Diesel Power Generation on Rural Areas in Brazil and Effective Opportunities for Renewable Sources

Luiz Artur Pecorelli Peres

Luiz Augusto Horta Nogueira

Germano Lambert Torres

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LUIZ ARTUR PECORELLI PERES
Rio de Janeiro State University – UERJ
Rua S. Francisco Xavier, nº 524, Bloco A, Sala 5029, Rio de Janeiro – RJ, 20559-900
BRAZIL

LUIZ AUGUSTO HORTA NOGUEIRA GERMANO LAMBERT-TORRES
Federal Engineering School at Itajubá – EFEI
Av. BPS, 1303, Itajubá, MG, 37500-000
BRAZIL

Abstract: - This work focuses the evaluation of air emissions from Diesel power generation, as a externality to be considered, in the decision process to choose other energetic supply alternative in rural remote areas.

Key-Words: - Energy, environment, power generation, country area, planing.

1 Introduction

The country population in Brazil is estimated in about 20 million inhabitants, living in remote areas, with no supply from the electric network power system. In those areas, the country communities' power supply frequently comes from conventional Diesel power generation. Also, it should be said that up to now, in Brazil, it was not possible to supply electric power for the whole population, once [1] 4 millions proprieties and homes do not have electric power supply. Considering that only 7% out of the 850 millions hectares of the country are used for agricultural purposes, it is possible to consider a wide range of options of renewable energy available in that area. Other alternatives have been considered, and there are favorable conditions for improvement of Brazilian country areas. As a contrast on this scenery, a small proportional population with regard to the Brazil's total territory area, is the concentration of 80% of the whole national population into urban areas, as a consequence of several unfavorable factors present in the last decades.

The technical literature shows a wide range of alternatives as to supply better quality energy at lower cost, that could be considered for those areas without electric energy supply, and also as substituting or as an additional complement to the existing resources [1, 2, 3]. Between the options there are the wind-motors, the light-cells, the sun-cells, and the small hydroelectric plants. Also it should be mentioned, as additional sources, the biomass, mainly the ethanol combustion cells, which production out of the sugar cane, is supported by a sound existing know-how in Brazil [4, 5].

The Diesel power generation is taken as a reference, in the technical and economic evaluations made for these enterprises. Nevertheless, it is an air pollution source, with effects not always taken into account consideration [6], because such items, generally, are labeled as *externalities*.

This work aims in the discussion of the Diesel power generation exhaust, pointing to its quantification. Despite the complexity regarding the corresponding costs, it is possible to set up these values, considering the international procedures [7], and the newly Kyoto conference's (CDM) Clean Development Mechanism. Some shown examples present the application of this calculus for the directions of the decision take process, with regard to choose and adequate the power supply projects for the country areas.

2 Methodological Aspects

In this paper the Diesel cycle exhaust emissions are classified in two major groups. The first one are the *very, i.e.,* inherent to the inside combustion that happen by the motor operation. The second group is the so called *indirect* [8], or the ones that comes from the fuel production process. While the very emissions happen by the time the motor is operating, the indirect emissions have already happen, previously, when the fuel used for the electric power generation was being prepared by the oil refinery. It should be noticed that the indirect emissions, as defined hereto, follow the useful life of the generator type considered, once its operation depends on the fuel supply. The methodology here in use looks for the evaluation of both allotments. With regard to the correspondents costs, they may be assigned based in international procedures, witch results in the guidance of the judgment of the economic alternatives of power supply, especially for the country areas where the Diesel power generation is a traditional choice.

Several pollution substances are wasted into the atmosphere by the Diesel cycle operated motors. The same happen by the time of production at the refinery. A short description of the characteristics of those substances is presented as follow [9]:

Carbon Monoxide (CO) – results from a partial carbon oxidation, that is regulated by the oxygen available by the time the combustion happen. The air and fuel rate set up may increase considerably the wasted CO quantity. This substance is known by its lethal capability when inhalated, because it combines with the blood hemoglobin, reducing the brain, hart and other organic tissues oxygenation. It makes dizziness, headache, sleep and reflex reductions, and may be lethal, depending on the environment conditions. The strongest action happens near the emission source.

Nitrogen Oxides (NO_x) – they are generated by combination of oxygen and nitrogen presents in the motor inlet air, at high temperature and pressure conditions. The Nox may generate irritation and constriction of the breathing system, reduce the organic resistance, helps to develop lungs emphysema, and in the same way the hydrocarbons does, they are quite active in the photochemical reactions that generates the "smog". The nitrogen dioxide reacts with water steam producing nitric acid, which may be present in the acid rain.

Sulfur oxides (SO_x) – they are a product of the fuel sulfur content oxidation. The sulfur oxides once inhaled by the upper breathing system may result in coughing suffocation, puffed breathing, rhinopharinxites, reduction of organic resistance to infections, chronic bronchitis, and lungs emphysema. The sulfur oxides action happen at local, regional and continental level. The sulfur dioxide reacting in the atmosphere results in particles of sulfuric acid and sulfites salts, and is present in the acid rain.

Particle Material (PM) – is made of small particles that come from the fuels and its additives poor burning. The Diesel motors show waste emission of carbon particles, which convey other substances like the hydrocarbons. The particles dust show an acute health treat once adhered into lungs tissues and may act at local , regional and continental level.

Carbon Dioxide (CO_2) – Because of its low toxicity it hasn't been taken as a pollutant. Nevertheless, in view of its important role in the mix of factors involved in the greenhouse effect and the implications at global level [10], its waste emissions have been object of special attention regarding monitoring, and subject to constant supervision by several national and international environment control agencies.

For a better understanding of the waste emission process, the Figure 1 bellow presents the structure to be used for the proposed evaluations.

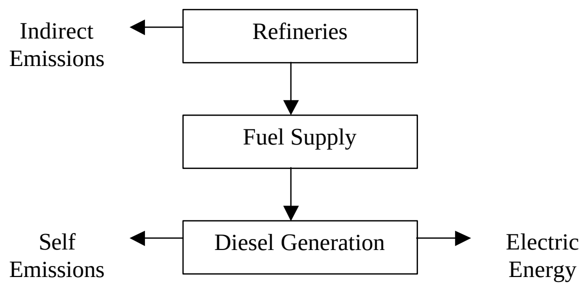

Figure 1 –Structure for Waste Emission Evaluation

In this way, the very waste emission as indicated in Figure 1 have a starting point in the previous knowledge of the expected energy generation for a known period, usually for one year period. The calculations of this type may be done considering the waste emission factors of the Diesel cycle, indicated in g/kWh.

Regarding the indirect emissions, originated by the oil refinery operations, they should be in relation with the fuel provided for the electric power supply considered. The approach is partially based in [11] the supposition that the emission factors of the gaseous pollutants from these stationary sources are available. The calculation of the refinery emissions may begin by the evaluation of the whole year emissions, as shown in equation (1).

$$[erefto(i)] = (volpetro).[emisref\,(i)].(mespet) \qquad (1)$$

Where:

$[erefto(i)]$ - refineries year pollutants emissions vector in kg, being $i = 1,2,...,5$, that corresponds respectively to : HC, CO, NO_x, SO_x,e.PM.

$volpetro$ - total volume of refined oil in m^3/year in the considered refineries.

$[emisref(i)]$ - oil refineries pollutants emissions factors vector in, kg / t

$mespet$ - oil specific mass in t / m^3 (typical value equal to 0,868 t / m^3)

Once having the Diesel oil required for the year supply of electric power, considered as an oil derivatives volume fraction, the produced fuel parcel included, results the indirect emissions wanted. The total very and indirect emissions of each pollutant substance are taken as impacts in the quality of the air because of the Diesel power generation, which money values may be added to the principal costs, the project operation and maintenance through its economic life. Generally, these last ones are evaluated by the required demand method [12], resulting into a comparative end value in US$/MWh. However, the pollution costs evaluation deserves some additional comments, as follow.

Alike [7], the neoclassic economy word used to designate the social environment is *externality;* witch means something outside the commercial transactions. These externality costs are forced into the society and the environment, and two concepts are used for their attribution: the cost of damage and the cost of control. The first try to express in money terms the "environment damage" for the society, while the second, the necessary "environment protection". Both the procedures are subject to criticism. One is the possible tariff increase, as a consequence of an option for a cleaner power alternative. Against this argument it is possible to say that the eventual tariff increase was a good sign regarding the price the society wants to pay for a wealthier life and a supported development. Comparing pollution unit costs given by public services authorities from U. S. A. results in important differences between them, which indicates a complexity regarding the set up of criteria and values, with respect to the *damage and control.* Table 1 shows an example of estimated pollution unit costs from the electric utilities companies located in the Los Angeles area in that country [7].

Regarding CO_2, as referred to, there is a close relationship between this gas and the greenhouse effect. In the 1997 Kyoto Conference this subject was discussed. As per [13], the well industrialized countries agreed upon to set up the emissions to the 1990 level, however postponed the problem to 2010 a 2015. To comply with the agreements, mechanisms were introduced, as the set up of emission quotes, that may be dealed on a common markets, in which the industrialized nations, which emissions are in excess regarding their quotes, could exchange bonus between them to provide a coverage for the excessive emissions. In the same Conference, also an instrument was set up labeled Clean Development Mechanism (CDM), which may be used by the same nations as a way for investments in projects in the nations in development stage which give support to, for example, the atmosphere carbon sequestration, to be accounted as a net emission reduction. This comprises a wide range of projects in which the substitution of Diesel power generation by other lower level emissions alternatives is considered. In this way, these exchanging operations provide the use of a "commodity" in the markets, called Carbon Emissions Reduction Certificate, with a money value, which may be dealed with the industrialized countries. As a consequence, it is expected that the CO2 suppressed emissions will be in a range of 10 to 100 US$/t.

Table 1: Pollution Unit Costs (USx10^3$/ t)

Pollutants	HC	NO_x	SO_x	PM
Cost (Control)	17,5	24,5	18,3	5,3
Cost (Damage)	6,9	14,7	8,5	4,6

3 Estimates and Analysis

For checking the influence of the very and indirect emissions in the Diesel power generation costs, some estimates were made with respect to a typical modulus of 500 kW, with a capacity factor of 0.5, consumption of 0.27 liters/kWh and typical accountable data. Considering the methodology from the previous item, the cost increase that is to be charged in the Diesel power generation, as a consequence of, for example only, of the HC emissions Table 2 bellow, indicates the additional complementary data

Table 2 – Additional Data

$fegerdi(HC)$ (1)	1.2 g/kWh
$erefto(HC)$ (2)	2.0 g/t
$volpetro$ (3)	80064566 m^3/ano
$volderi$ (4)	76061338 m^3/ano
$voldi$ (5)	28209600 m^3/ano

Notes :
(1) – value issued by CENPES (PETROBRAS Research Center)
(2) – value according with typical data from the World Bank mentioned in [14]
(3) –value according with [15], for 1997
(4) –same as previous, but referred to the year volume of oil derivatives produced.
(5) – same as previous but referred to the Diesel oil volume produced.

Calculating the very and the indirect emissions from the Diesel power generation discussed and the data referred to, applying the HC damage cost, as per Table 1, result the year values from Table 3, bellow.

Table 3 – HC Emissions and Related Costs

Description	Emissions (t)	Costs (USx10^3$)
Very	2.63	18.15
Indirect	1.07	7.38
Total	3.70	25.53

The value to be added to the Diesel power generation cost, because of HC emissions, amount to about US$ 11,7/MWh. If only the very emissions of CO2 were considered, taking the typical emission factors (IPCC Guidelines) and the same indicated procedures, the added value would be in the estimated range of 2.65 up to 26.5 US$/MWh.

Analyzing these results, it is possible to see that, including the emissions in the Diesel power generation costs, major increases may happen when compared to other power supply alternatives. Actually the price of a Diesel powered generator modulus typical in use in the country areas in Brazil, as the one considered in this paper, without the addition of these parcels, is the range of 128 up to 173 US$/MWh [3,5]. It is possible to notice that the influence of the considered emissions, result in impact in cost, increasing in more than 10% the usual prices of the Diesel power generation. It turns to be an important element for the analysis of alternatives. In addition, in the specific case of HC, conclusion was that the indirect emissions level from the consumption of Diesel fuel for the power generation, amounted to 30% of the total, which show how important is this aspect.

4 Conclusion

In this work an attempt was made toward an investigation of the impacts of the atmospheric emissions that come from the use of Diesel power generation in the country areas. For this purpose initially the considered emissions were described, included the indirect from the refineries operation for production of the required fuel for the generation of power supply. A typical modulus of 500 kW was taken as a reference. Examples of quantification of very and indirect emissions were made, indicating also, their influence in the end price of Diesel generation.

Specifically with regard to HC, discussed in this study, its indirect emissions reach signifficative values, i.e., about 29% of total, based in international procedures regarding the inclusion of damage cost.

Considering the expected cost of CO2 emissions limited only to the very ones, conclusion is that an increase higher than 10% may happen in the price of traditional Diesel power generation, which should be considered when analysis is made for electing the most convenient alternative to supply electric power.

As a consequence of Kyoto’s Conference, it is acceptable as a prognostic that considerable investments will be made available, yielding from the emissions reductions that the industrialized countries should make in the nations in stage of development. It is encouraging to realize that the results achieved show an effective opportunity potential for the alternatives of better environmental quality may compete in a more attractive way regarding the sustained development

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