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 - 0.01".

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. Update Icon-2P_unb in Table 145-16 as follows:

Class 5: 0.555
Class 6: 0.687
Class 7: 0.789
Class 8: 0.943

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

Parameter	Unit	Class 5	Class 6	Class 7	Class 8
ILIM-2P (spec) D3.2.	A	***0.578***	***0.716***	***0.823***	***0.992***

4. ***Change the factors in Equation 145-26 as follows:***
   -for class 5 from 2.17 to 2.182

5. ***Update Rload_min/max numbers as follows:***

Table 145–18—PSE unbalance test fixture resistances

PSE Class	$R_{load1\_min}(\Omega)$	$R_{load1\_max}(\Omega)$	$R_{load2\_min}(\Omega)$	$R_{load2\_max}(\Omega)$	Additional information
5	0.087	0.101	0.638	1.518	Low link section resistance conditions. All resistances within ± 1% range.
6			0.538	1.183	
7			0.483	1.017	
8			0.439	0.894	
5	5.41	6.25	0.704	1.026	High link section resistance conditions. All resistances within ± 1% range.
6			0.564	0.822	
7			0.491	0.717	
8			0.430	0.629	

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 at the PSE PI	V	50	50	52	52	
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
1	Icon-2P_unb For the lowest 4-pair model Rpse_min/Rpse_max value (simulation results)	mA	549.37	681.2	783.56	889.2			767.3	914.5
2	I(R41) =Icon-2P_unb For Rpse_min and Rpd_min range: Class 5,6: Up to 1 Ω for PSE, adding 0.3 Ω for PD to complete total PD to ~1 Ω total. Class 7,8: Up to 0.5 Ω for PSE, adding 0.3 Ω for PD to complete PD to total ~1 Ω total	mA	Same	same	783.9	NA			776	937.31
3	Extended power for class 8 (89.7W). I(R41) =Icon-2P_unb For Rpse_min and Rpd_min range: Class 8: Up to 0.5 Ω for PSE. For PD, Rpd_min is as in the 4-pair model.	mA	NA	NA	NA	1.0971A	NA	NA	NA	NA
4	Test verification components accuracy effect on Icon-2P_unb, Δ Icon-2P_unb.	mA								
5	Icon-2P_unb (spec D3.1)		560	695	793	937	560	695	793	937
6	Icon-2P for the spec should be (adding 2mA for Iunbalance spec) , for D3.2	mA	552	684	786					940 Ext 1.099
7	Ipeak-2P_unb simulations	mA	576	714.27	821.2					990 Ext: 1.165A
8	ILIM-2P=Ipeak-2P_unb+2mA (Spec D3.1).	mA	0.562	0.702	0.829					0.996
9	ILIM-2P=Ipeak-2P_unb+2mA (Spec D3.2).	mA	578	716	823					992 Ext: 1.167A

Notes:

1. Ppse (not shwon here) is lower than expected at perfect balance cable due to the unbalance effect that works for us in lowering cable resistance.
2. The test verification components accuracy is limited to ±1%. The effect of changing the values of the test verification model components in the range from -1% to 1% on Icon-2P_unb (item 3) is subtracted from the simulation results in row 2 to ensure PSE PI to meet Icon-2P_unb by Equation 145-13 in D3.1.
3. PSE PI is tested with test verification model consist of Rload_min1/2 and PD is tested with the PD test verification model with Rsource_min/max independently from the PSE.
4. It is possible that if a PSE that implemented with Rpse_min upper range value and a PD with Rpd_min upper range value will be connected as a system, the total Icon-2P_unb will increase and this number should be the final spec number. As a result, the simulation executed for worst case effect of Rpse_min+Rpd_min which in most cases the effect of Rpd_min range was negligible.

Equations Derivations

1. Equations are derived at short link
2. Rload and Rsource are derived from the data in short ling and long link conditions

Short Link results:

#	Parameter (Sim October 2017)	Units	Class 5	Class 6	Class 7	Class 8
1	I(R41)	mA	549.386m	681.223m	783.580m	889.377m
2	I(R42)	mA	251.608m	340.448m	410.967m	484.786m
3	-I(R20)	mA	512.302m	642.283m	743.707m	848.840m
4	-I(R19)	mA	288.692m	379.387m	450.840m	525.322m
5	V(VPSE_A)	V	49.996	49.994	51.993	51.992
6	V(VPSE_B)	V	50.035	50.036	52.038	52.039
7	V(PPSE_PI)	W	40.056	51.092	62.127	71.468
8	V(ICON)	A	800.993m	1.0217	1.1946	1.3742
9	V(IDIFF_POS)	A	297.778m	340.775m	372.613m	404.590m
10	V(VPD_IN)	V	49.942	49.921	51.905	51.889
11	V(PPD)	W	39.992	50.989	61.986	71.284
12	V(RPSE_MIN_A)	Ω	57.798m	61.321m	63.238m	64.756m
13	V(RPSE_MAX_B)	Ω	91.000m	91.000m	91.000m	91.000m
14	V(RCH_MIN_A)	Ω	87.350m	87.351m	87.351m	87.351m
15	V(RCH_MAX_B)	Ω	100.516m	100.516m	100.515m	100.515m
16	V(RPD_MIN_A)	Ω	637.957m	538.467m	483.417m	439.307m
17	V(RPD_MAX_B)	Ω	1.5184	1.1834	1.0173	893.479m
18	V(RUNB)	m	371.761m	333.547m	311.928m	294.427m
19	V(URATIO)	---	2.1835	2.0010	1.9067	1.8346
20	V(PSE_EQUATION_BETA)	---	-35.202m	-31.700m	-29.574m	-27.800m
21	V(PD_EQUATION_BETA)	---	125.415m	105.970m	95.609m	87.537m
22	V(VPSE_PI_B_POS,VPSE_PI_A_NEG)	---	50.005	50.005	52.005	52.005

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. Some number that used in the spec was rounded for margin and other considerations.

Long link results:

#	Parameter (Sim October 2017)	Units	Class 5	Class 6	Class 7	Class 8
1	I(R41)	mA	485.633m	641.504m	767.305m	914.460m
2	I(R42)	mA	406.338m	539.969m	647.837m	774.030m
3	-I(R20)	mA	484.550m	640.618m	766.579m	913.922m
4	-I(R19)	mA	407.421m	540.856m	648.563m	774.568m
5	V(VPSE_A)	V	50.015	50.015	52.016	52.016
6	V(VPSE_B)	V	50.008	50.005	52.003	52.001
7	V(PPSE_PI)	W	44.609	59.086	73.602	87.817
8	V(ICON)	A	891.971m	1.1815	1.4151	1.6885
9	V(IDIFF_POS)	A	79.295m	101.535m	119.469m	140.431m
10	V(VPD_IN)	V	44.847	43.168	43.813	42.228
11	V(PPD)	W	39.996	50.994	61.991	71.289
12	V(RPSE_MIN_A)	Ω	55.408m	60.412m	62.967m	65.065m
13	V(RPSE_MAX_B)	Ω	91.000m	91.000m	91.000m	91.000m
14	V(RCH_MIN_A)	Ω	5.4047	5.4047	5.4047	5.4047
15	V(RCH_MAX_B)	Ω	6.2500	6.2500	6.2500	6.2500
16	V(RPD_MIN_A)	Ω	704.416m	564.331m	491.233m	430.285m
17	V(RPD_MAX_B)	Ω	1.0265	822.235m	716.816m	629.510m
18	V(RUNB)	m	88.898m	85.939m	84.422m	83.169m
19	V(URATIO)	---	1.1951	1.1880	1.1844	1.1814
20	V(PSE_EQUATION_BETA)	---	24.779m	19.229m	16.421m	14.131m
21	V(PD_EQUATION_BETA)	---	184.647m	151.788m	134.994m	121.158m
22	V(VPSE_PI_B_POS,VPSE_PI_A_NEG)	---	50.005	50.005	52.005	52.005

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.