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Overhaul Scheduling of the Generation Units In a Deregulated Power System Based on a Reliability Approach

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ABSTRACT

In this paper, using reliability indices in a well known power system a simple method for maintenance scheduling of generation units is proposed. This method is based on a systematic matrix based programming in which the ISO is capable to determine GENCOs overhaul intervals for in presence of variable loads and bids. Simulation of the proposed method on IEEE-RBTS system is done to show its effectiveness and simplicity.

KEYWORDS: Reliability, Maintenance, Power System Restructuring, LOEE.

1. INTRODUCTION

In recent years, the power systems in many countries are interested to be deregulated or restructured in order to increase efficiency, to reduce operational cost, and to give consumers more alternatives. For this aspect, a great deal of more research has been needed to achieve better intelligent knowledge process. With the promotion for the deregulation of electric power systems, maintenance scheduling in a restructured power system is becoming critical [1,2]. A deregulated power system can be divided into three main segments: generation companies (GENCOs), transmission companies (TRANSCOs) and distribution companies (DISCOs). The main tasks of these components will remain the same as conventional systems, however, to comply with Federal Energy Regulatory Commission (FERC) orders, new types of unbundling, coordination and rules are to be established to guarantee competition and non-discriminatory open access to all users. Each segment has certain responsibilities so that the system would have the required reliability. Therefore, each segment is responsible for performing the necessary maintenance on their facilities in order to sustain the competitive energy market. In this system, units maintenance scheduling will not be decided only by independent system operator (ISO) any more but will be mainly decided by GENCOs. GENCOs will try to schedule their unit’s maintenance according to the operating conditions of their units [3]. It is naturally the goal of GENCOs to maximize their benefit. All of them hope to minimize the maintenance investment loss (MIL) from their own interests. So every GENCO hopes to put its maintenance on the weeks when the market clearing price (MCP) is lowest, so that MIL descends [3]. Therefore, objective function for the GENCO is to sell electricity as much as possible, according to the market clearing price forecast. Various constraints such as generation capacity, duration of maintenance and maintenance continuity are being taken in to account. The goal of ISO is to maximize the reserve of the system at every time interval subject to the purchase cost doesn’t increase from a pre-determined amount when the units of GENCOs are in outage for maintenance [4, 5].In the deregulated systems, system operators balance between buyers and sellers and may be produced using methods to ensure efficient and economical limitations of the system is acceptable [6,7].The economic benefit to the community, so that providers can take to generate the highest price, while energy consumers to buy electric power at the same time to pay the lowest price. Prices are determined in a free market economy and are limited only by the power exchange rules [8-12].Operation and maintenance costs by increasing the rate of exchange can be paid more to maintain system reliability [13, 14].Ina vertical power structure, maintenance scheduling is done by the owner of the equipment in the system coordinately. The unique advantage of this process is the answer could be focused on reliability and cost-efficient operation of the entire system from the power company [15].

2. Perspective on maintenance scheduling of power systems

Result of changes in the business strategies, change in the dominant paradigms in manufacturing and some other factors, such as society's progress towards the information society. There are different strategies

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for maintenance and repairs. Some of these important strategies are as follows: Preventive Maintenance [17], Corrective Maintenance [18], Condition Based Maintenance [17], Reliability Centered Maintenance [19], Lean Maintenance [20], Total Productive Maintenance (TPM) [21], Lean TPM [22], Reliability Based Maintenance (RBM) [23], Agile Maintenance [24,25].

Various types of systems such as power system, production lines, and aircrafts are subject to deterioration with usage and age. In order to improve the performance of these complex systems, effective maintenance has to be carried out. In the literature, three maintenance policies have been investigated: Corrective Maintenance (CM), Preventive Maintenance (PM) and Condition Based Maintenance (CBM). In the case of CM, maintenance is performed when components fail, with high failure cost and large downtimes. PM, on the other hand, refers to any maintenance action performed when the components are still functioning, thus prolonging components life to the designed level. However, in PM, information used is acquired from average life statistics regardless of the actual deterioration of components. Maintenance actions, such as cleaning and adjustments, are often performed at predefined intervals. When the components have degraded, the fixed maintenance interval may become less than necessary and result in catastrophic failures. With the advances of condition monitoring [26-28], fault diagnostic [29,30] and prognostic technologies [31,32], CBM has attracted researchers and industries recently aided by monitoring the condition of the components online. Both PM and CBM mean that maintenance actions are scheduled before components fail. In the case of PM, the fixed downtime intervals make it unpractical due to lack of real time information about the deterioration of components. Based on the condition monitoring system, CBM, however, can predict the appropriate maintenance time for individual components more accurately. As a result, it becomes much easier to make maintenance decisions for individual components. Furthermore, as most systems are the organic composition of various different components, appropriate maintenance time of individual components may differ from one another and lead to contradictions between individual components and the system. Considering the interacted dependencies among different components, CBM should also be planned to deal with the contradictions and get the optimal compromise between the individual and the whole.

3. Review of units methods scheduling and maintenance

Most methods proposed maintenance plan using conventional mathematical programming or heuristic methods. Basic heuristic methods proposed solution is based on trial and error. Mathematical methods based on optimization techniques are quite distinct from classical programming heuristic method is trial and error. This method scheduled maintenance is proposed to solve small problems. Heuristic methods may lead to the optimal solution for complex problems; this method is the starting point shifted a local minimum. Heuristic method of solving planning problems in the maintenance of centralized power system due to its simplicity and flexibility was used. Mathematical optimization techniques such as integer programming [35], dynamic programming, branch and bound [36] have been proposed to solve the maintenance scheduling. For small problems, this approach leads to an optimal solution precision. However, the problem size is increased, and its size is huge. To solve this problem, modern techniques such as Simulated Annealing and Genetic Algorithm was proposed as an alternative to traditional methods [37].These methods are completely distinct from classical planning and trial and error methods are heuristic. Principles of natural genetics and natural selection similar to the GA approach to search and optimize deals. Principles of natural genetics and natural selection similar to the GA approach to search and optimize deals.SA methods like cooling the molten metals to form a search method deals with the phenomenon.

4. Reliability Evaluation

To evaluate reliability of the power system, in a hierarchical division, one can separate it into three segments (Figure 1). The generation segment is the first hierarchical level (HLI), generation and transmission system in the second hierarchical level (HLII) and whole system is in the third hierarchical level (HLIII).

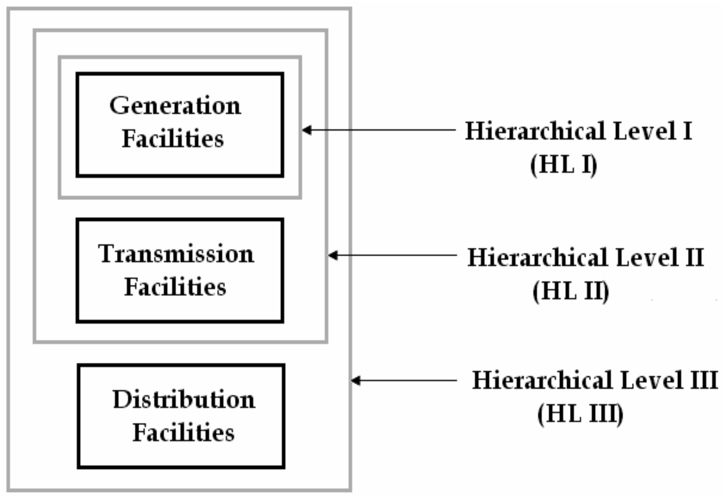

Figure 1.*A hierarchical classification of power system*

Due to the main focus of this paper to generation unit's maintenance, studied are done in HLI. The reliability indices, which are calculated in these studies, owe Loss Of Load Expectation (LOLE), Loss Of Energy Expectation (LOEE), and Loss of Load Probability (LOLP). These Indices definition can be found in Table 1.

Table 1.*Reliability indices for HLI*

Index	Definition
LOLP	The probability of a system demand will exceed capacity during a given period
LOLE	The expected number of days per year a system demand will exceed capacity
LOEE	The expected energy not served per year in a system

5. The proposed Method

GENCOs are trying to schedule their units maintenance so that their cost to be minimized. As a result each GENCO preferred to do it at week in which the MCP is minimum. Beside, because ISO as an independent decision maker. In the network change suggested maintenance programs so that the reliability and economic of the whole system to be guaranteed.

In this paper the fallowing procedure is proposed for ISO maintenance scheduling:

1. State matrix containing all possible generation states is built. For N generation units, it is dear that this matrix has 2^N rows and N columns. Each column contains a few '0' and '1', where the i^{th} element is '1' when the unit G_i is 'up' and '0' when it is 'Down'. Then each row shows a 'state' in which some of generators are in service and some of them are not.
2. For each state from Eq.(1) to (3), the individual probability is calculated.

$$U = FOR \tag{1}$$

$$A=1-U \tag{2}$$

$$Probability=A*U \tag{3}$$

3. Because overall capacities in some states are similar, individual probabilities of the repeated capacities are added together.
4. A capacity outage table (COPT) for is built for the system with descending sort of the capacities.
5. Considering the Load level in each months of the year, LOEE is evaluated using Eq.(4).

$$\text{LOEE=The area under the LDC curve} \tag{4}$$

6. A sporadic outage scenario for the units is examined. After each unit outage for all over the year and all loads, LOEE is evaluated again. Fig.(5) show the different outages effect on LOEE for 12 months a year.
7. Based on the results of the previous step, for each unit, the time in which the less LOEE is obtained is determined as the recommended time for overhaul.
8. Due to the ISO recommended maintenance program GENCOs change their bids for each days of the year. As there is several choices for outage at each time interval as well as different bids, ISO finally chose the best arrangement of the units outage to maximize the consumers benefits.

6. Simulation Results

IEEE-RTS test system is used for simulations [38]. This system is shown in Fig.(2) and its units data such as Forced Outage Rate (FOR), Mean Time To Failure (MTTR), and Mean Time To Repair are shown in Table(2). Also a typical load levels for 12 months a year are shown in Fig.(3).

Running the above mentioned proposed method for RBTS system leads to the results of the Fig.(6) to (14). Here the best overhaul time of all units are obtained in these figures the vertical axises shows the values of specific states in which LOEE is obtained equal to zero and the horizontal axises shows the number of these states.

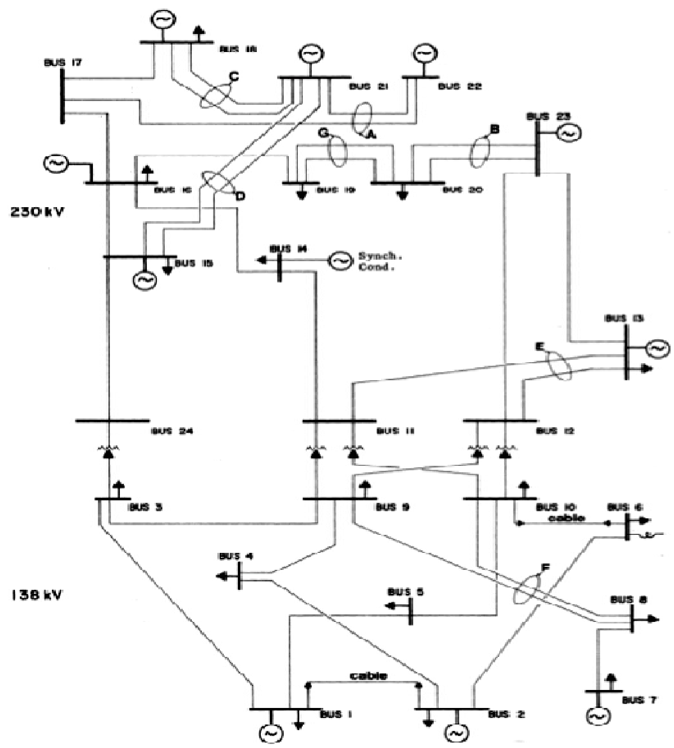

Figure 2.*IEEE-RBTS test system*

Table 2. *IEEE-RBTS test system parameters*

Unit capacity(MW)	Forced Outage Rate(#/y)	MTTF(h)	MTTR(h)
12	0.02	2940	60
20	0.1	450	50
50	0.01	1980	20
76	0.02	1960	40
100	0.04	1200	50
155	0.04	960	40
197	0.05	950	50
350	0.08	1150	150
400	0.12	1100	150

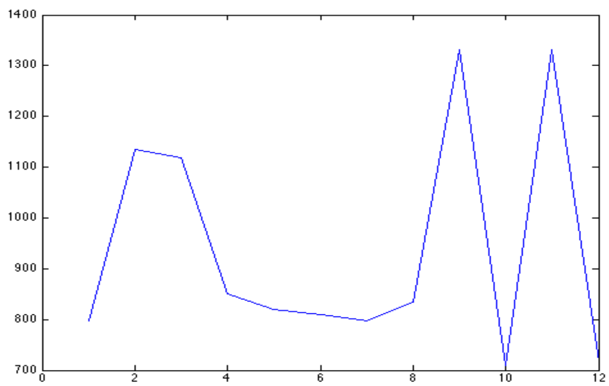

***Figure3.**load in 12 Months (MW)*

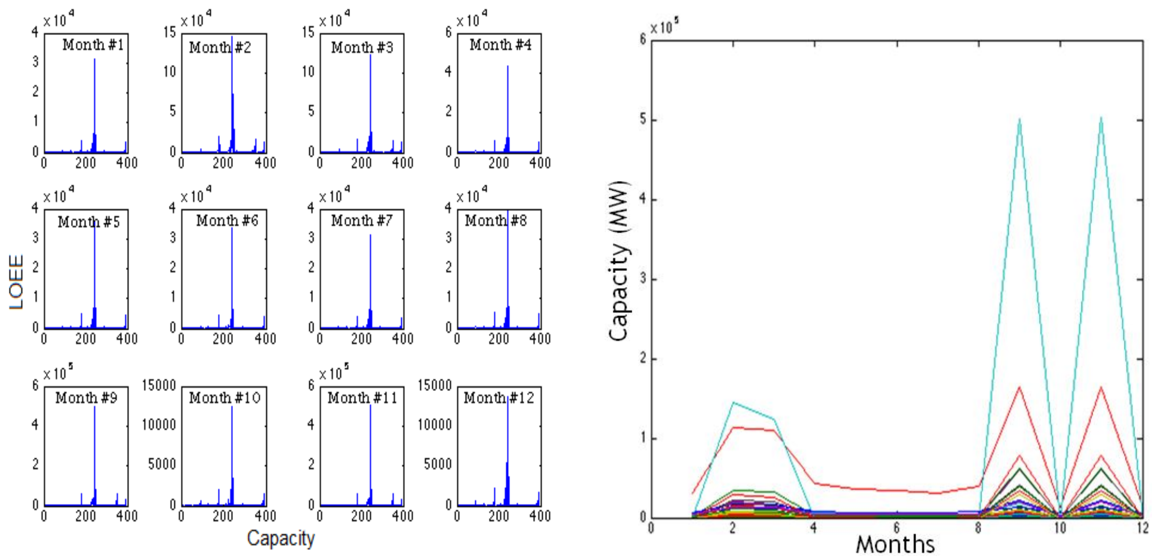

***Figure4.**non duplicate capacity (based on the MW capacity vertical axis and the horizontal axis shows the number of states.)*

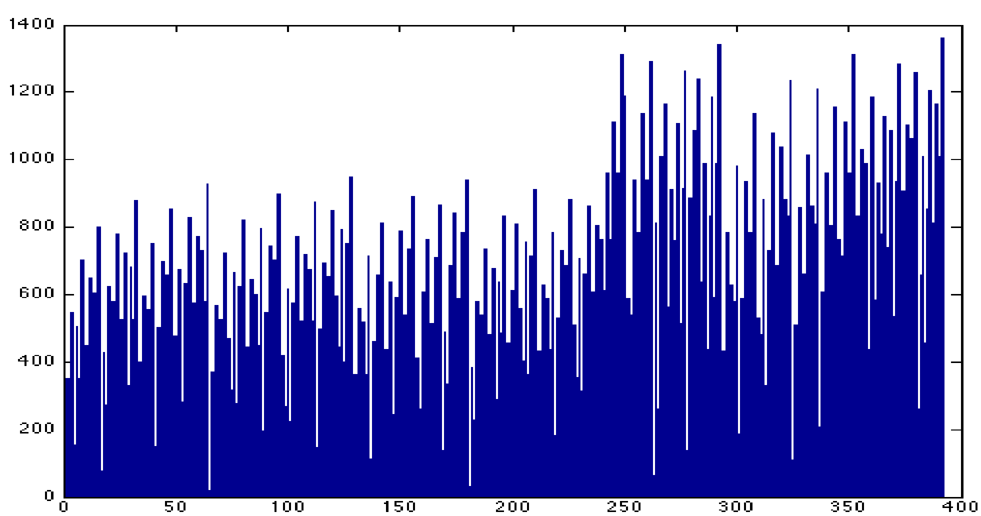

***Figure 5.** The amount LOEE for different load*

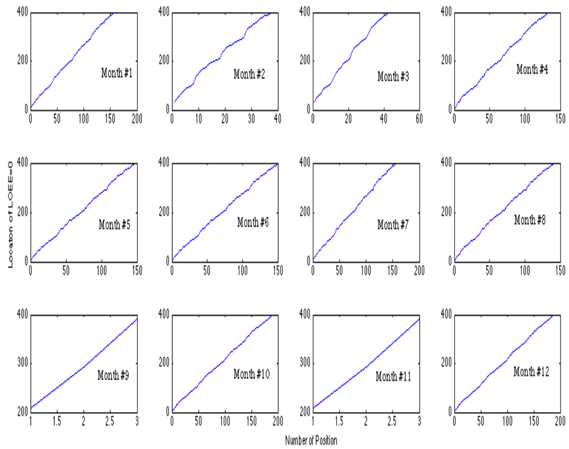

Figure 6. *Outage of 12^{MW} unit*

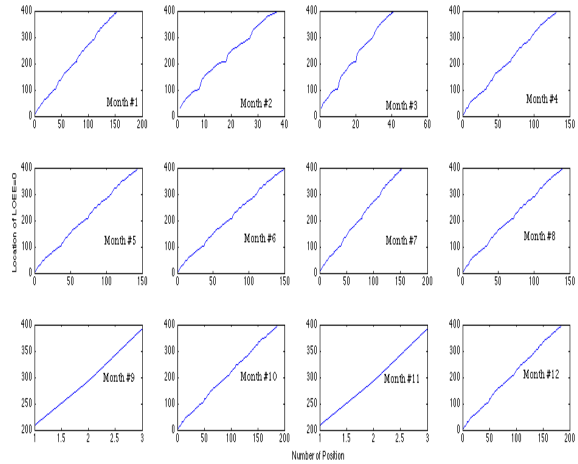

Figure 7. *Outage of 20^{MW}unit*

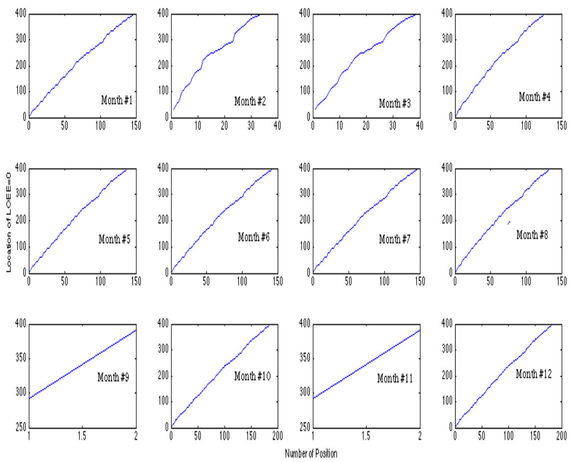

Figure 8. *Outage of 50^{MW} unit*

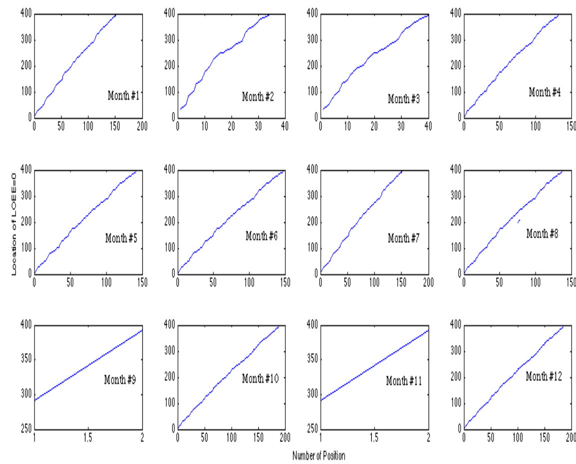

***Figure 9**. Outage of 76^{MW} unit*

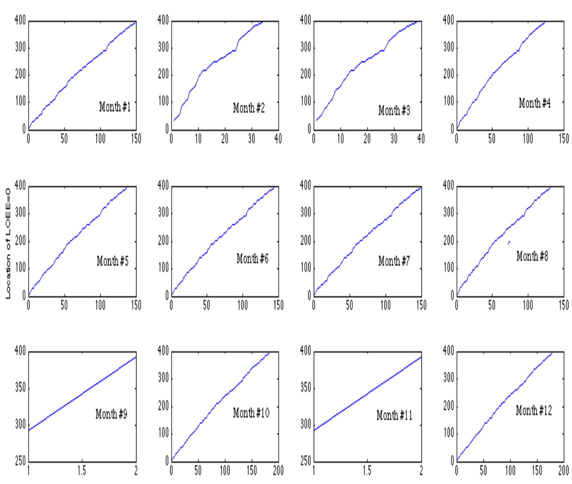

***Figure 10**. Outage of 100^{MW} unit*

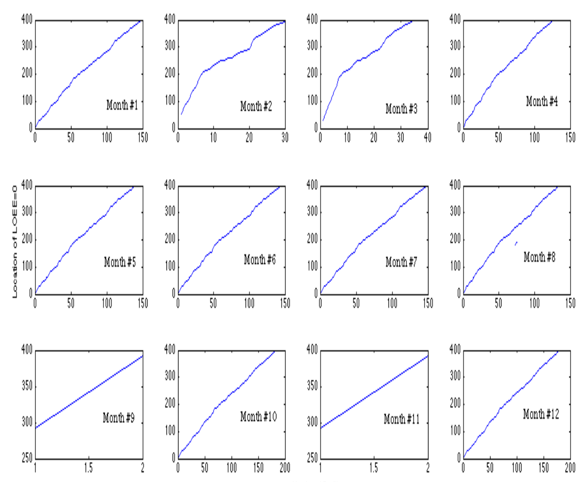

Figure 11. *Outage of 155^{MW} unit*

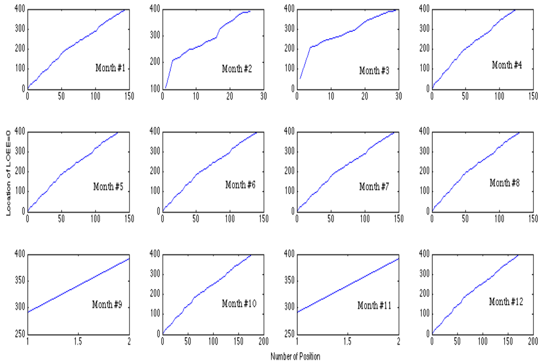

Figure 12. *Outage of 197^{MW} unit*

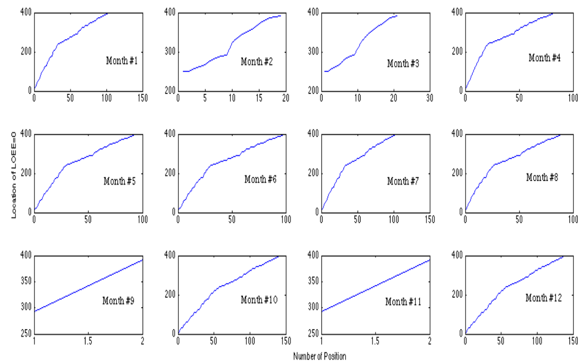

Figure 13. *Outage of 350^{MW} unit*

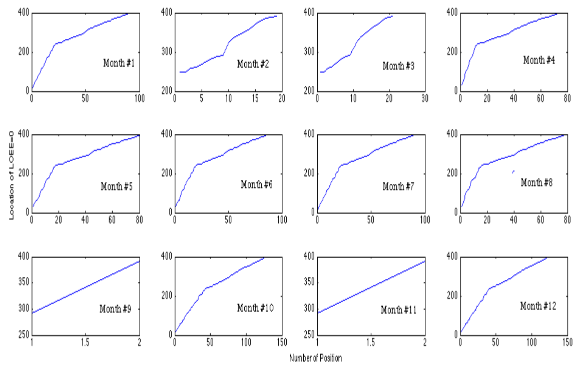

Figure 14. *Outage of 400^{MW} unit*

7. Conclusion

In this paper, a reliability-based method is investigated for generation unit's maintenance scheduling in a deregulated power system. Using a state matrix to taking into account all possible outage states the individual probability is calculated for them by COPT. Then considering the Load level in each months of the year, LOEE for a sporadic outage scenario of the unit and the time in which the less LOEE is obtained is determined as the recommended time for overhaul. Due to the ISO recommended maintenance program GENCOs change their bids for each days of the year. As there is several choices for outage at each time interval as well as different bids, the best arrangement of the units outage to maximize the consumers benefits is derived. The proposed method is examined successfully on the IEEE-RTS system.

REFERENCES

1. M. Shahidehpour and M. Marwali, Maintenance scheduling in restructured power system, USA -2000 .
2. M. Shahidehpour S.M Alomoush, Restructured electrical power system operation trading and volatility, USA-2001 .
3. R. Billinton and A. Abdulwhab, "Short-term generating unit maintenance scheduling in a deregulated power system using aprobabilistic approach", IEE, Proc. Gener. Trans., Vol. 150, No. 4 ,PP. 463-468, July 2003 .
4. W. Pang, M. Rui and H. Renmu, "Research on multi-objectiveoptimum model of unit maintenance scheduling under the conditionof electricity market", IEEE Int. Conf. on Electric Utility Deregulationand Power Technologies, pp. 196-199, April 2004 .

5. M. Negnevitsky and G. Kelareva, "Application of genetic algorithms for maintenance scheduling in power systems", IEEE Trans. OnPower System, Vol. 9, No. 3, PP. 447-452, August 2001.

6. G. B. Sheble, "Computational Auction Mechanism for Restructured Power Industry Operation", Kluwer Academic Publishers, Boston, 1998.

7. M. Ili´c and J. Zaborszky, "Dynamic and Control of Large Electric Power Systems",WileyInterscience Publication, New York, 2000.

8. F. Milano. "Pricing System Security in Electricity Market Models with Inclusion of Voltage Stability Constraints", Thesis for the degree of Doctor of Philosophy in Electrical Engineering., Italy, April 2003.

9. M. Madrigal and V. H. Quintana, "A security constrained energy and spinning reserve markets clearing system using an interior-point method", IEEE Transactions on Power Systems, Vol. 15, No. 4, Nov. 2000 pp. 1410-1416.

10. M. Flynn, W. P. Sheridan, J. D. Dillon and M. J. O'Malley, "Reliability and reserve in competitive market scheduling", IEEE Transactions on Power Systems, Vol. 16, No. 1, Feb. 2001, pp. 78-87.

11. Jin Zhong, Kankar Bhattacharya. " Design of Competitive Markets for Spinning Reserve Services", IEEE Power Engineering Society Summer Meeting, 2002

12. Y. Q. Song, Z. J. Hou, F. S. Wen, Y. X. Ni, and F. F. Wu, "Analysis of market power in oligopglistic electricity market based on game theory," presented at the 1st Proceeding of international Institute for Critical infrastructures (CRIS'2002), Beijing, China, Sep. 2002.

13. M. Shahidehpour and M. Marwali, Maintenance scheduling in restructured power system, USA -2000.

14. M. Shahidehpour S.M Alomoush, Restructured electrical power system operation trading and volatility, USA-2001.

15. Seok-Man Han, Koo-Hyung Chung and Balho H. Kim, 'ISO Coordination of Generator Maintenance Scheduling in Competitive Electricity Markets using Simulated Annealing' Journal of Electrical Engineering & Technology Vol. 6, No. 4, pp. 431~438, 2011 DOI: 10.5370/JEET.2011.6.4. 431

16. R. Eshraghnia, M.H. ModirShanechi, Senior Member IEEE and H. RajabiMashhadi, 'Generation Maintenance Scheduling in Power Market Based on Genetic Algorithm' PSCE 2006.

17. A.K.S. Jardine, D. Lin, D. Banjevic, A review on machinery diagnostics and prognostics implementing condition-based maintenance, Mechanical Systems and Signal Processing 20 (2006) 1483–1510.

18. M. Carmen CarneroMoya, The control of the setting up of a predictive maintenance programmed using a system of indicators, Omega Volume 32, Issue 1, February 2004, Pages 57-75

19. S. Eisinger and U. K. Rakowsky, Modeling of uncertainties in reliability centered maintenance — a probabilistic approach, Reliability Engineering & System Safety Volume 71, Issue 2, February 2001, Pages 159-164

20. C. Davis, Measuring the Effectiveness of Lean Thinking in Maintenance, London University, 2004

21. http://www.plant-maintenance.com/maintenance_articles_tpm.shtml

22. Dennis McCarthy and Dr Nick Rich, Lean TPM - A Blueprint for Change, Elsevier, 2004

23. N.S. Arunraj, J. Maiti, Risk-based maintenance Techniques and applications, Journal of Hazardous Materials 142 (2007) 653–661

24. Naresh Jain, Offshore Agile Maintenance, AGILE 2006 (AGILE'06) pp. 327-336

25. Van Houten F., Kimura F., «The Virtual Maintenance System: A Computer-based support tool for robust design, product monitoring, fault diagnosis and maintenance planning», Laboratory of Design, Production and Management, University of Twente, Netherlands, Department of Precision Machinery Engineering, University of Tokyo, Japan, 2000.

26. D. Aschenbrenner, H.G Kranz, et al, "On line PD measurements and diagnosis on power transformers," IEEE Transactions on Dielectrics and Electrical Insulation. Vol. 12, pp. 216-222, 2005.

27. Yang Lin, Hao Yanpeng, Li Weigu,et al, "A mechanical calculation model for on-line icing-monitoring system of overhead transmission lines," Proceedings of the CSEE,vol.30, no.19, pp.100-105, 2010 (in Chinese).

28. Gong Xianfeng, Yi Honggang, Wang Changsong,et al, "Research on temperature monitoring of isolators in HV switchgear," Proceedings of the CSEE, vol.26, no.1, pp.155-158, 2006 (in Chinese).

29. J. Ma and C. J. Li, "Detection of localized defects in rolling element bearings via composite hypothesis test," Mechanical Systems and Signal Processing, vol. 9, no. 1, pp. 63–75, Jan. 1995.

30. H. Sohn, K. Worden, C.R. Farrar, "Statistical damage classification under changing environmental and operational conditions," Journal of Intelligent Material Systems and Structures, vol. 13, pp. 561–574, 2002.

31. J. Yan, M. Koc, and J. Lee, "A prognostic algorithm for machine performance assessment and its application," Production Planning and Control, vol.15, no. 8, pp. 796–801, 2004.

32. Y. Li, S. Billington, C. Zhang, T. Kurfess, S. Danyluk, S. Liang, "Adaptive prognostics for rolling element bearing condition," Mechanical Systems and Signal Processing, vol. 13, no. 1, pp. 103113, Jan. 1999.

33. R. Keith Mobley, AN INTRODUCTION TO PREDICTIVE MAINTENANCE, 2nd edition, Elsevier Science,2002

34. Feld, W.M., Lean Production: Tools, Techniques and how to use them. APICS Series on Resource Management, 1998.

35. Marwali, M. K. C. and Shahidehpour, S. M.''Integrated Generation and Transmission Maintenance Scheduling with Network Constraints",IEEE Transactions on Power Systems, vol. 13, no. 3, pp. 1063-1068.

36. Egan, G. T., Dillon, T. S. and Morsztyn, K. "An Experimental Method of Determination of Optimal Maintenance Schedules in Power Systems using the Branch-and-Bound Technique", IEEE Transactions on Systems, Man and Cybernetics, vol. 6, no. 8, pp. 538–547.

37. Dahal, K. P., Siewierski, T. A., Galloway, S. J., Burt, G. M., and McDonald, J. R. "An Evolutionary Generation Scheduling in an Open Electricity Market", Proceedings of Congress on Evolutionary Computation, pp. 1135-1142.

38. IEEE RELIABILITY TEST SYSTEM; "A report prepared by the Reliability Test System Task Force of the Application of Probability Methods Subcommittee, "IEEE Transactions on Power Apparatus and Systems, Vol. PAS-98, No.6 Nov./Dec. 1979.