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On Optimization of Air Pollution and Electricity Production of Thermal Power Plants of Delhi using Goal Programming

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Abstract
Air pollution is a serious problem in today's rapidly developing world. Burning of fossil fuels has been the source of air pollution since ages. Coal is a major source of electricity production in India. About 56% of total electricity produced is from Thermal Power Plants (TPPs). In Delhi we have taken 5 TPPs producing about 2800 MW of energy catering to the desire of the nation for this study.Sulphur dioxide (SO_2), Oxides of Nitrogen (NO_x), Total Suspended particulate matter (TSPM) are the main pollutants emitted from TPPs. Due to burning of coal in huge amount in TPPs a large amount of pollutants is emitted in the air. But on the contrary we cannot stop this process completely as coal is efficient as well as easily available resource in this day and other non conventional sources like solar, tidal, wind power etc. are in their infancy in the country. In this paper we are trying to optimize pollutants of air emitted from TPPs and electricity production in aggregate from 5 TPPs working in Delhi using a Goal Programming (GP) model.
Keywords: Thermal Power Plant (TPP), SO_2, NO_x, TSPM, Optimization, Goal Programming (GP)

1. Introduction

Air pollution is a serious problem which has taken a serious shape with rapid industrialization. Generation of pollutants of air from burning of fossil fuels comprise a major part of the total air pollution. Coal, petrol, diesel, kerosene, etc. are main fuels which are extensively used in today's developing world. Fossil fuels occupy an important place among all sources of energy due to high calorific value and extensive and easy use. Apart of CO_2 the other harmful gases and pollutants released in air are Sulphur dioxde (SO_2), oxides of Nitrogen (NO_x) and Total Suspended particulate matter (TSPM).

Today a major part of total electricity produced is by burning fossil fuels in thermal power plants (TPPs) which although is convenient and cheap than other non conventional sources but on the contrary is equally harmful for the quality of ambient air. In India coal and other fossil fuels are major source of energy in different sectors like domestic, industrial, power production, etc. A huge amount of coal and other fossil fuels are burnt in TPPs in the process of production of electricity which is causing huge amount of air pollution. These major qualitative pollutants are causing huge damage to the environment and health of people.

There are a number of ways to control the quantity of these pollutants in ambient air like use of precipitators, reduce consumption of fossil fuels, treatment of gaseous effluents from industries before allowing them to go into air, etc. It is also estimated that increase in the use of non conventional sources like solar, tidal, wind energy etc. will definitely reduce this air pollution but in our country it is still in its infancy. Its administration is a lengthy process in our country and it is costly and not in easy access to the masses. Thus it becomes necessary to find out some means that may help in reduction of this kind of air pollution without actually effecting the production of electricity in the country.

2. Goal Programming

Goal programming (GP) is an important analytical approach devised to solve many real world problems, where targets have been assigned to all attributes and where decision makers (DM) are interested in minimizing the non achievement the corresponding goal. [Chin Nung Laio]. GP was first introduced by Charnes and Cooper (1961) and further developed by Lee (1972), Ignizio (1976), Tamiz et.al. (1998), etc.

Generally GP minimizes undesired deviations from target values. In this method the DM can consider many goals simultaneously during the search for compromise solution and is supported by Mathematical Programming Optimization Potential (Martel and Aouni, 1998). GP is a powerful tool which draws upon the highly developed and tested techniques of LP but provides a simultaneous solution to a complex system of competing objectives (Banashri Sinha and N Sen, 2011).

GP is a mathematical programming technique which treats the constraints of linear programming problem as their goal. Linear programming as a goal in the objective function, optimization means coming as close as possible to achieve these goals in order of priority by the decision maker. Goal programming is applicable to single or multiple goal although it is a greater usefulness occurs when the multiple goal are conflicting and cannot satisfied simultaneously.

Goal Programming is a fancy name for a very simple idea: the line between objectives and constraints is not completely solid. In particular, when there are a number of objectives, it is normally a good idea to treat some or all of them as constraints instead of objectives.

The only difference between linear programming and goal programming is that goal programming is multi dimensional in nature. Goal programming is the achieving the multiple goal simultaneously. In the linear programming the max/min function is set for only one quantity to control on its optimum value. Goal programming carries many goals related to each other and they have to be achieved. In this the minimum and maximum deviation are also set for the achieving the goal. Goals are arranged in an order according to priority which helps to minimize the deviations between the achievement and aspiration levels.

3. Air Pollution from TPPs

Today in India a large amount of electricity is produced from thermal power plants. Here coal and other fossil fuels are burnt extensively to boil water and thus produce electricity. SO_2, NO_x, are major qualitative pollutants produced as a byproduct by burning of coal and other fossil fuels. TSPM is a quantitative pollutant but its quantity is very high in the space of TPPs which makes it extremely harmful.

Sulphur dioxide (SO_2): It is a qualitative pollutant that is its presence in any quantity is injurious. Its major sources are combustion of coal and oil, rubber vulcanization plants and chemical industries.

Oxides of Nitrogen (NO_X): These are quantitative pollutants and are produced due to burning of coal, gas, oil, gasoline, etc. when combustion temperatures are very high, from chemical industries.

Total Suspended Particulate Matter (TSPM): These in ambient air is a complx multi phase system consisting of particle sizes ranging from less than 0.01 µm to more than 100 µm. (wan kun et. Al. 2006; Devi, dahiya, Gadgil, singh, kumar, 2007). It is a quantitative pollutant which is produced from soil, plants and different human activities in different forms.

A major reason not to stop TPPs and rely only on non conventional sources is that the non conventional sources are not efficient enough to satisfy the demands of rapidly developing and highly populous nation like ours. So, it becomes very necessary to find a sustainable path which may not reduce electricity production but must reduce the increasing pollutants.

In this paper we are trying to propose a GP model which may be helpful to reduce the rising quantity of pollutants from TPPs as well as help min optimizing energy production and profit goals.

4. Case Study

There are a number of TPPs in Delhi in working condition and are catering to the electricity desires of the nation. These are producing electricity by consumption of fossil fuels like coal, petroleum products and natural gas. Coal comprises the major part of the total fossil fuels burnt. A huge amount of pollutants is being produced by burning of these fossil fuels. In this paper we are considering 5 TPPs running in delhi viz. Rajghat, Indraprasth gas turbine (IGT), Indraprasth (IP), Badarpur and Pragati power station. These TPPs are producing electricity in different amounts and consuming various fossil fuels in different amount, thus producing pollutants in different amounts.

Name of TPP	Power Production in MW
Rajghat	135
IGT	1500
IP	135
Badarpur	705
Pragati	350
TOTAL	2825

The amount of SO_2 produced by different TPPs are as

Name of TPP	Amount of SO_2 in mg/ m^3
Rajghat	189.73
IGT	0.26
IP	116.90
Badarpur	319.60
Pragati	0.0037
TOTAL	626.4937

The amount of NO_x produced by different TPPs are as:

Name of TPP	Amount of NO_x in mg/ m^3
Rajghat	55.73
IGT	32.66
IP	74.65
Badarpur	1050.79
Pragati	61.69
TOTAL	1275.52

The amount of TSPM from various TPPs are as:

Name of TPP	Amount of TSPM in mg/ m^3
Rajghat	57.80
IGT	0.93
IP	37.58
Badarpur	616.64
Pragati	1.81
TOTAL	714.76

The CPCB standards related to these pollutants are as:

Area / Pollutant	Industrial Area	Residential Area	Sensitive Area
SO_2	80μg / m^3	60 μg / m^3	15 μg / m^3
NO_X	80 μg / m^3	60 μg / m^3	15 μg / m^3
TSPM	360 μg / m^3	140 μg / m^3	70 μg / m^3

PRIORITY STRUCTURE:

[P1]: To maximize the amount of electricity production from various TPPs.
[P2]: To minimize the amount of SO_2 emitting from various TPPs.
[P3]: To minimize the amount of NO_x emitting from various TPPs.
[P4] To minimize the amount of TSPM emitting from various TPPs.

5. Goal Programming Model

$$\max Z_1 = 135X_1 + 1500X_2 + 135X_3 + 705X_4 + 350X_5.$$

$$\min Z_2 = 189.73X_1 + 0.26X_2 + 116.90X_3 + 319.60X_4 + 0.0037X_5.$$

$$\min Z_3 = 55.73X_1 + 32.66X_2 + 74.65X_3 + 1050.79X_4 + 61.69X_5.$$

$$\min Z_4 = 57.80X_1 + 0.93X_2 + 37.58X_3 + 616.64X_4 + 1.81X_5.$$

subject to:

$$135X_1 + 1500X_2 + 135X_3 + 705X_4 + 350X_5 \geq 2825;$$

$$189.73X_1 + 0.26X_2 + 116.90X_3 + 319.60X_4 + 0.0037X_5 \leq 626.4937;$$

$$55.73X_1 + 32.66X_2 + 74.65X_3 + 1050.79X_4 + 61.69X_5 \leq 1275.52;$$

$$57.80X_1 + 0.93X_2 + 37.58X_3 + 616.64X_4 + 1.81X_5 \leq 714.76;$$

RESULT

The model was solved using Lindo and following results were obtained:

HEAD	ORIGINAL	OPTIMIZED
Amount of electricity	2825	3067.7
Amount of SO_2	626.4937	625.9737
Amount of NO_x	1275.52	1210.2
Amount of TSPM	714.76	712.9

6. Conclusion

Here after analysis of the table we can easily conclude that we have successfully achieved our goal. The amount of electricity has increased to 3067.7 MW which shows 8.59% increase in the amount of electricity production. The amount of SO_2 has been reduced by 0.52mg/m^3 which is although a very small quantity but shows reduction.

The amount of NO_x has been reduced by 65.32 mg/ m^3 which is 5.12% of the previous and can be considered a significant change. The amount of TSPM has also shown a very small change but in the desired direction. It has been reduced by 1.86mg/ m^3 which is 0.26% decrease.

Although air is a very dynamic element of nature and this makes its analysis very difficult but here we have tried to achieve some amount of optimization on this element without effecting our electricity production. More study can be easily carried out to improve the short comings in this work and more amount of success can be achieved in this field of study.

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