Comment (clause 145.2.8, Page 162, Line 15)

(Comments r01-199, r01-366, r01-441, r01-444)

Up to D3.0 the spec was build according to the following concept:
Once Icon-2P_unb per class were specified, Ipeak-2P_unb is specified per the same 4-pair model with Ppeak_PD instead of Pclass_PD.
ILIM-2P is specified per the Equation ILIM-2P=Ipeak-2P_unb+2mA.

Now we have new parameter Iunbalance that is a maximum value that we should not cross and Icon-2P_unb that is a minumum current value that a PSE should support. The difference between these two values need to be very small due to cost considerations and no technical justification for larger margins.
The approach that was chosen is: Iunbalance=Icon-2P_unb -2mA.
(If we would have choose Iunbalnce>Icon-2P_unb then Icon-2P_unb will have to support Iunbalance which contradict the definition of Icon-2P_unb as a minimum value that represents the minimu current capacity support by the PSE) As a result, we need to add additional 2mA to the values of Icon-2P_unb (which are the true simulation results for the maximum current of the pair at worst case unbalance conditions) in order to keep the simulation results still valid when Iunbalance will be specified as Iunbalance=Icon-2P_unb -2mA.

In addition:
-In D3.1 we have updated the Icon-2P_unb numbers to address Rpse_min range up to specific maximum value (1 ohm or 0.5 pending the class) of Rpse_min. (The same done for Rpd_min range). This was done to verify that the value of Icon-2P_unb in the spec is correct for the current equations for Rpse_min/max and Rpd_min/max and the values of Rload and Rsource when Rpse_min and Rpd_min has a range of values and not only one value as the one used as the worst case model value. See annex B for all unbalance equation derivation process.

-In addition, we need to update ILIM-2P values per the latest updates on Icon-2P_unb in order to keep the correlations from ILIM-2P down to Icon-2P_unb to match physics as shown by simulations.

Suggested Remedy:

1. In Table 145-17 and Table 145-31, make the following changes:

A) In the 2nd row, in the assigned class column change from "5" to "5 to 8".

B) In the 2nd row, in the Value column change from "0.56"

To: "Iunbalance-2P=Icon-2P_unb - 0.002".

C) Delete rows 4-6.

Not part of the baseline
These changes is in sync with the concept that Ipeak_2P_unb is a maximum value and it can't be equal to ILIM-2P which is a minimum value although theoretically, by definition, they converge to Ɛ. That is why ILIM-2P=Ipeak-2P_unb+0.002.

2. Add 2mA to the values of Icon-2P_unb in Table 145-16 and changed them to:

Class 5: 0.562
Class 6: 0.697
Class 7: 0.795
Class 8: 0.939

3. Change ILIM-2P spec in Table 145-16 to:

[Adding 2mA to the values of ILIM_MIN due to the changes in (2)]

Parameter	Unit	Class 5	Class 6	Class 7	Class 8
ILIM-2P (spec) D3.2.	A	***0.588***	***0.729***	***0.832***	***1.002***

4. ***Change the factor in Equation 145-26 for class 5 from 2.17 to 2.182*** to correlate with updated simulations and mathematical derivation.

End of baseline

Annex A – Simulated data: Pclass_PD, Icon-2P_unb-Iunbalance

Updated simulations result for Icon-2P_unb:

a) For PSE and PD when in the 4-pair system model.
b) Calculating for PSE when connected to test verification model including Rpse_min range effect.
c) Calculating for PD when connected to test verification model including Rpd_min range effect.
d) Combining (b)+(c) for worst case values for Icon-2P_unb.
e) Determine Iunbalance=Icon-2P_unb-2mA.

Updated simulations result for Ipeak-2P_unb:

f) Simulating for Ipeak-2P_unb for PSE and PD when in the 4-pair system model.
g) Calculating Ipeak-2P_unb for PSE when connected to test verification model including Rpse_min range effect.
h) Calculating Ipeak-2P_un for PD when connected to test verification model including Rpd_min range effect.
i) Combining (f) and (g) for worst case Ipeak-2P_unb.
j) Determine ILIM-2P=Ipeak-2P_un+2mA. (Later to add extra 2mA due to the increase of 2mA in Icon-2P_unb] due to the definition that Iunbalance=Icon-2P_unb-2mA.

Operating conditions

	Units	Class 5	Class 6	Class 7	Class 8	
Vpse	V	50.3	50.3	52.31	52.31	
Pclass_PD	W	40	51	62	71.3	
Ppeak_PD (simulations)=1.05*Pclass_PD	W	42	53.55	65.1	74.865	
Ppeak_PD (spec)	W	42	53.5	65.1	74.9	
Long cable	m	100	100	100	100	
Short cable	m	2.65	2.65	2.65	2.65	
Connectors for short cable	-					0
Connectors for long cable	-					4
Cordage resistance per meter for short link	Ω/m					0.096
Cable resistance per meter for short link	Ω/m					0.074
Cable and cordage resistance per meter for long link	Ω/m					0.123
Vport_PSE_diff	mV	10	10	10	10	
Vport_PD_vdiff (imbedded in Equations 145-26 in IEEE802.3bt D3.1). Specified at 1mA.	mV	60	60	60	60	

Simulated data: Pclass_PD, Icon-2P_unb.

		Short Cable (2.65m)				Long Cable (100m)			
Parameter	Unit	Class 5	Class 6	Class 7	Class 8	Class 5	Class 6	Class 7	Class 8
I(R41) (***)=Icon-2P_unb	mA	547.464	679.133	781.398	887.222	483.366	638.831	764.430	911.615
Icon-2P_unb (spec)		560	695	793	937	560	695	793	937
PPD	W	39.991	50.988	61.986	71.283	39.996	50.994	61.992	71.289
VPSE-2P_1	V	50.194	50.165	52.152	52.129	50.203	50.168	52.150	52.118
VPSE-2P_2	V	50.232	50.207	52.197	52.176	50.196	50.158	52.138	52.102
PPSE (*)	W	40.053	51.088	62.122	71.463	44.560	59.012	73.508	87.707
VPD_IN	V	50.140	50.092	52.064	52.026	45.059	43.350	43.979	42.360
(**) Vport_PD_2p (spec)	V	44.3	42.5	42.9	41.1	44.3	42.5	42.9	41.1

(*) Note: Ppse is lower than expected at perfect balance cable due to the unbalance effect that works for us.
(**) Vport_PD_2p (spec) is lower than simulation results which is OK.
(***) simulated Icon-2P_max-2P is lower than the spec that includes test verification model inaccuracies including the valid range of Rpse_min for Equation 145-13 to be accurate. In addition, there is no need to sum the Rpse_min range setup effects and Rpd_min range setup effects accuracies due to very low chance to happen at the same time with PSE and high power dissipation at the PD for Type 4 to use Rpd_min=1 ohm.

Simulated data: Ppeak_PD, Ipeak-2P_unb

		Short Cable (2.65m)				Long Cable (100m)			
Parameter	Unit	Class 5	Class 6	Class 7	Class 8	Class 5	Class 6	Class 7	Class 8
I(R41) , simulated. (***)	mA	570.965	709.484	815.972	926.905	510.625	677.002	812	973
Adding test verification model margins + the effect of pse_min/Rpd_min range as we did for Icon-2P_unb =(Spec D3.1 values-simulated values).	mA	13.069	16.505	12.314	--------	----------	---------	---------	25.385
ILIM-2P (spec) D3.2. =Ipeak-2P_unb+0.002 (****)	mA	***586***	***727***	***830***					***1000***
ILIM-2P (spec)	mA	*562*	*702*	829	996	562	702	829	996
Ppeak_PD	W	41.991	53.537	65.085	74.847	41.996	53.543	65.091	74.852
VPSE-2P_1	V	50.189	50.158	52.145	52.120	50.197	50.160	52.140	52.104
VPSE-2P_2	V	50.228	50.201	52.190	52.168	50.189	50.149	52.126	52.088
Ppeak_PSE	W	42.059	53.65	65.235	75.045	47.095	62.558	78.095	93.537
VPD_IN (over_load)	V	50.131	50.081	52.052	52.011	44.759	42.930	43.456	41.695
(**) Voverload_2P (spec)	V	41.4	41.4	40.4	40.4	41.4	41.4	40.4	40.4
(**) Voverload_2P (calculated at worst case conditions 6.25Ω cable with 100% balance) for SS PD	V	-	-	-	-	46.169	44.039	42.039	42.405

(**) Simulated and calculated VPD_IN (over_load) values is higher than spec. Spec is OK.
(***) simulated Ipeak-2P_unb. ILIM-2P need to be Ipeak-2P_unb+0.002.
(****) Need to update ILIM-2P in D3.2 per the results above.

The following is needed to be added to the specifications

Parameter	Unit	Class 1	Class 1	Class 3	Class 4	Class 5
Ppeak_PD	W	5	8.36	14.4	28.3	37.4325
(**) Voverload_2P (calculated at worst case conditions 12.5Ω cable with 100% balance) for DS PD	V	48.717	47.814	46.095	41.470	40.425

Equations Derivations

#	Parameter (Sim October 2017)	Units	Class 5	Class 6	Class 7	Class 8	Notes
1	I(R41)	mA	547.464	679.133	781.398	887.222	
2	I(R42)	mA	250.348	339.032	409.467	483.288	
3	-I(R20)	mA	510.422	640.223	741.550	846.705	
4	-I(R19)	mA	287.390	377.941	449.315	523.806	
5	V(VPSE_A)	V	50.194	50.165	52.152	52.129	
6	(VPSE_B)	V	50.232	50.207	52.197	52.176	
7	(PPSE_PI)	W	40.055	51.090	62.125	71.466	
8	(ICON)	A	797.812m	1.0182	1.1909	1.3705	
9	(IDIFF_POS)	A	297.116m	340.101m	371.931m	403.934m	
10	V(VPD_IN)	V	50.140	50.092	52.065	52.026	
11	(PPD)	W	39.991	50.988	61.985	71.283	
12	(RPSE_MIN_A)	Ω	57.734m	61.275m	63.202m	64.729m	
13	(RPSE_MAX_B)	Ω	91.000m	91.000m	91.000m	91.000m	
14	(RCH_MIN_A)	Ω	87.354m	87.354m	87.353m	87.353m	
15	(RCH_MAX_B)	Ω	100.515m	100.515m	100.515m	100.515m	
16	(RPD_MIN_A)	Ω	639.749m	539.760m	484.449m	440.108m	
17	(RPD_MAX_B)	Ω	1.5248	1.1874	1.0203	895.630m	
18	(RUNB)	m	372.414m	334.034m	312.320m	294.732m	
19	(U_RATIO)	---	2.1868	2.0032	1.9083	1.8358	
20	(PSE_EQUATION_BETA)	---	-35.254m	-31.744m	-29.611m	-27.829m	
21	(PD_EQUATION_BETA)	---	125.765m	106.212m	95.796m	87.678m	
#	Parameter (Spec D3.1)	Units	Class 5	Class 6	Class 7	Class 8	Notes
21	(U_RATIO) PSE	---	2.182	1.999	1.904	1.832	(1) U_error: 0.5%, 0.55%, 6.7%, 6%. Theoretical, U, need to be the same number.
22	(U_RATIO) PD		2.17	1.988	1.784	1.727	
23	(PSE_EQUATION_BETA)	---	-40m	-40m	-30m	-30m	
24	(PD_EQUATION_BETA)	---	125m	105m	80m	74m	
#	Parameter (Spec D3.2)	Units	Class 5	Class 6	Class 7	Class 8	Notes
25	(URATIO) PSE	---	2.182	1.992	1.904	1.832	
26	(URATIO) PD		2.182	1.988	1.784	1.727	
27	(PSE_EQUATION_BETA)	---	-40m	-40m	-30m	-30m	
28	(PD_EQUATION_BETA)	---	125m	105m	80m	74m	

1. Theoretically the U factor (which is the alfa factor in equation 145-13 and Equation 145-26 is identical. However, in the PD equation, this factor was reduced in previous drafts by ~6% to account for Extended power for classes 7 and 8 which practically will use active diode bridges that easily can meet the slightly tighter unbalance requirement that was derived with diodes in the PD for class 7 and 8 as a worst case.
2. Changes proposed for D3.2 are marked with RED.

Test verification model numbers:

#	Parameter (Sim October 2017)	Units	Class 5	Class 6	Class 7	Class 8	Notes
12	(RPSE_MIN_A)	Ω	57.734m	61.275m	63.202m	64.729m	No changes needed for D3.2
13	(RPSE_MAX_B)	Ω	91.000m	91.000m	91.000m	91.000m	
14	(RCH_MIN_A)	Ω	87.354m	87.354m	87.353m	87.353m	
15	(RCH_MAX_B)	Ω	100.515m	100.515m	100.515m	100.515m	
16	(RPD_MIN_A)	Ω	639.749m	539.760m	484.449m	440.108m	
17	(RPD_MAX_B)	Ω	1.5248	1.1874	1.0203	895.630m	

We got insignificant changes in October 2017 simulations above at low link section resistance conditions. As a result, the values for the test verification model obviously will have even lower differences for the High link section resistance.

Annex B - Derivation of Equations 145-13, 145-26, Resource (Equation 145-27) and Rload (Table 145-18)

System End to End Pair to Pair Resistance Unbalance (PSE, Channel and PD), E2EP2PRunb, in short, Runb :

(1) $$Runb = \frac{(Rpse_{\max} - Rpse_{\min}) + (Rch_{\max} - Rch_{\min}) + (R_{PD\max} - R_{PD\min})}{(Rpse_{\max} + Rpse_{\min}) + (Rch_{\max} + Rch_{\min}) + (R_{PD\max} + R_{PD\min})}$$

All the resistance in Equation 1 are effective resistances i.e. the resistance is the equivalent of the voltage drop on the element divided by the current through the element. This method simplifies the analysis by taking in consideration nonlinear effect of voltage difference between the pairs caused by diodes or cause by the PSE source voltage differences between the pairs.

Presenting (1) is a shorter form:

(2) $$Runb = \frac{\left(\sum R_{\max} - \sum R_{\min}\right)}{\left(\sum R_{\max} + \sum R_{\min}\right)}$$

Opening and solving (2) in terms of Rmax/Rmin ratio and E2EP2PRunb:

$$\left(\sum R_{\max} - \sum R_{\min}\right) = Runb \cdot \left(\sum R_{\max} + \sum R_{\min}\right)$$

$$\sum R_{\max} - \sum R_{\min} = Runb \cdot \sum R_{\max} + Runb \cdot \sum R_{\min}$$

$$\sum R_{\max} - Runb \cdot \sum R_{\max} = Runb \cdot \sum R_{\min} + \sum R_{\min}$$

$$(1 - Runb) \cdot \sum R_{\max} = (1 + Runb) \cdot \sum R_{\min}$$

The value of Runb is taken from simulations by calculating current unbalance from Iunb=(Imax-Imin)/(Imax+Imin)= Runb.

(3) $$\frac{\sum R_{\max}}{\sum R_{\min}} = \frac{(1 + Runb)}{(1 - Runb)} = U$$

As a result from (3):

(4) $$\frac{\sum R_{\max}}{\sum R_{\min}} = U$$

And we get the general system unbalance equation:

(5) $$U \cdot \sum R_{\min} - \sum R_{\max} = 0$$

The general system unbalance equation (5) can be expended back by expressing all its components:

(6) U*Rpse_min + U*Rch_min + U*Rpd_min - Rpse_max - Rch_max - Rpd_max=0

Deriving the PSE PI equation

Deriving from (6) the PSE PI equation by solving for Rpse_max:

(7) Rpse_max =U*Rpse_min +U*Rch_min + U*Rpd_min - Rch_max - Rpd_max

(8) Rpse_max =U*Rpse_min +β1 (This is the form of Equation 145-13 in D3.1)

β1 = U*Rch_min + U*Rpd_min - Rch_max - Rpd_max

(The values are taken from simulation by finding R_i=dv_i/I_i)

Additional information:

1. Equation 8 can be presented as function of Rload_min and Rload_max during testing for compliance which makes it clear why PSE cannot be tested only for Icon-2P_unb by only connected it to Rload_min and Rload_max and need also to meet equation 8 (or 145-13 in IEEE802.3bt D3.1).
2. PSE must be designed for the worst case unbalance since it needs to support all PDs (PDs on the other hand need to be designed only for their required Pclass-PD or lower power).

From (7) Rpse_max =U*Rpse_min +U*(Rch_min + Rpd_min) – (Rch_max + Rpd_max)

By definition:

Rload_max =Rch_max+Rpd_max

Rload_min =Rch_min+Rpd_min

(9) Rpse_max =U*Rpse_min + U* Rload_min – Rload_max = U*Rpse_min + **β1**

Derivation of the PD PI equation:

Deriving from (6) the PD PI equation:

(6) U*Rpse_min + U*Rch_min + U*Rpd_min - Rpse_max - Rch_max - Rpd_max =0

From (6) we can solve for Rpd_max :

(10) Rpd_max = U*Rpd_min + U*Rpse_min + U*Rch_min - Rpse_max - Rch_max

(11) Rpd_max = U*Rpd_min + β2 **(This is the form of Equation 145-26 in D3.1)**

β2= U*Rpse_min + U*Rch_min - Rpse_max - Rch_max

Additional information:

1. Equation 10 can be presented as function of Rsource_min and Rsource_max during testing for compliance.
2. PD must be designed for the worst-case unbalance per its required Pclass_PD or lower power.
3. It is clear that if the PD meets Equation 10, then it will meet Icon_2P_unb by definition since Equation 10 is a complete solution of system equation (6).

(10) Rpd_max = U*Rpd_min + U*Rpse_min + U*Rch_min - Rpse_max - Rch_max

By definition:

Rsource_max =Rpse_max + Rch_max

Rsource_min =Rpse_min + Rch_min

(12) Rpd_max = U*Rpd_min + U* Rsource_min – Rsource_max = U*Rpd_min + β2

Deriving Rload_min and Rload_max when PSE is tested for compliance

From (6): U*Rpse_min + U*Rch_min + U*Rpd_min - Rpse_max - Rch_max - Rpd_max =0

Finding Rload_max and Rload_min as function of the other system parameters:

By definition the PSE is loaded by:

Rload_max =Rch_max+Rpd_max

Rload_min =Rch_min+Rpd_min

As a result from (6):

(7) Rload_max = Rch_max+ Rpd_max = U*Rch_min + U*Rpd_min U*Rpse_min - Rpse_max -

(8) Rload_max = U*Rload_min + (U*Rpse_min - Rpse_max)

The values of Rload_max and Rload_min (Table 145-18 in D3.1) are measured by simulation and are identical to the computed Rload_min and Rload_max in equation 8.

Deriving Rsource_min and Rsource_max when PD is tested for compliance

From (6): U*Rpse_min + U*Rch_min + U*Rpd_min - Rpse_max - Rch_max - Rpd_max =0

Finding Rsource_max and Rsource_min as function of the other system parameters:

By definition the PD is connected to the following source resistance:

Rsource_max = Rpse_max + Rch_max

Rsource_min = Rpse_min + Rch_min

As a result from (6):

(9) Rsource_max = Rpse_max + Rch_max =U*Rpse_min +U*Rch_min +(U*Rpd_min - Rpd_max)

(10) Rsource_max = U*Rsource_min +(U*Rpd_min - Rpd_max)

The values of Rsource_max and Rsource_min (Clause 33.3.8.9 D3.1) are measured by simulation and are identical to the computed Rsource_min and Rsource_max in Equation 9. For simplicity, due to the fact that the values for Rsource_min/max are very close for all classes in short and long link, we have find a single equation by curve fitting to describe Rsource_max as a function of Rsource_min instead of using Table form for Rsource_min/max for each class as we did for Rload_min/max.