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Fossil-Fuelled Power Generation during Haze

C. Palanichamy*

Faculty of Engineering and Science, Curtin University, CDT 250, 98009 Miri, Sarawak, Malaysia;
drcpc1119@gmail.com

Abstract

Malaysia is facing haze problems for many years and the Government's major budget has been utilized for eradicating this issue so as to provide a healthy environment for its people. Apart from the peat and forest fires, the electricity generation through fossil-fuelled power stations also significantly contributes to the environmental issues in Malaysia. For the sustainable development of the country and to become a prime land in the Asean region, the Government of Malaysia has to pay more attention to exterminate the ongoing haze problem. During haze, as the power plant emissions augment the environmental issues, two operational strategies of fossil-fuelled power stations are presented to reduce their emissions. The efficacy of the proposed strategies has been demonstrated through a 24-bus, 11 fossil-fuelled generator test system at different load conditions during a 24-hour period.

Keywords: Fossil-Fuelled Power Stations, Haze, Power Generation Strategies, Weather Effects

1. Introduction

Haze has been an on-going problem in Malaysia. Not only the capital but also many parts of Malaysia have been affected[1–6]. Borneo's rainforest are natural resources and generally free from forest fires[7–11]. People for their own needs disturb them instead of preserving them for their future generations[11,12]. Such disturbances result in forest dry out and increase the possibility of forest fires. Once fire started even at a small level, it is very difficult to control it due the huge volume and density of the forests; ultimately results in forest fire and haze. The haze is harmful for public health and is polluting the atmosphere.

Kuala Lumpur, Malaysia's capital lacks in air quality not primarily by industrialization and urbanization, but significantly due to haze. Several times, the pollution level exceeds the safe statutory level set by the Pollution Control Board, the Ministry of Energy and Environment, and the Ministry of Health[7–12]. Not only get the capital city, many territories in Peninsular and East Malaysia affected. During the raining period, the effect of haze is less pronounced whereas the summer aggravates the haze effect on human health and environment. There is no point in blaming Malaysia alone for the haze though there are few forest fires; the islands of Indonesia also contribute significantly. Figures 1, 2 and 3[7,10–12] depict the seriousness of haze in Port Klang, Kuala Lumpur, and around the Twin Tower in Kuala Lumpur.

2. Power Plant Emissions

Apart from the peat and forest fires, the electricity generation through fossil-fuelled power stations also significantly contributes to the environmental issues in Malaysia[12–16]. As Malaysia is bestowed with fossil fuels, more than 3/4th of electricity generation is from thermal power stations and renewable energy resources such as hydroelectric and solar energy conversion systems hardly account for the rest 1/4th of electricity generation in the country. It is the well-known fact that hydroelectric and solar energy conversion systems don't produce any emissions and they are environmental friendly. However, the thermal power stations liberate hazardous pollutants such as carbon-di-oxide, nitrogen oxide and sulphur-di-oxide, etc. They are harmful to the human health and prime sources for environmental degradation.This situation becomes aggravated during haze. Controlling the power plant emissions along with the haze issues will be a major financial and administrative burden for the Malaysian

**Author for correspondence*

Figure 1. Haze in Port Klang.

Figure 2. Kuala Lumpur

Figure 3. Twin tower with Haze

Government and it is answerable to its citizens being a service minded Government.

Afroz et al.[17] and Finlay et al.[18] identified mobile sources, open burning sources and stationary sources as major sources of air pollution in Malaysia. The Department of Environment Malaysia also identified three main sources of air pollution in Malaysia, such as industry (including power stations - or stationary sources), motor vehicles (mobile sources) and open burning (Department of Environment Malaysia, 2001 to 2010). However, Department of Environment Malaysia also included trans-boundary pollution sources as a significant contribution to air pollution emissions (Department of Environment Malaysia, 2004 to 2006).

Muniroh Hamat et al.[19] figured out that the emission from industries, power plants, motor vehicles and others are 47.82%, 25.52%, 9.98% and 16.68% respectively. However, the percentage contribution of industry and power plants are significantly different for years and the highest contribution comes from power plants with more than 9000 metric tonnes per year. According to Palanichamy et al.[20] and Bozkurt et al.[21] the total carbon-di-oxide emissions from thermal power stations may be double the amount in another two decades and the biggest source of carbon-di-oxide emissions would be the thermal power stations, followed by the domestic transport sector, and lastly the industry sector. So as to give priority to public health and environmental concern, the emission due to fossil fuels for power generation need to be reduced to the safer level considering the frequent hazes in the various parts of the country.

3. Weather Effects on Pollution and Haze

Almost all parts of Peninsular and East Malaysia are experiencing haze problems irrespective of monsoon and day and night weather conditions. Apart from this, the thermal power plant emissions also join together to degrade the regional and national environments and public health. The day and night weather conditions play an important role on the pollution concentration[22–25]. Nowadays, haze control in Malaysia has become an international issue since it involves several countries like Malaysia, Indonesia, Brunei, Singapore and Thailand. Whereas, the thermal power plant emissions and its control are within the capacity of electric utilities of Malaysia. Hence, thermal power plants shall plan for electricity generation such

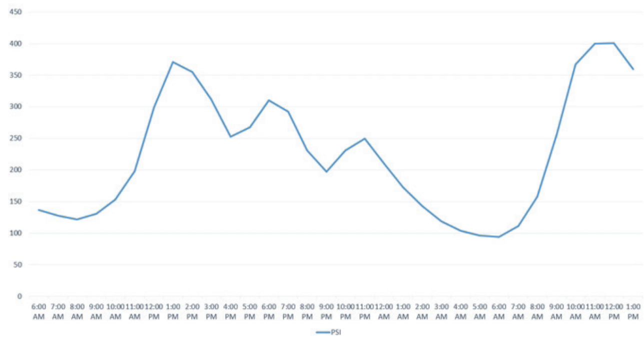

Figure 4. Power plant emission.

that the emissions shall be higher during hot weather (day time) and lower during cold weather (night time) as shown in Figure 4 so that the ground level concentration will be less, which is good for health.

4. Power Generation Strategies

The electric utilities don't have any control on the peat and forest fires; however they shall help to curb the power plant emissions to maintain a sustainable environment for the society. The primary aims of the utilities are to provide power to the consumers on demand at an affordable cost with quality and reliability. To do that, the utilities generate power such that the consumers' load demand is well balanced without violating their physical and operating constraints and their unit cost of electricity generated is attractive to their consumers. This is known as power dispatching. In this paper, two operating strategies are proposed:

4.1 Economic Power Dispatch Strategy

The economic power dispatch problem is stated as to minimize

$$F_t = \sum_{i=1}^{n} (a_{(i)} P_i^2 + b_{(i)} P_i + c_i) \ \text{\$/hr}; \quad i = 1, 2, \ldots\ldots n \qquad (1)$$

Where F_t- total operating cost of fossil-fuelled power plants in \$/hr,

P_i- power output of the i^th^ generating plant in MW,
a_i, b_i, and c_i- fuel cost coefficients of i^th^plant, and
n - Number of fossil-fuelled plants in operation.

This optimization is subject to usual equality and inequality constraints.

4.2 Emission Power Dispatch Strategy

The emission dispatch problem is stated as to minimize

$$E_t = \sum_{i=1}^{n} (d_{(i)} P_i^2 + e_{(i)} P_i + f_i) \ \text{kg/hr}; \quad i = 1, 2, \ldots\ldots n \qquad (2)$$

Where E_t- total emission of fossil-fuelled power plants in kg/hr,
P_i- power output of the i^th^ generating plant in MW,
d_i,e_i, and f_i- emission coefficients of i^th^plant, and
n - Number of fossil-fuelled plants in operation.

This optimization is subject to usual equality and inequality constraints.

Though two strategies are proposed, depending upon the haze and weather conditions, the appropriate strategy has to be chosen. This has been demonstrated through a 24-bus, 11 fossil-fuelled generator test system[26–27] shown in Figure 5.Tables 1, 2 and 3 show the test system data.The optimization algorithm is based on the direct power dispatching technique developed by Palanichamy et al[27].

Table 1. Fuel cost coefficients

Unit #	Fuel Cost Coefficients			P_{min}	P_{max}
	a_i	b_i	c_i		
1	0.00762	1.92699	387.85	20	250
2	0.00838	2.11969	441.62	20	210
3	0.00523	2.19196	422.57	20	250
4	0.00140	2.01983	552.50	60	300
5	0.00154	2.22181	557.75	20	210
6	0.00177	1.91528	562.18	60	300
7	0.00195	2.10681	568.39	20	215
8	0.00106	1.99138	682.93	100	455
9	0.00117	1.99802	741.22	100	455
10	0.00089	2.12352	617.83	110	460
11	0.00098	2.10487	674.61	110	465

Table 2. Emission coefficients

Unit #	NO_x Emission Coefficients		
	d_i	e_i	f_i
1	0.00419	-0.67767	33.93
2	0.00461	-0.69044	24.62
3	0.00419	-0.67767	33.93
4	0.00683	-0.54551	27.14
5	0.00751	-0.40006	24.15
6	0.00683	-0.54551	27.14
7	0.00751	-0.40006	24.15
8	0.00355	-0.51116	30.45
9	0.00417	-0.56228	25.59
10	0.00355	-0.41116	30.45
11	0.00417	-0.56228	25.59

Table 3. 24 – Hour load data

Time	MW	Time	MW	Time	MW
0-1	1590	8-9	2150	16-17	2150
1-2	1450	9-10	2270	17-18	2280
2-3	1345	10-11	2320	18-19	2345
3-4	1200	11-12	2320	19-20	2270
4-5	1200	12-13	2150	20-21	2150
5-6	1345	13-14	2225	21-22	1925
6-7	1450	14-15	2250	22-23	1740
7-8	1750	15-16	2170	23-24	1615

Table 4. Results of economic and emission dispatches

Method	For 24-Hours period		
	Total Operating, Cost, $	Total NO_x Emission, kg	Unit Cost of generation, $/kWh
Economic Dispatch	245055	35890	0.0537
Emission Dispatch	272515	22031	0.0597

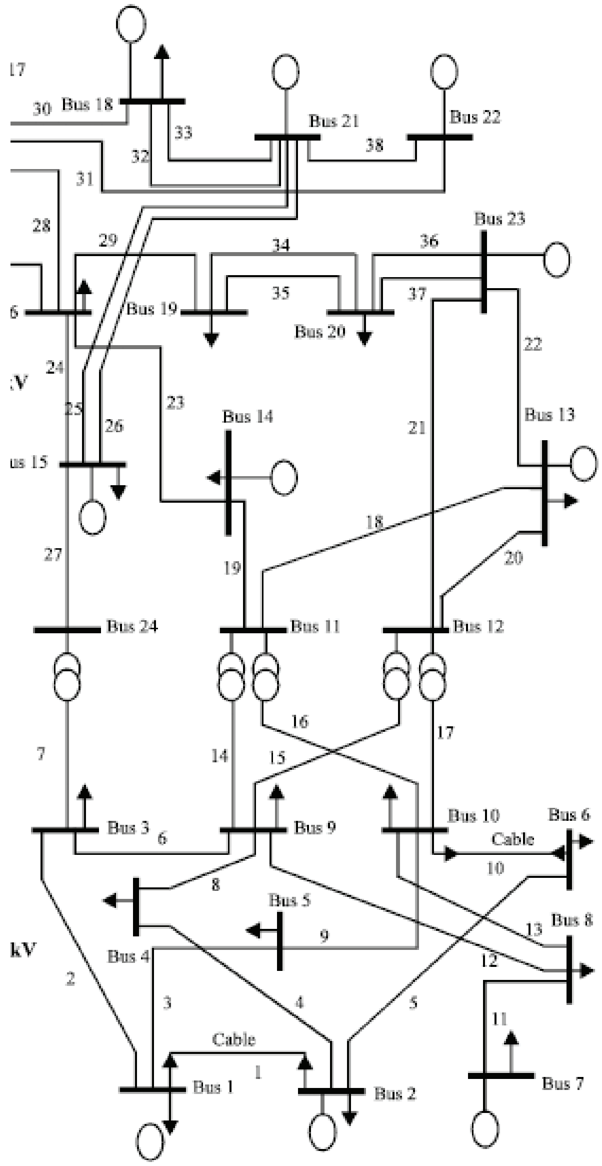

Figure 5. 24 bus, 11 generator test system.

The economic dispatch strategy has been applied when there is no haze and the weather is hot and the results were given in Table 4. The total operating cost, total emission and unit cost of generation are found to be $245055, 35890 kg and 0.0537 $/kWh respectively. Then assuming a day with haze, emission dispatch strategy has been performed and the results are presented in the same Table 4 for easy comparison. The total operating cost, total emission and unit cost of generation are found to be $272515, 22031 kg and 0.0597$/kWh respectively. The emission dispatch shall be applied in cold weather conditions also irrespective of the haze conditions.

From the results of Table 4, it is seen that the total operating cost and the NO_x emission by the economic and emission dispatch methods are considerably different. The average unit cost of generation by emission dispatch is higher by 11.21% compared to economic dispatch. However, the reduction in NO_x emission for the 24-hour period even with haze is found to be 13859 kg (62.61%) and the NO_x emission is well below the stipulated pollution standard. Hence by choosing the proper mode of operation, the electric utilities shall help to reduce the environmental burden on the Government.

5. Conclusions

This paper has addressed the on-going problem of haze in Malaysia. Apart from the peat and forest fires, the electricity generation through fossil-fuelled power stations also significantly contributes to the environmental issues in Malaysia. Though the problem of haze is not fully related to fossil-fuelled electricity generation, the electric utilities shall help the Malaysian Government to keep the environment healthy and under control. This paper explored two power dispatching strategies such that the power plant emissions during haze periods are minimum that helps the environmental control issues easy and effective. However, the full control of haze is beyond the scope of this paper. The efficacy of the proposed strategies has been demonstrated through a 24-bus, 11 fossil-fuelled generator test system at different load conditions during a 24-hour period and the strategies are found to be realistic and suitable for real-time applications.

6. References

1. Threats to Borneo forests - The Heart of Borneo under siege. Available from: http://wwf.panda.org/what_we_do/where_we_work/borneo_forests/borneo_deforestation/
2. Available from: www.wwf.org.au/our_work/saving_the_natural_world/forests/forests_work/heart_of_borneo/threats/
3. Available from: http://news.yahoo.com/malaysia-air-quality-unhealthy-haze-obscures-skies-050404181.html
4. Air pollution in Malaysia. Available from: https://en.wikipedia.org/wiki/Air_pollution_in_Malaysia
5. MCIL Multimedia Sdn Bhd. Malaysia air quality 'unhealthy' as haze obscures skies. 2014. Available from: http://www.mysinchew.com/node/100330
6. Available from: http://www.rappler.com/world/regions/asia-pacific/64687-malaysia-air-quality-unhealthy-haze
7. Available from: http://www.straitstimes.com/asia/se-asia/unhealthy-air-quality-recorded-in-9-areas-in-malaysia
8. Available from: http://phys.org/news/2014-07-malaysia-air-quality-unhealthy-haze.html
9. Available from: http://www.ndtv.com/world-news/malaysia-air-quality-unhealthy-as-haze-obscures-skies-595548
10. Available from: http://www.nationmultimedia.com/aec/Haze-makes-air-in-Malaysia-hit-unhealthy-level-30239749.html
11. The Star Online. Haze: Malaysia calls for immediate action by Indonesia. 2014. Available from: http://www.thestar.com.my/News/Nation/2014/06/25/Haze-Malaysia-Indonesia/
12. Merchant C. The Haze Situation in Malaysia: What is Malaysia doing about it? 2014. Available from: http://www.expatgomalaysia.com/2014/10/10/the-haze-situation-in-malaysia-what-is-malaysia-doing-about-it/
13. Rahim NA, Hasanuzzaman Md, Hasanuzzaman Md. Energy situation in Malaysia: Present and its future, Malaysia Country report. 2013. Available from: http://www.seeforum.net/countryreport/malaysia.html
14. Available from: http://www.unep.org/geo/geo4/report/01_Environment_for_Development.pdf
15. Ekholm T et al. Effort sharing in ambitious, global climate change mitigation scenarios. Energy Policy. 2010; 38(4):1797–810.
16. Rahman et al. Energy for sustainable development in Malaysia: Energy policy and alternative energy. Energy Policy. 2006; 34(15):2388–97. Available from: http://www.seeforum.net/countryreport/malaysia.html
17. Afroz R, Mohd Nasir H, AkmaNI. Review of air pollution and health impacts in Malaysia. Environmental Research. 2003 Jun; 92(2):71–7.
18. Finlay et al. Health Impacts of Wildfires, Version 1. PLoS Curr. 2012 Nov 2; 4:e4f959951cce2c.
19. Hamat M et al. Public perception of air quality in Seberang Jaya, Malaysia. 5th International Conference on Science and Technology Applications in Industry and Education (ICSTIE 2014); 2014.
20. Palanichamy C, Nasir M, Veeramani S. Wind cannot be directed but Sails can be adjusted for Malaysian renewable energy progress. IOP Publishing - IOP Conf. Series: Materials Science and Engineering. 2015; 78:012028. doi:10.1088/1757-899X/78/1/012028. Available from: http://iopscience.iop.org/1757-899X/78/1/012028/pdf/1757-899X_78_1_012028.pdf
21. Bozkurt C, Akan Y. Economic Growth, CO_2 Emissions and Energy Consumption: The Turkish case. International Journal of Energy Economics and Policy. 2014; 4(3):484–94. Available from: file:///C:/Users/HP/Downloads/878-2699-1-PB.pdf, http://www.econjournals.com/
22. Available from: http://www.bredl.org/air/ncnox070500.htm

23. Available from: http://www.bredl.org/air/comments_PAozonetrans.htm
24. Palanichamy C, et al. Day–Night Weather Based Economic Power Dispatch. IEEE Transactions on Power Systems. 2002 May; 17(2):469–75. Available from: engsci.curtin.edu.my/electrical-and-computer.../a-p-dr-palanichamy
25. Palanichamy C, et al. Renewable energy investment opportunities in Mauritius—an investor's perspective.Renewable energy.2004; 29(5):703–16.
26. Palanichamy C, et al. Simple Algorithm for Economic Power Dispatch. Electric Power Systems Research. 1991; 21:147–53. Available from: http://engsci.curtin.edu.my/electrical-and-computer-engineering/staff/a-p-dr-palanichamy
27. Palanichamy C, et al. Analytical Solution for Combined Economic and Emissions Dispatch. Electric Power Systems Research. 2008; 78(7):1129–37. Available from: http://engsci.curtin.edu.my/electrical-and-computer-engineering/staff/a-p-dr-palanichamy