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PowerizeD

Digitalization of Power Electronic Applications within Key Technology Value Chains

Deliverable	**D3.1.4 Summary Report on demonstrators along the value chain of the Mobility Use Cases**		
Involved WPs	WP3	**Deliverable type**	Public
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1 Publishable summary

Project acronym	**PowerizeD**
Project Logo	
Project full title	Digitalisation of Power Electronic Applications within Key Technology Value Chains
Project Coordinator	Mr. Jochen Koszescha, Jochen.koszescha@infineon.com Infineon Technologies AG
Coordinating Entity	Infineon Technologies AG

The objective of this deliverable is to summarise the demonstrators along the value chains within the use cases of the Mobility domains of the PowerizeD project. The publicly available documentation of the demonstrators is primarily provided in the form of videos prepared for each use case according to the following list:

- UC1.1 Rail propulsion system (ALSTOM)
- UC1.2 Traction Converters (IPT)
- UC1.3 PEBB for DC/DC Converters (IPT)
- UC1.4 BEHDV drive inverter for high voltage (SCANIA)
- UC1.55 FCEV-Fuel Cell and PT Inverter (RB)
- UC1.6a MILCA Mobile In-line Charger (XC)
- UC1.6b Medium Power Modular Stationary Charger (ELC)
- UC1.6c Large Power Stationary Charger (PRE)
- UC1.7 System of Systems (OTH/EDI)

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2 Introduction & Scope

2.1 Purpose and target group

The objective of this deliverable is to provide an overview documentation of the demonstrators for each of the Use Cases in the Mobility domain, developed within the Cross Domain Topics of WP2 with subsequent integration and validation in the value chains carried out in WP3.

The scope consists of:

- Description of each demonstrator
- List of the relevant aspects they contribute to the product value chain
- The corresponding link to the high-level objectives.

2.2 Contributions of partners

The following table explains which partners contributed to the respective sections of the report with the use case leaders indicated in bold text.

TABLE 1: CONTRIBUTIONS

Chapter	Partner	Contribution
ALL	**ALSTOM**	Editor
3.1	**ALSTOM**, RISE, IFAG	Inputs for UC1.1
3.2	**IPT**, UNIOVI	Inputs for UC1.2
3.3	**IPT**, UNIOVI, FRENETIC, ETHZ	Inputs for UC1.3
3.4	**SCANIA**, KTH	Inputs for UC1.4
3.5	**RB**, MBAG	Inputs for UC1.5
3.6	**XC**, PLEXIM, PTB	Inputs for UC1.6a
3.7	**ELC**, FAG, IFI, IFAT, FPG, HEPO, SERI, UNIBO and ETH	Inputs for UC1.6b
3.8	**PRE/KEM**, TUDE and VSL	Inputs for UC1.6c
3.9	**OTH/EDI**, HUA, UNIBO, PLEXIM and RISE	Inputs for UC1.7

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2.3 Relation to other activities in the project

The relation to the Cross Domain Topics of WP2 for each use case can be seen in the table below:

UC vs CDT Matrix

					Reliability, Modelling & Digital Twins				Substrates, Materials & Integration			Intelligent Sensing		Tools & Standards				Sustainability
Domain	Leader	UC	UC Title	Leader	CDT1.1	CDT1.2	CDT1.3	CDT1.4	CDT2.1	CDT2.2	CDT2.3	CDT3.1	CDT3.2	CDT4.1	CDT4.2	CDT4.3	CDT4.4	CDT5.1
					Reliability	Modelling	Digital Twins	Federated Learning	Substrates	Interconnection Materials	Packaging and Cooling	SW-related Control Approaches	HW-related Sensing & Control Approaches	HW-Tools	SW-Tools	Measurement Equipment & Standards	EMC prediction & design optimization	Comparison of environmental impacts of SiC MOSFET vs Si IGBT modules
Intelligent Energy for Mobility	MBAG	UC1.1	Railway Propulsion Systems	ALSTOM	x	x	x	x			(x)	x	x	(x)	(x)		x	(x)
		UC1.2	PEBB for Traction Converters	IPT		x	x	x*				x*	x*					
		UC1.3	PEBB for DCDC Converters	IPT		x	x	x*										
		UC1.4	BEHDV (Battery Electric Heavy-Duty Vehicle) Drive Inverter for High Voltage	SCANIA	x	x	x				x	x	x					
		UC1.5	FCEV- Fuel Cell and Powertrain Inverter	RB	x	x	x	x		x	x							
		UC1.6a	Mobile In-Line Charger (MILCA) & Large Power Stationary Charger	XC								x		x	x			
		UC1.6b	Medium Power Modular Stationary Charger	ELC	x	x	x	x	x	(x)								x
		UC1.6c	Large Power Stationary Charger	PRE	x	x			x	(x)						x		
		UC1.7	Charging infrastructure	OTH/EDI			x	x	x	(x)					x			x

FIGURE 1 USE CASE RELATIONSHIPS WITH CROSS DOMAIN TOPICS

- **Inputs:** Video material compiled by Use case provider partners as publicly available content derived from D3.1.3 [1].
- **Outputs:** Public video for dissemination of project technology demonstrators across the value chain.

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3 Summary report on demonstrators along the value chains in the Mobility Use Cases

This chapter provides an overview of the public demonstrators and their validation within the value chains for the use cases in the Mobility domain. For these purposes the demonstrators have primarily been documented in a video format. This documentation can be found along with similar material from all the other domains in the PowerizeD project website as per the following link:

https://powerized.eu/index.php/resources/demonstrators [2]

The material is stored under each corresponding use case heading on this website. The following table shows the list with titles of the use cases in the mobility domain and the respective use case leaders.

TABLE 2: LIST OF USE CASES IN THE MOBILITY DOMAIN

Domain	Leader	UC	UC Title	Leader
Intelligent Energy for Mobility	MBAG	UC1.1	Rail propulsion system	ALSTOM
		UC1.2	Traction Converters	IPT
		UC1.3	PEBB for DC/DC Converters	IPT
		UC1.4	BEHDV drive inverter for high voltage	SCANIA
		UC1.55	FCEV-Fuel Cell and PT Inverter	RB
		UC1.6a	MILCA Mobile In-line Charger	XC
		UC1.6b	Medium Power Modular Stationary Charger	ELC
		UC1.6c	Large Power Stationary Charger	PRE
		UC1.7	System of Systems	OTH/EDI

The subsequent sections describe the demonstrator materials per use case and the associated partner contributions.

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3.1 UC1.1 Rail propulsion system

The Use Case focuses on compact integration solutions for railway propulsion systems by new power semiconductor generations, smart operation and maintenance of railway propulsion systems using intelligent electronics as well as enhanced reliability and robustness by data driven accelerated verification. Three demonstrators are presented in the documentation for this use case:

1. Demonstration of smart sensing functions in intelligent gate drive platform and controller developed by **ALSTOM**, replacing or augmenting discrete / stand-alone sensors using capabilities built into gate drive.
2. Demonstration of test system and methods for AI enhanced verification of railway propulsion systems, improving reliability and robustness testing of power electronics in terms of test time and test coverage including a test circuit developed by partner **RISE**, a mission profile-based method for thermal cycling of SiC MOSFET equipped power semiconductor modules provided by partner **IFAG** for subsequent AI augmented Remaining Useful Life analysis according to a method developed by **RISE**.
3. Demonstration of an energy harvester function, developed by partner **RISE**, to power wireless sensors in railway propulsion converter equipment for specific measurement during, for instance, commissioning and warranty periods.

3.2 UC1.2 Traction Converters

The video shows the work carried out in the design and manufacturing of PEBBs for medium-voltage and medium-power traction converters, and the contribution of our partner **UNIOVI**.

3.3 UC1.3 PEBB for DC/DC Converters

The video shows the work carried out in the design and manufacturing of PEBBs and inductive elements, one for High frequency auxiliary converter and another one for medium frequency Energy Storage System converter, and the contribution of our partners **UNIOVI**, **FRENETIC** and **ETHZ**.

3.4 UC1.4 BEHDV drive inverter for high voltage

At present, the first back-to-back inverter prototype has been successfully constructed by partner **KTH**. The single-phase operation has been tested, confirming the functionality of the control and cooling systems. The next step is to evaluate the three-phase operation, and once the VECTO drive cycles are applied to operate the inverter under different load conditions and the efficiency of the inverter has been assessed, the entire setup will be replicated for the second prototype. The final goal is to compare the performance of both prototypes in terms of efficiency, losses, and thermal behaviour.

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3.5 UC1.5 FCEV-Fuel Cell and PT Inverter

Within the UC1.5, the objective was to implement a compact digital twin, carry out virtual release via referencing by means of credible simulations and extend the solutions in future for PHM applications. In this regard, for establishing credible simulation methodology for virtual release, verification and validation activities were carried out in which the Multi Chip Power Package with integrated iForce sensor was used as the demonstrator for validation of FE-model under passive and active operating conditions. The work has resulted in four demonstrators

Demonstrator 1: Multi-Chip Power Package with Integrated iForce Sensor.

Demonstrators have been developed by partner **RB** for validation of FE-models for passive temperature cycling and active power cycling conditions, respectively. The demonstrators have been equipped with a piezoresistive stress sensor, also known as iForce sensor, which will help validate the FE-model predicted stress states at their respective locations within the demonstrators.

Demonstrator 2: SiC-Inverter Demonstrator:

The inverter demonstrator that has been assembled during the project is a demonstration platform for the various PHM and digital twin algorithms developed by **MBAG** and **RB**.

Demonstrator 3: SmartCooler Demonstrator

The video shows the work carried out in the design, manufacturing and functional testing of SmartCooler demonstrator with direct cooling of power module. The cooler has been designed using 3D printing technologies using two different materials: aluminium and polymer. Work has been carried out by partners **imec**, **Materialise**, **nano-join**, **BNT**, **Sadeschaf**, **Bosch Romania** and **Bosch Germany** in close collaboration with CDT 2.3 (led by imec).

Demonstrator 4: BLR demonstrator with discrete packages

Demonstrator boards have been developed by **RB** for use in accelerated board level reliability tests to provide EoL data by provoking degradation processes within the solder joints and wire bonds.

3.6 UC1.6a MILCA Mobile In-line Charger

In this use case, the objective is to develop a demonstrator for a back-up DC-charging solution for EVs based on the latest generation of GaN semiconductors. The video shows the running demonstrator of the mobile inline charger. The first half of the video introduces the main converter showing the running of the topology of the discontinuous series resonant converter (DSRC), and the second half shows the DSRC running in combination with the AFE in the topology of the bridgeless totem pole PFC at different load points and full power. The solutions have been developed by **PLEXIM, XC, PTB**.

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3.7 UC1.6b Medium Power Modular Stationary Charger

Use Case UC1.6b concerns the development of a 50-kW bidirectional grid-connected charging infrastructure, built from 25-kW modular units that include a three-phase AC/DC converter and a high-frequency isolated DC/DC converter, combined with an integrated energy storage system designed to provide grid support or enable emergency charging for connected electric vehicles. The work for this use case had been led by **ELC** in collaboration with partners **IFAG**, **IFI, IFAT**, **FPG, HEPO, SERI, UNIBO** and **ETH**.

1. AFE PFC CONVERTER TEST

Lab demonstration of 50kW bidirectional energy flow from High-voltage battery to public grid (and vice-versa) via an Active Front-End (AFE) system, consisting of 2 paralleled 25 kW units (blue PCBs). The power flow is set and slowly increased by a PC connected via a CAN interface to the microcontroller located directly on the AFE PCBs.

2. EMERGENCY HIGH-VOLTAGE BATTERY SYSTEM

Two videos have been prepared to document the assembly, wiring architecture, and functional testing of a modular high-voltage battery system and serves as a technical reference for a research project on the system integration of lithium-ion battery modules.

3. INTELLIGENT SiC POWER MODULE AND DC/DC CONVERTER

The short video showcases the hardware developed for the 25-kW modular unit of the DC/DC converter including an overview of the top side of the gate-driver board and its integration into the power module.

4. DC/DC CONVERTER TEST

The video presents the demonstrator of the DC/DC converter unit equipped with the IMS-based Intelligent Power Module (IPM), operating under different operating conditions. The test is performed using a dedicated experimental setup, which enables system-level measurements (input and output voltages and currents, and converter efficiency) as well as voltage and temperature monitoring at the power-device level, thereby validating the IPM's integrated diagnostic features.

3.8 UC1.6c Large Power Stationary Charger

The work for this use case had been led by **PRE** and **KEMP** in collaboration with partners **TUDE** and **VSL**.

The demonstrator video provides a clear step-by-step overview of the complete Powerized setup, supporting both CCS and MCS charging. The video opens with a wide view of the system architecture and then zooms in on the individual power-conversion stages. It first shows the passive 50kVA / 3X80A, 6-pulse rectifier, followed by the 30kVA / 3X50A Active Front End (AFE), with PFC and reactive power control where the improved harmonic performance becomes visible through active control. The video then highlights the 90kW (3x 30 kW) power modules and their role within the DC bus.

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The centrepiece is the newly developed 2×50 kW Dual Active Bridge (DAB) converter, created as an upgrade to the originally planned 25 kW modules. This 100-kW bidirectional isolated DC/DC converter supports both a 750 V DC microgrid and series operation up to ±750 V and integrates a new DC droop-control algorithm that ensures stable, reliable charging performance in combination with Active Front Ends. With its wide operating range, the module is compatible with both CCS (150–1000 V, PE-isolated) and MCS (500–1500 V, symmetrical to PE), always maintaining <1000 V to PE for safety.

The video concludes with a full system view of the demonstrator: the power cabinet containing the passive rectifier, AFE and interleaved DC/DC modules, and the dispenser cabinet housing the CCS/MCS controllers, liquid-cooled cabling, cooling system and user interface.

3.9 UC1.7 System of Systems

The work for this use case has been led by **OTH**/**EDI** in collaboration with **HUA, UNIBO, PLEXIM** and **RISE**.

Federated Learning System with Enhanced Protection through Differential Privacy

As one of the UC1.7 demonstrators, this demonstrator showcases an additional Differential Privacy (DP) protection module for the Federated Learning (FL) system, highlighting the benefits of enhanced privacy. The demonstrator illustrates the AI module's training process using the CALCE dataset to estimate a battery's Remaining Useful Life (RUL). The DP module is implemented with the OPACUS DP library and can be toggled "on" or "off". Multi-client FL training is simulated with separate processes within a single Docker container. Protection levels can be monitored via epsilon values (the ε-privacy budget), which the system calculates at the end of each training cycle.

Simulated Electric Vehicle Fleet for Battery Remaining Useful Lifetime Estimation

In this video, we demonstrate the functionality of our system through a step-by-step walkthrough. First, input data for the battery is generated using a simplified EV model. In the next step, the battery is discharged based on load values derived from a repeated WLTC driving cycle. Afterwards, the recorded battery data is pre-processed on a full-cycle basis to prepare it for AI training. In the final step, the FL client collects the data over time and incorporates it into the training process. To provide a clearer understanding of the overall system, selected data is visualized in an interactive dashboard.

State-of-Charge estimation and optimal route calculation

A visual demonstration is presented of the proposed framework for the integration of CARLA, energy-efficient path planning algorithms (PPAs) and energy model.

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4 References

[1] D3.1.3 Report on the demonstration and validation in the value chains of the Mobility Use Cases

[2] https://powerized.eu/index.php/resources/demonstrators

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5 List of figures

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6 List of tables

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7 List of Abbreviations

TABLE 3: LIST OF ABBREVIATIONS.

Abbreviation	Description	First Mentioned
2L	2-Level	UC1.2
3D	3-Dimensional	UC2.4
3L	3-Level	UC1.2
AC	Alternative Current	UC1.6a
Ag	Silver	UC3.1a
AlN	Aluminium Nitride	UC1.6b
BEHDV	Battery Electric Heavy-Duty Vehicle	UC1.4
BLR	Board Level Reliability	UC1.5
BMS	Battery Management System	UC2.1
CbM	Condition Based Monitoring	UC3.2
CCS	Combined Charging System	UC1.6c
CDT	Cross Domain Topic	UC1.1
CNC	Computer Numeric Control	UC3.2
Cu	Copper	UC3.1a
DC	Direct Current	UC1.3
DT	Digital Twin	UC3.2
ED3	EconoDual 3	UC3.1a
EMC	Electromagnetic Compatibility	UC2.3
EMU	Electric Multiple Unit	UC1.2
EV	Electric Vehicle	UC1.6a
FC	Fuel Cell	UC1.3
FCEV	Fuel Cell Electric Vehicle	UC1.5
FL	Federated Learning	UC1.1
FPGA	Field Programmable Gate Array	UC1.1
GaN	Gallium Nitride	UC1.6a
GPR	Gaussian Process Regression	UC3.2
HF	High Frequency	UC1.6b
HW	Hardware	UC1.2
iFORCE	Piezo-electric stress sensor	UC1.5
IGBT	Insulated Gate Bipolar Transistor	UC1.1
IHV	IGBT High Voltage	UC1.2
IMS	Insulated Metal Substrate	UC1.6b
KPI	Key Performance Indicator	UC1.1
LED	Light Emitting Diode	UC2.3
LSTM	Long Short-Term Memory	UC3.2

MCS	Megawatt Charging Standard/System	UC1.4
MDN	Mixture Density Network	UC3.2
MILCA	Mobile in-line Charger	UC1.6a
ML	Machine Learning	UC1.7
MOSFET	Metal Oxide Semiconductor Field Effect Transistor	UC1.1
NTC	Negative Temperature Coefficient	UC3.1a
OBC	On-Board Charger	UC1.6a
OEM	Original Equipment Manufacturer	UC1.6b
PDE	Power Demand Estimation	UC1.7
PEBB	Power Electronics Building Block	UC1.2
PHM	Prognostics and Health Management	UC1.5
PLC	Power Line Communication	UC1.6a
PSpice	Personal Simulation Program with Integrated Circuit Emphasis	UC1.5
PV	Photovoltaic	UC2.4
PWM	Pulse Width Modulation	UC3.2
RDSon	On-State Drain-Source Resistance	UC2.2
RUL	Remaining Useful Life	UC1.7
SiC	Silicon Carbide	UC1.1
SLID	Solid Liquid Interdiffusion	UC3.1a
SoA	State-of-the-Art	UC1.4
SoC	State of Charge	UC1.7
SRC	Series Resonant Converter	UC1.6a
STO	Safe Torque Off	UC3.2
SW	Software	UC1.2
TIS	Thermal Impedance Spectroscopy	UC1.5
Tj	Junction Temperature	UC3.1a
UC	Use Case	UC1.1
UNIBO	University of Bologna	
UPS	Uninterrupted Power Supply	UC2.4
V2G	Vehicle to Grid	UC1.6b
WBG	Wide Band Gap	UC1.1
XHP	eXtremely High Performance	UC1.2
Zth	Transient Thermal Impedance	UC3.1a

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