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Gas turbine selection for hot windbox repowering on 200 MW fossil fuel power plant

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Abstract

This paper focuses on and discusses the concept of hot windbox repowering in an existing steam cycle power plant. Using commercial software, for that process based on the fraction of oxygen in exhaust gases, nine different models of gas turbines were tested in power plant model with a fossil fuel boiler. Then thermodynamic analysis of the power plant model before and after hot windbox repowering was conducted. This work seeks to select the best fit gas turbine for hot windbox repowering for a 200 MW fossil fuel power plant and to gain a deeper understanding of the effect of hot windbox repowering. To this end nine models of gas turbines with different net electrical power (from 50 to 125 MW) were tested and General Electric production GE Energy Oil&Gas MS9001E SC (GTW 2009) 123 MW gas turbine was selected as the most suitable for the model of the power plant and, after repowering, the total power of the power plant rose to 398 MW. Calculations were performed in 2 stages: 1) calculation and comparison of the thermodynamic parameters as well as carbon dioxide emissions of power plant model before and after repowering with nine different gas turbines, 2) calculation of thermodynamic parameters of the combined cycle power plant model before and after repowering in values 100%, 90%, 80%, 70%, 60% of fossil fuel boiler heat loads.

Keywords: fossil boiler; hot windbox repowering; combined cycle power plant; CO_2 emissions; GateCycle^{TM}

1. Introduction

Rising global consumption of electricity generated mainly by combustion of finite fossil fuel reserves, environmental pollution and greenhouse gas emissions are driving research into analyzing methods of enhancing power and efficiency of fossil fuel fired generation using these fuels and methods of cutting related undesirable emissions [1]. One promising solution is to be found in repowering.

1.1. Combined cycle power plants

Combined cycle plants combine two thermal cycles in one plant. When two cycles are combined, the efficiency that can be achieved is higher than that of a single cycle. Thermal cycles with the same or different working media can be combined; however, a combination of cycles with different working media is potentially more interesting, because their advantages can complement one another. The concept of a steam and gas turbine (GT) cooperating in a common system essentially arises directly from a review of the main advantages and disadvantages of steam and gas systems treated separately. The advantage of the steam turbine is its very low ratio of compression work to expansion work (due to water condensation which runs at a constant temperature, only slightly higher, 5...7°C, than ambient temperature). The disadvantage of this system is the process of heat supply, implemented through a metal wall, mechanically and thermal loaded. Substantial heat transfer surfaces are needed, forcing a reduction in the temperature used in the live steam to below about 570°C. The most efficient solution from the viewpoint of the efficiency of the system is the classical Gas Turbine Combined Cycle (GTCC) [2, 3].

1.2. Repowering of steam Power Plants

Repowering (RP) is broadly defined as an addition to or replacement of existing power plant equipment, retaining serviceable permitted components to improve generation economics, extend life, improve environmental performance, enhance operability and maintainability, and more effectively use an existing site [4]. Repowering makes it possible to continue using at least parts of older steam power plants that have become uneconomical. Moreover, repowering an existing combined cycle plant can boost the efficiency of an existing plant to a level relatively close to that of new combined-cycle plants [5].

Repowering existing power plants with gas turbines can be a competitive option to increase power plant capacity, improve efficiency and cut the environmental load and thereby

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achieve better compliance with ever stricter environmental regulations.

Repowering can lead to a better utilization of existing facilities and may save capital costs and costs for site development and licensing [6].

1.3. Repowering Methods

There are several alternatives to combine and integrate a gas turbine into an existing steam power plant. Repowering methods have two categories which are applicable in fossil fuel power plants.

The choice of repowering options is conditioned on (i) the size and technical condition of the existing plant (i.e. remnant life) and (ii) typical needs of the utility [6].

1. repowering of nonsolid fuel power plants
2. repowering of solid fuel power plants

These methods can be divided into two main categories:

1. complete repowering
2. partial repowering (PR)

and partial repowering (PR) includes the following methods:

1. hot windbox repowering (HWBR)
2. feed water heating repowering (FWHR)
3. supplementary boiler repowering (SBR) [7].

1.4. Hot windbox repowering (HWBR)

Hot windbox repowering (HWBR) can be applied using three methods [8].

1. In the first method, the exhaust gas from the gas turbine is fed into the original boiler, and the oxygen (O_2) content of the exhaust gas is generally enough to fire the fuel particles. However, due to the high temperature of the exhaust gas, the burner section has to be upgraded with high-temperature-resistant materials. This method is called direct hot windbox repowering (Fig. 1)
2. In the second method, the exhaust gas can be diluted by fresh air to lower the temperature of the combustion gases and increase the oxygen (O_2) content of the gas stream. This method is called fresh air dilution hot windbox repowering (Fig. 2).
3. In the third method, to lower the temperature of exhaust gases and avoid the cost of upgrading the burner section with high-temperature-resistant materials, the economizer is installed after the gas turbine to heat feed water. This method is called pre-cooling hot windbox repowering (Fig. 3).

The advantages of hot windbox repowering over simple combined-cycle installations:

- coal can be burned in the steam generator,
- part load efficiency is very good.

... and the disadvantages:

- lower efficiency,
- higher investment costs,
- more complex installations are more difficult to operate and maintain, especially with a coal-fired steam generator [9].

This paper looks at direct hot windbox repowering and fresh air dilution hot windbox repowering (methods 1 and 2 above).

2. Software used for simulation

Mathematical modeling is the perfect way to establish the characteristics of the object, as well as to evaluate the technical optimization. For this purpose commercial General Electric software GateCycle [10] is used for design and performance evaluation of thermal power plant systems at both design and off-design points. It has a library with more than 100 gas turbines along with saved correction curves. This allows mathematical modeling of the power plant (gas turbine) to determine performance for conditions other than ISO or for variable load without the need for detailed data from the vendor. In this paper the nine selected gas turbines are investigated using the GateCycle™ library. Despite using ready-made gas turbine models from the GateCycle library, the calculation results are not very close to the real parameters, because some details were not factored in (expander and combustion chamber cooling models). Nevertheless, this paper has been written for an academic case only and its purpose is to show the process of selecting the right gas turbine for repowering.

3. Description of the model before and after repowering (design point)

The choice of gas turbine size and features for repowering an existing steam power plant depends on the behavior of the steam plant when it is fed by both the existing fossil fuel source as well as by extra inlet thermal energies. This mandates a preliminary analysis that focuses on evaluating the performance and the new working conditions of the steam plant when the thermal power discharged by the Brayton cycle gas turbine is supplied to the steam generator [11].

The existing steam cycle power plant with 200 MW nominal electric power consists of a fossil fuel boiler with 0.55 GW heat load and 165 kg/s steam generating capacity and one 200 MW condensing steam turbine with 130 bar and 535°C live steam parameters. Then based on the fraction of oxygen in exhaust gases, nine different gas turbine models were selected from the GT Library for hot windbox repowering of the existing steam cycle power plant:

1. Centrax Gas Turbine Trent 60 DLE SC (GTW 2009) - A,
2. Alstom GT8C2 50Hz SC (GTW 2009) - B,
3. Hitachi PG6101(FA) SC (GTW 2009) - C,

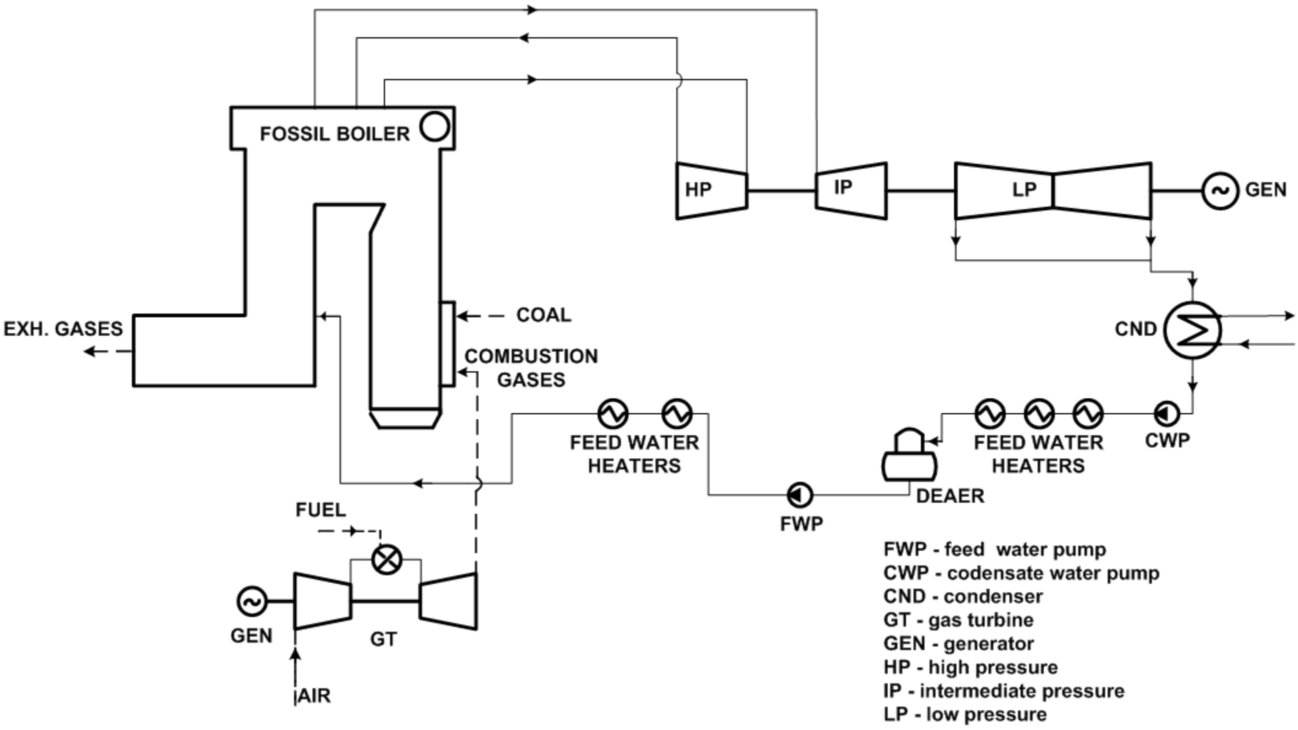

Figure 1: Direct hot windbox repowering

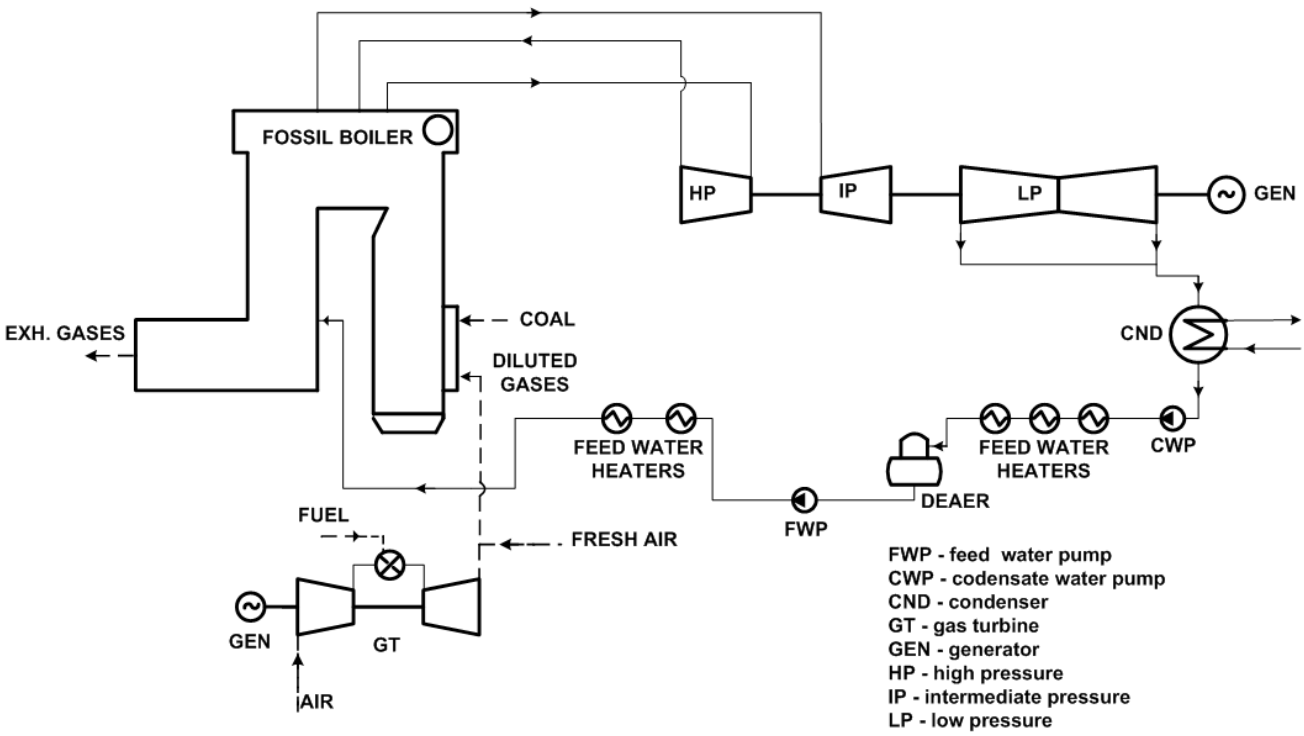

Figure 2: Fresh air dilution hot windbox repowering

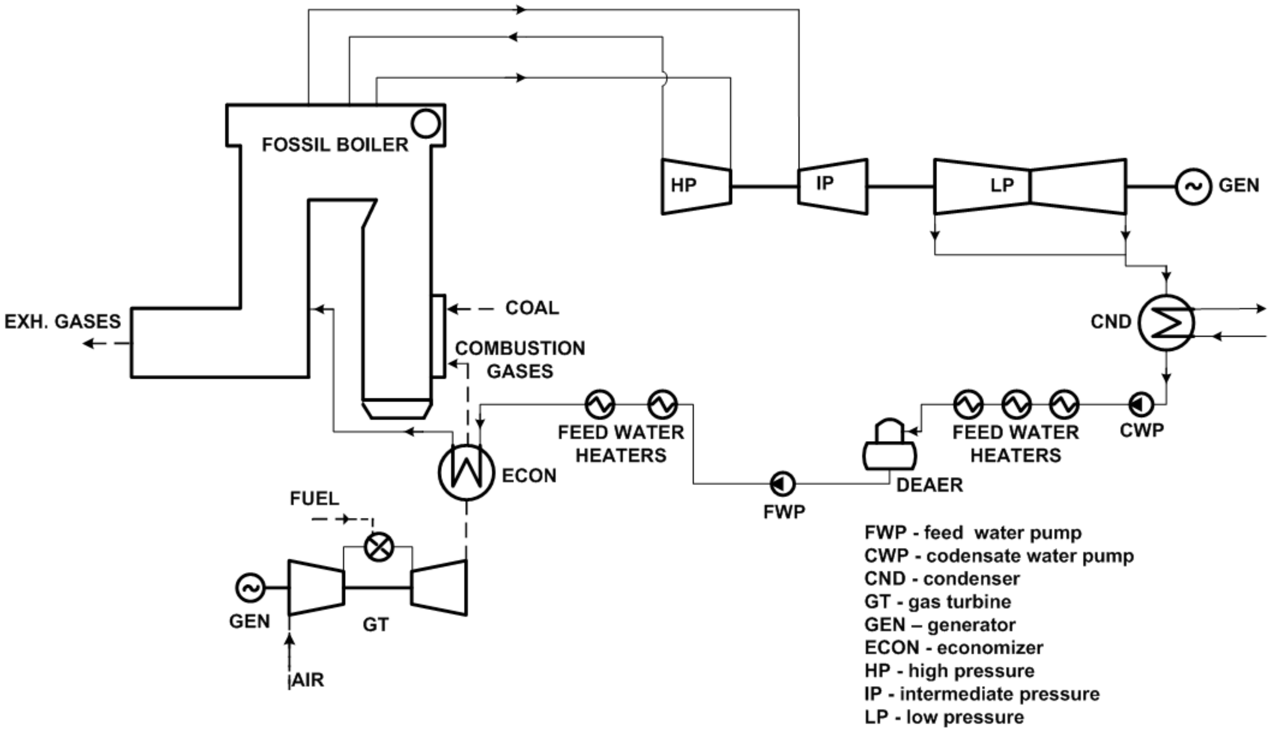

Figure 3: Pre-cooling hot windbox application

4. Ansaldo Energia V64.3A SC (GTW 2009) - D,
5. GE Energy Heavy Duty PG7121 (EA) SC (GTW 2009) - E,
6. Westinghouse 401 (97 GT World) - F,
7. Siemens V84.2 -98 Vendor Data - G,
8. Mitsubishi M501DA SC (GTW 2009) - H,
9. GE Energy Oil&Gas MS9001E SC (GTW 2009) - I.

(In Figs. 6–10 the selected gas turbines are marked A to I).

In direct hot windbox repowering the volume of oxygen in exhaust gases must correspond to oxygen consumption by the boiler. But that is not necessary in fresh air dilution hot windbox repowering, because the diluted fresh air replenishes the oxygen.

Ambient parameters for all models of gas turbines are the same, inlet pressure and temperature are 1.0132 bar and 15°C, respectively in 60% relative humidity. The fuel used here is 100% CH_4 with 50044 kJ/kg Lower Heating Value (LHV).

In Table 1 performance parameters of these GTs were shown, where: Nel. - Net electrical power, Eff.—Gas turbine efficiency, CPR—Compressor pressure ratio, COT—Combuster outlet temperature, $G_{ex.g.}$—Mass flow of exhaust gases after turbine, TAT—Temperature of exhaust gases after turbine, $O_{2\ m.\ fr.}$—Oxigen mole fraction in exhaust gases.

The boiler part was developed by modeling the fossil fuel boiler and heat exchangers separately. The equipment used was as follows: fossil fuel boiler, high pressure super heater (HPSH), intermediate pressure super heater (IPSH), economizer (ECON). Also installed were: a drum, splitters, pipes and temperature control mixers, which control steam temperature after HPSH and IPSH. The GT exhaust gas duct was connected to the boiler burners and supply oxygen for the burning process. In the steam cycle regime air is supplied to the boiler through two ducts: the primary air duct and secondary air duct. In the combined cycle regime the primary air duct is partially opened only when there is insufficient oxygen in the GT exhaust gas for the burning process in the boiler, otherwise those ducts are closed.

Table 1: Performance parameters for GTs

	Nel.	Eff.	CPR	COT	Gex.g.	TAT	O2m.fr.
GT	MW	%	-	°C	kg/s	°C	%
1	50.5	38.7	35.9	1321.6	150.4	447.3	14.4
2	55.1	33.4	17.5	1211.3	195.4	511.4	14.1
3	69.9	34.1	14.9	1322.3	205.2	593.7	12.9
4	75.5	35.5	17.0	1352.7	211.6	590.1	12.9
5	82.8	32.1	12.6	1190.2	296.7	541.5	13.9
6	89.6	37.8	19.0	1366.7	227.2	582.3	12.6
7	107.7	33.6	10.9	1176.1	357.7	550.6	13.7
8	113.5	34.8	13.9	1249.5	345.6	543.6	13.3
9	122.9	33.2	12.5	1210.9	413.9	547.2	13.7

Table 2 shows the design parameters of the fossil fuel boiler.

The steam turbine (ST) consists of three parts: high-pressure part (HPST), intermediate-pressure part (IPST)

Table 2: Design parameters of fossil boiler

Parameter	Unit	Value
Heat load	GJ/s	0.55
Live steam pressure	bar	130
Live steam temperature	°C	535
Steam generating capacity	kg/s	165.23
Secondary steam pressure	bar	29
Secondary steam temperature	°C	535
Total fuel flow	kg/s	21.66

and low-pressure part (LPST). The efficiency of particular parts was calculated using the Design Efficiency Method and the Isentropic Expansion Efficiency was 0.9 for all parts. The Design Pressure Method was used to calculate the inlet steam pressure for all parts of the steam turbine. For the high pressure part the inlet pressure was fixed at 130 bar, but for the next two parts it was calculated automatically. These all calculation methods are available in GateCycle software. The steam turbine part was equipped with a regeneration system consisting of five feed water heaters (FWH) and a deaerator (DA). Two of the five FWH were installed in the high pressure part of the feed water and three in the low pressure part.

Fig. 4 and Fig. 5 show model diagrams before repowering (BR) and after repowering (AR) respectively.

4. Results of calculations and analyses (off-design)

This section presents the calculation and analysis results relating to thermodynamic parameters of the model after hot windbox repowering in off-design mode. The off-design model is used mostly to simulate the behavior of a particular system in conditions different than designed, so as to access key parameters of that system in variable conditions.

1) Analyses of thermodynamic parameters and carbon dioxide (CO_2) emissions of the power plant with nine selected gas turbines after hot windbox repowering. Selection of the most suitable gas turbine for hot windbox repowering on 200 MW fossil fuel power plant.

2) Calculations of thermodynamic parameters of the power plant after repowering with selected GT at values 100%, 90%, 80%, 70%, 60% of fossil fuel boiler heat load to show the advantage of hot windbox repowering in part loads.

Re. 1.

In the first part thermodynamic parameters of the power plant model before and after repowering with nine selected gas turbines were analyzed and charts were made which describe the effect of direct hot windbox repowering and fresh air dilution hot windbox repowering. CO_2 emissions were calculated before and after repowering. Fig. 6, shows GT power ratios (%) as well as the rate of increase in steam turbine (ST) power (%) and increase in total net power of the combined cycle power plant (CCPP) (%) after repowering in the nine different GT models.

The GT power ratio can be defined as the power value of added GT for repowering to the power value of existed steam cycle power plant (SCPP) before repowering, as given in Eq. 1.

$$GT_{power\ ratio} = {}^{N_{GT}}/_{N_{SCPP^{BR}}} \times 100\% \tag{1}$$

The subscripts SCPP and BR symbolize the steam cycle power plant after and before repowering, respectively.

The rate of increase in ST power and the rate of increase in total net power of CCPP can be defined as the power values of ST and whole power plant before repowering to the corresponding values after repowering.

These charts show that, after repowering in nine different cases, the GT power ratio changes from 25.14% to 61.12% and that GE Energy Oil & Gas MS9001E SC (GTW 2009) gas turbine (123 MW) has the highest values of GT power ratio and rate of increase in ST and CCPP power. They are 61.12%, 36.57% and 97.69% accordingly.

Repowering (after adding a new gas turbine in the existing steam cycle) has the effect of increasing the heat energy provided to the steam turbine, because it increases the amount of heat energy provided to the steam boiler from the gas turbine side.

This effect can be harnassed in two ways:

-Keep the fuel mass flow to the steam boiler stable and modernize the steam boiler and steam turbine equipment. This means for example enlarging the heat exchange surface and changing the installation of steam turbine electrical generator. These actions result in increasing the power of the steam turbine and increasing in turn the power of the combined cycle too.

-Reducing the fuel provided to the steam boiler until the power of the steam turbine reaches the level it was at before repowering. This improves the fuel economy of the steam boiler and increases the efficiency of the combined cycle power plant.

In this paper the first version is presented. As mentioned earlier, the authors wanted to show the effect of repowering on the power of the steam turbine for academic purposes only.

Fig. 7 shows LHV heat rate (%), condensate mass flow rate (%) and net electrical efficiency (%) variations were shown. The charts show the highest variation or increase in net electrical efficiency for Mitsubishi M501DA SC (GTW 2009) with 113.5 MW and 6.74%. But, for example, when there is a minimal difference of only 0.07% when comparing that value with the variation or increase in net electrical efficiency for the GE Energy Oil & Gas MS9001E SC (GTW 2009) gas turbine (6.67%), which has the biggest capacity (123 MW).

Repowering efficiency and GT leverage were presented through charts in Fig. 8. Gas turbine leverage and repowering efficiency are very important parameters for the repowering analysis. Repowering efficiency can be defined as the

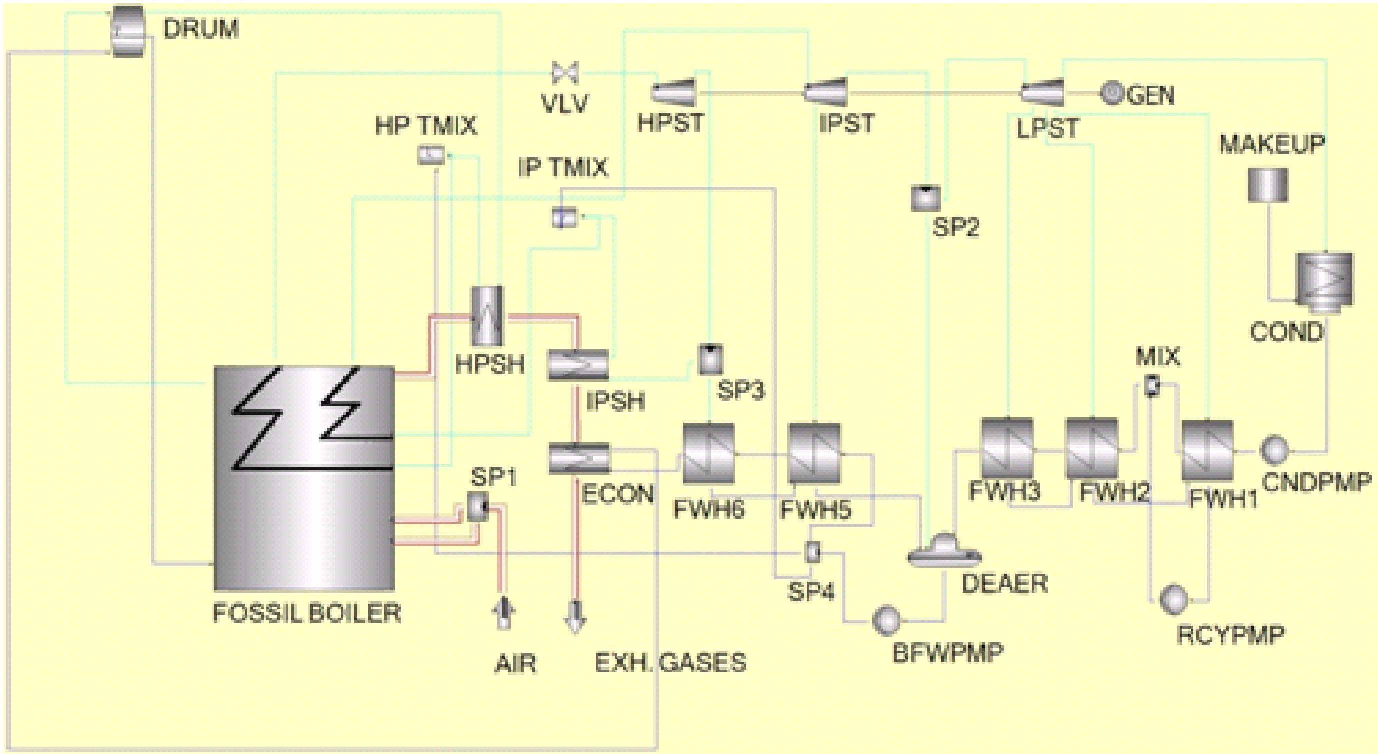

Figure 4: Model diagram of simulated power plant Before Repowering (BR): HPST—high pressure steam turbine, IPST—intermediate pressure steam turbine, LPST—low pressure steam turbine, COND—condenser, CNDPMP—condensate pump, RCYPMP—recirculation pump, MIX—mixer, FWH1,2,3,5,6—feed water heaters №1,2,3,5,6, DEAER—deaerator, BFWPMP—boiler feed water pump, SP1,2,3,4—splitter №1,2,3,4, ECON—economizer, HPSH—high pressure super heater, IPSH—intermediate pressure super heater, GEN—steam turbine generator, AIR—ambient air, EXH. GASES—exhaust gases

rate of increment in electricity generation to the increment in heat added to the cycle, given in Eq. 2.

$$\eta_{RP} = \frac{P_{AR} - P_{BR}}{Q_{in\,AR} - Q_{in\,BR}} \quad (2)$$

where P and Q_{in} are the electric power and heat energy added to the cycle. Gas turbine leverage can be defined as the rate of increment in electricity generation to the gas turbine installed capacity, given in Eq. 3.

$$\lambda_{GT} = \frac{\Delta P_{el}}{P_{el,GT}} = \frac{P_{AR} - P_{BR}}{P_{el,GT}} \quad (3)$$

The subscripts AR and BR denote after repowering and before repowering, respectively.

The charts in Fig. 8 show the highest repowering efficiency–of 0.62–for fresh air dilution hot windbox repowering with Centrax Gas Turbine Trent 60 DLE SC (GTW 2009) (50.59 MW) and the lowest repowering efficiency–of 0.53–for direct hot windbox repowering with GE Energy Oil & Gas MS9001E SC (GTW 2009) (123 MW). The variation of GT leverage is from 1.49 to 1.70.

The charts in Fig. 9 show the values of mass flow of GT exhaust gases and primary air to the boiler, kg/s, as well as the temperature of GT exhaust gases or GT exhaust gases and fresh air mixture (in the case of hot windbox repowering with fresh air dilution) directed to the burners of the boiler.

According to these charts the GT models can be divided in two groups:

Hot windbox repowering with fresh air dilution group:

- Centrax Gas Turbine Trent 60 DLE SC (GTW 2009),
- Alstom GT8C2 50Hz SC (GTW 2009),
- Hitachi PG6101(FA) SC (GTW 2009),
- Ansaldo Energia V64.3A SC (GTW 2009),
- Westinghouse 401 (97 GT World),

And direct hot windbox repowering:

- GE Energy Heavy Duty PG7121 (EA) SC (GTW 2009),
- Siemens V84.2 -98 Vendor Data,
- Mitsubishi M501DA SC (GTW 2009),
- GE Energy Oil&Gas MS9001E SC (GTW 2009).

In the first case GT exhaust gases were diluted by fresh air, which lowers the temperature of the combustion gases and increases the oxygen (O_2) content of the gas stream. In that case the burner section is not upgraded with high-temperature-resistant materials, but the disadvantage is that the spectrum of GT power is lower than in direct hot windbox repowering.

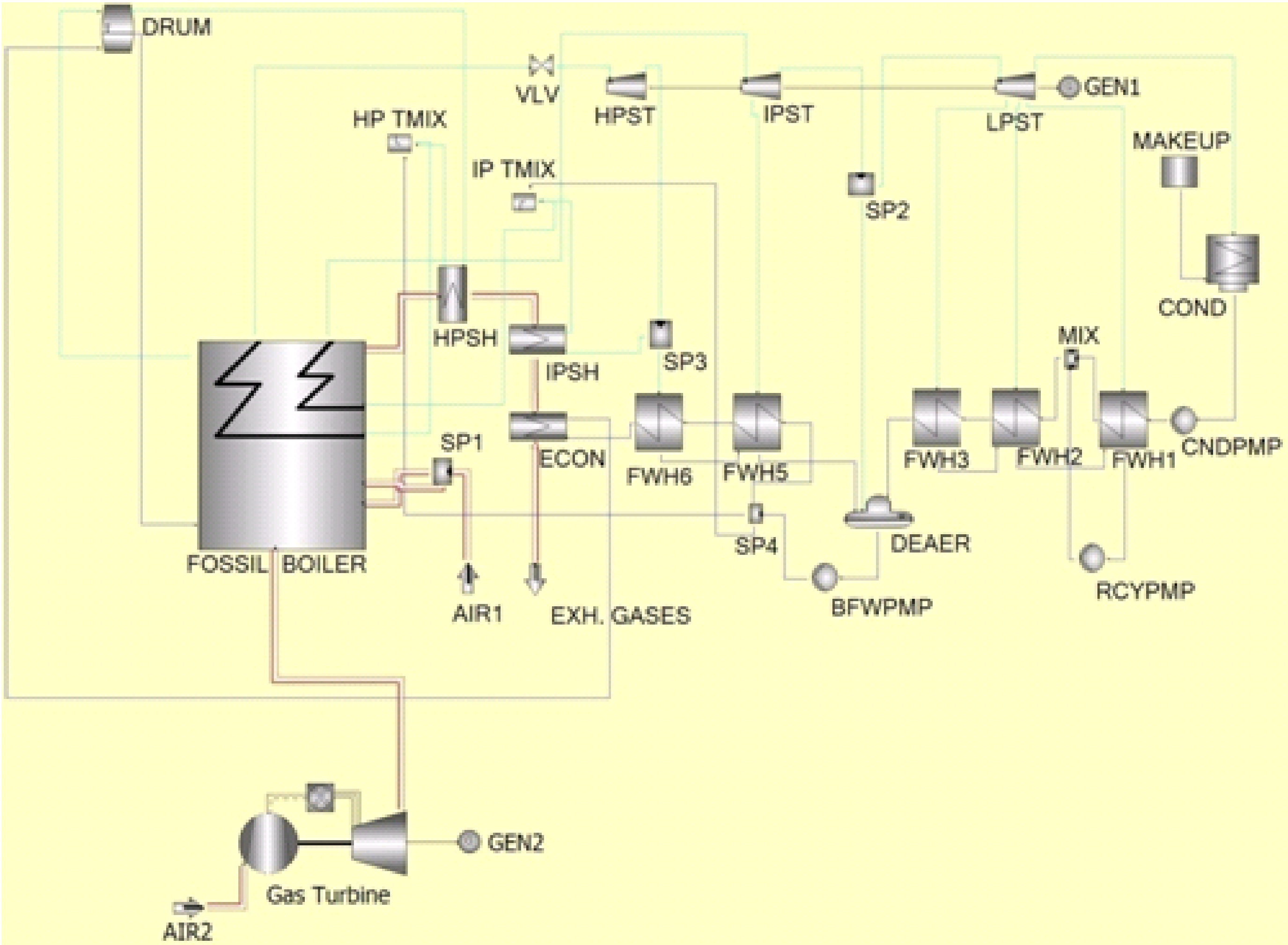

Figure 5: Model diagram of the simulated power plant After Repowering (AR): HPST—high pressure steam turbine, IPST—intermediate pressure steam turbine, LPST—low pressure steam turbine, COND—condenser, CNDPMP—condensate pump, RCYPMP—recirculation pump, MIX1,2,3—mixer №1,2,3, FWH1,2,3,5,6—feed water heaters №1,2,3,5,6, DEAER—deaerator, BFWPMP—boiler feed water pump, SP1,2,3,4—splitter №1,2,3,4, ECON—economizer, HPSH—high pressure super heater, IPSH—intermediate pressure super heater, HP TMIX—temperature control mixer in high pressure part, IP TMIX—temperature control mixer in intermediate pressure part, GEN1—steam turbine generator, GEN2—gas turbine generator, AIR—ambient air, EXH. GASES—exhaust gases

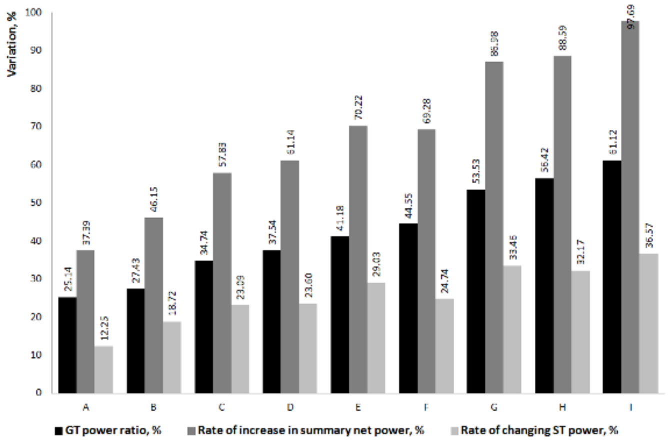

Figure 6: Variation of GT power ratio, rate of increase ST and CCPP power after repowering

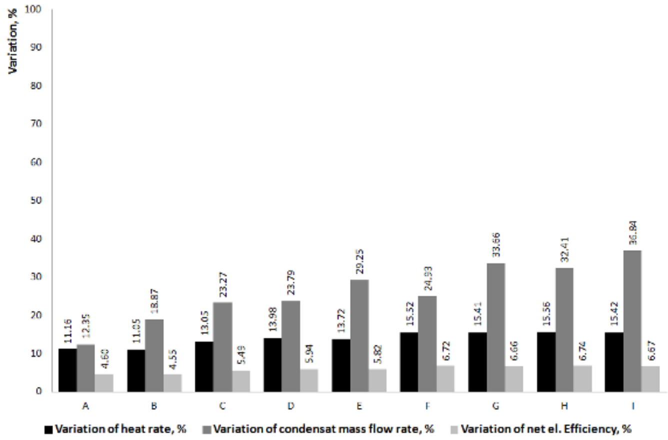

Figure 7: The variation of LHV heat rate, rate condensate mass flow rate and net electrical efficiency of CCPP after repowering in nine different cases

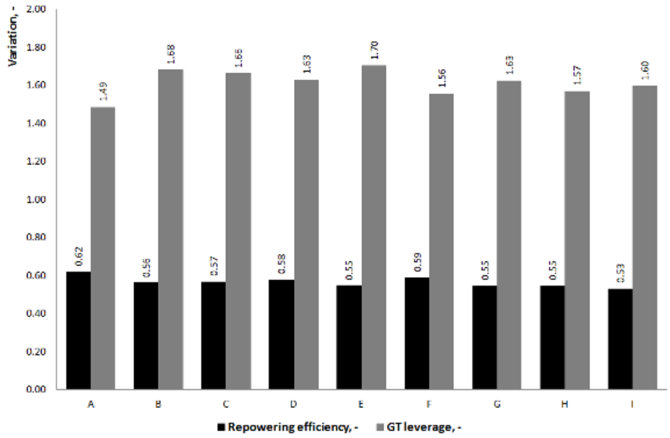

Figure 8: Repowering efficiency and GT leverage in nine different cases

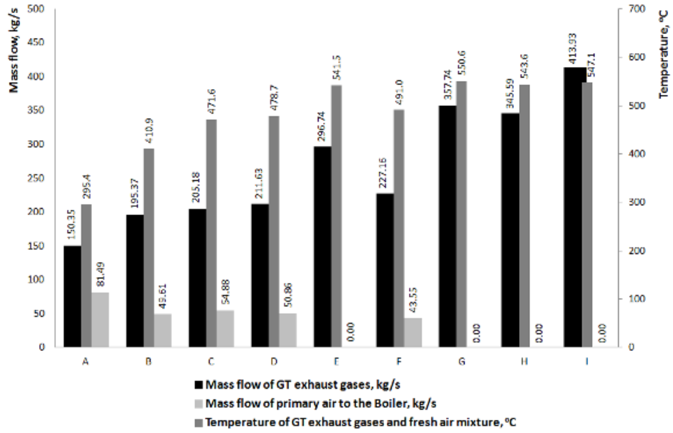

Figure 9: Variation of mass flow of GT exhaust gases and boiler primary air and the temperature of GT exhaust gases or GT exhaust gases and fresh air mixture (if it is needed)

In the second case the mass flow of primary air to the boiler is 0, because the oxygen (O_2) content of the GT exhaust gas is generally enough to fire the fuel particles. So in that case although the fresh air fans for the fossil fuel boiler were switched off and service power of power plant was decreased, due to the high temperature of the GT exhaust gases, the burner section has to be upgraded with high-temperature-resistant materials, thereby incurring additional capital costs.

The optimal GT will have a bigger value of GT exhaust gases mass flow and lower temperature exhaust gases.

The lowest temperature (295.4°C) of GT exhaust gases and fresh air mixture is available in the first case (Centrax Gas Turbine Trent 60 DLE SC (GTW 2009), but the values of GT exhaust gases mass flow (150.35°C) and electrical power (50.59 MW) are not bigger.

In the sixth case (Westinghouse 401 (97 GT World)) although the temperature of the mixture is more than 56°C lower than in the ninth case (GE Energy Oil&Gas MS9001E SC (GTW 2009), the rate of increase in total net power of CCPP is less than 28.41% (Fig. 6).

Fig. 10 shows an interesting fact that although the fraction of CO_2 was increased by variation from 13.10% to 40.12% after repowering, CO_2 emissions in boiler exhaust gases per megawatt power was decreased by variation from 17.77% to 29.20%. This finding may indicate that it is possible to increase the installed capacity while reducing pollutant emissions by hot windbox repowering of thermal power plants.

So, summing up the calculations, it is merits underlining once again that the main purpose of repowering is to increase the power of an existing power plant using at least parts of older steam power plants that have become uneconomical. And that is the reason for selecting the ninth case: GE Energy Oil & Gas MS9001E SC (GTW 2009)—123 MW. In sum: the highest value of GT power ratio—61.12%, the highest rate of increase in ST power value—36.57% (274.81 MW) and rate of increase in summary net power of CCPP—97.69% (397.8 MW).

In that case:

- variation of LHV heat rate was 15.42% (2.312 kJ/kW-s),
- variation of condensate mass flow rate was 36.84% (164 kg/s),

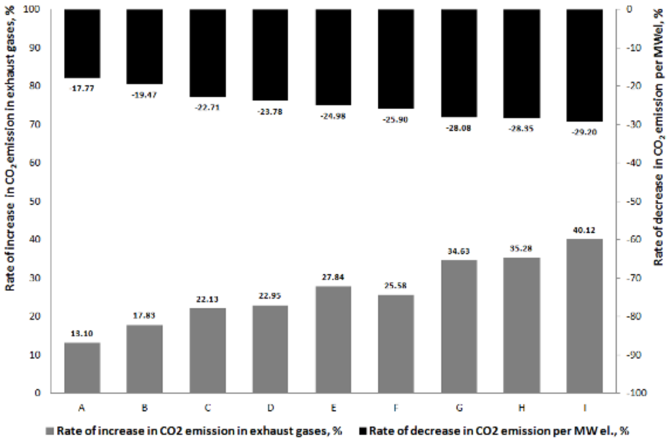

Figure 10: Rate of increase in CO2 emission in exhaust gases and decrease in CO2 emission per MW electrical power

- variation of net electrical efficiency was 6.67% (43.25%),
- repowering efficiency was 0.53,
- GT leverage was 1.60,
- mass flow of combustion gases (GT exhaust gases) was 413.93 kg/s (without fresh air dilution),
- temperature of combustion gases (GT exhaust gases) was 547.1°C,
- rate of increase in CO_2 emission in exhaust gases was 40.12% (45.46 kg/s),
- rate of decrease in CO_2 emission in exhaust gases in per MW electrical power was 0.29% (0.1142 kg/s per MW).

Re. 2.

In the second part of the analyses, after selecting the most suitable GT for hot windbox repowering, the fossil fuel boiler heat load was decreased from 100% to 60% to establish the advantage of directed hot windbox repowering in part loads. Decreasing the heat load of boiler to below 60%, the gas turbine (GT) load has to be changed. This paper discussed only the effect of changing boiler heat load without changing GT load. To change the boiler heat load the required value was input manually in the “Boiler Load Method/Desired LHV Heat Load” section.

Fig. 11 showed the electrical power values of steam cycle power plant (SCPP) before repowering and also showed CCPP total electrical power and ST power values after repowering, depending on live steam mass flow in part loads of the fossil fuel boiler.

According to the curves in Fig. 11 the variation of CCPP power was from 397.8 MW to 306.6 MW and within these limits live steam mass flow variation was from 225.9 kg/s to 148.5 kg/s.

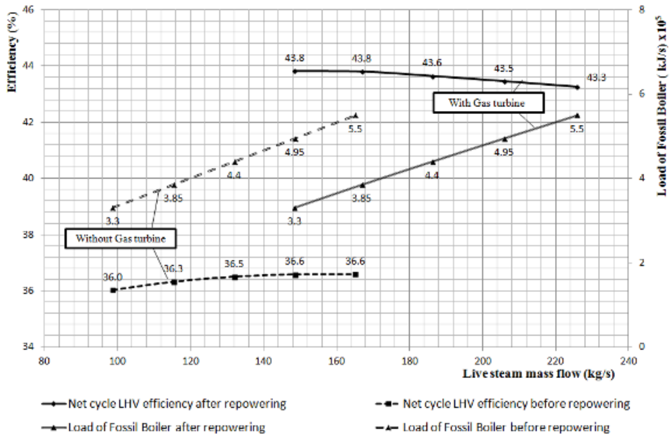

Figure 11: Variation of Electric Power in part loads

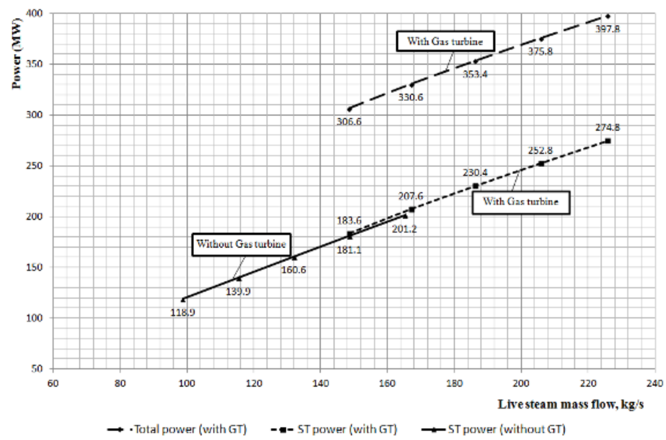

Figure 12: Net cycle LHV efficiency variation depending live steam mass flow in part heat loads of boiler

Fig. 12 12) shows net cycle LHV efficiency (%) variation as well as fossil boiler heat load variation ((kJ/s)x10^5) in part loads before and after repowering. The highest efficiency–43.8%–was for 60% boiler heat load. In that case boiler heat load was 0.33 GW and live steam mass flow 148.54 kg/s. This shows the advantage of Combined-Cycle power plants with direct hot windbox repowering, which enjoy high efficiency in part loads. It means that during part-load regimes the heat of exhaust gases coming from GT can compensate the heat balance when the mass flow of fuel at the inlet of boiler burner is decreased.

The opposite of this effect can also be seen. Without a gas turbine, steam cycle power plant efficiency fell with decreasing boiler heat load. For example in 60% boiler heat load efficiency is decreased to 36.0%, when live steam mass flow was 98.77kg/s.

5. Conclusions

This paper presented analyses of the effect of hot windbox repowering of a fossil fuel power plant with 200 MW and led to selection of the more suitable gas turbine for that power plant.

Calculations were performed in 2 parts:

1. Calculation and comparison of thermodynamic parameters as well as CO_2 emissions of the power plant model before and after repowering in nine different cases (with nine different GT models).
2. 2) Calculation of thermodynamic parameters of CCPP after repowering, i.e., after adding a GE Energy Oil & Gas MS9001E SC gas turbine with 123 MW in values 100%, 90%, 80%, 70% and 60% of fossil fuel boiler heat loads.

Based on the fraction of oxygen in the exhaust gases, nine different gas turbine models were selected for hot windbox repowering.

For hot windbox repowering with fresh air dilution:

- Centrax Gas Turbine Trent 60 DLE SC (GTW 2009),
- Alstom GT8C2 50Hz SC (GTW 2009),
- Hitachi PG6101(FA) SC (GTW 2009),
- Ansaldo Energia V64.3A SC (GTW 2009),
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And for direct hot windbox repowering:

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- Mitsubishi M501DA SC (GTW 2009),
- GE Energy Oil&Gas MS9001E SC (GTW 2009).

Then, with the main purpose of repowering being to increase the power of an existing power plant using at least parts of older steam power plants that have become uneconomical, the GE Energy Oil & Gas MS9001E SC (GTW 2009) gas turbine with 123 MW selected.

In that case the highest value of GT power ratio was 61.12%, the highest rate of increase in ST power value was 36.57% (274.81 MW) and the rate of increase in total net power of CCPP was 97.69% (397.8 MW). Net electrical efficiency of CCPP was 43.25% (6.67 % higher than before repowering).

CO_2 emission in exhaust gases increased by 40.12% (45.46 kg/s), but fell by 0.29% per MW electrical power (0.1142 kg/s per MW) compared with results before repowering.

In part-loads net cycle LHV efficiency of the combined cycle power plant increased from 43.3% to 43.8%, boiler heat load decreased from 0.55 GW to 0.33 GW and steam cycle LHV efficiency decreased from 36.6% to 36.0%.

References

[1] K. Mehrabani, S. Faniyazdi, A. Mehrpanahi, S. Naserabad, Optimization of exergy in repowering steam power plant by feed water heating using genetic algorithm, Indian Journal of Scientific Research 1 (2) (2014) 183–198.

[2] M. Wołowicz, J. Milewski, K. Badyda, Feedwater repowering of 800 mw supercritical steam power plant, Journal of Power Technologies 92 (2) (2012) 127–134.

[3] M. Wołowicz, K. Badyda, Gas turbine selection for feedwater repowering, Journal of Power Technologies 95 (4) (2015) 302–308.

[4] H. Stoll, R. Smith, L. Tomlinson, Performance and economic considerations of repowering steam power plants, GE Power System GER-3644D.

[5] R. Kehlhofer, B. Rukes, F. Hannemann, F. Stirnimann, Combined-cycle gas and steam turbine power plants, 3rd edition.tulsa, oklahoma.

[6] P. Ploumen, J. Veenema, Dutch experience with hot windbox repowering, ASME-96-GT-250.

[7] R. Ahmadi, Gholam, D. Toghraie, Parallel feed water heating repowering of a 200 mw steam power plant., Journal of Power Technologies 95 (4) (2015) 288–301.

[8] Z. Yilmazoglu, Mustafa, A. Durmaz, Hot windbox repowering of coal-fired thermal power plants, Turkish Journal of Engineering & Environmental Sciences (37) (2013) 33–41.

[9] R. Kehlhofer, Combined-cycle gas and steam turbine power plants. tulsa, oklahoma.

[10] https://getotalplant.com/GateCycle/docs/GateCycle/index.html.

[11] G. Negri Di Montenegro, M. Gambini, A. Peretto, Intercooled and brayton cycle gas turbines for steam power plant hot windbox repowering, ASME-98-GT-198.