STEAM POWER PLANTS REPOWERING WITH GAS TURBINE - REVIEW

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ABSTRACT

Repowering with gas turbine means integration of new gas turbine in existing power plant. Such integration yield higher efficiencies lower operating and maintenance costs and reduction in pollution emission. This paper summarizes the results of a feasibility study that inquired the possibilities of such integration in Israel Electric Corporation - IEC's existing steam power plants (oil fired).

INTRODUCTION

The IEC's oil fired power plants are relatively old, some of them are operating since 1952. Those units are used as cycling units that provides the additional capacity "above" the coal fired units that operates as "base load" units. The expected new environmental regulations, in addition to the relatively high electricity production cost in those units, will remarkably decrease the compatibility of those units in the future.

The electricity production in Israel is based mainly on coal and fuel oil (oil No.6). The option of importing natural gas for electricity production may improve the operating characteristics of the existing generating units. Therefor, to meet the requirements of reduced emission and reduced production costs, IEC studied the different well proven options of gas turbine -GT integration in those units.

DESCRIPTION

Hot Wind Box repowering

The HWB configuration utilizes the gas turbine exhaust gas for the primary fuel combustion (due to the large oxygen content - 15% O_2 dry) in the boiler – see figure 1. The fact that the exhaust gas thermal energy is utilized, the boiler air preheating system is not required any more. By this integration, it is possible to increase the unit gross efficiency up to 48% and the total unit output up to 20%, depending on turbine type and size.

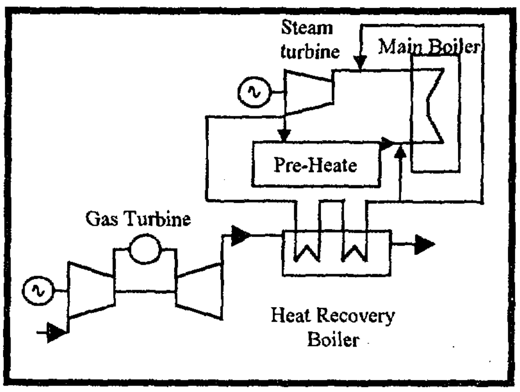

Figure 1: HWB repowering scheme.

Feed Water Heating Repowering

The gas turbine exhaust gases used to preheat the condensate water and the boiler feed water in heat recovery steam generator (HRSG). The cooled gases are discharged via separate stack to the atmosphere. The feed water preheating in the HRSG is eliminating the extracted bleed streams (all or part of them) from the steam turbine, and larger amount of steam is expanding in the turbine.

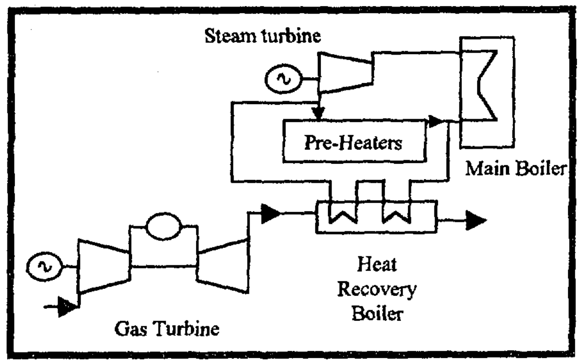

Figure 2: FWH Repowering scheme.

The improvement in gross efficiency in such scheme is relatively small, in some cases the efficiency could be raised up to 44%, depending on the gas turbine size, type and the physical condition of the repowered unit.

Parallel Repowering

Similar to the FWH scheme, the exhaust gas from the GT is used to preheat the condensate and feed water. Additional superheated steam is produced in the HRSG and provided to the unit steam cycle. By this arrangement, part of the steam is produced in high thermal efficiency and the original boiler provides the other part in lower efficiency. The efficiencies that can be achieved strongly depend on the ratio between the gas turbine output and the steam turbine output. The reduction in the emission is also depending on this ratio.

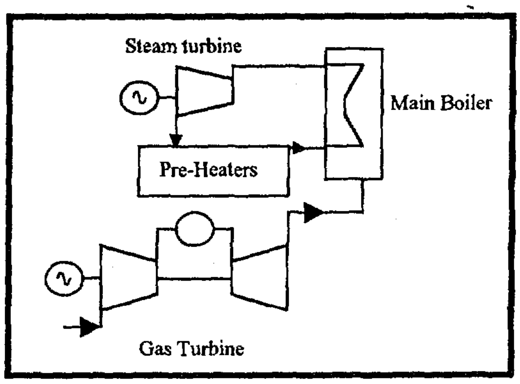

Figure 3: PR repowering scheme.

Full Repowering

In this option, the original boiler is removed, and all the required steam to the steam turbine produced in the HRSG by recovering the GT exhaust gas. This configuration provides the highest efficiency and the highest emission reduction. On the other hand, the repowered unit will be able to utilize only noble fuel (gas or distillate fuel).

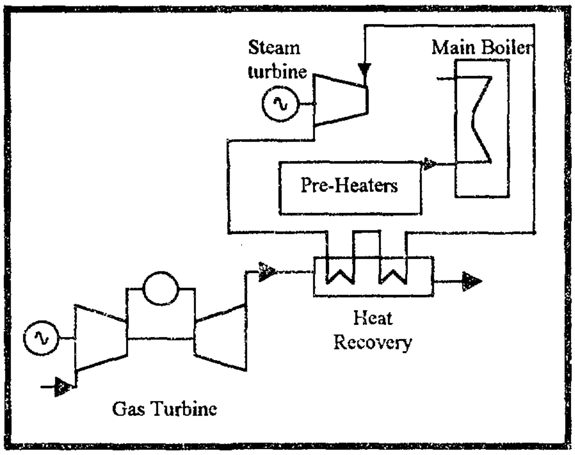

Figure 4: FR scheme.

In this scheme, very high efficiencies can be reached (50-55%) depending on degree of matching between the installed GT and the existing steam turbine.

New Combined Cycle

This option was analyzed as a reference case. The existing unit is demolished, and new modern combined cycle is built, without utilizing the existing equipment. The scheme is similar to FR option.

TECHNOECONOMICAL COMPARISON

Table 1 summarizes the main features of the different configurations:

	Capacity (1)	*Efficiency* (2) *improvement*	*Relative investment* (3)	*Emission reduction* (4)
HRB	20-25%	4-6%	0.45-0.65	50-80%
FWH	15-20%	1.5-3%	0.35-0.6	10-20%
PR	50-100%	5-13%	0.2-0.5	20-70%
FR	200%	10-20%	0.6-0.7	80-90%

(1) Additional capacity to the existing capacity.
(2) Additional percentage efficiency to the existing efficiency.
(3) Relative to NCC investment of the same capacity.
(4) Reduction in nitrogen oxides (NO_x) relative to existing emissions.

Table 1: Main parameter comparison between the different repowering configurations.

The technical and the economical parameters where used to calculate the electricity production cost. The evaluation that provided here does not include the HRB and the FWH option due to their low benefit comparing to the other options.

Electricity Production Cost

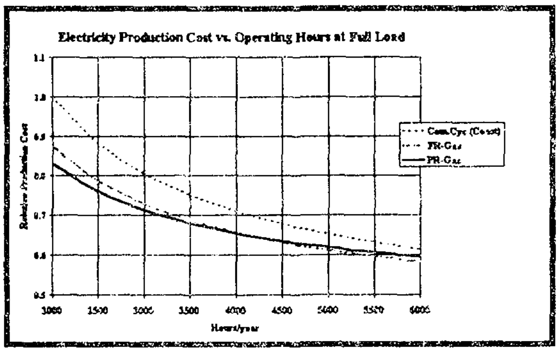

Figure 5: Electricity production cost vs. operating hours in full load.

Sensitivity analyses to gas price

At this stage, the exact gas price is unknown. This factor has a major influence on the feasibility of applying each one of the options. The production cost for different gas prices was calculated and shown for two cases: 2000 hours of operation and 4000 hours of operation.

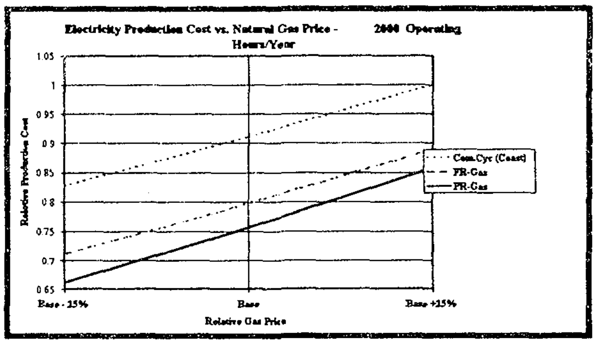

Figure 6: Electricity production cost vs. gas price at 2000 hours of operation at full load

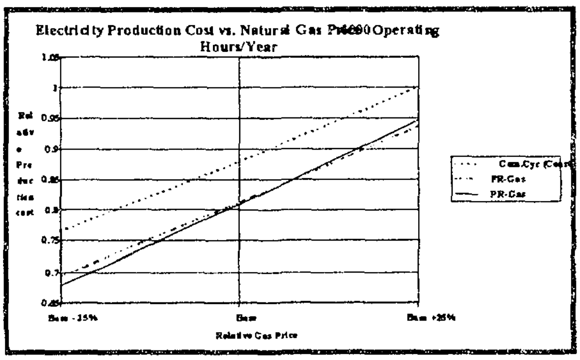

Figure 7: Electricity production cost vs. gas price at 4000 hours of operation at full load.

Pay Back Period Analyses

All of the repowering options require extensive investment. In this section, the pay back period was analyzed for different operating hours. Sensitivity test was performed for variation in gas price.

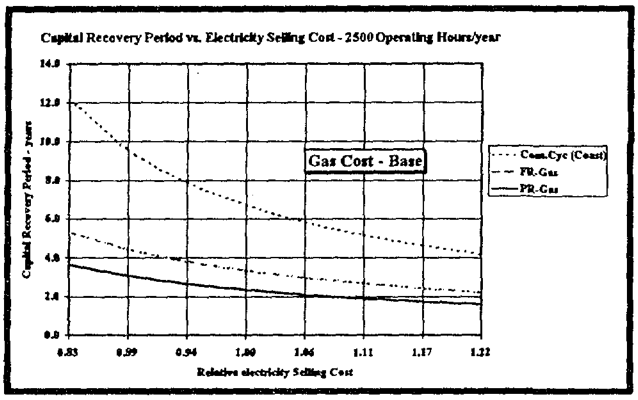

Figure 8: Pay back period vs. electricity selling price at 2000 hours of operation.

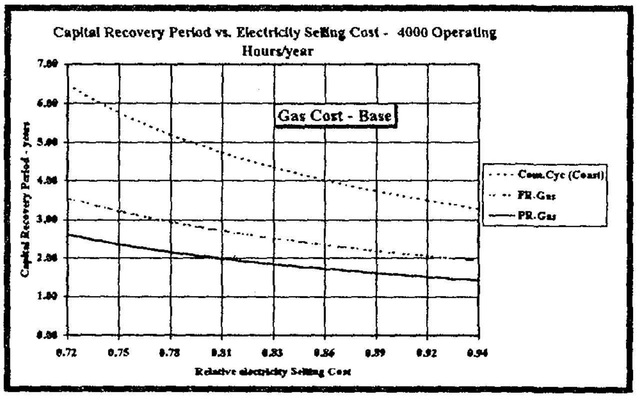

Figure 9: Pay back period vs. electricity selling price at 4000 hours of operation.

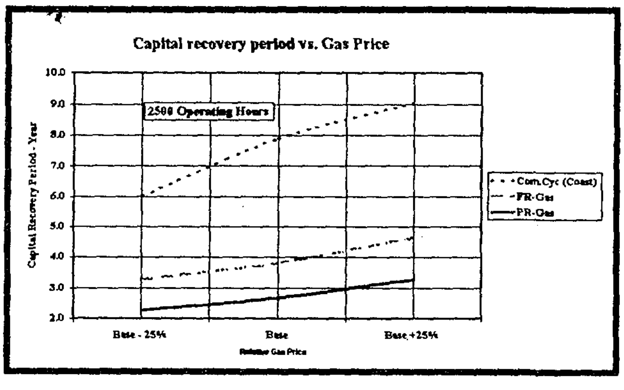

Figure 8: Pay back period vs. gas price at 2500 hours of operation.

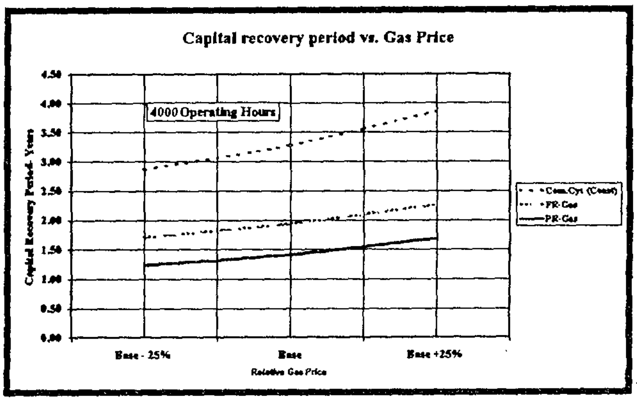

Figure 10: Pay back period vs. gas price at 4000 hours of operation.

DISCUSSION

(1) The repowering options were compered to new gas fired combined cycle. The gross production cost (including investment cost) favors the repowering options especially at the low-medium range of operation. In the lower range, the PR option is favorable and in higher range, the FR option is better due to the lower heat rate.

(2) The uncertainty in gas price for long term makes the PR option favorable, as shown it is less sensitive than the NCC to gas price variation, due to the lower investment. The sensitivity becomes higher at low-medium range of operation. If the unit will be considerably utilized the differences will be smaller due to the superior heat rate of the NCC and the FR options.

(3) In order to get fair financing terms, it is important to assure short payback period. The PR and the FR options shows remarkably shorter and stable pay back periods than the NCC.

(4) The long-term availability of the gas due to the political situation at our region is not very clear. With those conditions, the PR option has an advantage due to the possibility to keep on operate with the original fuel.

SUMARY

Importing of natural gas will bring several changes to the energy production sector in Israel. The integration of independent power producers (IPP) in the Israeli market will push IEC to improve the economical characteristics of the existing generating units. The study shows that repowering of existing oil fired power plants with gas turbine could be effective to achieve this goal in addition, reduction in emission with minimal investment will be achieved.