A Technical paper on

"Co-generation", "Combined Heat and Power (CHP)"

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Abstract

The main objective of this technical paper on co-generation, combined heat and power brings about the need of the co-generation to meet the present demand of electricity. It also bridges the gap between supply and ever increasing demand of electrical energy and becoming self reliant in terms of captive electrical power rather depends on the state grids. It also talks about the co-generation technology, benefits, applications and potential beneficiaries for the amateurs who are keen to implement this technology to meet their needs and serves nation as a whole by reducing the load on grids and reduction of CO_2 emissions to protect the environment.

It is followed by case study of 1 MW tri-generation reciprocating natural gas based engine, which includes scenario and costs before and after installation. Our experience and benefits from this co-generation system is also included along with our comments/suggestions to potential aspirers.

Contents

1. INTRODUCTION

1.1 Definition

Co-generation is defined as the sequential generation of two forms of useful energy from a single primary energy source, typical two forms of energies are mechanical energy and thermal energy. Mechanical energy may be used may be used to either to drive an alternator to produce electricity or rotate an equipments like motor, compressor, pump or fans etc., for delivering different services. Thermal energy may be used directly for the process for heating purpose or indirectly to produce the steam generation, hot water or hot air for dryer and chilled water generation for process cooling.

Generation of three different forms of energy from the single primary energy source is called as Tri-generation, i.e., generation of Electricity, Steam or Hot water and Chilled water from single source of primary fuel. Above both systems is also called as “Total Energy System”

1.2 Need of co-generation

Thermal power plants are major sources of electricity supply in India. The conventional method of power generation and supply to the customer is wasteful in the sense that only about a third of the primary energy fed into the power plant is actually made to available to the user in the form of electricity (Figure 1). In conventional power plant, efficiency is only 33% and remaining 65% of energy is lost. The major loss in the conversion process is the heat rejected to surrounding water or air due to the inherent constraints of the different thermodynamic cycles employed in power generation. Also of further losses of around 10-15% are associated with the transmission and distribution of electricity in the electrical grid.

Through the utilization of the heat, the efficiency of the co-generation plant can reach 90% or more. In addition, the electricity generated by the co-generation plant is normally used locally, and then transmission and distribution losses will be negligible. Co-generation therefore offers energy savings ranging between 15-40% when compared against the supply of electricity and heat from the power stations and boilers.

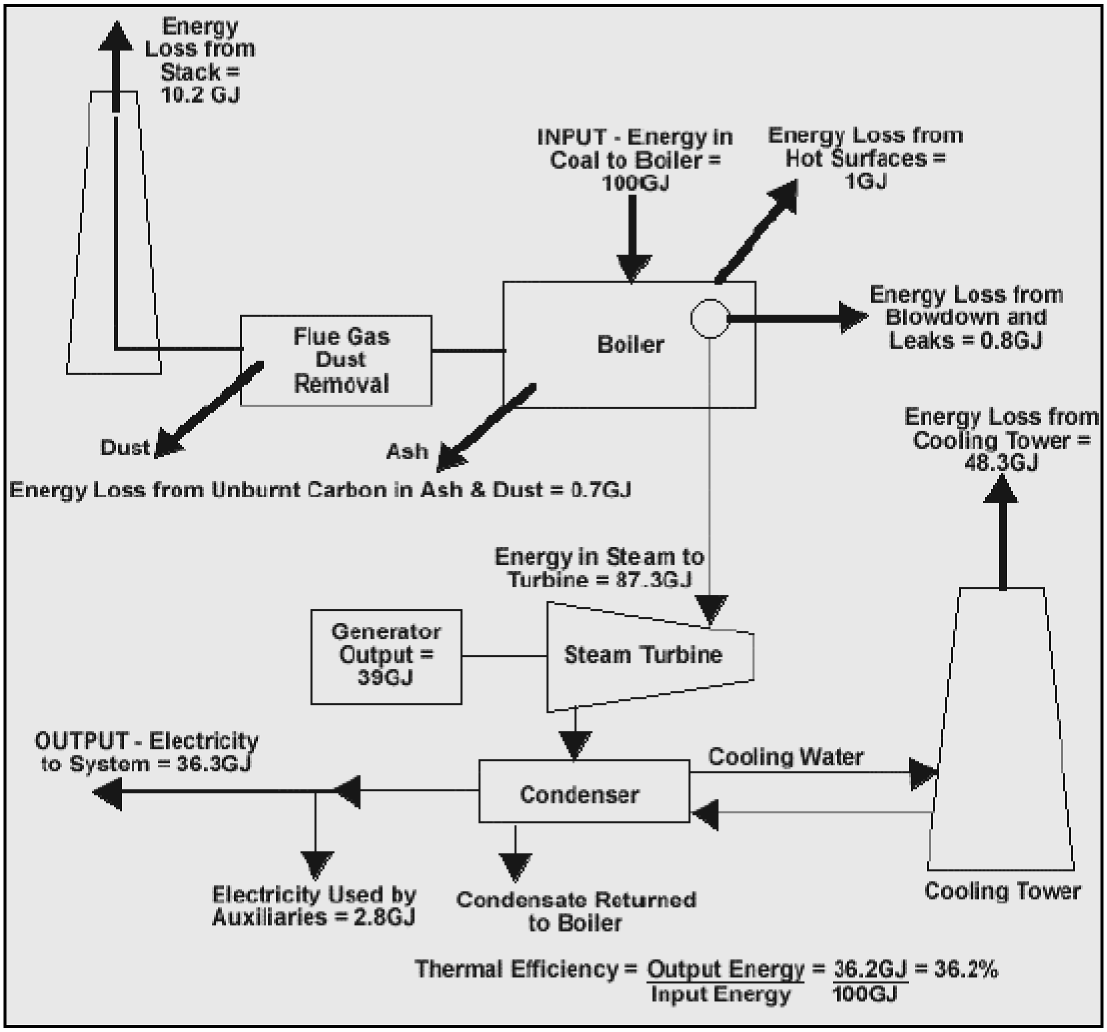

Figure 1: Balance in a typical coal fired power station
(For an input energy of 100 Giga joules (GJ))

1.3 Benefits of co-generation

Provided the co-generation is optimized in the way described above, the following benefits arise as co-generation is a well proven technology, recognized world over as a cleaner alternative to traditional centralized generation. Its long term future in the global energy markets is secured by its ability to provide operational, financial and environmental benefits from t a single unit of a fuel.

Operational advantages:

- Base load electrical supply
- Security of supply
- Increased diversity on heating and hot water

- Steam raising capabilities
- Tri-generation, using absorption/mechanical chillers for cooling

Financial advantages:

- Reduced primary energy cost
- Stabilized electricity cost over a fixed period
- Flexible procurement solutions
- Reduced investment in surrounding plants eg. Boilers

Environmental advantages:

- Improved fuel efficiency
- Reduced CO2 emissions
- No transmission losses
- Lower SOX emissions with the use of Natural gas as a fuel

1.4 Applying co-generation

Consistent demands for the thermal energy, and considerable electrical base loads are most appropriate for co-generation. One can consider the co-generation in the following cases of situation.

- Designing a new building
- Installation of new boiler plant
- Existing site re-development
- Continuity of power supply
- Increasing energy efficiency
- Improving financial performance
- Positive environmental effect
- Supporting the company's green image

1.5 Potential users of co-generation

Co-generation has a long history of use in many types of industry, particularly in the pulp & paper and bulk chemicals industries, which have large concurrent heat and power demands. In recent years the greater availability and wider choice of suitable technology has meant cogeneration has become an attractive and practical proposition for a wide range of applications. These include the process industries, commercial and public sector buildings and district heating schemes, all of which have considerable heat demand. These applications are summarized in the table below. The table also list renewable fuels that can enhance the value of co-generation, although fossil fuels, particularly natural gas, more widely used.

Possible opportunities for application of co-generation:

<u>Industrial</u>

- Pharmaceuticals and fine chemicals
- Paper and board manufacture
- Brewing, distilling and malting
- Ceramics
- Brick
- Cement
- Food processing
- Textile processing
- Mineral processing
- Oil Refineries
- Iron and Steel

<u>Buildings</u>

- District heating
- Hotels
- Hospitals
- College campuses and schools
- Airports
- Supermarkets and large stores
- Office buildings

1.6 Technical options for co-generation

Co-generation technologies that have been widely commercialized include extraction/back pressure steam turbine, gas turbine with heat recovery boiler and reciprocating engines with heat recovery boiler.

1.4.1 Steam turbine co-generation systems

Two types of steam turbine most widely used are the back pressure and extraction-condensing types (Figure 2). The choice between back pressure turbine and extraction-condensing turbine depends mainly on the quantities on the quantities of power and heat, quality of heat and economic factors. The extraction points of steam from the turbine could be more than one, depending on the temperature levels of heat required by the processes.

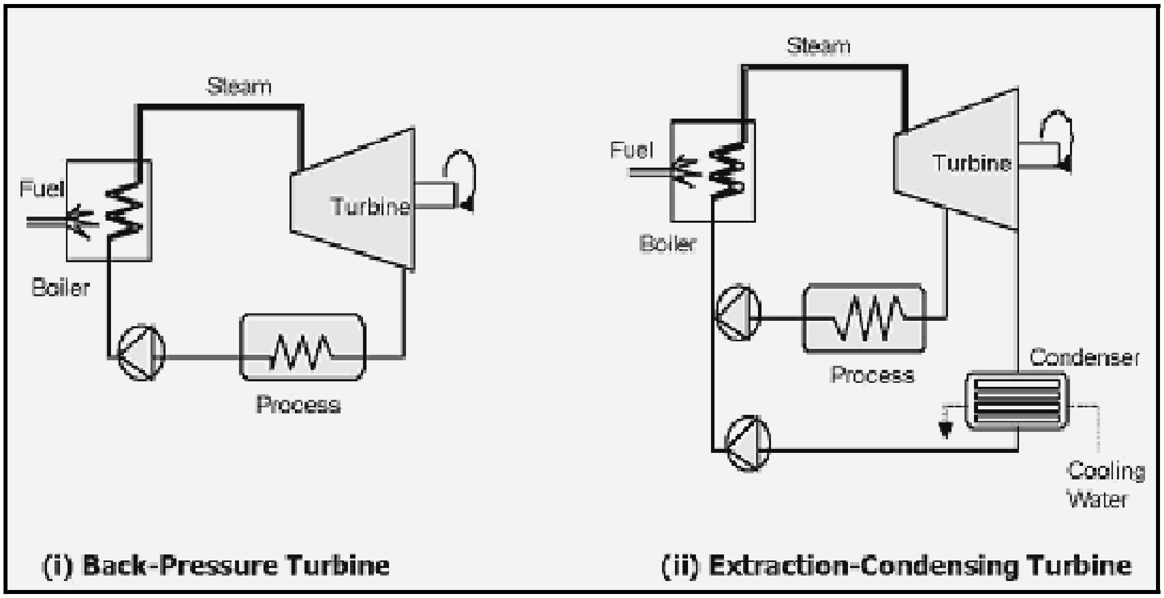

Figure 2: Schematic diagrams of steam turbine co-generation systems

The specific advantage of using steam turbines in comparison with the other prime movers is option for using a wide variety of conventional fuels as well as alternative fuels such as natural gas, fuel oil and biomass.

1.4.2 Gas turbine co-generation systems

Gas turbine co-generation system can produce all or part of the energy requirement of the site, and the energy released at high temperature in the exhaust stack can be recovered for various heating and cooling applications (Figure 3). Though natural gas is most commonly used, other fuels such as light fuel oil or diesel can also be employed. The typical range of gas turbines varies from a fraction of a MW to 100 MW.

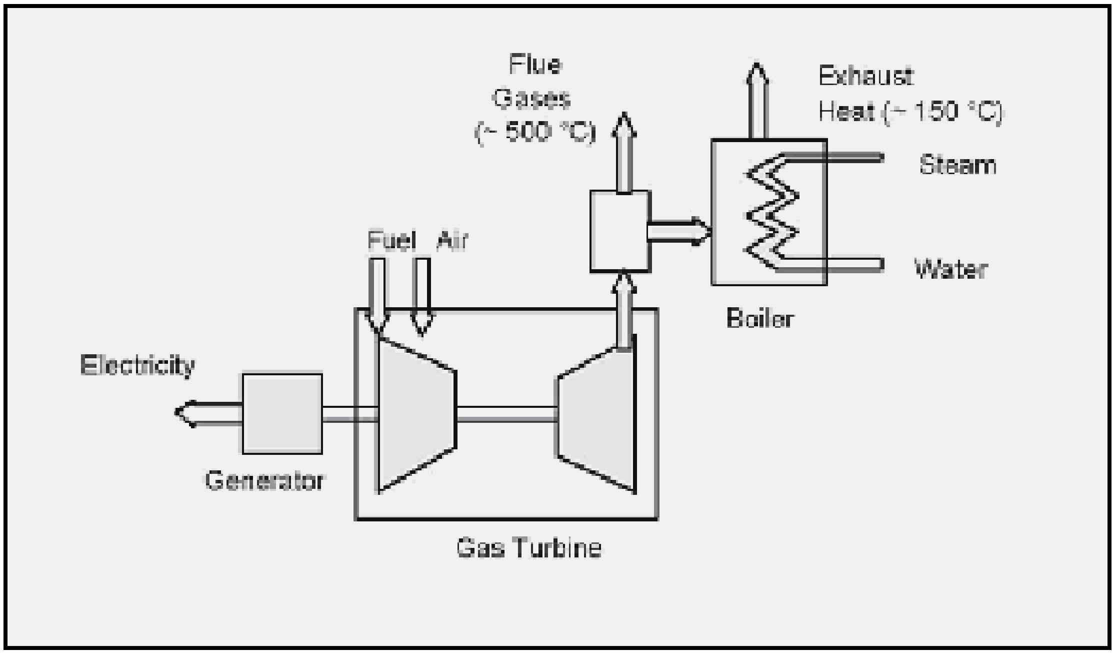

Figure 3: Schematic diagrams of gas turbine co-generation systems

1.4.3 Reciprocating engine co-generation systems

It is also known as internal combustion engines, these co-generation systems have high power generation efficiencies in comparison with other prime movers. There are two sources of heat recovery: 1) From exhaust gases at high temperature and 2) From engine jacket cooling water system at low temperature (Figure 4). As heat recovery can be quite efficient for smaller systems, these systems are more popular with smaller energy consuming facilities, particularly those having a greater need for electricity than thermal energy and where the quality of heat required is not high.

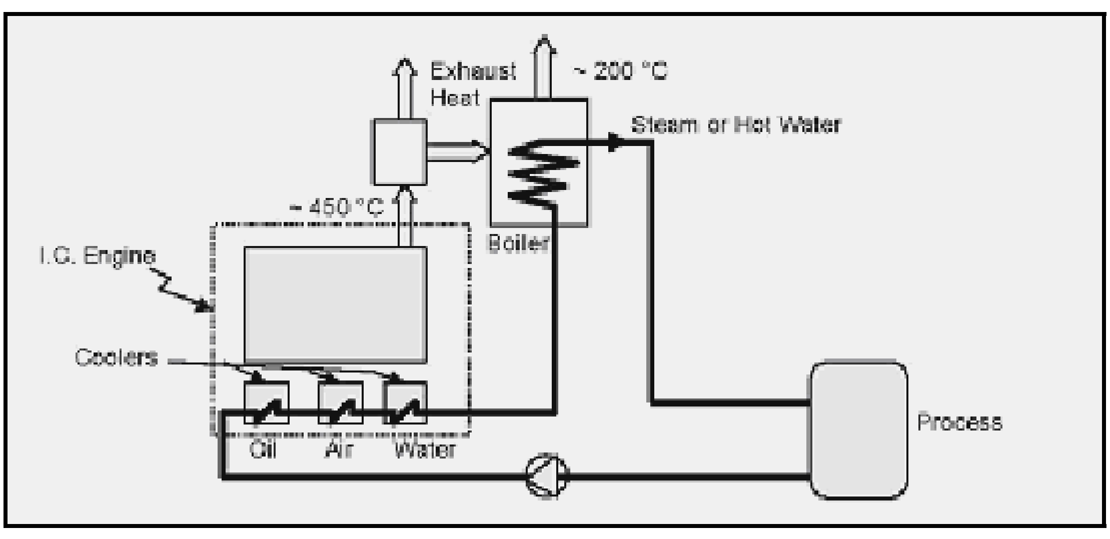

Figure 4: Schematic diagrams of reciprocating engine co-generation systems

2. CASE STUDY

This case study pertains to a chemical industry engaged in manufacture of agrochemicals and related intermediates and having manufacturing locations all across India. The technical grade product manufacturing activity of this organization involves various equipment / machineries driven by electrical energy. One of such site located in Gujarat is having an approximate maximum demand of electricity up to 1.35 MW, Steam requirement up to 2.5 TPH and Chilled water @ 5 deg C up to 90 TR.

The high cost of power coupled with the cost for generation of steam and chilled water of desired temperature was eating into the bottom line of the products in the highly competitive market. A cost effect analysis pointed to power cost as the main target to work upon. Captive generation of power as a stand alone project either using conventional or new generation fuels was calculated to be not that cost effective. Since the three resources required by the unit had some common features that are interdependent, the study turned to a system that can cater to all the three utilities in totality.

After much exploration into various technologies available in the market, the management decided to go for a captive power plant with tri-generation to meet the above requirement so as to reduce the utility cost of the products and thereby making the products price competitive in the market.

Scenario before installation of co-generation plant:

The above requirement is fulfilled by state electricity, 3 Ton steam boiler and Vapor compression refrigeration of reciprocating compressor of CHW systems.

Cost to the company before installation for the above requirement as follows,

Equipment	Fuel/Electricity consumption (per hour)	Unit cost (Rs)	Cost per hour (Rs)	Total cost per 8000 hrs of year (Rs Lacs)
Grid power	1064 kWh	5.5	5852	744
Boiler	195 Nm3/h	9.7	1892	
CHW system	95 kWh	5.5	523	
DG Set*	60 lit/h	35	2100	

Notes:

1.	Contract demand of grid power	1700 KVA
2.	Maximum demand of plant	1350 KVA
3.	CD charges per month	2.1 Lacs
4.	Cost of unit power(kWh) (Average)	5.5 Rs
5.	Total power bill per 8000 hrs	593 Lacs

6. * Exclusively for one critical reactor for 12 hrs running per day per batch as grid power is not reliable and is not desired by the reaction.

Selection criteria for choosing the reciprocating machine:

An aspect – impact analysis was carried out in the course of selection of the right type of technology that would be most appropriate for the unit keeping in mind the modes of benefits specifically required in contributing to savings. The following aspects were considered and vetted during selection of engine by an expert team of 4 members.

1. The said team identified and visited those locations where captive power plants have been already installed and had detailed discussions with the users and their experiences were captured for evaluation and as a learning process.
2. Team also learned about the 2-3 failures of other type of machines in and around the location and recorded about that type engine (the name of the engine is not mentioned in the light of code of conduct)
3. Coincidently one of our senior managers had some hands on experience with this type of reciprocating engine.
4. It is the triple effect requirement of three utilities, namely Electricity, Steam and Chilled water that prompted for selection of tri-generation system. Had it not been so selection would have been for co-generation system
5. Since the company is a an enterprise of a big business group, information from group companies could be gathered and taken into consideration at the finalization stage of this project
6. A comparative study based on the techno-commercial aspects rated reciprocating engine as the lowest cost and high returns system.

Scenario after installation of co-generation plant:

A reciprocating gas machine from GE Jenbacher installed with the following parameters on June 2006.

1. Generation of electrical energy at full load – 1064 kWh
2. Generation of steam at full load – 1 TPH
3. Generation of CHW (Inlet -11 ^{0}C & Outlet – 6 ^{0}C) – 92 TR

Reciprocating engine of GE Jenbacher is being operated with natural gas as a primary fuel. The schematic diagram of tri-generation system is shown in the figure 5.

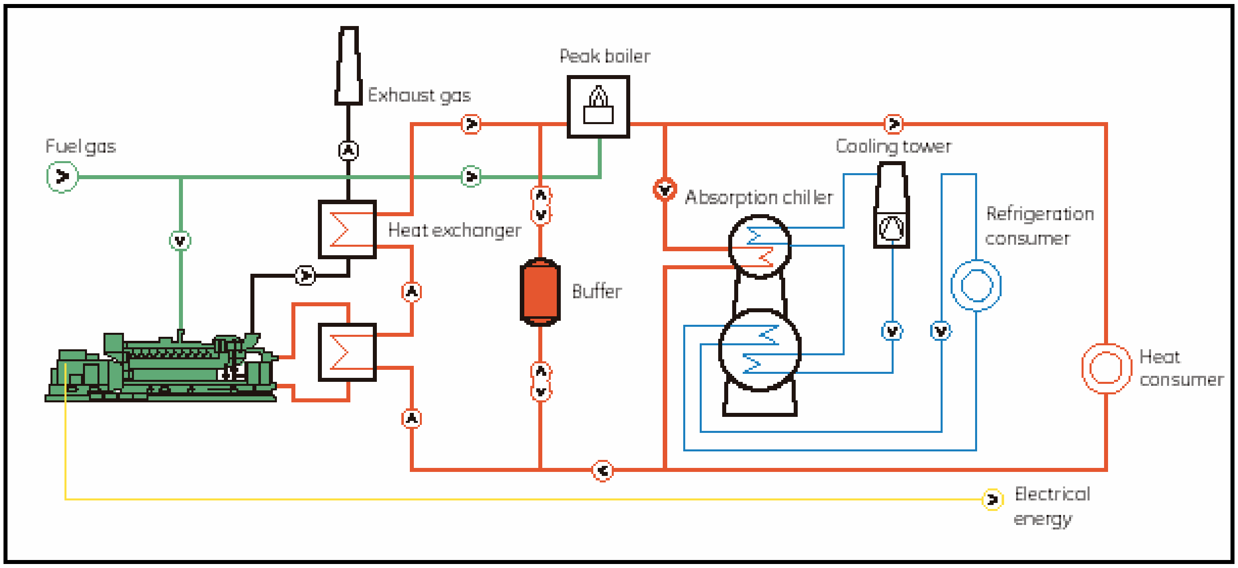

Figure 5: Schematic diagrams of tri-generation of reciprocating engine co-generation systems

Equipment	Fuel/Electricity consumption (per hour)	Unit cost (Rs)	Cost per hour (Rs)	Total cost per 8000 hrs of year (Rs Lacs)
Captive power	1064 kWh	3.3	3511	
Grid power	285 kWh	5.5	1568	
Boiler	125 Nm3/h	9.7	1213	503
CHW system**	NIL	-	-	
DG Set***	NIL	-	-	

<u>Notes:</u>

1. Contract demand of grid power 700 KVA
2. Maximum demand of plant 1350 KVA
3. CD Charges per month 0.62 Lacs
4. Cost of unit power(kWh) (Average) 5.5 Rs
5. Total power bill of grid electricity per 8000 hrs 126 Lacs
6. ** VCR system of compressor is stopped completely
7. *** As co-generation power is reliable, load of critical reactor connected to co-generation plant.

Net savings per year, Rs Lacs ****	259
Cost of captive power plant , Rs Lacs	350
Simple payback period, Months	16
Month and year of commissioning of system	June'2006
Actual accrued savings till Feb'2007,Rs Lacs #	138

Important notes:

1. **** Net savings are calculated by assuming 8000 hrs of operation per year.

Net savings = Cost difference between grid and captive electricity
+
Reduction in contract demand charges
+
Elimination of compressor in VCR of CHW generation
+
Elimination of costly HSD fuel through stopping of DG set

2. # Due to delayed commissioning of VAM system, surrendering of grid power, stopping of DG set and part loading of three generations (Electricity, steam and Chilled water) savings are minimized.

Efficiency of generation of three utilities:

Form of energy	Efficiency on Fuel
Electrical power	42%
Steam generation from exhaust gases	26%
CHW generation from jacket hot water	13%
Total efficiency on fuel input	**81%**

Advantages with GE Jenbacher Reciprocating engine:

- High power efficiency achievable over a wide range
- Relatively low cost per kWh electrical power output
- Wide range of unit sizes from 3 kWh and upward
- Part load operations from 30% to 100% with high efficiency
- Fast start-up time of 15 second to full load (gas turbine needs 0.5 – 2 hrs)

- Real multi fuel capability, it can also use FO as fuel
- Can overhaul in site with normal operators
- Can be operated remotely

Problems (with recommendations) faced during initial stage of commissioning:

Some unforeseen problems and delays occurred during executing of captive power plant

During installation of power plant and WHR unit:

- Delay by 15 days has occurred in civil construction works due to water fountain during excavation and non availability of required manpower due to festivals, etc.,
  → This can be avoided by better project management schedules after taking into the considerations festivals and etc which can be avoided during project period.
- Modifications based on the boiler inspector suggestions after installation of WHRU
  → This delay can be avoided by approaching boiler inspector prior to the installation of WHRU
- Completion of all statutory requirements
  → This delay can be minimized by proper planning and follow-up with concerned departments and officers

During installation of VAM system:

VAM system could not be commissioned along with power generation and steam generation unit due to following reasons,

- Miscommunication between engine makers and VAM makers.
- VAM makers recommended certain changes in High Temperature hot water from engine jacket, and it has been done later on tool ample amount of time as we were to import the particular thermal element.

  → The above mentioned delays can be minimized well with the proper planning and felicitation of discussions between suppliers of other accessories with engine suppliers.

Benefits achieved since inception of project:

- ***Monetary***: Rs 138 Lacs has been saved and it has helped to improve the bottom line of the company.
- ***Self reliance***: Self reliance in terms of captive electric power achieved and it has helped to improve the productivity as there is no break down of the plant due to power outages.

- ***Reduction of CO_2 emissions***: Total quantity of 1326 Tons of CO_2 emissions reduced as on end of Feb'2007 Vs potential of 7992 Tons per year at 100% load.
- ***CDM Benefits***: Reduction of CO_2 emission could be traded with World Bank as per Kyoto protocol. These benefits will be exploited soon by submitting a detailed project for our all initiatives in this regard.
- ***SH&E policy***: Helped to stick and work towards our SH&E policy for greener environment.
- ***Serving nation***: By reduction of 1 MW load on the state grid, helped nation to bridge the gap between supply and demand

3. CONCLUSION

Co-generation is well proven technology, recognized world wide as a cleaner alternative to traditional centralized power centralization and it is highly energy efficient whereas tri-generation applied in our case is upcoming technology having higher efficiency than typical cogeneration system delivering a number of positive financial and environmental benefits. This will help to any organization individually and nation as a whole.

From the case study we have seen, it was evident that the co-generation and tri-generation system would substantially reduce the operating cost of industries. The rate of return for this tri-generation project is very attractive and payback period would fall in between 1 to 2 years.

Further in today's the growing concern towards global warming and cleaner development mechanisms, most of the CO_2 emissions stem from the burning of fossil fuels for the purpose of electricity generation. Coal accounts for 93 percent of the emissions from the electric utility industry. Going for Co-generation and tri-generation will substantially reduce CO_2 emissions when compared with traditional heat and power generating stations.

Thus, apart from monetary savings, Co-generation is a cost effective way to conserve depleting fossil fuels and contributing to sustainable development. Climate change and carbon emission reduction is an increasingly dominant factor in co-generation's future.

By seeing the above mentioned success and advantages with tri-generation plant, it is strongly recommended the aspirers to go for the implementation of this system and get benefited in terms of monetary and environmentally.

4. REFERENCES

1. Energy efficiency in Thermal utilities – BEE
2. A Guide to co-generation – EDUCOGEN
3. GE Jenbacher manual