WATT &WELL

CONVERTING POWER INTO CONFIDENCE

Polytech' Nancy

Develop Electrical Vehicle CHARGERS using MATLAB/Simulink

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AGENDA

1. Company presentation
2. Electrical mobility application examples
3. Technical challenges
4. Software design using MATLAB/Simulink

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WATT & WELL Presentation

Company Data:

- **Turnover:** 5 M€ (2019)
- **Growth:** +40% per year
- **Privately Owned**

International by essence:

- 45 people, 3 locations (France & USA)
- 10 nationalities
- 50% Export

Innovation in Power Electronics across Industries

- 70% engineers & PhD
- Diversification from Oil & Gas market to Aerospace and E-Mobility applications (EV, Charging Infrastructure)

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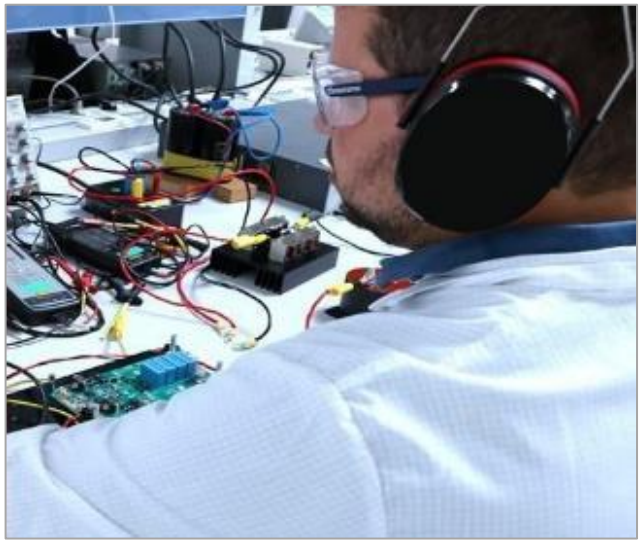
Watt & Well Presentation

Global Footprint

Paris,
Aix-en-Provence,
Houston



Expertise

45 Employees,
75% of Engineers

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Working for leaders

“ We support designers of technological systems facing the most demanding constraints thanks to our core expertise in power electronics.”

THEY TRUST US

THEY SUPPORT US

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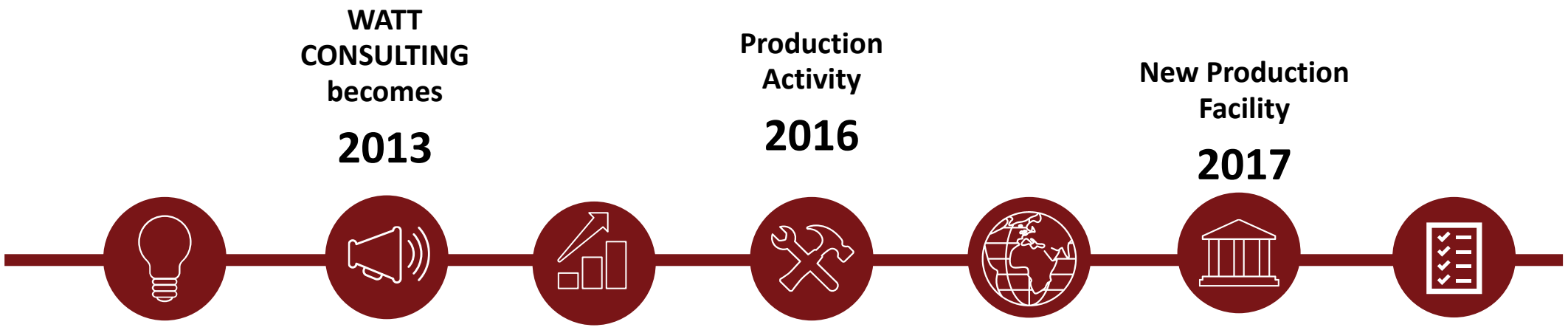
Over 10 years of experience



2007
Creation of

2013
WATT CONSULTING becomes

2015
ISO 9001

2016
Production Activity

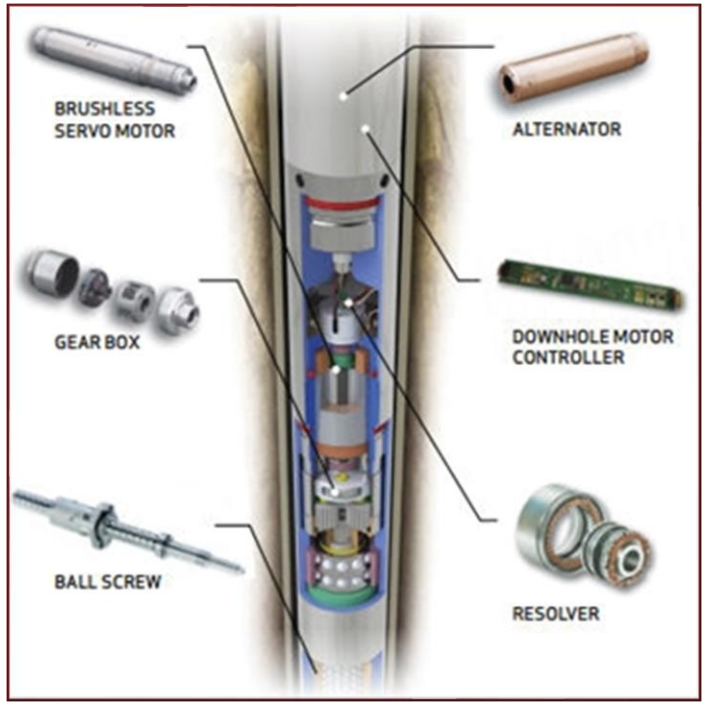
2016
Creation of subsidiary
WATT & WELL USA INC.

2017
New Production Facility
Aix-en-Provence

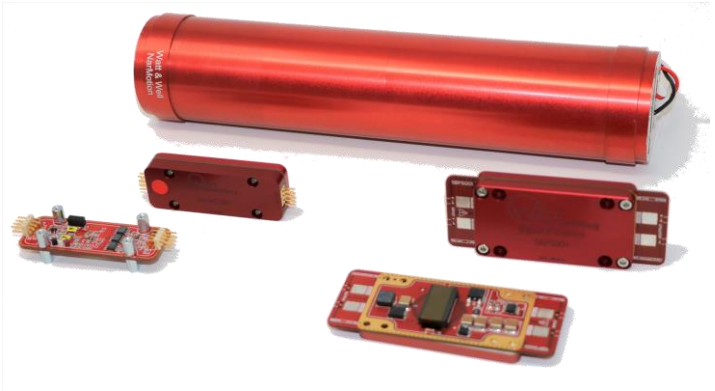
2019
EN 9100

O&G - OVERVIEW

- **Present in that business for 20 years:**
  - 10 at Schlumberger
  - 11 at Watt & Well
- **Our primary expertise in the O&G:**
  - Downhole electronics and firmware
- **Working for O&G service companies: leaders and start-up**
  - More than 1000 downhole equipment in the field so far (motor controller and power supplies).
  - Subsidiary set in Houston with the primary focus to supporting our O&G Customers.



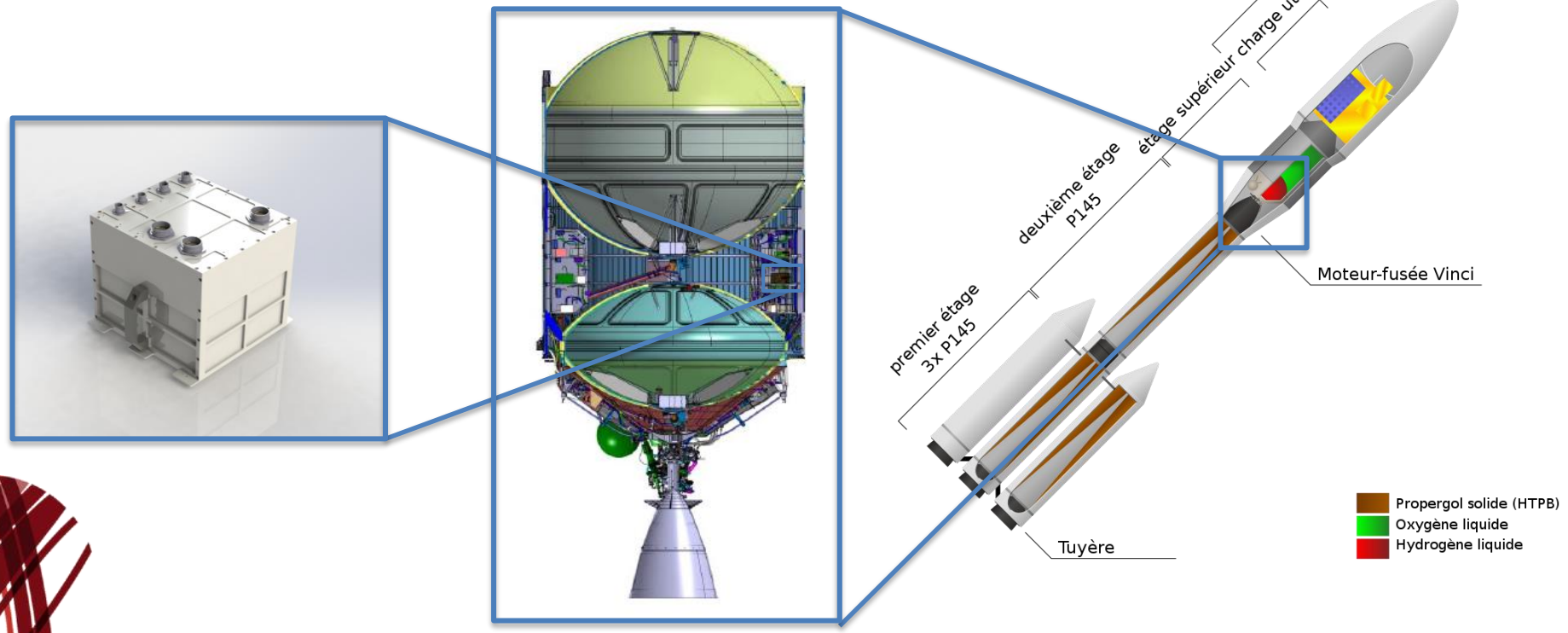
At 35,000 ft deep expect over:
- 400 °F degrees
- High pressure and shock levels

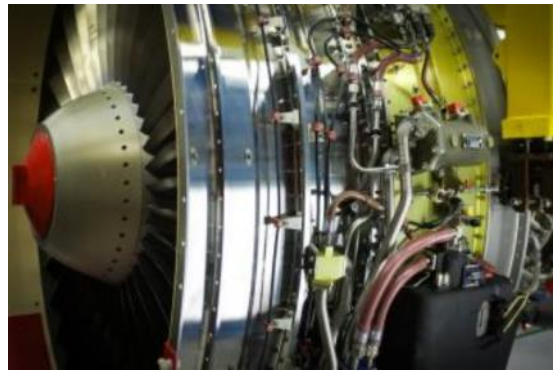


Nar products catalog:

AEROSPACE PROJECTS PORTFOLIO

Ariane 6
Fail Operational Motor Controller





Safran
More Electrical Aircraft
Auxiliary Motor Controller

Stratobus
Motor Controller

e-MOBILITY PORFTOLIO

Product range:

BMPU-R2-500-35-FXX
11 kW Bidirectional Modular Power Unit

MPU-R3-500-63-XX
25 kW Modular Power Unit for EVSE

DIS-R3-450-400
100 kW Development Inverter Stack

DIS-R3-750-D20
2×10 kW Dual Inverter Stack

EV Interface
Combo and CHAdeMO EV communication

Engineering services:

ANALOG DEVICES

RENAULT NISSAN MITSUBISHI

4 generations of chargers

Gen 1
2011 - 2015

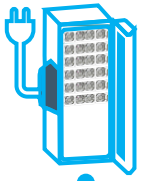
IGBT based
Single phase 16A and 32A

Renault (OBC)

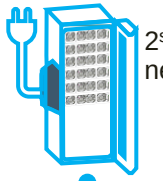
Gen 2
2016

SiC based
3Φ, 25 kW Modular
For fast and ultrafast EVSE

MPU-R3 25kW



1st large scale mfr:
feed-back & improvements



2st large scale mfr:
new functionalities & high-reliability

V1G
UNIDIRECTIONAL

V2G
BIDIRECTIONAL

EV Interface 1.0

EV Interface Next Gen

Vedecom (reversible charger)

BMPU-R3 11kW

Gen 2.5
2017

SiC based & bidirectional
3Φ, 11 kW
Target: V2G, V1G

Renault
(Zoé V2G fleet)

Gen 3
BMPU-R2 11kW

2021
SiC based & bidirectional
4 phases: 3Φ 16A and 1Φ 32A
Target: V2X (V2G, V2L, V2H, V2V)

e-MOBILITY PORFTOLIO

MPU-R3 25kW

- Unidirectional power unit (V1G)
- Modular design
  - Highly scalable 25, 50, 100, 150+ kW
  - Multi-outlet support
  - N+1 redundancy
- SiC based
- Three phases (w. or w/o neutral)
- Target: fast and ultrafast EVSE

BMPU-R2 11kW

- Bidirectional power unit (V2G)
- 4 phases design: 3Φ 16A and 1Φ 32A
  - Active support of neutral
  - On-grid (current) and off-grid (voltage) operation
- Target:
  - V2X (V2G, V2L, V2H, V2V)
  - EVSE / Wallbox, ESS
- Scalable modular design

EV Interface

- Dual CHAdeMO and Combo communication(V1G & V2G)
- Open computing platform RPI CM3+ based (4 cores, 16 GB)
- Dual license approach
  - Pre-installed communication stacks CHAdeMO, Combo
    - Pay-as-you-go license
    - One-time-fee
  - Bring-your-own stack

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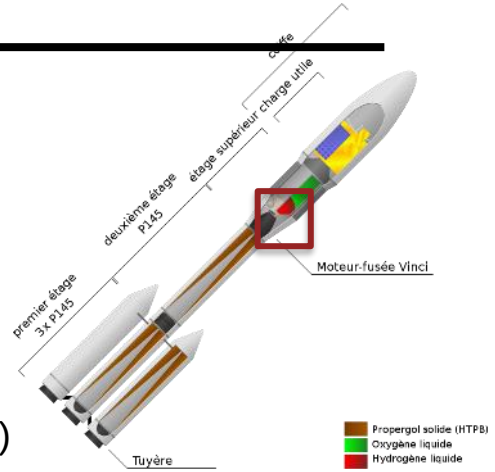
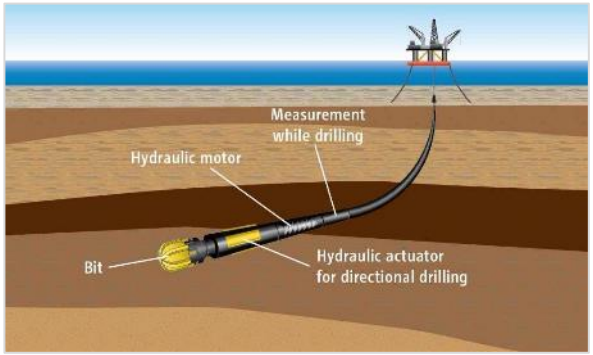
Multi-industry expertise

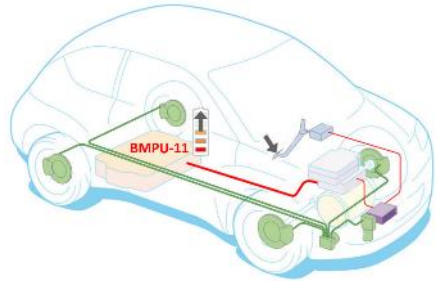
- Fault tolerant power topologies and hot-redundant systems
- RAMS (Reliability, Availability, Maintainability, Safety)
- EMI/EMC
- Radiation tolerant designs
- High reliability up to DAL-B (DO254 & ECSS), equivalent to ASIL-D (ISO 26262)



- Extreme temperatures from -40°C to 175°C with passive cooling
- New Technologies: SiC, GaN, Sol, Magnetics
- High shocks (up to 500g) & vibrations
- Lifetime tests (HALT) and thermal cycling



- Highly innovative topologies (resonant converters, boundary conduction mode)
- DFx (DFM, DFT, …)
- Normative compliance (ISO, IEC, UL,…)
- Up to 98% efficiency and high-power density



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5. Internships

Example 1 of E-Mobilty applications

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MPU-25: 25kW charger product

Overview

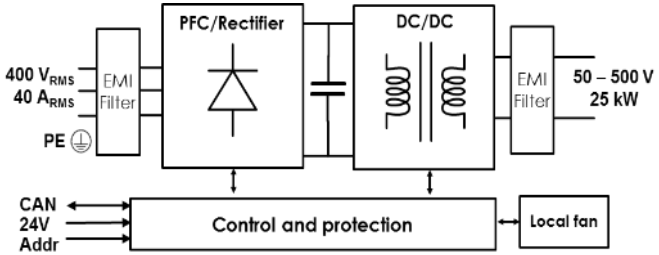
- Made for Fast Charger Applications
- Modular design et parallelizable (25 kW to 350 kW)
- MTBF : 7 years

SIMULINK Enabled

MathWorks Partner

Characteristics

- Input : 400V 3-phases AC, 50 Hz
- Output : 50-500V, 0-63A, 0-25kW
- High density: rack 19”, 3U
- Efficiency (95%)



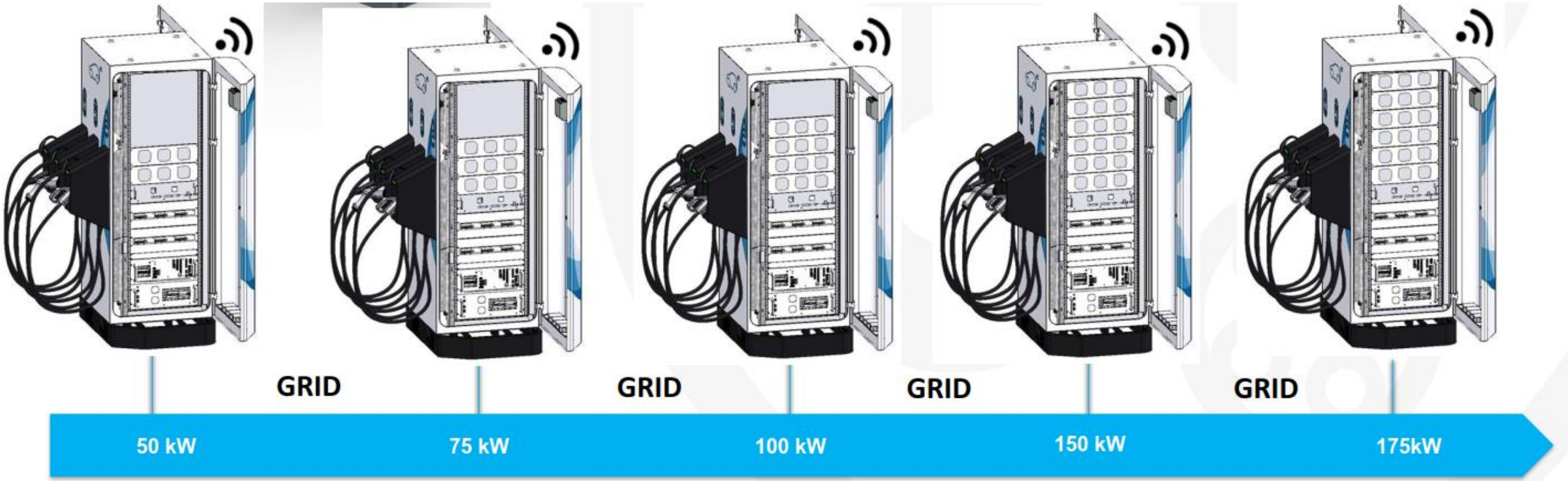
Compatibilities

- CE marking :
  - NF EN 61204-7
  - NF EN 61000-6-2
  - NF EN 61000-6-3
- Compatible with DC charher system (CHAdeMO, CCS)

20

Quick charger – Low power density

Quick charger – High power density



Example 2 of applications

BMPU 11 kW Bidirectional Modular Power Unit

Overview

- Designed for V2X charger systems
- High efficiency (up to 95%)

Features

- Input : 400V 3-phases AC, 50 Hz
- Output : 240–450V, ±40A, ±11kW
- 19” rack, 3U

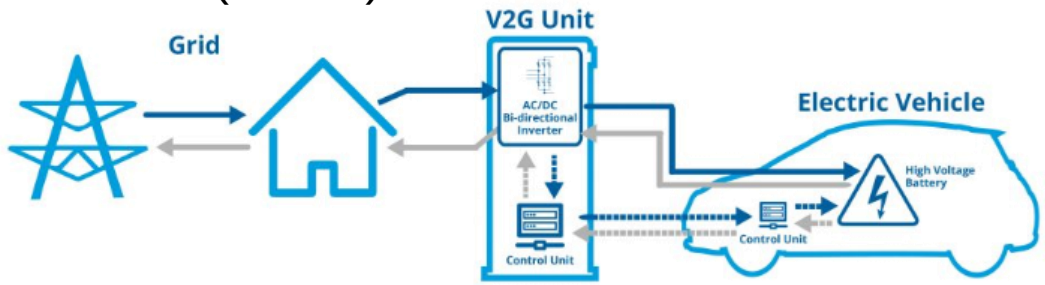
- Integrated protections including AC and DC pre-charge switches, OCP, OTP and UVLO
- Input/output reinforced galvanic isolation
- Forced air cooling with integrated fans
- Integrated output fuse
- Advanced monitoring & logging capabilities via CANopen bus

Compatibility

ISO 11452-4	Immunity to bulk current injection (BCI)
IEC 61000-4-11	Voltage dips, shorts, swell
IEC 61000-4-13	Immunity to AC power harmonic level 3
IEC 61000-4-28	Immunity to frequency variations
IEC 61000-3-2	Measurement of harmonic emission
ISO 16750-2	Immunity to transients and power variation

Vehicle to X Applications

- V2G : Vehicle to Grid : battery energy is used to “help” the grid
  - Balance production and demand mismatch due to renewable energy
    - Special interest to stabilize a weak grids (ie islanded network).
  - Trading of energy
- V2L : Vehicle to Load : battery energy is used to create a local grid
  - Enable to power AC electric tools
  - V2G charger used as a voltage source
- V2H : Vehicle to Home
  - Enable to smooth home energy consumption (cf V2G)
  - Enable to have home autonomy in case of grid failure (cf V2L)



Credits : https://www.automobile-propre.com/

V2G application

- Renault as first customer
  - 20 converters to be deployed in test fleets to work on V2G use cases
  - 10 countries in the world
  - Start with Porto Santo island (Portugal)

Credits: Renault Communication

BMPU 11KW Bidirectional Modular Power Unit

Example 3 of applications

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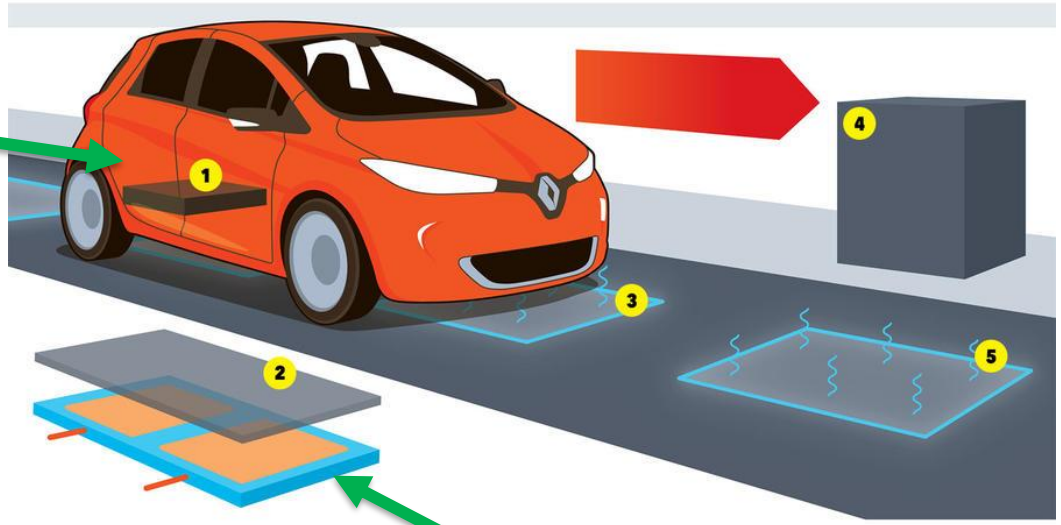
On road wireless charger



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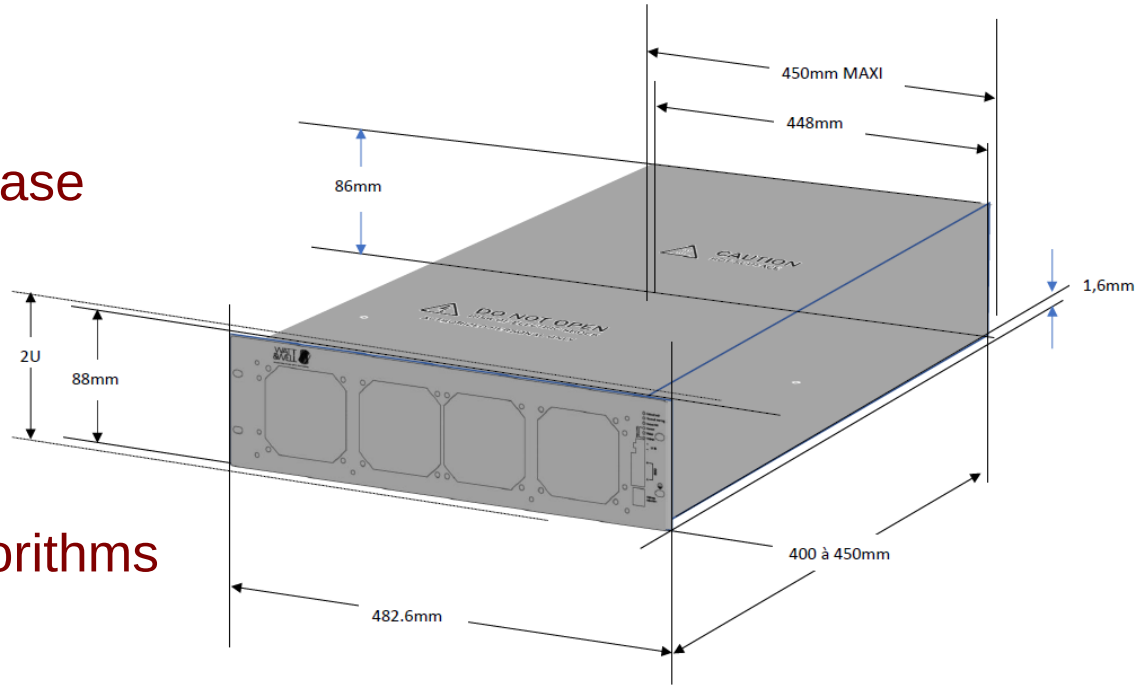
High Density Power Unit

- New generation of Bidirectional chargers : higher power density to decrease size and weight
- Optimized magnetics and power legs to decrease power losses
- Decentralized control architecture
- Development of high-performance control algorithms



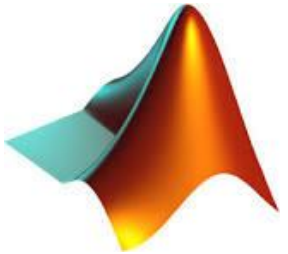
Technical challenges -Time to market

- Need to go from conception to real world **very quickly** (<6 months per iteration)

- Hardware design
  - Re-use of existing technology bricks when possible
  - Modular design

- Software/Control design
  - Control algorithms to be design for a wide range of converter topologies
  - Mutualization of Code Generation model with Simulation model
  - GUI to be configured automatically during code generation process

How do MATLAB/Simulink help solve technical challenges ?



- Control algorithms are pre-designed and validated thanks to Simulink Power System
- Code Generation is used directly from Simulation model
- Design iteration can be easily done by going back to Simulation and next generate the code again.
- GUI is configured automatically during code generation process via MATLAB scripts and customized signal and parameter classes .

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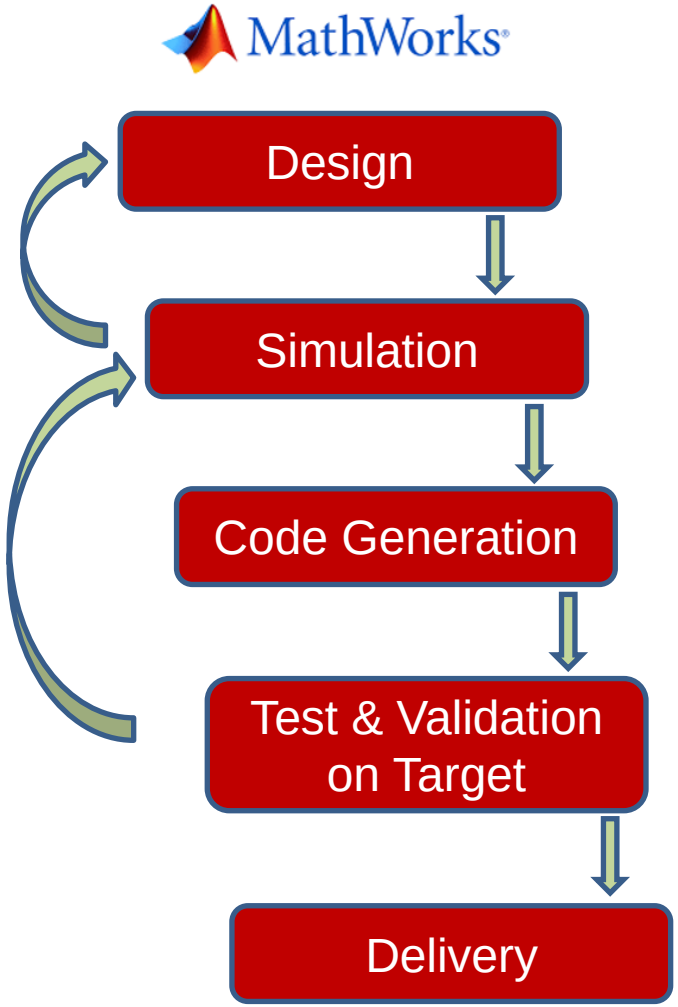
Automatic code generation

- Watt&Well uses two Model-Based Design processes to generate C Code source files or C Code projects with different levels of automation,
  - Basic code generation process
    - Example : Atmel SAMD21
  - Advanced code generation process (fully automated)
    - Example : Texas Instruments TMS320F28xxx



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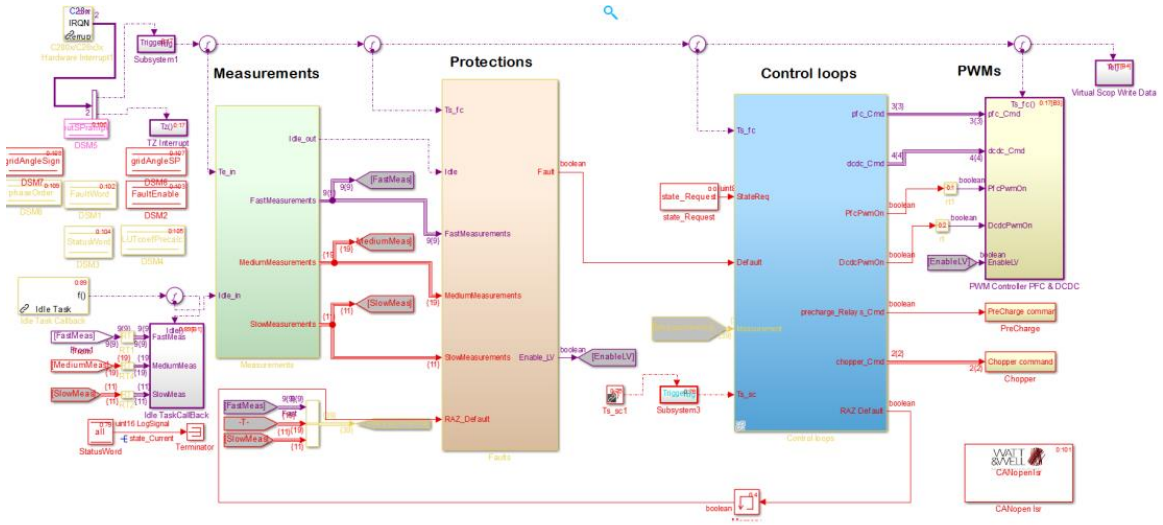
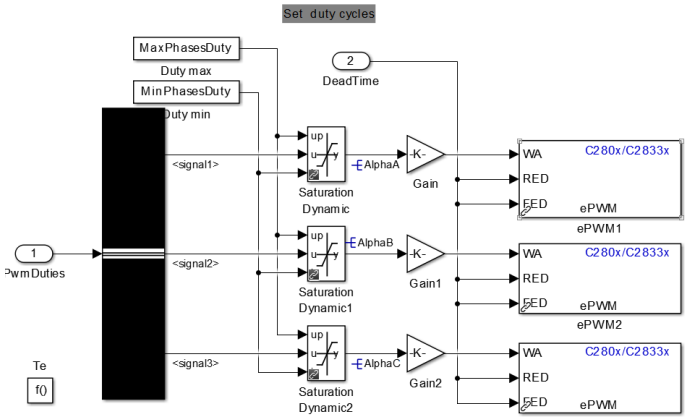
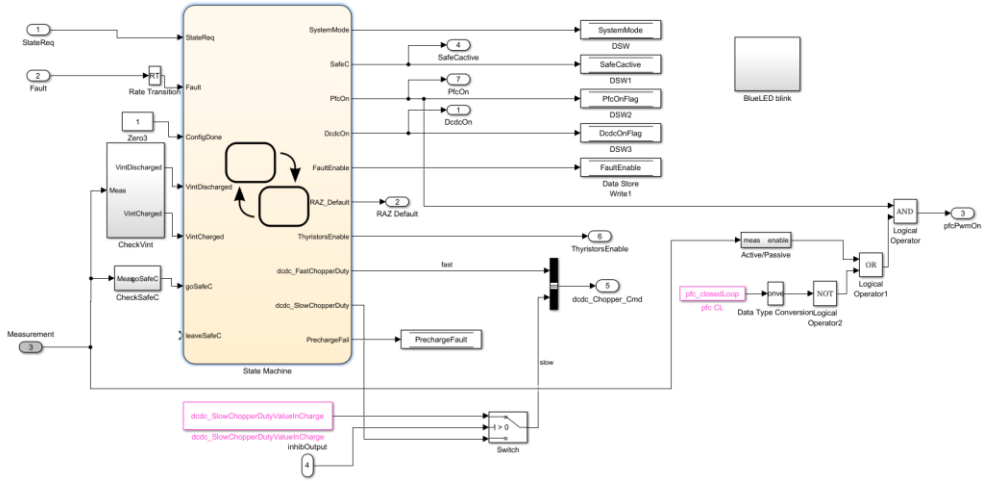
Design phase

- Physical Modeling
- Control architecture and parameters
- Simulation
- State machine and task scheduling definition (State flow)
- Signals mapping to target (DSP, µC…)
- I/O Signals conditioning





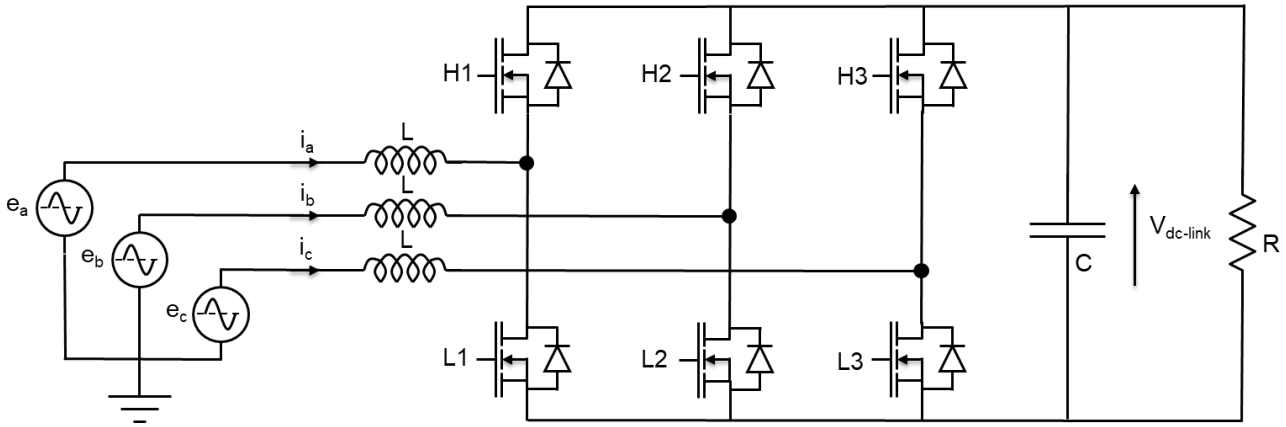


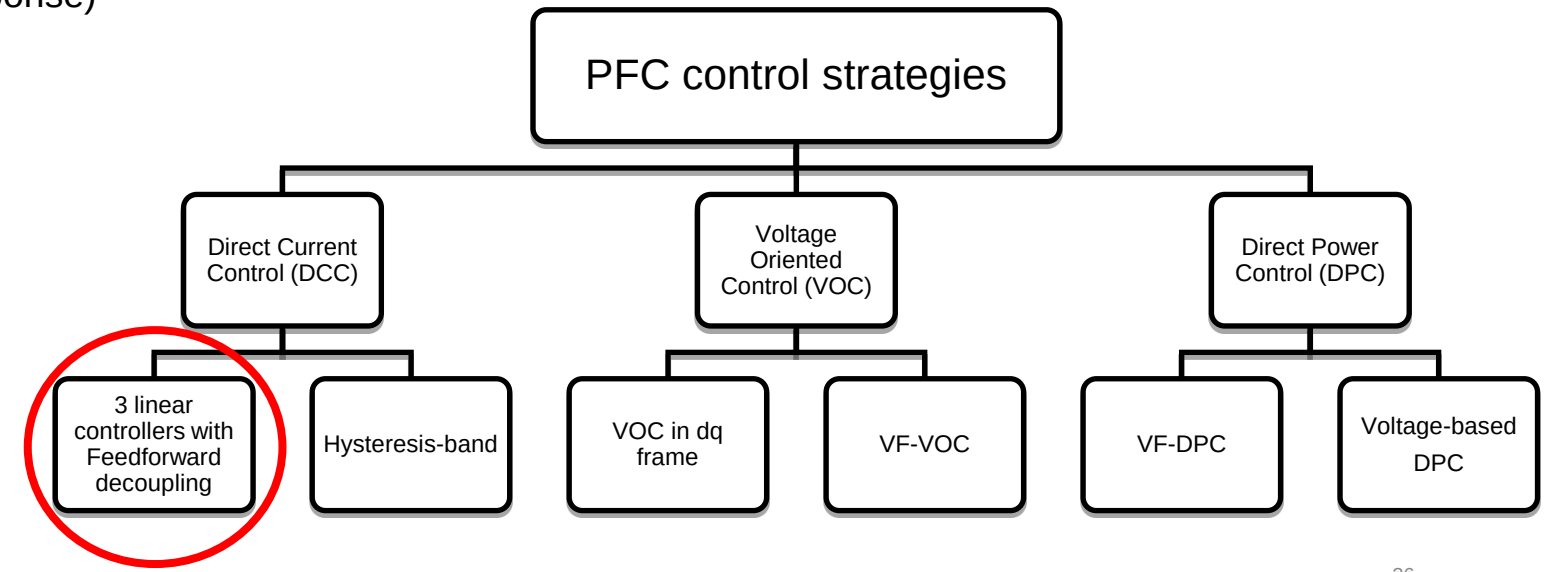
Control design example

- PFC : Power Factor corrector → AC/DC converter (rectifier/inverter)

- Topology and Control objectives

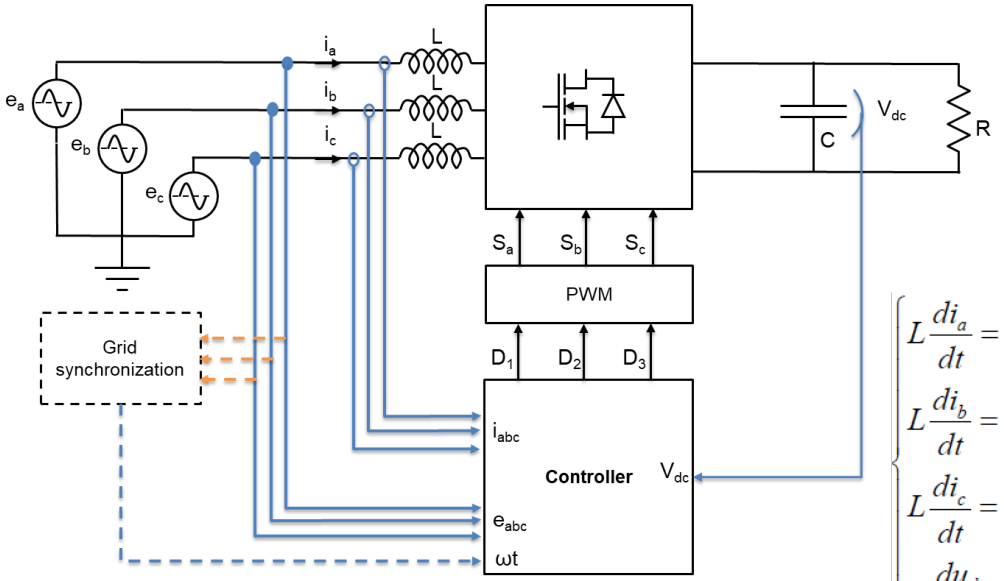
  - Constant dc-link voltage
  - Sinusoidal phase currents (high dynamic response)
  - Controllable power factor
  - Constant switching frequency
  - Reduced ripple
  - Reduced harmonic content



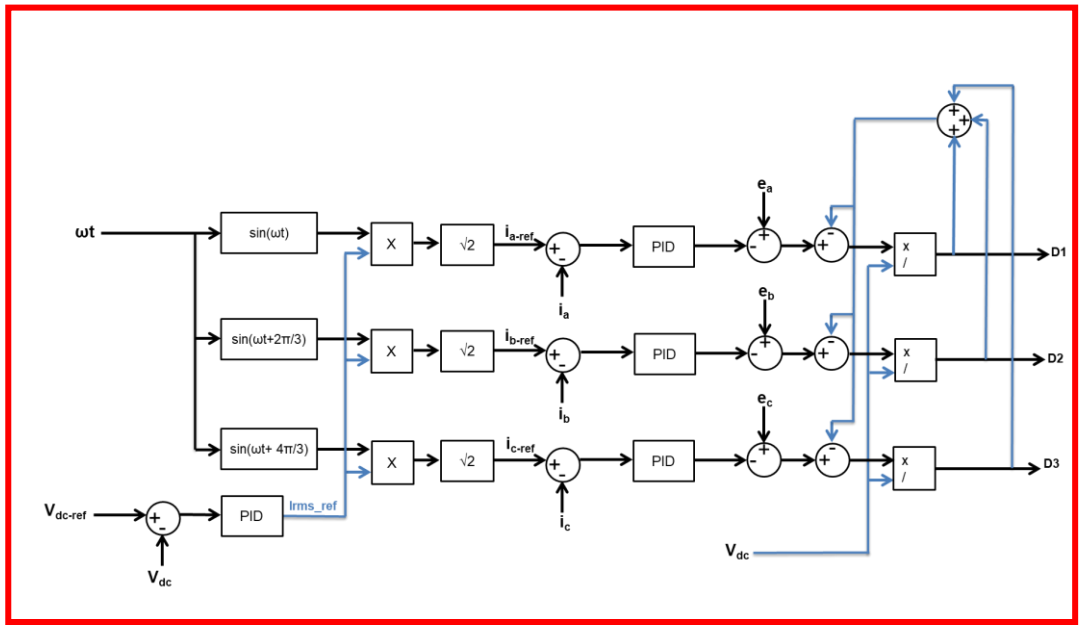


Control design example

- Control strategy based on linearizing controller



$$
\begin{cases}
L\dfrac{di_a}{dt} = e_a - \dfrac{u_{dc}}{3}(2d_a - d_b - d_c) \\
L\dfrac{di_b}{dt} = e_b - \dfrac{u_{dc}}{3}(2d_b - d_a - d_c) \\
L\dfrac{di_c}{dt} = e_c - \dfrac{u_{dc}}{3}(2d_c - d_a - d_b) \\
C\dfrac{du_{dc}}{dt} = (i_a d_a + i_b d_b + i_c d_c) - \dfrac{u_{dc}}{R}
\end{cases}
$$



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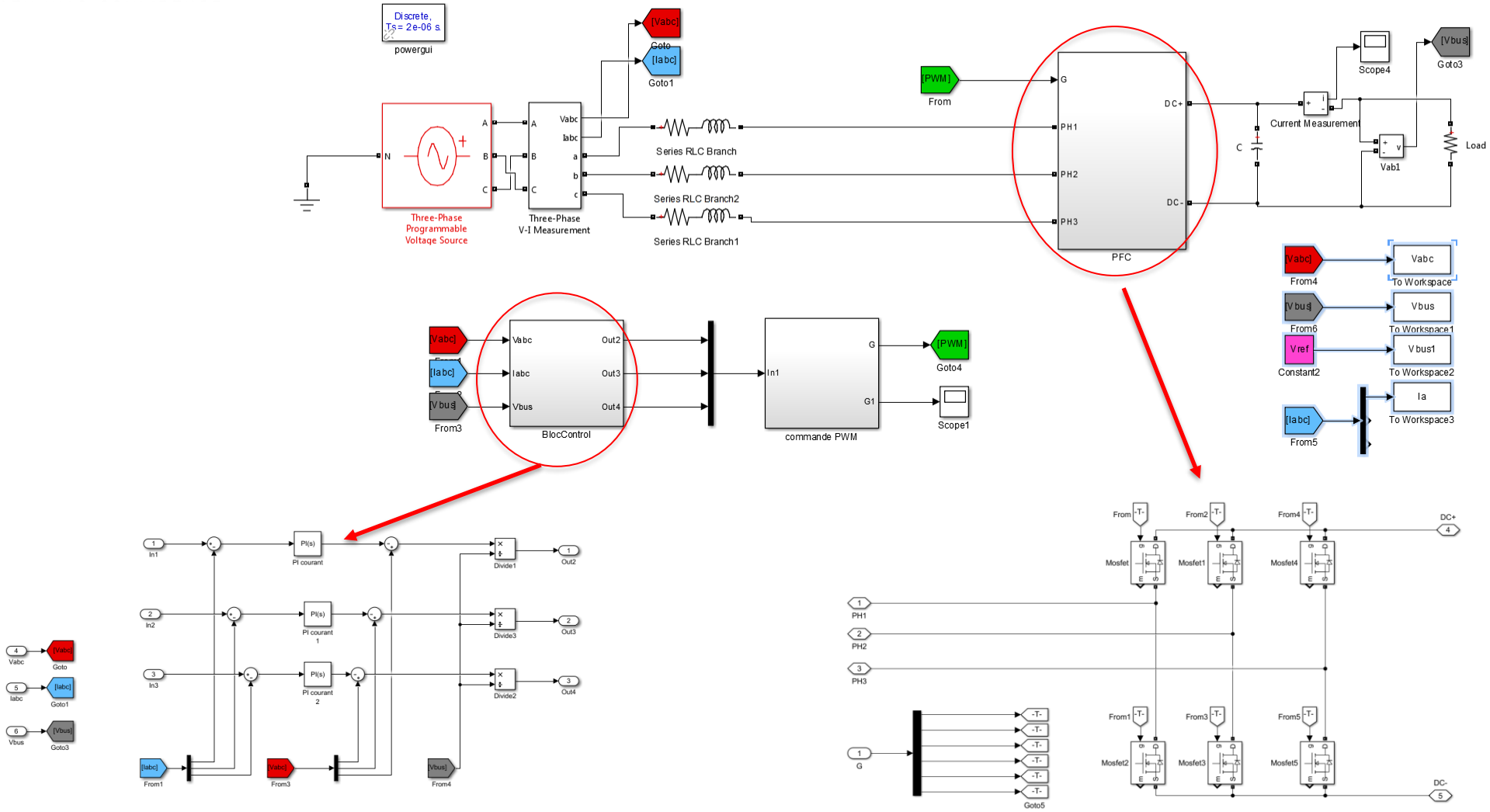
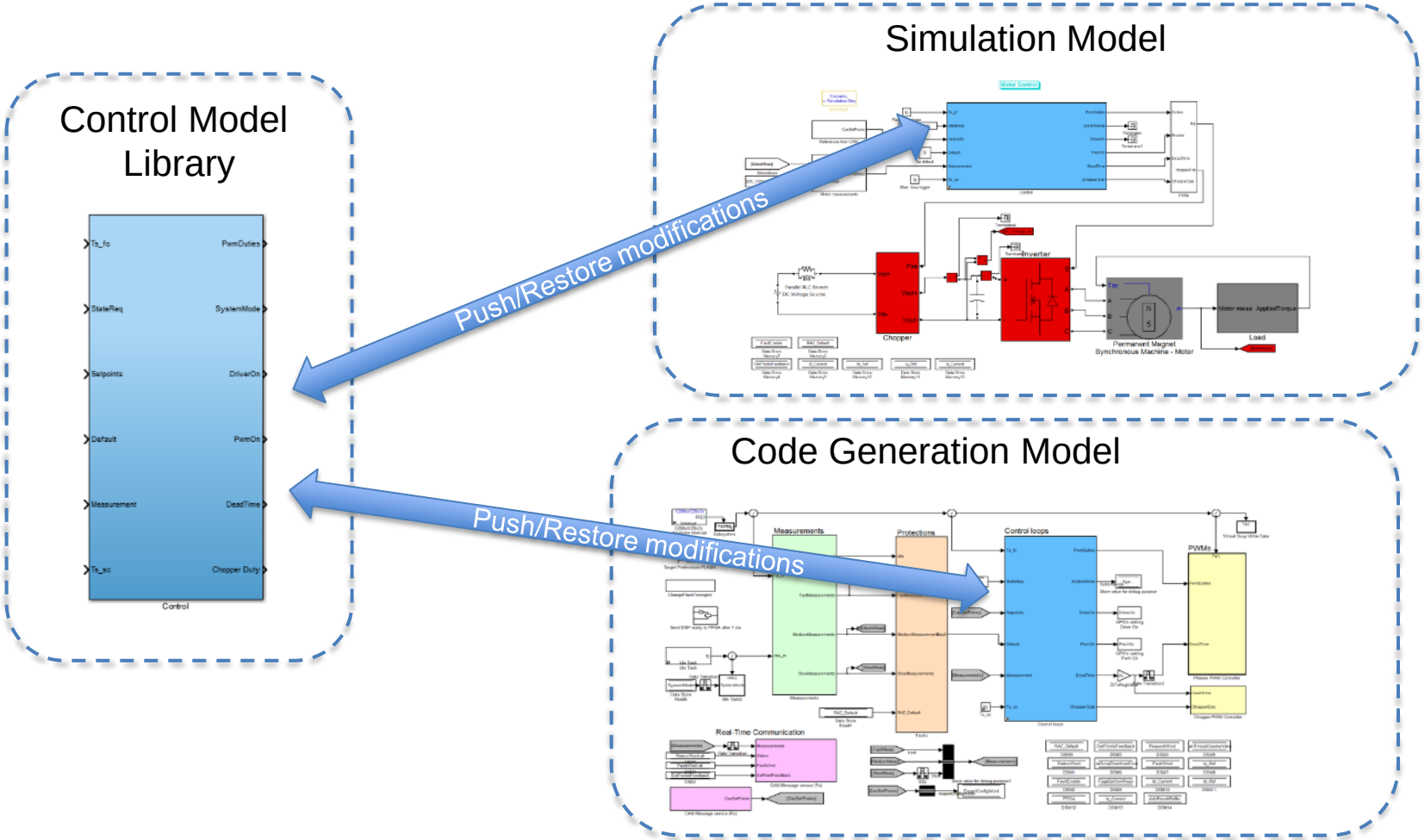
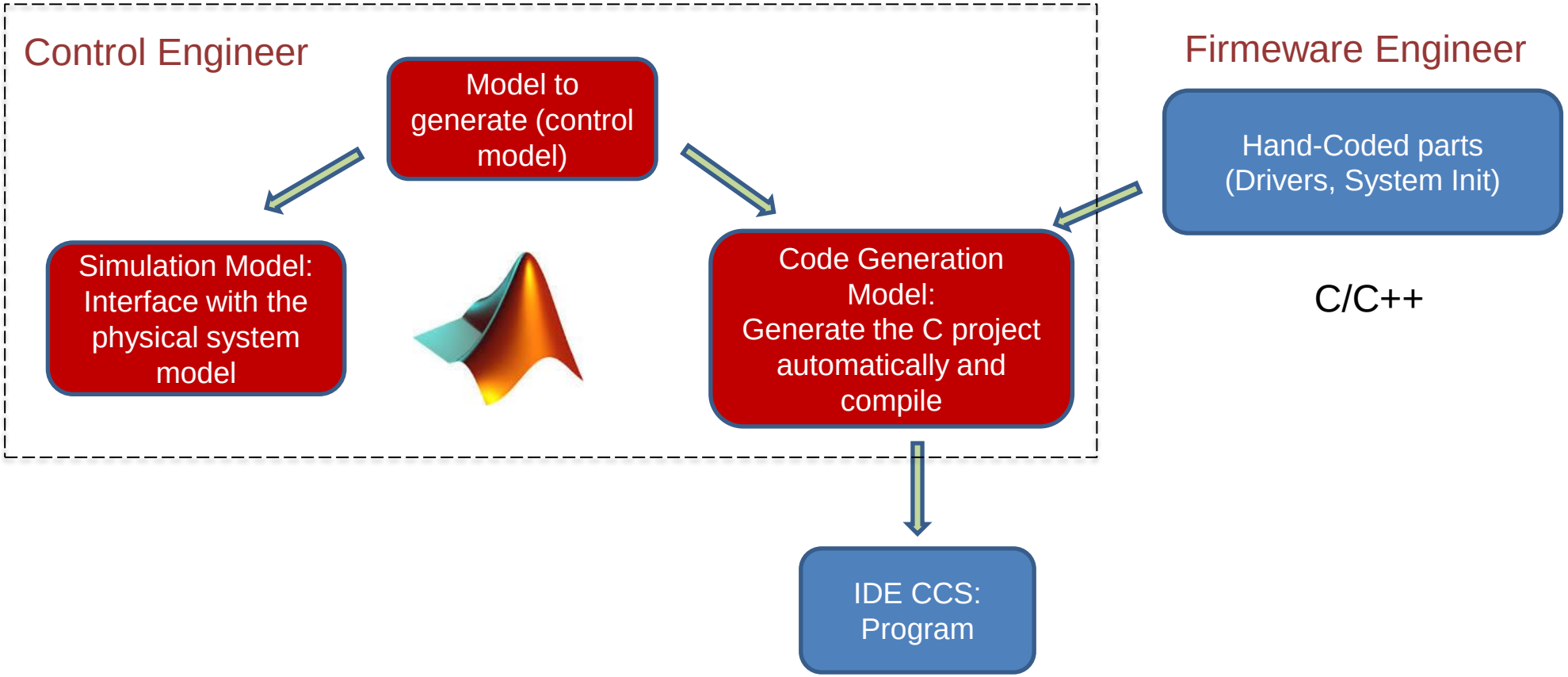
Control design example



code generation process



Code generation process



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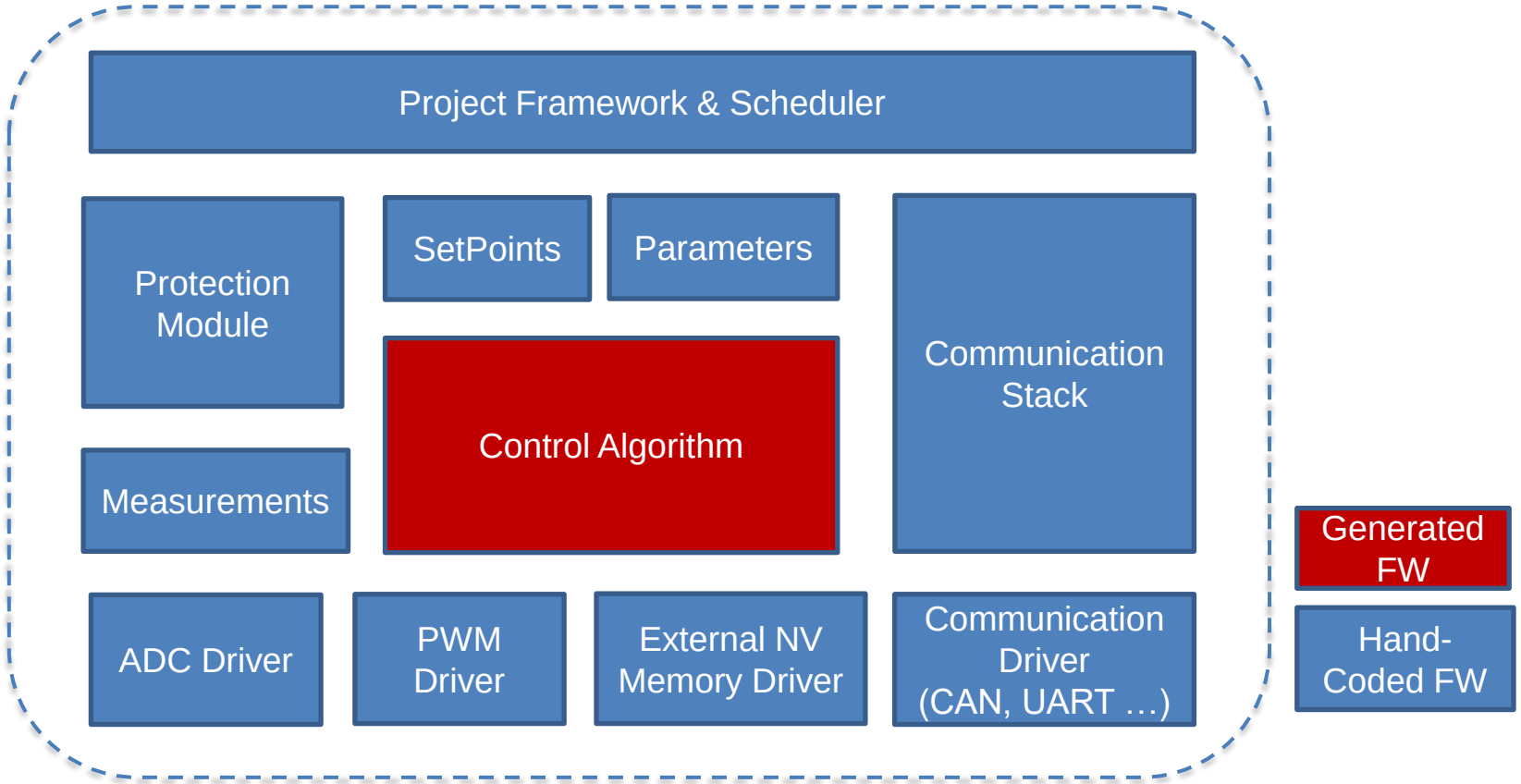
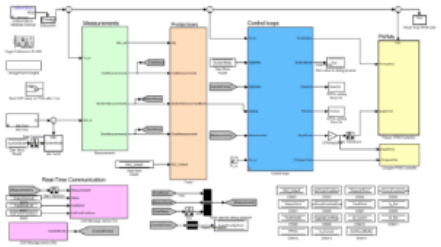
code generation process



Real-Time Test phase



Simulink model

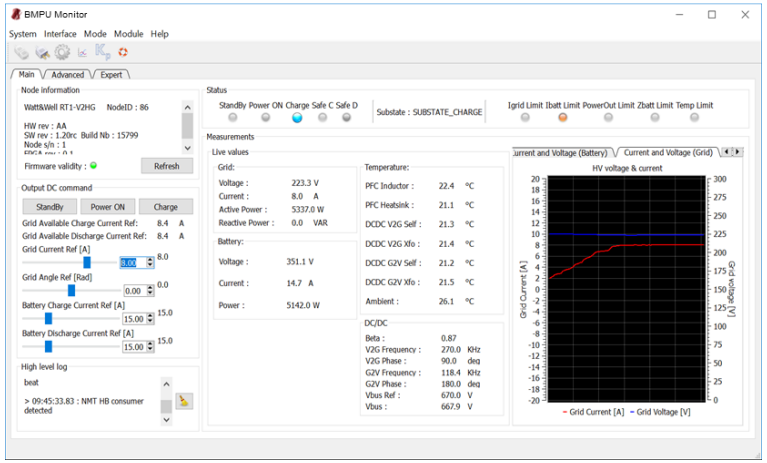
Generate & program

DataDefinition.Xml

Configure

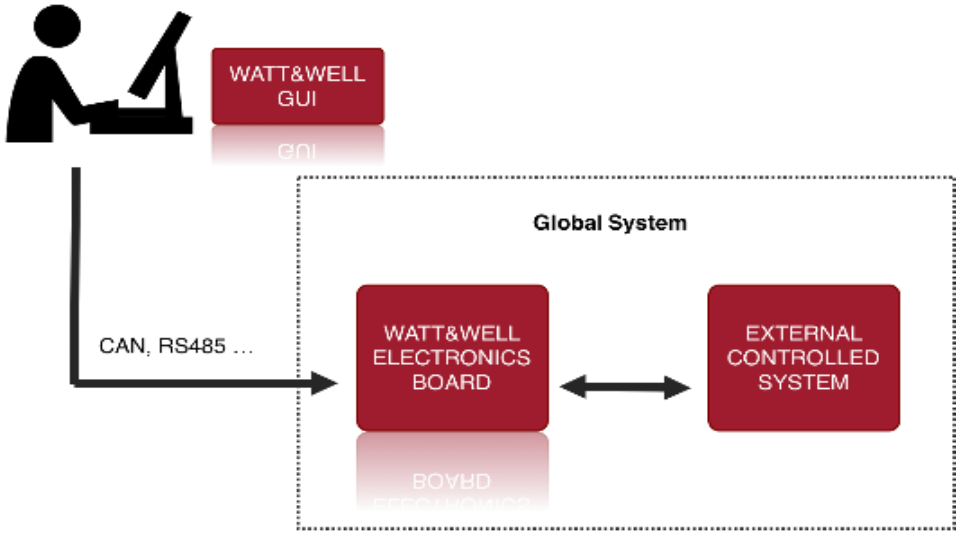
An Object Dictionary is generated to allow system parameters and signals access.

W&W GUI



The RT Monitoring Tools provide the ability to:

- Configure the system: set parameters
- Control the system: send commands and setpoints
- Diagnostic the system: get feedbacks and measurements



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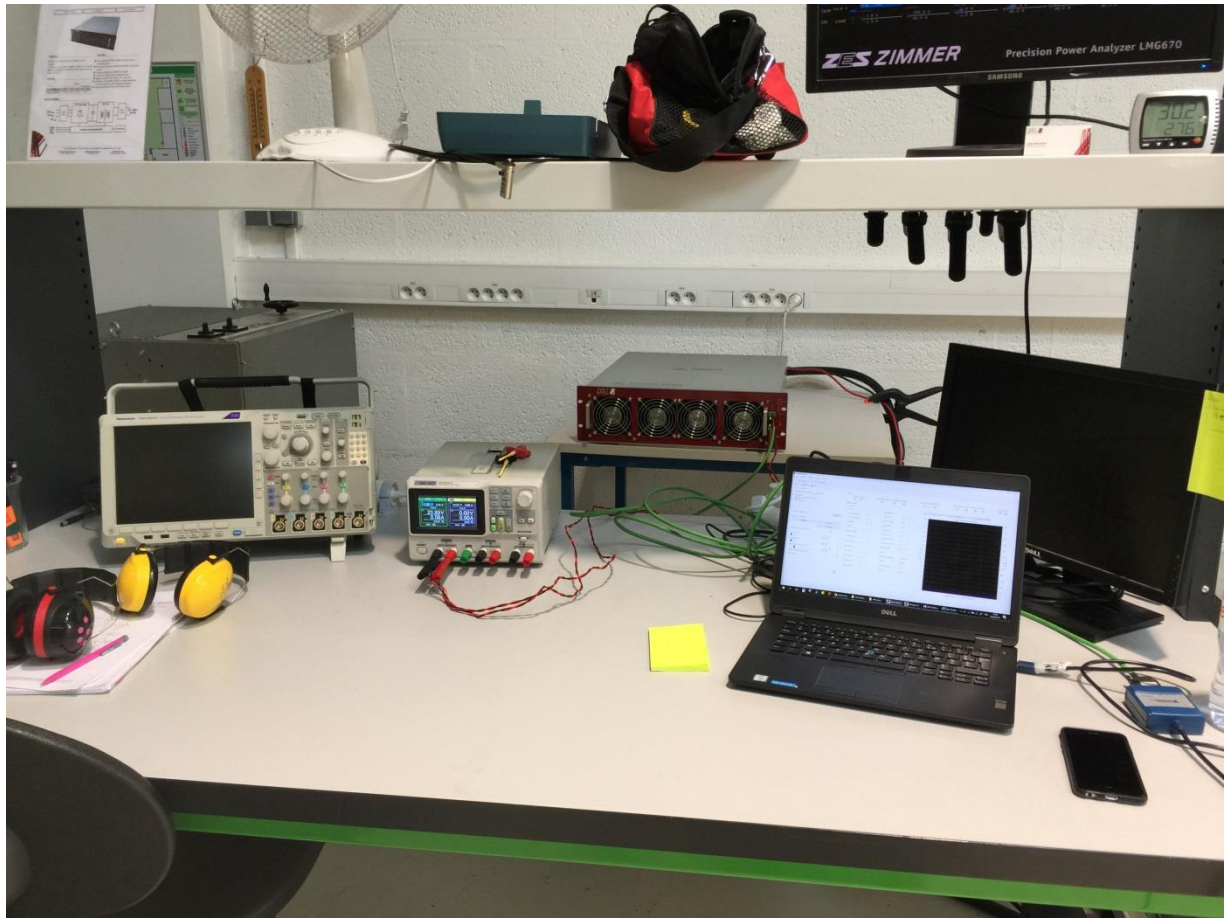
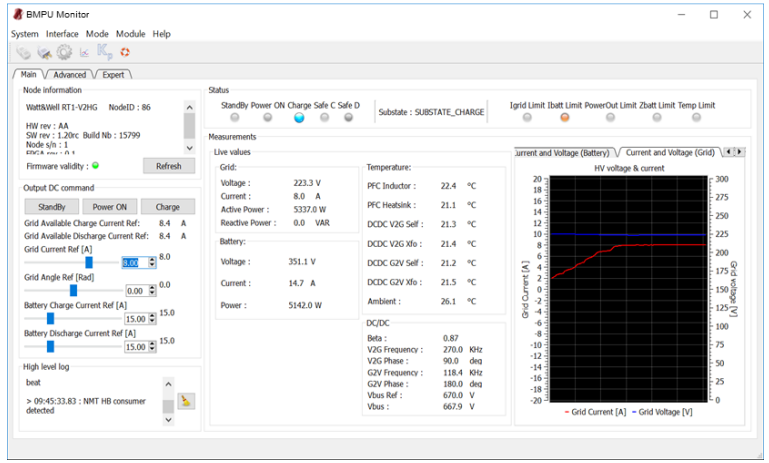
Real-Time Test phase





control interface

Bidirectionnal load

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