Techno-economic study
on Indo-German TRIGEN project

Nurmukhanbetova Karakoz, Kazakhstan (PPRE 2011/13)
karakoznur@gmail.com

Abstract: A trigeneration technology (Trigen) was studied on example of the TRIGEN project in India. The project was implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in an Indian Governmental hospital, New Delhi. The technology allows to utilize the waste heat from the power generation and the overall efficiency can reach up to 90%. A payback calculation of a Trigeneration system for an Indian hospital was made.

1 Introduction

This article based on the Master's thesis, which is a result of three months practical training in the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, New Delhi. Trigen project is jointly implemented by the Bureau of Energy Efficiency (BEE, Ministry of Power, India) and GIZ.

Trigeneration is the simultaneous production of electricity, heat and cooling. Such a system can reach overall efficiencies of 80% at the end users site, as it can utilize the waste heat from power generation to cover the heating and cooling demand of the facility. In addition to this, there are no transmission losses. The spectrum of possible applications includes hotels, hospitals, airports, commercial building, industries and etc.

By taking into account the world energy scenarios which show almost total fossil fuel exhausting to the end of 21st century, the trigeneration seems a good means of energy conservation. In the case of the developing countries the energy sector assumes a critical importance in view of the ever-increasing energy needs requiring huge investments to meet them. The investigations and payback calculations showed that the payback time of Trigen system is strongly depends on cost of electricity from the National grid, piping gas availability and prices of gas and diesel.

2 Trigeneration plant at JPNATC

2.1 What is Trigeneration?

Trigeneration technology (Trigen) simultaneously produces the electricity, heat and cooling. By utilizing the waste heat from the power generation the overall efficiency can reach up to 90%. Trigen system is decentralized, i.e. it is installed close to the consumption point what improves of power supply reliability and efficiency of electric utility services, reduce losses on the distribution grid, alleviate of need for grid reinforcement and for replacement of old central power plants. Due to the high efficiency, the consumption of primary energy decreases and consequently the harmful environmental emissions reduce. Moreover if the renewable energy sources (solar, biofuel, wood) use as a fuel for power generation, it can decrease the rate of the fossil fuel depletion. The system has high economic viability, since of the reduction of energy costs, securing against the energy price fluctuation and the large annual operation time by using waste heat for cooling. [1]

2.2 Trigeneration project

TRIGEN project was implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in New Delhi. The services delivered by the GIZ draw on a wealth of regional and technical expertise and tried and tested management know-how. As a federal enterprise, it supports the German Government in achieving its objectives in the field of international cooperation for sustainable development. The key funding sources are: German Federal Ministry for Economic Cooperation and Development (BMZ), Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and other ministries, the European Commission, the United Nations and the World Bank, and private enterprises. GIZ currently operates in more than 130 countries worldwide.

Germany has been cooperating with India by providing expertise through GIZ for more than 50 years. To address India's priority of sustainable and inclusive growth, GIZ works jointly with many Indian partners in almost all states in the country. In India the GIZ focuses on the following sectors:

- Energy – Supporting energy efficiency in power generation and its consumption. Exploring and main streaming renewable energy options to mitigate carbon emissions;
- Sustainable Economic Development – Consist of Financial Systems Development, Private Sector Development and Social Protection;
- Environmental Policy, Conservation and Sustainable Use of Natural Resources – Consists of Natural Resource Management, Sustainable Habitat and Industrial Development departments.

Key partners in India are various Ministries of Government and subordinated authorities, State Departments and their Authorities, Industry Associations, Universities, other academic and training institutes.

Particularly the Indo-German Energy Program (IGEN) has a focus to support the implementation of the Energy Conservation Act. The project is jointly implemented by GIZ and the KfW Development Bank.

The bilateral cooperation brings in local and international professional expertise and support to undertake the following activities:

- Labeling of household appliances and energy intensive industrial equipment with respect to energy efficiency,
- Certification of energy managers and energy auditors,
- Setting of norms and standards for energy intensive industries,
- Transferring and promoting cutting-edge technology to reduce energy consumption,
- Promoting public-private partnerships to advance awareness of the need to save energy,
- Operating one of the largest web portals (*www.energymanagertraining.com*) on this subject in India,
- Clean Development Mechanism (CDM) projects cooperate actively with the National CDM Authority of India for the institutionalization of CDM projects in India.

Moreover, in the frame of IGEN program the GIZ is supporting Bureau of Energy Efficiency (Ministry of Power, Government of India) in the implementation of demo project “TRIGEN”. It is funded by the Federal Ministry of Environment, Nature Conservation and Nuclear Safety (BMU), Federal Government of Germany. Dalkia Energy Servises Ltd (DESL) has been assigned to setup a trigeneration system to ensure that the demo project becomes a successful showcase. The main objective of the project is to increase in the use of trigeneration-based energy efficient cooling technologies to reduce India’s power shortage and to decrease greenhouse gas emissions.

Stakeholders of the TRIGEN project are:

- Bureau of Energy Efficiency (BEE, MoP),
- Technology Providers, Manufacturers, Suppliers (Operations and Management),
- Service Providers (Consultants, Training, Financial, Energy service companies),
- Buildings and Industries (Hotels, Hospitals, Airports),
- Utilities Distribution Companies, Coordinating Equipment Research Committee.

The main strategic objectives of the TRIGEN project is to facilitate market entry for small and medium scale trigeneration systems, demonstrate costeffective and sustainable decentralized trigeneration systems, and draw attention to innovative cooling technologies, which are more environmentally-friendly than compression cycles.

The project comprises of the following activities:

- Setting up of a pilot plant in a public building,
- Dissemination of information,
- The website *www.trigenindia.com* provides a platform to energy auditors, energy managers, users, engineers, architects, policy makers, energy service companies, manufactures, service providers, etc.,
- Market analysis, energy checks and audits,
- Providing information to trigeneration plant users, suppliers, manufacturers, etc.,
- Developing a concept for improving the legal and economic framework for trigeneration and cogeneration. [1]

Selection of target sectors is done by using a set of criteria with large energy demand including the simultaneous requirement of continuous, uninterrupted power supply with cooling and/or heating requirement. Cities with large power consumption, big municipal corporations, availability of natural gas and with applications demanding uninterrupted and reliable power are selected. Pre selection of target sectors includes:

- Public & Private Hotels,
- Public & Private Sector Hospitals,
- International & Domestic Airports,
- Industries, Date Centers, Offices etc.

The objectives of site selection in frame of the TRIGEN project included the identification of location where:

- All the trigeneration equipments & its auxiliaries can be placed,
- The cost for the installation and integration of plant is minimum,
- The integration of new plant with the existing system should be easy and have minimum cost.

As per selection criteria the demo project has being implemented in Jai Prakash Narayan Apex Trauma Center (JPNATC). JPNATC is established as the apex centre of country at Raj Nagar, New Delhi. The building consists of hospital, hostel, laundry and office. [2]

Project Landmarks:

- June 2010: Project stakeholders (JPNATC, BEE and GIZ) agreed to feasibility of Trigen at Jai Prakash Narayan Apex Trauma Center;

- December 2010: MoU signed between JPNATC, BEE and GIZ;
- March 2010: Site preparation activities begins;
- June 2010: Civil work including foundation of equipments begin;
- September 2010: Installation of equipments commence;
- December 2011: Installation completed successfully;
- January 2012-May 2012: Site preparation;
- May 2012: Commissioning commenced;
- October 2012: Inauguration of Trigen system.

My project timeline was covering October 2012, thus I participated to the inauguration ceremony. It was a great event and several Indian and German officials as Mrs. Gudrun Kopp (Parliamentary State Secretary to the German Federal Minister for Economic Cooperation and Development (BMZ) and Member of the German Bundestag) and Mrs. Jyoti Arora (Director General – Bureau of Energy Efficiency & Joint Secretary, Ministry of Power) and others were participating there.

The TRIGEN project elaborated the technological, economical, financial and political/ administrative aspects for Trigeneration. There are big potential for successful development of the trigeneration market in India.
ration time by using waste heat for cooling. [1]

3 Trigeneration plant at JPNATC

3.1 Payback calculation of Trigeneration system for Indian hospital

The calculation of payback time is a very good instrument to simplify a process of decision making about applicability of Trigeneration. The mail limitation of the payback calculation is instability of initial data used, such as:

- cost of grid electricity, which depends on type of building, power 5iquefie, type of contract between power company and customer. The price per kWh varies significantly across States as well as customer segments within a State.;
- price of gas, which also depends on a type of contract between gas supply company and customer;
- diesel price;
- cost of Trigeneration system and its maintenance;
- availability of gas supply – building of a new gas-pipeline can increase initial price;
- way of utilization of building – this information can give an idea about power/heat/cooling demand proportion;
- duration of power shortfalls.

The price data was taken from different web sites and correspond to autumn 2012 period of time. Moreover, the hospital was chosen to simplify calculations. Hospitals, being heavy consumers of energy in all three forms (power/heating/cooling) in India, can be very attractive for installation of Trigen system. It was taken by default that there is enough space for Trigen system placement and the hospital has access to piping natural gas (PNG).

Typical power sources in Indian Governmental hospitals include electricity from the grid and diesel generator sets (standby emergency power). Moreover they need fuel for thermal applications (e.g. piped natural gas). Worthy to note is that the standby diesel (or gas) generators are used in India with improper maintenance, thus lowering the conversion efficiency to just about 20%, while the rest amount of energy (~80%) is wasted in terms of heat. [3] The breakdown of consumption for a typical government hospital is distributed as: 91% of electricity, 6% 6iquefied petroleum gas (LPG) and 3% of fuel oil. The same distribution by cost values is: 95% of electricity, 2% of LPG and 3% of fuel oil. Thus, typically 90 to 95% of the total energy cost is due to electricity consumption (including self generation from standby diesel generators sets), balance being from petroleum fuels like fuel oil and LPG. While electricity is used to meet all major applications, such as heating, ventilation, air conditioning (HVAC), lighting and water pumping; fuel are used for standby power generation, hot water generation etc. Typical power and energy consumption for major services in a sample of hospitals analyzed indicate the following energy consumption pattern (Figure 1). [4]

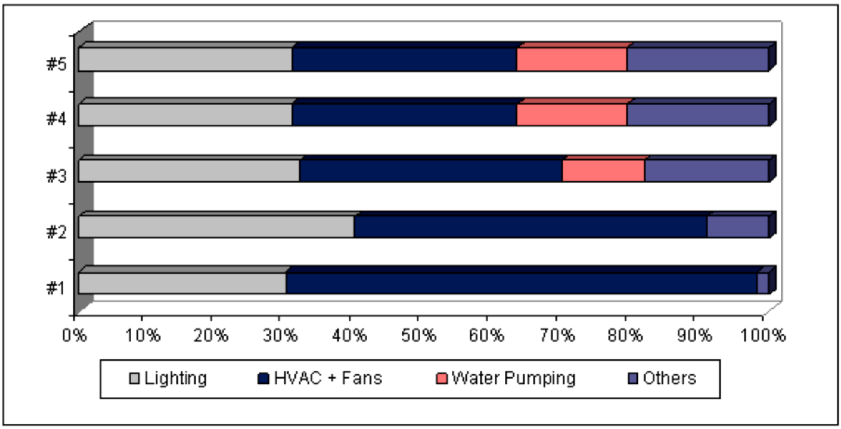


Figure 1: Electricity consumption pattern in five hospitals

Source: Ravi Kapoor, Satish Kumar, 2011

Other applications include office facilities such as computers and photocopies, utilities such as lifts, refrigerators, water coolers, laundry equipment; kitchen and canteen equipment; ovens and geysers and medical equipment including autoclaves. Share of consumption amongst different end uses is related to some divergent factors related to service offering, occupancy and climate zone. However, generally lighting and HVAC applications constitute about 75% combined. [4]

Two recent studies, one by Maharashtra Electricity Regulatory Commission (MERC), and another by India's Bureau of Energy Efficiency (BEE), show that AC power demand forms the biggest share of peak demand in Indian cities. While the MERC study pegs power demand from Acs at 40% of the total demand for the city of Mumbai in a peak summer month, the BEE study estimates that a staggering 60% of peak demand is used up by air-conditioners. Thus Air conditioners account for a staggering 40% to 60% share of peak electricity demand during the summer months in many Indian cities. [3] Thus in further calculations it will be assumed that the energy consumption in India in average distributes as: 40% of electricity load, 50% of cooling load, 10% of heating loads.

As an example of the seasonal distribution of cooling demand one can see Figure 2, where the monthly maximum and the average cooling load in terms of tones of refrigeration (TR) demand profile for the Trauma Center (JPNATC) is shown. The maximum is restricted by the project boundary, since the Trigen system was initially designed to cover just 355 TR of the total cooling capacity. Proposed Tri-generation plant have one exhaust fired VAM of 105 TR and one centrifugal chiller of 250 TR. [2]

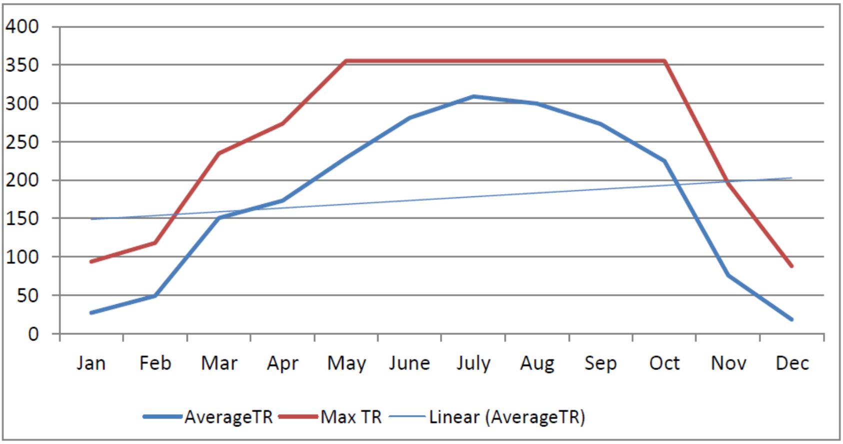


Figure 2: Monthly maximum and average cooling load (TR) demand profile

Source: Dalkia Energy Servises Ltd, November 2010, 2010

As it shown above, the cooling load has the biggest fraction in energy demand. Accordingly, the Trigen system can be designed in two ways:

1) According to the cooling demand – the system produces more electricity than the electricity demand and accordingly more cooling, meanwhile the extra produced electricity can be used by a conventional electrical chiller to cover the rest of the cooling demand.
2) According to the electricity load demand – the system covers maximum of electrical and part of cooling demand. The rest of the cooling demand can be supplied by a direct fired Vapor Absorption Machine (VAM) working on the natural gas.

The calculation starts with a load data. The rate of power consumption can be known from the total annual electricity consumption of the building and taken as:

$$\text{Power rate} = \frac{\text{Annual consumption,kWh}}{\text{8640 h}}.$$

The averaged value of total annual consumption was taken as the load profile and different demands were found as:

Electricity demand=0.4⋅Power rate [kWe],

Cooling demand=0.5⋅Power rate⋅COP of compression machine/3.516 [TR], Heating demand=0.1·Power rate·COP of heat boiler/3.516 [TR].

According our example the hospital's energy demand meets by the National grid and a diesel generator used as a backup system and meeting total electrical and cooling load during power shortage. The total annual energy consumption is 4271 kWe [5]. As hospitals working 24✕7, the operational time is 8640h annually. Moreover it was taken into account that approximately 2h per day there are failure of national grid supply. This 2h the diesel generators supply energy.

A margin factor can be used to size a gas generator properly. In the current work the margin factor is 1.1. Therefore the size of prime movers is 1.1*ED. The heat produced by the generator was found from a heat to power ratio (HPR) for reciprocating engines, which was found as:

$$\mathrm{HPR} = \frac{\text{Heat output,kWth}}{\text{Electricity output,kWe}}$$

and equal to 1.3 [6].

Then from the Heat output the HD was subtracted. It was assumed that the rest heat converted to cooling by VAM. $\mathrm{COP_{VAM}}$ of typical VAM is 0.7 [6]. Therefore the cooling which obtained from the VAM was calculated as:

$$\text{Cooling VAM} = \mathrm{COP_{VAM}} \cdot (\text{Heat output} - \mathrm{HD}).$$

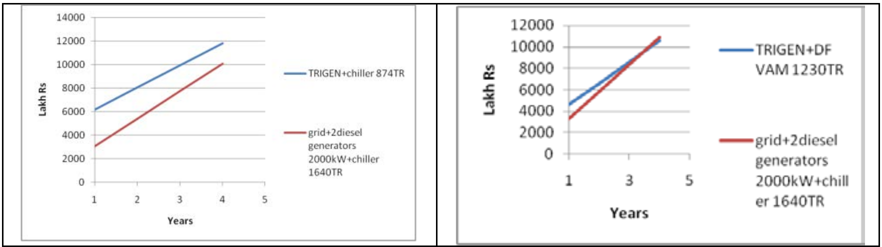
Then the Cooling VAM was subtracted from CD to obtain a supplementary cooling demand.

After the sizing of the system one can find information about the fuel consumption by respective generator (gas&diesel) from a manufacture's site (in this example: Caterpillar, *www.cat.com*) and use it to find annual fuel consumption. Then the annual operational cost can be found by multiplying the fuel consumption to the price of the fuel. The initial cost of TRIGEN was taken as one million Euro for each 1MW power.

The payback time was found as:

$$\text{Payback time, years} = \frac{\text{Cost of TRIGEN,Lakh Rs}}{\text{Annual savings,Lakh Rs/year}}.$$

The two different methods of Trigen design showed different results. As it was expected the oversized system trying to cover all cooling demand is economically unprofitable. The second method designed to cover just electricity demand and the supplementary cooling demand is covered by direct fired VAM. It has lower investment cost and therefore likely to be economically more attractive, what can be seen from the result of the comparative calculations (Figure 3). The payback time calculated for the first design is 9 years, meanwhile for second one is 5 years.



a) Extra electricity from the generator supplies chiller	Supplementary cooling demand covered by direct fired VAM

Figure 3: Comparative calculations of different TRIGEN systems

The results of the payback calculations were compared with the results of Final Report on Feasibility Study on the implementation of Indo German TRIGEN Project at Jai Prakash Narayan Apex Trauma Center made by Dalkia Energy Servises Ltd. [2]. It was shown that the total Trigen project's payback time period is 3.2 years for JPNATC. This result corresponds well with the calculation result made in the current thesis. The main difference in the results is due to the price of grid electricity in the Final Report was taken higher, since JPNATC has special contract with the power supplier, meanwhile in the current paper it was taken price (autumn 2012) for the common hospital buildings.

4 Conclusion

The Trigeneration technology is very suitable for hot countries like India. Moreover, India is an ideal place for introducing the Trigen technology, since it is not rich in natural resources, the economy and consequently the energy consumption is increasing daily, and the frequent power shortages force the owners of hospitals, hotels, offices and others to buy a power backups like diesel generators, with the conversion efficiency just about 20%. The calculated payback time in example of the hospital has shown that properly designed, installed and maintained Trigen system has return of investment of about 5 years, with operation time at least 20 years. Moreover the world policy of the carbon emission reduction and the improvement of energy efficiency make the Trigen system very attractive.

Overall, Trigeneration is very attractive for hot countries with growing industry and energy consumption. It has to be considered in energy strategy decisions of any country, and appropriate market assessment and payback calculation have to be done for each particular case.

5 References

1. Indo-German Energy Programme (IGEN). www.trigenindia.com
2. Final Report on Feasibility Study on the implementation of Indo German TRIGEN Project at Jai Prakash Narayan Apex Trauma Center. Dalkia Energy Servises Ltd, November 2010
3. Natural Resources Defence Council Staff Blog.

http://switchboard.nrdc.org/blogs/ajaiswal/bhaskar_deol_guest_blog_reduci.html

4. Energy efficiency in hospitals. Best Practice Guide. Ravi Kapoor, Satish Kumar. USAID ECO-III project, International Resources Group. March 2011
5. Energy Audit Results, presentation, BEE, GIZ
6. M. Ozdenefe, U. Atikol. Assessing the applicability of Trigeneration in the Hotel Sector, Recent Advances in Energy & Environment