Article: Practical application of the latest generation IGBT transistors in the ENI-PTC750/52 auxiliary power supply - part I

Introduction

The aim is to show the practical application of 7th generation IGBTs, based on the example of the latest ENI-PTC750/52 Auxiliary Power Supply (APS) from Enika. This was designed for the Light Rail Transit Authority (LRT1) in Manila, where the trains have been in operation since May 2019. A comparison is made between the latest 7th generation IGBT and the previous 5th generation IGBT.

ENI-PTC750/52

Basic information

The LRT1 line in Manila opened in 1984, and after more than 30 years of operation the systems required refurbishment. Enika participated in this process, and was a supplier of the APS system for the refurbished trains. Figure 1 shows a typical train used on the LRT1 line in Manila.

Figure 1. A train used on the LRT1 line

The supplied APS had to have exactly the same dimensions, electrical parameters, mounting brackets and terminals as the converter it was to replace. The physical distance between Enika and Manila meant that the system had to be:

- very simple and robust in topology,
- modular in construction, for quick and easy maintenance.

Figure 2. ENI-PTC750/52 installed on a train.

Mechanical design

Figure 3 shows the APS dimensions, terminals, and mounting brackets.

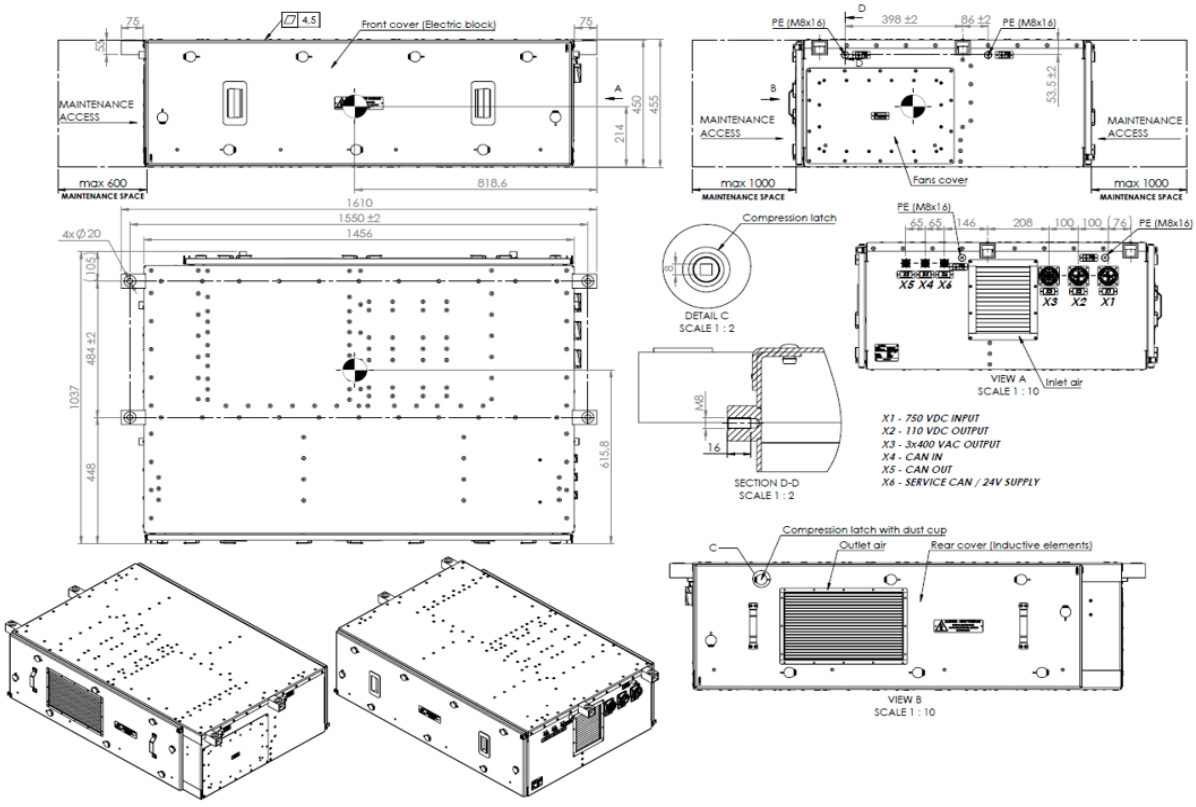

Figure 3. Dimensional drawing of ENI-PTC750/52

The requirements in section Basic Information lead to the division of the converter into 4 parts:

- Input circuit: line contactors, pre-charge circuit, autostarter (Figure 4),
- Main inverter: IGBT modules, voltage and current measurement, controller, power suppliers, DC-Link capacitors (Figure 4),
- Battery charger: diode rectifier, DC/DC converter, controller, power supply (Figure 4),
- Inductive element compartment (Figure 6).

Figure 5 and Figure 6 show the construction of the APS. In figure 5 the modules are shown partially extended from the case. This solution has many advantages, including a time to exchange each module of less than 20 minutes, requiring only the removal of 2 screws, operation of the eject lock and, depending on the module, disconnection of several power cables. Access to the modules is from the front of the converter (on the side of the train, see Figure 2), which allows easy removal of the modules, at any location, and without any special tools. The weight of the inverter module is less than 30 kg and the weight of the input module and battery charger module is less than 15 kg, hence each module can be removed by one or two people. An additional advantage is that a broken module can be repaired in the workshop, where access to each element is easy. Recommissioning after repairs can also be done in the workshop.

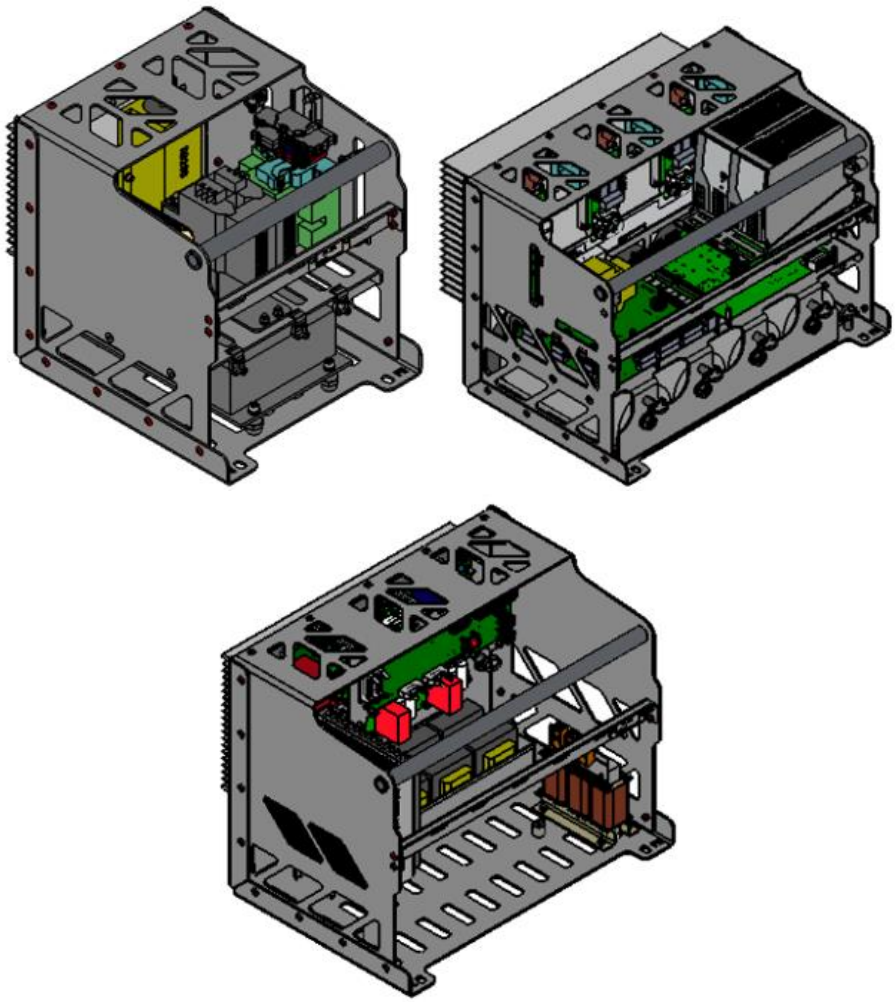

Figure 4. Converter modules (left to right): input, inverter, and battery charger

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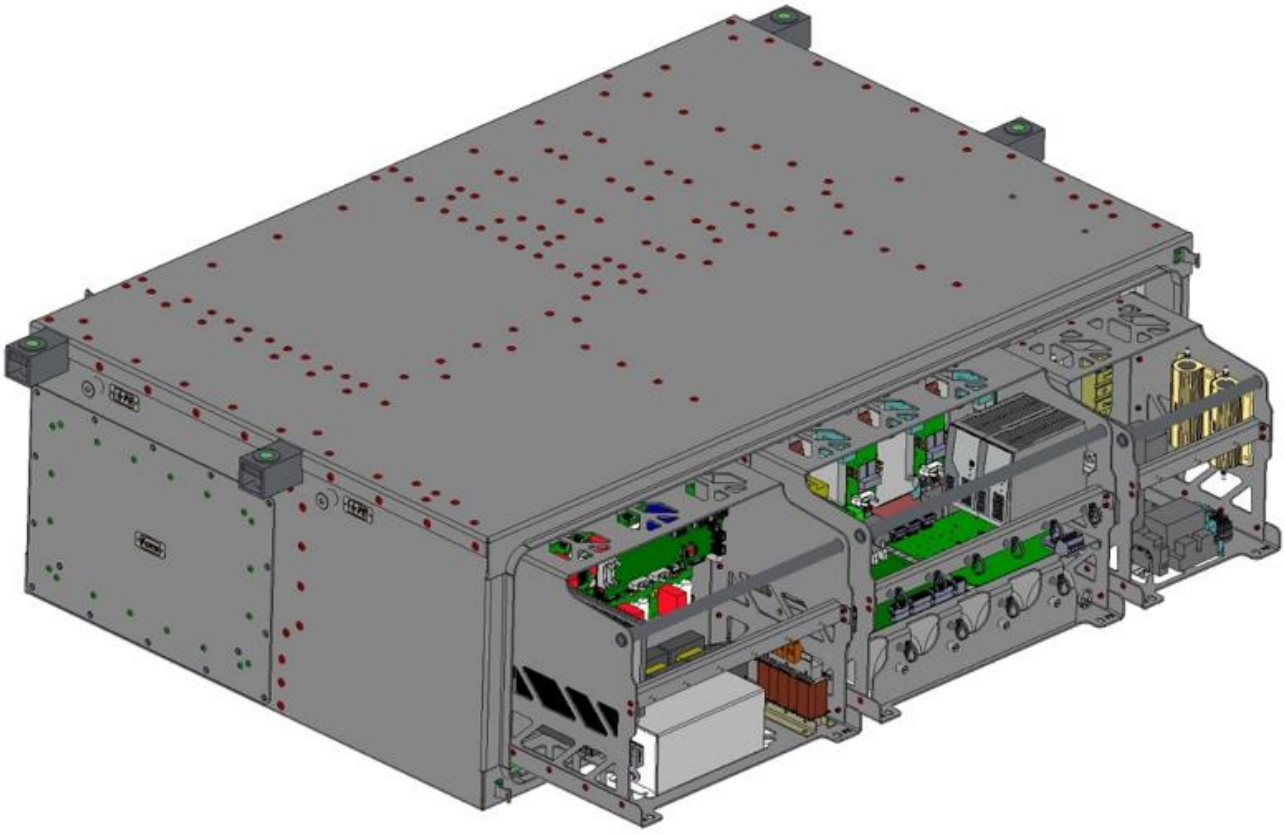

Figure 5. Front side of APS showing the modules: (left to right) battery charger, inverter, and input

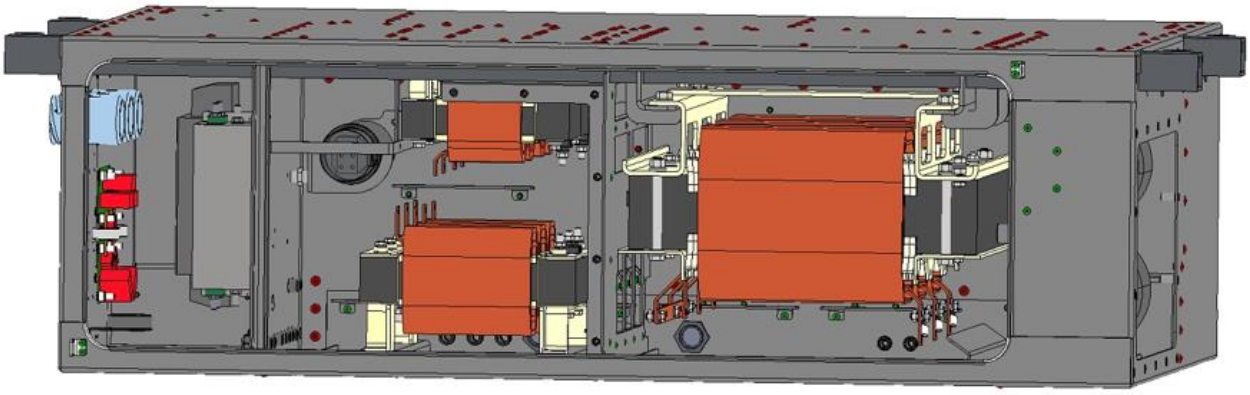

Figure 6. Reverse side of APS showing the inductive compartments

The converter has forced cooling, with fan redundancy. Air enters through the inlet grill, located on the side of the converter, flows through the heatsink fins of each module and then through the fans and inductive elements before exiting through the outlet grill on the back of the converter.

Electrical design

The APS is supplied from the 750 V_{DC} traction system and generates 3x400 V + N / 50 Hz / 45 kVA and 110 V_{DC} / 7 kW. See Table 1 for the electrical parameters.

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Table 1. Electrical parameters of ENI-PTC750/52

General Design	Parameter	Value
Fire Protection	According to DIN5510	
Input Data	Input voltage 750 V_{DC} (-33% - +20%)	
Output Data 110 V_{DC}	Output Voltage	116 V
	Rated Power	7 kW
	Max. short time power	9 kW (30 s)
	Battery charging current	63 A
	Load specification	Auxiliary 110 V_{DC} circuits, battery charging
Output Data 3x440 V_{AC}	Output Voltage	3x400 V_{RMS} (sinusoidal)
	Rated Power	45 kVA (cosφ≥0.8)
	Output Frequency	50 Hz
	Overload	135 kVA (5 sec)
	Frequency Stability	±1 Hz
	Voltage Stability	±3% stat. ±5% dyn.
	Harmonic Content	≤ 5%
	Load Specification	Auxiliary circuits, motors
Maximum Power	52 kW	
Efficiency	> 90 %	
Environmental Conditions	-25°C - +40°C	
Cooling	Forced air cooling	
Protection Class	IP55	
Dimension	2000 mm x 1900 mm x 500 mm	
Weight	≈ 425 kg	

The topology of the converter is based on a three phase direct inverter supplied directly from the 750 V_{DC} supply, fed through a sine filter, 50 Hz transformer to ensure galvanic separation. The delta-star configuration of the transformer means there is a neutral wire on the AC output. A simplified scheme of the ENI-PTC750/52 main circuit is shown in Figure 7, which also shows the content of each block.

This topology has only one power conversion between the input and output of the APS, which allows higher efficiency to be achieved along with fewer semiconductors and other electronic components. The converter has a very simple structure, and the output transformer ensures natural resistance to short-circuits and overloads. The converter is equipped with an autostarter, which allows the converter to start operating even when the on-board battery pack is discharged.

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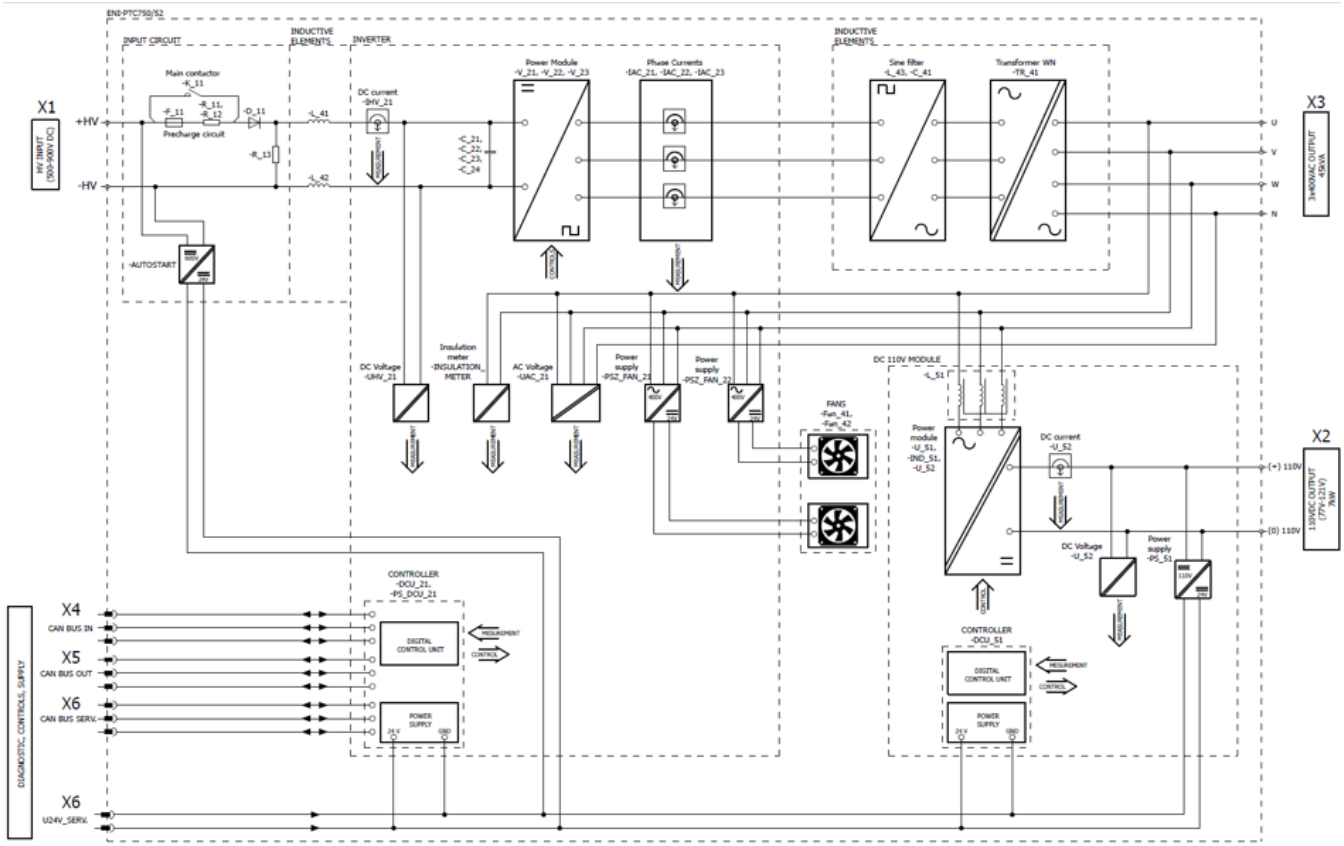

Figure 7. Block diagram of ENI-PTC750/52

The battery charger module is supplied from the 3x400 V_{AC} taken from the output of the transformer. On the input of the module is a 6 pulse diode rectifier. The rectified voltage is supplied to capacitors to create the DC-Link circuit, used to supply the SiC modules operating under the half-bridge topology. The frequency range of a SiC module is 60-100 kHz. High frequencies allow a reduction in the inductive element dimensions and, thanks to the SiC technology, the achieved module efficiency is about 94% even if the switching frequency is very high.

Conclusions

The ENI-PTC750/52 project is a success. In Manila, 48 converters are operated without any failures, even though the environmental conditions are very demanding in terms of humidity and temperature. The customer is very satisfied with the modular construction of the converter. During the training in Manila, the customer's technicians were able exchange modules without any difficulties. On-site commissioning went very smoothly, which was also welcomed.

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