4.1 Preamble

The Power System (PS) is the oldest concept in the electrical system which has experienced significant revolution in both industrial and technological industry. These industries were considering the futuristic demands in PS, i.e., different power requirements of consumers. With all these, the PS mainly needs to fulfil the economic aspects, and it must provide the reliable power supply. But, the design process of economical, reliable PS is the biggest concern in the research domain. This chapter describes the design and implementation of a robust framework which is meant for incorporating the prediction based modelling scheme to sustain the dynamic load variation in the load. An analytical approach is used in the modelling scheme that helps computation of demands, capacity, and outage.

4.2 State of The Art

The distributive generation unit utilizes both the conventional and renewable energy resources. The power demand in today's world is increasing very rapidly, and it needs better up-gradation in the distribution unit. But some of the countries adopt the traditional method to generate the power which leads to saturation of conventional energy resources. Hence the adoption of renewable resources for power generation is increasing exponentially. The use of these resources is the only replacement of traditional power resources (non-renewable) but is filled with various problems. One of the concerns associated with the renewable resources is that it highly depends on the different inputs which change with usage circumstances. The generated energy with these resources leads to higher power fluctuations, and the detection of this behaviour is quite a difficult task. Currently, there exist various components in power transmission offering better résistance towards the faults but accurate prediction of these faults are very difficult. Under these scenarios, meeting the power requirements using renewable resources is very complicated.
4.3 Research Problem

By analysing the current state of the art in the distributive generation, it is found that:

- Rarely researchers considered the predictive based scheme for distributed generation.
- Most of the researches were not emphasizing on fault capacity and were not significantly aiming towards meeting load demands.
- Limited studies towards practical researches under different fault conditions.
- Limited benchmarked researches and also not much contribution towards fault tolerance ability.

In this chapter, a cost-effective fault tolerant model is introduced which incorporates an efficiently reliable predictive based modelling scheme for the power system.

4.4 Research Solution

The above-stated research problem can be tackled by following the research solution described Figure 4.1. In this system, the analytical mechanism is considered to design a predictive based scheme to compute the fault tolerance in the power distribution system. The significant features of the stochastic modelling are implemented to develop the model for both the system failure and system restart process.

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity Demand</td>
<td>Computation of Power Availability</td>
<td>Computation of Dynamic Load Estimation</td>
</tr>
<tr>
<td>2. Algorithm: 1</td>
<td>Computation of Power Availability</td>
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<tr>
<td>Computation of Power Availability</td>
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<tr>
<td>3. Algorithm: 2</td>
<td>Computation of Dynamic Load Estimation</td>
<td></td>
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<td>Computation of Fault tolerance</td>
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<td>4. Algorithm: 3</td>
<td>Computation of Dynamic Load Estimation</td>
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<td>Computation of Fault tolerance</td>
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<td>5. Algorithm: 4</td>
<td>Computation of Fault Analysis</td>
<td></td>
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<tr>
<td>Fault occurrence Stage</td>
<td></td>
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<tr>
<td>6. Performance Analysis</td>
<td>Computation of Fault Analysis</td>
<td></td>
</tr>
<tr>
<td>Fault Duration</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.1 Architectural Model of Research Solution
Figure 4.1 indicates the implementation of research solution, which includes construction of stochastic matrixes of demand and capacity for different resources (non-renewable, renewable resources) of power generation. The algorithm: 1 is introduced to compute the power availability. Then the probability based scheme is implemented for computation of the capacity and outage. The recent researchers found that most of the futuristic power applications utilize the renewable resources for power generation and ensuring the fault tolerance ability among them is a very challenging task as they provide the time variant outputs depending upon the inputs availability. Hence, the stochastic scheme offers a significant way of prediction-ability by considering more number of consumers for load modelling mechanisms. The proposed framework aims to study the load demands by considering different kinds of power resources.

The dynamic load is estimated to identify the significant configuration of the system. For the system model, failure rate and restoration are considered as inputs which further adds the novelty in the modelling of prediction based scheme by using power distribution segments. The research solution also describes an algorithm which exhibits the property of predicting the fault occurrences. The main significance of the stochastic modelling is that it allows the users to predict the success as well as failure rate in the transmission unit under dynamic load condition. Here, the time-variant usage statistical data are considered for fault tolerance modelling, and the thresholding value is not considered for its trustworthiness. The final results of the model are compared with respect to the error occurrences at different iteration levels and the probability of capacity.

4.5 Algorithm Implementation

The algorithms introduced to develop the stochastic model of the proposed solution are described in this section. The overall operations of the designed algorithms are partitioned into two sub-divisions such as modelling of stochastic matrixes for capacity and demand. The overall design flow of the algorithms is given as below:
4.5.1 Development of Stochastic Matrixes for Capacity and Demand

The primary step of the algorithm implementation is mainly meant for computation of total power capacity required to meet the demands of consumer needs. The system modeling begins with the computation of power availability by taking the rate of power system failure \( \eta_f \) and restore \( \eta_r \) into consideration. In algorithm 1- both the \( \eta_f \) and \( \eta_r \) are considered as inputs to compute the power availability \( \rho_\lambda \) as well as power unavailability \( \rho_v \). The algorithm-1: has got the significant feature of computing the power availability which also idealizes the level of fault tolerance model for the distributed power generation.

In order to implement the algorithm-1: in a simple manner, a probability-based scheme is applied in which the low rate of \( \eta_f \) are considered and \( \eta_r \) are considered for the moderate range. Hence, the algorithm is initialized \( \eta_f \) with a lower probability range from 0.2 to 0.3 and \( \eta_r \) is initialized with a moderate probability value of 0.5.

Algorithm 1: Computation of Power Availability

\[
\text{Input:} \eta_f, \eta_r \\
\text{Output:} \rho_\lambda, \rho_v \\
\text{Start:} \\
1. \text{Initialize} \rightarrow \eta_f, \eta_r \\
2. \rho_\lambda \leftarrow \frac{\eta_f}{(\eta_f + \eta_r)} \\
3. \rho_v \leftarrow \frac{\eta_r}{(\eta_f + \eta_r)} \\
\text{End}
\]

The implementation of the algorithm-2: aims for computation by considering different distributive generation sources like conventional, solar, and wind. The algorithm-2: aims to perform the probability based computation for power capacity and outage during the supply.
Different stages involved in the algorithm-2 are expressed below:

The algorithm-1 and algorithm-2 are mainly intended to obtain the stochastic matrix \( \delta_{i,j} \) by considering distributive generation. The \( \delta_{i,j} \) is obtained through randomization of the data subjected to the utilization days \( U_d \) and hours of utilization \( U_h \). In order to formulate the yearly utilization, the research solution considers 365 days and 24 hrs of utilization. The \( \delta_{i,j} \) exhibits possible values hence it is required to sort this in descending order which generates the sequential data for a year. The variable \( \delta_{i,j}_{\text{dec}} \) indicates the matrix consisting of randomized data of days and hours in descending order. The proposed model involves purely analytical modeling process, and the research solution concentrates on data distribution process which involves the number of units \( \sigma \). The partition of the data in these units helps for easier analysis. These units are mainly utilized to define the range of power levels \( \rho_{ol}(\sigma) \).

Further step considers all these \( \sigma \) and verifies the existence of cumulative duration to be presented within the range of \( \sigma \). For the stochastic modelling, a condition is formed by verifying the found \( \delta_{i,j}_{\text{dec}} \) within the range of \( \rho_{ol}(\sigma) \) first to last. Only under this condition, the algorithm allows increasing the count value for all the \( \delta_{i,j}_{\text{dec}} \) value. These counts represent the elapsed time \( E_r \). These stages of the algorithm help in exploring the performance of time duration spend per unit in one hour. The probability factor \( P_b \) can be computed by dividing \( E_r \) with \( U_d \times U_h \) given by Eq 4.1.

\[
\text{i.e. } P_b = \frac{E_r}{U_d \times U_h} \quad (4.1)
\]

**Algorithm 2: Computation of Capacity and Outage Probability**

**Inputs:** \( \sigma \), \( U_d \) and \( U_h \)

**Outputs:** \( C_{pb} \) and \( C_{out} \)

**Start:**

1. Initialize \( \sigma \), \( U_d \) and \( U_h \)
2. $\delta_{1} \leftarrow \text{rand} (U_{d}, U_{h})$

3. $\delta_{1, \text{dec}} \leftarrow \text{sort} (\delta_{1})$

4. Define $\rho_{ct} (\sigma)$

5. for $i=1$: $\sigma$

6. for $j=1$: size ($\delta_{1, \text{dec}}$)

7. if $\delta_{1, \text{dec}} (j) < \rho_{ct} (i) \&\& \delta_{1, \text{dec}} (j) > \rho_{ct} (i+1)$

8. Count = Count + 1

9. end

10. end

11. $E_{t} \rightarrow \text{Count}$

12. $P_{r} \rightarrow E_{t} / \text{length} (\delta_{1, \text{dec}})$

13. $C_{out} \rightarrow 100 \times (1 - i) / i$

14. if $i = \sigma$

15. $C_{pb} (i) = \rho_{A} \times \text{Count} / (U_{h} + P_{U})$

16. else,

17. $C_{pb} (i) = \rho_{A} \times \text{Count} / (U_{h} + P_{U})$

18. end

19. end

The next stage of the algorithm is introduced to compute the probability of outage and capacity of power. The probability of outage ($C_{out}$) is given in Eq.4.2 and can be formed as,

$$C_{out} = 100 \times (1 - i) / i$$  \hspace{1cm} (4.2)

In order to find the probability of capacity, the conditions associated with over or under capacity are introduced. i.e.,

$$i = \sigma$$  \hspace{1cm} (4.3)
Where \( i \) stands for round or iterations in the probability of capacity (\( C_{pb} \)) and \( C_{pb} \) can be found in the above algorithm 2. Finally, the capacity outcome is explored as an outage in this algorithm. The above-mentioned operation for the stochastic capacity matrix (\( \delta_{capacity} \)) can be considered for construction of stochastic demand matrix (\( \delta_{demand} \)). This involves the selection of demand type, system load demand matrix and sorting of load demand units followed by probability computation for both demands and outage.

**4.5.2 Stochastic Modeling for Fault Tolerant Evaluation System**

In this, the fault factor is computed to explore the tolerance level. It helps in obtaining the load in a practical scenario. This gives the easiest way to analyse the nonlinear load to mitigate to a better extent. The following algorithm explains the computation of nonlinear load.

**Algorithm 3: Computation of Non-linear load:**

Input: \( \sigma_1, \sigma_2, C_{pb}, D_{pb} \)

Output: \( \mathcal{G}_k \)

Start

Init \( \rightarrow \) \( \sigma_1, \sigma_2 \)

for \( i=1: \sigma_1 \)

for \( j=1: \sigma_2 \)

if \( C_{pb}(j) < D_{pb}(i) \)

\( \text{sum} = \text{sum} + 1; \)

end

end

\( pbl = \text{sum} / \sigma_1 \)

\( \mathcal{G}_k \leftarrow D_{pb}(i) \times pbl \)

end

end
The computational algorithm 3 considers the units in $\delta_{\text{capacity}}$ ($\sigma_1$), units in $\delta_{\text{demand}}$ ($\sigma_2$), capacity probability ($C_{pb}$) and demand probability ($D_{pb}$) to process the computation of dynamic load estimation ($\mathcal{J}_E$). This algorithm aims to analyse the status of the power system with less available load with respect to higher load demand causing to failures in the system.

At the beginning of the algorithm 3, the input parameters ($\sigma_1$, $\sigma_2$, $C_{pb}$ and $D_{pb}$) are initialized and processed in the inner for loops, and the condition of $C_{pb}$ subject to the demand matrix is analysed and has been found that the actual $D_{pb} < C_{pb}$. This analysis gives the computation of the probability ($pbl$) leading to the computation of dynamic load estimation ($\mathcal{J}_E$). Through this probability based algorithm a better idea of fault tolerance is achieved. This system does the load point computation based on the load point selection of distributed generation. The next section of algorithm implementation gives the computation of fault tolerance using the process of fault tolerance and time duration of fault occurrence.

Algorithm 4: Computation of fault tolerance

**Inputs:** $R_f$ – the rate of fault occurrence/year, $U_d$, $U_h$, $R_r$ – the rate of system restoration and $D(pbl)$ – probability factor to initialize and acquire the distributed generation.

**Output:** Fault occurrence process ($\mathcal{J}_f$) and Fault occurrence duration ($\mathcal{J}_d$)

**Start:**

\[ \text{init} \rightarrow R_f, R_r, U_d, U_h \text{ and } D(pbl) \]

if $(DG)_r \rightarrow 1$

\[ \text{init} \rightarrow (R_f / U_d)_1 \text{ and } (R_r / U_d)_1 \]

else if $(DG)_r \rightarrow 2$

\[ \text{init} \rightarrow (R_f / U_d)_2 \text{ and } (R_r / U_d)_2 \]

else

\[ \text{init} \rightarrow (R_f / U_d)_3 \text{ and } (R_r / U_d)_3 \]

for $S_{\mathcal{J}_1}$,

\[ S_{\mathcal{J}_1} \rightarrow [ R_f, R_f (R_D \times D(pbl)), (R_D (1 - D(pbl))] \]
\begin{align*}
\mathcal{J}_f & \leftarrow S_{1f}, \quad \mathcal{J}_f \text{days} \leftarrow \sum S_{1f} \text{days} \\
\mathcal{J}_f & \leftarrow \mathcal{J}_f / T_U \\
\mathcal{J}_d & \leftarrow \mathcal{J}_d \text{days} / T_U \\
\text{End}
\end{align*}

The algorithm 4: presented for the computation of fault tolerance by considering the input parameters such as \( R_f \), \( U_d \), \( U_s \), \( \eta \), and \( D(pbl) \) and provides the fault occurrence event and fault occurrence duration. Based on the type of generation sources, i.e., 1) conventional, 2) Solar and 3) Wind, various fault parameter values are initialized. Later annual failure, repair rate is formulated. The above-mentioned data will be considered to get the state matrix. Then the fault occurrences along with duration are computed based on a number of users available at the base end. Thus this algorithm 4 is capable of performing the computation of fault tolerance by use of a predictive mechanism for distributed generation for one year of heuristic usage. Hence, it can be selected as a robust, cost-effective method using a stochastic approach.

4.6 Result Analysis

The core idea of analysis was to assess the robustness of the proposed algorithm in the presence of renewable resources. The assessment is carried out with respect to utilization of the distributed power system respectively. The proposed model is analysed over a 4-bus design under standard test scenario to assess the accomplished fault tolerance level. The test-bed considers 1000 end users which are supposed to be served with power supply under no failure case. The performance analysis is done by considering the failure rates 4 and 2 for conventional energy and solar energy respectively. The system considers the restoration time of 48hours with maximum probability of 0.95 to initiate and acquire the distributed power generation and 12hours is considered as system repairing time.
4.6.1 Results of Stochastic Capacity Matrix

Capacity matrix is computed by assessing the dimensional size of the elements corresponding to the storage unit of the distributed system of power. The idea to assess the maximum amount of energy that can be deposited in the storage unit. The evaluation of this part of the study uses probability theory and statistical analysis to interpret the outcomes. In this system, the system failure rate is adjusted as 0.3 and system restore rate as 0.5 to calculate the power availability and power unavailability, i.e., power availability=0.625 and power unavailability=0.375. Then the distributive power generation is selected on the basis of Conventional, solar and wind energy.

![Year hours vs. DG power](image)

**Figure 4.2 Year Hours Vs. DG Power**

The outcome in Figure 4.2 shows that generation of DG power is quite spontaneous and numerically good as it ranges between 0.3 to 0.8 in average in increasing time duration of one year (year is divided into 8760 hours). Later, the stochastic matrix is obtained and then arranged in the descending order. The probability is computed by dividing the matrix into ten units and then capacity probability, and the outage is computed. This outcome also shows that it offers the capability to relay spontaneous power supply in order to cater up dynamic demands
Once the power availability and unavailability is calculated then the system is executed for a stochastic matrix of all the distributive power generations of the type conventional, wind and solar. Figure 4.2 illustrates the plot of generated DPG against yearly hours, in which the power is generated with respect to the distributive nature of resources in real time, i.e., wind, solar and conventional. In order to analyse this power accurately the plot is sorted to descending order (Figure 4.3). The outcome shows that the proposed system offers significant control over the generated power. The prime agenda of this test is to assess if the generated power can be controlled or reduced in the progressive manner as renewable resources are potentially required to be controlled in an effective way for optimizing the storage system. Hence, the outcome shows that it can perform linear controlling of the generated power to the lowest point of the probability in increasing duration of usage in terms of hours. This pattern also shows that the proposed system offers better control over the generated power system.

The next part of the analysis is about the total number of hours of the successful operation with respect to the increasing number of units. The output level of power is defined as the units of rated power and for each unit the total time is measured which falls within the unit. Here the rated power units are defined and divided into ten units with respect to a number of hours (Figure 4.4).
The outcome basically shows that the proposed system offers the consistent performance of operational time with increasing number of units. The unit on the x-axis basically represents distributed power storage units. An interesting fact to observe is that there are lesser dependencies on power units as even an increase of power units don’t have any significant effect over the number of operational hours. This also shows that the proposed system offers better utilization of the power units to ensure better power generation system and there is no need to increase the number of units in order to obtain increased operational hours.

The probability of each unit is basically calculated by dividing the selected number of power units by a total number of power units. The efficiency is excellent if there is less number of fluctuations in this probability factor. However, for better efficiency, the proposed system substitutes time with a number of power units. Therefore, the system computes the probability of each power unit as the total time of each unit is divided into total number of hours for one year. The generated plot for the probability is represented in the Figure 4.5.i.e.Probability of each unit = Total time of each unit/Total number of hours in one year. Using the probability of each unit and the mechanical availability of unit, the capacity probability is computed for each unit.
Figure 4.5 The Probability of Each Unit Vs. Unit Number

The outcome basically shows that there is a minor fluctuation of probability and its practical value is retained within 0.08-0.1, which is highly reduced. Hence, the variation shown in the proposed system is highly negligible and thus offers more consistency in effective maintenance of the power units.

The next assessment is carried out for capacity probability which is computed favourable capacity of the storage unit to total capacity of the storage units. The generated plot for the capacity probability is shown in Figure 4.6.

Figure 4.6 Capacity Probabilities Vs. Unit Number

The outcome in Figure 4.6 shows that the proposed system offers consistent capacity probability with respect to increasing number of power units. The outcome offers inference to two facts, i.e., i) there is a good consistency of the capacity probability and ii) it is not dependent on the number of power units. Hence, in order to cater up
high-end power needs, the proposed system does not need to use an increasing number of power units. Further, the capacity outage is generated against the unit number, which is shown in Figure 4.7. Typically, the capacity is computed by convolving the output of power that is time-variant of the distributive generated while the assessment assists in investigating the influence of the distributed generated over the load. Therefore, the capacity outage is computed against the number of the power units. The outcome shown in Figure 4.7 highlights that the proposed system offers a progressively lower capacity outage with an increase of power unit number. This shows that progressive monitoring is required for the proposed system to assess the complete outcome to prove that the proposed system offers a good supply of power using a distributed system.

![Figure 4.7 Capacity Outage against the Unit Number](image)

### 4.6.2 Results of Stochastic demand matrix

The primary outcome of the proposed system is load profile analysis for one day and is illustrated in Figure 4.8 and is given in Table 4.1. It is found that the load demand for the industrial sectors is higher and then follows the load demands of commercials and residential. From the graphical representation, it has been found that the different power environments are framed in the proposed system.
In order to analyse the failures in the power load distribution, different failure conditions are considered which includes:

- The process of DPG does not begin with intermittent power system breakage,
- Switch failure to isolate the DPG along with load,
- Internal circuit issues,
- Least output power.

![Image of Load Demand Analysis](image-url)

**Figure 4.8 Load Demand Analysis of Various Resources**
Further, the system executed for stochastic demand matrix of all the distributive power generations of type conventional, wind and solar. The Figure 4.9, illustrates the plot of load demand in descending order against yearly hours, in which the load demand varies with hourly basis. In order to analyse, the output level of power, it is defined as the units of rated power and for each unit the total time is measured which falls within the unit. Here the rated power units are defined and divided into ten units with respect to a number of hours (Figure 4.10). Further to calculate the probability of each unit for load demand, the total time of each unit is divided with a total number of hours for one year. The generated plot for the probability is represented in Figure 4.11. i.e. Probability of each unit = Total time of each unit/ Total number of hours in one year. Using the probability of each unit and the mechanical availability of unit, the capacity probability is computed for each unit. The generated plot for the capacity probability of load demand is shown in Figure 4.12.
Figure 4.10 Number of Hours per Unit Vs. Unit Number

Figure 4.11 The Probability of Each Unit Vs. Unit Number

Figure 4.12 Demand Probability Vs. Unit Number

The Figure 4.13 illustrates the RBTS of bus 4, which is considered to evaluate the distributive power generation. In this the failure cases on 11kV as well as 33kV
feeders and transformers are considered. In order to simulate the complexity of this bus system, the interruption devices as well as customarily opened (NO) switches are considered as reliable one. In the bus system, all the load ends and respective customer types and reliability data are given. The same industrial load model is considered for small industrial users, and the DPG is connected to load points ranging from load points (LP) 1 to 38. The load duration for each LP is aggregated load demand for all the consumers connected to that bus. i.e., if the DPG is connected at LP (x) cannot supply the full load demand then the DPG will be disconnected from all the customers connected to LP (x).

Figure 4.13 RBTS of Bus Four System

The proposed model utilizes the stochastic based mechanism to compute the capacity and outage probability with respect to different fault parameters shown in Table 4.2. It indicates the numerical outcomes achieved from a 4bus system by testing 30 load points to assess the Fault occurrence process \( \tilde{Z}_j \) and Fault occurrence duration \( \widetilde{z}_j \)
respectively by considering power cases - industrial, commercial and residential loads. The Fault occurrence process ($\mathcal{F}_f$) parameter is used to assess the influence set up for multiple units of DPG at separate load points.

<table>
<thead>
<tr>
<th>Type of load/Generation</th>
<th>Values</th>
<th>No. DPG</th>
<th>Wind</th>
<th>Solar</th>
<th>Traditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial</td>
<td>$\mathcal{F}_f$</td>
<td>0.1727</td>
<td>0.1747</td>
<td>0.1752</td>
<td>0.1781</td>
</tr>
<tr>
<td></td>
<td>$\mathcal{F}_d$</td>
<td>4.3372</td>
<td>4.3344</td>
<td>4.3339</td>
<td>4.2013</td>
</tr>
<tr>
<td>Commercial</td>
<td>$\mathcal{F}_f$</td>
<td>0.1727</td>
<td>0.1783</td>
<td>0.1781</td>
<td>0.1777</td>
</tr>
<tr>
<td></td>
<td>$\mathcal{F}_d$</td>
<td>4.3372</td>
<td>4.3100</td>
<td>4.3198</td>
<td>4.2772</td>
</tr>
<tr>
<td>Residential</td>
<td>$\mathcal{F}_f$</td>
<td>0.1731</td>
<td>0.1764</td>
<td>0.1778</td>
<td>0.1781</td>
</tr>
<tr>
<td></td>
<td>$\mathcal{F}_d$</td>
<td>4.3372</td>
<td>4.2958</td>
<td>4.2989</td>
<td>4.2697</td>
</tr>
</tbody>
</table>

Thus, extraction of Fault occurrence duration ($\mathcal{F}_d$) values give the criticality condition for failures with respect to the duration. Hence, the simple and cost-effective probabilistic approach is applied to the pattern of both the Fault occurrence process ($\mathcal{F}_f$) and Fault occurrence duration ($\mathcal{F}_d$) with increasing load points by one up to 38 in the RBTS system (Figure 4.14). The following Figure 4.14 illustrates the frequencies of Fault occurrence process ($\mathcal{F}_f$) and it is observed more frequency of fault occurrences is for solar sources followed with wind energy in comparison with conventional DPG.

Similarly Figure 4.15, indicates the Fault occurrence duration ($\mathcal{F}_d$) where the failure duration is high at wind energy and solar energy than conventional DPG.
Figure 4.14 Analysis of Fault Occurrence Process ($\bar{\tau}$) for Different Load Points

Figure 4.15 Analysis of Fault Occurrence Duration ($\bar{\tau}_{f}$) for Different Load Points

Figure 4.16 Demand Outage Vs Unit Number
Along with the failure patterns evaluation, the proposed system performs the performance analysis of the probability factors such as a capacity outage in Figure 4.17 while demanding outage in Figure 4.16. The observational analysis over the Figure 4.16 and Figure 4.17 are almost similar, in both the demand and capacity outages are decreasing with respect to increasing load points. These outcomes will assist the decision construction for prediction of fault tolerance point to obtain a better solution offering the robustness for stochastic modelling. The proposed system is able to identify the accurate position of an outage as proof from the unit number. Also, the curve is decreasing at the slow pace that indicates the fault tolerance level as well as non-incorporation of overheads in the system leading to further failure cases. Thus, the possibilities of fault can be predicted. The outcome evidently shows that the proposed system is successfully capable of minimizing the demand outage with increasing number of power units. Figure 4.16 and Figure 4.17 are in agreement to each other where the proposed method offers evidence to show that the proposed method provides a significant reduction in demand outage (Figure 4.17) as well as capacity outage (Figure 4.18) with increasing number of power units.

![Figure 4.17 Analysis of Capacity Outage](image-url)
To make the perfect remark on the effectiveness of the proposed model, its outcomes are compared with recently implemented technique, i.e., fuzzy logic based methods [115]-[119] to solve the challenges associated with prediction based issues. The proposed system finds that fuzzy logic was most frequently adopted by various researchers; however, a very simplistic approach was always used by differing the cases of implementation. It was also seen that the proposed study offers significantly competitive outcomes in contrast to the existing system:

Table 4.3 Comparative Analysis of Existing System

<table>
<thead>
<tr>
<th>Approaches</th>
<th>Capacity probability</th>
<th>Error monitored per Epoch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dran&amp;Vartini [115]</td>
<td>0.201</td>
<td>4.561</td>
</tr>
<tr>
<td>Holbertan and Lin [116]</td>
<td>0.189</td>
<td>4.78</td>
</tr>
<tr>
<td>Luo et al. [117]</td>
<td>0.172</td>
<td>6.25</td>
</tr>
<tr>
<td>Xiong et al. [118]</td>
<td>0.192</td>
<td>6.82</td>
</tr>
<tr>
<td>Simsir et al. [119]</td>
<td>0.199</td>
<td>5.98</td>
</tr>
<tr>
<td>Proposed</td>
<td>0.764</td>
<td>2.21</td>
</tr>
</tbody>
</table>
The proposed system is compared with the existing approaches where all the above researchers have used fuzzy logic based approach. A closer look into the analysis shows that the proposed system offers significantly better capacity probability as compared to fuzzy-logic based as shown in Table 4.3. The prime reason behind this is the fuzzy-based logic approach is not scalable and depends on the rule set defined by the service provider, while the proposed system offers significant scalability over the capacity performance (Figure 4.19) dynamically. Similar performance can be observed in case of error analysis (Figure 4.20), where the proposed system was witnessed with half the error compared to existing system. Hence, the proposed system offers more precision in its value. Therefore, numerical averaging of the existing system has been carried out to exhibit the outcome shown in Figure 4.19 and Figure 4.20. Thus, a separate function is defined to explore the effect of both the proposed as well as fuzzy logic system performance with respect to computation of capacity probability and error rate. The Figure 4.18, illustrates the capacity probability of the proposed system is higher than the existing fuzzy logic method. Similarly, the Figure 4.19 indicates the performance subjected to occurrences of error and is found that the proposed system exhibits low error with increased load demands. The fuzzy logic based method uses the static set of rules and hence it fails to decide the random load distribution. Also, the proposed model is capable of performing the fault tolerance prediction with higher accuracy even at a non-linear load condition.

![Figure 4.19 Analysis of Probability of Capacity](image)

Figure 4.19 Analysis of Probability of Capacity
The implementation of the probability mechanism further does the evaluation faster with respect to computational time. The proposed model takes approximately 2.76 secs to process the complete algorithm, while the existing system takes approximately 5.6 secs. Thus, it can be said that the proposed model is computationally useful, cost-effective and trustworthy fault tolerant system to ensure different power transmission flows with respect to application needs.

The capacity probability of the proposed system is 0.764 compared to the existing methods which have 0.201, 0.189, 0.172, 0.192 and 0.199 respectively. Hence the proposed system has a better capacity probability. The error per epoch of the proposed system is 2.21 compared to the existing methods which have 4.561, 4.78, 6.25, 6.82 and 5.98 respectively. Hence the proposed system has the least error compared to the existing methods.
The proposed system performs error analysis with respect to the increasing demands of load. The error analysis is carried out for both the proposed system and the cumulative value of the existing system. Usage of fuzzy logic is restrained with the scope of their membership functions that are manually constructed on the basis of the assumed higher and lower value of error. Hence, when the error value is arbitrarily used than it fails to retain the uniformity and consistency in its outcome and consistently keeps on fluctuating in its value. Therefore, the error rate significantly varies for existing fuzzy-based approach as compared to the proposed probability-based approach to show that it offers more capability to enhance the performance of the distributed power generation system.

4.7 Summary

This chapter explained the implementation of the stochastic modelling for fault tolerance analysis for distributive power generation for industrial, commercial and residential loads. The yearly power output is used to compute the rate of the power supply and load demand by using a stochastic approach. The proposed model presents the accurate results of fault tolerance estimation with less error rate with higher power capacity.