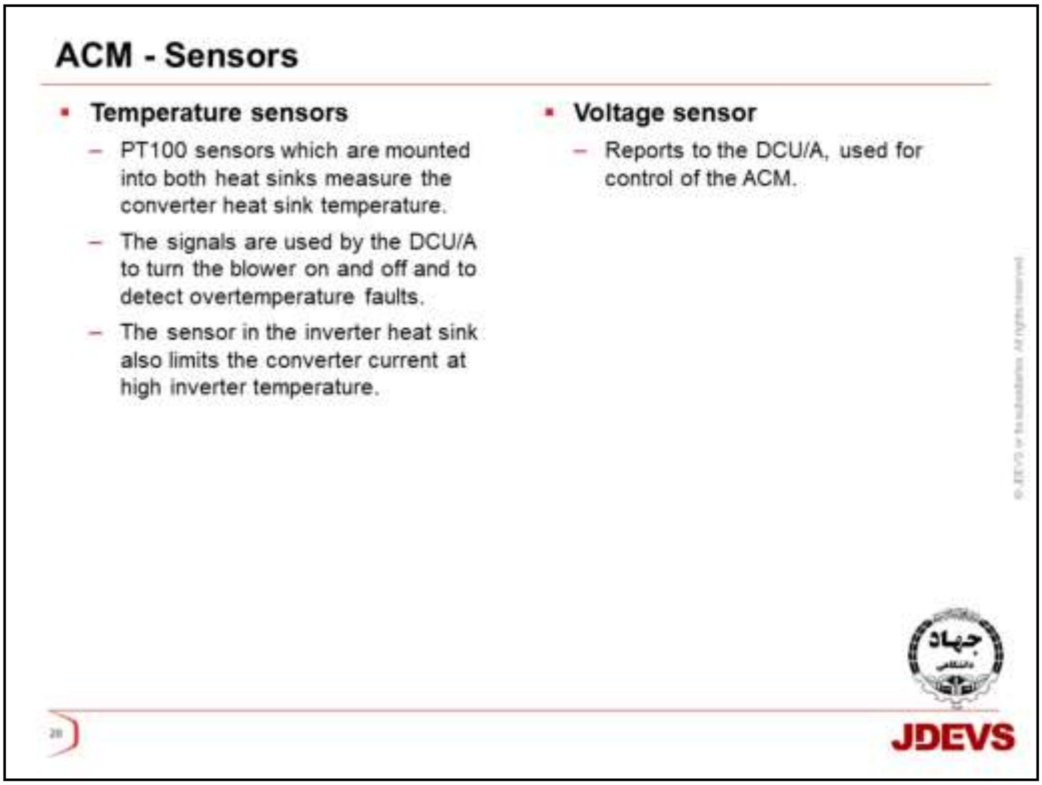
- The battery charging and discharging current is monitored by the DCU/A and communicated on the LAN to the IDU.
- The battery charger current and the current to the battery are measured.





The ACC/I supervises and protects the functions and equipment in the ACM. Some faults result in blocking of the ACM. If more than a specified number of faults, normally three, are detected within a specified time, normally 30 minutes, the ACM is permanently blocked. In suchthis cases the failure must be located and corrected.

Some faults generates texts if the text generation is enabled.



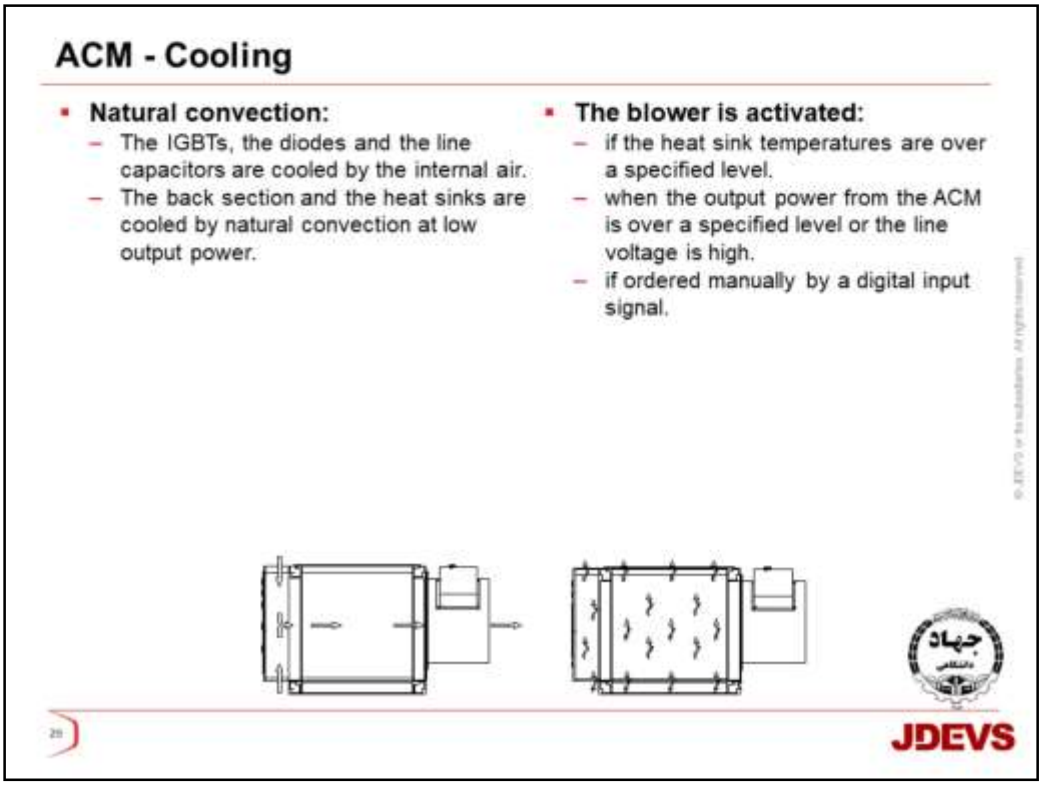
Temperature Sensor

The temperature in the converter heat sink and the diode heat sink is measured by the DCU/A with two PT100 (100 at 0°C) sensors. One in the converter heat sink and one in the diode heat sink. The signal is used by the DCU/A to turn the fan on and off and to detect over temperature faults. The PT100 sensor in the inverter heatsink also limits the converter current at high inverter temperature. The sensor operating temperature range is -40 - +100 C.

There is two **voltage sensors** in the ACM to measure the input filter capacitor voltage. These transducers have a galvanic separation between primary and secondary side.

The first voltage sensor reports the voltage to the DCU/A. This information is used for the control of the ACM, especially for blocking and deblocking the inverter and activating the overvoltage protection circuit.

The second voltage sensor reports the voltage to the integrated supervision system (ISS) only. This system is separated from the inverter control and can therefor not be used to supply the DCU/A with data. The sensor has a test winding, used to check the sensor’s functionality.

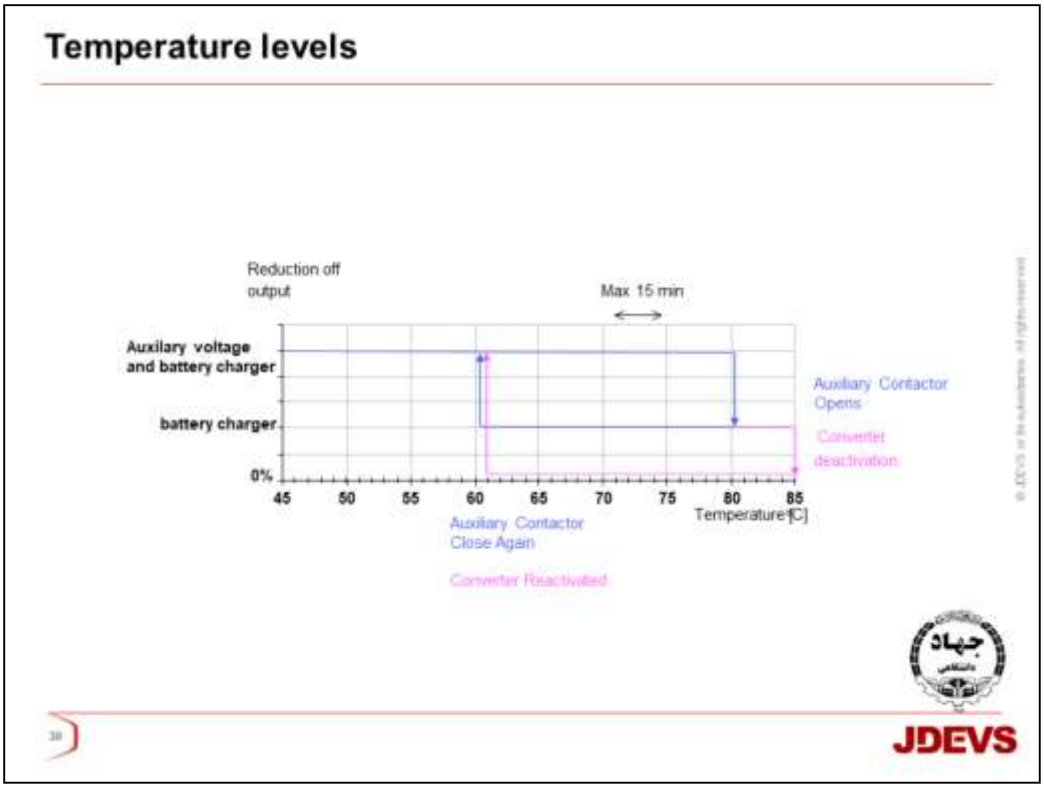


Cooling The ACM is designed to be cooled by natural convection at low output power. The IGBTs and the diodes are mounted on the heat sinks and the line capacitors are mounted inside the front section and cooled by the internal air.

The back section and the heat sinks are cooled only by natural convection when possible. When needed the blower will be activated.

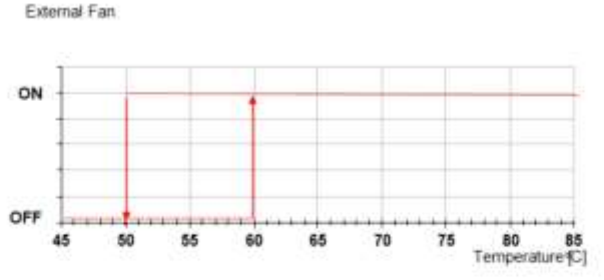
The IGBT heat sink and the rectifier diode bridge heat sink temperatures are monitored, and the blower will be activated if the temperature is over a specified level.

The blower will also be activated when the output power from the ACM is over a specified level or the line voltage is high. It is also possible to start the blower manually by a digital input signal.



low battery indication level 80 V, auxiliary contactor opened, 100 V closed

External Fan Control



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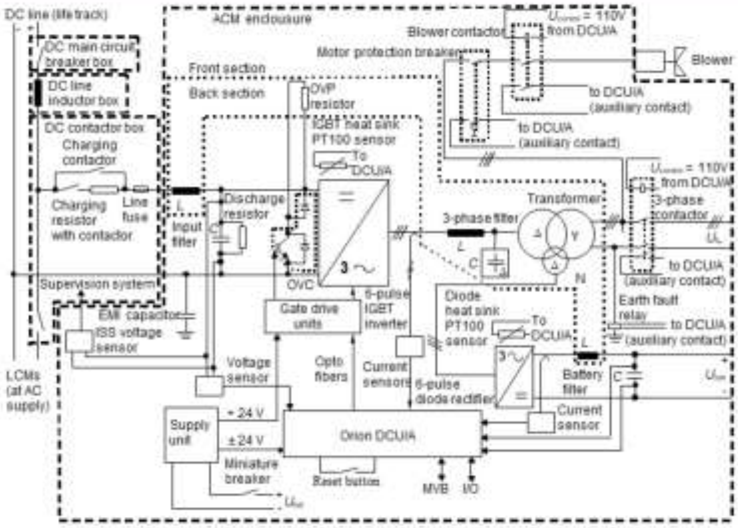
Auxiliary converter module, ACM



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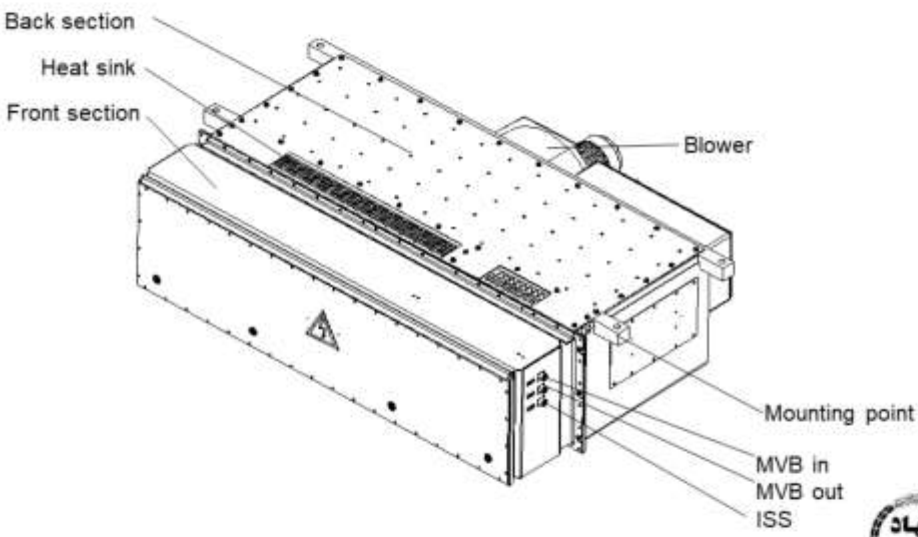
ACM - Exterior



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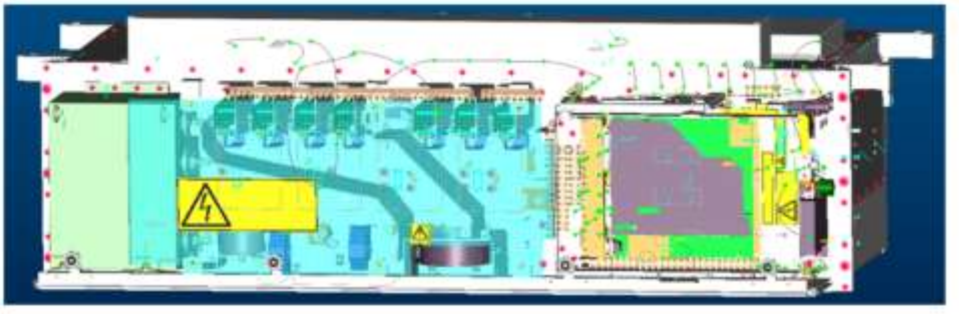
ACM - Front section



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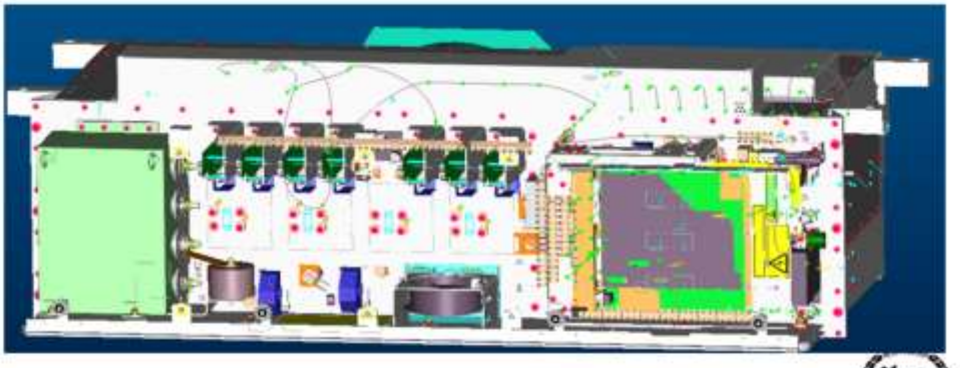
ACM - Front section



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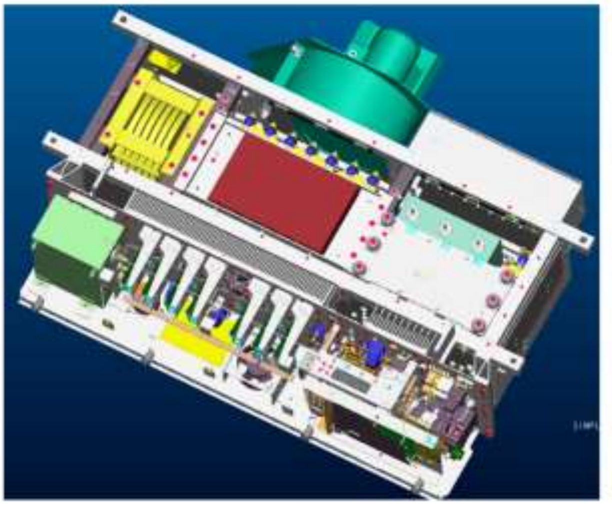
ACM – Back section, top view



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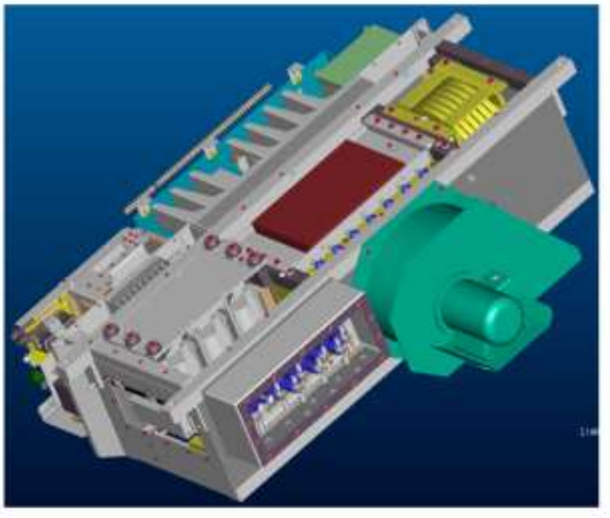
ACM – Back section, rear view



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