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# Relianility Assessment for Electric Power System Considering System and Loadpoints

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**Abstract:** Composite power system (CPS) reliability evaluation involves the analysis of the combined generation and transmission system in regard to its ability to serve the system load and load points. This paper presents reliability evaluation of (CPS) operating economically the reliability evaluation and economic dispatch as well as conducted using the optimal flow (OF) and probabilistic method. The reliability evaluation includes system evaluation and load point's. the basic types indices are probability of failure, frequency of failure, and those are used in derive many other reliability indices for the system and load points. The investigated reliability indices are used in design flexible system and Avery useful to long-term system capacity expansion planning of electric power systems. Method of solution first the (OPF) analysis then following indices computed based on the result of (OPF) analysis. Appropriate load curtailment is performed if the load demand is unable to be fully satisfied.consequequently; a pertinent load shedding strategy is introduced. Finally the proposed methods are verified by an application system.

**Key wprds:** composite power system, load points, reliability evaluation,

## INTRODUCTION

Reliability evaluation of a complete electric power system including generation, transmission, station and distribution facilities is an important ability in overall power system planning and operation (Ching-Tzong su and Ji-wong," 2007; Debnath and Goel, 1995; Verma,*et al*., 2005; Yongji et.al., 1999) System reliability may be defined as the system to supply it s load taking into account transmission constrains as well as scheduled and unscheduled outages of composite power system facilities. The reliability degree of the system has been known by customer varies from one to one instance such as residential customer and industrial customer, actually , electrical utilities have been continuously investing on infrastructure important to satisfy the growing demand on reliability .since customers outages costs are different ,their desire level of reliability are also different. In order to achieved the flexible power supply reliability for different type of customers, the evaluation of load points reliability in system becomes essential.(Mohammoud and Ahmed, 2009).

The electric power system reliability evaluation began in 60s, and the study was mainly on establishing a reliability model Billinton and Allan, (1984) three different states-normal, fault, and switching states-for modeling components of the system are presented Billinton and Allan, (1984) A more accurately model where a fault is subdivided into passive and an active state then evaluated Debnath and Goel, (1995) The techniques used to evaluate power system reliability can be classified into two basic categories of Analytical and simulation methods which have been applied in composite power system (generation. transmission and distribution functional zones). Analytical techniques have a disadvantage considering complex situations such as restorative action. Many studies have been performed recently to overcome a disadvantage. The Monte Carlo techniques is currently receiving considerable attention as the simulation method is quite general and is not restricted also is powerful reliability evaluations method which becoming increasingly popular in modern power system reliability assessment Yongji et.al., (1999). Ajit Kumar Verma *et al*., (2005) use a fuzzy linear programming method, which can include uncertainties that exist in certain coefficient and overcome the limitations of minor constraint violations in crisp linear programming model, is introduced.Saman and Singh[?????] develop genetic algorithm-based method for composite system evaluation where the system constrains are represented by fuzzy membership functions. an innovative method using genetic algorithms for the assessment of generation system reliability is presented. in (Nader, 2004) the genetic algorithm is used as a search tools to truncate the probability state space and to track the most probable failure states. This study is proposed system reliability is evaluated also load points reliability is investigated. As mentioned above, in

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order to design flexible reliability for different types of electricity users, the capability of evaluation load point's reliability is essential.

This paper organized as follows: Section two, theoretical background which includes introduce direct current power flow and mathematical model for optimal dispatch generations following up by basic reliability indices and derivative indices of system and load points. Then proposed methods of assessment finally, simulation Result and Conclusion are in Section four and five respectively.

## *2. Theoretical Background:*

### *A) Direct current power flow:*

An ac power flow analysis is the determination of the bus voltage magnitude and phase angle. Generation and load at each bus in megawatts and Megavars, flow of real and reactive powers on each transmission line, etc. Power flow analysis is essential in planning and future development of system and satisfactory operating the system. Dc power flow is a further simplification of the ac power flow. It is a completely linear, non iterative power algorithm .it is seemed that each bus voltage magnitude is 1.0 per unit. The power flow on the transmission line connecting buses *i* and bus *j* is:

$$Pik = \frac{1}{Xij}(\theta i - \theta j) \tag{1}$$

$P_{ij}$: *power flowing from bus I to bus j on the line connecting bus I and bus j.*
$\theta_i$: *phase angle at bus i*
$X_{ij}$: *reactance of the line from bus i to bus j*

### *B) The Mathematical Model for the Optimal Generation Dispatch:*

Conventionally, economic dispatch methods of composite systems are based on the used B-coefficients or the Jacobins inverse matrix to determine penalty factors .traditionally, the economic dispatch problem is solved by mathematical programming methods and optimization techniques. an alternative method applying transportation technique is presented for calculating production cost of generation and transmission systems, but the method does not consider apparatus forced outages (Ching at et., 2007; 2004; James A.Momoh, 2008). Generally, the power stations are not located at the same distance from the load centers and they may use different fuels with different costs. Accordingly, there are a lots of generation combinations for the power stations. the issues for generation scheduling is an optimization problem, the objective is so to search for a power generation scheduling is an optimization problem, the target is to seek for a capacity generation of power scheduling for each power station or plant in order to minimize the operation cost subject to few operating constraints, such as generator capability limits, transmission lines capability,etc .the issues for finding an optimal generation scheduling is called optimal dispatch of generation

The mathematical model for the optimal generation dispatch can be formulated as follow:-

$$Min\ c_{Rtot} = \sum_{k=1}^{Stot}\sum_{i=1}^{NGb}\sum_{j=1}^{Nig} dk\ \ Ci\, Pi,j \tag{2}$$

s.t

$$P_{i,j}^{min} \leq Pi,j \leq P_{i,j}^{max} \tag{3}$$

$$f_{ln}^{0} + \sum_{i=1}^{NGb}\sum_{j=1}^{Nig} \alpha(l_n, ij)\Delta P_{ij} \leq f_{ln}^{max} \tag{4}$$

$$\sum_{i=1}^{NGb}\sum_{j=1}^{Nig} P_{i,j} = \sum_{i=1}^{NLb} L_i \tag{5}$$

Where

$Min\ c_{Rtot}$ : Total generation cost

$Pi,j$ : power generation of generator j at bus i

$P_{i,j}^{min}$, $P_{i,j}^{max}$ : power generation limits for maximum and minimum for generator j at bus I ,respectively

$f_{ln}^{0}, f_{ln}^{max}$ : intial line flow and transmission capacity of line i.

$\alpha(l_n, ij)$ : Generation shift factor of generator j at bus l on line n.

*k*: system state
: Time duration of state *k*.
*Stot*: total number of system states.
*NGb:* Total number of generator at bus *i.*
*Ci,j: unit* generation cost of generator *j* at bus *i.*
*NLb*: Total number of load buses.
*Li*: load demand at bus *i*

***C) System and Load Points Reliability Index:***

Defining appropriate reliability index is the first step of reliability evaluation. In the paper, eight reliability indices two are basic the probability of failure and frequency of failure at individual loadpoint,other indices can be defined .the individual load point , however more indices can be aggregated to produce system indices. The indices used in this work are described as follows:

Expected Unserved Energy (EUE)

$$EUE = \sum_{k \in s} Ldef, ik.\ Dik.Fk(MWh) \tag{6}$$

Where:
*Dik*: duration in hours of load curtailment arising due to the outage *k*
*Fk* : frequency of occurrence of outage *k.*
*Ldef,ik:* load curtailment at bus I due to contingency *k*
*s:* set of states with load curtailment
Expected Load Curtailed (ELC)

$$ELC = \sum_{k \in s} Ldef, ik\ Fk \tag{7}$$

Expected Duration of Load Curtailment (EDLC)

$$EDLC = \sum_{k \in s} Dik\ Fk \tag{8}$$

System Power Interruption Ind ex (SPII)

$$SPII = \frac{\sum_i \sum_{k \in s} Ldef, ik\ Fk}{\sum_{i=1}^{Nib} Li} \tag{9}$$

System Average Power Curtailment/Disturbance (SAPC/D)

$$\frac{SAPC}{D} = \frac{\sum_i \sum_{k \in s} 60Ldef, ik\ Dik\ Fk}{\sum_{i=1}^{Nib} Li} \tag{10}$$

System Energy Curtailment Index (SECI)

$$SECI = \frac{\sum_i \sum_{k \in s} Ldef, ik\ Dik\ Fk}{8760 \sum_{i=1}^{Nib} Li} \tag{11}$$

***3. Proposed Method of Assessment:***

The proposed methodology will follow all the basic steps of contingency enumeration approach. Computation procedures for reliability evaluation using the proposed methods are given in the following sequential order:

1- Selection of contingency level.
2- Selection of contingency within that level
3- Implementation of the developed equivalent optimization model for testing and evaluation of the selected contingency is to be selected; otherwise, the next step is to be followed.
4- Calculation of probability and frequency of outage occurrence of the selected outage contingency.
5- Implementation of appropriate load curtailment policy
6- Evaluation of annualized load point and system reliability indices using probability, frequency and load curtailment values of each contingency.
7- Repetition of steps ((3)-(6)) for all the contingencies and accumulation of results.

Firstly choose an appropriate outage level is very important in the reliability evaluation of a composite power system. The computation time increases rapidly as the contingency level considered increases. In ordered to limit the number of outage events, only the single and double contingencies are taken in to account.
Another important consideration in composite electric power systems reliability evaluation is the load curtailment in the event of deficiency in the system capacity.

Secondly curtailment of load can be done in a lot of ways depending on the relative priority given to individual load centre. Generally the load at each bus can be classified in to two categories, namely, firm load and curtail able load. The proposed rule of load curtailment is to interrupt the curtail able load first, and then the firm load if necessary.

The step procedures of the proposed method assessment comprise four steps:
A-conducting a dc power flow analysis to each state of the system
B- Each state of system considering only the single and double contingencies.
C- Rescheduling generation. i.e, conducting again dispatch of generation in case of diciency in system capacity.
D-conducting load curtailment if necessary, considering the rule of load curtailment mentioned above.
E- computing the load points reliability indices EUE, ELC, EDLC, using equation (6) &(8) and the system reliability indices –EUE,SPII,SAPC/D,SECI, using equations(9)-(11).

***4. Simulation Result:***

The sample system selected for reliability investigation is a Network of five-bus .The method described in preceding section for has been applied in 5-Bus application system which is clear in Figure Ching-Tzong su and Ji-wong, (2007) is employed for demonstrating the effectiveness of the proposed method.

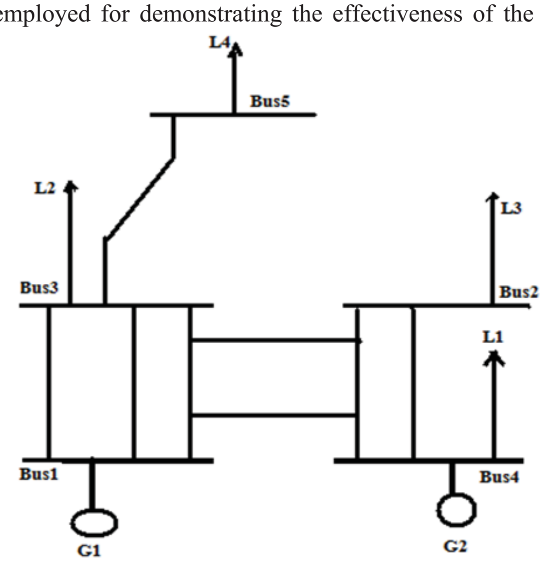


**Fig. 1:** Ching-Tzong su and Ji-wong, (2007) Single Line Configuration of Five Bus composite Systems

The given data to this application system for computing the system and load point reliability mainly include:
(a)generating unit data comprising :capacity, forced outage rate (FOR),expected failure rate($\lambda$)expected repair rate ($\mu$) as shown in Table (1), and operation cost as shown in Table (2);
(b) Load data comprising: MW peak load, as shown in Table (3);
(c)Transmission line data, as shown in Table 4.

The results in Table 5 are shown the outage probability and outage frequency for each load point, and the indices ELC, EUE, EDLC result for each load point, as well as the indices EUE, SPII, SAPC/D, SECI for the system.

**Table 1:** Generation and load data

| Bus No | No .of units | Capacity of each unit(Mw) | Total bus capacity (Mw) | FOR (probability of outage ) | $\mu$(r/yr) | $\lambda$(f/yr) |
|---|---|---|---|---|---|---|
| 1 | 4 | G1,1-G1,4 | 20 | 0.015 | 73 | 1.1 |
| 2 | 7 | G21,1 –G21,7 | 5 | 0.005 | 100 | 0.5 |
| | 1 | G22,1 | 15 | 0,005 | 100 | 0.5 |
| | 4 | G23,1-G23,4 | 20 | 0.005 | 100 | 0.5 |
| Total | | | 210 | | | |

**Table 2:** The Transmission Line Data

| Line | Failure Rate $\lambda$(f/yr) | Expected Repair Duration MTTR(hrs) | Resistance R(ohm) | Reactance X(ohm) | B/2(mho) | Capacity(Mw) | FOR |
|---|---|---|---|---|---|---|---|
| TL1-3-1 | 1.5 | 10 | 0.03 | 0.18 | 0.0106 | 100 | 0.0017 |
| TL2-4 | 5.0 | 10 | 0.11 | 0.60 | 0.0352 | 110 | 0.0056 |
| TL1-2 | 4.0 | 10 | 0.09 | 0.48 | 0.0282 | 90 | 0.0045 |
| TL3-4 | 1.0 | 10 | 0.02 | 0.12 | 0.0071 | 90 | 0.0011 |
| TL3-5 | 1.0 | 10 | 0.02 | 0.12 | 0.0071 | 90 | 0.0011 |
| TL1-3-2 | 1.5 | 10 | 0.28 | 0.18 | 0.0106 | 90 | 0.0017 |

**Table 3:** The Data Load

| Load | Peak load(MW) |
|---|---|
| L1 | 20 |
| L2 | 85 |
| L3 | 40 |
| L4 | 10 |

**Table 4:** Power Production Cost for each generator

| Capacity | Fixed Cost(RM/h) | Variable Cost |
|---|---|---|
| 20 | 5.66 | 12.20 |
| 5 | 1.42 | 0.5 |
| 15 | 4.26 | 0.5 |
| 20 | 77.60 | 0.5 |

**Table 5:** Computation result indices

| Load | FOR | OUTAGE FREQUENCY | EDLC | EUE | ELC | ENLC |
|---|---|---|---|---|---|---|
| L1 | 0.001 | 0.103 | 4.2679 | 24.727 | 0.602 | 0.103 |
| L2 | 0.016 | 12.920 | 138.49 | 1577.1 | 153.48 | 12.926 |
| L3 | 0.002 | 2.727 | 16.753 | 271.9 | 41.59 | 2.727 |
| L4 | 0.001 | 1.224 | 11.075 | 103.02 | 11.23 | 1.224 |
| composite system | | SPII:1.335 | SAPC/D:12.19Mw/disturbance | | | |
| | | EUE :1976.747 | SECI:0.00145 | | | |

***Conclusion:***

This paper illustrates the importance of collecting and utilizing for composite generating unit and transmission line operating economically and securely is presented. System reliability and load points are evaluated considering only the single and double contingencies in the system. In case of system capacity deficiency, unit generation rescheduling is conducted .load curtailment is performed according to present rule for load curtailment if important .the proposed method is applied to modified five-bus application system to demonstrate it s feasibility and effectiveness .computation results of the system and load points are useful for expansion planning of composite systems that includes generations and transmissions.

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