Developing Tools of Short-Term Reliability Evaluation Using a Fast Sorting Technique (FST)

Mohd Khairul Na'im bin Uyup
Faculty of Electrical Engineering
Universiti Teknologi MARA Malaysia

Abstract—**This paper discusses the application of Fast Sorting Technique (FST) that have been developed by Institution of Engineering and Technology and this technique will be applied in the calculation of short terms reliability [1]. By considering speed and accuracy requirements, this technique will quickly select the required number of systems state in descending order probability. After several calculations, the stopping rule for the evaluation will be met. This stopping rule is defined as the relative accuracy of a given reliability index. By using this technique to evaluate the reliability, only a small number of system states are needed to achieve the high accuracy of the short-terms reliability and this will take a minimum evaluation of comparisons and also the number of comparisons.**

Keywords **Power systems Reliability Evaluation Fast Sorting Technique (FST)**

1. INTRODUCTION

Nowadays, the need for reliable power systems is very important since the world is growing fast. Most of the product in this world use electricity even the car also is being invented to use the electrical energy. In order to ensure all these products, industry, and buildings operate successfully, the electricity that supplied must be reliable to avoid any breakdown or other problems. Thus, the calculation of reliability has been developed. This reliability evaluation comes from power system planning and operation [1-3].

Generally, reliability can be known as a performance of the components, machines, equipment or a system when it is operating. This reliability can also be defined as a probability of the components, machines, equipment or a system that will satisfactory the needed of the consumer under a specific time or periods [4, 10].

Since the reliability consider the fail and operating condition, the probability method is applied to calculate the reliability. To make it clear, as example, given the probability of reliability is 0.9, that is mean the components can operate at 90 percent and the probability of this component fail is only 10 percent. So, if the reliability is near to 1, the component or the systems are operating very successful. But in the real world, to have ideal systems is mostly impossible. There is a lot of method that have been used to calculate the reliability of power systems such as by using Markov's theory, decision tree theory and could be another method that have been created [5,7]. In this paper, one method that evaluates the reliability of power systems is presented. The method that depends on the time-dependent state probabilities of the component is called as Fast Sorting Technique, FST. This technique is developed by Institution of Engineering and Technology [1]. This method have a lot of advantages especially the time that will be used in calculating the reliability and this is why the calculation of reliability is called as short-terms reliability evaluation.

Using this Fast Sorting Technique, FST the data taken in order to calculate the reliability are from the components that operates well and also when the component is down. Mean times that taken from the component of power systems, which are mean time to repair, MTTR and mean time to failure, MTTF, the Availability, $p(t)$ and Unavailability, $q(t)$ are evaluated. Mean time to repair, MTTR is the average time when the maintainability of the components while the mean time to failure, MTTF, can be defined as the average time starting when the components have fault until the component met the next fault. The sum of these MTTF and MTTR can be defined as the period, T [1, 4-8]. Then, the components with their own Availability, $p(t)$ are sorted in ascending order. The next step of this FST method is sorting the state and this procedure will be explained in this paper. Lastly the reliability indices are obtained. Fig. 1 shows the framework of short-term reliability evaluation.

In this paper, the basic methodology of short-term reliability evaluation is presented in section 2. In section 4, the system analysis including the procedure of sorting technique and rescheduled model are discussed. The results of the reliability evaluation using this FST technique are described and analyzed are shown in section 6. Some advices to improve the reliability of the systems are also proposed.

2. SHORT TERM RELIABILITY EVALUATION

This short-terms reliability evaluation depends on the time-dependent state probabilities of the components. The evaluation are considering two-state model since the probability of the components, systems, machines and equipments only considered the mean time of failure and repair. Markov process has explained more details about the two-state model by considering the time-dependent state probability. Actually, the evaluation of this short-term reliability is a combination of Markov process with the sorting technique. Using Markov process, the basic equations are applied to deduce this time-dependents state probability of the components.

There are two initial states of the components which are up-state and down-state. Fig. 2 shows the time-dependent probabilities of the component if the component is in the up-state while Fig. 3 shows the initial state of component is in down-state. The graphs are showing the Availability, *p(t)*, and Unavailability, *q(t)* with respects to its initial states [1, 3, 7].

$$[p(t), q(t)] = \left[\frac{\mu}{\mu+\lambda} + \frac{\lambda}{\mu+\lambda}e^{-(\mu+\lambda)t}, \frac{\lambda}{\mu+\lambda} + \frac{\lambda}{\mu+\lambda}e^{-(\mu+\lambda)t}\right] \quad (1)$$

Where λ = unit failure rate
μ = unit repair rate

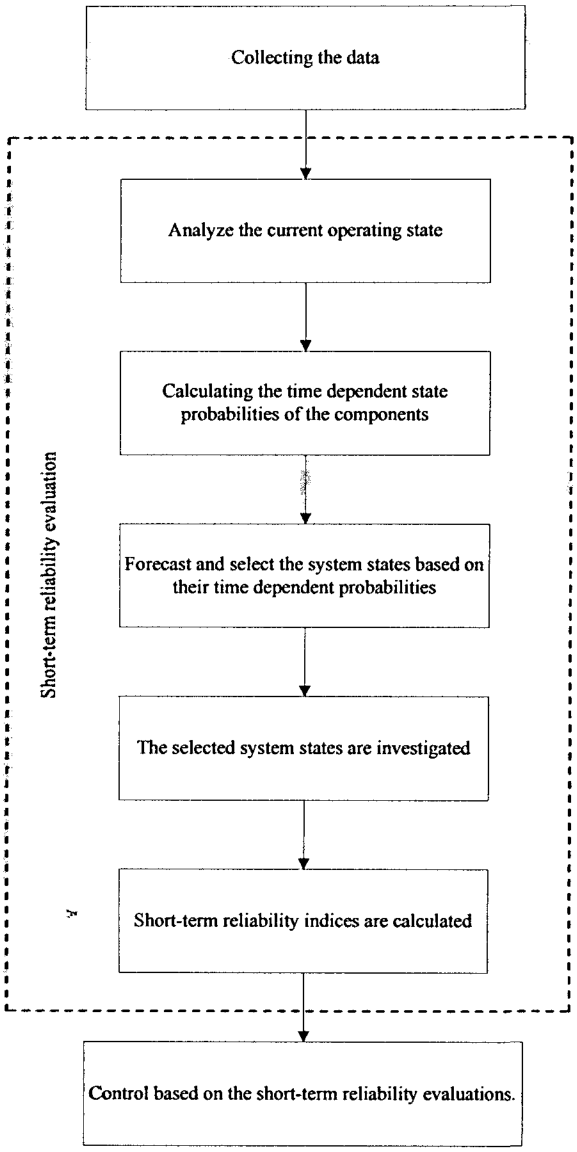

Fig. 1: Framework of short term reliability evaluation.

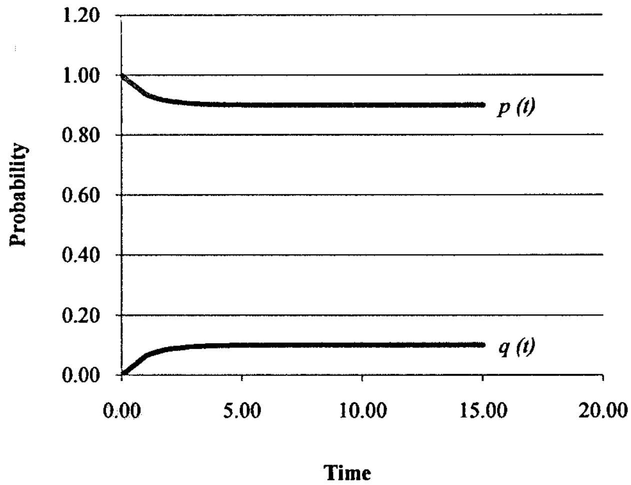

Fig. 2: Time dependent probability (initial state is up-state)

Similarly, if the component is in the down state at time $t=0$, the associate time-dependent probabilities are

$$[p(t), q(t)] = \left[\frac{\mu}{\mu+\lambda} - \frac{\mu}{\mu+\lambda}e^{-(\mu+\lambda)t}, \frac{\lambda}{\mu+\lambda} + \frac{\mu}{\mu+\lambda}e^{-(\mu+\lambda)t}\right] \quad (2)$$

For both up-state and down-state, as $t \to \infty$, the steady-state probabilities are

$$[p(t), q(t)] = [p(\infty), q(\infty)] = \left[\frac{\mu}{\mu+\lambda}, \frac{\lambda}{\mu+\lambda}\right] \quad (3)$$

From this time dependent probabilities for both up and down state, it can be conclude that the equation for the Availability, *p(t)*, is defined by equation (4).

$$p(t) = \frac{\Sigma[up\ time]}{\Sigma[down\ time] + \Sigma[up\ time]} \quad (4)$$

The unit can be expressed in terms of unit's failure and repair rates.

$$p(t) = \frac{\mu}{\mu+\lambda} = \frac{m}{m+r} \quad (5)$$

Where λ = unit failure rate
μ = unit repair rate
m = mean time to repair, MTTR
r = mean time to failure, MTTF
$T = m+r$ = mean cycle time

And then, from equation 5, the equation for Unavailability, *q(t)*, can be defined as

$$q(t) = \frac{\lambda}{\mu + \lambda} = \frac{r}{m + r} \quad (6)$$

Since the highest probability is 1.0, the simplest way to evaluate the Unavailability, *q(t)* is the subtraction of Availability, *p(t)* with 1 as shown below,

$$q(t) = 1 - p(t) \quad (7)$$

The unit of Unavailability, *q(t)* is the commonly referred as the Forced Outage Rate, FOR. Actually Forced Outage Rate, FOR, is not a rate but it is a ratio as shown in equation (8).

$$\begin{aligned} &Forced\ outage\ rate, FOR \\ &= \frac{forced\ outage\ hours}{in\ service\ hours + forced\ outage\ hours} \end{aligned} \quad (8)$$

After a long period, the Forced Outage Rate, FOR is equivalent to the unit of Unavailability, *q(t)*.

$$Forced\ Outage\ Rate, FOR = Unavailability, q(t) \quad (9)$$

The time-dependent probabilities of the system states and the time dependent reliability indices are caused by the time-dependent state probabilities of components [1].

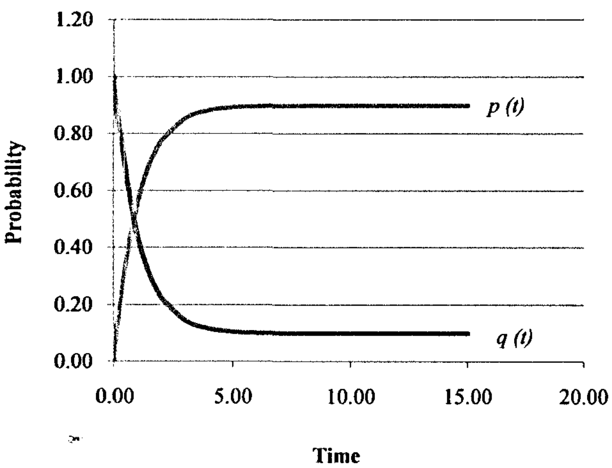

Fig. 3: Time dependent probability (initial state is down-state)

The objective of this evaluation is to analyse and evaluate the reliability using Fast Sorting Technique, FST. The evaluation of reliability is important because can give advantages to the system operator to take any action if there are any breakdowns or failure occurs as soon as possible. This evaluation also can let them know where are the problem always occurs and they can take action to reduce or prevent the failure. The evaluation also can estimate the satisfactory of the power systems that will be supplied to the consumers.

After all evaluation of the reliability has been made, the components with their own probability of Availability, *p(t)* are sorted in ascending order. Then, the highest probability of the component is selected using Fast Sorting Technique, FST that proposed in this paper. The FST are using sorting technique which are divided into two, level-*i* state and all-level state. After all sorting procedures are applied, the probabilities that have been calculated are used to evaluate the short-term reliability indices which are define in equation 17 and 18. Finally, the short-term reliability of power system is known.

3. DIFFERENCE BETWEEN FAST SORTING TECHNIQUE EVALUATION WITH CONVENTIONAL TECHNIQUE

Long-term reliability is analyzed by conventional reliability evaluation based on the steady-state probability of a component while the short-term reliability evaluation is using the time-dependent state probability of a component. Table 1 compares the different between both techniques [1].

Table 1: The comparison between long-term and short-term reliability evaluations

Technique	Long Term	Short Term
Component parameter	Using steady state probability which is time-dependent probability at t=∞	Time-dependent state probability at a future time *t*.
System condition	Using annual peak load or load duration curve; generation and transmission install capacity	Real-time load, generation, reserve and network.
Application	Planning problems	Operation problems

4. FAST SORTING TECHNIQUE

The Fast Sorting Technique, FST is a method to evaluate the reliability of the systems. By using this technique, the time and the state that need to be considered are less compared to the conventional method. The definitions of preprocess and FST are described as following.

4.1 Basic definitions and preprocess

4.1.1 Preprocess:

Rearranged all component in a power system at time *t* according to (10) and numbered as 1, 2, 3,..., *n*.

$$P_{1,max}(t) \leq P_{2,max}(t) \leq P_{3,max}(t) \leq \cdots \leq P_{n,max} \quad (10)$$

Where i) $p_{j,max}(t) = max\{p_j(t), q_j(t)\}$,

ii) $p_j(t)$ and $q_j(t)$ are the time-dependent probabilities of component j in up and down state respectively.

iii) n is the total number of system component.

4.1.2 Definition 1:

Probability of S_1 is a probability of a system state that have largest probability in all system states where S_1 is a system state. The probability can be determined using

$$P_{S_1}(t) = \prod_{j=1}^{n} p_{j,max}(t) \tag{11}$$

4.1.3 Definition 2:

System state in transition component is defined as level-i transition state while transition component is defined as the level-i components that have changed their states. As an example, for level-3 system state, it can be represent as S(1, 2, 3) where 1, 2, and 3 are transition components. For the probability, the systems states in transition level-i are arranged in descending order. $S_{i,1}, S_{i,2}, \ldots, S_{i,m}, \ldots$, are used to represent this system states, where i is the number of components. As example for 4 components and 2 level states, $S_{2,1}$, $S_{2,2}$, $S_{2,3}$, …, $S_{2,6}$. The value of m can be calculated by using the equation where n is the number of components that used and i is the number of level.

$$m = {}_nC_i \tag{12}$$

The probabilities arrangement of system states are shown as following:

$$P_{S_{i,1}}(t) \geq P_{S_{i,2}}(t) \geq \cdots \geq P_{S_{i,m}}(t) \geq \cdots, \tag{13}$$

4.1.4 Definition 3:

For level-i transition state and let l is the neighbouring of m. Applying in this sorting technique, the transition state $S_{i,l}$ is neighbouring with $S_{i,m}$ if only when the transition component of $j+1$ is different with transition component j in system state $S_{i,l}$ and $S_{i,m}$ respectively. For example on level-3 state, $S_{3,m}$ = S(1, 2, 4) the neighbouring states are S(1, 2, 5) and S(1, 3, 4) where the changes is happened at component 2 and 4 of state $S_{3,m}$ = S(1, 2, 4). Therefore, $DS_{i,m}$ = { S(1, 2, 5), S(1, 3, 4)}.

4.2 Sorting states by level

There are two level of sorting that will be evaluated in this technique which are sorting level-i states and sorting all level states. These two sorting procedures are shown as following and also the examples of these two procedures are shown in Table 4 and Table 5[1]:

4.2.1 Procedure for sorting level-i states

To determine the first m states of level-i ($S_{i,1}$, $S_{i,2}$,…, $S_{i,m}$), sorting technique for level-i are applied and the probability of the states are arranged in descending order without searching all states. The procedure of this sorting technique is shown as following steps:

Step 1: Given m=1, the first level-i state $S_{i,1}$=S(1,2,…,i) are determined.

Step 2: The neighbouring states of $S_{i,m}$, $Ds_{i,m}$ are determined.

Step 3: $D_{i,m}$ is determined using equation 14

$$D_{i,m} = \begin{cases} D_{S_{i,m}}, m = 1 \\ D_{S_{i,m-1}} \bigcup\limits_{1<m<nC_i} D_{S_{i,m}} - \{S_{i,1}, S_{i,2}, \ldots, S_{i,m}\}, \end{cases} \tag{14}$$

Step 4: $S_{i,m+1}$ which is the state with the largest probability in $D_{i,m}$ is determined.

Step 5: Let $m=m+1$ and step 2 is repeated if m is smaller than the required number. Otherwise, the process is stopped.

4.2.2 Procedure for sorting all-level states

This procedure is to determine the first k system states S_1, S_2, … , S_k. The probabilities of each state are also arranged in descending order and without searching all system states. The basic procedure is as follows:

Step 1: Determine the first state $S_1=S_{0,1}$ where $k=1$

Step 2: Determine $S_{i_k,m_{k+1}}$ applying level-i_k state sorting algorithm if required. Given $S_k=S_{i_k,m_k}$.

Step 3: Determine $S_{i_{k+1},1}$ by applying level-(i_k+1) state sorting algorithm if required.

Step 4: Determine D_k using 15

$$D_k = \begin{cases} \{S_{1,1}\}, k = 1 \\ D_{k-1} \cup \{S_{i_k,m_{k+1}}\} - \{S_{i_k,m_k}\} \\ k>1 \text{ and } m_k<nC_{ik} \text{ and } m_k\neq 2 \\ D_{k-1} \cup \{S_{i_k,m_{k+1}}\} \cup \{S_{i_k+1,1}\} - \{S_{i_k,m_k}\} \\ k > 1 \text{ and } m_k < nC_{ik} \text{ and } m_k = 2 \\ D_{k-1} - \{S_{i_k,m_k}\} \\ k > 1 \text{ and } m_k = nC_{ik} \end{cases} \tag{15}$$

Step 5: The state with the largest probability in D_k which is S_{k+1} is determine.

Step 6: Let k=k+1 and step 2 is repeated if k is smaller than the required number. Stop otherwise.

As example for these procedures, four-component of power systems are considered to make the application of FST is clear. The four-component are including three generation and one transmission line. Table 2 shows the value of Availability, $p(t)$ for each component at t=1. The Availability, $p(t)$ is calculated using equation 1 or 2.

First of all, the four components of power systems are arranged in ascending order depends on its probability, $p_{j,max}(t)$. The arrangements are shown in Table 3. Then, using level-i sorting procedure, the value of probability of each state are obtained and arranged in descending order. So, if at $S_{2,2}$ state sequence have two neighbouring, the highest value of probability will be selected to be the value of $Ps_{2,2}(t)$ and so on. The same method is applied at sorting all-level procedure. For all-level state sorting-algorithm, the results are shown in Table 5 and the whole system has sixteen states by using this equation:

$$k = {}_nC_0 + {}_nC_1 + {}_nC_2 + \ldots + {}_nC_n \qquad (16)$$

Where n is the number of components.

The third columns of Table 4 and 5 are explained about the number of the system states. This number is to select the first m level-2 states, $NS_{2,m}$ and also for all-level states, NS_k. For example, considering at level-2 state, to select the first four level-2 states, S(2,3), S(1,4) and S(2,4) are calculated and compared. Therefore the value of $NS_{2,4}$ is equals to three. The same method is applied to the all-level state. To select the first seven states, six states are calculated and compared which are, $S_{1,3}$, $S_{2,1}$, $S_{1,4}$, $S_{2,2}$, $S_{2,3}$ and $S_{3,1}$. So the value of NS_k is equal to six. For the last columns of both Table 4 and 5, it is shown the probability of each state in descending order.

Table 2: Component data

Component	Availability, $p(t)$ (t=1h)
Line 1	0.99956
Gen 1	0.90000
Gen 2	0.90000
Gen 3	0.88005

Table 3: Component sequence

Series number	Component	$p_j(t)$	$q_j(t)$	$p_{j,max}(t)$
1	Gen 3	0.88005	0.11995	0.88005
2	Gen 1	0.90000	0.10000	0.90000
3	Gen 2	0.90000	0.10000	0.90000
4	Line 1	0.99956	0.00044	0.99956

4.3 *Evaluation procedure*

The algorithm can be summarized in the following steps and the flowchart of this evaluation procedure is shown in Fig. 4 [1].

Step1: Input reliability and operation data of components and systems obtained.

Step 2: Perform AC power flow analysis for the current operating state.

Step 3: By using equation (1) or (2), the time-dependent state probabilities of components at time t are calculated. Repair process is neglected if t is much shorter than the component repair time. Because of that, the value of μ in equation (1) and (2) are equals to zero. The repair process must be considered, so the value of t is not relatively short.

Step 4: By using FST, the system state with largest probability in the remaining states is determined.

Step 5: The network connections for the selected system state are checked.

Step 6: Short-term reliability indices are calculated.

Step 7: The number, total probability of selected states and relative accuracy of the index are updated.

Step 8: Lastly, if stopping rules are reached, output the reliability indices, otherwise proceed to *Step 4*.

Table 4: Level-2 sorting procedure

State sequence	$D_{2,m}$	$NS_{2,m}$	$PS_{2,m}(t)$
$S_{2,1}$=S(1,2)	{S(1,3)}	0	1.079e-2
$S_{2,2}$=max($D_{2,1}$)= S(1,3)	{S(2,3), S(1,4)}	0	1.079e-2
$S_{2,3}$=max($D_{2,2}$)= S(2,3)	{S(1,4), S(2,4)}	2	8.797e-3
$S_{2,4}$=max($D_{2,3}$)= S(1,4)	{S(2,4)}	3	4.257e-5
$S_{2,5}$=max($D_{2,4}$)= S(2,4)	{S(3,4)}	3	3.485e-5
$S_{2,6}$=max($D_{2,5}$)= S(3,4)	-	3	3.485e-5

The system state can be selected and examined again in descending order of probability until the stopping rules are met. The stopping rules are shown as following:

i. The number of selected system states is larger than or equal to the specified number.
ii. Total probability of the selected system states are greater than or equal to the given value.
iii. Relative accuracy of an index is higher than or equal to acceptable accuracy.
iv. Variation of an index is less than a given tolerance.

5. RELATIVE ACCURACY OF A RELIABILITY INDEX

To obtain the exact reliability indices evaluation that requires investigating all possible unforeseen event states is impossible. However, the lower and upper bounds of a reliability index can be defined to estimate the accuracy of the evaluation.

Table 5: All-level sorting procedure

State sequence	D_k	NS_k	$Ps_k(t)$
$S_1=S_{0,1}$	$\{S_{1,1}\}$	0	7.125e-1
$S_2=\max(D_1)=S_{1,1}$ =S(1)	$\{S_{1,2}\}$	0	9.712e-2
$S_3=\max(D_2)=S_{1,2}$ =S(2)	$\{S_{1,3}, S_{2,1}\}$	0	7.916e-2
$S_4=\max(D_3)=S_{1,3}$ =S(3)	$\{S_{1,4}, S_{2,1}\}$	2	7.916e-2
$S_5=\max(D_4)=S_{2,1}$ =S(1,2)	$\{S_{1,4}, S_{2,2}\}$	3	1.079e-2
$S_6=\max(D_5)=S_{2,2}$ =S(1,3)	$\{S_{1,4}, S_{2,3}, S_{3,1}\}$	4	1.079e-2
$S_7=\max(D_6)=S_{2,3}$ =S(2,3)	$\{S_{1,4}, S_{2,4}, S_{3,1}\}$	6	8.797e-3
$S_8=\max(D_7)=S_{3,1}$ =S(1,2,3)	$\{S_{1,4}, S_{2,4}, S_{3,2}\}$	7	1.199e-3
$S_9=\max(D_8)=S_{1,4}$ =S(4)	$\{S_{2,4}, S_{3,2}\}$	8	3.136e-4
$S_{10}=\max(D_9)=S_{2,4}$ =S(1,4)	$\{S_{2,5}, S_{3,2}\}$	8	4.275e-5
$S_{11}=\max(D_{10})=S_{2,5}=$ S(2,4)	$\{S_{2,6}, S_{3,2}\}$	9	3.485e-5
$S_{12}=\max(D_{11})=S_{2,6}$ =S(3,4)	$\{S_{3,2}\}$	10	3.485e-5
$S_{13}=\max(D_{12})=S_{3,2}$ =S(1,2,4)	$\{S_{3,3}, S_{4,1}\}$	10	4.750e-6
$S_{14}=\max(D_{13})=S_{3,3}$ =S(1,3,4)	$\{S_{3,4}, S_{4,1}\}$	12	4.750e-6
$S_{15}=\max(D_{14})=S_{3,4}$ =S(2,3,4)	$\{S_{4,1}\}$	13	3.872e-6
$S_{16}=\max(D_{15})=S_{4,1}$ =S(1,2,3,4)	-	13	5.278e-7

5.1 Reliability indices

The lower bound $I(t)_{Low}$ and upper bound $I(t)_{Up}$ of an index $I(t)$ are, respectively, defined in (17) and (18)

$$I(t)_{Low} = \sum_{k=1}^{ns} F_{S_K} P_{S_k}(t) + F_{Low}\left(1 - \sum_{k=1}^{ns} P_{S_k}(t)\right) \quad (17)$$

$$I(t)_{Up} = \sum_{k=1}^{ns} F_{S_K} P_{S_k}(t) + F_{Up}\left(1 - \sum_{k=1}^{ns} P_{S_k}(t)\right) \quad (18)$$

Where;

i. S_k is the kth system state

ii. Fs_k is the value of the index for state S_k

iii. $Ps_k(t)$ is the time-dependent state probability of S_k.

iv. n_s is the number of system state selected

v. F_{Low} and F_{Up} are the lower and upper bounds of the index value for the remaining system states, respectively.

5.2 Probability of load curtailment (PLC)

The lower and the upper bounds of PLC can be obtained by

$$PLC(t)_{Low} = \sum_{k=1}^{ns} F_{S_K} P_{S_k}(t) \quad (19)$$

$$PLC(t)_{Up} = PLC(t)_{Low} + \left(1 - \sum_{k=1}^{ns} P_{S_k}(t)\right) \quad (20)$$

If there is load curtailment for S_k, PLC index, $Fs_k = 1$, otherwise $Fs_k = 0$. Since the PLC is a probability, $F_{Low} = 0$ and $F_{Up} = 1$.

5.3 Expected demand not supplied (EDNS)

The unit of EDNS is in megawatt (MW). For the EDNS index, Fs_k is the total system load curtailed for S_k to improve operation constraint violations. Therefore the value of F_{Low} is equal to 0 and F_{up} is equal to the total system load. The lower and upper bounds of EDNS are:

$$EDNS(t)_{Low} = \textstyle\sum_{k=1}^{ns} F_{S_K} P_{S_k}(t) \quad (21)$$

$$EDNS(t)_{Up} = EDNS(t)_{Low} + L_{SYS}\left(1 - \sum_{k=1}^{ns} P_{S_k}(t)\right) \quad (22)$$

Where L_{SYS} is the total system load

The relative accuracy of the index I*, PLC* and EDNS* are respectively defined as

$$I(t)^* = \frac{I(t)_{Low}}{I(t)_{Up}} \quad (23)$$

$$PLC(t)^* = \frac{PLC(t)_{Low}}{PLC(t)_{Up}} \quad (24)$$

$$EDNS(t)^* = \frac{EDNS(t)_{Low}}{EDNS(t)_{Up}} \quad (25)$$

Equation (17) and (18) indicate that the difference between the upper and the lower bounds decreases and both bounds approach the exact index as the number of the system states considered increases. In this case, the relative accuracy of an index approaches 1. Therefore the relative accuracy of an index can be used as a stopping rule in evaluation.

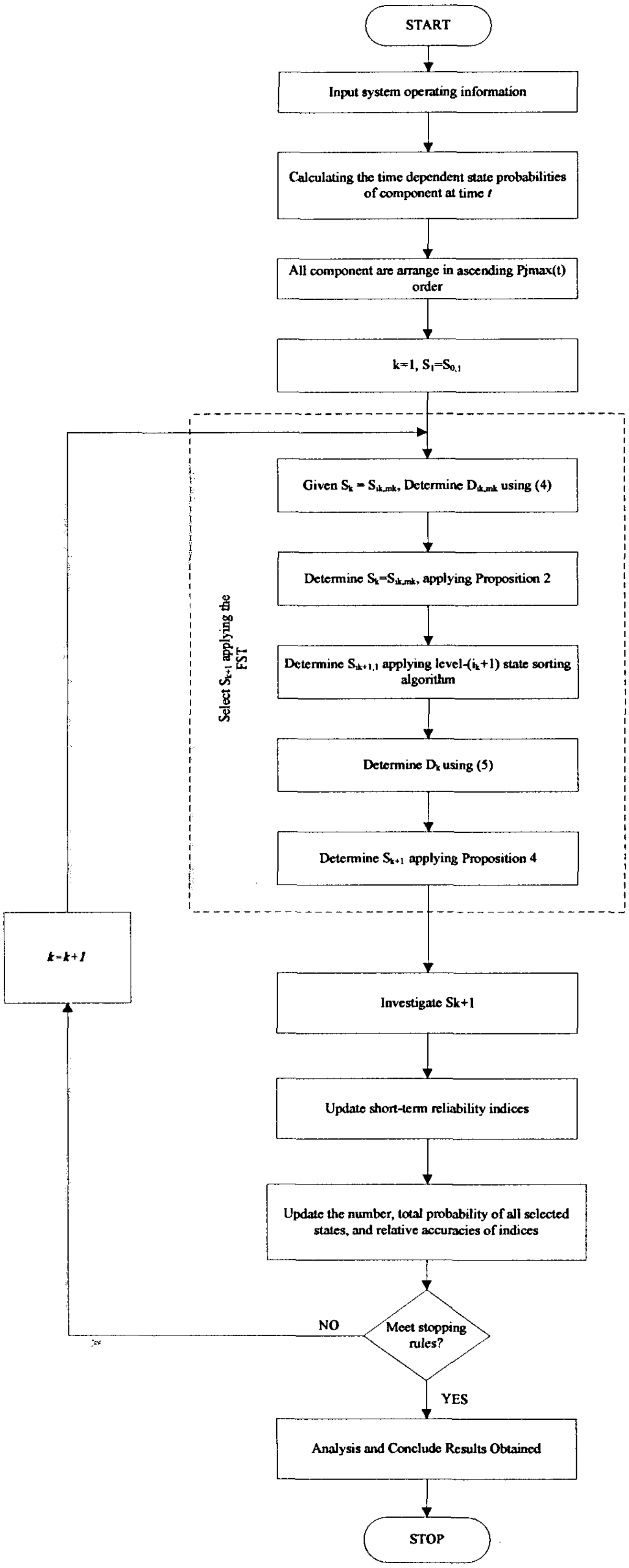

Fig. 4: Flowchart of short term reliability evaluation

6. CASE STUDY

The value of Expected Demand Not Supplied, EDNS is calculated using Fast Sorting Technique, FST and conventional method. This evaluation is calculated in order to prove that the Fast Sorting Technique, FST is applicable to calculate the reliability indices. Fast Sorting Technique, FST is applied to three units of power system and the result from FST method is compared with the conventional technique.

Consider a system that have three 25 MW units (Unit 1, Unit 2 and Unit3) with the Forced Outage Rates, FOR of 0.02, 0.06 and 0.04 respectively.

Table 6: Shows the units and its Availability, $p(t)$ and Unavailability $q(t)$

Unit	Availability, $p(t)$	Unavailability, $q(t)$
1	0.98	0.02
2	0.94	0.06
3	0.96	0.04

To calculate the reliability indices, the data from Table 6 will be used. This is an example of generation model. The model is combined with the load as shown in Fig. 5 and representing a simplified load duration curve.

An on-peak load of 70 MW is assumed to last 40% of the time (3500h) and an off-peak load of 40 MW to be present the rest of the year. The capacity of the system above the peak load or system reserve is 5 MW, or approximately 7% of the peak load.

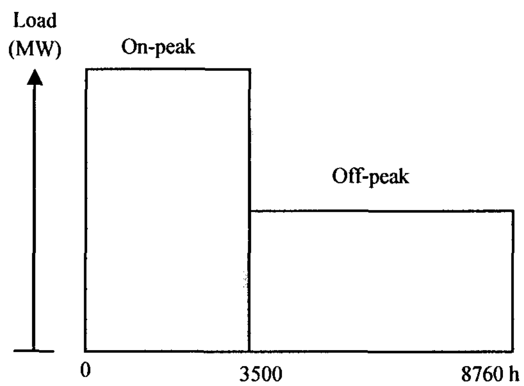

Fig. 5: Load model for calculations

6.1 Conventional method

Using conventional method, the reliability indices value is determined [3].

Expected Demand Not Supplied, EDNS,

$$= \sum[(Component(MW) - system\ reserve(MW)) \times probability \times t]$$

= [20MWx(0.056448+0.036848+0.018048) + 45MWx(0.002352+0.001152+0.000752)]x0.4+ [15MWx(0.002352+0.001152+0.000752)] x 0.6
= 1.005664 MW

From the calculation, the value of Expected Demand Not Supplied, EDNS, is equal to 1.005664MW. This result is used as benchmark and then the value of Expected Demand Not Supplied, EDNS is recalculated using the Fast Sorting Technique, FST. The results are:

6.2 Fast Sorting Technique, FST

Fast Sorting Technique, FST is applied to the data given to determine the Expected Demand Not Supplied, EDNS. As results, Fig. 6 shows a graph of EDNS.

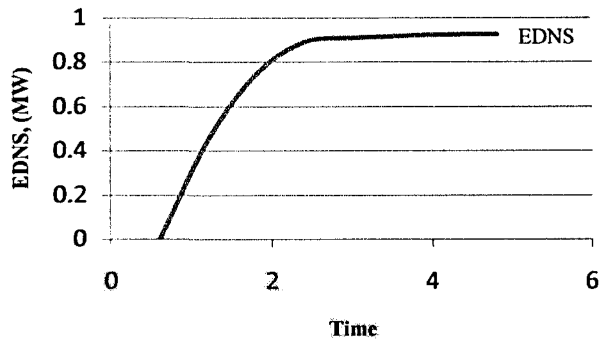

Fig. 6: Reliability index in relation to operating time

From the graph, the short-term indices increase with time and approach its limiting values. The limiting value is known as long-term indices obtained by using the steady-state probability of each component.

Using Fast Sorting Technique, FST, the value of Expected Demand Not Supplied, EDNS is equal to 0.925194 MW. This value is slightly different compared to the value that was determined using conventional method, (1.005664MW). So, this Fast Sorting Technique, FST is able to estimate the Expected Demand Not Supplied, EDNS.

7. CONCLUSION

As conclusion, the value of reliability indices, which is the Expected Demand Not Supplied, can be evaluated using the Fast Sorting Technique, FST. In order to reduce the evaluation time and also the system states, the FST is developed. The short-term reliability evaluation is based on the time varying operating conditions of a system. So, the time-dependent state probability of the systems should be used. The relative accuracy of an index is defined as the stopping rule for this short-term evaluation technique. Only a small number of system states are required in order to calculate the reliability to achieve high accuracy compared to the conventional method. Since the smaller number of system states, the evaluation required shorter evaluation time than using the existing technique.

8. RECOMMENDATION

Fast Sorting Technique, FST is applicable to calculate the reliability indices so this project should be proceed to the software development. The reliability evaluation is very important in order to determine the characteristic and the availability of a system. Next, if there are new systems that want to develop, the system must have components that have highest probability of availability. This is important in order to avoid any problem or breakdown occurs.

9. ACKNOWLEDGEMENT

The author would like to thanks Mr. Mohd Fuad Bin Abdul Latip, supervisor of this project for his guidance, supports, encouragement and patience during the work.

REFERENCES

[1] H.Liu, Y.S., L.Cheng, P.Wang,and F.Xiao, "Online short-term reliability evaluation using fast sorting technique" (The Institution of Engineering and Technology, 2008), paper first received 5th April and in revised form 10th September 2007.
[2] Chen Bo, Z.H., Liu Feng, Bie Zhaohong, "Reliability Evaluation on Northwest China Power system Using Monte Carlo Simulation".
[3] Prada, J.F., "The Value of Reliability in Power Systems, Pricing Operating Services".
[4] Yaacob, A.P.I.Z., "Engineer In Society", (Universiti Teknologi MARA Malaysia).
[5] S. Ward, T.D., W. Higinbotham,, "Improving Reliability for Power System Protection", (RFL Electronics Inc. April 28 - 30, 2004).
[6] Frank L. Cassidy Jr. "Larry" Chairman (Washington), E.J.B.V.C.O., Tom Karier (Washington), Jim Kempton (Idaho), Judi Danielson (Idaho), John Brogoitti (Oregon), Stan Grace (Montana), Leo A. Giacometto (Montana), "Reliability Standards for the Northwest Power System", (Northwest Power Planning Council, October 10, 2001).
[7] Anderson, P.M., "Power System Protection". (IEEE Press, 1998).
[8] R. Billinton, Ronald Norman Allan, "Reliability assessment of large electric power systems" (Springer, 1988).
[9] IEEE-RTS, Reliability Test System Task Force, "IEEE reliability test system", (IEEE Trans. Power Appar. Syst., 1979, 98, (6), pp. 2047–2054).
[10] R. Billinton, "Power System Reliability Evaluation" (Gordon and Breach Science Publishers).