DECISION SUPPORT SYSTEM OF EVAPORATING SYSTEM OF SUGAR PLANT

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Abstract

This paper addresses an analysis methodology for assessing the efficacy of a evaporating system in a sugar industry. A stochastic Petri nets technique is employed to simulate the interactions between the subsystems. A software package, "Petri module," from GRIF, was licensed. The performability of subsystems has been evaluated, and fluctuations in repair and failure rates have been observed. The maintenance order priority was assigned to the subsystems of the evaporating system based on the criticality of failure. Finally, a decision support system is implemented to assist maintenance personnel in making more informed decisions during the development of maintenance policies. It has been noted that the evaporator is an essential component that requires the complete attention of the plant manager.

Keywords: availability analysis, evaporating system, sugar industry, petri nets.

I. Introduction

In the current scenario, modern process facilities must be run at high levels of availability due to the high cost of installation, operation, and maintenance [1]. As a result, achieving high levels of availability is crucial for ensuring their efficiency and economic viability. In this regard, a reliability study should evaluate its availability and provide a method for identifying possible event combinations that might lead to disastrous failures and assess the prospect that they would occur [2]. The assessment process should include cost-related elements and be able to examine other performance metrics [3]. The state-transition diagram (Markov models), Petri nets (PNs), fault tree analysis, event tree analysis (FTA and ETA), and network models are some of the key modeling techniques used in reliability analysis [4]. Models of networks are function-oriented. These models may address structural defects that impair system performance. Maintenance procedures, human and software errors, and other cost-related factors are complicated to include in network models [5]. Trees of faults are event-oriented. Including the repair processes and component reliance in the model is complex [6]. The static structure of failure trees makes it difficult to simulate dynamic behaviour such as standby redundancies and time-delay situations. The inflation of state space is the main disadvantage of Markov models. State-space explosion restricts the use of this formulation, despite the fact that it may describe the dynamic behaviour and reliance between components [7]. When creating a Markov model of a complicated system, it may be challenging to ensure that every conceivable outcome in a subsystem has been considered [8]. State-transition diagrams are also highly challenging to employ for model validation. In this research, a complicated system that is concurrent, asynchronous, distributed, parallel, and non-deterministic is studied using PN, a graphical and mathematical modeling tool. Using PNs for reliability analysis makes the modeler's job much more manageable. The process involves sketching a net that describes a system model and labeling it with the appropriate transition firing timings [9], [10]. If tools could be developed to automate the process of determining the probability of markings and the algorithms for constructing the set of all reachable markings of a Petri net (PN), analysts would be able to focus more on addressing reliability concerns, rather than spending time writing and solving the equations for the underlying stochastic process. PNs provide for a systems approach as they employ a common vocabulary to represent human behaviour, software, and hardware. Safety and fault tolerance standards may also be included.

II. Literature Review

Malik and Tiwari [11] conducted an assessment of the Coal Ash Handling System's performance at a subcritical thermal power plant. This model combines State probabilities using a normalizing condition. Parkash and Tiwari [12] created performance modeling and suggested a DSS to prioritize repair activities for an assembly line system. Kumar [13] highlighted the importance of many practical units in his Decision Support Priorities framework. Sheikh and Tewari [14] examined the applicability of Reliability, Availability, Maintainability, and Safety ideas in several process sectors to improve performability. Stochastic processes address unpredictability in systems, particularly about unpredictable temporal changes. Performability analysis enhances the understanding of the system's performance behaviour. This enables us to make better-informed decisions on the design and operation of systems to enhance their reliability and efficacy. Mehta et al. [15] examined the steel plant's sheet production unit's dependability, availability, and maintainability. The extractor, conveyors, de-scaling unit, furnace, roughing mill, Steckel mill, strapping machine, and down coiler were among the eight systems that were part of the unit. Simpson's 3/8 rule and the Runge–Kutta fourth-order approach have been used in MATLAB to assess the system's availability. Kumar and Ram [16] used the Markov approach to examine a number of reliability metrics, including availability, reliability, and MTTF for the sugar factory. Apart from the bagasse carrying mechanism, the system's MTTF declined for all failure scenarios. With the exception of the bagasse carrying method, dependability appears physically the same in all failure kinds. Aly et al. [17] used a model based on the Markov technique and state probability to assess systems' availability, dependability, and maintainability for the oil and gas sector. Jalal et al. [18] used SPNs modelling to offer a power production facility's reliability, availability, and maintainability (RAM) analysis. This model assumed that the maintenance and repair crews would always be accessible, regardless of the number of components that failed at any one moment. They showed that, in comparison to the reliability block diagram simulation, SPN modeling produced a smoother exponential curve when analyzing the system's mean availability.

Most models for estimating complex system availability and reliability are based on FMECA, FTA, Markov, and Bayesian network approaches, and few process plants use PNs to consider subsystems and component dependencies.

III. System Description

The evaporation system (ES) removes water from the juice received from the clarifier system. All cells in the ES are in series. A three-subsystem ES is presented below. Fig. 1 shows the ES flowchart.

Evaporator (EV): The system consists of a single unit, and its failure results in the complete failure of the entire system. Under this subsystem, a low vacuum is used to heat the juice.

Syrup Sulphitor (SY): The system consists of two units: one operational unit and one standby unit. If one unit fails, the system continues to operate at a reduced capacity. However, if both units fail, the system fails entirely. This subsystem heats juice at a high vacuum and passes SO2 gas.

Sulphited Syrup (SU): The system consists of three units. If one or two units fail, the system continues to operate at a reduced capacity. However, if all units fail, the system fails entirely.

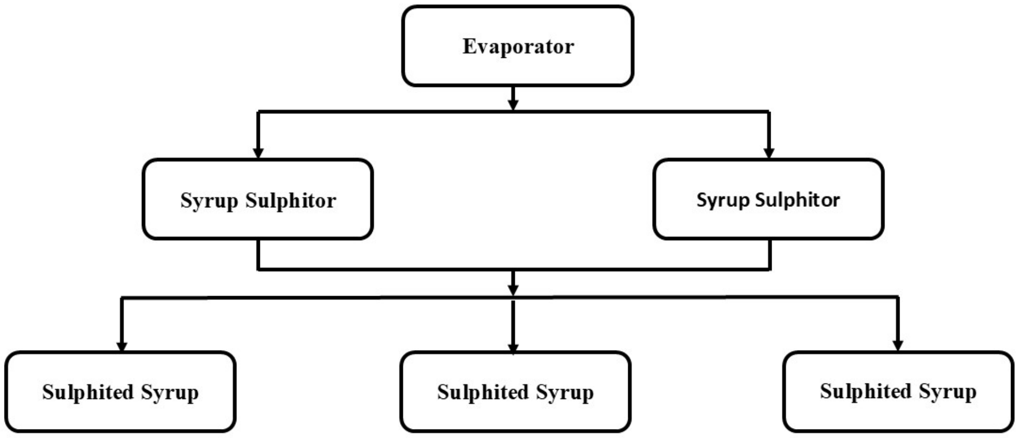

Figure 1. *Flow diagram of ES*

IV. Petri Nets Modelling

This section assesses several components of ES in the sugar industry. The maintenance workers and supervisors helped us extract component FRs and RRs from maintenance and repair manuals. FR and RR values were considered to be Weibull-distributed. The Monte Carlo Simulation Approach-based MOCA-Computation engine modelled ES performance. This was accomplished using the SPN, as seen in Figure 2.

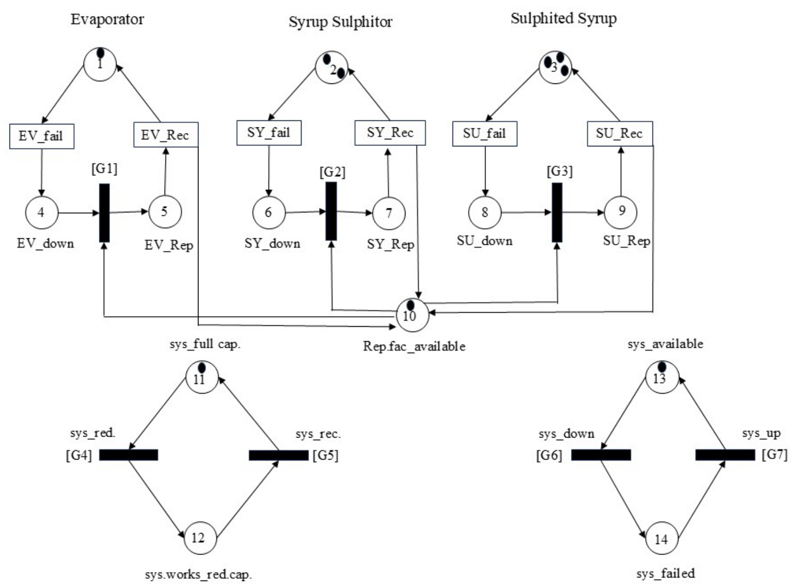

Figure 2. *PNs modelling of ES*

I. Assumptions Notations

The following assumptions were used to employ PNs for availability analysis:

- The FRs and RRs of a number of components follow exponential distributions.
- Individual component failures occur.
- The functionality of repaired components is equivalent to that of new ones.
- Repairs comprise both component replacements and repairs.
- It is not anticipated that two or more components will fail simultaneously.
- Active systems are functionally equivalent to standby components.
- The patterns of FRs and RRs remain statistically independent and stable over time.

II. Places

sys_available: signifies that the entire system is operational and available for use.
sys. works_full cap.: denotes the system's condition when operating at full capacity.
sys.works_red.cap: signifies that the system is operating at a reduced capacity.
sys_failed: denotes the system's state during downstate.
rep. facilities_available: denotes the facility's capacity to undergo swift repairs.
EV_up, SY_up, and SU_up: denote the operational condition, which is the status of the EV, SY, and SU systems, respectively.
EV_down, SY_down, and SU_down: denote the non-operational condition of the EV, SY, and SU systems, respectively.
EV_Rep, SY_Rep, and SU_Rep: represent the restored conditions of the EV, SY, and SU systems, respectively.

III. Transitions

EV_fail, SY_fail, and SU_fail represent timed transitions related to the failure patterns of EV, SY, and SU systems, respectively.
EV_OK, SY_OK, and SU_OK represent cautious transitions associated with the repair patterns of the EV, SY, and SU systems, respectively.
Rep. avail_ EV, Rep. avail_ SY, Rep. avail_ SU: These instantaneous transitions imply that the EV, SY, and SU systems are all instantly available.
sys_ red, sys_ recovered, sys_ fail, and sys_ ok: These are instantaneous transitions that are fire without delay.

IV. Guard Function (GF)

[G1]: = (#4>0 and #10>0) rep. avail_ EV transition was initiated when the GF ensured.

[G2]: = (#6>0 and #10>0) rep. avail_ SY transition was initiated when the GF ensured.

[G3]: = (#8>0 and #10>0) rep. avail_ SU transition was initiated when the GF was ensured.

[G4]: = (#2<2 and #2>0 or #3<3 and #4>0) sys_ red transition initiated when the GF ensured.

[G5]: = (#2>1 and #3>2) blocks transition from firing sys_ recovered.

[G6]: = (#1<1 or #2<1 or #3<1) sys_ fail transition was initiated when the GF ensured.

[G7]: = (#1>0 and #2>0 and #3>0) blocks transition from firing sys_ ok.

V. Performance Analysis

The system's dynamic behavior was evaluated using variables to determine its performance characteristics. After consulting with plant maintenance experts, the acceptable failure and repair rates for subsystems (Table 1) were established. These parameters are also examined about repairman availability. The findings are shown in Tables 2-11 and discussed further below.

Table 1: *Availability matrix for EV*

σ \ Ψ	0.25	0.35	0.45	0.55	0.65
0.021	0.8269	0.8375	0.8442	0.8490	0.8529
0.026	0.8181	0.8277	0.8344	0.8407	0.8456
0.031	0.8061	0.8179	0.8265	0.8332	0.8374
0.036	0.7954	0.8078	0.8175	0.8249	0.8309
0.041	0.7837	0.7973	0.8083	0.8173	0.8240

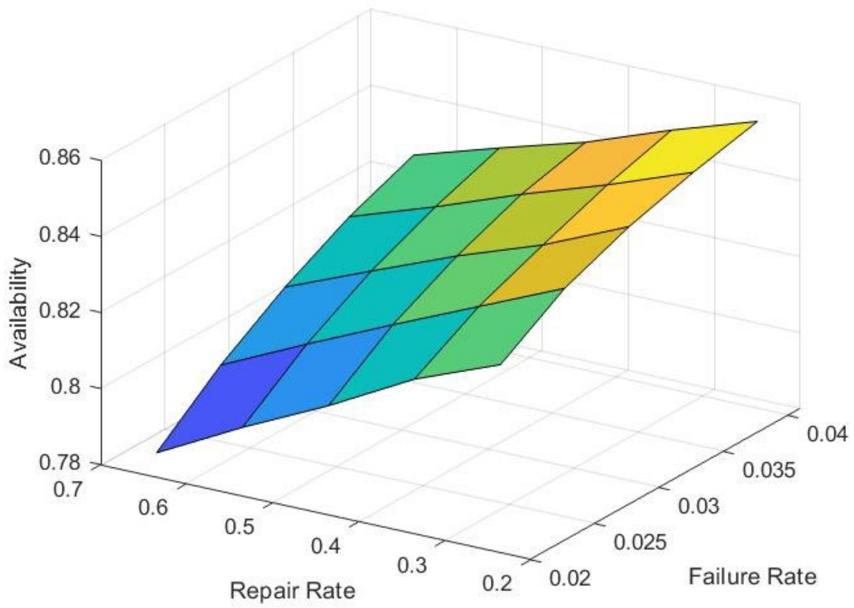

Figure 3. *Influence of varying FR and RR of EV on the availability*

Table 1 and Fig. 3 illustrate the influence of FRs and RRs in the EV on the ES's overall availability. With an increase in the FR from 0.021 to 0.041, there is a significant decrease in system availability, equivalent to a 5.22% decrease. In contrast, the increase in RRs from 0.25 to 0.65 resulted in a slight improved system availability of 3.04%.

Table 2: *Availability matrix for SY*

σ \ Ψ	0.47	0.57	0.67	0.77	0.87
0.040	0.8287	0.8327	0.8365	0.8379	0.8397
0.045	0.8227	0.8270	0.8303	0.8328	0.8345
0.050	0.8179	0.8223	0.8265	0.8279	0.8304
0.055	0.8124	0.8180	0.8207	0.8237	0.8259
0.060	0.8066	0.8121	0.8152	0.8194	0.8232

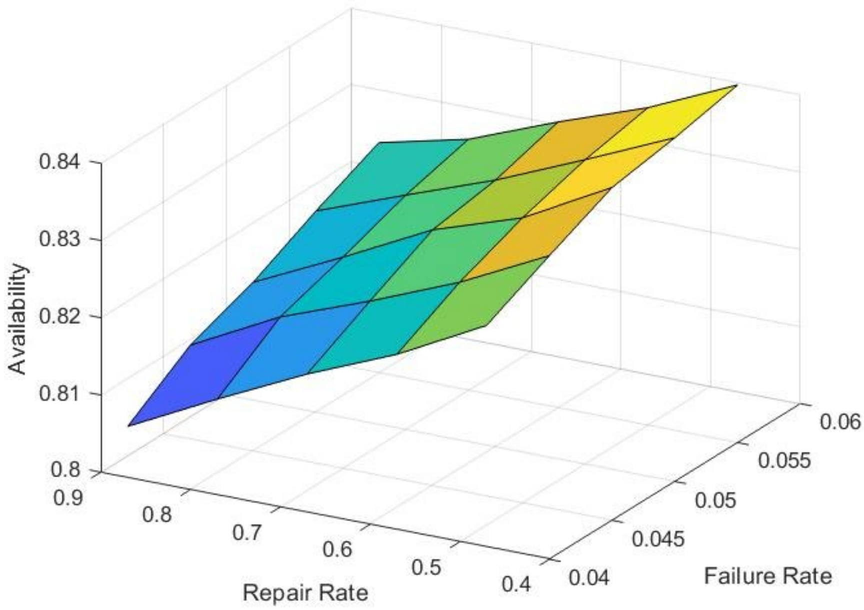

Figure 4. *Influence of varying FR and RR of SY on the availability*

Table 2 and Fig. 4 illustrate the impact of FRs and RRs on the availability of the ES, with a particular emphasis on the SY. When the SY's FR is increased from 0.040 to 0.060, there is a slight decrease in system availability of 2.66%. Conversely, the system's availability is marginally enhanced by 1.3% as a result of the RR being increased from 0.47 to 0.87.

Table 3: *Availability matrix for SU*

σ \ Ψ	0.10	0.20	0.30	0.40	0.50
0.017	0.8258	0.8328	0.8362	0.8397	0.8427
0.022	0.8201	0.8251	0.8299	0.8335	0.8374
0.027	0.8117	0.8188	0.8265	0.8294	0.8303
0.032	0.8019	0.8089	0.8164	0.8209	0.8259
0.037	0.7945	0.8015	0.8091	0.8141	0.8189

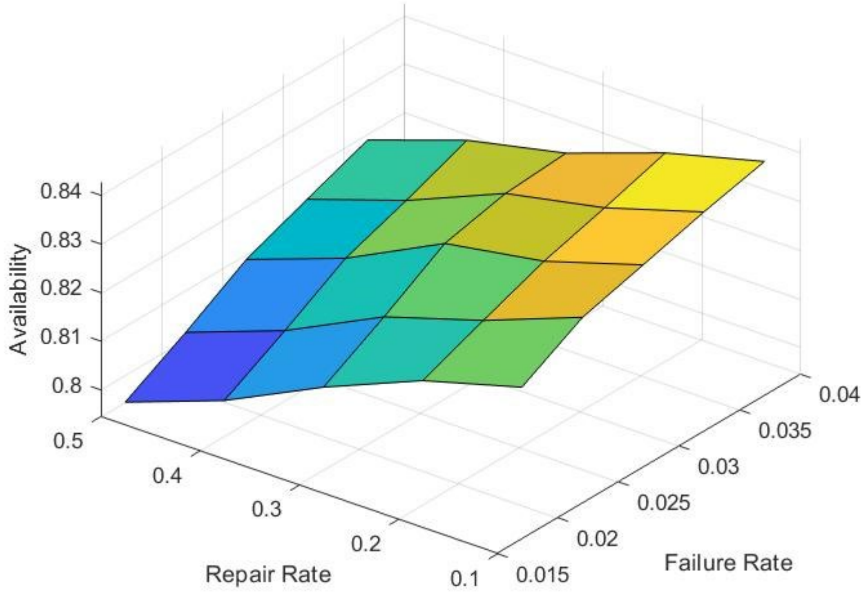

Figure 5. *Influence of varying FR and RR of SU on the availability*

The availability of the ES is influenced by FRs and RRs, as illustrated in Table 3 and Fig. 5, with a particular focus on the SU. The SU's FR increases from 0.019 to 0.039, resulting in a minor decrease in system availability of 3.8%. When the RR is increased from 0.37 to 0.57, the system's availability rises by 2.01%.

According to the study's findings, the EV failure immediately affected total system availability by 5.22%. Thus, the EV is shown to be the most crucial part of the ES, with an FR of 0.031. Likewise, the SY is the least significant element, with an FR of 0.050. Therefore, according to the ES system's ideal FRs and RRs, the maintenance priorities need to be allocated in the following order (as shown in Table 4).

Table 4: *List of maintenance priority*

Component	FR	RR	Reduction in Av due to FR	Elevation in Av due to RR	Maintenance priority No.
EV	0.021 -0.041	0.25-0.65	5.22	3.04	I
SY	0.040- 0.060	0.47-0.87	2.66	1.3	III
SU	0.019 - 0.039	0.37-0.57	3.8	2.01	II

Table 5: *Influence of variation in the RF on availability of CSPS*

No. of RF	1	2	3	4
Availability	0.8265	0.8520	0.8621	0.8621

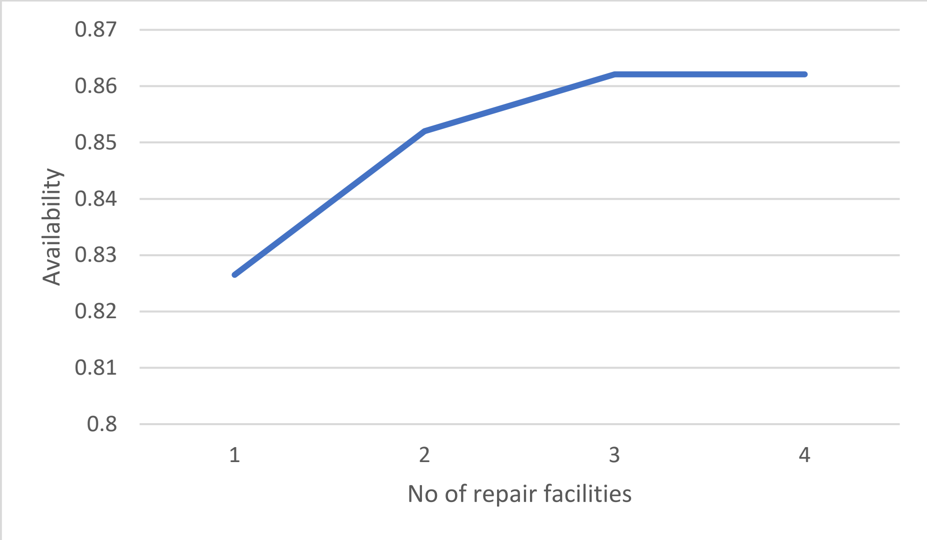

Figure 6. *Influence of variation in RF on the availability of CSPS*

Table 5 and Fig. 6 show the effect of higher RF on the ES's total availability. From 82.65% to 85.20%, the system's overall performance improves considerably as the number of RF increases from one to two. When RF goes up from 2 to 3, availability goes up from 85.20% to 86.21%, which is a significant improvement. The performance becomes stable at three RF, indicating that the service is consistently available.

VI. Conclusion

The model demonstrates efficacy in evaluating the performance of various ES components, facilitating maintenance decision-making. The study enabled us to assess the impact of several factors, namely FRs and RRs, on the unit's availability. The system's availability diminishes as the failure rate rises. Conversely, higher RRs result in increased system availability. Consequently, increasing the RRs and decreasing the FRs across all four subsystems is essential to improve the ES's performance. Therefore, optimizing FRs and RRs data is essential for attaining high efficiency. The suggested model is effectively used to evaluate the performance of ES in the sugar industry, facilitating decision-making about maintenance measures. Performance metrics indicate that the EV component is crucial for maintenance. Immediate care is necessary since the failure rates of the EV significantly impact system availability relative to other subsystems. Further, the SY component emerges as the least crucial, as the FRs of the SY have minimal influence on the system availability. As industries progress, the insights derived from these evaluations are essential for sustaining system performance and minimizing downtime.

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