CentraleSupélec

Advanced methodologies for predictive maintenance, risk analysis and diagnosis in industry

GE HealthCare

Context

GE HealthCare

Summary

System Analysis

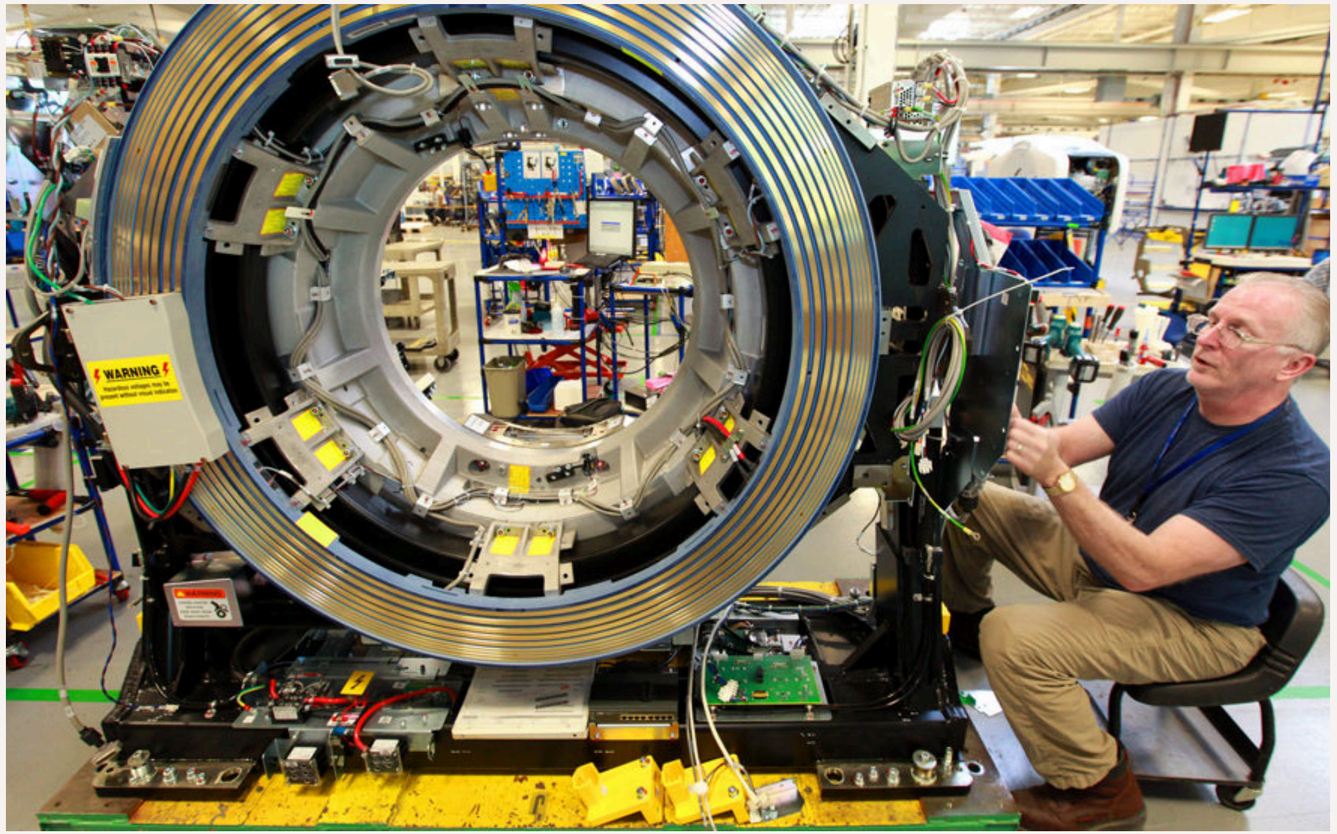
Data Drivren reliability estimation

System reliability modeling

Predict future demand

Advice to GEHC

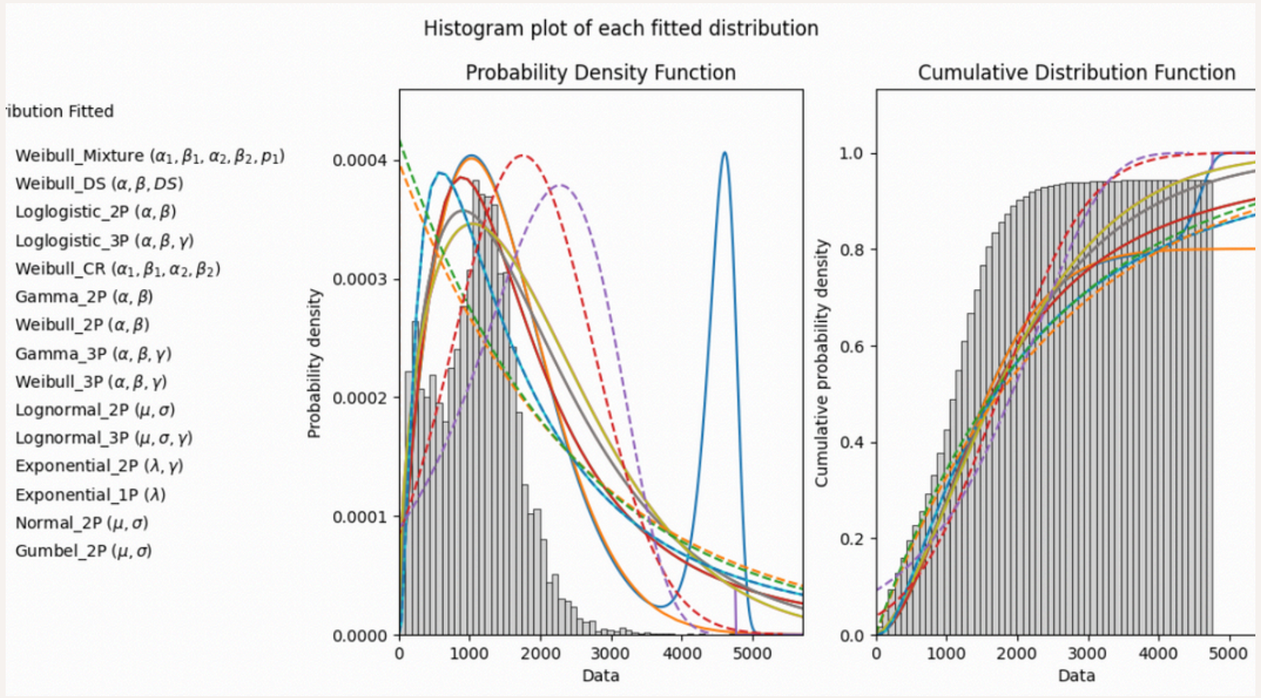
System Analysis



Data driven reliability estimation

	D	E	F	G	H	I	J	K	L	
s	Previous repair po	MFG date	ITEM	Repair Center	Duration(days	Mode	V700 Mosf	Gate drive	V700 busba	
	MFG	2013-06-04 00:00:00	5341543-2	MFG	1260	V1E1	0	0	0	0
	760078638	2013-06-04 00:00:00	5341543-2	GPO REPAIR 528	1319	V1E2	0	0	0	0
	760137409	2013-06-04 00:00:00	5341543-2	GPO REPAIR 528	1397	V1E2	0	0	0	0
	MFG	2013-06-07 00:00:00	5341543-2	MFG	2159	V1E1	0	0	0	0
	600809572	2013-06-07 00:00:00	5341543-2	GPO ASIA 511	1836	V1E2	0	0	0	0
	MFG	2013-06-04 00:00:00	5341543-2	MFG	399	V1E1	0	0	0	0
	600489272	2013-06-04 00:00:00	5341543-2	GPO ASIA 511	508	V1E1	0	0	0	0
	600584898	2013-06-04 00:00:00	5341543-2	GPO ASIA 511	3056	V1E2	0	0	0	0
	MFG	2013-06-10 00:00:00	5341543-2	MFG	751	V1E1	0	0	0	0
	600552997	2013-06-10 00:00:00	5341543-2	GPO ASIA 511	1554	V1E2	0	0	0	0
	MFG	2013-06-05 00:00:00	5341543-2	MFG	911	V1E1	0	0	0	0
	600577643	2013-06-05 00:00:00	5341543-2	GPO ASIA 511	1371	V1E2	0	0	0	0
	600816726	2013-06-05 00:00:00	5341543-2	GPO ASIA 511	1672	V1E2	0	0	0	0
	MFG	2013-06-07 00:00:00	5341543-2	MFG	1068	V1E1	0	0	0	0
	600605108	2013-06-07 00:00:00	5341543-2	GPO ASIA 511	797	V1E2	0	0	0	0
	600754100	2013-06-07 00:00:00	5341543-2	GPO ASIA 511	503	V1E2	0	0	0	0
	600850651	2013-06-07 00:00:00	5341543-2	GPO ASIA 511	127	V1E2	0	0	0	0
	600880444	2013-06-07 00:00:00	5341543-2	GPO ASIA 511	1453	V1E2	0	0	0	0
	MFG	2013-06-11 00:00:00	5341543-2	MFG	1074	V1E1	0	0	0	0
	600609133	2013-06-11 00:00:00	5341543-2	GPO ASIA 511	746	V1E2	0	0	0	0
	600748184	2013-06-11 00:00:00	5341543-2	GPO ASIA 511	635	V1E2	0	0	0	0
	600868262	2013-06-11 00:00:00	5341543-2	GPO ASIA 511	1517	V1E2	0	0	0	0
	MFG	2013-06-05 00:00:00	5341543-2	MFG	3571	V1E1	0	0	0	0
	MFG	2013-06-05 00:00:00	5341543-2	MFG	1051	V1E1	0	0	0	0

Data driven reliability estimation



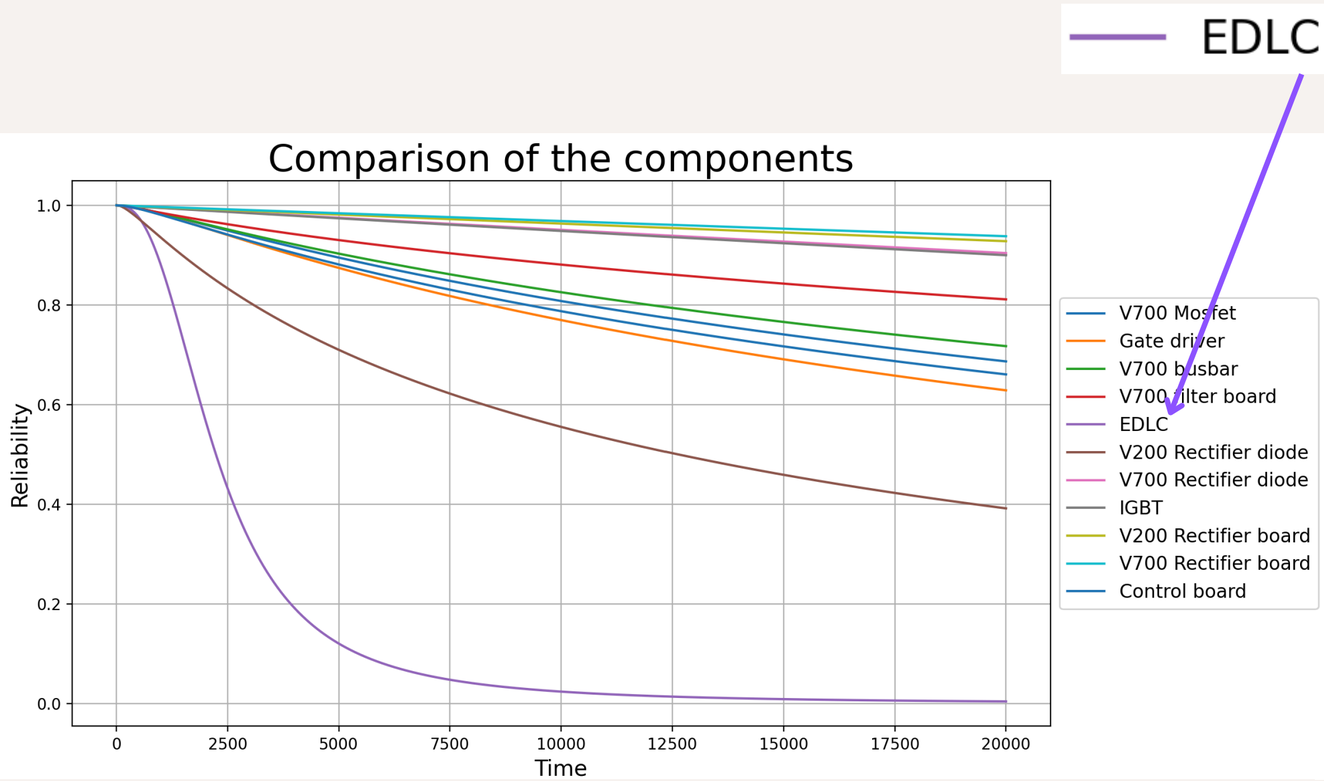
- Each component has an estimated law
- The whole system has an estimated law

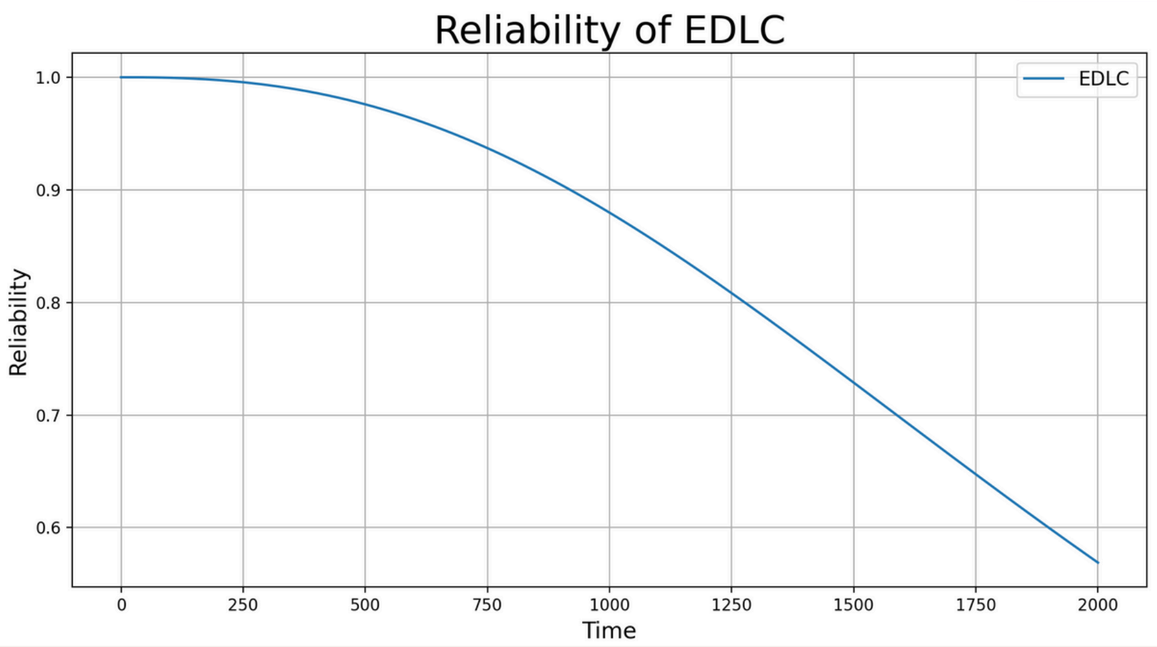
Data driven reliability estimation

COMPONENT	LAW
V700 Mosfet	Lognormal_2P (10.7827, 1.80569)
Gate driver	Lognormal_2P (10.4597, 1.69239)
V700 Busbar	Lognormal_2P (11.0049, 1.91443)
V700 filter board	Lognormal_2P (11.9588, 2.32809)
EDLC	Loglogistic_2P (2237.75, 2.47091)
V200 Rectifier diode	Lognormal_2P (9.4441, 1.67407)

V700 Rectifier Diode	Exponential_1P (5.03434e-06)
IGBT	Exponential_1P (5.27125e-06)
V200 Rectifier Board	Exponential_1P (3.73133e-06)
V700 Rectifier Board	Exponential_1P (3.19828e-06)
Control board	Lognormal_2P(10.6521, 1.8062)

Most critical component



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Mean time to failure (MTTF) of EDLC: 2977.58 days
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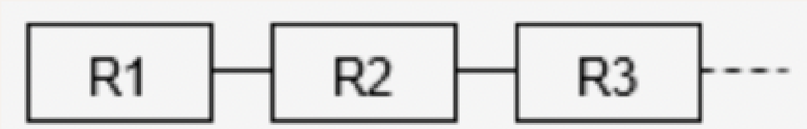
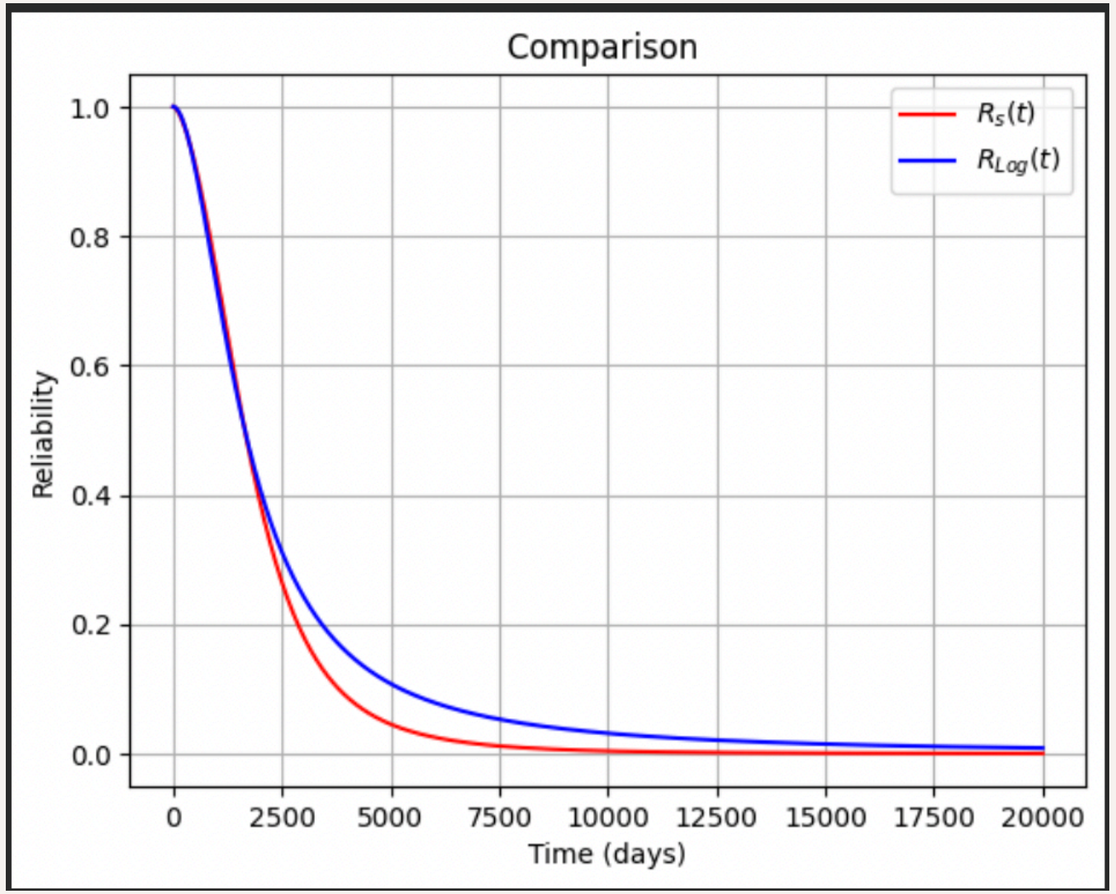
System reliability modeling

First Approximation : components are independant



$$R(t) = \prod_{i=1}^{n} R_i(t)$$



Correlation

Covariance Matrix

$$\begin{bmatrix} \mathrm{Var}(x_1) & \cdots & \mathrm{Cov}(x_n, x_1) \\ \vdots & \ddots & \vdots \\ \mathrm{Cov}(x_n, x_1) & \cdots & \mathrm{Var}(x_n) \end{bmatrix}$$

$$\begin{aligned} c_{xy} &= \frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y}) \\ &= \frac{1}{n}\sum_{i=1}^{n}(x_i y_i - \overline{x} y_i - x_i \overline{y} + \overline{x}\,\overline{y}) \\ &= \left(\frac{1}{n}\sum_{i=1}^{n} x_i y_i\right) - \overline{x}\,\overline{y}\ . \end{aligned}$$

Correlation

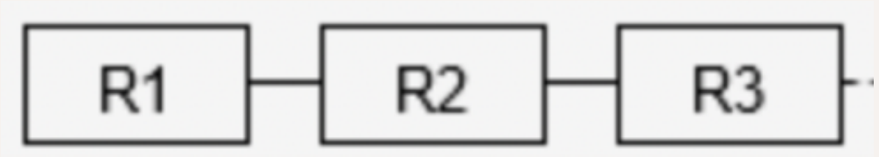
	V700 Mosfet	Gate driver	V700 busbar	V700 filter board	...	IGBT	V200 Rectifier Board	V700 Rectifier board	Control board
V700 Mosfet	2.6343	1.5323	2.0638	0.234771	...	0.297789	0.0453515	0.291058	0.150907
Gate driver	1.5323	3.0827	1.52223	0.22551	...	0.400177	0.118316	0.296603	0.234525
V700 busbar	2.0638	1.52223	2.48382	0.328616	...	0.31408	0.0235509	0.314421	0.216313
V700 filter board	0.234771	0.22551	0.328616	1.90595	...	0.0311192	0.0345004	0.0825254	0.25011
EDLC	0.338627	0.691089	0.395092	0.392306	...	0.137151	0.107516	0.028421	0.986072
V200 Rectifier diode	0.0328576	0.2679	0.055352	-0.0239038	...	0.104984	0.29529	0.00556225	0.163696
V700 Rectifier Diode	0.360137	0.288897	0.39901	0.108074	...	0.0556225	-0.00372495	0.261891	0.0702203
IGBT	0.297789	0.400177	0.31408	0.0311192	...	0.728244	0.0488362	0.0347086	0.00761463
V200 Rectifier Board	0.0453515	0.118316	0.0235509	0.0345004	...	0.0488362	0.556541	-0.00237042	0.0734876
V700 Rectifier board	0.291058	0.296603	0.314421	0.0825254	...	0.0347086	-0.00237042	0.421743	0.0474359
Control board	0.150907	0.234525	0.216313	0.25011	...	0.00761463	0.0734876	0.0474359	2.99055

[11 rows x 11 columns]

V700 Mosfet, Gate Driver, V700 Bushbar are strongly correlated

Correlation

V700 Mosfet Gate Driver V700 Bushbar



laws : lognormal_2P

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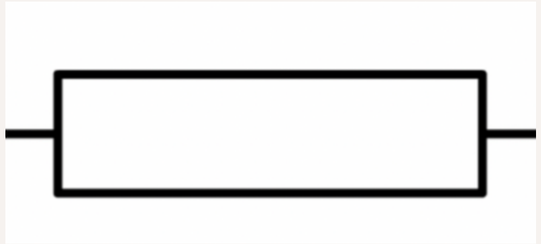
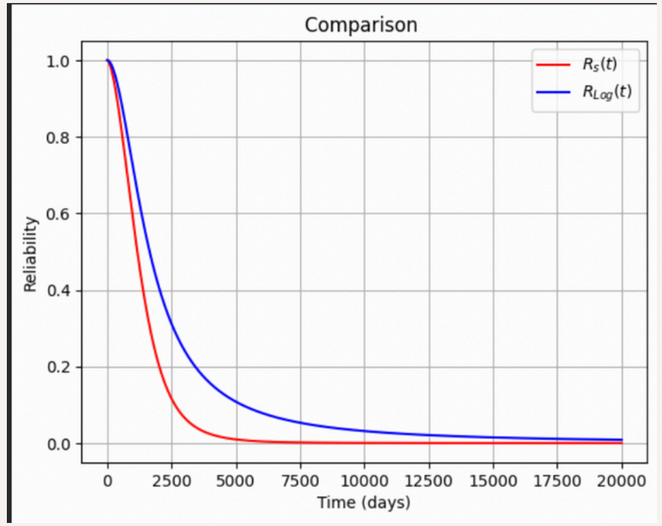
New component



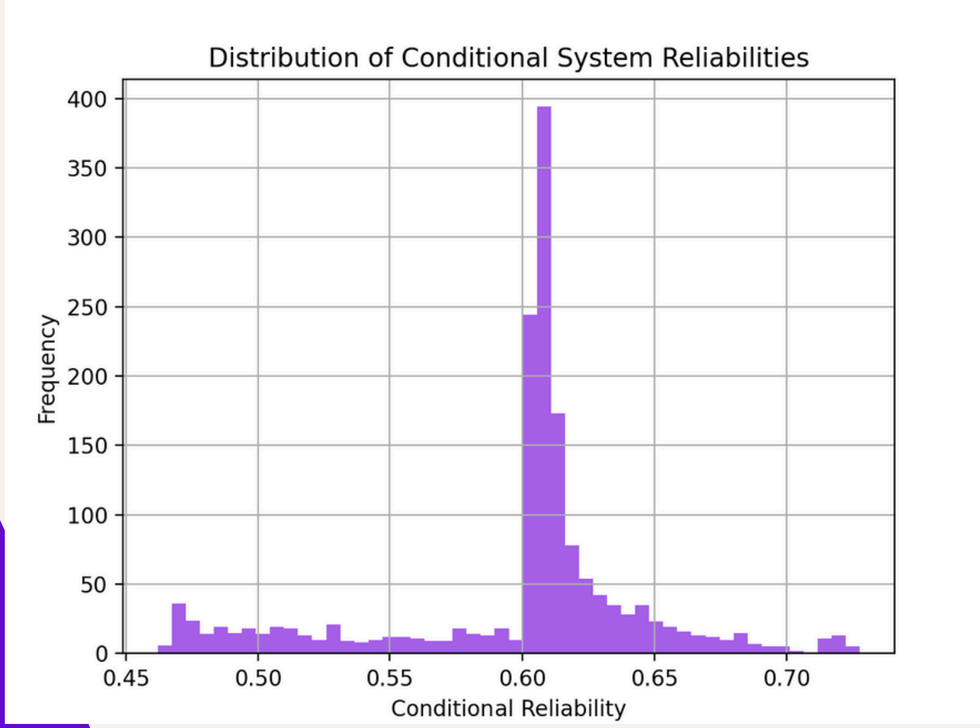
law: Loglogistic_2P (1859.73, 1.76161)

V700 Mosf	Gate drive	V700 busba	the new compone
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
1	1	1	1
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0



Expected number of system failures given the correlation

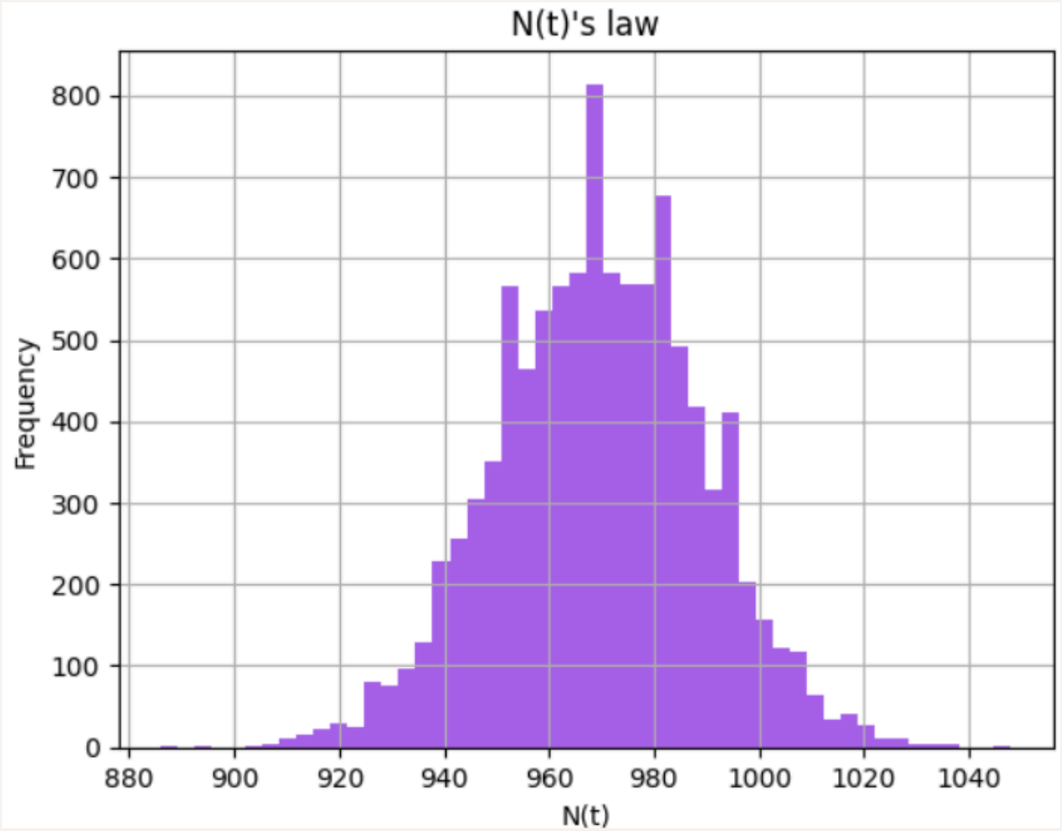
First method



- First method based on the sum of conditional reliabilities (given the ages of the components at t=0)
- Average number of systems still alive at t=730 days: **969**
- **95% Confidence Interval: [965; 974]**
- Average number of failed systems: **652**
- **95% Confidence Interval: [647;656]**

Expected number of system failures given the correlation

Second method



- N(t) = number of systems working at time t
- 10 000 simulations
- $P(N(t) \geq 923) = 0.99$
- $P(\text{failure} < 697) = 0.99$

Predict number of failure

Conclusion and advices to GEHC

- Improve the reliability of the EDLC component (predictive maintenance for example)
- Have a maintenance capacity that allows repairing 700 systems in 2 years given 1620 systems at time t=0

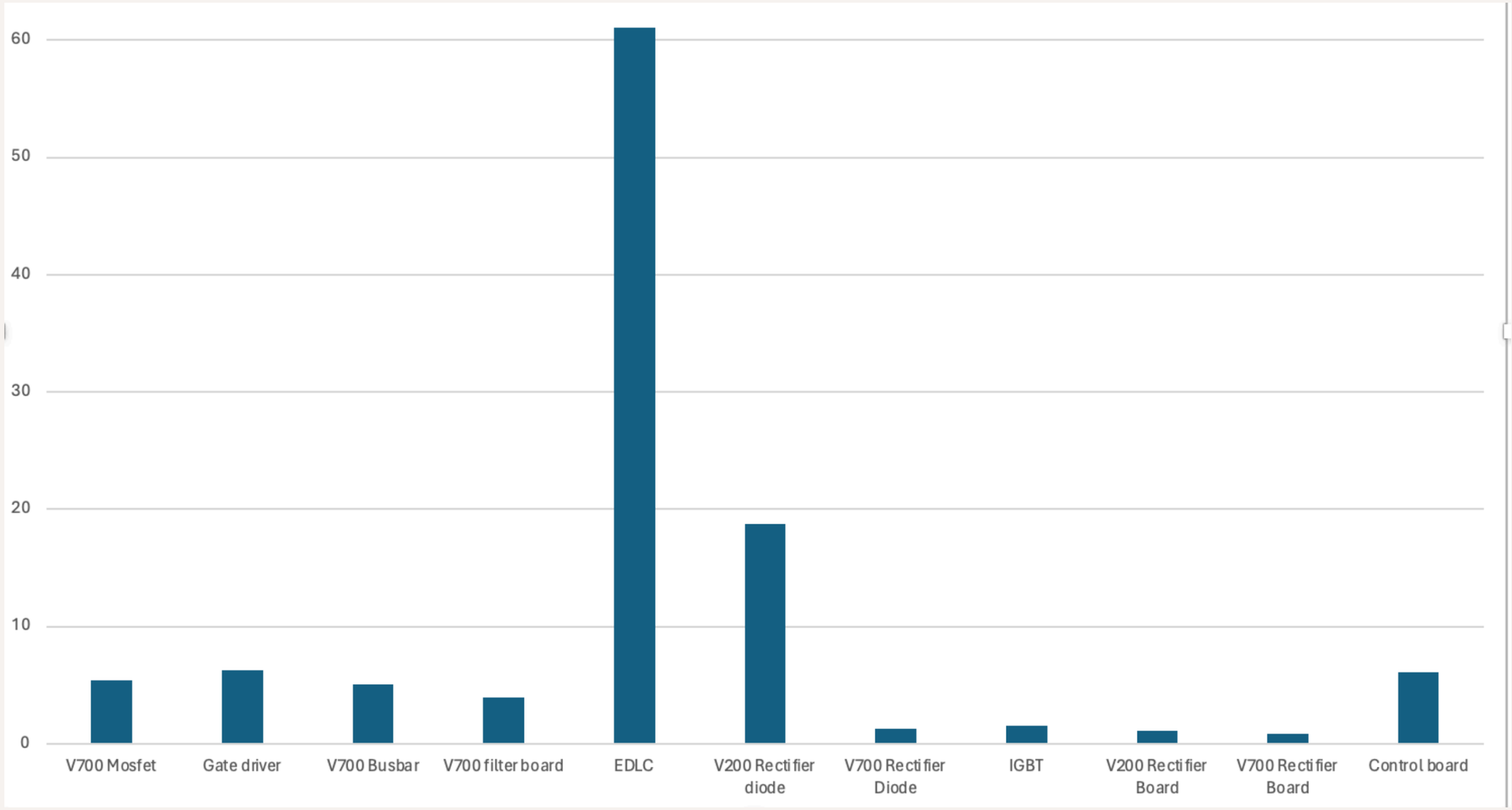
Derive the component future demand

- Determination of the proportion of failures for each component

COMPONENT	Proportion of failed per system
V700 Mosfet	5.4%
Gate driver	6.3%
V700 Busbar	5.1%
V700 filter board	3.9%
EDLC	61.1%
V200 Rectifier diode	18.7%

V700 Rectifier Diode	1.3%
IGBT	1.5%
V200 Rectifier Board	1.1%
V700 Rectifier Board	0.8%
Control board	6.1%

Proportion of Failure (%)



Derive the component future demand

- Number of failed systems in 2 years: 697, We take a 10% margin of error on these proportions.
- We consider that there is a unique component of each type per system.

COMPONENT	Demand
V700 Mosfet	42
Gate driver	49
V700 Busbar	39
V700 filter board	30
EDLC	469
V200 Rectifier diode	144
V700 Rectifier Diode	11
IGBT	12
V200 Rectifier Board	9
V700 Rectifier Board	7
Control board	47

Safety Stock (700 system failures / y)

- We take a 20% margin on the number of spare parts for failures

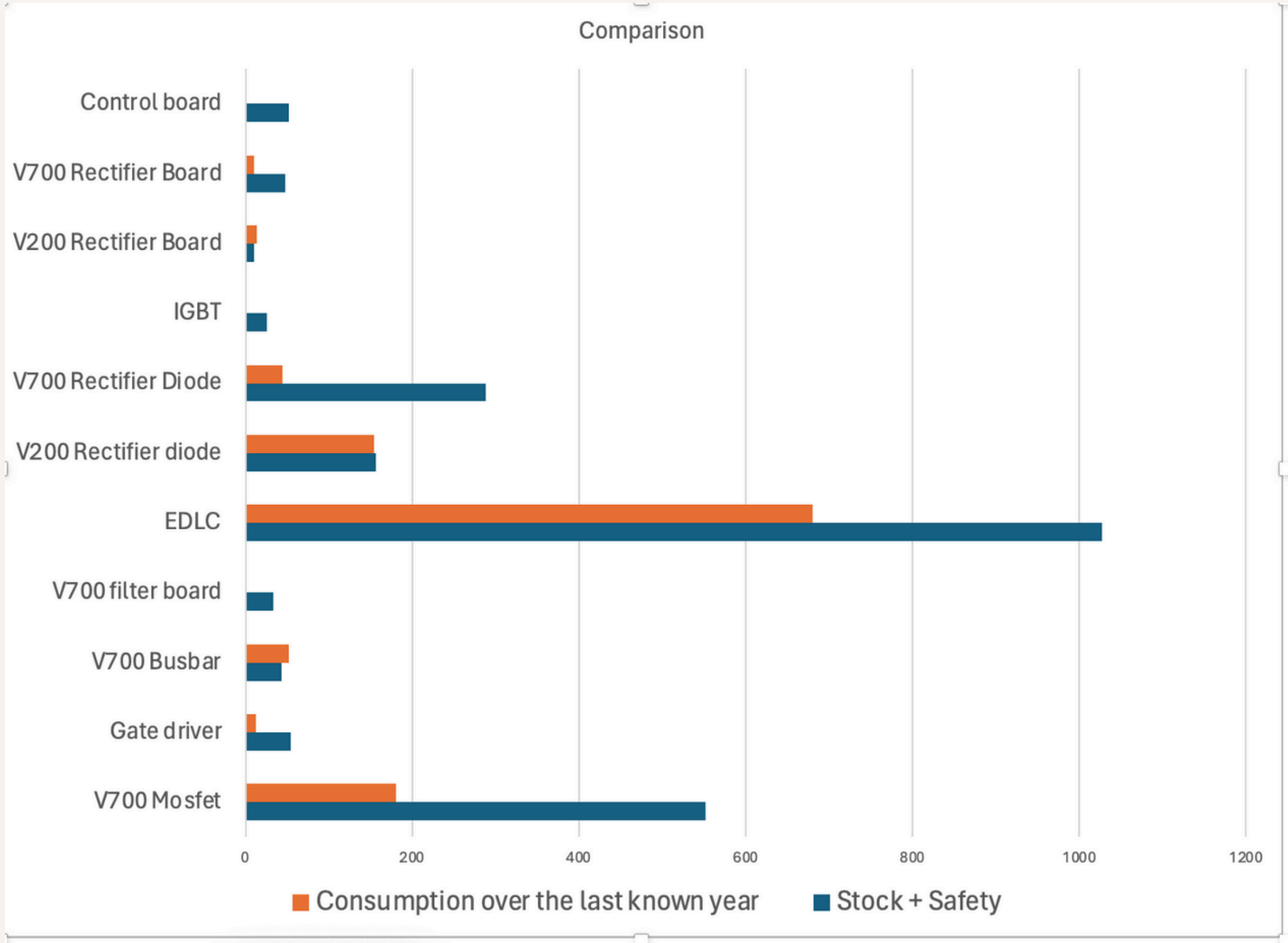
COMPONENT	Factor	Safety + Stock
V700 Mosfet	12	552
Gate driver	1	54
V700 Busbar	1	43
V700 filter board	1	33
EDLC	2	1028
V200 Rectifier diode	1	157
V700 Rectifier Diode	24	288
IGBT	2	26
V200 Rectifier Board	1	10
V700 Rectifier Board	6	48
Control board	1	52

Comparison between the safety stock and the previously consumed parts.

- The probability densities have been determined using data from 2020 to 2024.
- The demand decreases in 2024 according to the component consumption data.

COMPONENT	Stock + Safety	Consumption over the last known year
V700 Mosfet	552	181 (2023-24)
Gate driver	54	13 (2023-24)
V700 Busbar	43	52 (2020-2021)
V700 filter board	33	
EDLC	1028	680 (2023-24)
V200 Rectifier diode	157	154 (2023-24)
V700 Rectifier Diode	288	45 (2023)
IGBT	26	
V200 Rectifier Board	10	14 (2023-24)
V700 Rectifier Board	48	10 (2023-24)
Control board	52	

Comparison between the safety stock and the previously consumed parts.



Suggest process changes to reduce the likelihood of such scenarios

Conclusion and advices to GEHC

- Use more reliable EDLC components
- Use more recent data, or take into account the changements made
- We have too much stocks on a few components, and not enough for ohter components
- Look at the safety stock we calculated

THANK YOU FOR LISTENING