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A Maintenance Scheduling Tool for Kaplan Turbines

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Introduction

60% of hydropower plants have operated for **more than 30 years**

Aging infrastructure raises concerns about operational reliability of major equipment like **turbines**

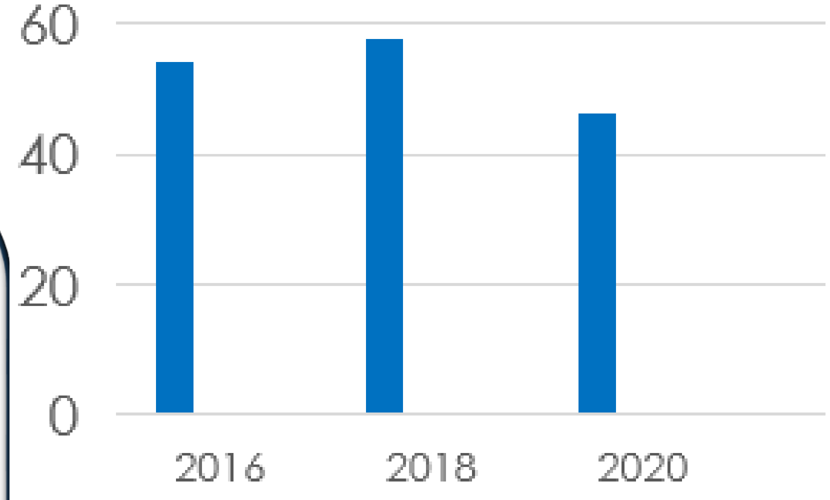
(IHA, 2023)

Hydropower plants in **sub-Saharan Africa** were able to operate for about **71%** of their expected service time.

Due to frequent mechanical failures and uncoordinated maintenance

(Lim, 2020)

Plant Capacity Factor



(Katutsi & Migisha, 2021)

Aging turbines demand smarter maintenace strategies

Problem

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- **Traditional maintenance** is associated with **sudden failures prolonged downtime**.
- **Precious time** is **lost in troubleshooting** thus taxing the availability of turbines (Andrew & Kumanan, 2020).
- Resulting in either **over-maintenance** (increased downtime and costs) or **under-maintenance** (higher risk of unexpected failures)(Katutsi & Migisha, 2021) **oil spills** + **prolonged disruption of flows**
- **SCADA systems** have come with collection of sensor data, calling for **data-driven models** to smartly schedule maintenance (S. Onwusinkwue, F. Osasona, I. Ahmad, et al 2024).

Turbine failure at Muela Plant (Lesotho)

Muela Plant is **34 years** old and generates 72 MW (**51%** of Lesotho's Electricity consumtion)

https://www.engineeringnews.co.za/article/lesothos-muela-hydro-power-station-under-repair-2022-07-27

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Methods

Failure Modes, Effects And Criticality Analysis

Expert judgement +

Development of Hidden Markov Model

$$C_r = f[(OI \times OF) + C_m + HSE]$$

$$F(t) = 1 - e^{-\left(\frac{t}{\lambda}\right)^{\beta}}$$

Matlab Tool

Weibull Analysis shape, scale and location parameters

Origin software

PERT Analysis

Fault Tree

Development of Maintenance Scheduling Tool

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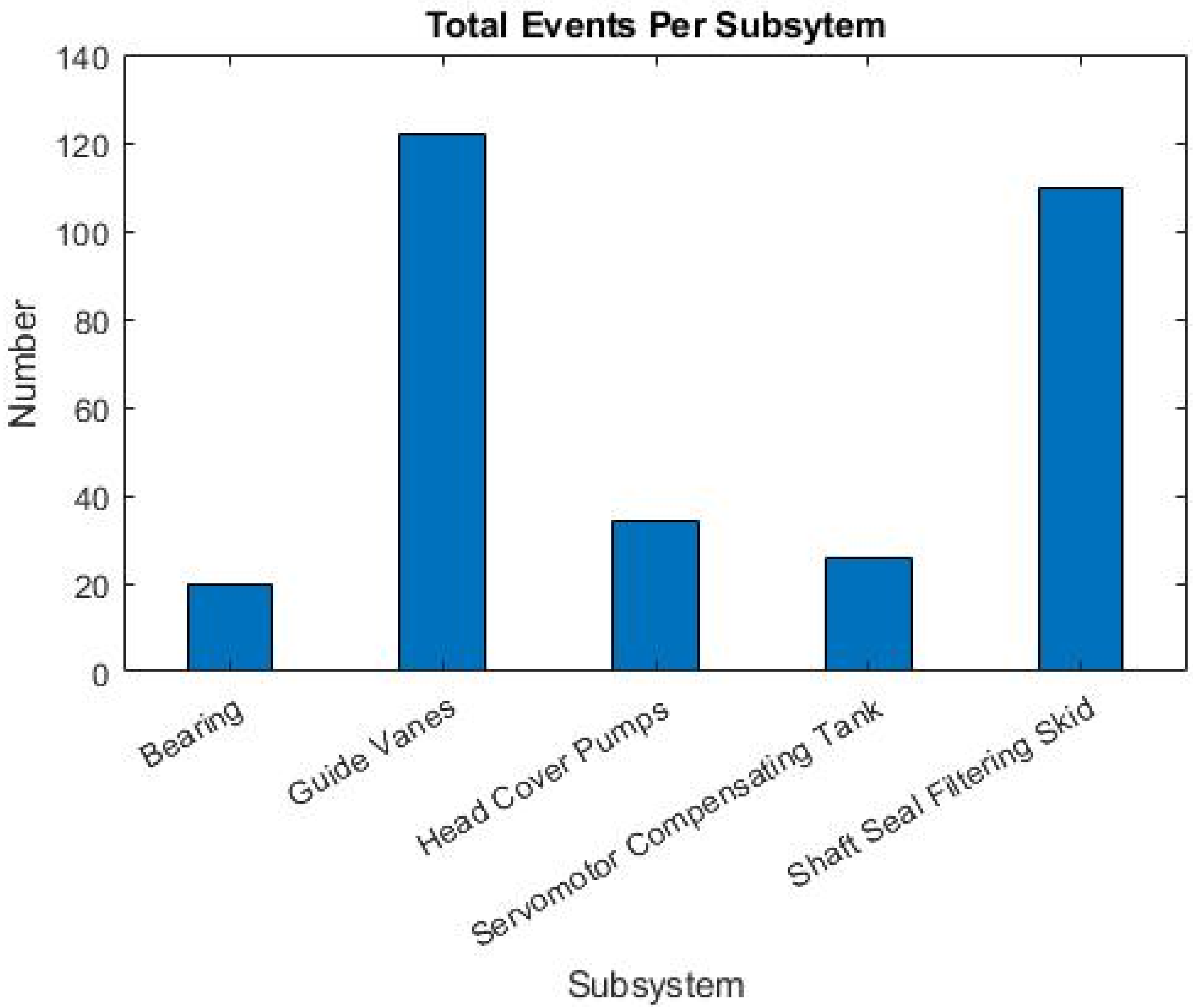
Results & Discussion

Guide vane failures are most frequent

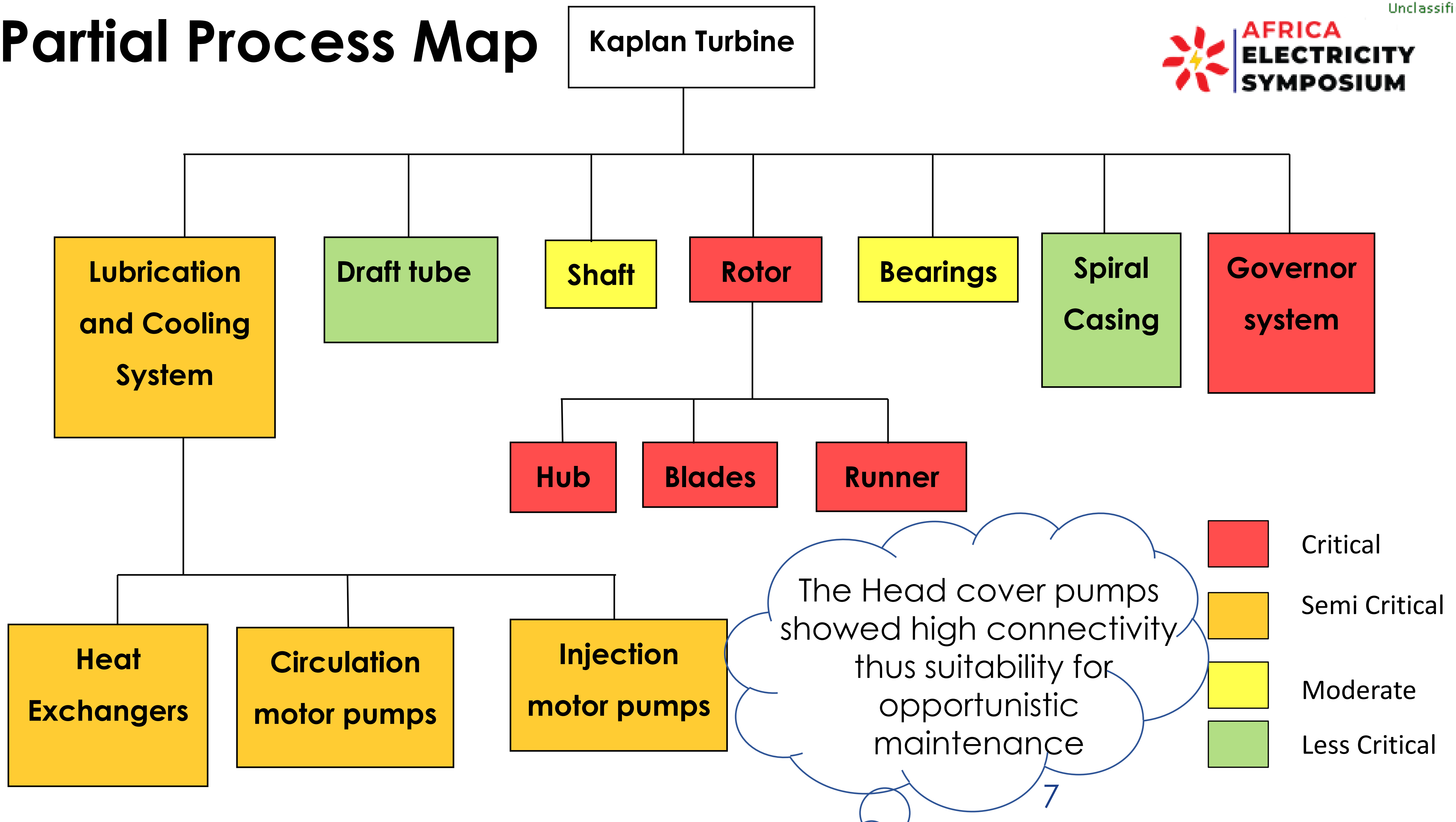


- ❖ Guidevanes had a highest frequency of 0.39 followed by Shaft seals with 0.35

WHY GUIDE VANES?

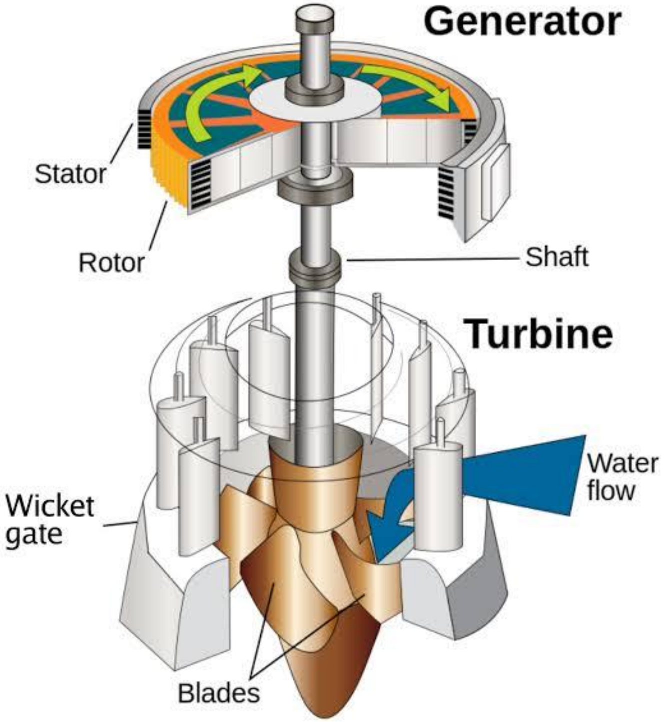
- ➢ Erosion form Abrasive particles such as Sediment load
- ➢ Corrosion from corrosive chemicals like acids
- ➢ Fatigue failure due to dynamic demand and water flows

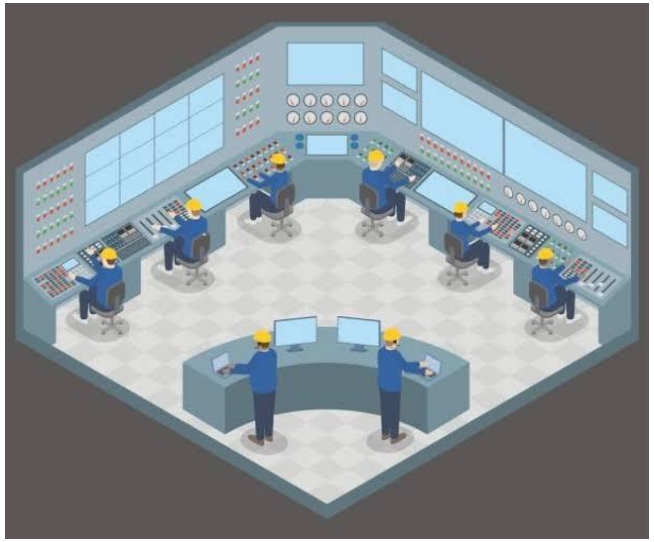
Partial Process Map



Hidden Markov Model

Hidden Failure Modes



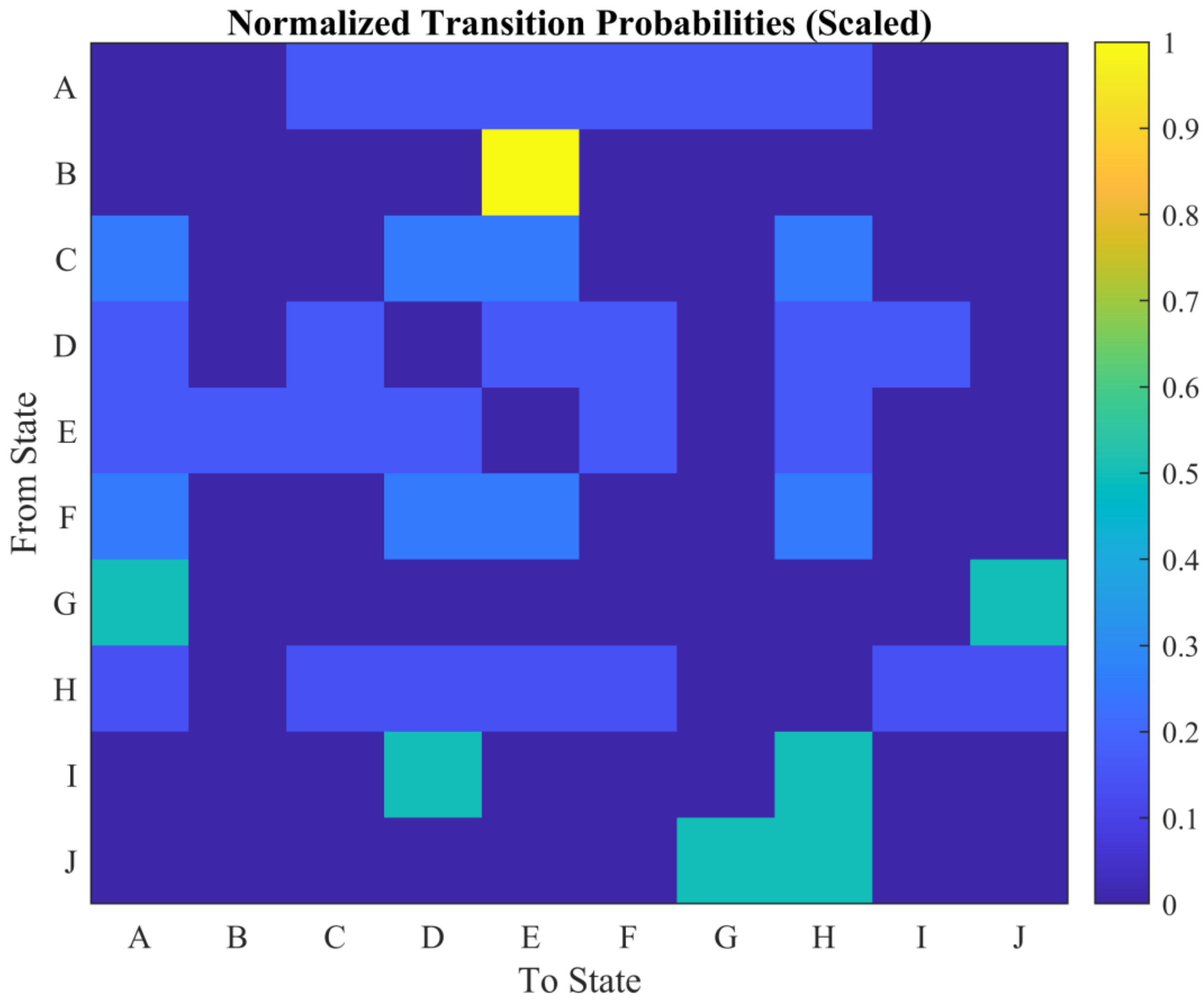


Observations (Control Room)

https://www.researchgate.net/figure/The-Kaplan-turbine-4_fig18_277307265

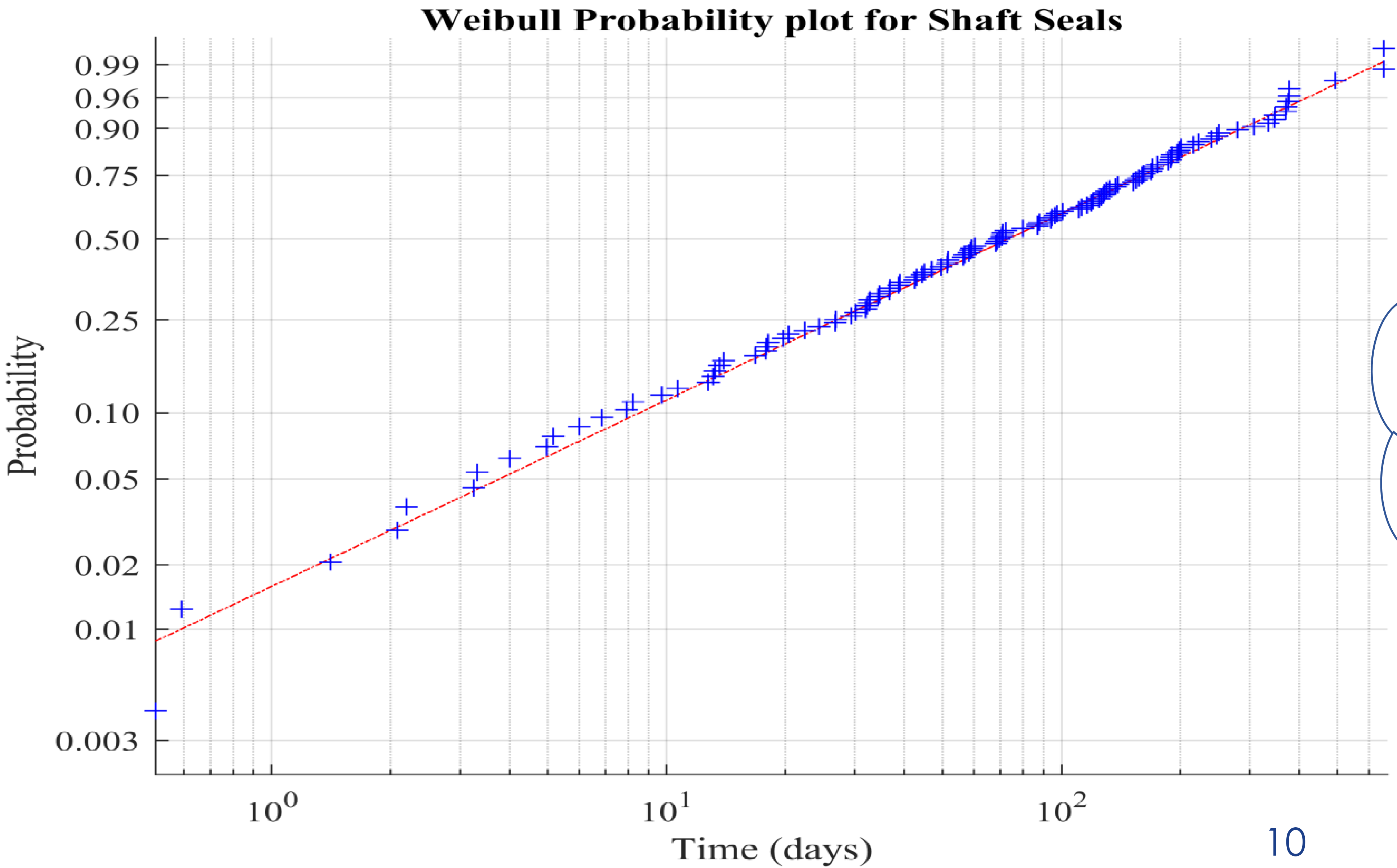
Partial Transition Matrix

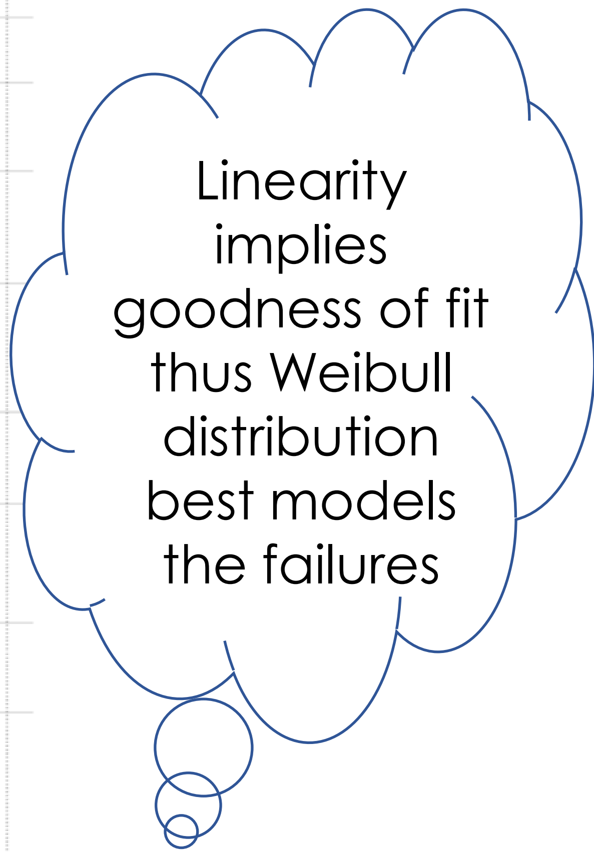
		A	B	C	D	E
Vibration	A	0.55	0	0	0	0.1
Cavitation	B	0.2	0.79	0	0	0.01
Jamming	C	0	0	0.65	0	0
Leakage	D	0	0	0	0.3	0
Rupture	E	0	0	0	0	0.9



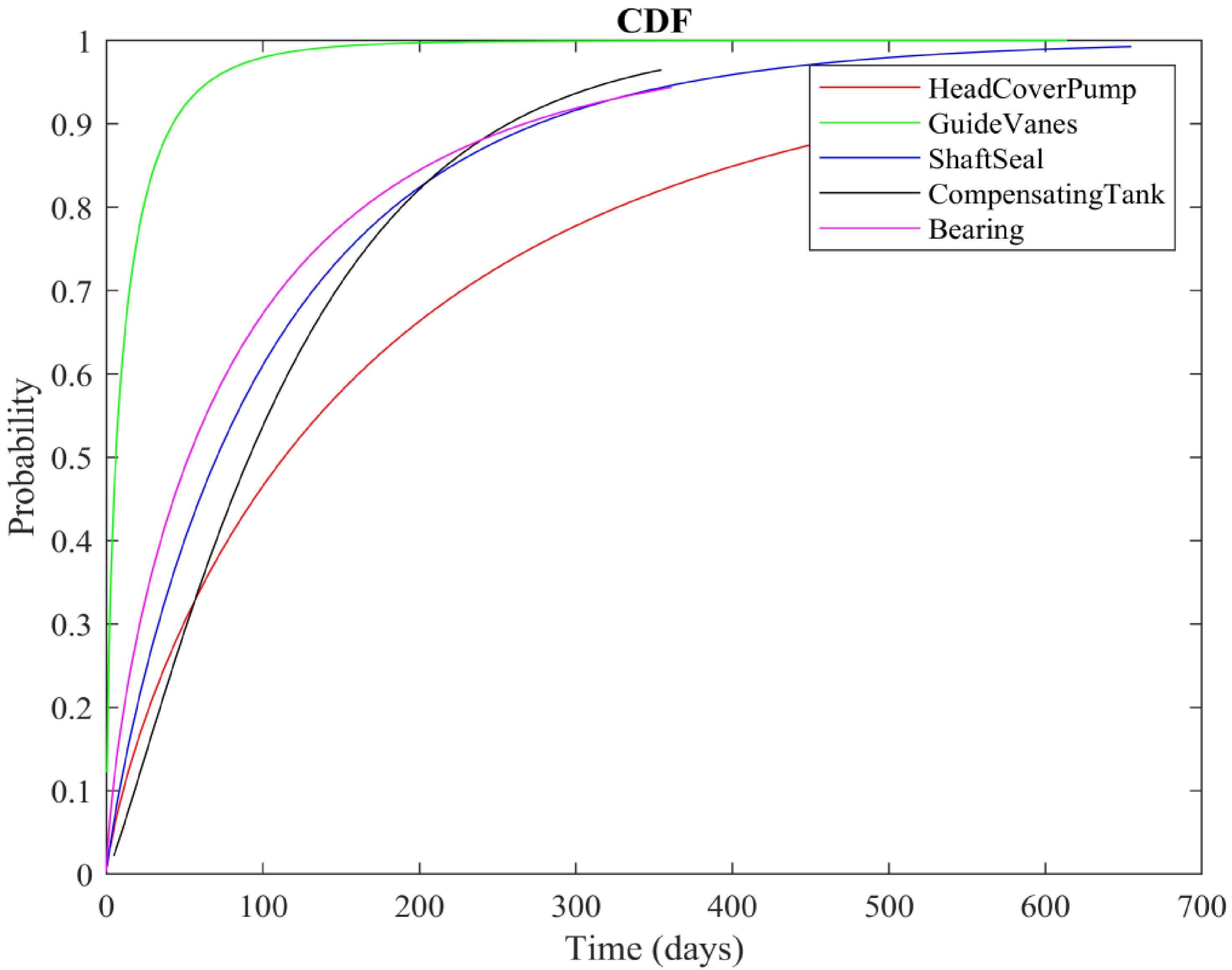
- Transition and emission matrices allowed for modelling of failure progressions

Goodness of Fit





Reliability Analysis



- Guidevanes had a failure probability greater than 60% at 360 hours, underscoring their need for a shorter maintenance cycle
- Head cover pumps that had a failure probability less than 60% even at 4800 hours
- Shaft Seal System and Guide vanes are in burn in stage underscoring priority for maintenance

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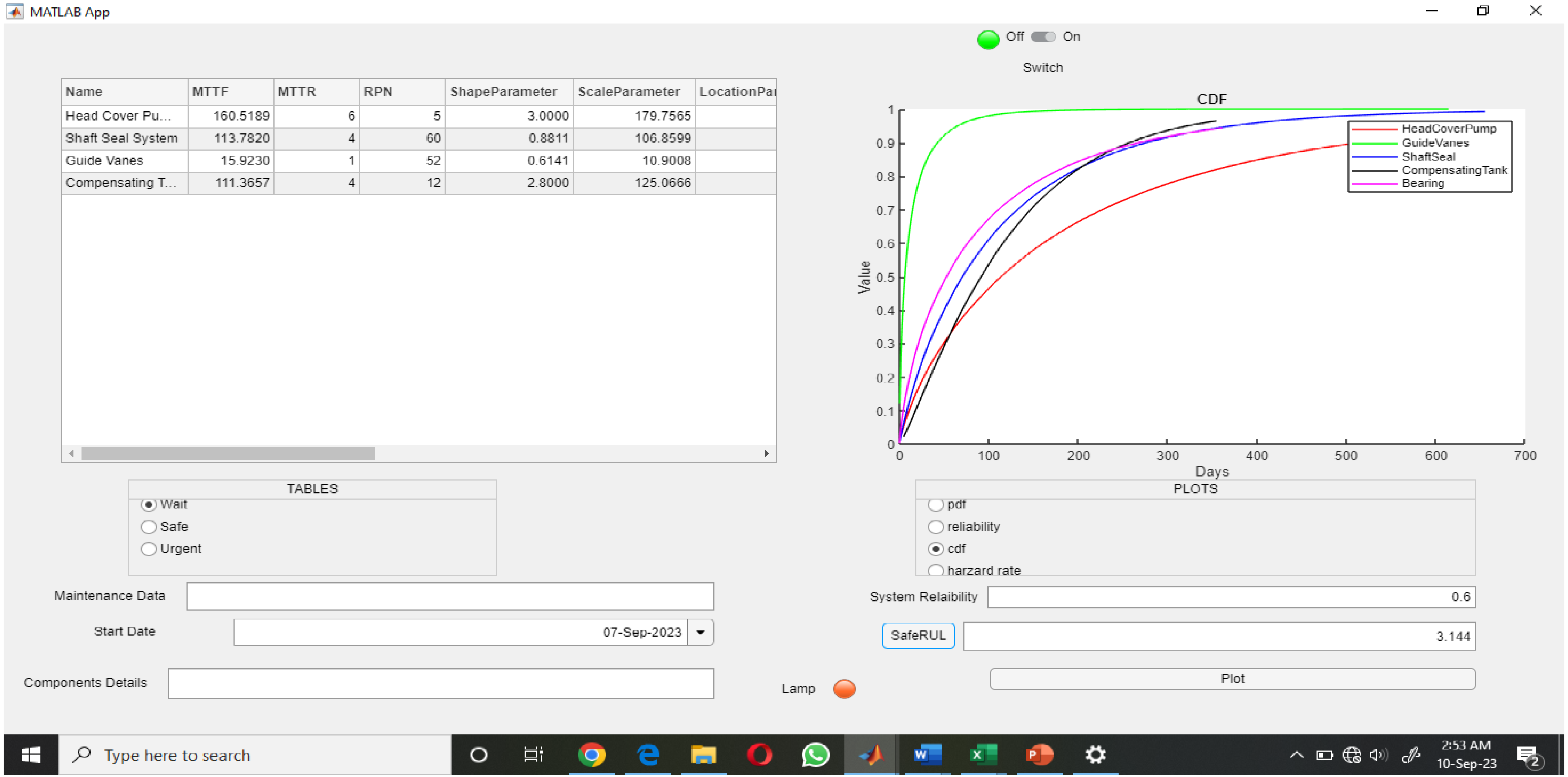
GUI for the Maintenance Scheduling Tool



Name	MTTF	MTTR	RPN	ShapeParameter	ScaleParameter	LocationPar
Head Cover Pu...	160.5189	6	5	3.0000	179.7565	
Shaft Seal System	113.7820	4	60	0.8811	106.8599	
Guide Vanes	15.9230	1	52	0.6141	10.9008	
Compensating T...	111.3657	4	12	2.8000	125.0666	

Moving Forward

- select more erosion-resistant materials or incorporate surface coatings to reduce wear in guide vanes

- Operationally, equip the turbine with sediment and debris filtration systems to minimize abrasive damage, especially in environments with high silt loads

- incorporate real-time sensor data to capture dynamic operating conditions and allow for adaptive scheduling of maintenance(Park et al., 2022).

- Explore other components of the Hydro power plant other than the turbine

- This research work strongly aligns with theme 1 of AES 2025, because it enhances power reliability, while extending the useful life of hydro-power plant components.

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References

- https://www.hydropower.org/publications/annual-report-2023-24

- Quaranta, E., Aggidis, G., Boes, R. M., Comoglio, C., De Michele, C., Ritesh Patro, E., Georgievskaia, E., Harby, A., Kougias, I., Muntean, S., Pérez-Díaz, J., Romero-Gomez, P., Rosa-Clot, M., Schleiss, A. J., Vagnoni, E., Wirth, M., & Pistocchi, A. (2021). Assessing the energy potential of modernizing the European hydropower fleet. *Energy Conversion and Management*, *246*(September). https://doi.org/10.1016/j.enconman.2021.114655

- Lim, J. (2020). Climate Impacts on African Hydropower. *Climate Impacts on African Hydropower*. https://doi.org/10.1787/7f8fc476-en

- Katutsi, V., Kaddu, M., Migisha, A. G., Rubanda, M. E., & Adaramola, M. S. (2021). Overview of hydropower resources and development in Uganda. *AIMS Energy*, *9*(6), 1299–1320. https://doi.org/10.3934/ENERGY.2021060

- Kumar, A., & Singal, S. K. (2024). Hydro-abrasive erosion in Kaplan turbines : a case study. 26(9), 2251–2260. https://doi.org/10.2166/hydro.2024.096

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