Comparative Study for Risk Criteria of Al-Qudus Plant between the Present and Planning of MOE

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ABSTRACT

The main function of a power system is to supply the customer load demands as economically as possible.

Risk criterion is the probability of not meeting the load. This paper presents a methodology to assess probabilistic risk criteria of Al-Qudus plant before and after expansion; as this plant consists of ten generating units presently and the Ministry Of Electricity (MOE) is intending to compact four units to it in order to improve the performance of Iraqi power system especially at Baghdad region. The assessment is calculated by a program using Matlab programming language; version 7.6.

Results show that the planned risk is (0.003095) that is (35 times) less than that in the present plant risk; (0.1091); which represents respectable improvement.

This probabilistic method can also be used to find the planned risk level of every plant to be compact in the Iraqi electrical network on the future; or any other power systems; and compare it with the present criterion which is very useful to determine the necessary generation capacity expansion.

Keywords: unit outage, risk level, forced outage rate, n generators, planned risk assessment.

دراسة مقارنة لمعامل الخطورة لمحطة القدس
بين الحاضر ومخطط وزارة الكهرباء

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الخلاصة

إن الغرض الرئيس من نظام القدرة هو تجهيز المستهلك بالحمل المطلوب وبشكل إقتصادي.

معامل الخطورة هو إحتمالية عدم تجهيز الحمل. إن هذا البحث يعرض طريقة تثمين عامل الخطورة, بطريقة الإحتمالية, لمحطة القدس قبل التوسعة وبعدها ؛ فهذه المحطة تتضمن عشر وحدات توليدية حالياً وستقوم وزارة الكهرباء بحسب خطتها التطويرية باضافة اربع وحدات توليدية في المستقبل لتحسين أداء منظومة القدرة الكهربائية وبالخصوص في منطقة بغداد. إن حساب عامل الخطورة تم باستعمال برنامج بلغة ماتلاب 7.6.

النتائج توضح أن معامل الخطورة المخطط هو(0,003095) وهذا اقل (35) مرة من معامل الخطورة الحالي؛(0,1091) ؛ والتي تمثل نسبة تطوير جيدة .

يمكن استعمال هذه الطريقة لايجاد عامل الخطورة المخطط له لأي محطة توليد تحتويها الشبكة الكهربائية العراقية في المستقبل او أي منظومة قدرة أخرى ومقارنته مع عامل الخطورة الحالي وهو مفيد لتحديد التوسع الضروري في سعة المحطة.

1. INTRODUCTION

Electrical energy supply should be sufficient to meet demand at all times. However, since supplies and demands are uncertain, there is always a small probability of loss i.e. the supply will be insufficient to meet demand.

Generation adequacy of a power system is an assessment of the ability of the generation on the power system to match the consumption on the same power system. This general definition implies that such an “ability” of the power system should be ensured at all times. However, capacity values are typically defined to correspond to an extended period such as a year, where the relevant probability distributions vary from day to day, or hour to hour, within that extended period, **Cailliau et al., 2011 and Zachary,** and **Dent, 2012**.

Adequacy is associated with static conditions, which do not include system disturbances. The adequacy studies of power supply system are conducted individually in three functional zones: generation, transmission, and distribution. The functional zones can be combined to give the hierarchical levels.

A model of bulk generation must consider the size of generation units and the two main processes involved in their operation, namely the failure and the restoration processes. A failure in a generating unit results in the unit being removed from service in order to be repaired or replaced; this event is known as an outage, **Dutta,** and **Sharma, 2012**.

Conventional power plants experience unplanned outages, because of mechanical or other malfunction. Episodes such as this are called forced outages.

There is always a non–zero probability that any single generating unit will be on forced outage.

Taking all such probabilities from each generator allows the calculation of the probability that enough generator units are on forced outage so that the utility will be unable to meet its load, **Milligan,** and **Parsons, 1997**.

The planning procedure for the expansion of generating capacity by adding new units, based on the criterion that a certain risk level should not be exceeded, is selected largely by economic considerations.

A widely used deterministic criterion is the N-1 criterion, which means that there must be sufficient spinning reserve on the system such that no load will lose power if any one line or any one generator fails. The probabilistic approach is a more realistic one in which a risk index enables a comparison to be made between various operating scenarios. The acceptable risk level is a management decision based on economic requirements.

Once a risk level has been defined, sufficient generation can be scheduled to satisfy this risk level. This process can be done using the concept of unit commitment risk, **Lewis, 1996**.

2. LITERATURE SURVEY

It is valuable to present a review of some studies dealing with the assessment of risk level.

W. Luan, et al., 2006 outline risk assessment method for diesel generation stations based on RISK_A. a model which was developed for assessing station reliability through assigning failure probabilities to all equipment and modeling their relationships. End-of-life failure probability for diesel generation unit has been derived based on its actual maintenance history and age profile.

C. N. Ning, et al., 2006 demonstrated two application examples of probabilistic risk assessment. In the first, a risk based method is proposed to take the uncertainty of contingency occurrence and impacts into account to provide an essential set of contingency cases for a transient stability special protection system (SPS) implementation. In the second, an approach for determining the power transfer limit of a longitudinal electric power system is presented.

M. Cepin, 2006 presented a definition of quantitative risk criteria considering probabilistic safety assessment. Development of risk criteria is considered separately for permanent and temporary changes in the nuclear power plant. Developed criteria can represent a standpoint for risk-informed decision-making.

O.B. Ajadi, et al., 2012 identified that hazards and risks are associated with installation, operation and maintenance of diesel powered generator using a 40kVA generator. Hazards of varying degrees were identified with every section and jobbing of the whole activities. The associated risk was classified, about 60 percent high risk to 40 percent medium risk.

This paper presents a comparative study for the risk criterion of al-Qudus plant for the present and planned cases depending on the technical operating data of 2011 that is provided by Republic of Iraq / MOE/ Training and Development Office / Control and Operation Office, and Generation and Production of Electrical Energy /planning section.

3. BASIS of RISK LEVEL ASSESSMENT

The probabilistic approach to unit commitment considers the size of generation units and the two states model (unit up and down states) where, λ and μ are the failure and repair rates respectively. The long-run failure probability, known as the unavailability of a unit, Un and the long-run success probability, known as the availability of a unit, A can be expressed in terms of unit's failure and repair rates as follows:

$$Un = \frac{\Sigma(\text{down time})}{\Sigma(\text{down time} + \text{up time})} \tag{1}$$

$$A = \frac{\Sigma(\text{up time})}{\Sigma(\text{down time} + \text{up time})} \tag{2}$$

$$Un = \frac{\lambda}{\lambda + \mu} \tag{3}$$

$$A = \frac{\mu}{\lambda + \mu} \tag{4}$$

The unit unavailability is commonly referred to as the 'forced outage rate', FOR.

$$FOR = \frac{\text{forced outage hours}}{\text{in service hours} + \text{forced outage hours}} \tag{5}$$

The step building of a generation model is to combine the capacity and availability of the individual units to estimate available generation in the system. The result is a capacity model; in which each generating unit is represented by its nominal capacity ci and its unavailability index Uni (or forced outage rate).

For each of the (N) generators in the system, the available capacity ci, for i =1…N, is a random variable that can take the value 0 with probability Uni and the value ci with probability $A_i = 1 - Un_i$

Note: (N) is the number of generators in the system.

The individual state probability is:

$$P_{(X)} = \begin{cases} A & xi = ci \\ Un & xi = 0 \end{cases} \tag{6}$$

Where:

$P_{(X)}$: probability of system for state x.

xi: is the state of the i th generator.
The cumulative state probability (or the distribution function) is:

$$P_{(X)} = \begin{cases} 0 & xi < 0 \\ Un & 0 \le xi < ci \\ 1 & xi \ge ci \end{cases} \tag{7}$$

The total generating capacity available (effective capacity) in the system is:

$$C_A = \sum_{i=1}^{N} (\; ci$$

As an example consider a system consisting of three 25 MW units, each one having forced outage rates of 0.02. **Table 1.** Shows capacity outage table, **Lewis 1996, Prada 1999, Singh 2008, Ehsani, et al. 2009.**
Computer Matlab programming software is realized for computing the capacity outage probabilities and the flow chart structure of it is shown in **Fig. 1**.

4. AL-QUDUS PLANT DESCRIPTION

Republic of Iraq / MOE/ Training and Development Office / Generation and Production of Electrical Energy /planning section, 2011

The plant consists of the following equipment:
a. Six (6) GE rating of 125MW
b. Four (4) GE rating of 43MW
i.e.
N=10 in Al-Qudus (present state).
The generators have the following nomenclature and rating:

Nomenclature	Rating	Voltage
a. U1-4 Frame 9E	154MVA	15kV
b. U5-8 LM6000	63MVA	11kV
c. U9-10	141MVA	15kV

Units' commission dates are provided below:

Unit name	Day	Month	Year
U1	21	May	2002
U2	5	July	2002
U3	10	August	2004
U4	8	September	2004
U5	29	August	2004
U6	8	June	2005
U7	25	August	2005
U8	11	August	2005
U9	14	May	2009
U10	14	May	2009

Al-Qudus gas power station single line diagram with its planned expansion is shown in **Fig. 2**. Based upon the life expectancy units 1-4 have approximately 8 more years of operation before they need to be given a life extension inspection. Units 9 and 10 have approximately 11 more years of operation prior to being given a life extension inspection.

5. CASE STUDY:

5.1 Present Case

Capacity outage probability table is an array of capacity levels and the associated probabilities of existence. In practical system the probability of having a large quantity of capacity forced out of service is usually quite small because this case requires several units to be out of service.

Risk level assessment of generating plants is of great importance especially for Al-Qudus plant that is part of Baghdad region network which suffers lack in supplying the load demand.

In this work plant generators are divided into groups. Each group consists of “N” units which are identical, i.e., have the same generation capacity, Un or FOR, and A.

For simplicity, it is assumed that each unit has only two states and can be either fully available or fully unavailable with probabilities:

A= 1-FOR and Un = FOR,

The following values of the forced outages; including the forced outages due to the lack in fuel; and availabilities that are calculated for the year 2011 are:

FOR for the units U1, U2, U3, U4, U9, U10= 0.092
i.e. A=0.908.
FOR for the units U5, U6, U7, U8= 0.074
i.e. A=0.926

Al-Qudus capacity outage probability table can be formulated; after calculations; for the present case as shown in **Table 2**.

Fig.3-1 represents the probability graph of available capacity meeting generation capacity, and **Fig.3-2** shows the cumulative probability graph.

5.2 Planned Case

The plan of MOE is to install four more frame engines at this site; i.e. N=14 in Al-Qudus (future state); with capacity of 125MW for each as illustrated in Fig.1 with two rectangles; each rectangle is surrounding two units.

This addition and the planned fuel availability will raise the availability; hence reducing unavailability; of all the plant units and from the experience it is expected to be as follows:

FOR for the units
U1, U2, U3, U4, U9, U10, U11, U12, U13, U14= 0.02
i.e. A=0.98.
FOR for the units
U5, U6, U7, U8= 0.05
i.e. A=0.95

Al-Qudus planned capacity outage probability table can be formulated; after calculations; as shown in **Table 3** which is truncated by omitting states more than 34 state, since it is not in the vision of risk level.

Fig.4-1 represents the probability graph of the planned available capacity meeting generation capacity, and **Fig.4-2** shows the planned cumulative probability graph.

6. RISK CRITERIA RESULTS

Risk is defined as the probability of not meeting the load, thus it is given by the value of cumulative probability corresponding to the outage state one increment below that which satisfies the load.

As an example, consider the previous example mentioned and illustrated in **Table 1**, if the load demand is 50 MW then:

Risk level= Cumulative Probability (when Capacity in is less than 50 MW)

i.e. Risk level= 0.0012

The two probabilistic; i.e. present case and planned case; risk level are determined assuming constant load demand and the future demand growth is neglected to clarify the plant development.

The average load demand at Al-Qudus bus-bar for 2011 was 750 MW, **MOE 2011**, and then the risk in each of the two systems; can be found from tables (2) & (3); are:

Risk in present case= 0.1091

Risk in planned case= 0.003095

7. CONCLUSION:

To reveal the improvement of Al-Qudus plant, the values of risk criteria must be compared; thus as it is found that:

Risk criterion of the present system is: 0.1091

Risk criterion of the planned system is: 0.003095

It is apparent from the comparison between the two results that present risk is (35 times) greater than that in the planned plant; which means that the four additional units is improving the performance of Al-Qudus plant with a good factor.

This result also confirms that the variation in risk criteria depends upon: forced outage rate, number of units, and definitely the load demand.

This study is useful to calculate planned risk criterion improvement which represents the performance upgrading for any plant of all power systems.

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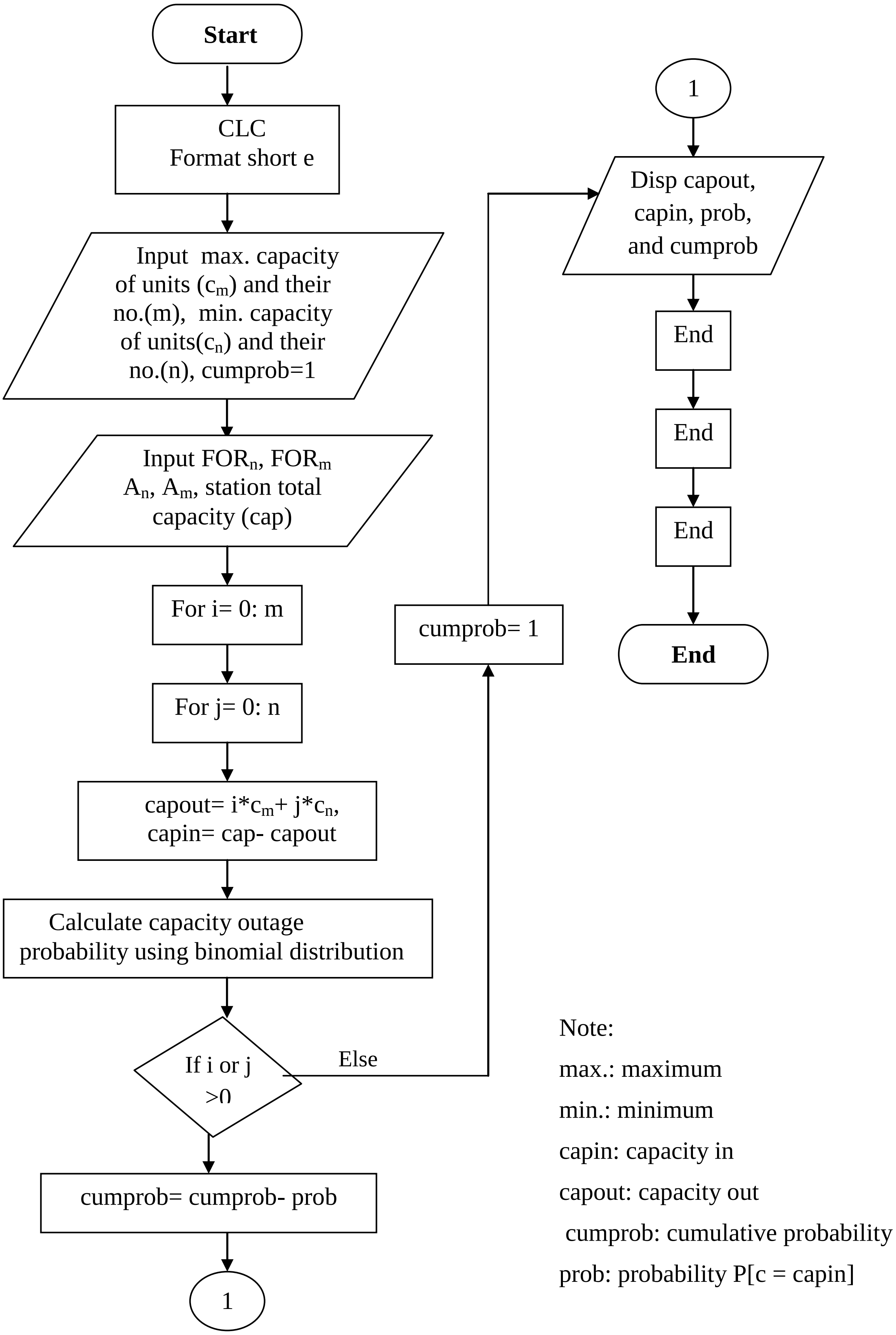
Table 1. Example for three-unit system capacity outage [J. F. Prada 1999].

Units out	Capacity out	Capacity in (CA)	Probability P[C = CA]	Cumulative probability P[C ≤ CA]
None	0 MW	75 MW	$(0.98)^3$= 0.9412	1.000
1 or 2 or 3	25 MW	50 MW	$3*(0.02)(0.98)^2$ =0.0576	1- 0.9412 =0.0588
1,2 or 1,3 or 2,3	50 MW	25 MW	$3*(0.98)(0.02)^2$ = 0.0012	0.0588- 0.0576 =0.0012
1,2,3	75 MW	0 MW	$(0.02)^3$=0.00000	0.0000



Note:

max.: maximum

min.: minimum

capin: capacity in

capout: capacity out

cumprob: cumulative probability

prob: probability P[c = capin]

Figure 1. Flow chart structure of the program that computes the capacity outage probabilities.

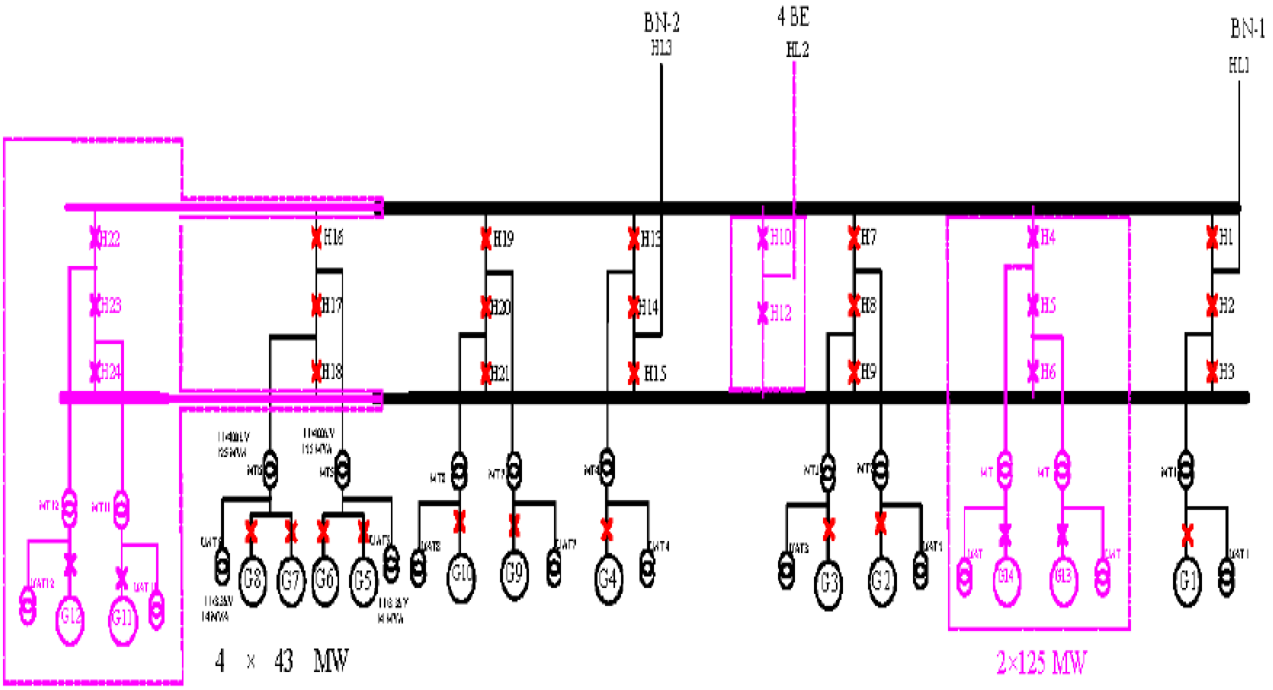
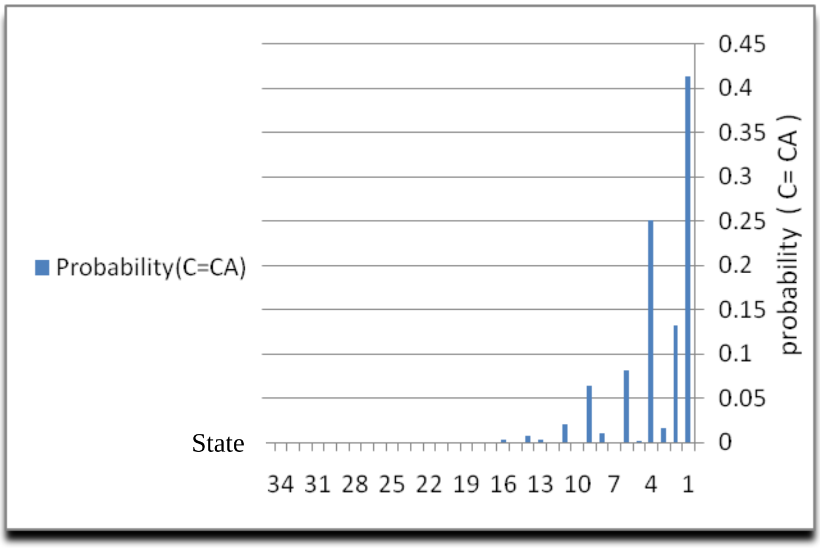


Figure.2. Al-Qudus single line diagram with its planned extension [Republic of Iraq / Ministry of Electricity/ Training and Development Office / Generation and Production of Electrical Energy /planning section, 2011].

Table 2. Present case actual capacity outage of Al-Qudus plant.

State	Capacity out(MW)	Capacity in(MW)	Probability (C=CA)	Cumulative probability
0	0	922	0.4121	1
1	43	879	0.1317	0.5879
2	86	836	0.0158	0.4562
3	125	797	0.2505	0.4404
4	129	793	0.0008412	0.1899
5	168	754	0.0801	0.1891
6	172	750	1.7e-5	0.10917
7	211	711	9.6e-3	0.1091
8	250	672	0.0634	0.0995
9	254	668	5.21e-4	0.0361
10	293	629	0.0202	0.0355
11	297	625	1.02e-5	0.0153
12	336	586	0.0024	0.0153
13	375	547	0.00697	0.0129
14	379	543	1.29e-4	0.00503
15	418	504	0.00217	0.0058608
16	422	500	2.6e-6	0.0036908
17	461	461	2.63e-4	0.0036882
18	500	422	3.91e-4	0.0034282
19	504	418	1.4e-5	0.0030372
20	543	379	1.25e-4	0.0030232
21	547	375	3e-7	0.0028982
22	586	336	1.5e-5	0.0028979
23	625	297	2.64e-5	0.0028829
24	629	293	7.98e-7	0.0028565
25	668	254	5.389e-8	0.002856
26	672	250	1.59e-8	0.002856
27	711	211	1.012e-6	0.002856
28	750	172	4.176e-8	0.002856
29	754	168	5.8e-8	0.002856
30	793	129	7.91e-10	0.002856
31	797	125	1.1e-9	0.002856
32	836	86	1.71e-8	0.002856
33	879	43	8.525e-11	0.002856
34	922	0	1.81e-11	0.002856



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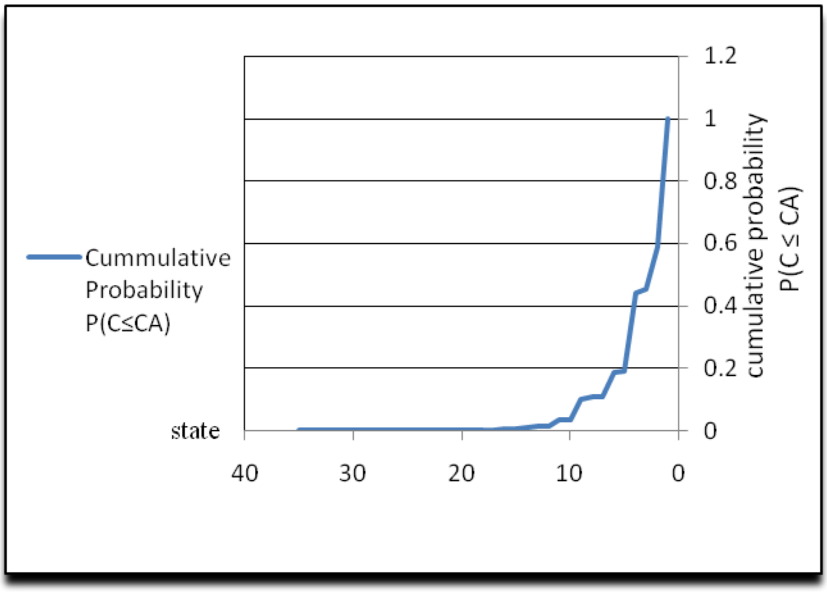

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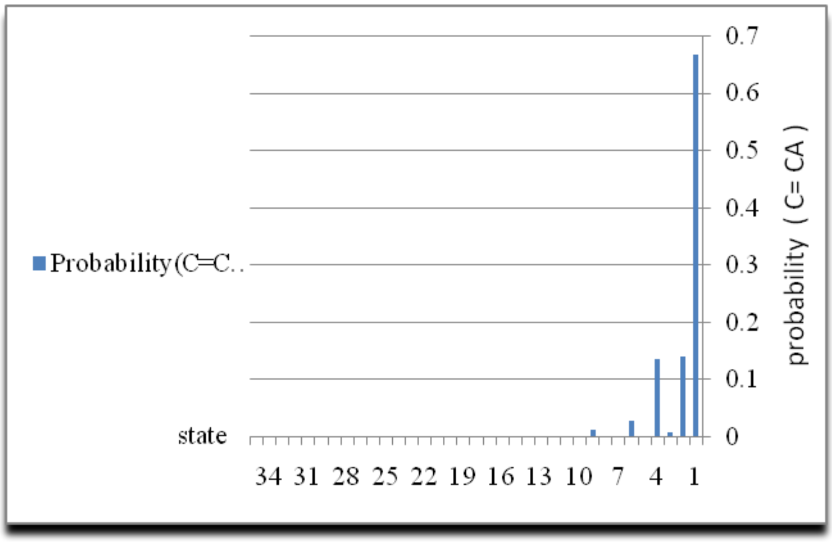
Figure 3. 1- Present available capacity meeting generation capacity probability.

2- Cumulative probability.

Table 3. Planned capacity outage of Al-Qudus plant.

State	Capacity out(MW)	Capacity in(MW)	Probability (C=CA)	Cumulative probability
0	0	1422	0.6655	1
1	43	1379	0.1401	0.3345
2	86	1336	8.154e-3	0.1944
3	125	1297	0.1358	0.1863
4	129	1293	3.8811e-4	0.0505
5	168	1254	0.0285	0.0501
6	172	1250	5.1067e-6	0.0216
7	211	1211	2.257e-3	0.0216
8	250	1172	0.01247	0.0193
9	254	1168	7.92e-5	0.006879
10	293	1129	2.626e-3	0.006793
11	297	1125	1.0422e-6	0.004167
12	336	1086	2.297e-4	0.004167
13	375	1047	6.788e-4	0.003938
14	379	1043	7.274e-6	0.003259
15	418	1004	1.429e-4	0.003252
16	422	1000	9.571e-8	0.003109
17	461	961	1.88e-6	0.003109
18	500	922	9.697e-6	0.003107
19	504	918	3.9587e-7	0.003097
20	543	879	2.042e-6	0.003097
21	547	875	5.209e-9	0.003095
22	586	836	1.61e-7	0.003095
23	625	797	1.319e-7	0.003095
24	629	793	5.655e-9	0.003095
25	668	754	2.78e-8	0.003095
26	672	750	7.44e-11	0.003095
27	711	711	1.462e-9	0.003095
28	750	672	1.68e-9	0.003095
29	754	668	7.69e-11	0.003095
30	793	629	3.54e-10	0.003095
31	797	625	1.012e-12	0.003095
32	836	586	2.797e-11	0.003095
33	879	543	9.814e-13	0.003095
34	922	500	1.29e-14	0.003095



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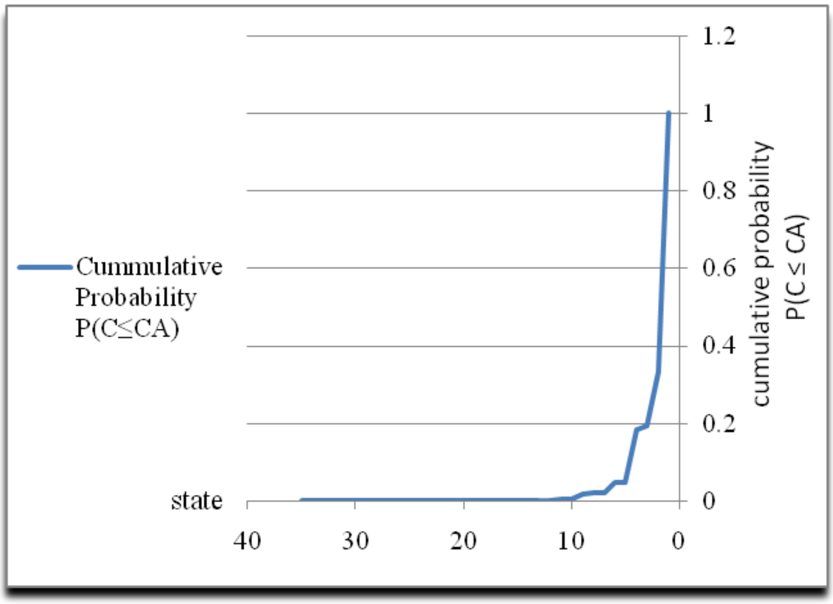

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Figure 4. 1- Planned available capacity meeting generation capacity probability.

2- Planned cumulative probability.