V2G Forum - TRACK A

What is an OBC and How Would it be Different in V2X OBC?

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DIAMOND & ZEBRA ELECTRIC

DIAMOND ELECTRIC HOLDINGS

Establish	2018, October	Capital	JPY 1236 Million
HQ	Osaka, Japan	CEO	YuuRi ONO
Net Sales	JPY 91 Billion (FY20)	Employee	4,091

Diamond and Zebra Electric
Develops and manufacturers automotive electronics, stationary inverters, coil products, and PCBs for home electronics

Diamond Electric
Develops and manufacturers ignition coils

Diamond Craft
Designs the casts and molds plastics

Automotive

【Ignition Coil】 【On Board Charger】

Home Electronics

【Inverter Unit】 【Transformer】 【Reactor】

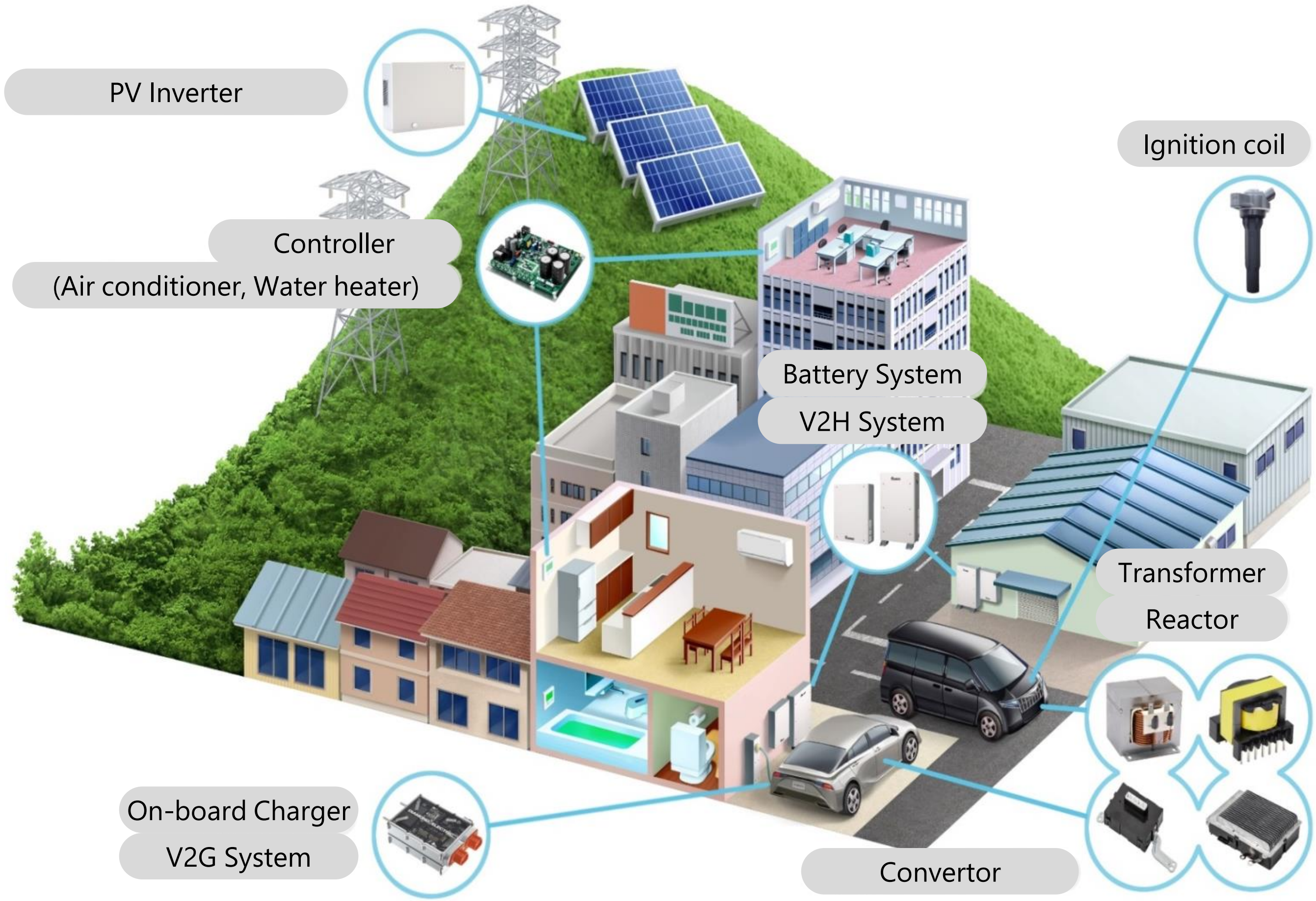
Energy Solution

【PV Inverter 】 【 Energy storage system】

ZEBRA (Tabuchi Electric) brand

DIAMOND & ZEBRA ELECTRIC

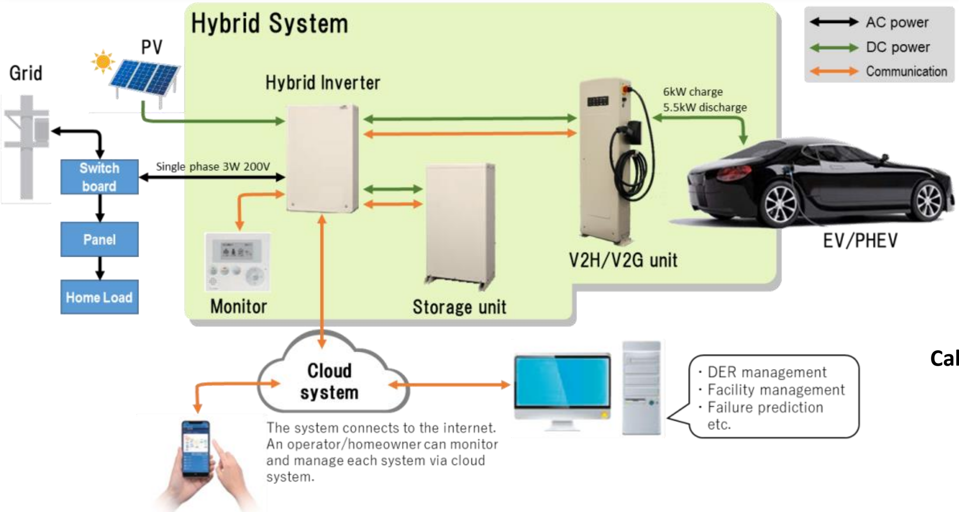
Corporate Vision: Connecting Automobiles and Homes with our MONOZUKURI



In today's world, where efforts to address issues such as global warming is being considered on a global scale, the technologies of automobiles and electronic devices are shifting in order to create a more sustainable world.
Our company provides the technologies necessary for a world, where various products are connected in pursuit of efficiency, thereby reducing the burden on the global environment and improving everyone's lives.

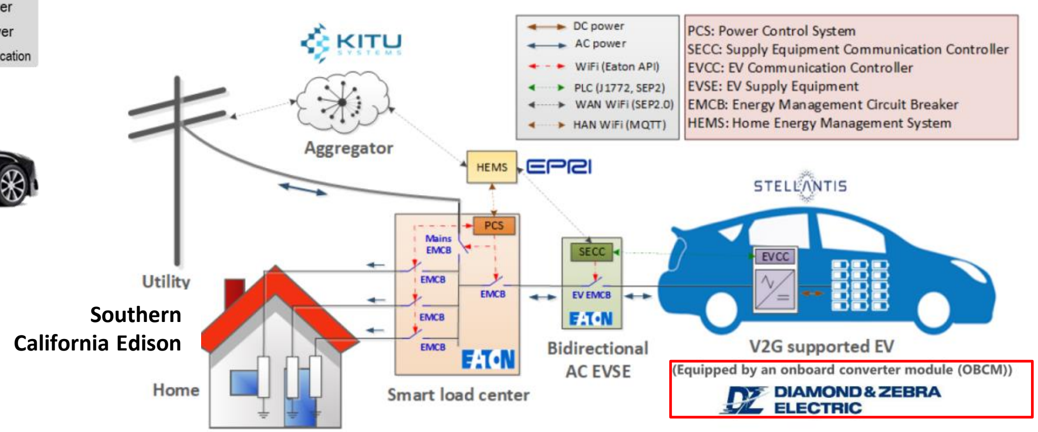
V2G Activities

Stationary



Output voltage	DC150 to 450 V
Power	+/- 6.0 kW
Standard	CHAdeMO V2H DC EVPS-002: 2018 v2.1.1
Dimension	W445 x H1450 x D198 mm
Weight	60 kg
Ambient temperature	-20 to 45 deg.C

Automotive



Nominal voltage	AC240 V
DC voltage	150 to 450 V
Power	+/- 7.2 kVA (at 240 V)
Standard	SAE J1772, IEEE 1547-2018 (Cat. B & III), SAE J3072
Dimension	426 x 261 x H55 mm
Efficiency	96.3% at maximum

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Charging – AC vs. DC

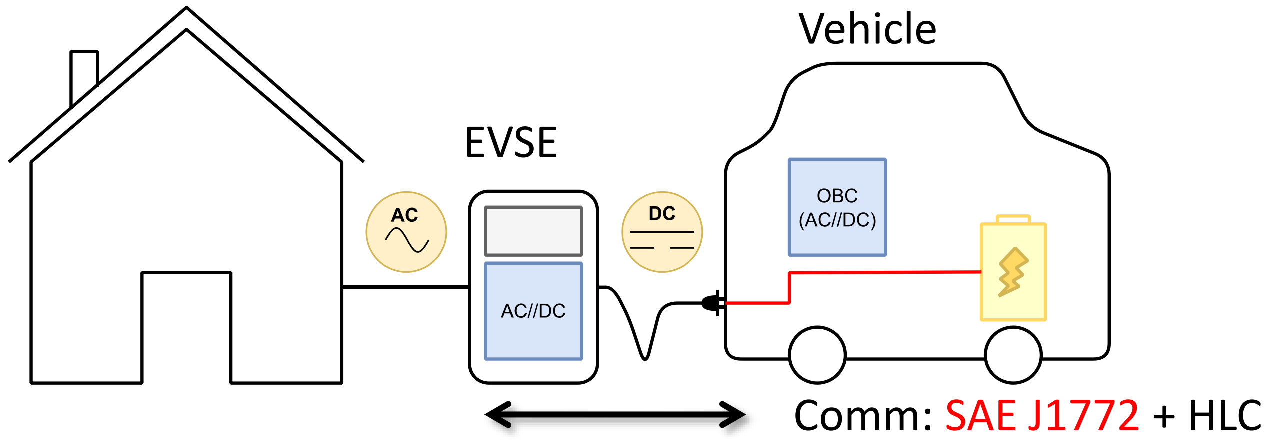
The heart of a charger is AC//DC converter and if it is in the vehicle, it is called as an OBC.

DC Charging

Use case
Highway, community

AC//DC
Offboard (EVSE)

Power
Few kW to MW

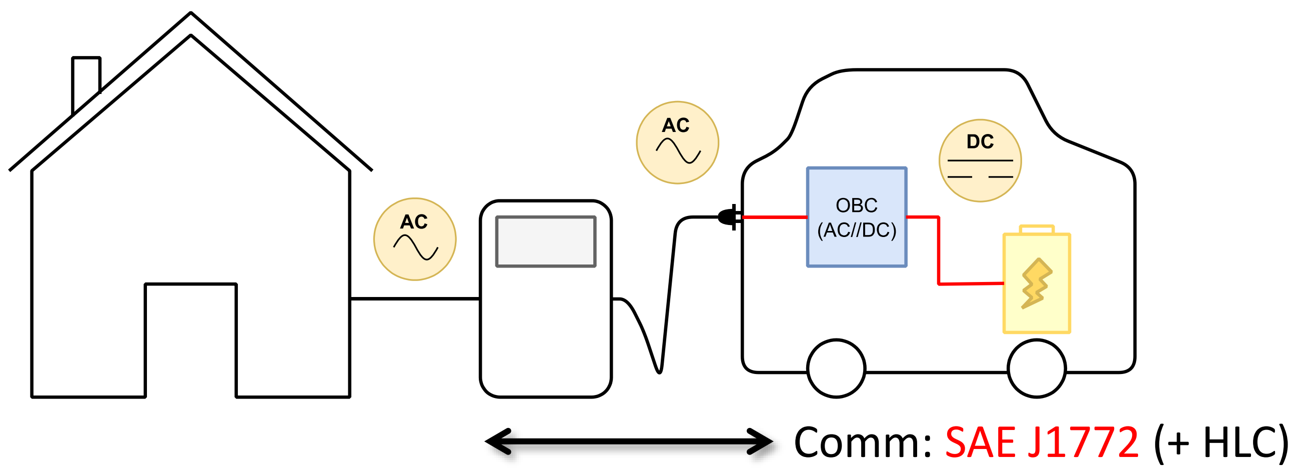


AC Charging

Use case
Residential, workplace

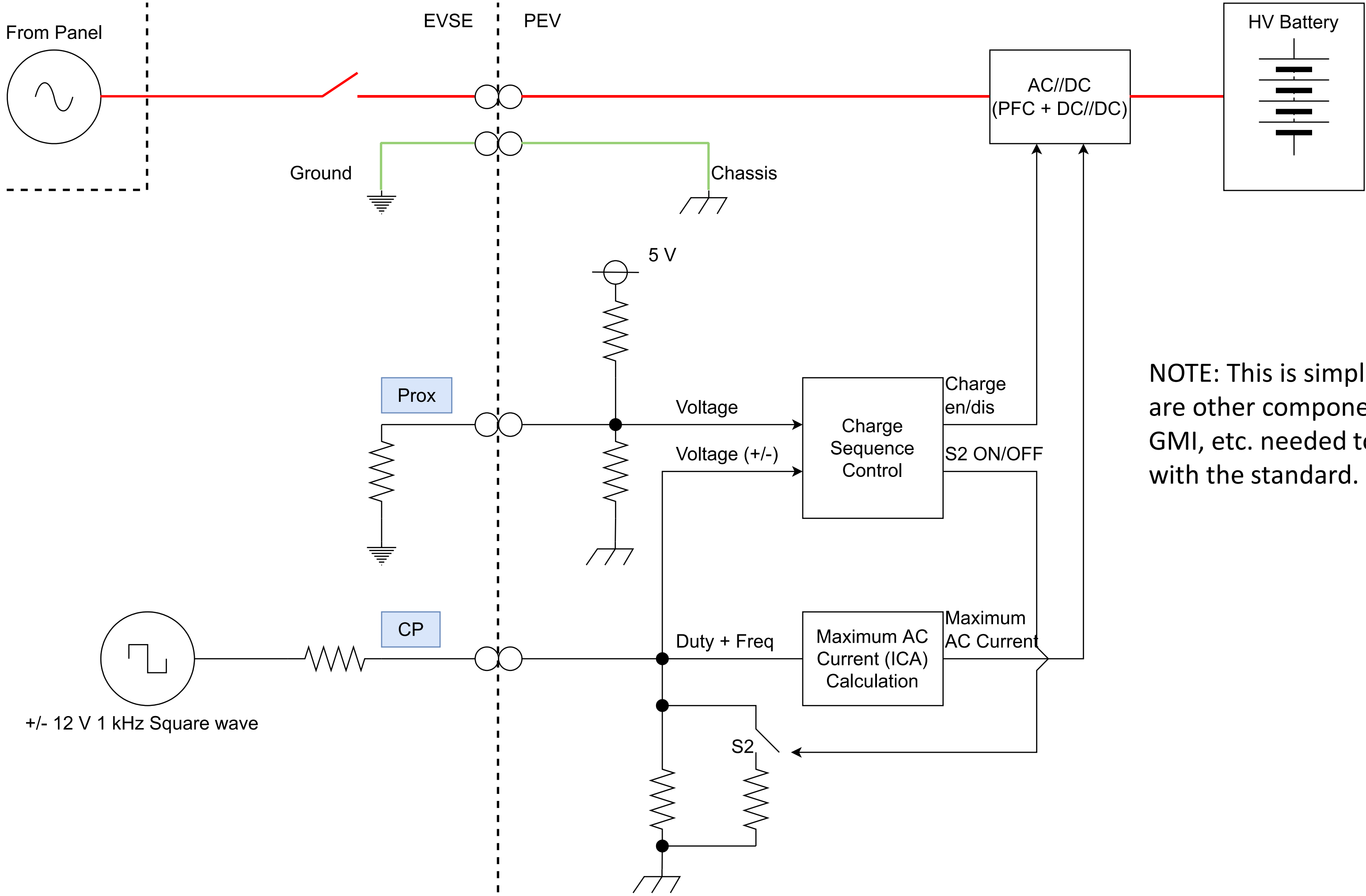
AC//DC
OBC (Vehicle)

Power
Up to 19.2 kW



NOTE: Use case is based on NREL's "2030 National Charging Network Fact Sheet"
https://www.nrel.gov/news/program/2023/building-the-2030-national-charging-network.html

AC Charging – What is a SAE J1772 I/F?

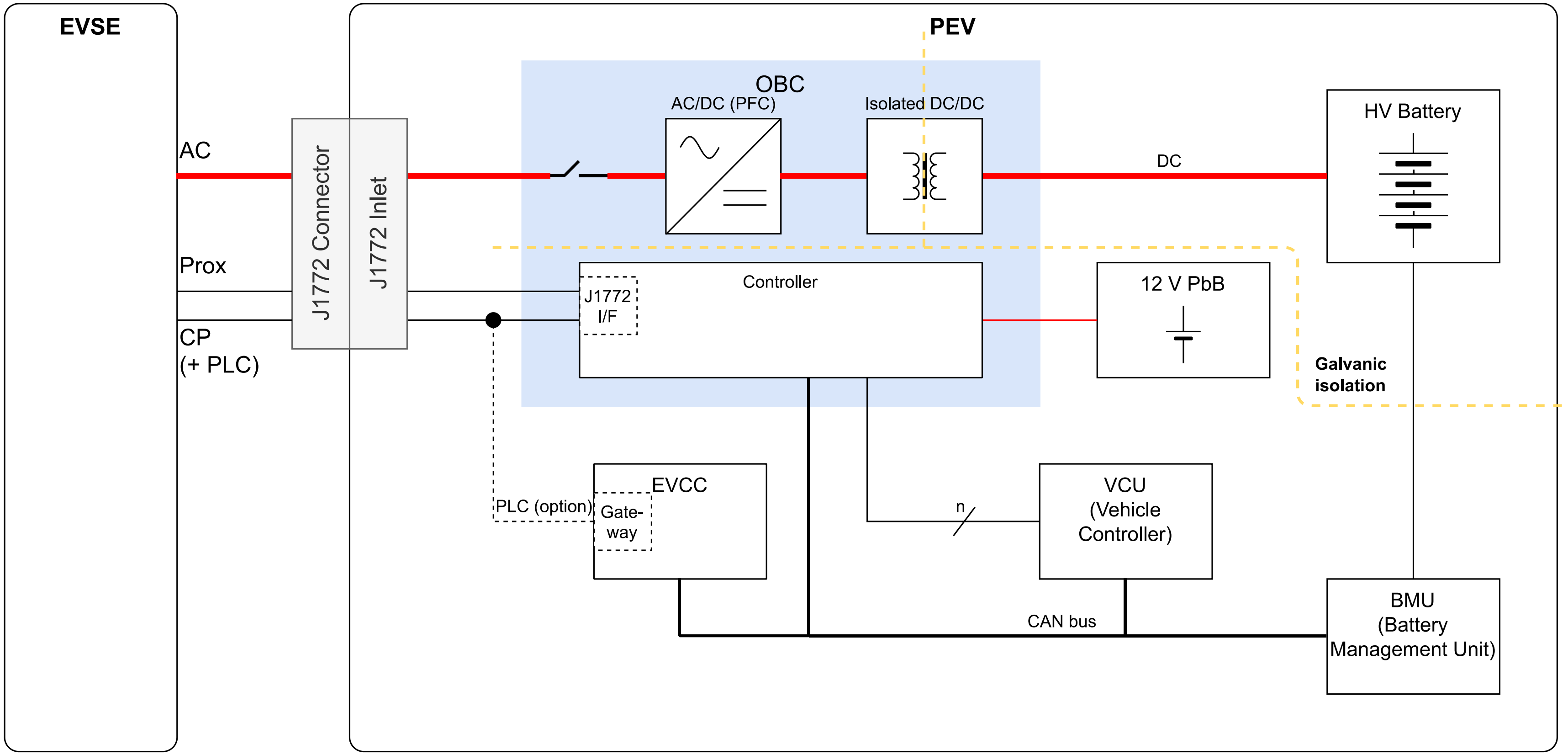


NOTE: This is simplified. There are other components, switches, GMI, etc. needed to comply with the standard.

Prox provides the connection status.

CP provides the readiness (status) of EVSE and EV for a charging session and the maximum AC current that the EV is allowed to draw.

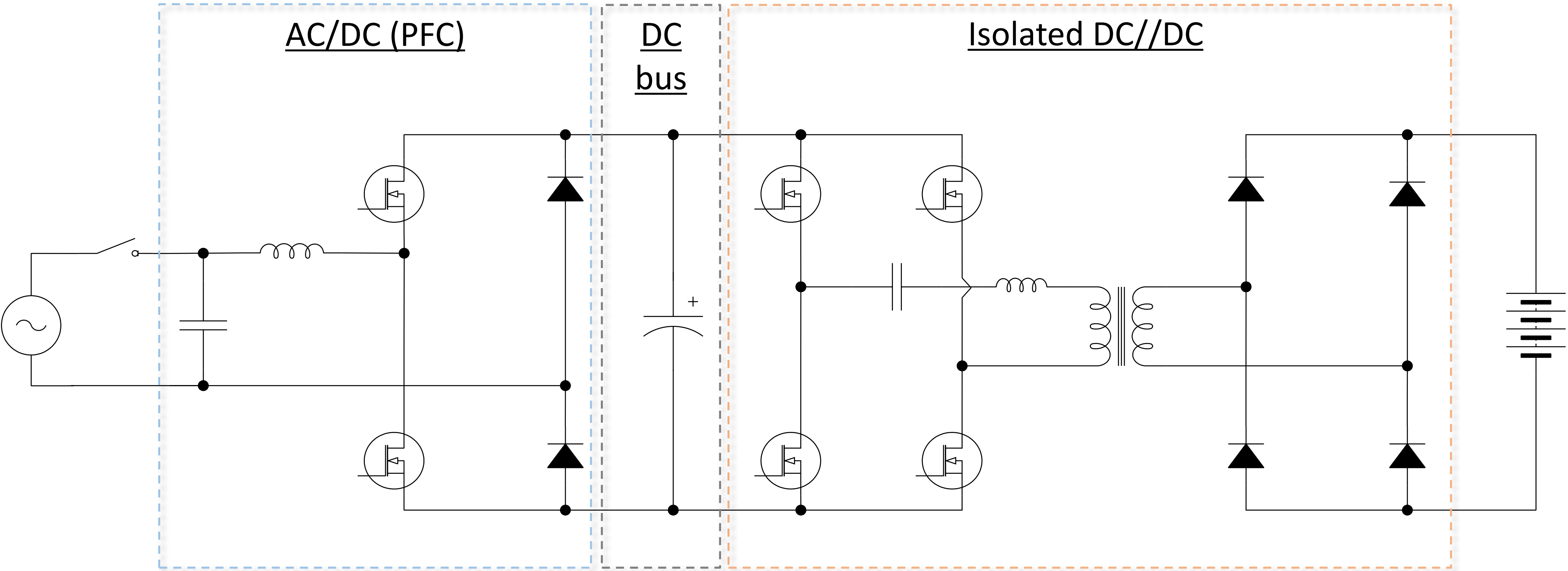
AC Charging – OBC's Role



An OBC;

- Converts AC power to DC power with a galvanic **isolation** at DC//DC converter (practically).
- Receives the vehicle and CP info and executes **CV/CC** operation and maintains high PF.
- Processes **Prox** and **CP** signals and handshakes with the EVSE to manage the charging session.
- May contain EVCC functions, e.g. PLC comm, additional I/O processes (locking, etc. if CCS)

AC Charging Control



PFC

- Maintains the DC bus voltage (at the *setpoint)*
- Maintains PF = 1, using AC voltage (NOT the phase! usually)

DCDC

- CC: Maintains the DC current at the *setpoint*
- CV: Monitors the DC voltage and intermittently charges to be within the safety limit.

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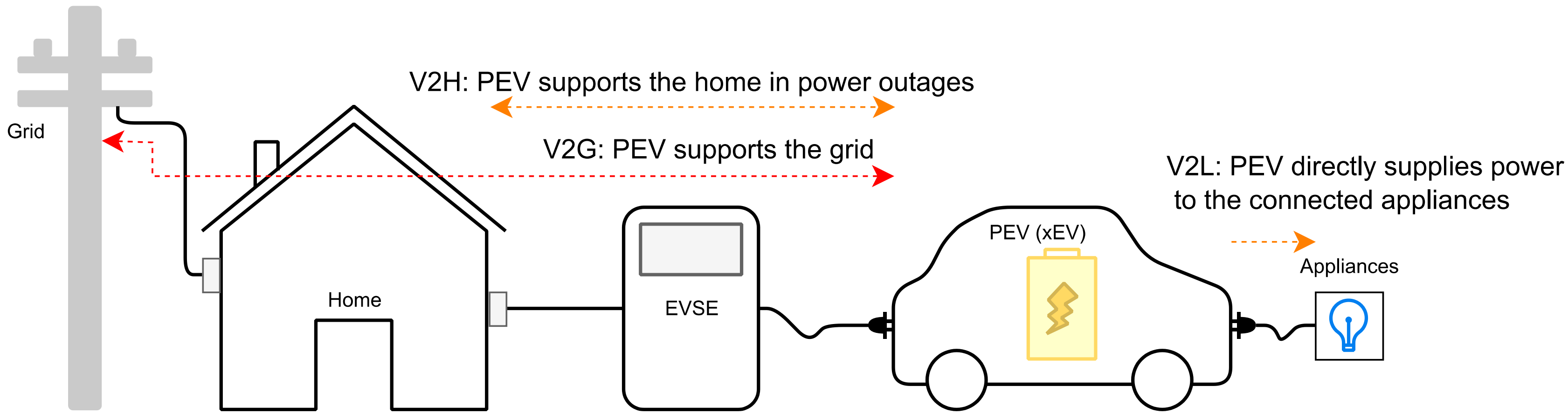
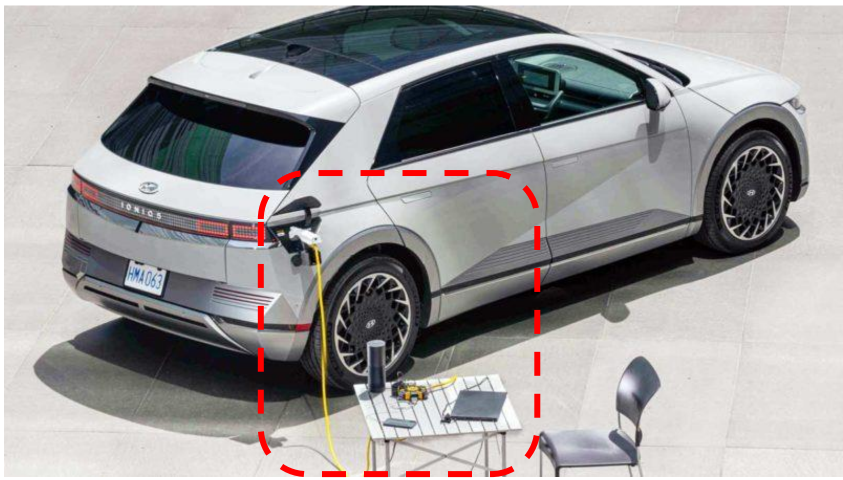
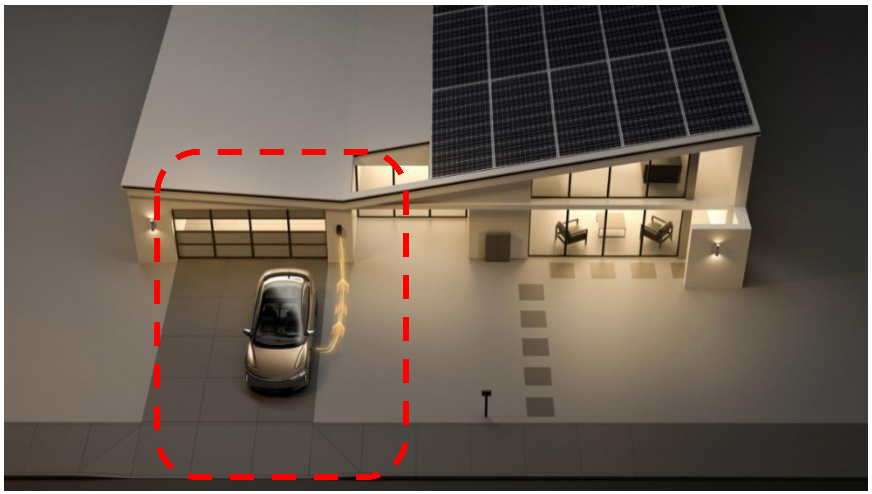
V2X is a collection of use cases of 4Q **power (active and/or reactive or DC)** flow from the vehicle.





Ioniq 5 – V2L

Image from: https://thedriven.io/2022/02/10/hyundai-ioniq-5-nabs-yet-another-major-award-alongside-merc-rivian-and-ford-evs/

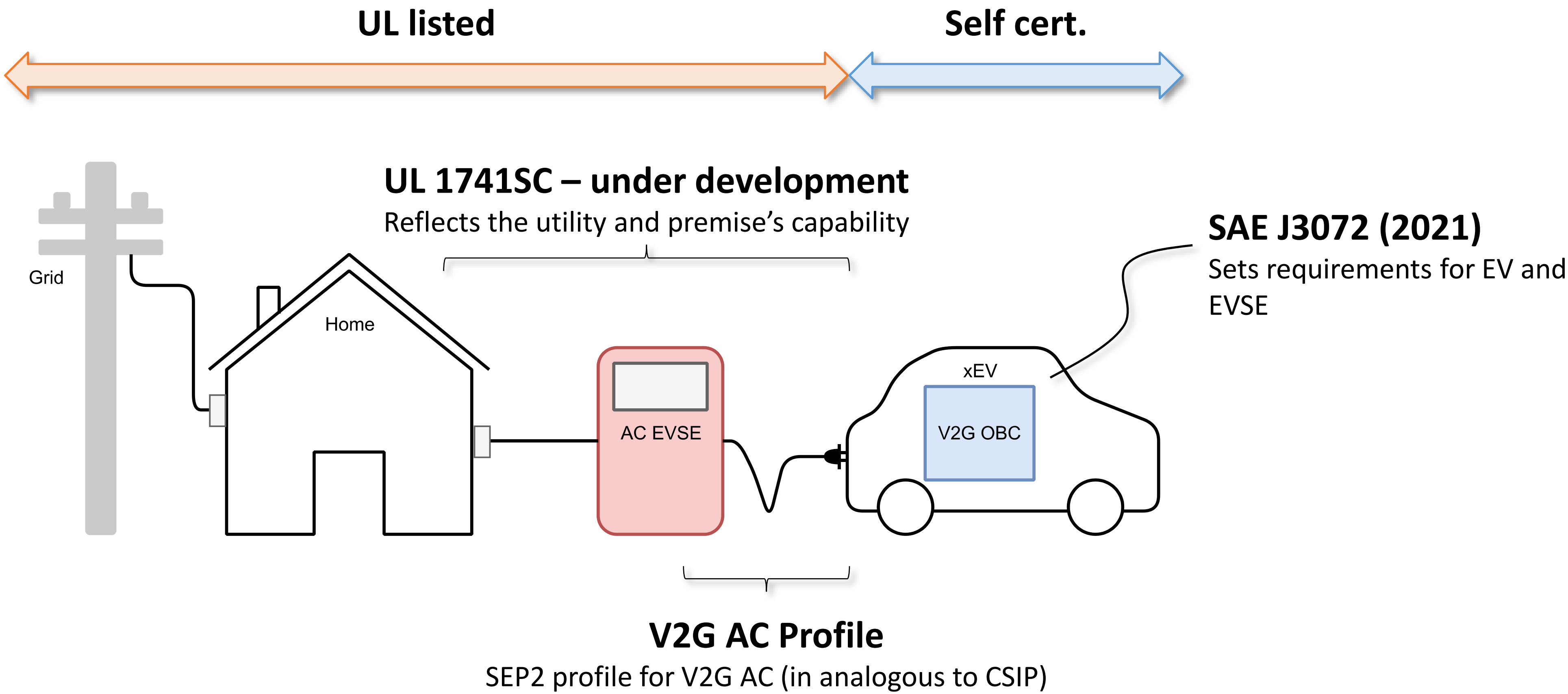


Lucid Motors – V2H

Image from: https://v2g.co.uk/2020/08/lucid-air-supports-ac-ccs-v2g/

What is V2G AC?

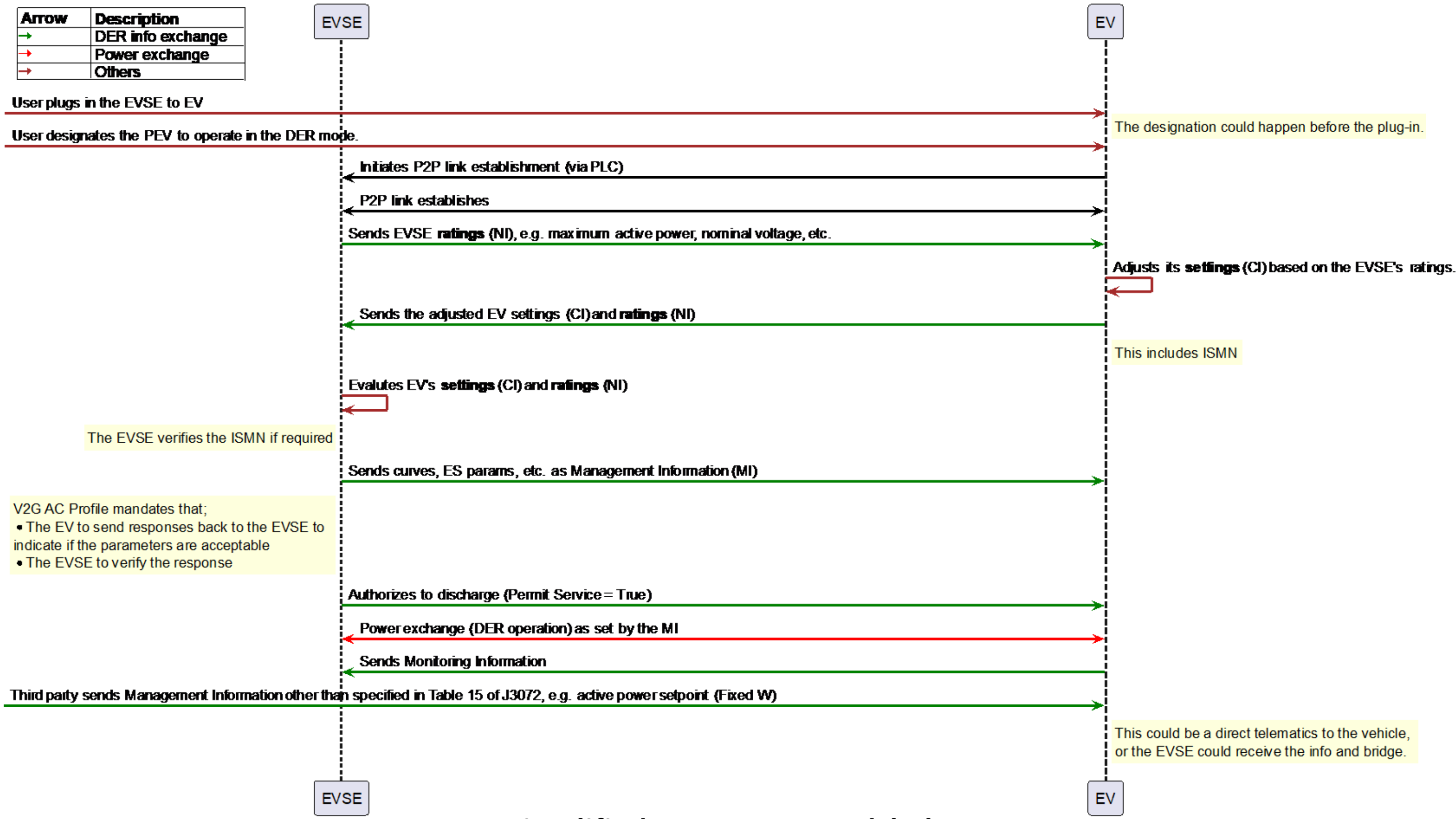
In V2G AC, an OBC in the EV acts as a DER with the compliance to the IEEE 1547.
The AC EVSE will interface w/ the upstream entities and act as a *gatekeeper*.



SAE J3072 Requirements

SAE J3072 sets requirements for onboard equipment, e.g.,

- IEEE 1547-2018 compliance and type testing against IEEE 1547.1-2020
- A chain of information exchange between the EVSE and the EV (aka handshake)
- Dynamic calibration



Simplified SAE J3072 Handshake

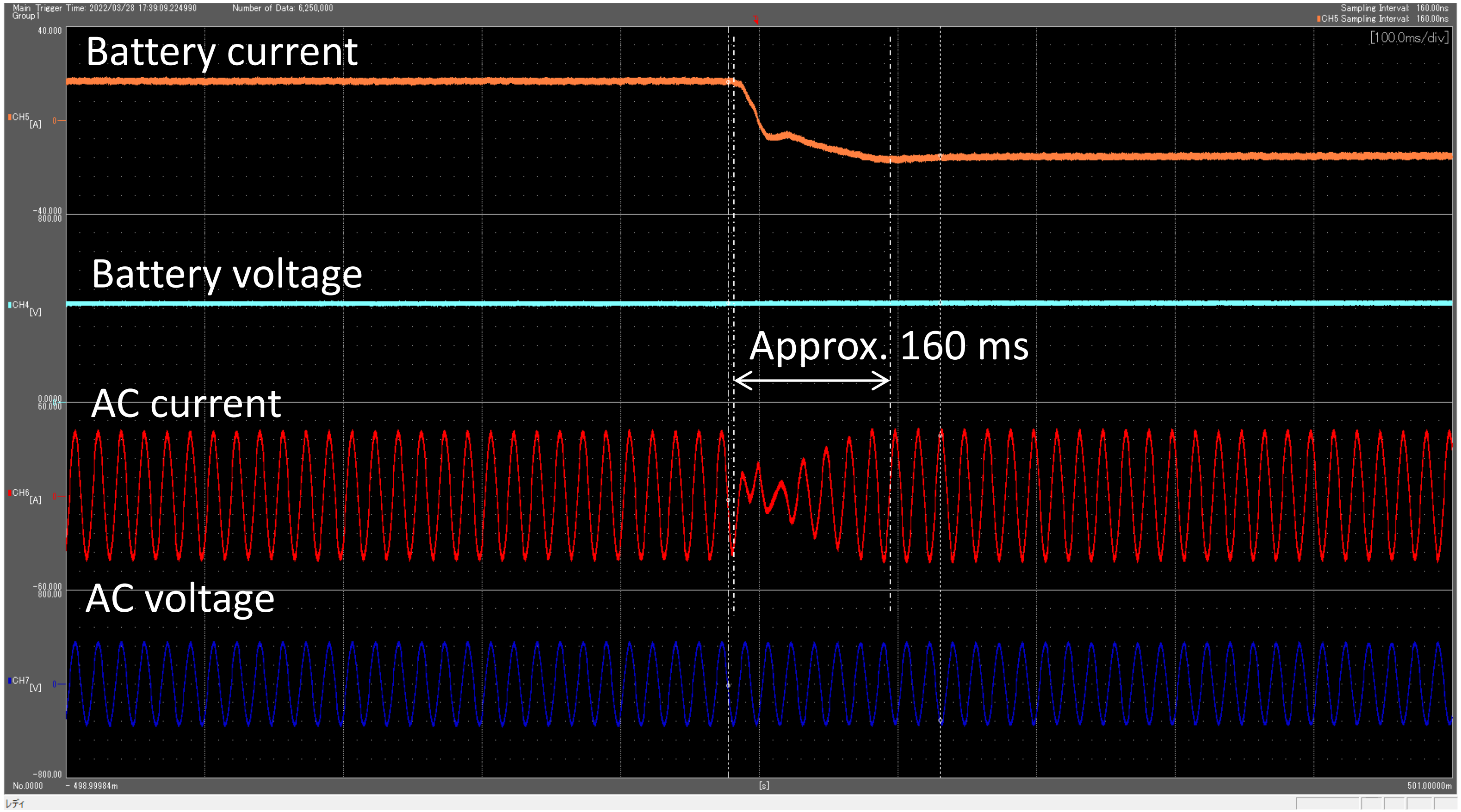
Functional Difference – Uni-D OBC vs. Bi-D OBC vs. V2G OBC

	Uni-D OBC	Bi-D OBC w/o V2H, V2L	V2G OBC OBC as a DER
Application Requirement		SAE J3072 (projected to be out of scope)	SAE J3072
	SAE J1772	SAE J1772	SAE J1772
IEEE 1547 Requirement			Anti-islanding; Curve functions; Enter Service Ride-through (V, F, PC, ROCOF); Trip (V, F,); PQ, MRA, etc...
PE Controls	Unity PF	Unity PF	Variable PF P, Q control
	CV/CC on DC side	CV/CC on DC side	DC voltage and current limit
PE Hardware	Uni-D AC//DC	Bi-D AC//DC	Bi-D AC//DC

MAJOR DIFFERENCES

- Variable PF (or the P, Q control) compared to PF = 1 – PLL is a must!
- Fast and accurate frequency and PLL as a basis for IEEE 1547 functions
- Fast power control – a seamless active power control is preferable to meet 0.2 s (within 12 cycles) requirement for frequency droop.

Fixed W: Following an active power setpoint



Response to the Fixed W Set Point Change

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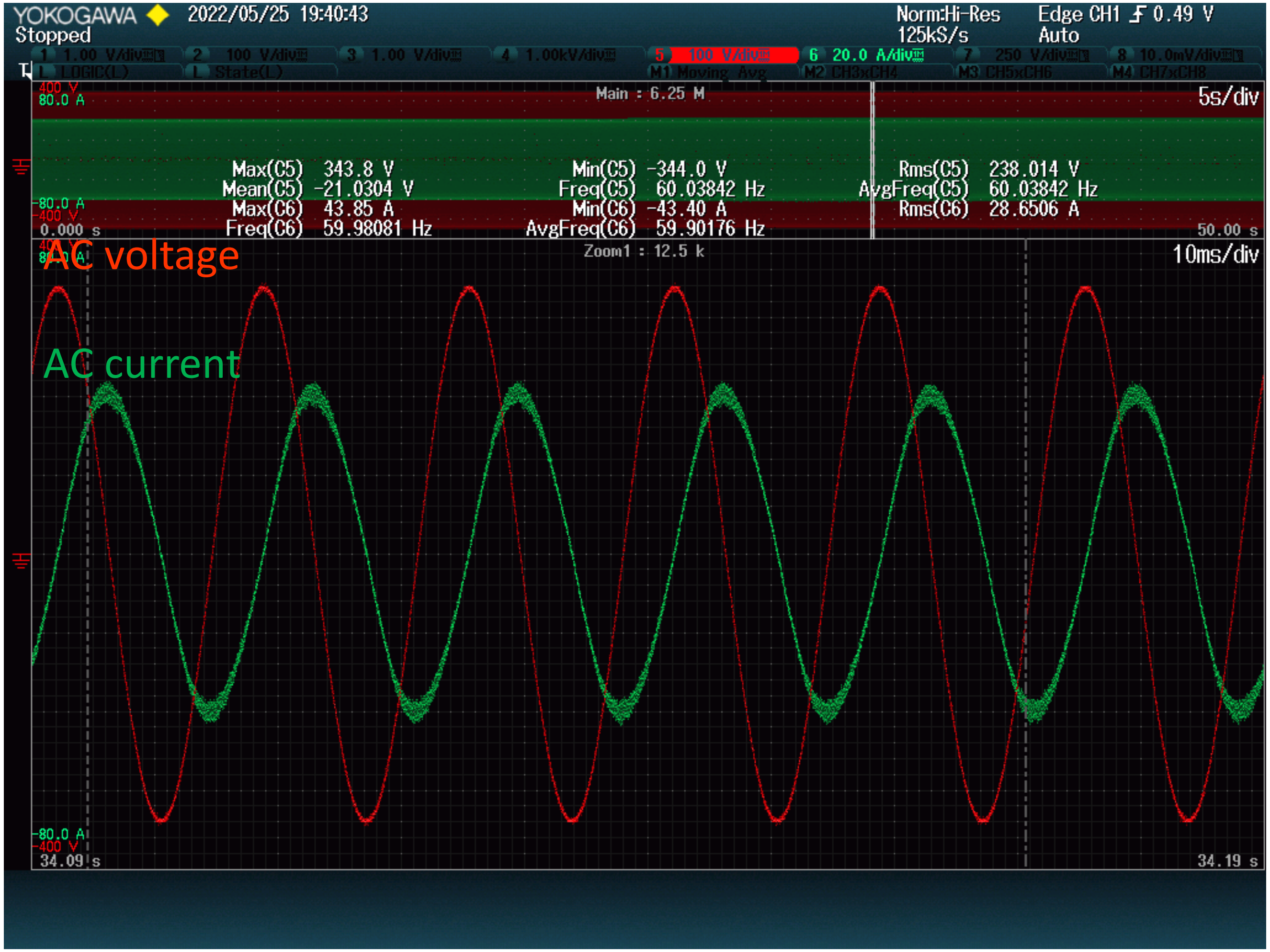
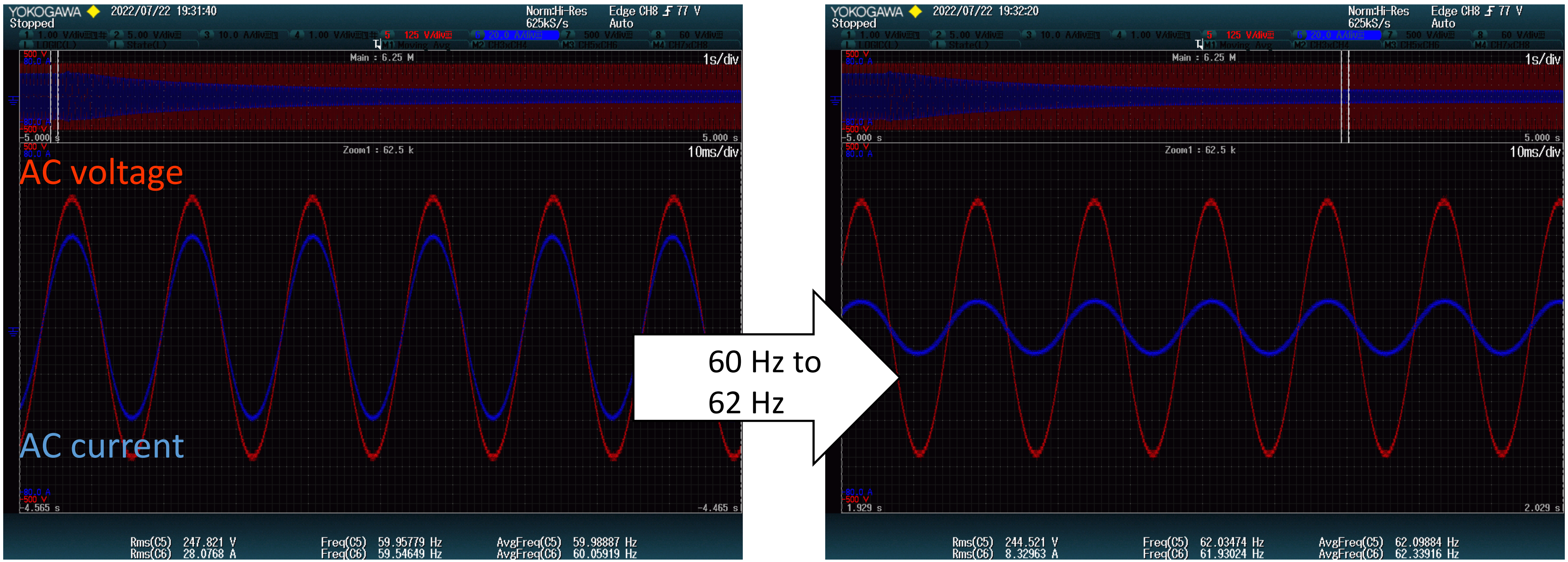
Fixed var: Following a reactive power setpoint



Fixed var (6600 var, PF ≃ 0)

<u>Frequency-droop (F/D)</u>

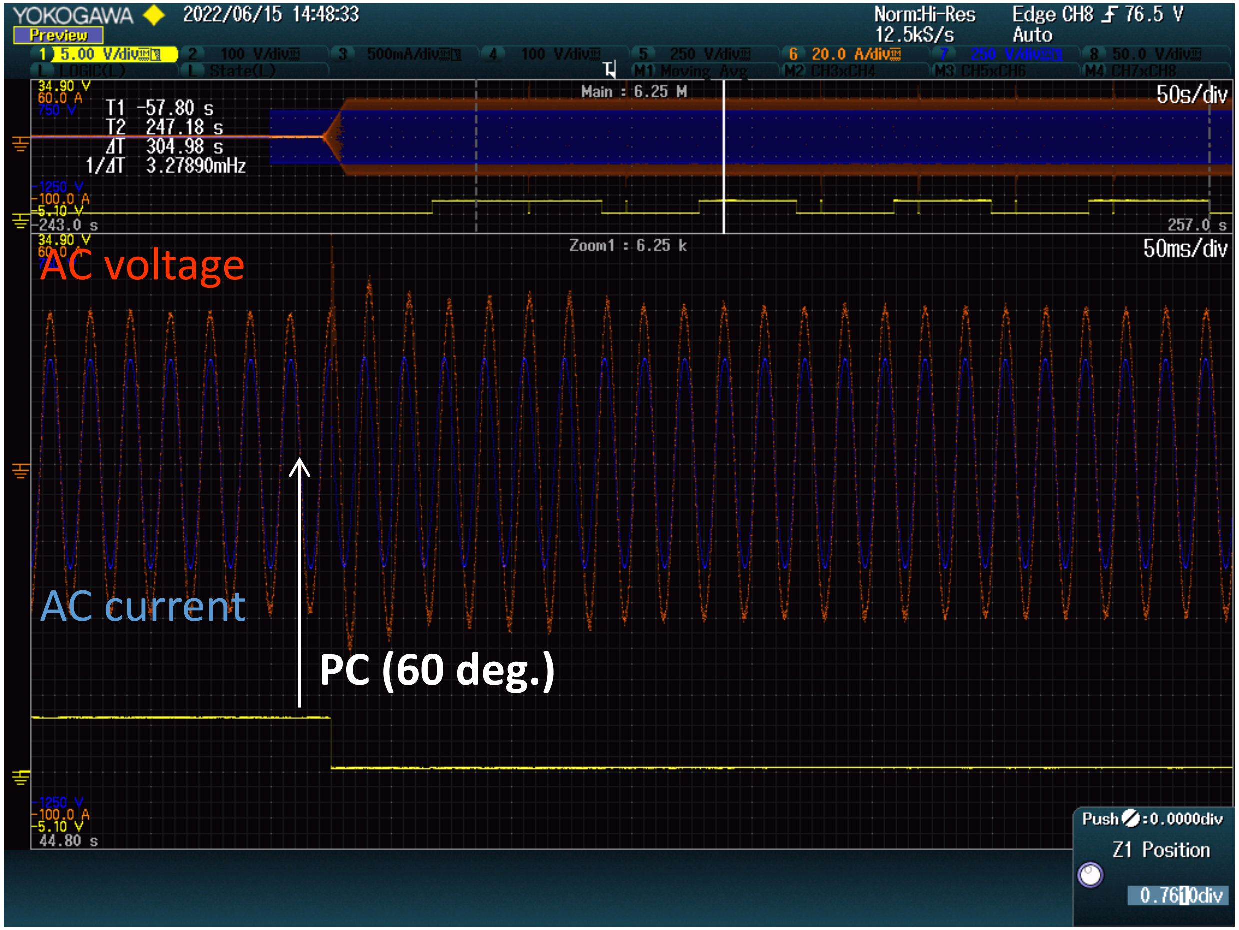
The V2G OBC adjusts active (charging) power in response to the frequency change based on a prescribed *setting*.



Response to the AC HF

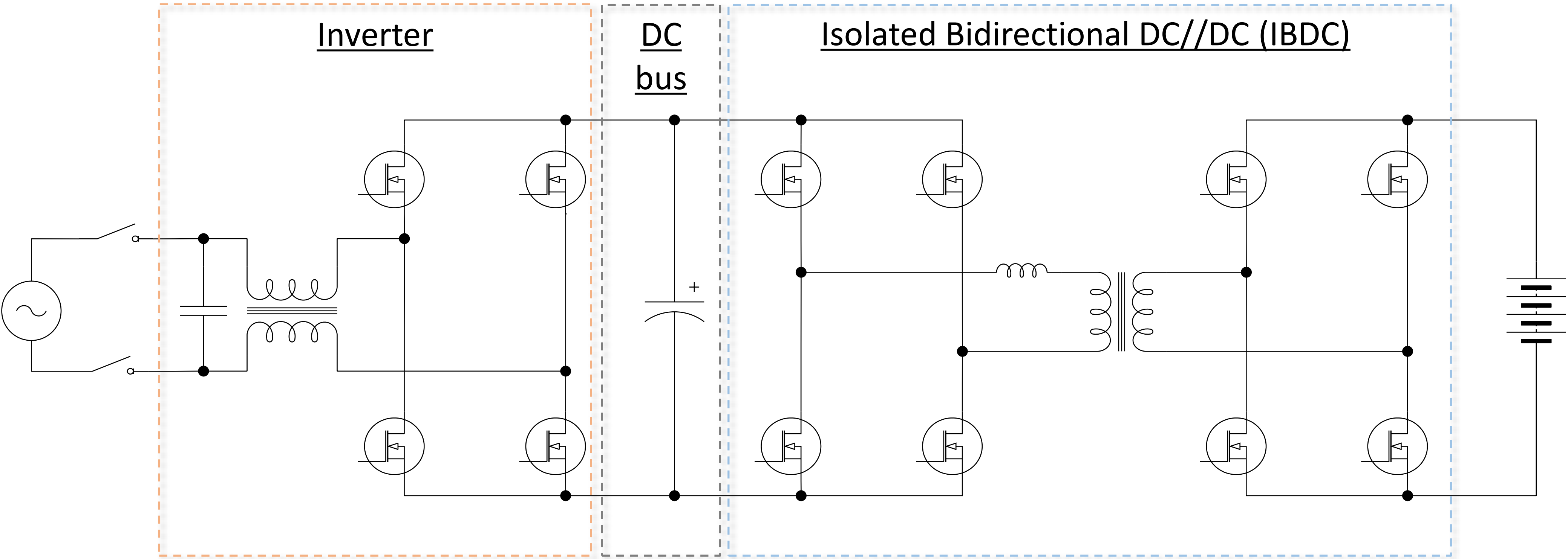
Ride-through (RT)

The V2G OBC needs to ride-through (not to trip nor oscillate) as specified in IEEE 1547-2018.
This includes the 60 deg. phase change.



PCRT

V2G OBC's (Seamless) Power Control



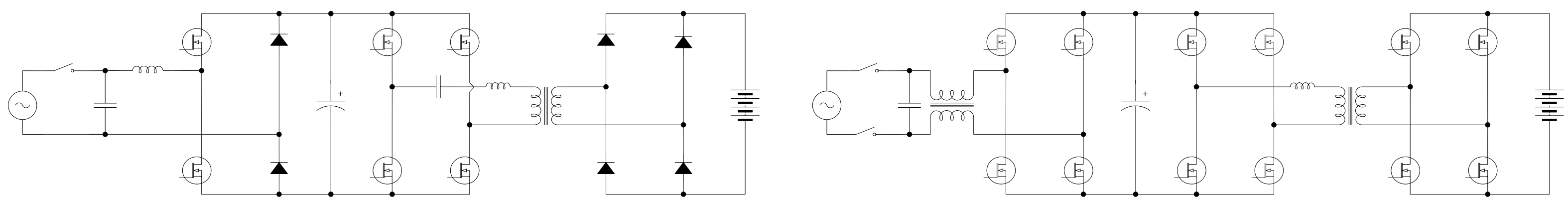
Inverter

- Maintains the AC power (active and reactive) at the *setpoint* – PLL is required!
- Monitors DC bus voltage and adjusts the power to stay within limits.

IBDC

- Maintains the DC bus voltage
- Monitors and limit the DC voltage and DC current for safety reasons

Uni-D OBC vs. V2G OBC Summary



	Unidirectional OBC	V2G OBC
Topology Example	Bridgeless PFC + LLC	H-Bridge inverter + DAB
Primary Control	CV/CC	AC power (current) control
Setpoint	DC current	Active and reactive power
Setpoint from	Main vehicle controller	OBC or an external entity
PFC/Inverter	DC bus voltage control + PF (PF = 1)	AC current control
DCDC Converter	CV/CC	DC bus voltage control
Measurement	AC voltage, AC current, DC current, DC voltage	AC voltage + frequency + phase, AC current, DC current, DC voltage

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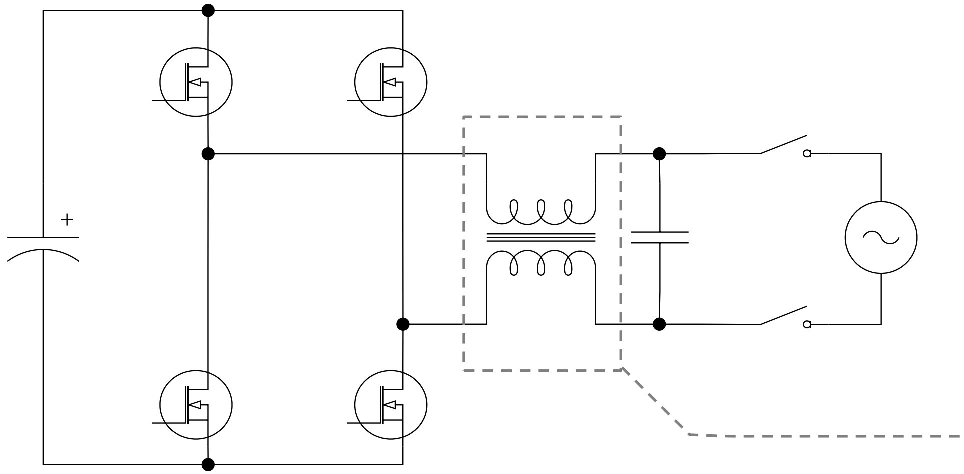
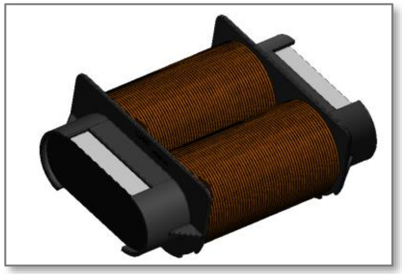
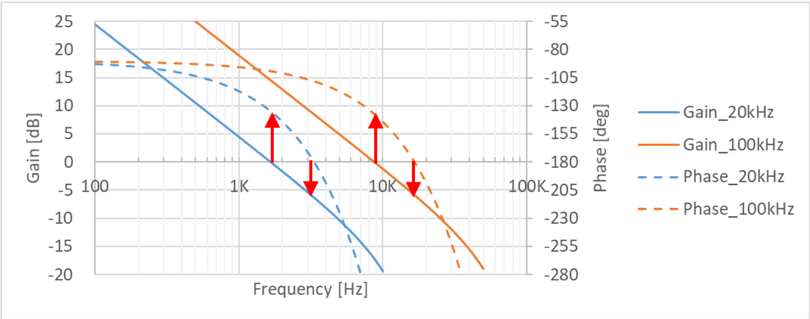
One good topology for an inverter is, a simple H-bridge. This is bidirectional by nature.



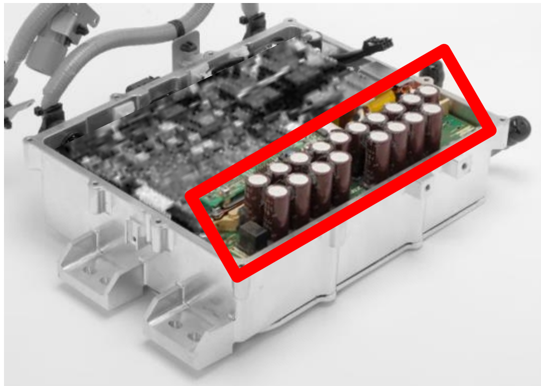


CHALLENGE

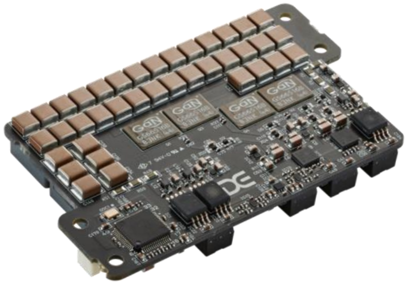
- Downsizing the inductor while maintaining the gain and phase margins
- Longer lifetime – 24/7 operation in the worst case



Gain and Phase Margins

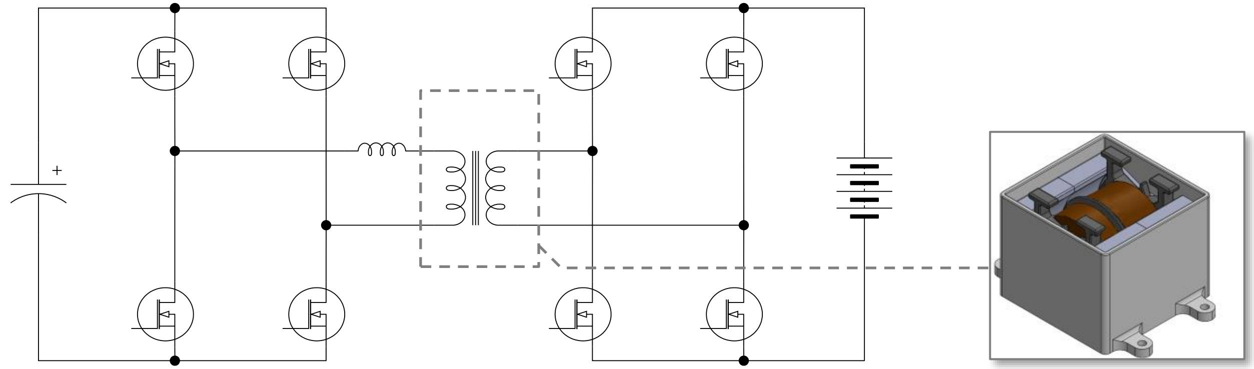


E-caps in 3.3 kW OBC



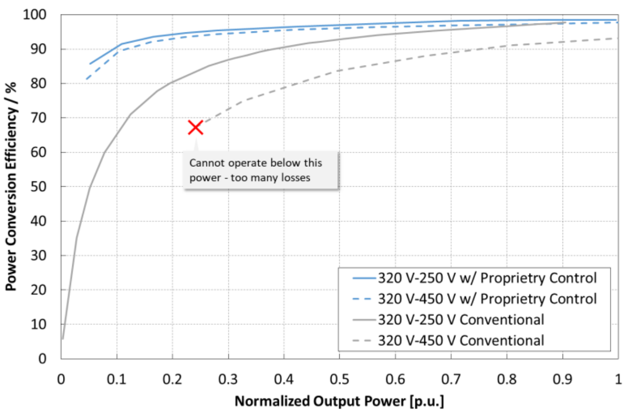
An alternative to e-caps – Active Power Decoupling

One good topology for isolated bidirectional DC//DC is Dual Active Bridge (DAB).
With it being a “power” controlled converter, it realizes seamless bidirectional power flow.

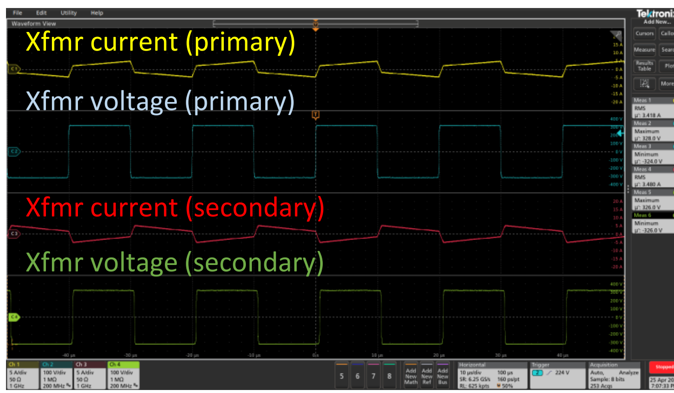


CHALLENGE

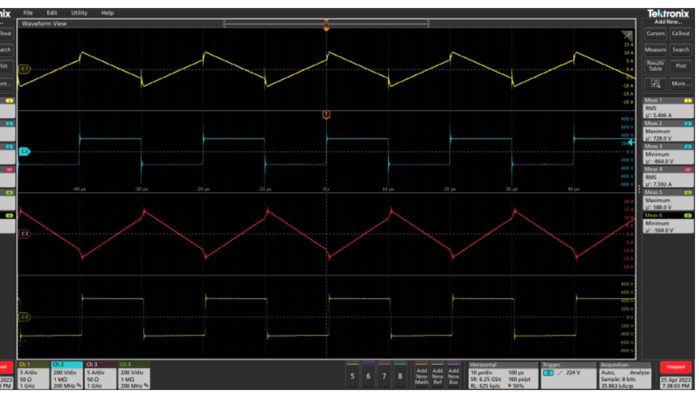
- Maintaining high efficiency under wide voltage and power range (ZVS fails)
- Downsizing transformer – high frequency square wave current flows



ZVS Matters – w/ and w/o DZ’s Proprietary Control



DAB’s Transformer Voltage and Current at 1:1 Conversion Ratio (ZVS Maintained)

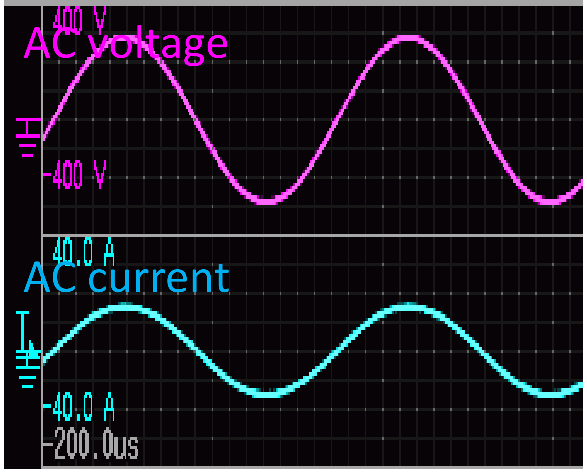


DAB’s Transformer Voltage and Current at Light Load(ZVS Failed)

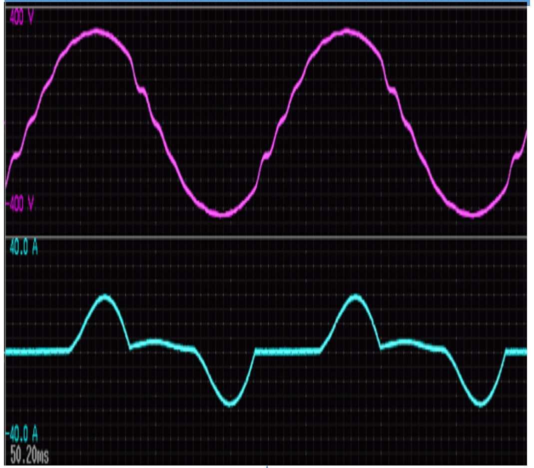
V2L/V2H AC – A Different Animal

CHALLENGE is to maintain "good" voltage quality under various load types.
The control design consideration is different from the one for V2G.

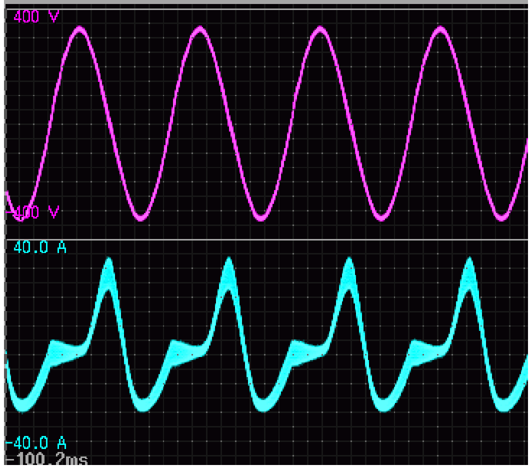
Linear Load



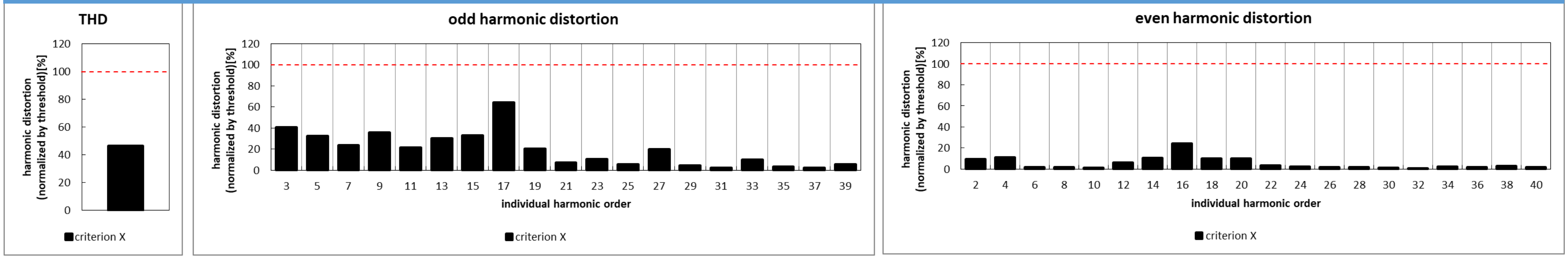
Non-linear Load



Half Rectifier Load



Voltage Quality Evaluation per IEC 62040-3:2021



V2X AC System

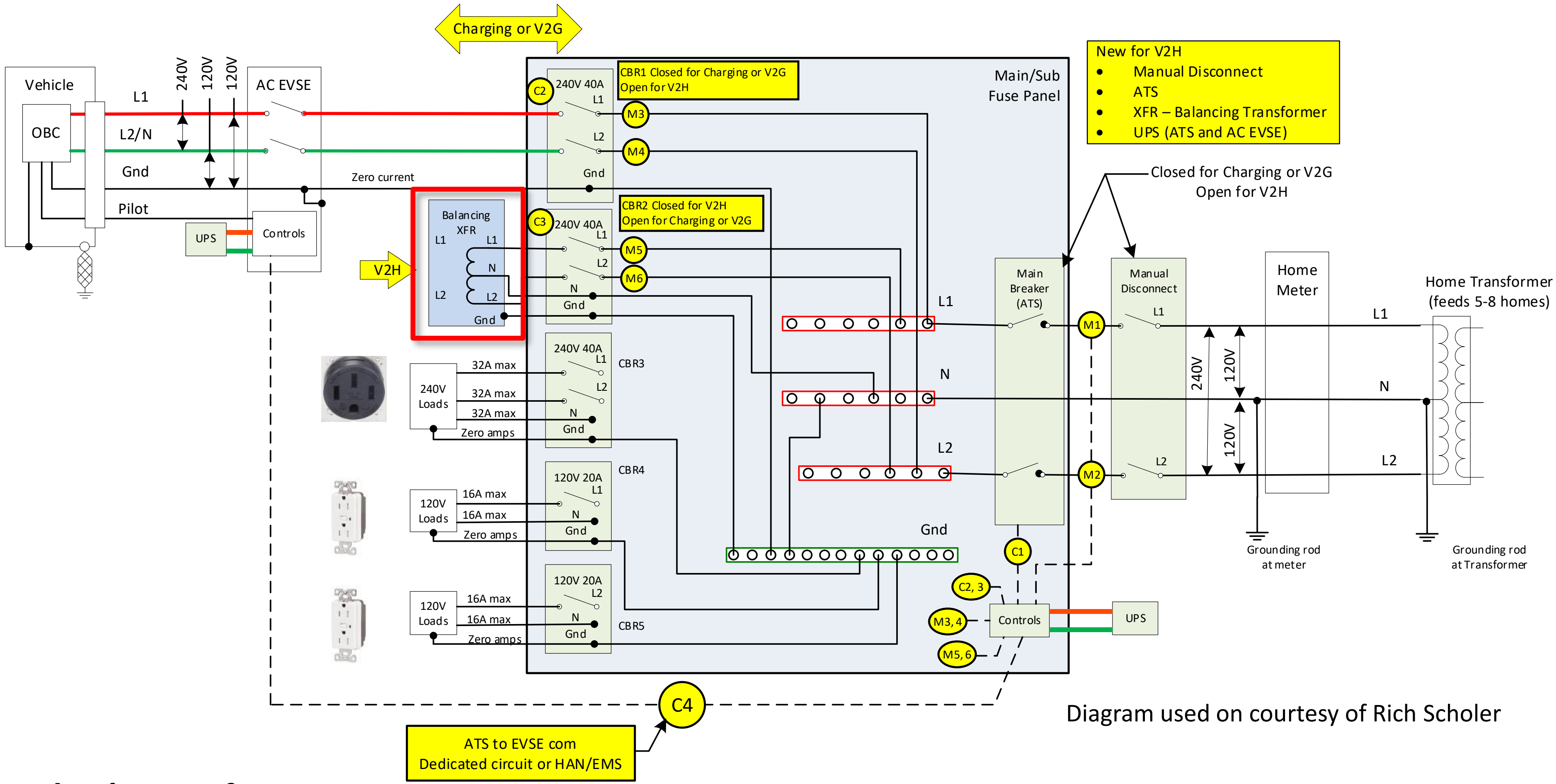


Diagram used on courtesy of Rich Scholer

What's New for EVSEs

- It must NOT interfere with the EV's V2G operation, including but not limited to, ride-through.
  - An example: LVRT goes down to 0 p.u. – the EVSE need to stay awake!
- Oversight functions per upcoming UL 1741SC

- SAE J1772 signals provide the connection status, readiness for (and during) a charging session, and **the maximum AC current that the EV can draw**.
- Hardware needs to consider the grid impedance impact, operation time, and wider DC voltage and operational power range, not to mention the bidirectional power flow.
- V2H is an different animal – a “good” **voltage controller** is necessary and a standard to evaluate V2H/V2L needs to be established.
- V2X AC system has unique additional requirements – **neutral forming device** and UL 1741SC compliance (including withstanding ZVRT event).

Uni-D vs. V2G OBC

	Unidirectional OBC	V2G OBC
Topology Example	Bridgeless PFC + LLC	H-Bridge inverter + DAB
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DCDC Converter	CV/CC	DC bus voltage control
Measurement	AC voltage, AC current, DC current, DC voltage	AC voltage + frequency + phase, AC current, DC current, DC voltage

Thank you!

If you have any questions, comments, etc.,
feel free to send me an e-mail at
yukihiro_hatagishi@dia-zbr.co.jp
or connect me via LinkedIn!

Application Report

SLUA896–June 2018

Power Factor Correction design for On-Board Chargers in Electric Vehicles

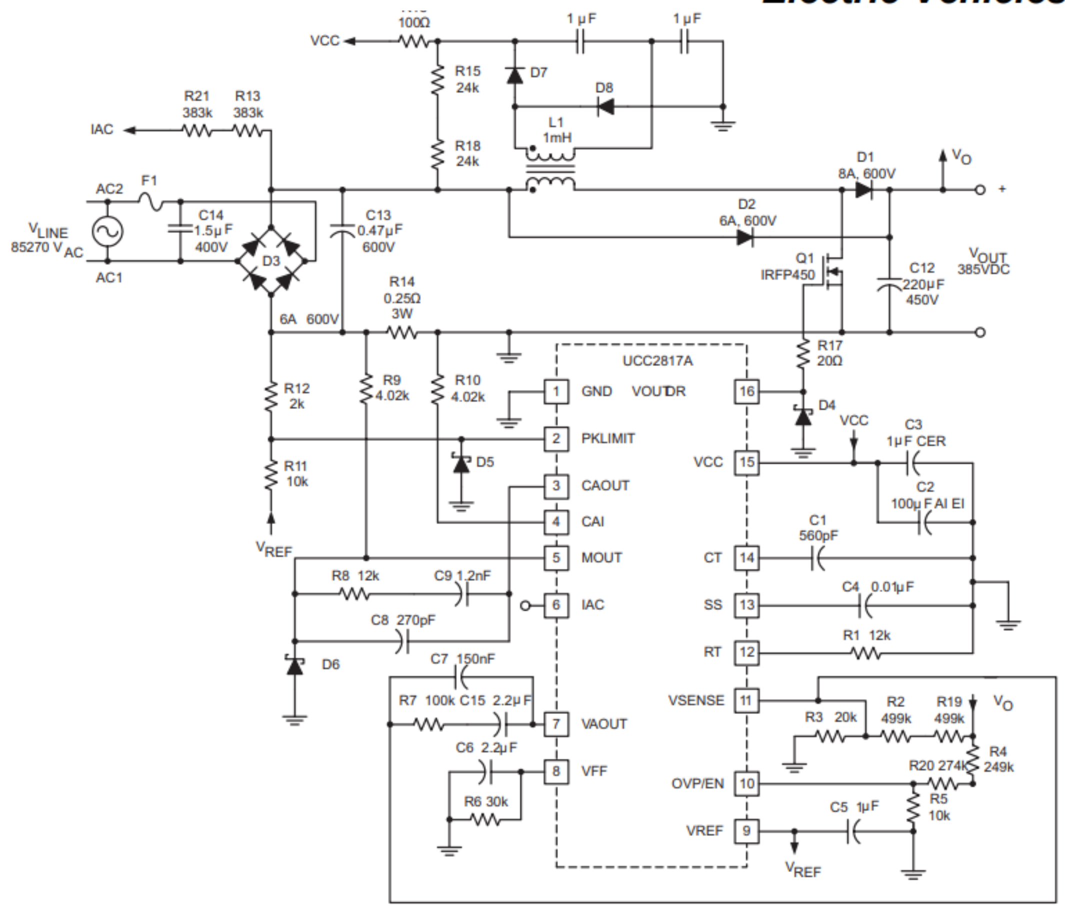
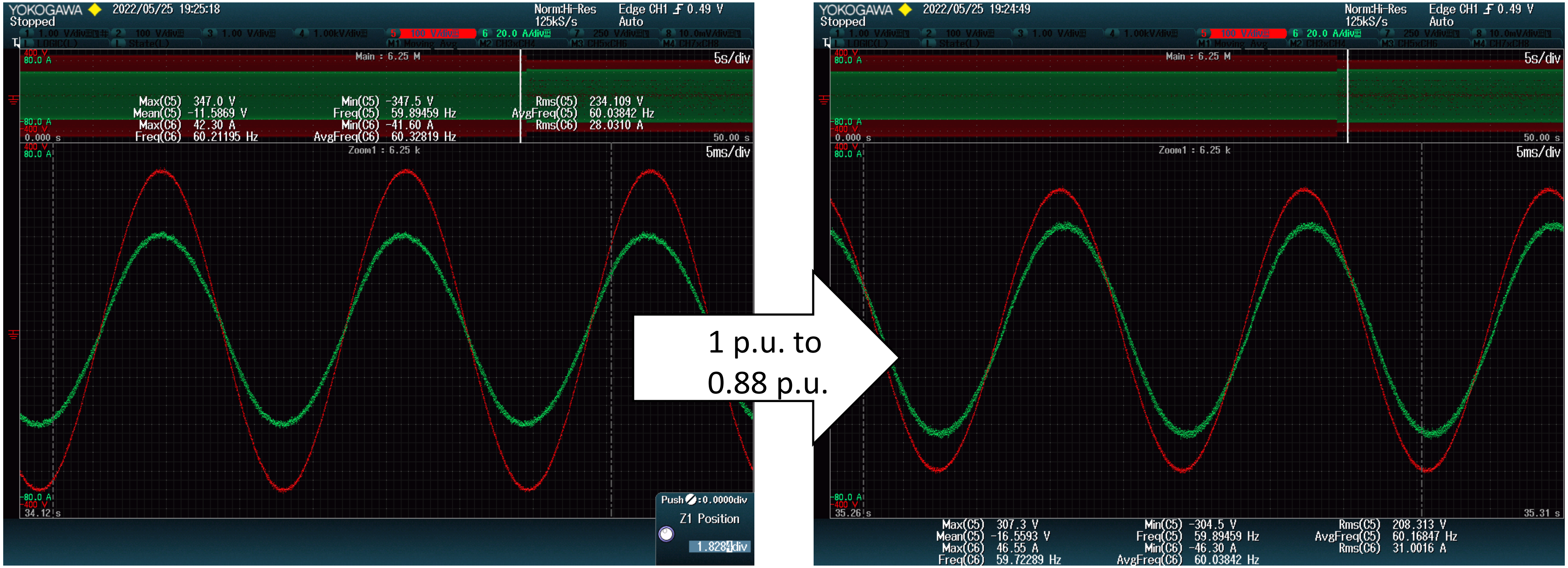


Figure 2. Typical Application Circuit that can be used with the UCC2818A-Q1

https://www.ti.com/lit/an/slua896/slua896.pdf?ts=1696942548455

Volt-var (V/Q): A curve function

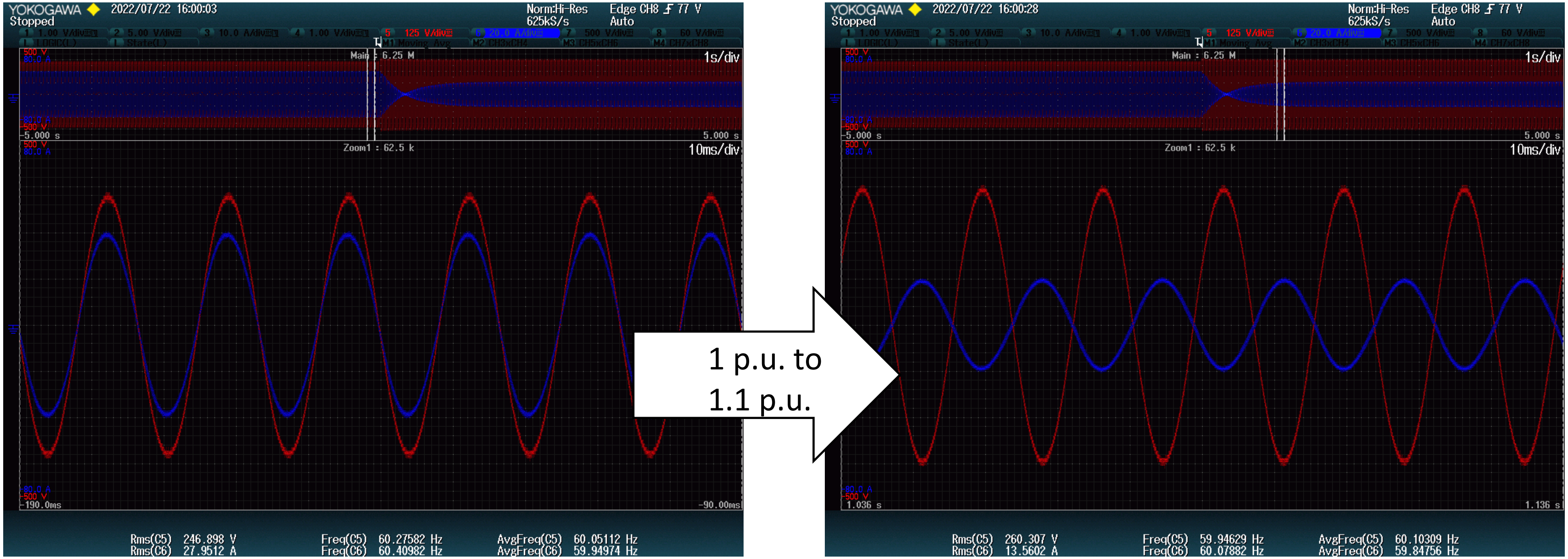
The V2G OBC adjusts reactive power in response to the AC voltage change based on a prescribed *curve* data.



Response to the AC Voltage Change (V/Q)

Volt-watt (V/W): A curve function

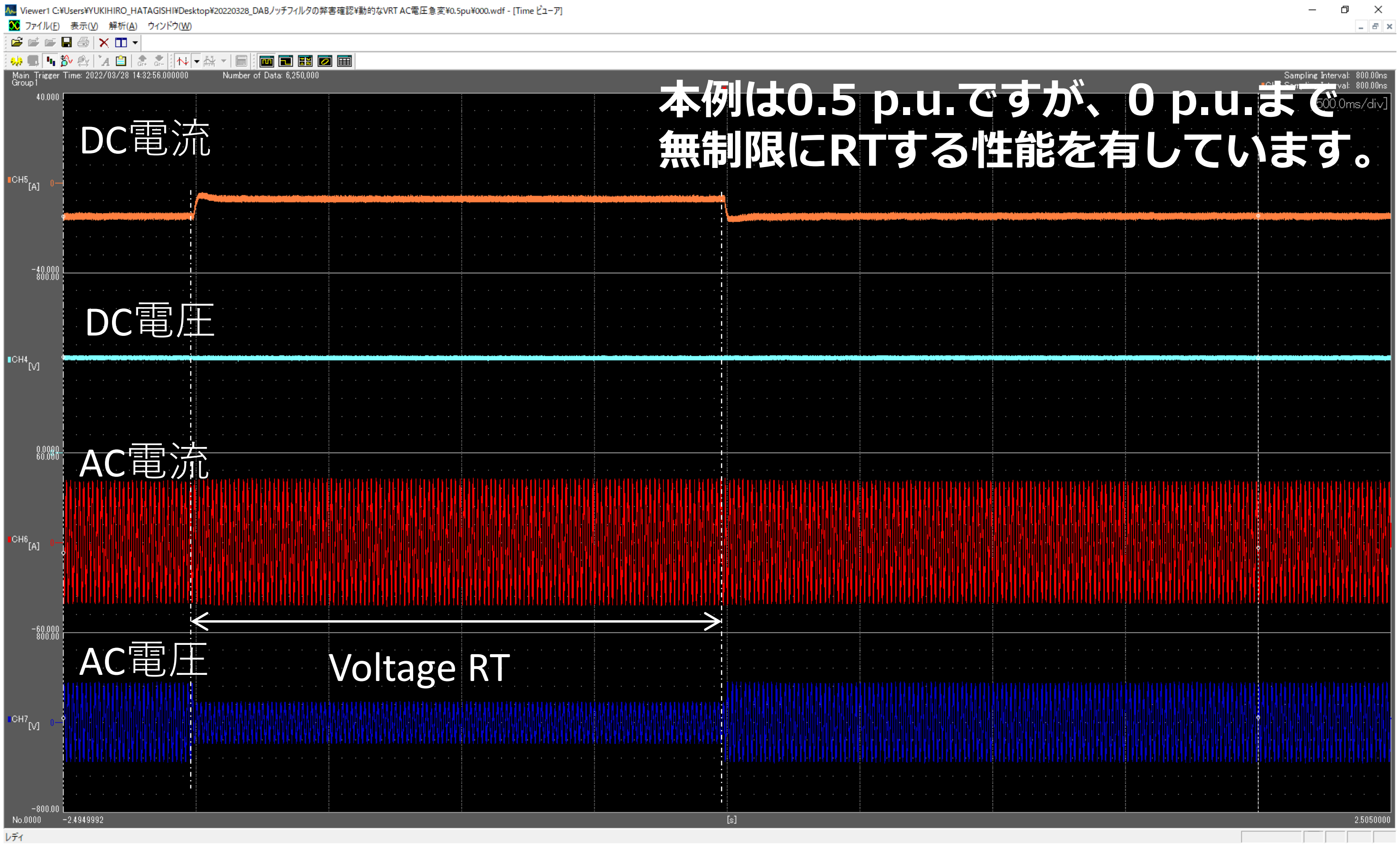
The V2G OBC adjusts active (charging) power in response to the AC voltage change based on a prescribed *curve* data.



Response to the AC Voltage Change (V/W)

北米での実証実験について – 製品性能

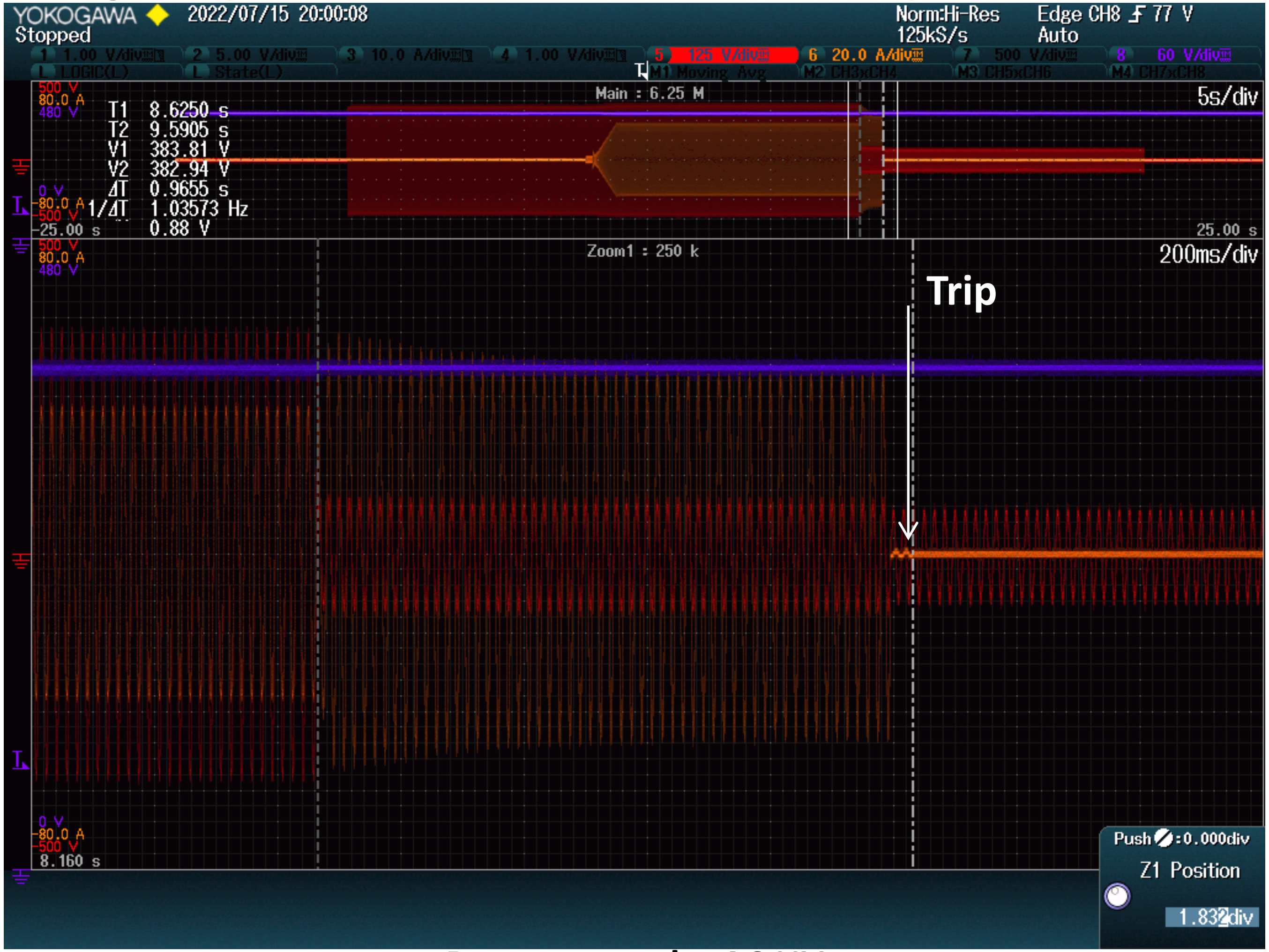
VTrip/RT – Voltage Trip曲線に従い、AC電圧に応じてTrip/RT



Response to the AC UV

北米での実証実験について – 製品性能

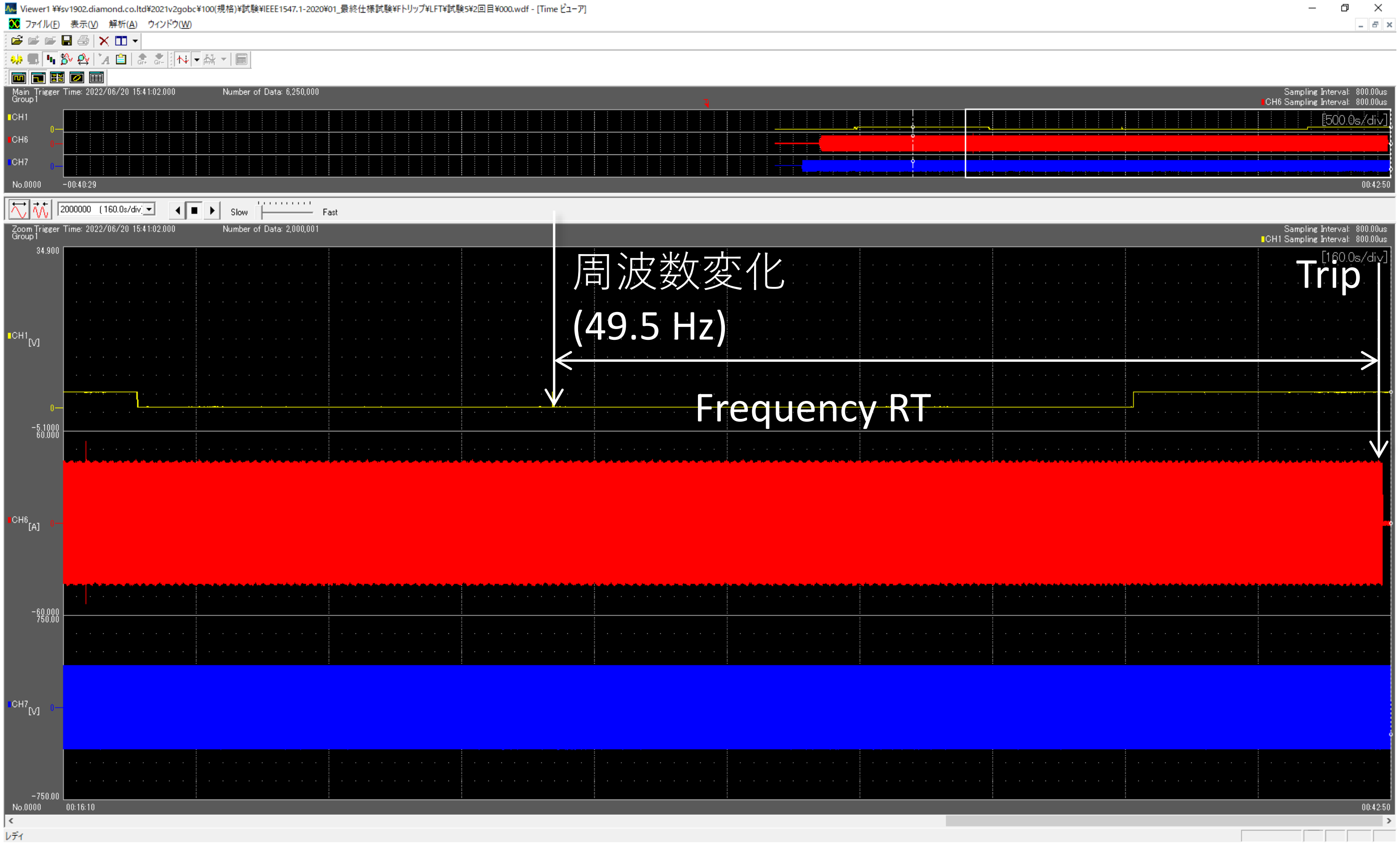
VTrip/RT – Voltage Trip曲線に従い、AC電圧に応じてTrip/RT



Response to the AC UV

北米での実証実験について – 製品性能

FTrip/RT – Frequency Trip曲線に従い、AC周波数に応じてTrip/RT



Response to the AC LF

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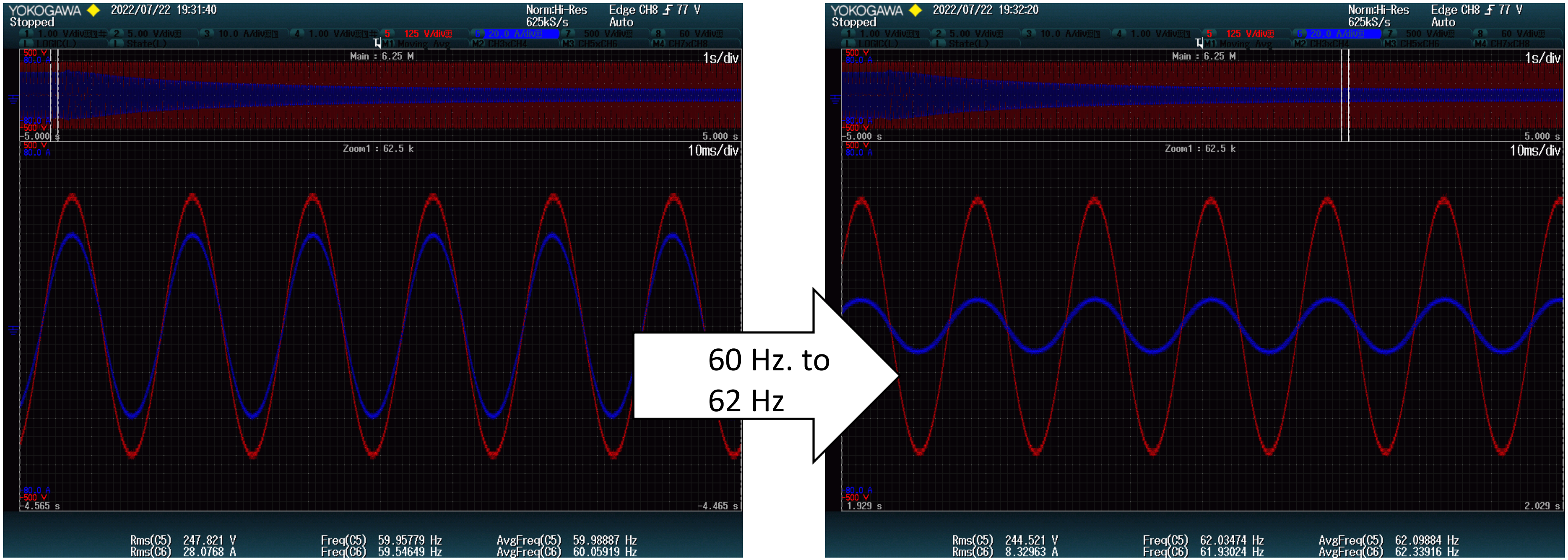
FD – FD設定に従い、AC周波数に応じて有効電力を自律調整する。



Response to the AC HF

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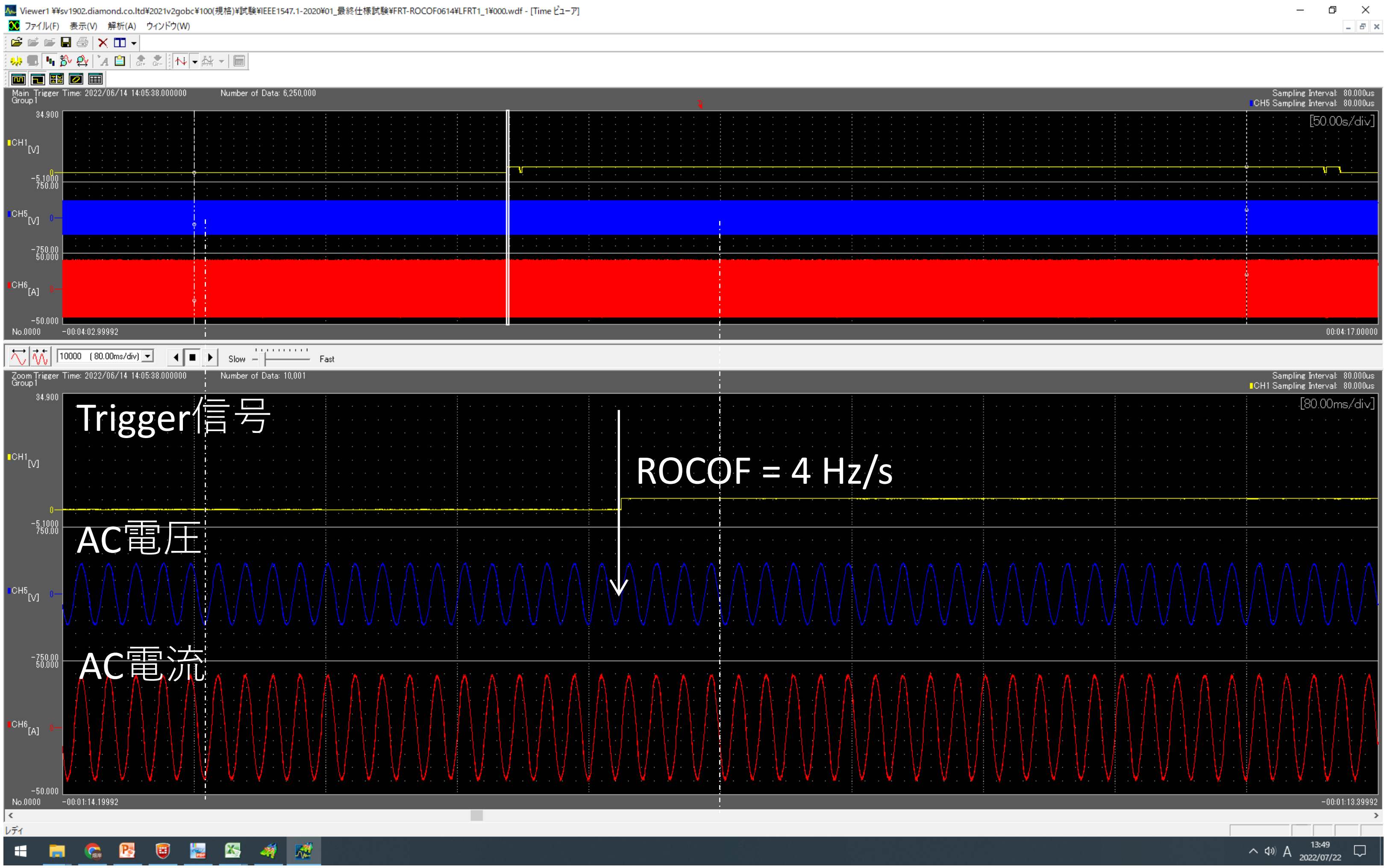
北米での実証実験について – 製品性能

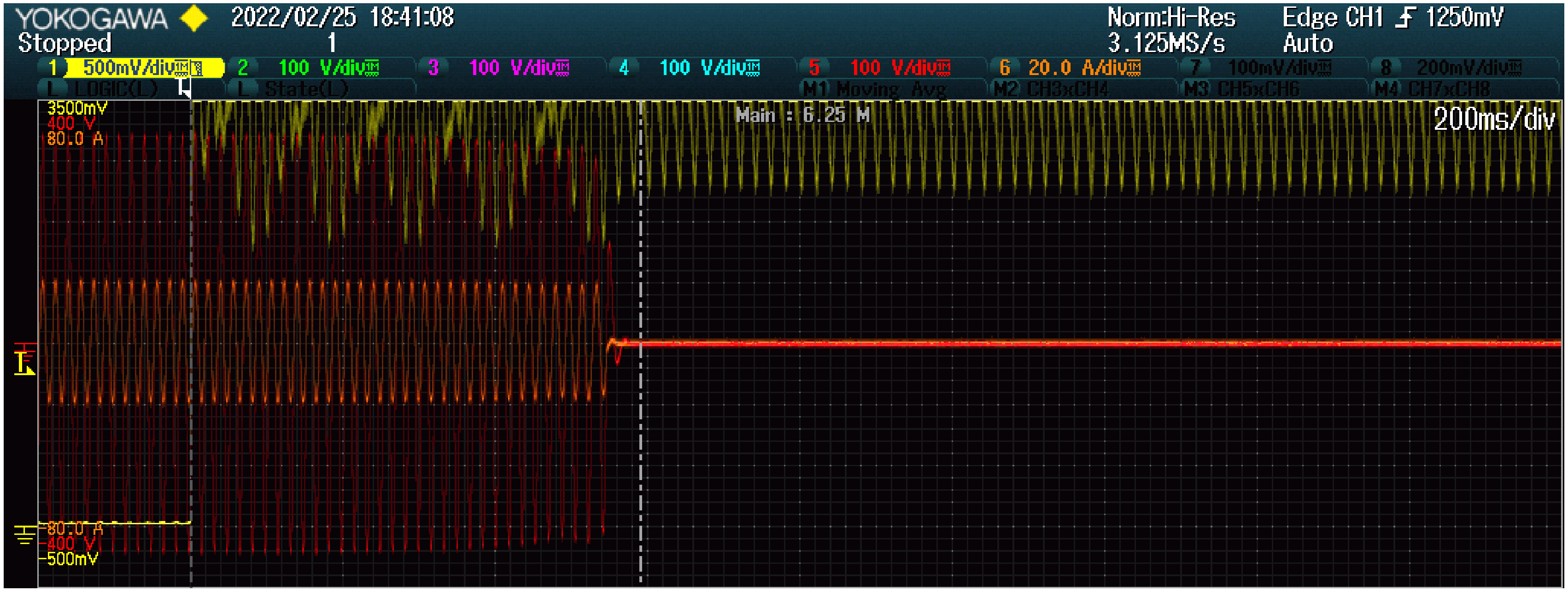
ROCOFRT – 3 Hz/s以下の周波数変化時に動作を継続(RT)する。



Response to the ROCOF (UF)

北米での実証実験について – 製品性能

AI – 単独運転状態(UI)を検出し、Tripします。



単独運転
状態形成

Trip

Response to the UI

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A Compensator that Negate the Influence of Grid Impedance based on Frequency Sweep Estimation Technique

KAMATANI Yuhki, NISHIKAWA Takeo, ZAITSU Toshiyuki and UEMATSU Takeshi

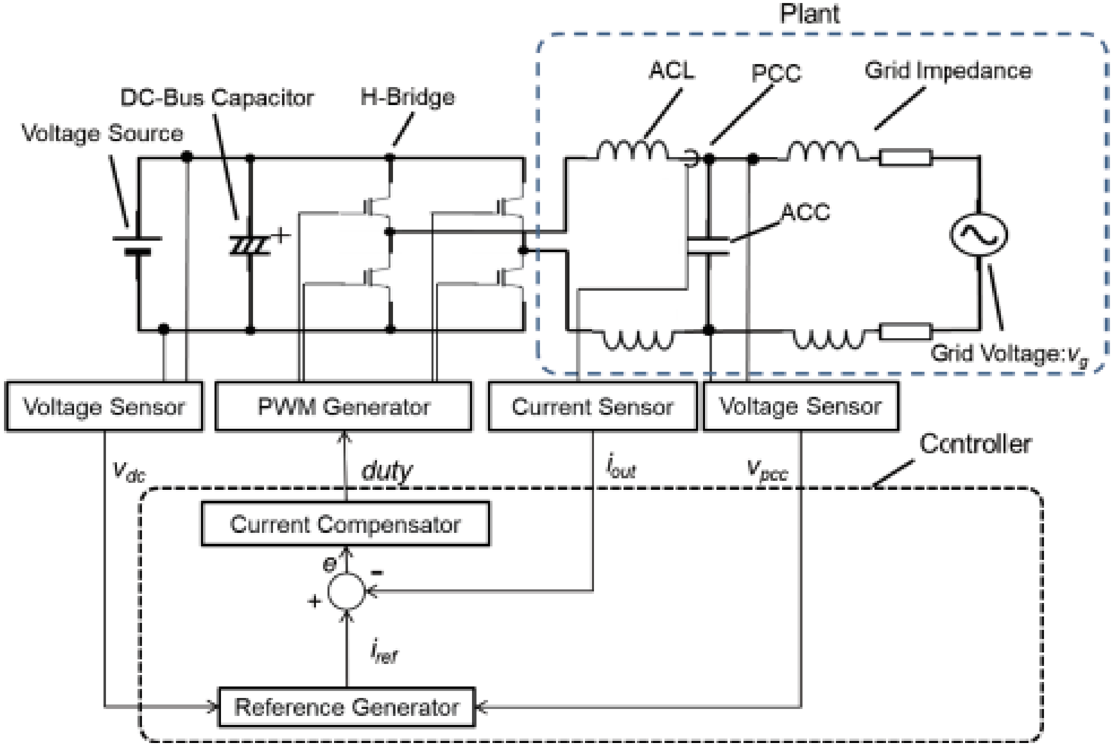
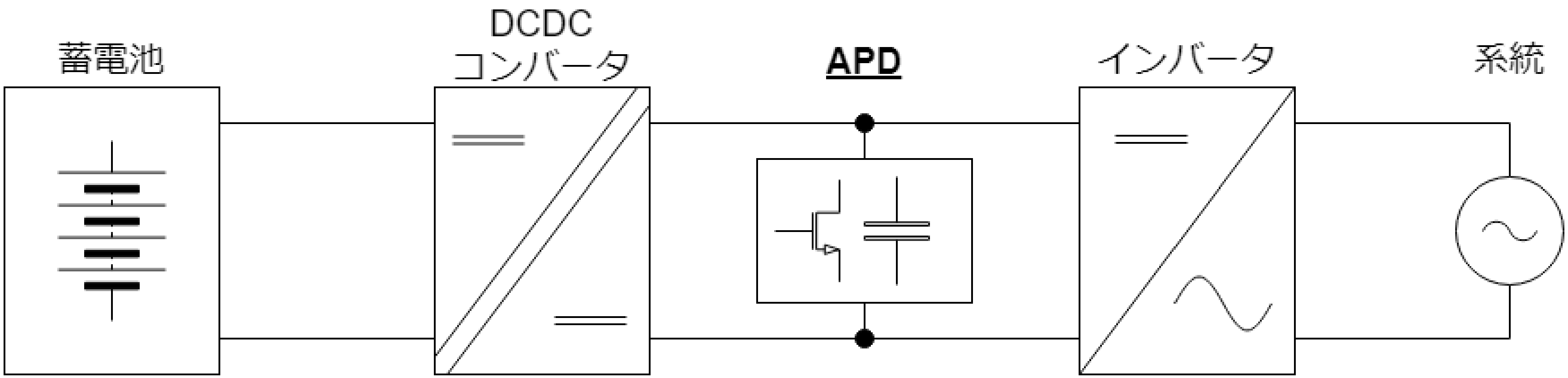
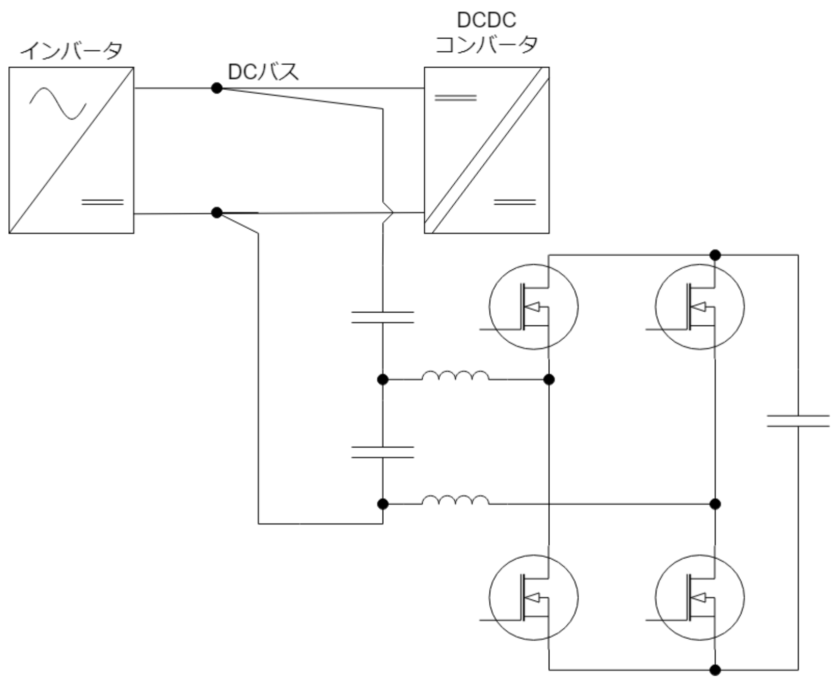


Fig. 3 System configuration of the Grid-Connect Control

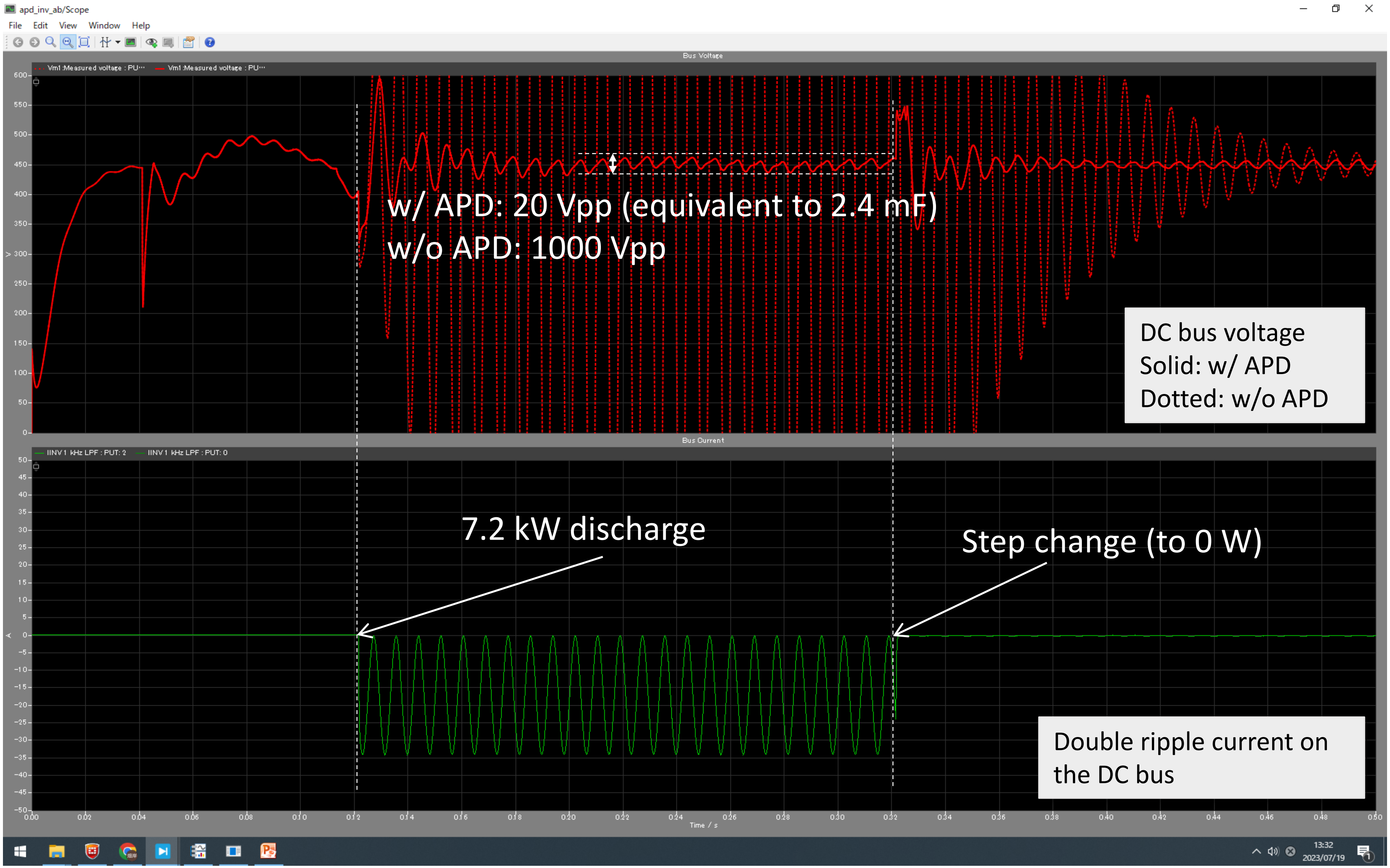
Cited from: https://www.omron.com/global/en/assets/file/technology/omrontechnics/vol50/OMT_Vol50_008.pdf

Active Power Decoupling (APD)



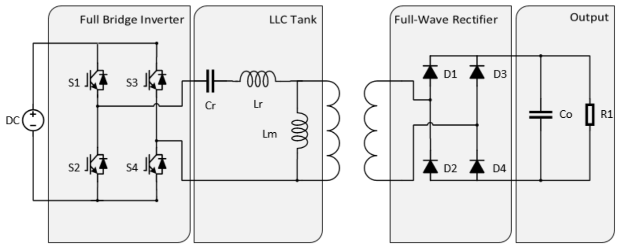


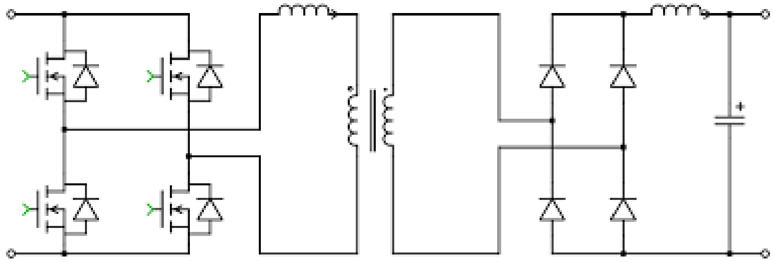
APD's Impact


apd_inv_ab/Scope
File Edit View Window Help
Bus Voltage
w/ APD: 20 Vpp (equivalent to 2.4 mF)
w/o APD: 1000 Vpp
DC bus voltage
Solid: w/ APD
Dotted: w/o APD
Bus Current
7.2 kW discharge
Step change (to 0 W)
Double ripple current on the DC bus
Time / s

DAB vs. Other Topologies

	DAB	LLC	PSFB	※note
一次側回路	フルブリッジ(FET)	フルブリッジ(FET)	フルブリッジ(FET)	要求スペックはほぼ同一 PSFBはやや要求高
AC部構成	Tr＋L	Tr+L+C	Tr(+L)	トランスサイズはほぼ同一
二次側回路	フルブリッジ(FET)	フルブリッジ(Di)	フルブリッジ(Di)＋L	PSFBのブリッジは SiCSBDの必要性高い
出力キャパシタ	大	大	小	DABとLLCは出力リプル大
ドライブ機構数	8	4	4	単方向動作においても DABは8ヶのSW駆動が必須
ソフトスイッチ	○	◎	×	LLCの方がより「ソフト」
双方向動作	◎	△	△	LLC…力行/回生時に異なる動作 PSFB…昇圧/降圧の排他動作
センサ回路	入力電圧・入力電流・出力電圧・出力電圧			トポロジー差はほぼなし。 主に製品仕様に依存する





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DAB's Pros n' Cons

DAB	当社従来
平滑・共振Lを一体化	平滑Lと共振Lが必要
双方向化が容易	双方向化難易度が高い かつ、入出力電圧に制限あり。
昇降圧動作が可能	昇圧・降圧動作のみ
原理的に出力電力に制限がある。	電圧条件を満足すれば 原理的には電力制限がない。
アプリのTYP動作に対する設計が可能	アプリのワースト状態に 合わせて設計が必要
二次側ブリッジが必須	二次側はセンタータップ可
二次側に自己消弧SW	二次側Diで構成可能
電流源動作に向く	電圧源動作に向く
制御ICなし	制御IC有り

5.3.4 Performance classification

5.3.4.1 General

The manufacturer shall classify UPS complying with this document in accordance with the coding AAA BB CC as detailed in 5.3.4.

AAA BB CC

- CC: An indicator of the dynamic performance (i.e. load change) when the UPS is generating AC voltage (i.e. V2H/V2L in V2X OBC case)
- BB: An indicator of the steady state performance when the UPS is generating AC voltage (i.e. V2H/V2L in V2X OBC case)
- AAA: An indicator of the performance when the grid is present.

…AAA can be ignored for the V2X purpose.

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5.3.4.3 Output voltage waveform BB

5.3.4.3.1 General

The output voltage waveform BB is a set of characters describing the steady state waveform of the output voltage when operating in:

– normal mode (1st character);

– stored energy mode (2nd character),

V2H/V2L need to address the 2nd character only.

where each character takes the form of either S, X or Y as described in the following subclauses.

Requirement Summary

Class	Waveform	THD	Individual Harmonics
S	Sinusoidal	≤8%	Table 3
X	Sinusoidal	≤12%	Table 4
Y	Non-sinusoidal	N/A	N/A

Load type

- Linear load
- Reference non-linear load

Table 3 – Compatibility levels for individual harmonic distortion of voltage in public low-voltage power supply systems

Odd harmonics non-multiple of 3		Odd harmonics multiple of 3 [a]		Even harmonics	
Harmonic order n	Harmonic voltage %	Harmonic order n	Harmonic voltage %	Harmonic order n	Harmonic voltage %
5	6	3	5	2	2
7	5	9	1,5	4	1
11	3,5	15	0,4	6	0,5
13	3	21	0,3	8	0,5
$17 \le n \le 37$	$2,27 \times (17/n) - 0,27$	$21 \le n \le 39$	0,2	$10 \le n \le 40$	$0,25 \times (10/n) + 0,25$

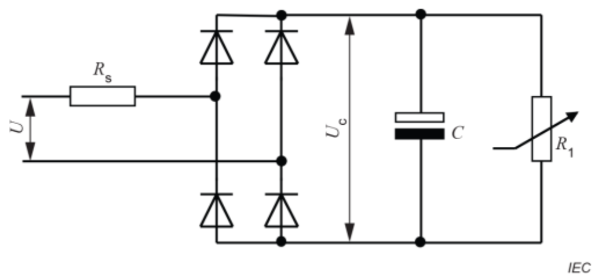
NOTE 1 All of the harmonic levels in this table are assumed not to occur simultaneously.

NOTE 2 Table 3 is an extract from the compatibility levels in Table 1 of IEC 61000-2-2 and IEC 61000-2-2:2002/AMD1:2017.

[a] The levels given for odd harmonics that are multiples of three apply to zero sequence harmonics. Also, on a three-phase network without a neutral conductor or without **load** connected between line and ground, the values of the 3rd and 9th harmonics may be much lower than the compatibility levels, depending on the unbalance of the system.

E.1 General

Non-linear load tests described in this document require each output phase of the UPS to be connected to a reference non-linear load as shown in Figure E.1 (or to a condition in which the UPS delivers such resulting output characteristics). This circuit contains a diode rectifier bridge that has a capacitor and a resistor in parallel on its output. The physical implementation of this circuit may consist of multiple circuits in parallel.



Refer to Clause E.4 for description of U, R_s, R_1, C, U_c.

Resistor R_s can be placed either on the AC or DC side of the rectifier bridge.

Figure E.1 – Reference non-linear load ≤ 8 kVA

U	**rated output voltage** of **UPS**, **RMS**;
f	**UPS** output frequency in Hz;
U_c	rectified voltage; $U_c = \sqrt{2} \times 0{,}92 \times 0{,}96 \times 0{,}975 \times U = 1{,}22 \times U$
S	**apparent power** across a **reference non-linear load**: **power factor** 0,7, i.e. 70 % of the **apparent power** S will be dissipated as **active power** in the two resistors R_1 and R_s;
R_1	**load** resistor: set to dissipate an **active power** equal to 66 % of the total **apparent power** S;
R_s	series line resistor: simulating a voltage drop in the power lines – see IEC 60364-5-52.

S = 2 kVA
U = 240 Vrms
Uc = 240 x 1.22 ≃ 300 V

Calculation to be used

$R_s = 0{,}04 \times U^2/S;$

$R_1 = U_c^2 / (0{,}66 \times S);$

$C = 7{,}5 / (f \times R_1)$

Rs = 1.15 ohm
R1 = 68.2 ohm
C = 1.83 mF

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