عدد خاص
بالمؤتمر الليبي الدولي للعلوم التطبيقية
و الهندسية
27-28- سبتمبر 2022

# Economic Load Dispatch for Minimizing the Cost of the Generating Units of Al- Khums Power Station

**Mahmoud Y. Khamaira, Mohammed Areibi, , Hesain. M. Alfrd, Abdolkarem S. Ebshish, and Khalid M. Alajel**

Elmergib University
mykhamair@elmergib.edu.ly

**الملخص:** ينقسم نظام القدرة الكهربائية إلى ثلاثة مكونات رئيسية، وهي محطات توليد الكهرباء ونقل الكهرباء وتوزيع الكهرباء. تعتبر محطات توليد القدرة أكبر عناصر نظام القدرة الكهربائية كلفة. تسمى عملية تقليل تكاليف التوليد بعملية التشغيل الاقتصادي. معنى التشغيل الاقتصادي هو تقسيم الاحمال على وحدات التوليد الموجودة في نظام القدرة الكهربائية على النحو الأمثل والاقتصادي بسعر تحميل معين. يعتبر التوزيع الاقتصادي اساس العملية الاقتصادية لنظام القدرة الكهربائية. باستخدام عملية التوزيع الاقتصادي، سوف يتم الحصول على الحد الأدنى من تكلفة توليد القدرة الكهربائية. في هذا البحث تم توزيع الاحمال بين وحدات التوليد اقتصاديا لتقليل تكلفة التشغيل لمحطة الخمس للطاقة باستخدام برنامج Neplane. النتائج أظهرت فاعلية الطريقة المقترحة في تقليل كلفة التشغيل للنظام المدروس.

**الكلمات المفتاحية:** التشغيل الاقتصادي، دالة الكلفة، تقليل الكلفة.

**Abstract:**

Electrical power system is divided into three main components, namely power generation, electricity transmission, and distribution of electricity. Power generation is the biggest cost component in an electrical power system. The analysis to minimize generational costs is called economic dispatch. The meaning of economic dispatch is the division of loading on existing generating units in the system optimally and economically at a certain load price. Economic Dispatch is considered the heart of economic operation of a power system. With the implementation of economic dispatch it will get a minimum cost of generation of electricity generation. In this work, economic load dispatch has been done to find out the minimum operating cost for the generating units of Al-khums power station. Simulation results show the effectiveness of the proposed method in optimizing the operating cost for studied system.

**Key words:** Economic dispatch; Cost function; Cost minimizing

## 1. Introduction

Economic operation is very important for a power system to return a profit on the capital invested. Rates fixed by regulatory bodies and the importance of conservation of fuel place pressure on power companies to achieve maximum possible efficiency. Maximum efficiency minimizes the cost of a kilowatt hour to the consumer and the cost to the company of delivering that kilowatt hour in the face of constantly rising prices for fuel, labor, supplies, and maintenance. Operational economics involving power generation and delivery can be subdivided into two parts-one dealing with minimum cost of power production called economic dispatch and the other dealing with minimum-loss delivery of the generated power to the loads. For any specified load condition economic dispatch determines the power output of each plant (and each generating unit within the plant) which will minimize the overall cost of fuel needed to serve the system load. Thus, economic dispatch focuses upon coordinating the production costs at all power plants operating on the system and is the major emphasis of this project [1]. Several studies on economic load dispatch problems have been carried out, such as the Lambda-iteration method [2-4], base point and participation factors method [5], the gradient method [6], Genetic Algorithms [7, 8], Simulated Annealing [9], Tabu Searches [10], Artificial Neural Networks [11-13] and Particle Swarm Optimization [14-16]

## 2. Al-Khums Power Station

Al-Khums power station is located in Alkums city, it is considered as one of the most important power generations in Libyan electric network. It produces around a 1600 MW fuel oil (Heavy fuel) and natural gas power station. It generates roughly 20 % of the current electricity capacity of the Libya. Alkhums powers station consists of four steam turbines and six gas turbines. Steam turbines stared up in 1982 and each of them produces 120 MW. On the other hand, gas turbines started up in 1995 and each unit generates maximum 150 MW. Figure 1 shows the generating units of Alkhums power station [17].

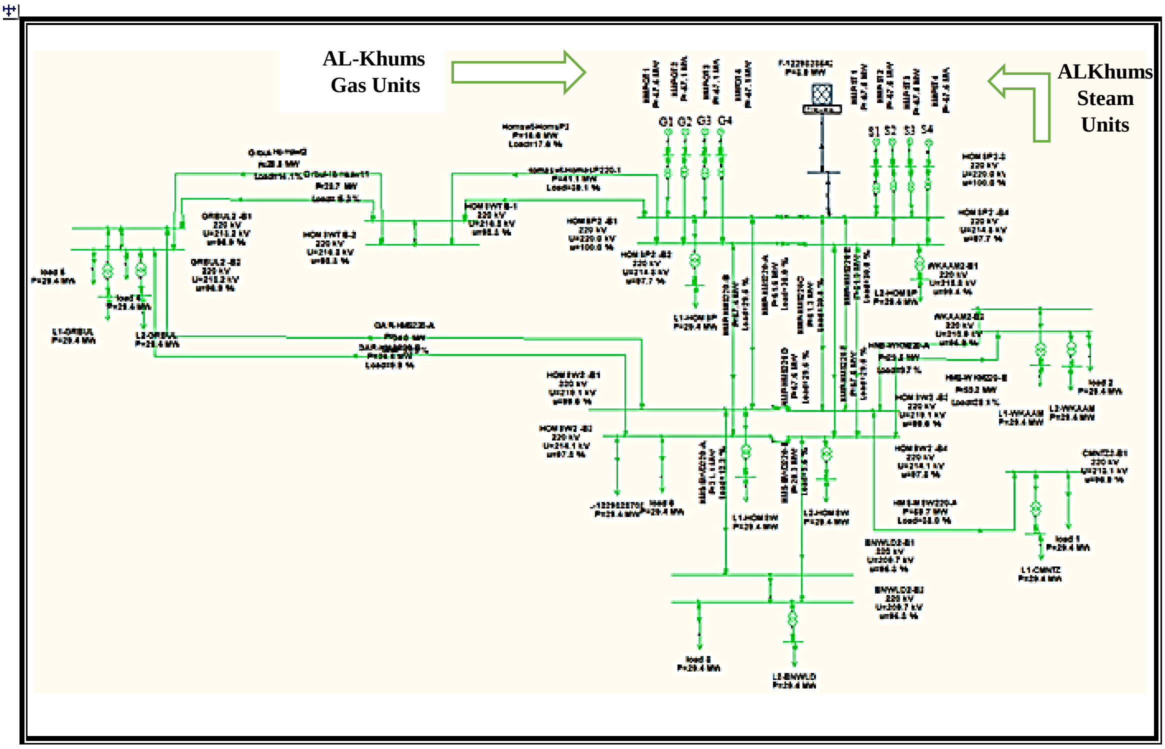


Figure (1) Alkhums power station

## 3. Operational Data of Alkhums Power Station

The following tables and figure show the operational data of Alkhums power station, which is used to calculate the fuel cost functions [17].

**TABLE 1. Type and fuel cost of Al Khums power station**

| Fuel Type | Cost (LD/ $m^3$) |
|---|---|
| Heavy fuel (Fuel oil) | 41.2 |
| Light fuel (Diels) | 156 |
| Natural gas | 0.00808 |

**TABLE 2. Operational data of Alkhums power station**

| Generated Power (MW) | Gas unit natural gas / $m^3$ | cost / LYD | Gas unit light fuel / $m^3$ | Cost / LYD | Steam unit heavy fuel / $m^3$ | Cost / LYD |
|---|---|---|---|---|---|---|
| 1 | 9179 | 257 | 18 | 2739 | 3 | 100 |
| 5 | 9920 | 278 | 18 | 2772 | 3 | 131 |
| 10 | 10854 | 304 | 18 | 2820 | 4 | 170 |
| 15 | 11795 | 330 | 19 | 2877 | 6 | 210 |
| 20 | 12742 | 357 | 19 | 2941 | 7 | 250 |
| 25 | 13696 | 383 | 19 | 3012 | 8 | 290 |
| 30 | 14657 | 410 | 20 | 3092 | 9 | 331 |
| 35 | 15625 | 438 | 20 | 3179 | 10 | 372 |
| 40 | 16600 | 465 | 21 | 3274 | 11 | 414 |
| 45 | 17581 | 492 | 22 | 3377 | 12 | 455 |
| 50 | 18570 | 520 | 22 | 3487 | 13 | 498 |
| 55 | 19565 | 548 | 23 | 3606 | 14 | 540 |
| 60 | 20567 | 576 | 24 | 3732 | 15 | 583 |
| 65 | 21577 | 604 | 25 | 3865 | 16 | 627 |
| 70 | 22592 | 633 | 26 | 4007 | 18 | 671 |
| 75 | 23615 | 661 | 27 | 4156 | 19 | 715 |
| 80 | 24645 | 690 | 28 | 4313 | 20 | 759 |
| 85 | 25681 | 719 | 29 | 4478 | 21 | 804 |
| 90 | 26725 | 748 | 30 | 4651 | 22 | 849 |
| 95 | 27775 | 778 | 31 | 4831 | 24 | 895 |
| 100 | 28832 | 807 | 32 | 5019 | 25 | 941 |
| 105 | 29896 | 837 | 34 | 5215 | 26 | 988 |
| 110 | 30967 | 867 | 35 | 5418 | 27 | 1034 |
| 115 | 32045 | 897 | 36 | 5630 | 28 | 1082 |
| 120 | 33129 | 928 | 38 | 5849 | 30 | 1129 |
| 125 | 34220 | 958 | 39 | 6076 | | |
| 130 | 35319 | 989 | 41 | 6310 | | |
| 135 | 36424 | 1020 | 42 | 6553 | | |
| 140 | 37536 | 1051 | 44 | 6803 | | |
| 145 | 38655 | 1082 | 46 | 7061 | | |
| 150 | 39780 | 1114 | 47 | 7326 | | |

## 4. Lambda iteration method

One of the most common traditional methods to deal with the problem of economic load dispatch, reducing the cost of generating unit is the lambda iteration technique. While the computational process of the lambda iteration method is difficult, it meets rapidly for this type of optimization problem. The lambda iteration method is more conventional to deal with lessening the cost of power generation to any demand. For a large number of units, lambda iteration method is more accurate and more accurate incremental cost curves of all generating units are found. Below is the lambda iteration formula for economic load dispatch [18].

$$F(total) = \sum_{i=1}^{n} a_i + b_i p_i + c_i P_i^2 \qquad (1)$$

where F(total) is the total fuel cost ($/h), a, b, and c are the fuel cost coefficients of the i-th generator, n is the number of generator in the power system and $P_i$ is the power generated by i-th generator.

## 5. Fuel Cost Function calculations

The stage carried out in this section is a processing, and calculation, where the fuel cost function for each generating unit in the Al-khums powers station is calculated by programming the equation 1 with simulation Matlab and Microsoft Excel. Results are found as following;

The fuel cost function for steam units (using heavy fuel)

$$F = 0.007587\ P^2 + 7.731\ P + 92.19 \qquad (2)$$

The fuel cost function for gas units (using light fuel)

$$F = 0.1551\ P^2 + 7.363\ P + 2731 \qquad (3)$$

The cost function for gas units (using natural gas)

$$F = 0.003847\ P^2 + 5.169\ P + 251.9 \qquad (4)$$

## 6. Economical load Dispatch procedure

Economic load dispatch of Al-khums power station is carried out by Neplan software as following;

***Step 1***; maximum loading operational limits of the generating units is set up, where 150 MW for steam units and 127 MW gas units. Moreover, the minimum loading for all units set up 30MW.
***Step 2;*** fuel cost coefficient, which were calculated in section 4.5, for all units set up.
***Step 3;*** load distribution during 24 hours is divided into four periods each 6 hours.
***Step 4;*** loading rate of each generating unit is considering during each period.
***Step 5;*** the fuel cost is found during each period and for each unit

## 7. Results and Discussion

In order to achieve the economic load dispatch and cost minmizing, the studied system (Alkhums power station), that is shown in figure 1, is simulated using NEPLAN. There are three cases were carried out as following;

### a. First Case

In this case, four generating steam units using heavy fuel and four gas generating units using light fuel are considered, and the daily load period is divided in to four periods each six hours.

#### i. First period (1am -8am)

In this period, the loading rate is considering 45% of maximum loading of each generating unit. Results of this period are displaying in table (5).

**TABLE 5. load distribution and economic load dispatch for first period**

| Steam units (MW) | | | | Gas units (MW) | | | | Cost (LD/h) |
|---|---|---|---|---|---|---|---|---|
| $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_1$ | $P_2$ | $P_3$ | $P_4$ | F |
| 57.15 | 57.15 | 57.15 | 57.15 | 67.5 | 67.5 | 67.5 | 67.5 | 18743.6 |
| Economic load dispatch | | | | | | | | |
| 102.3 | 89.9 | 103.9 | 91.4 | 30 | 30 | 30 | 30 | 16629.2 |

From results, it can be clearly seen that the load distribution between generating unit is redistributed, which led to minimize the total fuel cost during this period. The total fuel cost is reduced from 18743.6 LD/h to 16629.2 LD/h which led to save about 2114.4 LD/h.

#### ii. Second period (8am-2pm)

In this period, the loading rate is considering 60% of maximum loading of each generating unit. Results of this period are viewing in table (6).

**TABLE 6. load distribution and economic load dispatch for second period**

| Steam units (MW) | | | | Gas units (MW) | | | | Cost (LD/h) |
|---|---|---|---|---|---|---|---|---|
| P1 | P2 | P3 | P4 | P1 | P2 | P3 | P4 | F |
| 76.2 | 76.2 | 76.2 | 76.2 | 90 | 90 | 90 | 90 | 22267.9 |
| Economic load dispatch | | | | | | | | |
| 127 | 127 | 127 | 127 | 40.5 | 40.2 | 40.6 | 40.3 | 18603.6 |

In this period, the economic load dispatch application leads to down the total fuel cost from 22267.9 LD/h to 18603.6 LD/h.

#### iii. Third period (2pm-9pm)

In this period, the loading rate is considering 95% of maximum loading of each generating unit. Results of this period are viewing in table (7).

**TABLE 7. load distribution and economic load dispatch for third period**

| Steam units (MW) | | | | Gas units (MW) | | | | Cost LD/h |
|---|---|---|---|---|---|---|---|---|
| P1 | P2 | P3 | P4 | P1 | P2 | P3 | P4 | F |
| 124 | 123 | 120 | 125 | 140 | 140 | 140 | 140 | 32911.0 |
| Economic load dispatch | | | | | | | | |
| 100 | 100 | 100 | 100 | 135.2 | 134.9 | 135.5 | 135.3 | 32252.3 |

In this period, the economic load dispatch application leads to down the total cost fuel from 32911 LD/h to 32252.3LD/h.

### iv. Fourth period (9pm-1am)

In this period, the loading rate is considering 75% of maximum loading of each generating unit. Results of this period are viewing in table (8).

**TABLE 8. load distribution and economic load dispatch for fourth period**

| Steam units (MW) | | | | Gas units (MW) | | | | Cost LD/h |
|---|---|---|---|---|---|---|---|---|
| P1 | P2 | P3 | P4 | P1 | P2 | P3 | P4 | F |
| 95 | 95 | 95 | 95 | 112 | 112 | 112 | 112 | 26226.6 |
| Economic load dispatch | | | | | | | | |
| 127 | 127 | 127 | 127 | 77.8 | 77.9 | 77.9 | 77.9 | 22602.9 |

In this period, the economic load dispatch achievement leads to minimize the total fuel cost

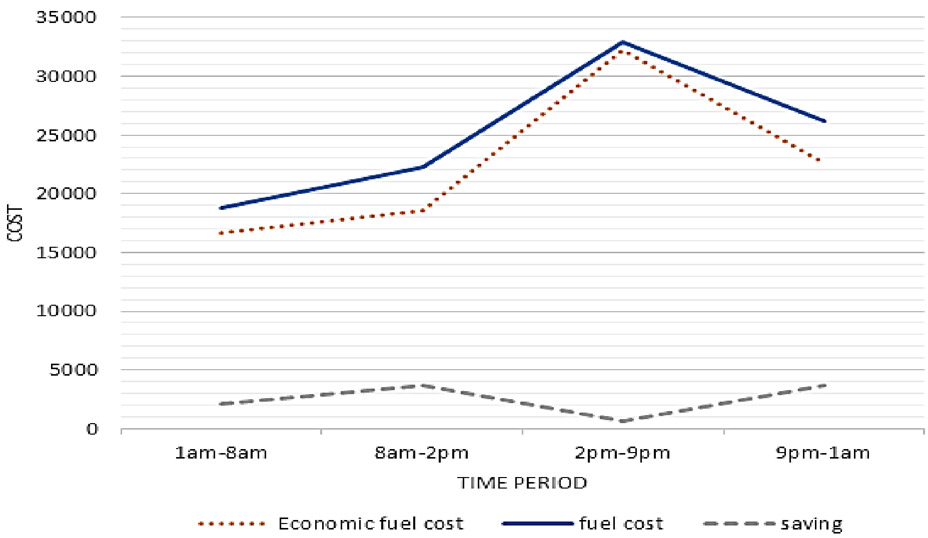


Figure (2) fuel cost, economic fuel cost and saving cost curves for first case

Figure (2) illustrations the curve of the total fuel cost during four periods with and with economic load dispatch. Moreover, it shows the fuel cost saving curve during each period for the 1st case.

### b. The Second Case

In this case, four generating steam units using heavy fuel and four gas generating units using natural gas are simulated.

#### *i. First period (1am -8am)*

In this period, the loading rate is considering 45% of maximum loading of each generating unit. Results are displaying in table (9).

**TABLE 9. load distribution and economic load dispatch for first period**

| Steam units (MW) | | | | Gas units (MW) | | | | Cost (LD/h) |
|---|---|---|---|---|---|---|---|---|
| P1 | P2 | P3 | P4 | P1 | P2 | P3 | P4 | F |
| 57.15 | 57.15 | 57.15 | 57.15 | 67.5 | 67.5 | 67.5 | 67.5 | 5503.42 |
| Economic load dispatch | | | | | | | | |
| 30 | 30 | 30 | 30 | 96.6 | 96 | 98.6 | 99 | 5094.82 |

It can be seen from table 9 that load between generating unit is redistributed, which led to lessen the total fuel cost during this period. The fuel cost is reduced from 5503.42 LD/h to 5094.82 LD/h.

#### *ii. Second period (8am -2pm)*

In this period, the loading rate is considering 60% of maximum loading of each generating unit. Results are displaying in table 10.

**TABLE 10. load distribution and economic load dispatch for second period**

| Steam units (MW) | | | | Gas units (MW) | | | | Cost (LD/h) |
|---|---|---|---|---|---|---|---|---|
| P1 | P2 | P3 | P4 | P1 | P2 | P3 | P4 | F |
| 76.2 | 76.2 | 76.2 | 76.2 | 90 | 90 | 90 | 90 | 6608.15 |
| Economic load dispatch | | | | | | | | |
| 30 | 30 | 30 | 30 | 138 | 135 | 141.6 | 138.9 | 6088.34 |

In this period, the economic load dispatch achievement leads to minimize the total fuel cost from 6608.15 LD/h to 6088.15 LD/h.

#### *iii. Third period (2pm -9pm)*

In this period, the loading rate is considering 95 % of maximum loading of each generating unit. Results are displaying in table (11).

**TABLE 11. load distribution and economic load dispatch for third period**

| Steam units (MW) | | | | Gas units (MW) | | | | Cost (LD/h) |
|---|---|---|---|---|---|---|---|---|
| P1 | P2 | P3 | P4 | P1 | P2 | P3 | P4 | F |
| 124 | 123 | 120 | 125 | 140 | 140 | 140 | 140 | 10474.5 |
| Economic load dispatch | | | | | | | | |
| 110 | 112 | 111.5 | 112.2 | 150 | 150 | 150 | 150 | 10045.9 |

In this period, the economic load dispatch achievement leads to minimize the total fuel cost from 10474.5 LD/h to 10045.9 LD/h.

### *iv. Fourth period (9pm -1am)*

In this period, the loading rate is considering 75 % of maximum loading of each generating unit. Results are displaying in table (12).

**TABLE 12. load distribution and economic load dispatch for fourth period**

| Steam units (MW) | | | | Gas units (MW) | | | | Cost LD/h |
|---|---|---|---|---|---|---|---|---|
| P1 | P2 | P3 | P4 | P1 | P2 | P3 | P4 | F |
| 95 | 95 | 95 | 95 | 112 | 112 | 112 | 112 | 8002.14 |
| Economic load dispatch | | | | | | | | |
| 60.7 | 59.3 | 61.6 | 60.4 | 150 | 150 | 150 | 150 | 7415.68 |

In this period, the economic load dispatch achievement leads to minimize the total fuel cost from 8002.14 LD/h to 7415.68 LD/h.

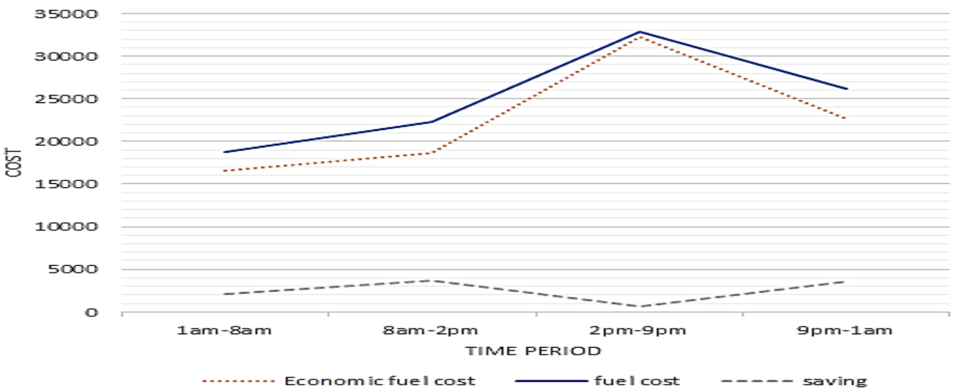


Figure (4) fuel cost, economic fuel cost and fuel cost saving curves for second case

Figure (4) shows the curve of the total fuel cost during four periods with and without economic load dispatch. Moreover, it shows the fuel cost saving curve during each period for the 2nd case.

## 8. Conclusions

In this paper, economic load dispatch is carried out for minimuzing the operating fuel cost of the generating units of Al-khums power station. The obtained results show the efficiency of the proposed method in optimizing the operating cost for studied system. Results display that the fuel cost can be decreased for the same generated power. The proposed method led to save around 12003 LD/h. However, the proposed technique can be upgraded by including the losses, which might lead to more results accuracy.

## References

[1]Stevenson Jr, William, and John Grainger. Power system analysis. McGraw-Hill Education, 1994.
[2]B. H. Chowdhury and S. Rahman, “A review of recent advances in economic dispatch,” IEEE Trans. Power Syst., vol. 5, no. 4, pp. 1248–1259, Nov. 1990.
[3]D. S. K., Jain, A. and Huddar, “Comparison of Particle Swarm Optimization with Lambda Iteration Method to Solve the Economic Load Dispatch Problem”, pp. 1900–1907, A. P. 2015.
[4]D. D. O., Adinfono, M. I. and Ogu, “Economic Dispatch of Generated Power Using Modified Lambda- Iteration Method”, 7(1), pp. 49–54, G. 2013.
[5]A. J. Wood and B. F. Wollenberg, Power Generation, Operation and Control New York: Wiley, 1984.
[6]C. L. Chen and C. L. Wang, “Branch-and-bound scheduling for thermal generating units,” IEEE Trans. Energy Convers., vol. 8, no. 2, pp. 184–189, Jun. 1993.
[7]A. M. Sasson, “Nonlinear programming solutions for load-flow, minimum- loss, and economic dispatching problems,” IEEE Trans. Power App. Syst., vol. PAS-88, no. 4, pp. 399–409, Apr. 1969.
[8]D. C. Walters and G. B. Sheble, “Genetic algorithm solution of economic dispatch with valve point loading,” IEEE Trans. Power Syst., vol. 8, no. 3, pp. 1325–1331, Aug. 1993.
[9]P. H. Chen and H. C. Chang, “Large-Scale economic dispatch by genetic algorithm,” IEEE Trans. Power Syst., vol. 10, no. 4, pp. 1919–1926, Nov. 1995.
[10] K. P. Wong and C. C. Fung, “Simulated annealing based economic dispatch algorithm,” Proc. Inst. Elect. Eng., Gen., Tranm. Distrib. vol. 140, no. 6, pp. 509–515, Nov. 1993.
[11] W. M. Lin, F. S. Cheng, and M. T. Tsay, “An improved tabu search for economic dispatch with multiple minima,” IEEE Trans. Power Syst., vol. 17, no. 1, pp. 108–112, Feb. 2002.
[12] R. H. Liang, “A neural-based re-dispatch approach to dynamic generation allocation,” IEEE Trans. Power Syst., vol. 14, no. 4, pp. 1388–1393, Nov. 1999.
[13] T. Yalcinoz and M. J. Short, “Neural networks approach for solving economic dispatch problem with transmission capacity constraints,” IEEE Trans. Power Syst., vol. 13, no. 2, pp. 307–313, May 1998.
[14] A. I. Selvakumar and K. Thanushkodi, “A new particle swarm optimization solution to nonconvex economic dispatch problems,” IEEE Trans. Power Syst., vol. 22, no. 1, pp. 42–51, Feb. 2007.

[15] J. B. Park, K. S. Lee, J. R. Shin, and K. Y. Lee, “A particle swarm optimization for economic dispatch with nonsmooth cost functions,” IEEE Trans. Power Syst., vol. 20, no. 1, pp. 34–42, Feb. 2005.

[16] Z. L. Gaing, “Particle swarm optimization to solving the economic dispatch considering the generator constraints,” IEEE Trans. Power Syst., vol. 18, no. 3, pp. 1187–1195, Aug. 2003.

[17] General Electricity Company of Libya (GECOL)

[18] T. Gonen,"Electric Power Distribution System Engineering", California State University, 1986.

 