Application Note – Start up sequence for dc EV charging stations

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1. Introduction

This document presents the startup sequence of BMPU dc side voltage control for dc EV charging stations applications.

2. BMPU control frames

The control frames are RPDO messages sent from the master to the BMPU to set targets and operation commands. These frames are described as follows

Frame ID	ID offset	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
x250	x200	8	State request	Mode request	Grid conf request	V2L frequency setpoint	V2L voltage setpoint		Battery voltage setpoint	
x350	x300	8	Charging current limit		Discharging current limit		Active power setpoint		Reactive power setpoint	

The frames ids are given here for a BMPU addressed with the value 0. If it is addressed with the value 2 the frames ids would be 0x252, 0x352.

The definition of all these fields is described in the datasheet.

Pay attention these words are either bit fields words or raw values on which a gain must be applied. The user is in charge to do the conversion on his own. You can find this information in the datasheet as well.

The different messages take the following values

- **State request:** StandBy = 1, PowerOn=2, Charge=3.
- **Grid conf request:** Single-phase 16A =1, Single-phase 32A =2, Three-phase without neutral =3, Three-phase with neutral =4.
- **Mode request:** V2L mode=1, G2V/V2G with AC power control=2, G2V/V2G with DC voltage control=3.

  For DC charging station applications, G2V/V2G with DC voltage control mode is to be used. Only this mode is considered in this document with its setpoints and limitation inputs. Other setpoints (shaded in the table above and omitted).

- **Battery voltage setpoint:** voltage target on the DC (battery) side. The unit is 0.1V (this means that the value 5000 must be sent to require 500V target).

- **Charging current limitation:** current limitation target during charging operation. The unit 0.1A.
- **Discharging current limitation:** current limitation target during discharging operation. The unit 0.1A.

Example:

1. Requesting 440V with 5A charging current limitation/2A discharging current on three-phase grid with neutral

Frame ID	ID offset	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
x250	x200	8	**3**	**3**	**4**	0	0	**4400**		
x350	x300	8	**50**	**20**	0	0				

2. Change voltage setpoint to 0V

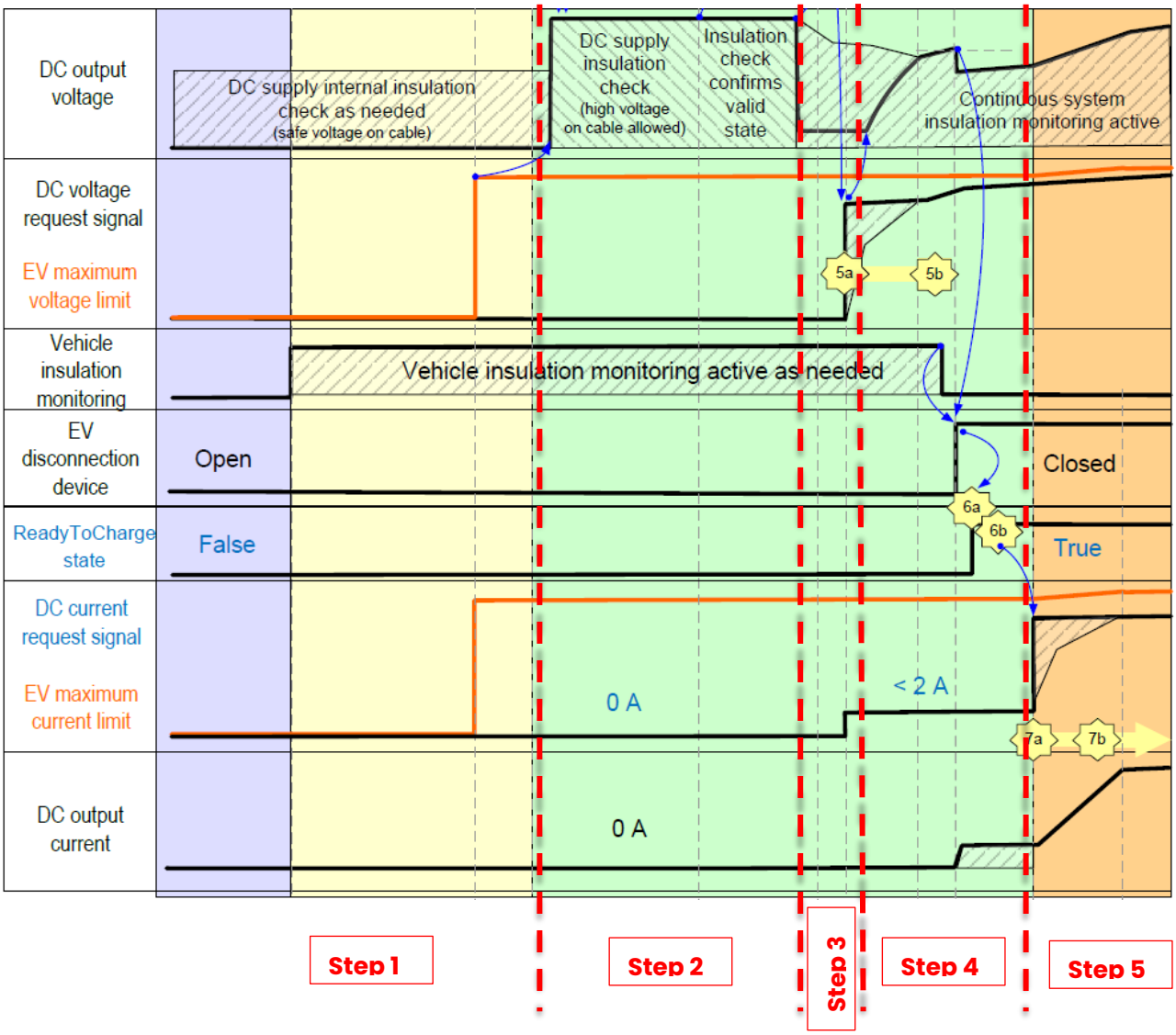
Frame ID	ID offset	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
x250	x200	8	**3**	**3**	**4**	0	0	**0**		
x350	x300	8	**50**	**20**	0	0				

3. Requesting StandBy to stop charging

Frame ID	ID offset	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
x250	x200	8	**1**	**3**	**4**	0	0	**0**		
x350	x300	8	**50**	**20**	0	0				

3. Start up with combined charging system (CCS)

Refer to Figure CC.1 – Sequence diagram for normal startup of IEC 61851-23



3.1. Sequence with previous firmware (Prior to v2.3.4r)

The following sequence is compatible with firmware versions prior to v2.3.4r Build 17120.

- **Step 1:** BMPU in stand by for configuration (mode and grid). Recall that mode request and grid conf are considered only with StandBy request.

Frame ID	ID offset	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
x250	x200	8	1		3	4	0	0		0

x350	x300	8	0	0	0	0

- **Step 2:** Output voltage set to EV maximum voltage limit for insulation check. BMPU receives Charge request with the desired voltage level (470V for the example). Charing current limitation must be different from zero to allow output control (2A for the example).
  To anticipate the next step request, discharging current is authorized (2A for the example).

Frame ID	ID offset	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
x250	x200	8	**3**	3	4		0	0		**4700**
x350	x300	8	**20**		**20**		0		0	

- **Step 3:** Output voltage is set to zero. The BMPU does not have an output diode, then output voltage must discharged either by fast discharge by requesting StandBy or by control by requesting 0V. Actual hardware is not equipped with fast discharge, then the second approach is to be used.

Frame ID	ID offset	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
x250	x200	8	3	3	4		0	0		**0**
x350	x300	8	20		20		0		0	

- **Step 4:** Output voltage is set to EV battery level (350V for the example)

Frame ID	ID offset	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
x250	x200	8	3	3	4		0	0		**3500**
x350	x300	8	20		20		0		0	

- **Step 5:** Output voltage is set to desired EV battery level (420V for the example). While the target is higher than the EV battery voltage, the control is in current control mode. The charging limitation current is set to EV maximum current limit with a ramp. This ramp can be applied by the master by sending a ramped target or configured to the desired value in the BMPU controller.

Frame ID	ID offset	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
x250	x200	8	3	3	4		0	0		**4200**
x350	x300	8	**300**		20		0		0	

- **From G2V to V2G** Output voltage is set to a value lower than the actual battery voltage (320V for the example). The discharging current limitation is set to the desired limit (32A for the example).

Frame ID	ID offset	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
x250	x200	8	3	3	4		0	0		**3200**
x350	x300	8	300		**320**		0		0	

3.2. Sequence with recent firmware (Since v2.4.4r)

Sequence with recent firmware version will be developed later. The updated sequence has been developed to be compatible with both CCS and Chademo. The main difference is that steps from 1 to 4 are performed with PowerOn request (DC voltage is controlled) while Precharge relay is closed (Main relay remains open) to limit inrush current (in Chademo there is no step where charger voltage is set around battery voltage → higher inrush current) then main relay is closed in step 5 by requesting Charge.

- **Step 1:** BMPU in stand by for configuration (mode and grid). Recall that mode request and grid conf are considered only with StandBy request.

Frame ID	ID offset	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
x250	x200	8	**1**	**3**	**4**		0	0		0
x350	x300	8	0		0		0		0	

- **Step 2:** Output voltage set to EV maximum voltage limit for insulation check. BMPU receives **Power On** request with the desired voltage level (470V for the example). This is one of the main differences with the previous firmware. In this case, a pre-charge circuit is used to limit inrush current when connected to the EV battery.

  Charing current limitation must be different from zero to allow output control (2A for the example). To anticipate the next step request, discharging current is authorized (2A for the example).

Frame ID	ID offset	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
x250	x200	8	**2**	3	4		0	0		**4700**
x350	x300	8	**20**		**20**		0		0	

- **Step 3:** The state request remains Power On. Output voltage is set to zero. Setting a non-null discharge current enables fast discharge of the output voltage

Frame ID	ID offset	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
x250	x200	8	2	3	4		0	0		**0**
x350	x300	8	20		20		0		0	

- **Step 4:** Output voltage is set to EV battery level (350V for the example)

Frame ID	ID offset	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
x250	x200	8	2	3	4		0	0		**3500**
x350	x300	8	20		20		0		0	

- **Step 5:** When EV sends Power Delivery Request with ReadyToChargeState, BMPU must receive **Charge** request to disable the pre-charge circuit and to close its DC main relay.

  Then, output voltage is set to desired EV battery level (420V for the example). While the target is higher than the EV battery voltage, the control is in current control mode. The charging limitation current is set to EV maximum current limit with a ramp. This ramp can be applied by the master by sending a ramped target or configured to the desired value in the BMPU controller.

Frame ID	ID offset	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
x250	x200	8	**3**	3	4		0	0		**4200**
x350	x300	8	**300**		20		0		0	

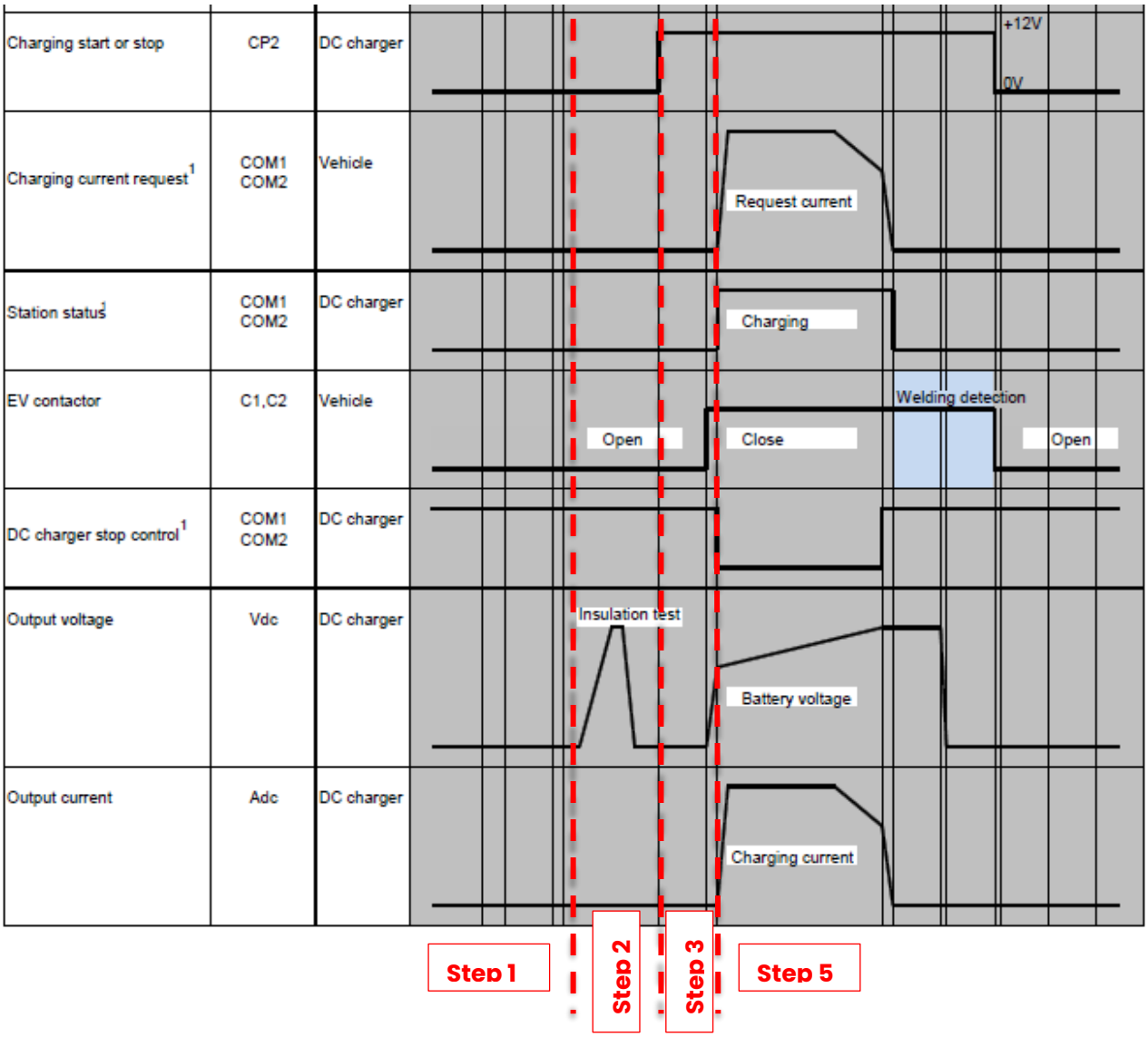
- **From G2V to V2G** Output voltage is set to a value lower than the actual battery voltage (320V for the example). The discharging current limitation is set to the desired limit (32A for the example).

Frame ID	ID offset	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
x250	x200	8	3	3	4		0	0		**3200**
x350	x300	8	300		**320**		0		0	

Remark: Going directly to Charge without requesting Power On will work as the previous firmware**.**

4. Start up with CHAdeMO

Refer to Figure AA.6 – Sequence diagram of system A of IEC 61851-23



For CHAdeMO protocol, same steps as for firmware V2.4.4 can be applied except for step 4. As it can be seen in the figure above, there is no step where battery voltage and charger output voltage are matched. Changing the request from **Power On** to **Charge** must be done after EV contactors closing to limit the current inrush (below 20A). Thus, the utilization of pre-charge circuit is necessary to avoid damaging the power unit.