A CRITICAL LITERATURE REVIEW AND FUTURE PERSPECTIVE OF RAM APPROACHES FOR COMPLEX SYSTEMS IN VARIOUS PROCESS INDUSTRIES

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Abstract

In the industrial systems there is a requirement that systems should work efficiently for long time. System performance is an important aspect for failure free operation but in real practice complete failure free operation of any production system is seldom possible. Detailed critical literature review for the past thirty three years of Reliability, Maintainability and Availability (RAM) approaches has been carried out which can help to improve performance of Complex systems. Review of some papers provided the detailed information about past and current scenario of RAM practices in research field and industries. Different RAM tools and techniques extracted from the review may be helpful in qualitative and quantitative analysis of the complex systems. In this paper, author tried to focuss on some major aspects of RAM approaches.

Keywords: Reliability, Availability, Maintainability, Safety, Markov, Petri Nets, Dependability.

I. Introduction

All assets would be developed in a perfect world with low failure rates, low maintenance costs and simplicity of use in mind. There should be adequate balance in the productivity of an asset with the cost of its purchase and maintenance. A team of design, systems, and reliability professionals will usually do RAM analysis during the design phase. Over the course of the asset's life, the study can be repeated by maintenance and service reliability engineers, who have vital information on the performance and health of the asset.

These three factors (Reliability, Availability and Maintainability) are all equally crucial and frequently complement one another. Machine is operational if it is available, reliable if it is likely to function correctly, and maintainable if it can be quickly rectified even if something goes wrong.

Reliability can be defined as the probability that a system will complete the task and run flawlessly in a specific environment for a set period of time. In reliability engineering, high levels of "lifetime" engineering uncertainty and failure hazards are addressed through prediction, prevention, and risk management. Although stochastic parameters influence and determine dependability, mathematics and statistics are not the only ways to achieve it. Reliability engineering is closely related to quality engineering, safety engineering and system safety.

Availability is a special parameter that combines serviceability and reliability criteria. It indicates the probability that an asset will be operational (neither maintained nor repaired) at any given time. Availability is measured at steady state, taking into account potential downtime during which the service may (and will) become unavailable during its expected useful life. In reliability engineering calculations, the failure rate is taken as the predicted strength of failure, assuming the component is fully functional in its original state.

Maintainability discusses the ease of maintenance on an asset and the resource requirements. The probability that an asset will resume its intended state after a maintenance duty can also be calculated using this method. Mean Time to Repair (MTTR) is a common metric used to evaluate it.

System engineers, logisticians and users are particularly interested in the three RAM (Reliability, Maintainability and Availability) characteristics of a system. Together these characteristics have an impact on a product or system's usefulness as well as its life-cycle costs. A decision-making tool known as Research on Reliability, Availability and Maintainability (RAM) is utilized to increase system availability, which in turn increase overall profitability and reduces cycle costs life. In engineering, the term "Reliability, Availability, Maintainability and Safety" is frequently used to describe a property of a product or system.

II. Critical Literature Review

Ciardo et. al. (1990) performed analysis of processing systems using semi-markov reward processes. The semi-markov reward process is an extension of an algorithm proposed by Beaudry, it was presented for the computation of accumulated reward in a semi-markov process [1]. **Viswanadham et. al. (1991)** formulated the performability of the fault-tolerant manufacturing system. Through examples, the authors try to show the importance of performability in automated manufacturing system design. Performability measures considered deal with throughput and manufacturing lead time, which essentially determine the competitiveness of a plant [2]. **Kumar et. al. (1992)** studied the analytic behavior of reliability and availability of the crystallizer system in sugar plants. The model was based on Chapman-Kolmogrov equations. The Laplace transform was used to derive steady-state availability and various state probabilities. The effect of failure and repair rates on availability has been studied [3]. **Sharma and Bazovsky (1993)** performed analyses of large and complex systems using Markov method. Laplace transform method was used to solve the differential equation. After the modeling, design engineers were able to evaluate their own design to increase the reliability of the system [4]. **Behera et. al. (1994)** used deterministic and stochastic based petri net to modelled the flexible manufacturing system. Performance evaluation of system has also been done. Generalized stochastic petri net was also used to modelled the flexible manufacturing systems. Performance measure obtained was almost equal for both deterministic petri net and generalized stochastic petri net [5].

Murty and Naikan (1995) investigated the optimization of a manufacturing plant's availability and maintenance costs. It has been concluded that before making any major decisions regarding the formation of the maintenance budget, it is prudent to carefully examine the economic viability of overspending on maintenance in order to increase plant availability [6]. **Kumar et. al. (1996)** assessed the shell gasification and carbon recovery processes in a urea fertilizer plant from a behavioral perspective. The author of this paper used straight forward probability considerations to formulate the issue. The equations for steady-state availability were derived, and they provided the equipment's behavior based on the analyses of the results. Based on the failure results, advise the maintenance manager with guidelines for carrying out the workplan for repairs, among other things [7]. **Arora and Mehta (1997)** evaluated the steam and power generation capacity of thermal power plants. The authors devised the expressions for steady-state availability and mean time between failures. Graphs illustrate how failure and repair rates affect system availability. The Chapman-Kolmogorov birth-death process and a probabilistic method were used in the modeling procedure. The critical system and subsystem made a decision to limit failures based on the results, and the plant staff was informed of the results so they could make plans for the system's failure-free operation [8]. **Pellegrini et. al. (1998)** used a statistical approach based on the semi-Markov technique to assess the availability and performance of electronic complex systems. The electronic system's resolution model of a semi-Markov process was identified from the findings, and the mean Laplace transform was used to calculate the asymptotic availability value [9]. **Singh and Mahajan (1999)** evaluated a production facility for utensils for availability and dependability. Differential equations resolved using the Laplace transformation. The Markovian method was used to investigate the effect of different parameter availability. The findings demonstrated that availability impacted when repair and failure rates are disrupted [10].

Borgnovo et. al. (2000) proposed modeling through Monte Carlo. The plant's tool management and operation were advised by Monte Carlo modeling. The paper's analysis looks at the operation and maintenance plan [11]. **Zhang and Horigome (2001)** looked at how the availability and dependability of the system's failure and repair rates evolved over time. The solution shows the system's availability and dependability with varying failure and repair rates [12]. **Wang and Loman (2002)** critically examined the K-out-of-N system's availability and dependability using M cold steady units. The design process for such power systems has been investigated and it has been found that this kind of design is capable of eliminating Single Point Failure (SFP), Common Mode Failure (CMF) and the greatest likelihood of human error [13]. **Dai et. al. (2003)** presented a model of a centralized heterogeneous distributed system in order to learn more about distributed system service availability and dependability. The model parameter's sensitivity was investigated. Conclusion has been made that the service reliability function can assist in appropriately allocating testing resources [14]. **Rauzy [2004]** described six approaches for calculating the time-dependent probability of Markov models. After a thorough investigation of techniques such full matrix exponentiation, Euler approach, Runge-Kutta method, and Adams-Bash ford multi-steps methods of order 2 and 4, it was shown that computers nowadays could potentially manage Markov networks with millions of transitions [15].

Marseguerra et. al. (2004) studied multi-objective optimization, which takes into account parameter uncertainty and is primarily based on genetic algorithms. This method gives the decision-maker a tool to use in order to find a solution that is also optimal in terms of expected safety behavior and allows for a high degree of assurance in the actual system performance after applying the procedure to more complex systems [16]. **Gupta et. al. (2005)** utilized the mathematical formulation of the model to propose a numerical analysis of the process's availability and reliability in the bute-oil processing plant. After discussion, it may indicate that the proposed technique is applicable to complicated systems that are also governed by substantial differential equations [17]. **Majeed and Sadiq (2006)** utilized the Markovian method to create a model for the Dokan hydro power station. The discussion and modeling of the issue led to the conclusion that power station reliability decreased annually. Conclusion has been made that a poor maintenance program and the inexperience of engineers and technicians affected availability adversely [18]. **Chuan ke and Kuangkhu (2007)** conducted a comparison of the availability of repairable redundant systems. Four bootstrap approaches were used to compute a comparison of confidence intervals for steady-state availability [19]. **Sharma and Kumar et. al. (2008)** presented the Markovian method of obtaining system behavior through the use of RAM analysis in crucial engineering systems. The transition diagram was used to create the differential equations. Based on the results, it has been advised to the managerial staff that characteristics like MTBF and MTTR are important for the system's planning and maintenance [20].

Goyal et. al. (2009) carried out an availability analysis of a part of Rubber tube production system under pre-emptive resume priority repair. The methodology used was Markov modelling. The purpose of the paper was to improve operational availability. Based on the results, the effect of failure and repair rates on availability was found. This information helps maintenance management improve the overall reliability and availability of the system [21]. **Adhikary et. al. (2010)** analyzed a coal-fired power plant's RAM. Before the data are fitted best with a probability distribution, a trend test and a serial correlation test are used to verify the distribution of failure and repair data. The significant subsystem has been identified through the use of Pareto analysis. The findings led to the conclusion that a rise in MTBF and a decrease in MTTR increase the power plant's availability [22]. **Vora et. al. (2011)** evaluated performance of turbo generator system of thermal plant using probabilistic approach. Markov approach has been used for problem formulation through transition diagram. Based on result availability graphs of failure and repair for maximum availability has been analyzed [23]. **Garg and Sharma (2012)** analyzed the performance of the synthesis unit in a fertilizer plant. The system's behavioral sensitivity has also been investigated. The Lamda Tau-Technique was used to investigate the behavior of a complex system that could be improved. Eight significant dependability parameters were also registered as fuzzy membership function [24]. **Wolde et. al. (2013)** discussed the issue of railway carrier inspections and maintenance. Using mathematical modelling, this study ties failure and repair rates to system performance. This modelling was used to evaluate inspection plans for any system, further optimizing its cost [25].

Suleiman K et. al. (2013) dealt with applying a probabilistic strategy to analyze stochastic data and evaluate thermal power plant performance. According to the findings of the analysis, availability decreases as the failure rate rises, while availability rises as the repair rate rises and vice versa. The plant management can use the result-based system for system availability analysis [26]. **Dewangan et. al. (2014)** investigated the reliability of thermal power plant's steam turbines. Investigation has been done based on failure database of five year. Failure modes and effect analysis (FMEA) used to categorize critical components. Based on investigation it has been concluded that well planning and regular scheduled maintenance can improve the reliability of plant [27]. **Aggarwal et. al. (2015)** proposed a performance model based on the Markov birth-death process for calculating RAM, dependability, MTBF and MTTR. Modeling has been done mathematically using Chapman-Kolmogorov differential equations and probabilistic considerations. Most critical subsystem pointed and suggested management to take utmost care [28] **Talebborouane et. al. (2016)** applied sophisticated fault tree and stochastic Petri Net formalisms to examine the availability of safety-critical systems. Generalized stochastic Petri Nets and fault tree driven Markov processes were utilized for analysis to get over the drawbacks of the Markov process and Petri Nets. It concluded that Petri Net is better for modeling as compared to fault tree driven Markov process [29]. **Kumar and Tewari (2017)** utilized Particle Swarm Optimization (PSO) to optimize and analyse the performance of a beverage plant system. Exponential distribution is considered for repair and failure rate, and Markov approach is used for mathematical modelling. Results have been discussed with plant management for the improvement of system performance [30].

Malik and Tewari (2018) modeled and prioritized maintenance for a coal-fired thermal power plant's water flow system. Chapman-Kolmogorov equations were derived to obtain performance modelling using the Markov approach. The authors demonstrated the proposed approach to assisting in this kind of decision-making process through the case study [31]. **Singhal and Sharma (2018)** used the Markov process and generalized fuzzy numbers to analyse the availability of industrial systems. The uncertainty of data has been dealt with generalized fuzzy numbers. Availability analysis has been analysed through different arithmetic operations. The system analyst observed the impact of failure and repair rates on the system [32]. **Velmurugan et. al. (2019)** used Markov process to analyze the reliability, availability and maintainability of the forming industry. MATLAB software was used to solve mathematical functions. Based on the results, most critical subsystem was established. The best maintenance policy has also been provided to the maintenance manager for optimal maintenance [33] **Elusakin and Shafiee (2020)** estimated the reliability of subsea blowout preventers using advanced analysis method stochastic Petri Nets with different failure modes. MTBF, availability and reliability terms obtained and analyzed. Sensitivity analysis was carried out to assess the impact that the redundancy design and fault coverage factor have on system performance. Based on the results, it defined that system availability and MTBF were significantly influenced by fault coverage and redundancy [34]. **Jagtap et. al. (2020)** optimized the availability of the boiler furnace system in coal-fired thermal power plant using Particle Swarm Optimization (PSO). The Markov method was used for the analysis of the system. Based on the results maintenance priority has been handed over to plant management [35].

Maihulla et. al. (2021) utilized RAMD (Reliability, Availability, Maintainability and Dependability) analysis to evaluate the efficiency of the complex system of reverse osmosis water purification equipment. The primary objective was to optimize the economy. The components were determined through sensitivity analysis. The RAM of a subsystem (the high-pressure pump) has a substantial effect on the system's overall availability, it was found after the discovery [36]. **Kumar et. al. (2021)** utilized the Petri Nets modeling method to examine the performance of a complex manufacturing system in order to influence the actual behavioral patterns of the many subsystems deployed in the plant. Subsystem that has been severely impacted by availability has been determined by the results [37]. **Parkash and Tewari (2022)** conducted modeling using the Markovian method and employed a probabilistic approach to design the Decision Support System (DSS) for assembly line maintenance. Probabilities for the steady state were determined using a transition diagram and by solving differential equations. The most important subsystem was found and subsystem maintenance priorities were finalized [38]. **Kumar and Tewari (2022)** evaluated performability features of ash handling system of a coal based thermal power plant using Petri Nets based techniques. Failure and Repair rate impact has been determined. Stochastic Petri Nets (SPN) applied for modeling. Based on the results, vital part of system has been identified. Petri Nets were found to reduce the time-consuming computational efforts required by Markov and other modeling methods while also ensuring better results [39] **Behnamfar et. al. (2023)** presented a continuous Markov process-based reliability analysis of wireless power transfer for electric vehicle charging. To determine overall system reliability, five subsystems were individually analyzed on individual reliability. Based on the results, it was discovered that the system was highly reliable over a twenty-year lifespan, with 66.31% availability [40]. **Malik et. al.**

(2023) evaluated the performability of the veneer cutting system of the Plywood Plant using a stochastic approach, and Particle Swarm Optimization (PSO) was used for the optimization of the results. Based on the analysis, maintenance engineers get help optimizing overall maintenance costs and overall production costs [41].

III. Research Gaps

In this section, the RAM approach has been used to discuss the brief findings of a literature survey conducted over the last three decades.

1. In this survey, it has been carried out that Researchers primarily focused on RAM approaches however very limited work is reported regarding RAMD (Reliability, Availability, Maintainability and Dependability) and RAMS (Reliability, Availability, Maintainability and Safety). Researchers missed the importance of effect of Dependability and Safety on Reliability. Safety is an important aspect of working in a safe environment; it also increases the motivation of team members to work in any hazardous environment, whereas dependability is also an important aspect or parameter which effected reliability in positive way by accomplishing its assigned mission or services.
2. Several researchers discussed their efforts to increase plant availability through the use of suitable maintenance procedures, policies, and different operational schedules. But very few researchers reported the relation between cost and maintenance policies with operations schedule. Factors which affected cost also need to be focused.
3. It is observed from the literature review that many techniques, including fault tree analysis, Markov models, and Lambda tau technology, have been applied. Each of these techniques has a variety of benefits and drawbacks. But there is a tool Markovian Petri Nets which can make good balance between modeling and decision making power. Application of this kind of tool is very limited in the literature survey.

IV. Concluding Remarks

Detailed overview of the literature illustrates various RAM issues, tools and techniques applied in various plants and process industries. In literature survey authors majorly focused on maintenance plan, lowering maintenance cost, production costs and increasing performability and productivity etc. In order to further improve the plant's performability, various RAM tools and techniques can be utilized in both the design and the operational stages.

In order to ensure that the systems remain operational for an extended period of time, each plant is divided into a number of systems or subsystems for effective maintenance planning. Markov Analysis, Failure Mode and Effects Analysis (FMEA), Fault Tree Analysis, Reliability Growth Analysis, Fuzzy Model, Monte Carlo technique, Chapman Kolmogorov birth- death process, Stochastic Petri Nets, Particle Swarm Optimization (PSO) and other techniques were utilized for the analysis and modeling. The paper also discusses the advantages and disadvantages of each of these techniques.

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Disclosure Statement

The authors declare that they have no conflict of interest.

References

[1] Ciardo, G., Marie, R. A., Sericola, B., and Trivedi, K.S., (1990). Performability Analysis Using Semi-Markov Reward Processes . *IEEE Transactions on Computers*, 1251–1264.

[2] Viswanadham, N., Narahari, Y., and Ram, R., (1991). Performability of Automated Manufacturing Systems. *Control and Dynamic Systems*, 77–120.

[3] Kumar, D., Singh, J., and Pandey, P.C., (1992). Availability of the Crystallization System in the Sugar Industry under Common-Cause Failure. *IEEE Transactions on Reliability,* 85–91.

[4] Sharma, T.C., and Bazovsky, I., (1993). Reliability analysis of large system by Markov techniques. *Annual Reliability and Maintainability Symposium*, 260–267.

[5] Behera, T.K., Mishra, B.S., Patnaik, L.M., and Girault, C., (1994). Modelling and performance evaluation of flexible manufacturing systems using deterministic and stochastic timed Petri nets. *IEE Conf. Publ.,* 362–368.

[6] Murty, A.S.R., and Naikan, V.N.A., (1995). Availability and maintenance cost optimization of a production plant. *International Journal of Quality and Reliability Management,* 28–35.

[7] Kumar, Sunand., Kumar, Dinesh., and Mehta, N.P., (1996). Behavioral analysis of shell gasification and carbon recovery process in a urea fertilizer plant. *Microelectronics Reliability*, 671-673.

[8] Arora, Navneet., and Kumar, Dinesh., (1997). Availability analysis of steam and power generation systems in the thermal power plant. *Microelectronics Reliability*, 795-799.

[9] Pellegrini, G. G., Catelani, M., and Iuculano, G., (1998). Measurement of the availability performance for electronic complex systems. *IEEE Instrumentation and Measurement Technology Conference, IEEE,* 51–54.

[10] Singh, J., Mahajan, P. (1999). Reliability of Utensils Manufacturing Plant. *A Case Study, Operational Research Society of India*, 260-269.

[11] Borgonovo, E., M. Marseguerra, M., and E. Zio, E., (2000). A Monte Carlo methodological approach to plant availability modeling with maintenance. *Reliability Engineering and System Safety*, 61-73.

[12] Zhang, T., and Horigome, M., (2001). Availability and reliability of system with dependent components and time-varying failure and repair rates. *IEEE Transactions on Reliability,* 151-158.

[13] Wang, Wendai., and Loman, James., (2002). Reliability/availability of K-out-of-N system with M cold standby units. *Annual Reliability and Maintainability Symposium,* 450-455.

[14] Dai, Y.S., Xie, M., Poh, K.L.,and Liu, G.Q., (2003). A study of service reliability and availability for distributed systems. Reliability Engineering and System Safety, 103-112

[15] A. Rauzy., (2004) "An experimental study on iterative methods to compute transient solutions of large Markov models, 1-25.

[16] Marseguerra, M., Zio, E., and Podofillini, L., (2004). Optimal reliability/availability of

uncertain systems via multi-objective genetic algorithms. *IEEE Transactions on Reliability*, 424–434.

[17] Gupta, P., Singh, J.,and Singh, I.P., (2005). Mission Reliability and Availability Prediction of Flexible Polymer Powder Production System, *Operational Research Society of India*, 152-167.

[18] Majeed, A. R., and Sadiq, N. M., (2006). Availability & Reliability evaluation of Dokan hydro power station. *IEEE/PES Transmission & Distribution Conference and Exposition*, 1-6.

[19] Ke, J.C., and Chu, Y.K., (2007). Comparative analysis of availability for a redundant repairable system. *Applied Mathematics and Computation*, 332–338.

[20] Sharma, R. K., & Kumar, S., (2008). Performance modeling in critical engineering systems using RAM analysis. *Reliability Engineering & System Safety*, 913-919.

[21] Goyal, A., Sharma, S. K., and Gupta, P., (2009). Availability analysis of a part of rubber tube production system under preemptive resume priority repair. *International Journal of Industrial Engineering*, 260-269.

[22] Adhikary, D.D., Bose, G., Mitra, S., and Bose, D.,(2010). Reliability, Maintainability & Availability analysis of a coal fired power plant in eastern region of India. *2nd International Conference on Production and Industrial Engineering*, 1505–1513.

[23] Vora, Y., Patel, M.B., and Tewari, P., (2011). Simulation Model for Stochastic Analysis and Performance Evaluation of Steam Generator System of a Thermal Power Plant. *International Journal of Engineering Science and Technology*, 5141-5149.

[24] H. Garg, H., and S. P. Sharma, S.P., (2012) Behavior analysis of synthesis unit in fertilizer plant. *International Journal of Quality and Reliability Management*,217–232.

[25] Wolde, M. Ten., and Ghobbar, A.A., (2013). Optimizing inspection intervals - Reliability and availability in terms of a cost model: A case study on railway carriers. *Reliability Engineering and System Safety*, 137–147.

[26] Suleiman, K., Ali, U.A., and Yusuf, I., (2013) Stochastic Analysis and Performance Evaluation of a Complex Thermal Power Plant. *Innovative Systems Design and Engineering*, 21–32.

[27] Dewangan, D.N., Jha, M.K., and Banjare, Y.P., (2014) Reliability Investigation of Steam Turbine Used in Thermal Power Plant. *International Journal of Innovative Research in Science, Engineering and Technology*, 14915–14923.

[28] Aggarwal, A., Kumar, S., and Singh, V., (2015). Performance modeling of the skim milk powder production system of a dairy plant using RAMD analysis, *International Journal of Quality and Reliability Management*,167–181.

[29] Talebberrouane, M., Khan, F., and Lounis, Z., (2016). Availability analysis of safety critical systems using advanced fault tree and stochastic Petri net formalisms. *Journal of Loss Prevention in the Process Industries*, 193–203.

[30] Kumar, P., and Tewari, P.C., (2017) Performance analysis and optimization for CSDGB filling system of a beverage plant using particle swarm optimization. *International Journal of Industrial Engineering Computations*, 303–314.

[31] Malik, S., and Tewari, P.C., (2018) Performance modeling and maintenance priorities decision for the water flow system of a coal-based thermal power plant. *International Journal of Quality and Reliability Management*, 996–1010.

[32] Singhal, N., and Sharma, S.P., (2019). Availability Analysis of Industrial Systems Using Markov Process and Generalized Fuzzy Numbers. *Journal of Metrology Society of India*, 79–91.

[33] Velmurugan, K., Venkumar, P., & Sudhakarapandian, R. (2019). Reliability availability maintainability analysis in forming industry. *International Journal of Engineering and Advanced Technology*, 822-828.

[34] Elusakin, T., and Shafiee, M., (2020). Reliability analysis of subsea blowout preventers with condition-based maintenance using stochastic Petri nets. *Journal of Loss Prevention in the Process Industries*, 1-16.

[35] Jagtap, H., Bewoor, A., Kumar, R., Ahmadi, M.H., and Lorenzini, G., (2020). Markov-based performance evaluation and availability optimization of the boiler–furnace system in coal-fired thermal power plant using PSO, *Energy Reports,* 1124–1134.

[36] Maihulla, A.S., Yusuf, I., and Bala, S.I., (2021). Performance evaluation of a complex reverse osmosis machine system in water purification using reliability, availability, maintainability and dependability analysis, *Reliability: Theory & Application*, 115-131.

[37] Kumar, A., Kumar, V., Modgil, V., Kumar, A., and Sharma, A., (2021). Performance Analysis of Complex Manufacturing System using Petri Nets Modeling Method. *In Journal of Physics: Conference Series, IOP Publishing Ltd*, 1-9.

[38] Parkash, S., and Tewari, P.C., (2022). Performance modeling and dss for assembly line system of leaf spring manufacturing plant. *Reliability: Theory & Application*, 403–412.

[39] Kumar, S., and Tewari, P.C., (2022) Performability Analysis of Multistate Ash Handling System of Thermal Power Plant With Hot Redundancy Using Stochastic Petrinets. *Reliability: Theory & Application*, 190–201.

[40] Behnamfar, M., Taher, M.A., Polowsky, A., Roy, S., Tariq, M., and Sarwat, A., (2023) Reliability Analysis of Wireless Power Transfer for Electric Vehicle Charging based on Continuous Markov Process. *Fourth International Symposium on 3D Power Electronics Integration and Manufacturing (3D-PEIM)*, 1–5.

[41] Malik, S., Kumar, N., and Kumar, S., (2023) Process Modeling and Numerical Investigation of Veneer Cutting System of a Plywood Plant With Stochastic Approach, *Reliability: Theory & Application*, 141–153.