Transformer Energization Study Case with PAMSUITE

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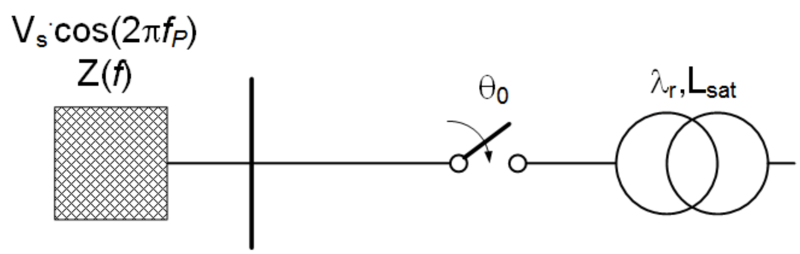
EMTP

PAMSUITE®

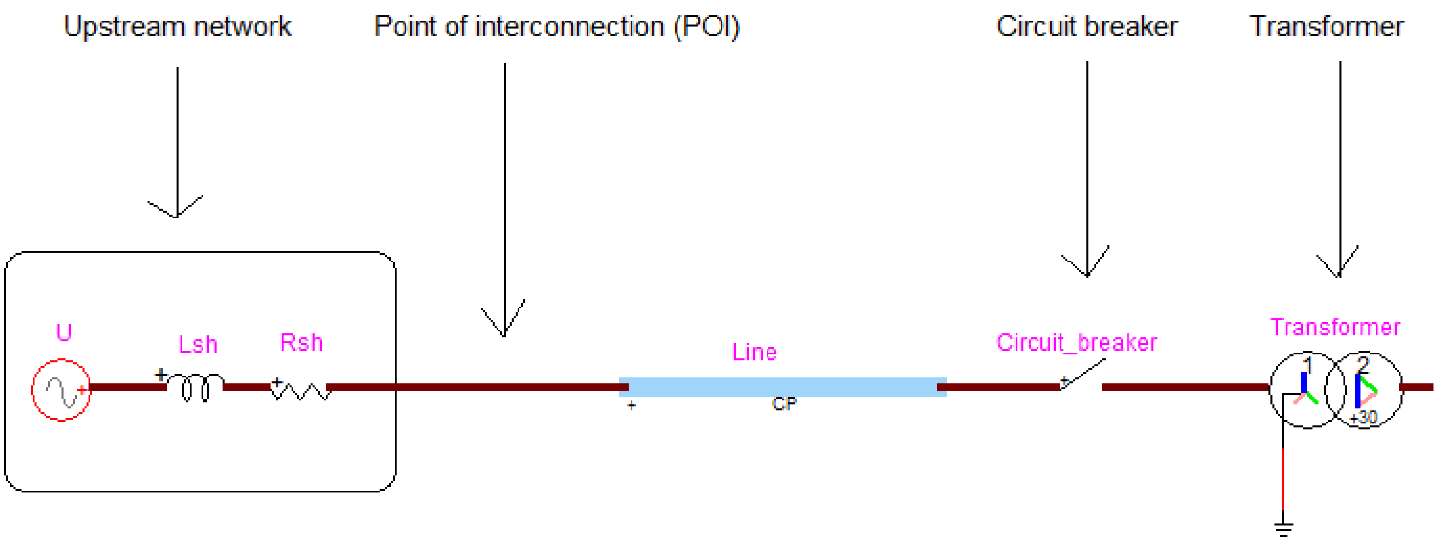
Parametric Modeling Suite for EMTP-RV

TRANSFORMER ENERGIZATION



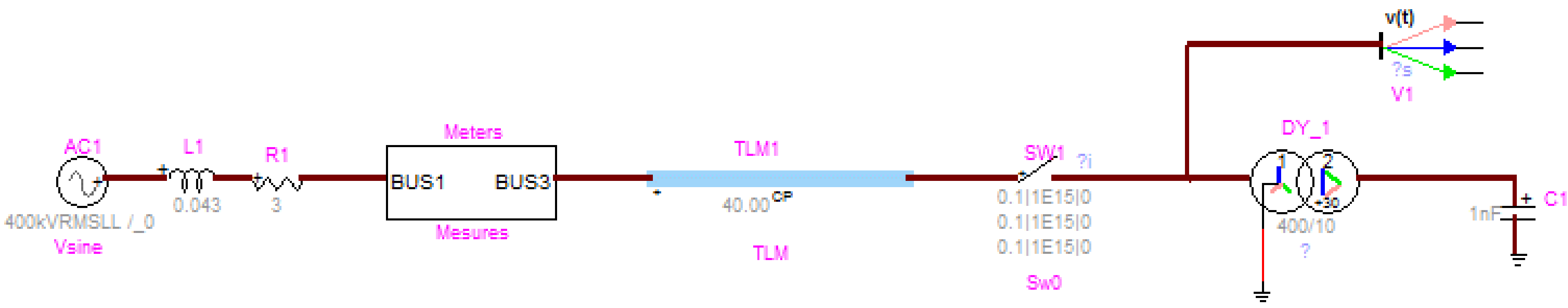
- Outputs of interest
  - Inrush current
  - RMS voltage drop at the point of interconnection (POI)
  - Resonant overvoltage at the transformer terminals
- Uncertainties on influential parameters
  - POI short-circuit power, S_{sh} and PF_{sh} → epistemic
  - Parameters of the line between POI and Tr → epistemic
  - Circuit-breaker closing-angle (θ_0=0-360°) → aleatory
  - Circuit-breaker closing-angle pole span ($\theta_A \neq \theta_B \neq \theta_C$) → aleatory
  - Transformer residual flux (amplitude and phase distribution) → aleatory
- Results
  - Statistical distribution: e. g., CDF of I_{inrush}, RMS-V_{drop} , OV
  - Probability of exceeding a threshold: e. g.: P(voltage drop>5%)

IN EMTP



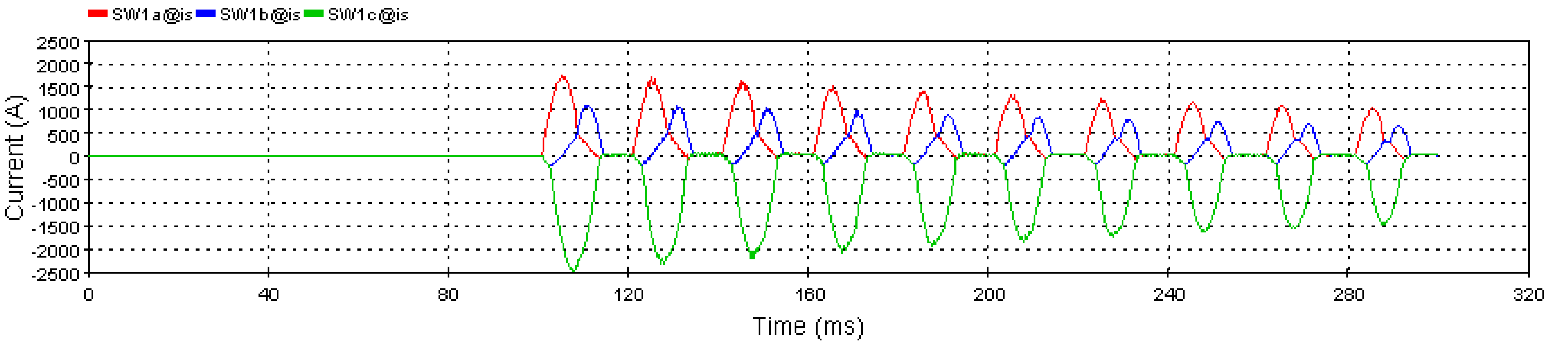
- **S_{sh}** & **PF_{sh}**
  - $Zsh = (U^2/S_{sh})$;
  - **Lsh** = $Zsh*\sin(PF_{sh})/(2*pi*50)$;
  - **Rsh** = $Zsh*\cos(PF_{sh})$
- Line parameters: length; **R0**, **R1**, **C0**, **C1,** and **L0**, **L1**, per unit length
- CB: **t_A**, **t_B**, **t_C**
- Transformer residual flux: **Phi_A**, **Phi_B**, **Phi_C**

ONE CASE

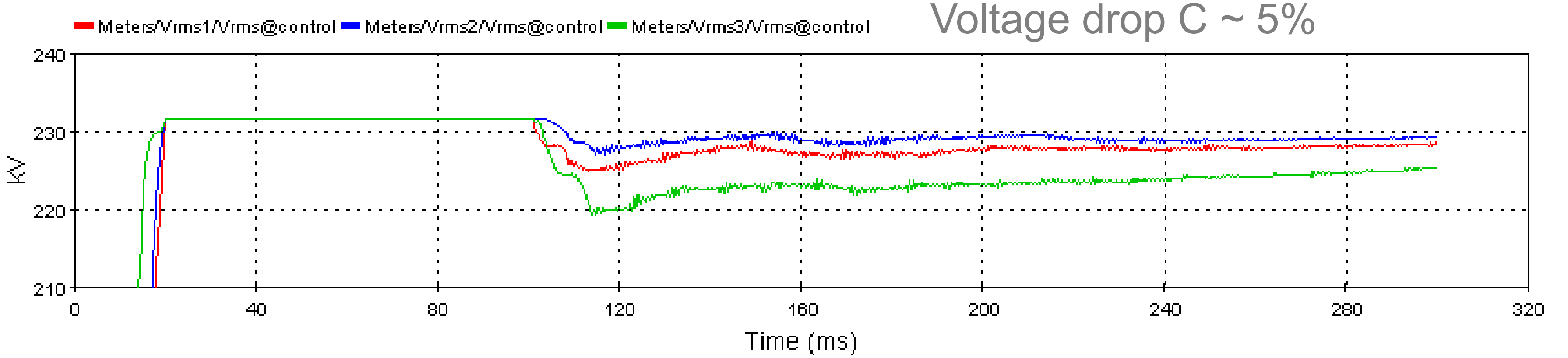


- S_{sh}=8 GVA & PF_{sh}=75°
- Line parameters: 40 km, R=; R0=0.3, R1=0.02, C0=0.008, C1=0.0126, and L0=3, L1=0.9
- Circuit breaker: t_A=t_B=t_C=100 ms
- Transformer residual flux:
  - Phi_A=0.8 pu,
  - Phi_B=-0.4 pu,
  - Phi_C=-0.4 pu

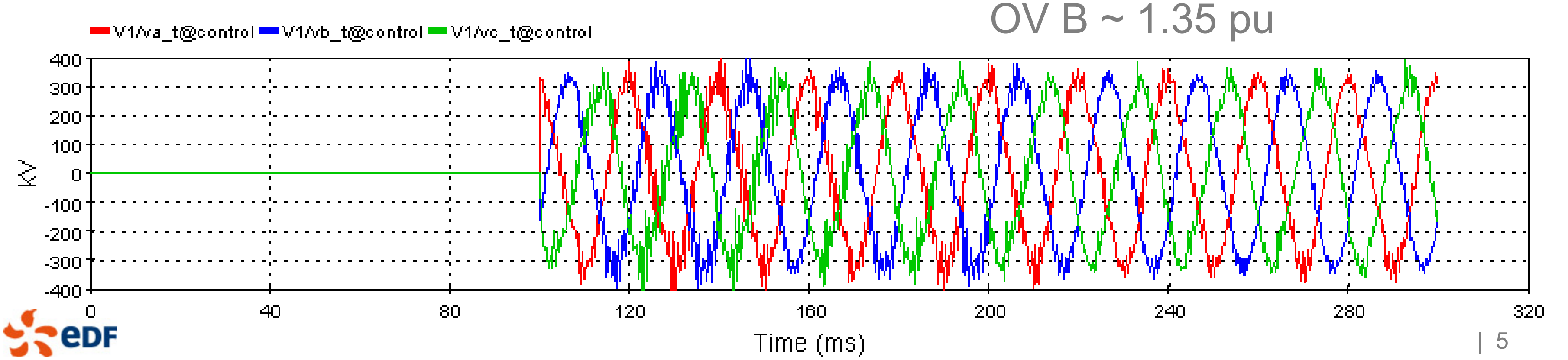
ONE CASE



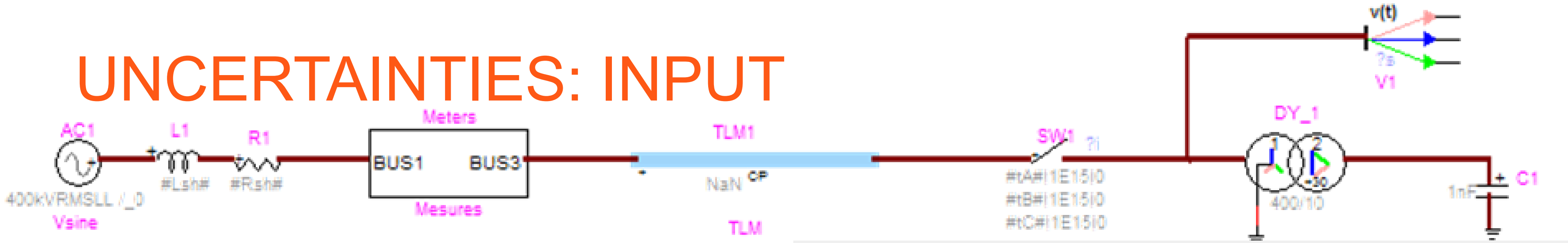
Voltage drop C ~ 5%



OV B ~ 1.35 pu



UNCERTAINTIES: INPUT

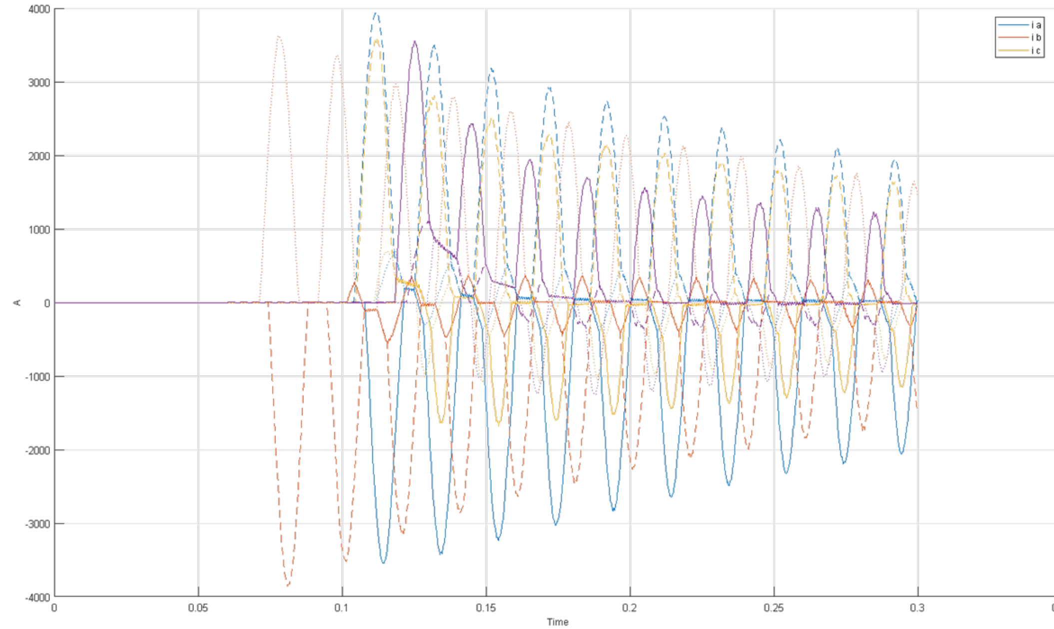


- S_{sh} = 8-15 GVA (& PF_{sh} =75°)
- Line parameters R, L, C: ± 5 %
- Circuit breaker:
  - t_A = 100 - 120 ms
  - $t_B \sim N(t_A, 5ms)$
  - $t_C \sim N(t_A, 5ms)$
- Residual flux:
  - λ_0 = 0-0.8 pu
  - θ_0=0-360°
  - $\lambda_k = \lambda_0 \cdot \cos(\theta+(k-1)\cdot 120°)$

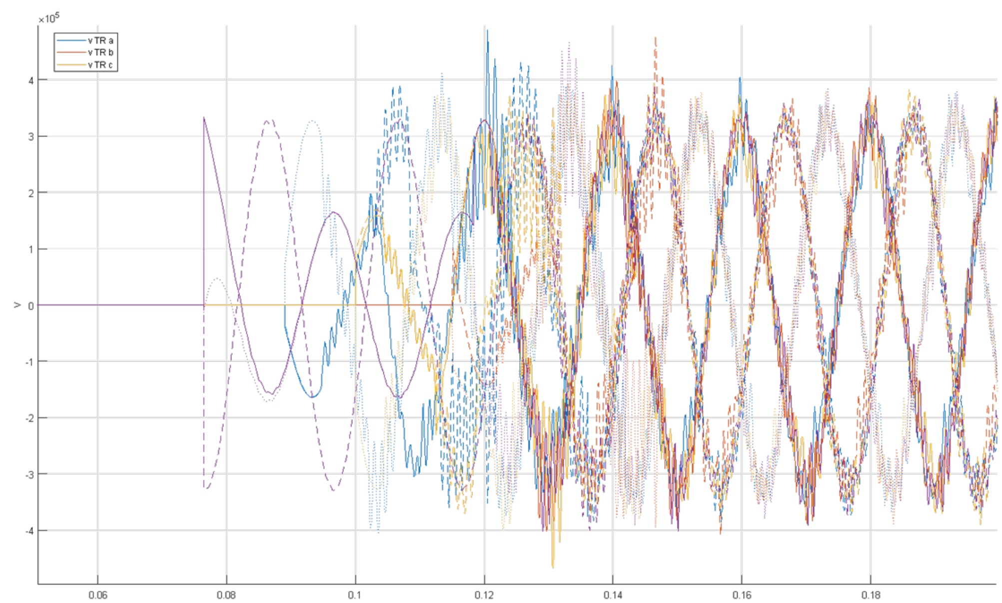
	Type	Name	Value	EMTP
1	U	Ssh	U[8,15]	
2	c	PF_sh	75	
3	c	line_length	40	length ~ TLM1[TI
4	f()	Zsh	Ur = 400e3 ...	
5	f()	Lsh	PF_sh_rad = PF_sh/360 * 2*pi ...	Lsh ~ L1[RLC]
6	f()	Rsh	PF_sh_rad = PF_sh/360 * 2*pi ...	Rsh ~ R1[RLC]
7	U	delta_R_line	U[-5,5]	
8	U	delta_L_line	U[-5,5]	
9	U	delta_C_line	U[-5,5]	
10	f()	line_R0	0.3.*(1+delta_R_line./100)	R0 ~ TLM1[TLM]
11	f()	line_R1	0.02.*(1+delta_R_line./100)	R1 ~ TLM1[TLM]
12	f()	line_L0	3.*(1+delta_L_line./100)	L0 ~ TLM1[TLM]
13	f()	line_L1	0.9.*(1+delta_L_line./100)	L1 ~ TLM1[TLM]
14	f()	line_C0	0.008.*(1+delta_C_line./100)	C0 ~ TLM1[TLM]
15	f()	line_C1	0.0126.*(1+delta_C_line./100)	C1 ~ TLM1[TLM]
16	U	t_CB_common	U[0,20E-3]	
17	N	Diff_t_CB_B	N(0,20e-3)	
18	N	Diff_t_CB_C	N(0,20e-3)	
19	f()	t_CB_0	100e-3	
20	f()	t_CB_A	t_CB_0+t_CB_common	tA ~ SW1[Sw0]
21	f()	t_CB_B	t_CB_0+t_CB_common+Diff_t_CB_B	tB ~ SW1[Sw0]
22	f()	t_CB_C	t_CB_0+t_CB_common+Diff_t_CB_C	tC ~ SW1[Sw0]
23	U	RemFluxAmplitude...	U[0,0.8]	
24	U	RemFluxAngle	U[0,2*pi]	
25	f()	RemFlux_A_pu	RemFlux_A_pu = RemFluxAmplitude_pu.*c...	
26	f()	RemFlux_B_pu	RemFlux_B_pu = RemFluxAmplitude_pu.*co...	
27	f()	RemFlux_C_pu	RemFlux_C_pu = RemFluxAmplitude_pu.*co...	
28	f()	Flux_rated	400e3.*sqrt(2./3)./(2.*pi.*50)	
29	f()	RemFlux_A	RemFlux_A_pu.*Flux_rated	Phiss01 ~ DY_1
30	f()	RemFlux_B	RemFlux_B_pu.*Flux_rated	Phiss02 ~ DY_1
31	f()	RemFlux_C	RemFlux_C_pu.*Flux_rated	Phiss03 ~ DY_1

UNCERTAINTIES: OUTPUT

- 4 highest currents

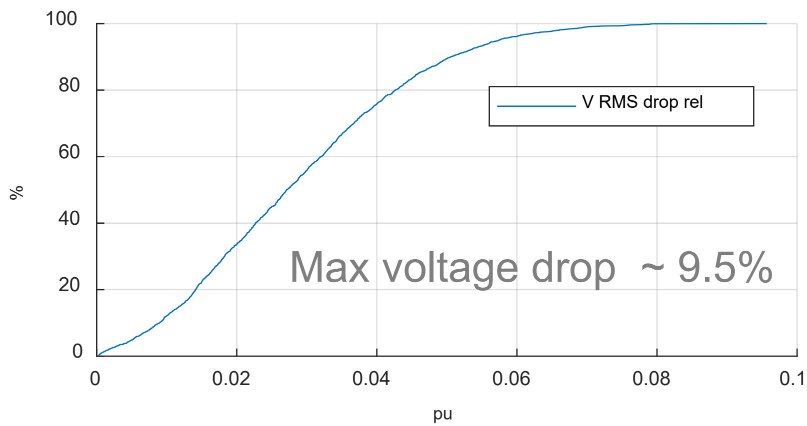


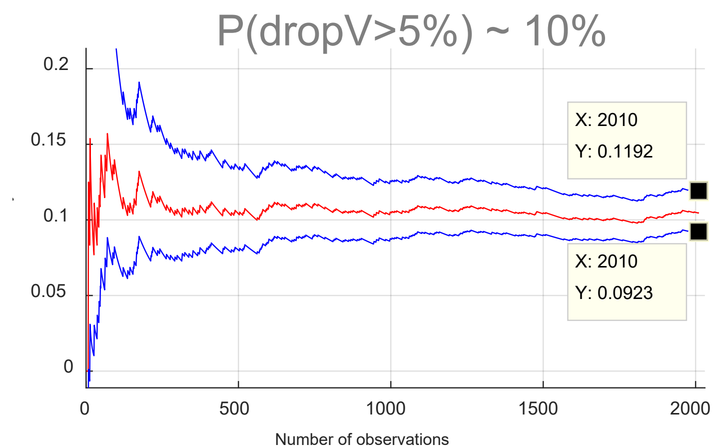
- 4 highest voltages



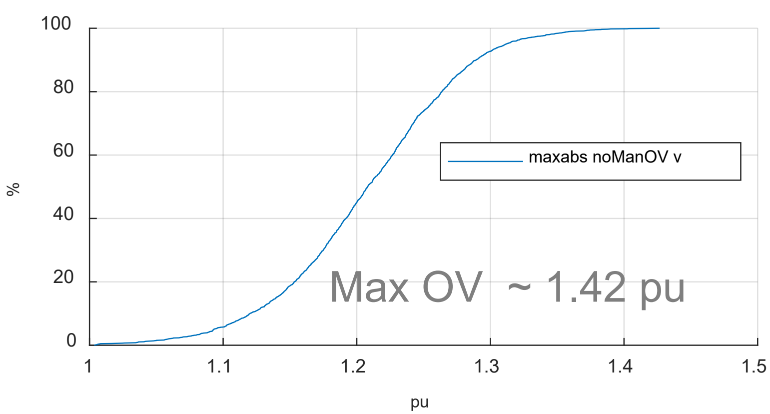
UNCERTAINTIES: OUTPUT

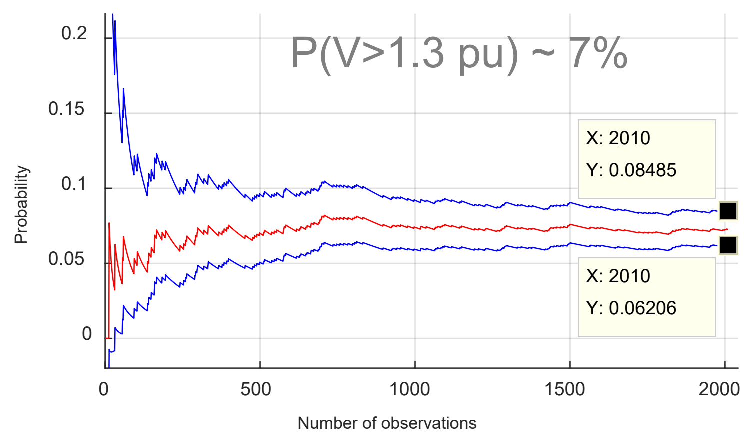
- RMS voltage drop





- Resonant OV





CONCLUSIONS

- **The methodology to carry out transformer energization has been presented;**

- **Parametric simulations are needed;**
- **To do so, PAMSUITE, the parametric modelling toolbox for EMTP is of great help, as it enables advanced parametric calculations but is yet easy-to-use.**

EMTP

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Parametric Modeling Suite for EMTP-RV

Thank you
Questions?