IEEE802.3 4P Study Group

Analysis of usable PD input power in 4P system

July 2013
Geneva Switzerland

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Supporters:

Objective

- To generate objective equivalent to the following:
  - The Project shall support a minimum of TBD watts at the PD PI
    - We need to specify the TBD.

Strategy Discussion - 1

- We already have Type 2 PD power of 25.5W
- A potential of at least twice the Type 2 PD exists (51W)
- The question is if at least 51W can be guaranteed without any working assumptions or limitations.
- We can’t imply or discuss implementations and we can't assume specific future implementations.
- However we can starting with worse case conditions assumption so it will help to meet current IEEE802.3 requirements for 2P systems in order to meet backwards interoperability and compatibility requirements.

Strategy Discussion - 2

- List of known data

1	Iport	600mA max.	Over 2P
2	Temperature rise	10°C max for 2x600mA max=1.2A, for 100 cables in a bundle per current spec.	Over each 2P simultaneously from temperature rise point of view.
3	Type 1 and Type 2 magnetic components	Designed for Type 1/2 Iport with margins for Icut	Over each 2P
4	Over current limitations	Icut / ILIM	Over 2P
5	PSE 4P output power	2x600mAx50V=60W	Over 4P
6	PD 4P input power	At least TBD Watts. See following discussion.	Over 4P

Strategy Discussion - 3

- Under **ideal conditions** where:
  - The same source voltage is applied to ALT A and ALT B and
  - The imbalance between Pairs (channel wise) is zero.

We can easily see the following outcome:

a) The power is equally divided between all 4 pairs so we can easily assume no effects on Icut, Ilim, magnetics and other parameters or adding factors that may or may not be a function of specific implementation in case of imbalanced P2P current.

a) If PD load is internally set to different power levels over each 2P in a way that current/power limitations as specified for 2P operation over each 2P is not violated.

- Than the answer is simply 2x25.5W=51W[1] is available so the objective can be: "The Project shall support a minimum of 51watts at the PD PI"

- However what would be the answer when the above conditions are different (Non-ideal)?.

1. 2x(0.6A*60V)-2x(12.5Ωx0.6A^2)=51W

Strategy Discussion - 4

- The following parameters need to be evaluated prior to set our conclusions:
- What is the Pair to Pair (P2P) current imbalance that will not affect:
  - Type 1 and Type 2 magnetic components performance
  - Cable temperature rise
  - Protection means if required such Overload conditions over 2P systems[1]

Notes:

1. could be argued if it is implementation dependent or not however the discussion is limited to (a) worst case scenarios (b) to what we have now and not what we potentially could have which is not or may not guaranteed)

Introduction: Pair Imbalance - 1

- Pair resistance imbalance is the resistance imbalance between the conduction path in a pair. Its requirements are defined in IEEE802.3-2012 as and ISO/IEC 11801. Pair imbalance affects channel data performance and magnetic components.
- Why we review it?
- Reviewing the concept of "unbalanced" calculations. It will help us later to calculate pair to pair unbalance which is relevant for 4P model.
- In 4P operation we have two cases of current imbalance:

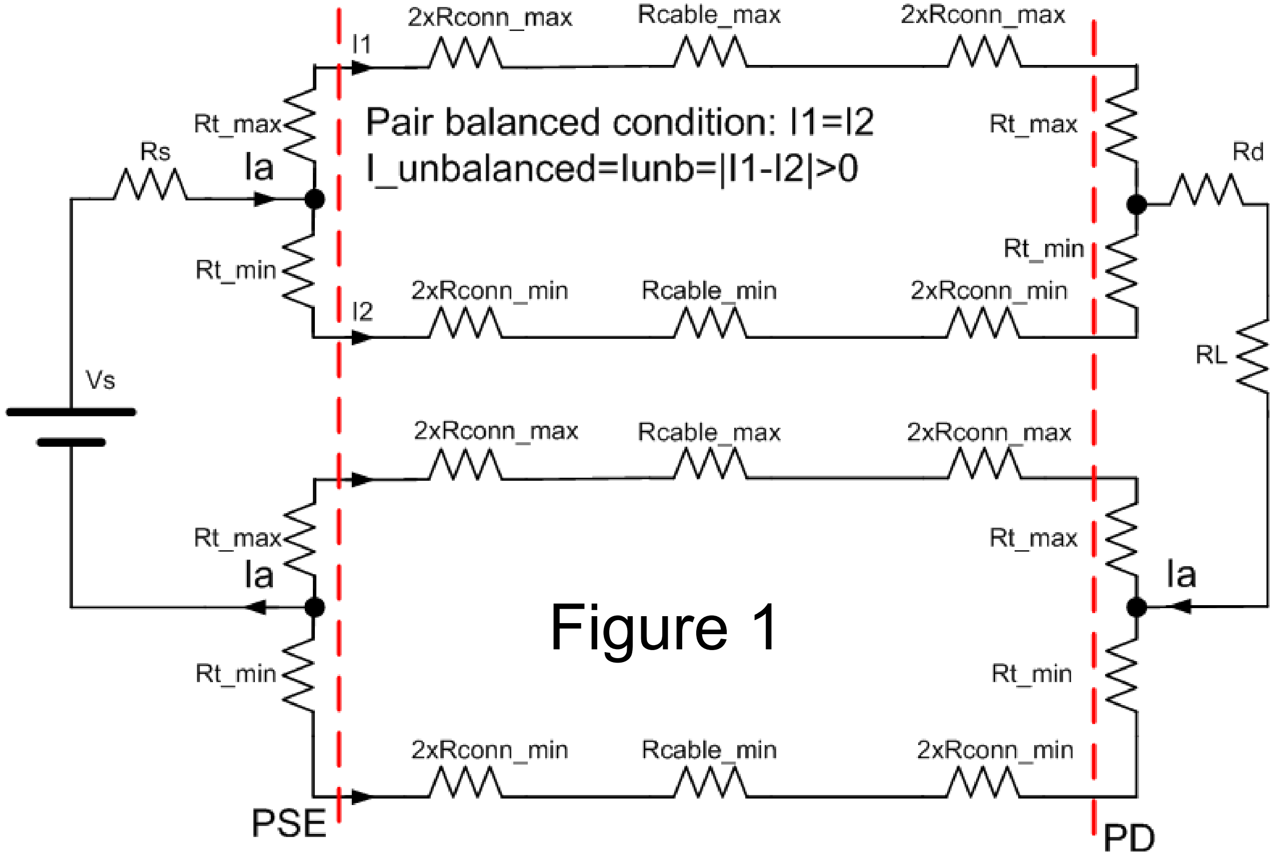
a) The imbalance between two wires in a pair.
b) The imbalance between ALT A current and ALT B current that may affect (a).

Introduction: Pair Imbalance - 2

- Pair resistance imbalance: The resistance imbalance between the conduction path in a pair. Its requirements are defined in IEEE802.3-2012 as and ISO/IEC 11801:

$$R_{UNB}[\%] = 100\% \cdot \frac{\sum R\max - \sum R\min}{\sum R\max + \sum R\min}$$

$$I_{UNB} = Ia \cdot R_{UNB}$$



- Rs is the resistance from vs. to transformer center tap.
- Rd is the resistance between transformer center tap to the load.
- Ia is the port current
- Rmin=Rmax – Runb, per component.

Introduction: Pair Imbalance - 3

- Simplifying 2P model drawing

R1_max=max{2xRt+4*Rconn+Rc}

R1_min=min{2xRt+4*Rconn+Rc}

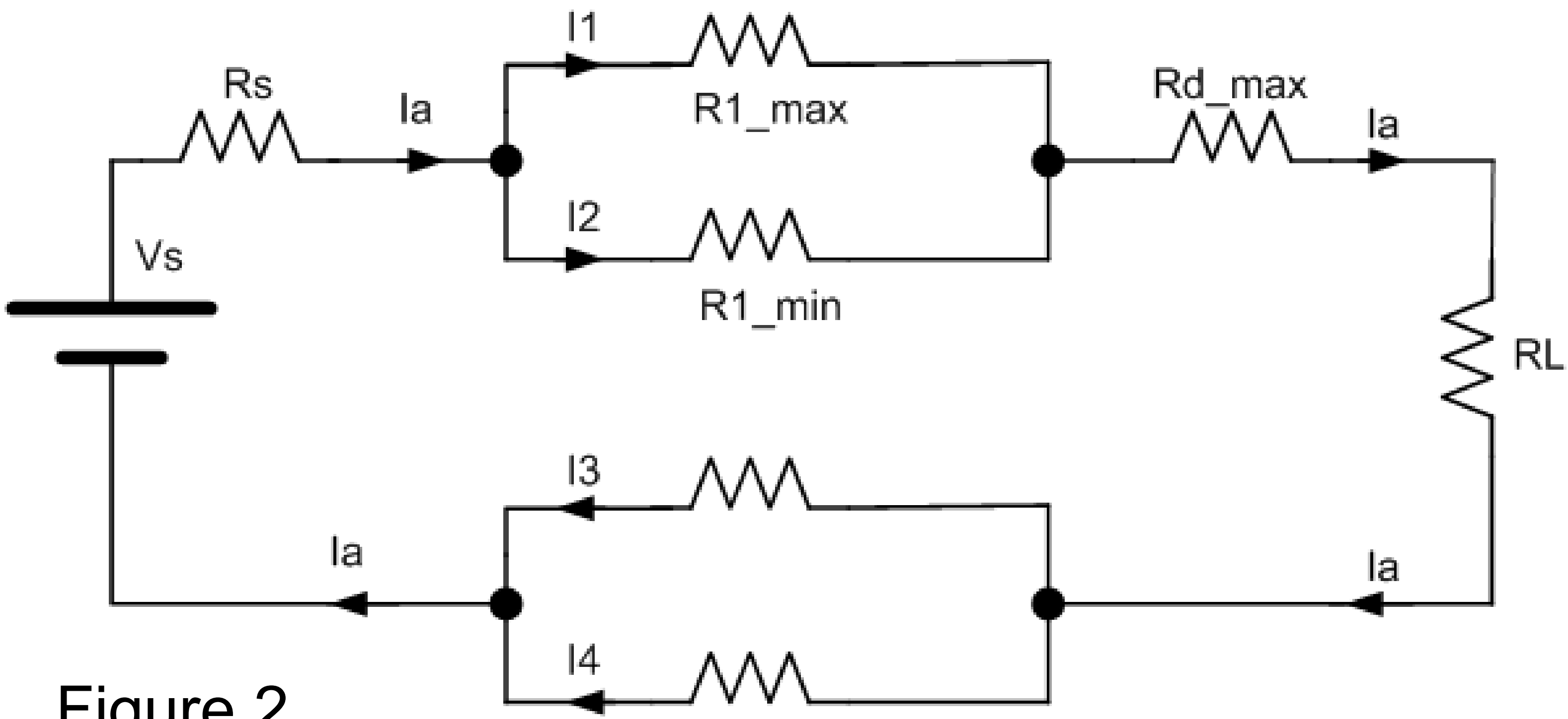


Figure 2

Introduction: Pair Imbalance - 4

- Using simple and fast technique to calculated imbalance
  - Use first, worst case analysis. If we can leave with the results. We done.
  - If we can't, use statistical analysis. Compute the rms value of all component resistance imbalance added to the cable (connectors, transformers etc.)
    - RMS value is the root of sum of squares of the imbalance of the all variables added to the cable

Introduction: Pair Imbalance - 5

- Specifications and data used in the pair model[2,3].

#	Component	Rmax [Ω]	Runb[Ω]	Runb[%]	Rmin[Ω]
1	Wire	9.5[3] /100m		2	=Rmax[L]*(1-2%)/(1+2%)
2	Channel			3	3% is maximum value for any channel length ≤100m.
3	Connector	0.2	0.05		Rmax- 0.05

- Transformer data

#	Component	Rmax [Ω]	Runb[Ω]	Runb[%]	Rmin[Ω]
1	Transformer winding	0.5[4]	0.03		Rmax – 0.05

- Notes
- 2. See www.ieee802.org/3/at/public/2006/01/diminico_1_0106.pdf
- 3. Based on 19Ω/100m loop resistance as defined by 61156-5 Cable - 3.2.1 Conductor resístanse. Analysis results are not significantly changed if cable resistance is increased to 23.4Ω/m. (25Ω - 8*0.2 Ω to reflect 25Ω total channel loop resistance.
- 4. Rmax for transformers is for Type 1 systems (vendor data, not spec.). may be lower in higher power devices than Type 1 systems.

Introduction: Pair Imbalance - 6

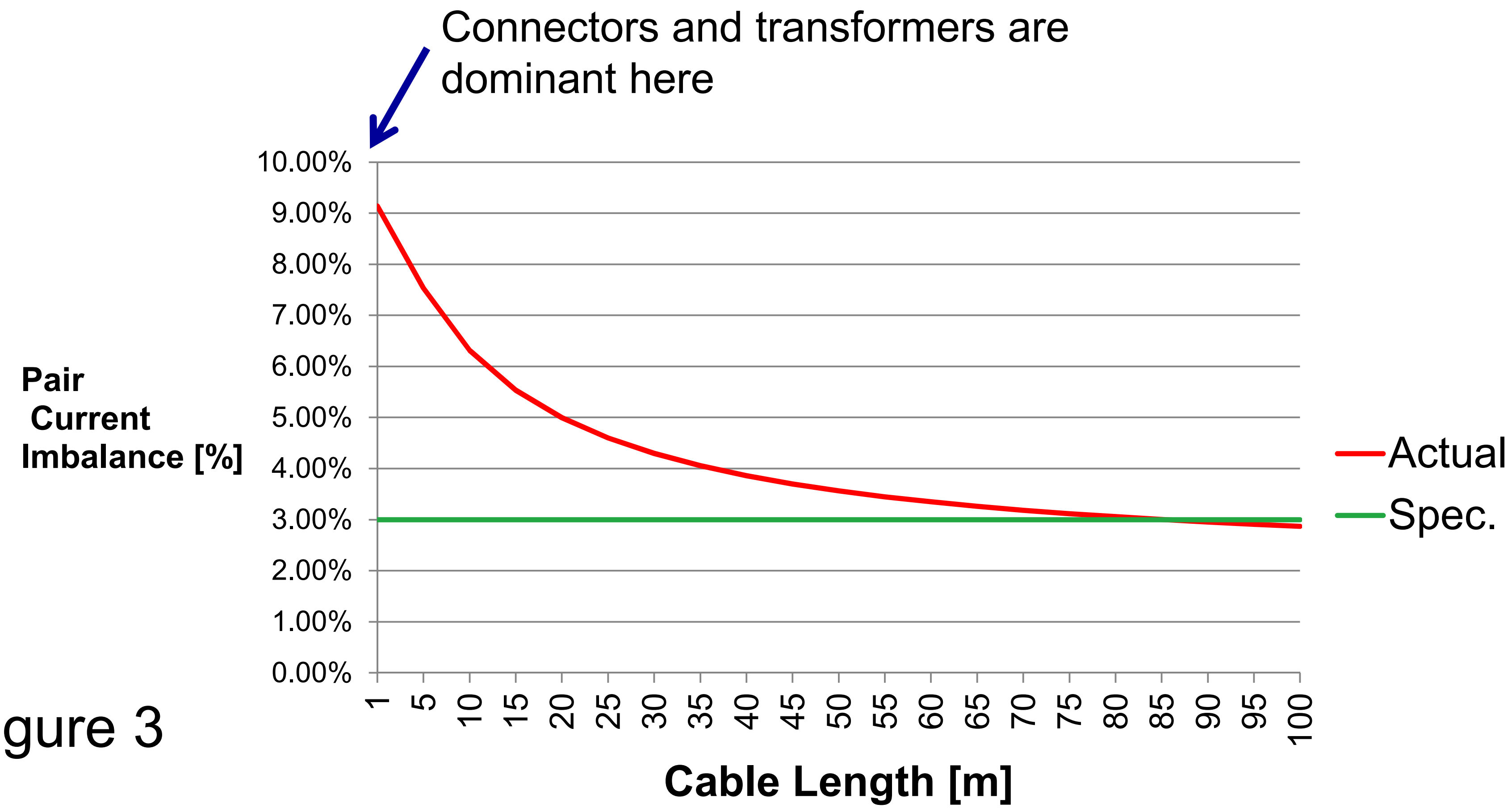


Figure 3

<u>How we resolved actual vs specification?</u>

Using statistical calculations instead of worst case analysis, actual transformers were designed for higher Iunb, reduction of inductance was tolerated by PHYs, typical Cable length was >>1m and Inductance specifications and droop concept was generate to allow improved design flexibility. So life was good. If not, (rare condition), the PD has handle it by using balancing technique as recommended in earlier versions of IEEE802.3 standard annexes.)

Pair to Pair (P2P) Imbalance - 1

- Pair to Pair (P2P) resistance imbalance: The resistance imbalance between wires in different pairs.
  - This parameter is not defined by the cabling standards nor by the IEEE standard[1].
  - In order to start some meaningful analysis, we will use:

a) Lab tests of current imbalance between pairs in a 4P system[2]

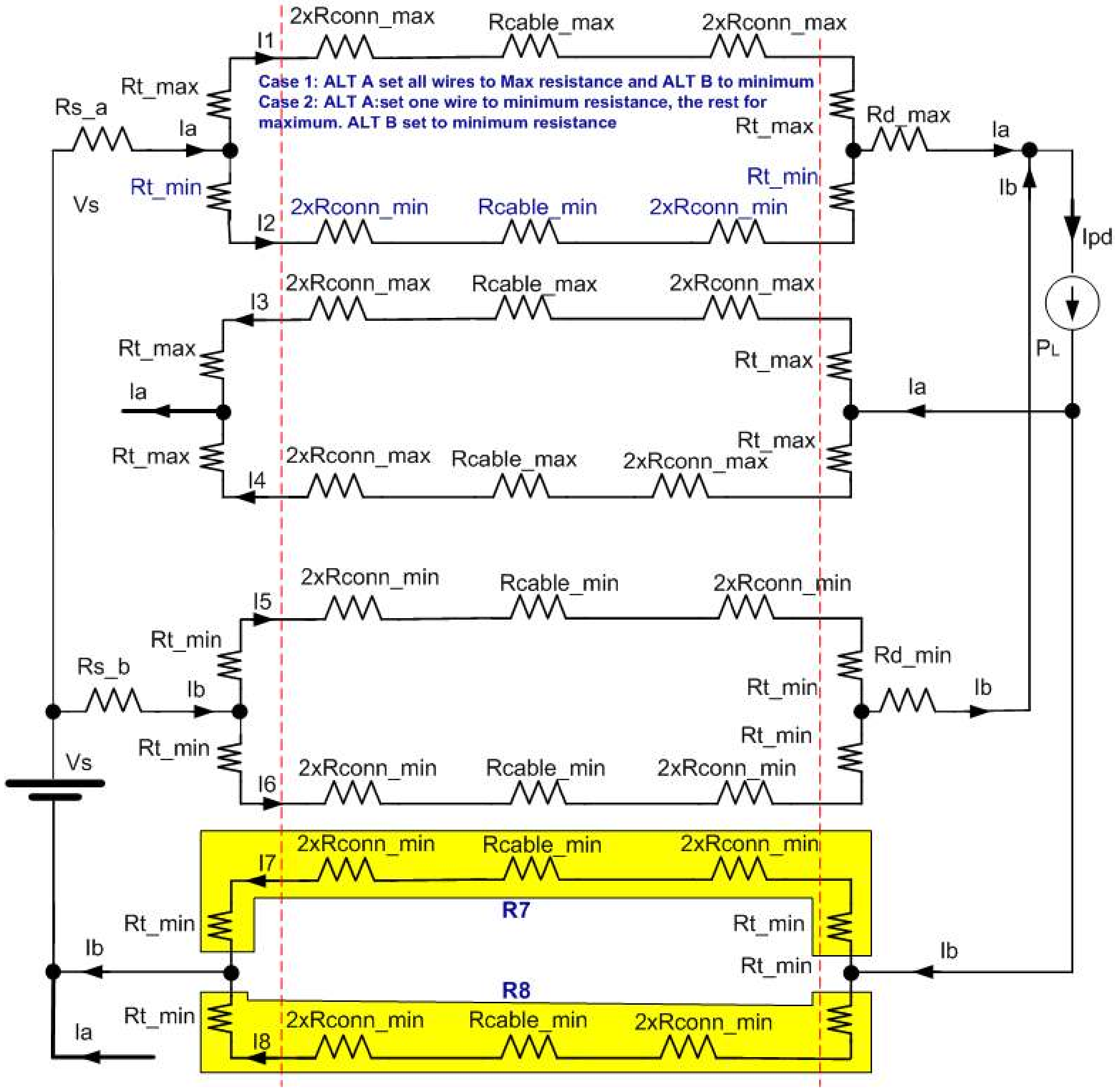
b) Lab measurements of P2P resistance imbalance of cables from different vendors[3]

c) Worst case calculations of P2P resistance imbalance based on pair imbalanced data if due to the fact that pair and P2P imbalance is within the same range.

Notes:

1. Cable vendor agree to test and supply P2P imbalanced data
2. Data analysis is in progress
3. We tested 6 vendors resulting with P2P max imbalance of <2%. In most cases it was <1%.

Pair to Pair (P2P) Imbalance - 2



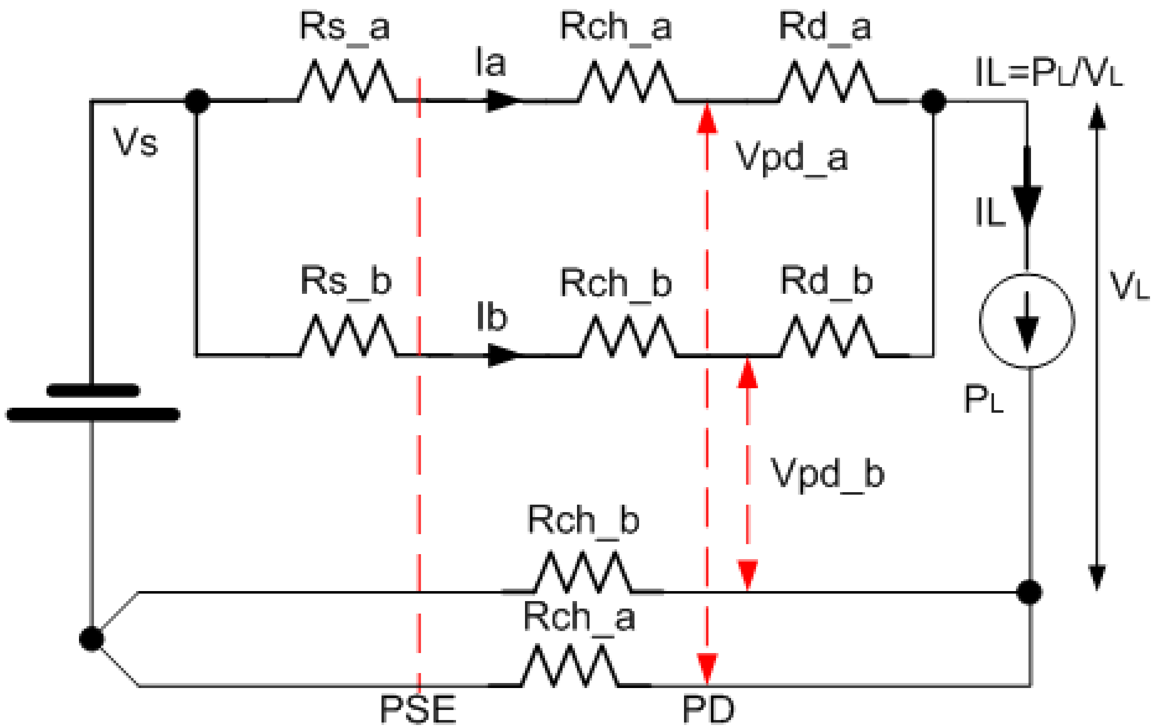
Rs: Resistance between voltage source to transformer center tap.

Rd: Resistance between transformer center tap to the load RL.

Figure 4

Pair to Pair (P2P) Imbalance - 3

- Simplified general model with:
  - Single load[1]
  - Rc_x is the pair equivalent resistance e.g. R7||R8=R7*R8/(R7+R8) shown full 4P model



Use cases for voltage source

Rs: Resistance between voltage source to transformer center tap.

Rd: Resistance between transformer center tap to the load RL.

Figure 5

Notes:
1. split load is easier to analyze and has no issue in regard to P2P current imbalance as long as Iport max specified over 2P is met

Pair to Pair (P2P) Imbalance - 4

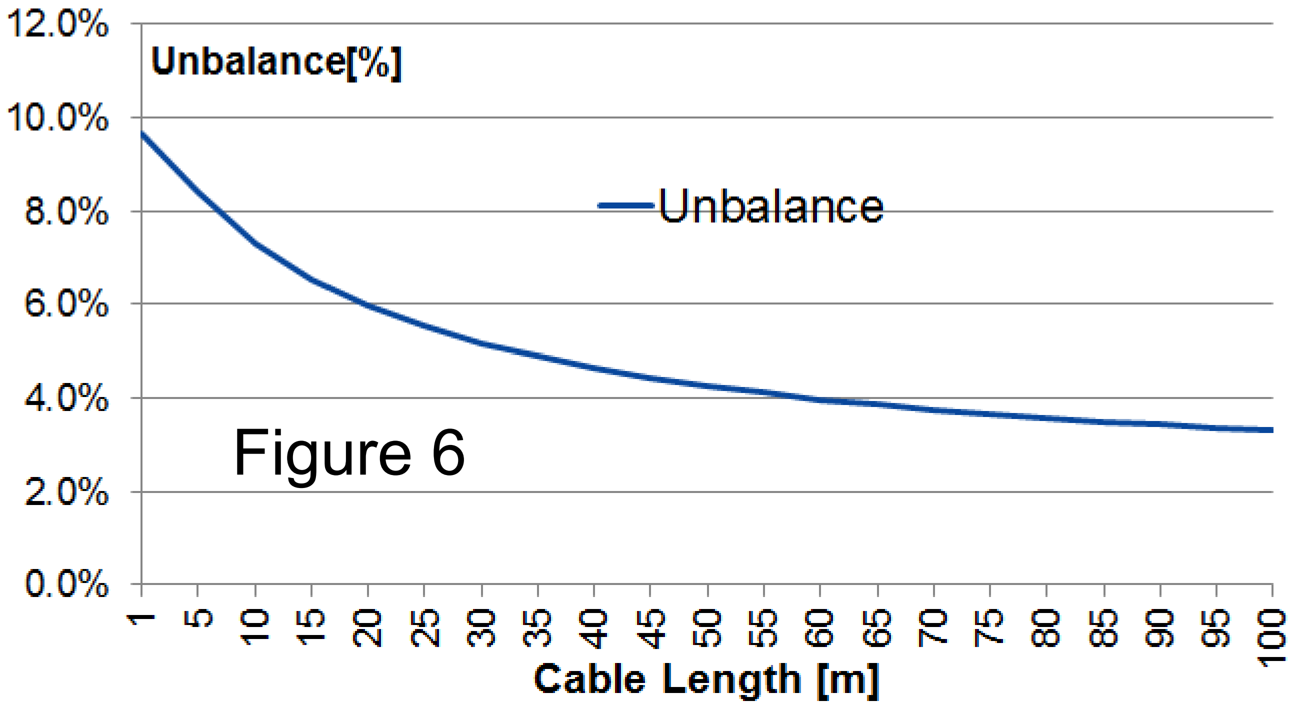


Figure 6

Results for:

Rs_max	**0.2Ω**
Rs_unb	**25%**
Rt_max	**0.5Ω**
Rt_unb	**0.03Ω**
Rconn	**0.2Ω**
Rconn_unb	**0.05Ω**
Rcable	**0.095Ω/m**
Rcable unb	**2%**
Rd_max	**0.3Ω**
Rd_unb	**25%**

- We can see that current imbalance between ALT A and ALT B is increased in short cable length were all channel components imbalance excluding cable has strong effect.
- Normally, if current sharing balance is required, it is best that PD will take care of it since only the PD knows its maximum working power since for PD input power below X level no special means are required.
- It will be advantageous in future 4P specification to define the resistance imbalance [%] of Rs_a and Rs_b, Rd_a and Rd_b

Pair to Pair (P2P) Imbalance - 5

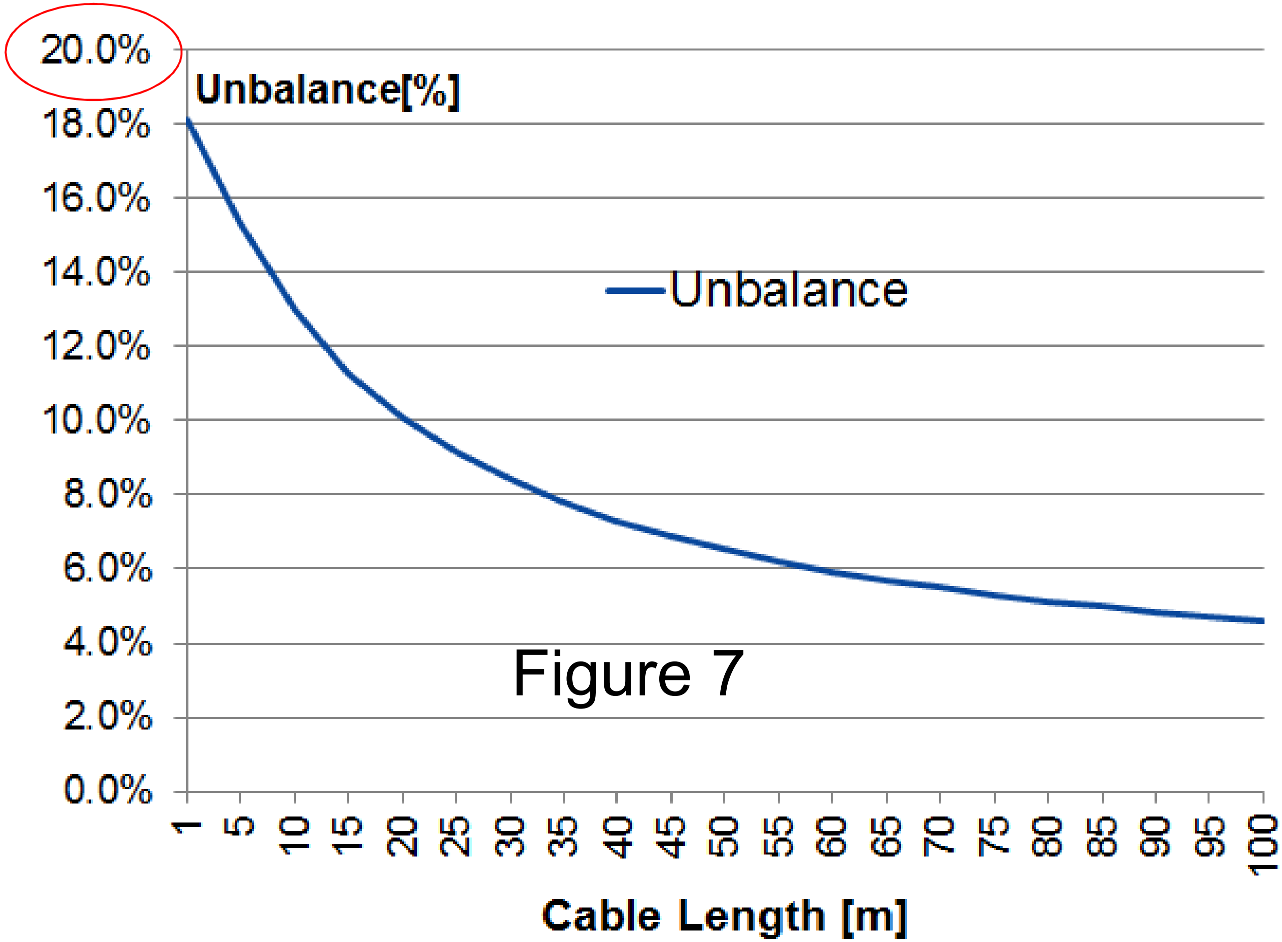


Figure 7

Rs_max	0.2Ω
Rs_unb	**50%**
Rt_max	0.5Ω
Rt_unb	0.03Ω
Rconn	0.2Ω
Rconn_unb	0.05Ω
Rcable	0.095Ω/m
Rcable unb	2%
Rd_max	0.3Ω
Rd_unb	**100%**

- Increasing Runb for Rs and Rd for sensitivity analysis

Simulations vs Calculation

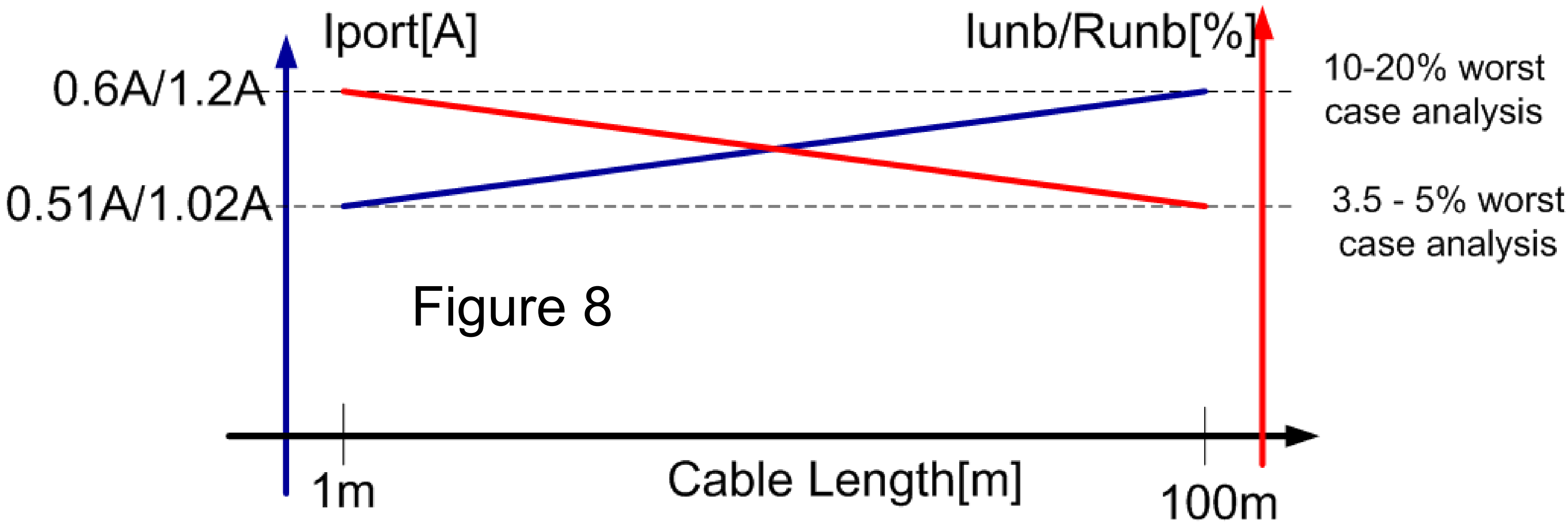
- Simulations shows good match with calculations.
  - At 100m: Ia=614mA, Ib=587mA, |Ia-Ib|=27mA at 100m.
    Ia<Icut=15%*0.6=90mA ➔ Good.
  - At 1m: Ia=585mA and Ib=445mA, |Ia-Ib|=140mA. Ia, Ib<600mA ➔ Good.

- In addition:
  - In short cable (1m) Vpd is going up so Iport is going down. Example:
    Vpd=~50V, Ppd=51W ➔ Iport=~1.02A (0.51A per channel if balanced)
  - In long cable (100m) Vps is going down so we get Iport max. Example:
    Vpd=42.5V, Ppd=51W, Iport=2x600mA=1.2A. (0.6A per channel if balanced)
- The difference is (-180mA) from 100m to 1m.
- Since we have higher R_unbalance in short cable, e.g. 10% per figure 6. which is equivalent to 10%*1.02A=102mA.
- So ALT A is decreased by 102mA/2 ➔ 510mA-51mA=459mA and ALT B is increased by 51mA i.e. 510mA+51mA=561mA.
- The net result is that ALT A and ALT-B are now <600mA despite the high %unbalance at short cable.

Results Analysis - 1

- Iport is decreasing when Cable length is decreases while current unbalance is Increased. It helps us to reduce the increase in Iport over 2P that crosses Iport max (600mA) on the lower resistance ALT_X.

- The lines in the curve are trends. They are actually not linear. Next work on the subject need to show accurate cancelation per meter. Only the start and end points are sufficiently accurate.



Results Analysis - 2

- The analysis was done for worst case i.e. all components set to max or min resistance.
- In reality it doesn't happen due to each component value distribution so %unbalance numbers at short cable are expected to be lower.
- Moreover Rs and Rd and Rt % unbalance values which are external components to the channel can be controlled so lower to reduce channel sensitivity to their resistance imbalance. Therefore under <u>controlled design and controlled specification</u>, Figure 6 results may be achieved.

Results Analysis - 3

- How P2P unbalance in 4P may affect Icut function of a 2P channel

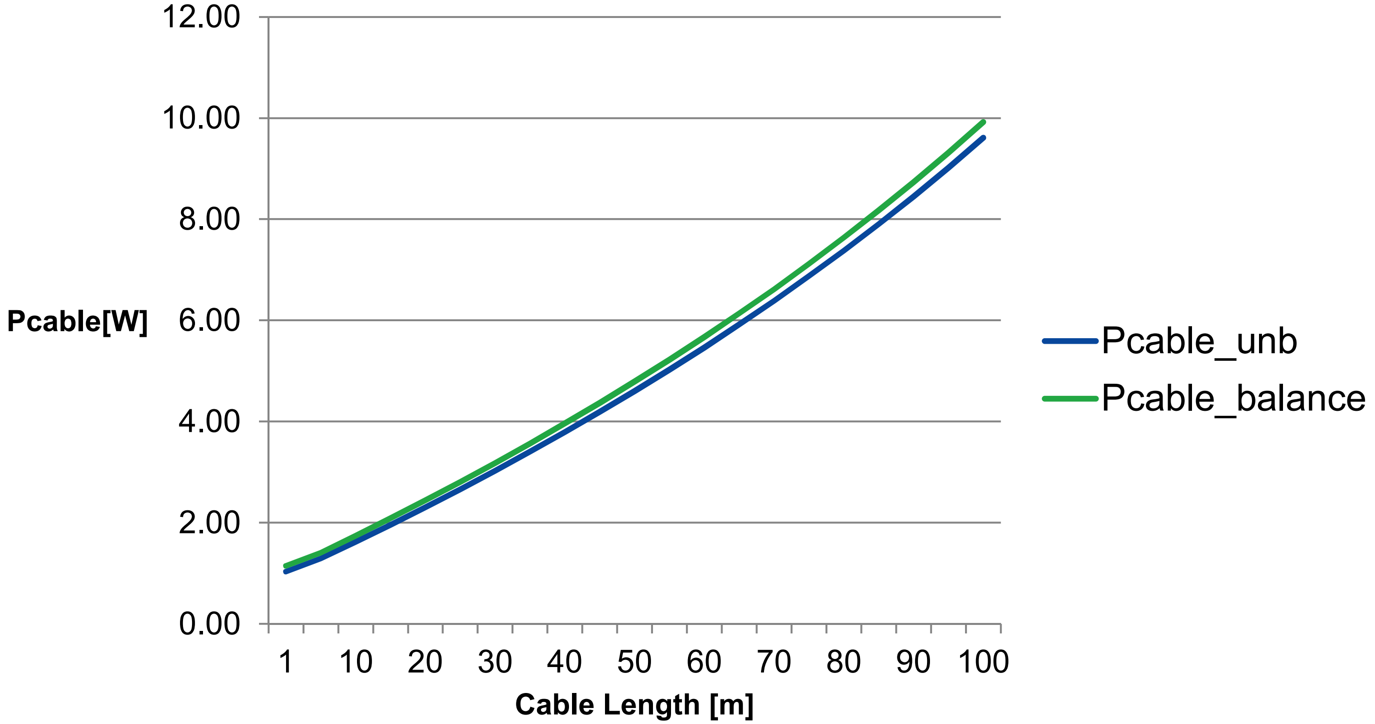
- We saw that for Figure 6 data of 10% maximum unbalance at 100m and 1m, (Iport-600mA)<Icut. So there is no issue.

- For higher %unbalance than 10% worst case analysis method, we need to revisit this subject since the margin from Iport_max to Icut is significantly reduced and it is required to addressed in the specifications[1]

Notes:
1. This is not implementation issue, it is worst case analysis that try to cover most main possibilities

Results Analysis - 4

- How I_unb affect cable temperature rise?
- The effect is negligible.
- Analytical Calculations will be presented in other presentation
- Power loss in unbalanced case is a bit lower than in balanced. Need to be verified in the analytical calculations.



Summary[1]

1	Worst Case P2P Current Imbalance calculation	<10%	With Typical controlled imbalance of external components to the channel. Can be easily reach to ~20-25% with uncontrolled ones. The value is for short cable. For 100m, the Imbalance is ~4%.
2	Effect of I unbalance on Magnetic components		Attention is required at 100m were Iport>Iport_max by ~40mA which will affect pair imbalance and therefore Magnetic component by Runbl*40mA<4mA. Not significant effect.
3	Temperature Rise due to P2P imbalance		Negligible
4	Current Imbalance effect on 2P overload.		The system works for us. At long cable the imbalance is small so Imbalance<Icut/Iport_max ➔OK. For short Cable Imbalance is maximum however port current is lower which add margin for Icut. Bottom line.
5	Can be state the objective regarding PD min power for 4P PD?		Yes, with adding text that the means to ensure interoperability and compatibility due to P2P imbalance will be done at the Task Force.

Conclusions

- It is proposed to use the following text or equivalent:

- The Task Force will address the means to control the P2P current imbalance in a 4P system to support 51W minimum at the PD input.

Thank You

References

Ref	Source
1	11801 © ISO/IEC:2002(E)
2	www.ieee802.org/3/at/public/2006/01/diminico_1_0106.pdf
3	Based on 19Ω/100m loop resistance as defined by 61156-5 Cable - 3.2.1 Conductor resístanse
4.	IEEE802.3at Transformer and Channel adhoc