COMPATIBILITY OF ADVANCED POWER GENERATION TECHNOLOGIES WITH THE INDEPENSENT POWER PRODUCTION

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ABSTRACT

Traditional philosophy of power producing state-owned utilities has been effected by their anonymous risk-sharing attitude. They needn't have bothered too much with brand-new technologies. Technological risk with unproved, although excellent nominal performance machinery was born by the end-users.
On the other hand, independent power producers' (IPP) philosophy is a little bit different. Their attitude is much more effected by risk evaluation. They have pretty good reasons to be risk-averse with technologies lacking a proven operational record. Any failure to obey their contractual liabilities could mean dramatic consequences to them. Consequently, old-fashioned players in the power generation industry may seem to have been pushing industry technical progress more effectively ahead than it would be with modern players - IPPs.
But this is only one side of the coin. Quite opposite reasons for IPPs' affinity to modern technologies are higher performance parameters which offer better revenues to them, more flexible choice of fuel and prompt readiness to react sensitively to market imbalance and volatilities. Obviously, a hardly-defined, yet sensible equilibrium under which both these trends coexist and inter-act here exists. In this paper we shall analyse factors affecting such equilibrium by presenting real examples of gas turbine-dependent power generation technologies.

INTRODUCTION

In the last decade turbulent market trends and mutually contradictory effects have been counter-acting in power generation business more than before.
In utilities ownership it was a dilemma if privatise or not to privatise.
In legislation it was a question if regulate or not to regulate.
In IPPs' short history there was their biggest dilemma even before they arouse: exist, or not to exist.
The vivid saying about "one good news and one bad news" has changed. There are two news and both are good. Both are addressed to project finance and project development executives and they read:

- CCGT (Combined Cycle Gas Turbine) systems will approach the magic 60% thermal efficiency threshold by 2000.
- The prices for new power plants have been driven down by 40% within the last 6 years.

Engineering, procurement and construction (EPC) firms may disagree whether the second news means a good message to them, but this is a problem which has nothing to change in view of the following facts:

- Private investment flows to developing countries increased from 60 to 244 billion USD within the last 6 years according to *Global Development Finance* issued by the World Bank in the Spring 1997.
- Private capital now represents 80% of the net long-term flows to developing countries, totalling 285 billion USD in 1996.
- Foreign direct investment moved up by 300% within the last 6 years.

Especially the latter point is encouraging as for direct investment by multinational corporations enhances technology transfer and management intelligence in developing countries.

A more complicated balance between state-owned and private power generation industry may take place in highly developed economies. The US market, which is generally considered as the trial laboratory of world's liberalisation, vision of a transformation similar to other capital-intensive industries like steel, railways or coal may be adequate. This would be a model of a few very big mergers coexisting together with some small operators. No space would be left for medium-sized players, similarly as it is in coal industry.

Returning back to EPC companies and other manufacturers of the technological systems we are finding the intersect in which movements in the financial- and engineering industries of the last decade meet together.

Gas turbine (GT) - dependent technologies called IGCC (Integrated Gasification Combined Cycle) and PFBC (Pressurised Fluidised Bed Combustion) to which we ascribe the future role of leading clean generation commercial systems will be taken as working example for this purpose.

Primary subject of our attention therefore is to recognise the impact of private sector upon the most important trends in new power generation technologies. In another paper (Luby and Susta, 1997) we were analysing contribution of IGCC technologies in the solid-fuel segment which has acquired only pre-commercial status and therefore required subsidisation to become economically acceptable to the operator.

In the present paper we will give examples of both state and private sector contribution to those heavy fuel clean technologies which have already achieved commercial status. IGCC systems applied in the oil refineries and PFBC systems applied in solid fuel commodity belong to them.

GAS TURBINE AS THE INTERFACE BETWEEN TWO INDUSTRIES

In the corresponding paper (Luby and Susta, 1997) we pointed out the expansion tendency of GT as the strategy element in the solid fuel commodity. IGCC systems applied in refineries make possible coproduction fusion between crude oil refineries and power generation.

Such fusion made possible to upgrade some interesting IGCC private projects from demonstration to commercial stage. Such projects would otherwise have needed financial support.

PRIVATE POWER POTENTIAL IN HEAVY FUEL OIL RESIDUES GASIFICATION

There is a growing trend in oil industry, in refining heavier crude oils that have proportionately higher sulphur- and heavy metals contents. However, oil refinery operators keep policy to increase the share of light products. That gives rise to even lower grade residues and causes waste disposal problem. Based on projected refinery capacities world-wide, annual heavy residue generation will go up four times, from 43 mtoe/y to 195 mtoe/y. (mtoe/y = 10^6 tons of equivalent fuel per year = 44.8 x 10^6 GJ/y) or the year 2010 an estimated 135 GW of power available from burning of oil refinery residues could be mobilised annually. With ever more stringent legislation to reduce polluting by-products IGCC is becoming very cost-effective especially if low quality residues are used.

(Theoretical possibility to convert heavy fuel oil into "light" automotive fuel does exist, yet, this would be too expensive because further product upgrading with gasification stage would be, anyway, required.)

REVIEW OF IGCC PROJECTS PROCESSING HEAVY OIL REFINERY RESIDUES

Today 9 IGCC plants are in operation with another 11 under construction or in final planning stages. 50 other IGCC projects are considered world-wide. Out of these projects, IGCC systems processing refinery residues are subject of our interest. In Table 1. selection of six most important IGCC projects of this kind is introduced. All of them are based on entrainment flow gasification technology either by Texaco (position 1-4), by PRENFLO (position 5) or by Shell (positions 6). A simplified block diagram of a general Texaco IGCC process is shown in Figure 1.

Sarlux, Refinery of Saras, Italy (Table 1, position 3) is the largest IGCC under construction today (Chambers, 1997). When ready, it will be double the size of Wabash River IGCC (Indiana, USA) which is the largest IGCC currently in operation. Sarlux is the 1st non-recourse, third Party financed IPP project of this kind. At the same time, it is the largest IPP in Italy. Coproduction character of this technology is an attractive selling point for any plant like this. Electricity, steam and hydrogen may be generated for refinery purposes while power can be sold over-fence, if appropriate. Texaco quench gasifier is applied. Thermal efficiency expected is 50%. Refinery visbreaker residues (bitumen and tar left over from the refinery process Saras) are used as the feedstock. Saras (the 2nd largest refinery in Europe) with 55% share and Enron with 45% share are owners. GE, Snamproggeti and Turbotecnica are the turnkey contractors. Mid 12/96 group of International banks approved the 1.3 billion USD loan for this project. Commercial operation is scheduled for 2000.

API Energia, Falconara, Italy (Table 1, position 1) will gasify 440 000 t/y of visbreaker tar, which is a heavy oil residue (MPS, 1997).

El Dorado, Kansas, USA (Table 1, position 4): Hazardous refinery waste streams are used as the feedstock in this project (Chambers, 1997). US Environmental Protection Agency (EPA) granted permission preferentially because hazards were to be removed. In addition, the gasifier will be exempt from the Resource Conservation and Recovery Act. It means that the Project's refinery wastes will be considered as a fuel for the Gasifier and the Refinery can avoid disposal expenses and possible long-term liabilities for materials which otherwise would be considered hazardous. All Gasifier feeds have low or negative costs to the Refinery. Additionally, future changes in market or regulatory conditions may allow to use gasification technology for production of hydrogene, methanol or other petrochemical feedstocks.

Puertollano, Spain (Table 1, position 5) is the first project to use the PRENFLO gasification process, developed by Krupp-Koppers and Siemens/KWU (Europower, 1997). A mixture of ash-rich petroleum coke from nearby refinery is used.

Pernis, Rotterdam, The Netherlands (Table 1, position 6): PER and Shell Refinery have installed a IGCC unit to generate power, steam and hydrogene (Chambers, 1997). Full operation is scheduled for this year (1997). Gasification takes place under 65 bar and 1300-1400°C. Raw gas is cooled to 400°C. CHP (Combined Heat and Power) plant comprises 2 x GT MS6541B with capacity 43MWe each and 1 x ST (Steam Turbine) 28MW + 1 x ST 15 MW, total 127 MWe. The whole PP (Power Plant) shall be integrated with process plant in the late Summer of 1997.

SUPERIORITY OF IGCC OVER TRADITIONAL REFINERY RESIDUES POWER GENERATION TECHNOLOGIES

Conventional heavy-fuel oil fired PPs and FBC (Fluidised Bed Combustion) which are the traditional oil residue based power generation technologies cannot remain the only tools to solve the increasing heavy residue disposal problem. IGCC is becoming highly competitive because it is fuel-universal. A wide range of feedstock with solid fuel like coal, petroleum coke via slurries to liquid residues of any kind can be processed with highest efficiency (for several examples refer to Table 1, column 3). Typically, oxygen as gasifying agent moderated by steam is applied. The product sulphur-free syngas is generated which meets high purity requirements for GT admission. High-quality sulphur as the revenue-improving by-product is generated. Nitrogen left after oxygen separation is effectively admixed as GT denitrification inhibitor. In addition to coproduction options like hydrogen and steam mentioned before, also methanol as secondary fuel or urea as fertiliser can be produced.

PFBC - CURRENT TECHNICAL STATUS

PFBC is another clean technology which offers an alternative to IGCC. A simplified technological scheme is shown in Figure 2. Three basic components are integrated in one simple cycle:

a fluidised bed boiler suspended in the interior pressure atmosphere of Combustor Vessel, then GT circuit and ST circuit. Typical inlet operating air pressure of 12 bar is generated by the GT compressor. The air is led into the combustion chamber from below, creating thus a fluidised bed with inert ash and the additive sorbent required for sulphur capture. There is virtually no residual carbon left after combustion has taken place. Power generation has a different heat distribution than IGCC. About 80% power is generated by ST and only 20% by GT. This is caused by the fact that deeper cooling (down to 800-900°C) must be achieved before entering the GT. PFBC is therefore thermodynamically less effective than IGCC. However, simplicity of this technology has caused that commercial status is by 5 years ahead of IGCC technology. The following projects (Table 2) which have been- or will be commercially available confirm ABB market hegemony (IPG 1994):

Värtan, Stockholm, Sweden (Table 2, position 1) is the first of the array of the initial 5 projects erected according to ABB Carbon technology subsequently within years 1991-1999. The remaining four projects are as follows:

1992 **Escatron, Spain** (Table 2, position 2),
1992 **Tidd, Ohio, USA** (Table 2, position 3),
1993 **Wakamatsu, Japan,** (Table 2, position 4),
1996 **Trebovice, Czech Republic** (Table 2 position 5), with another one yet to be realised, namely:
1999 **Cottbus, Germany** (Table 2, position 6)

All of these projects have standard parameters given by ABB technology type designation P-200, i.e. power output 70-80 MW, efficiency 42-43%, with all other parameters as listed in Table 2.

ABB hopes to achieve capacity and efficiency upgrading up to 360 MW and 45% respectively, with project:

1998 **Karita, Japan** (Table 2, position 7) which is now being under construction.

PFBC activities in the USA are represented by the 170 MW **Lakeland, USA** project listed in Table 2, position 8.

Efficiencies of these projects are chronologically plotted in Figure 3 together with analogical parameters for some IGCC residue refinery projects taken from Table 1.

Attractivity to IPP developers potentially consists in the following attributes which beat conventional coal-fired systems:

1. Thermodynamic efficiency 42-45% surpasses considerably conventional steam plants parameters, although not in par with the latest IGCC technologies like Sarlux. Good efficiency is guaranteed by favourable kinetic parameters in the fluid bed. A typical reactor of ABB P-200 technology has a 3.5 m fluid bed height, what means that by typical fluid bed velocities of 0.9 m/s sufficiently long contact time exists resulting in very efficient desulphurisation conversion.

2. Environmental friendliness is excellent as is also shown in Table 2. Indicated parameters are very well below the tough limits prescribed by most of European governments, particularly the German Federal Emissions Control Act which calls for 400mg/Nm3 limit for SO2 and 200 mg/Nm3 for NOx.
3. Residue from PFBC consists of a mixture of coal ash and partly sulphated limestone or dolomite. It forms a stable end-product which can be safely disposed. It is well self-binding, water-resistant and non-leaching. As such, it is very well suitable as a building material, synthetic gravel, etc.

IGCC & PFBC AS INDICATORS OF PRIVATE / STATE OWNERSHIP PREFERENCES

All of the above mentioned factors mean strong incentives which for sure will make PFBC very lucrative technology for IPPs in the future. This is, however, not the case yet. As we can deduce from the last column Table 2, entitled “Ownership” most of these owners are state utilities. Non of these projects was developed by an IPP. As is obvious, 6 years of proven commercial record which passed from 1991 when the first commercial power plant in Värtan was commissioned still is not enough that private developers trust to new technologies.
A different situation prevails with IGCC projects processing refinery residues. Too explanations are due to be accentuated in this case. Private refinery owners have a different philosophy then their power generation colleagues. Tradition of both these industries plays a role here, in which the crude oil processing industry has always been more flexible in adopting innovations.
The other reason is a technical one. A more versatile option in product composition makes IGCC refinery residue technology more safe and universal than PFBC set in power generation industry.

CONCLUSIONS

Our outlook as per the adaptability to advanced technologies comparing state ownership versus private ownership is such, that there exists a time shift in adopting modern and less proved technical means. This time shift may mean 5-10 years gain in favour of state-owned developers. In the future, however, by gaining self-confidence as being ever more firmly established and internationally recognised subjects, new IPP players will increasingly reduce this “induction period” to nil and in the decade following 2010 IPPs will become technical development boosting forces No. 1.
This is our statement of who and how is driving ahead the technical progress in the new clean power generation technologies now and such is our outlook for the near future.

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