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Review Article

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A Novel Concept of Reducing Carbon Footprint through Green Energy Recovery at NRL (Huge Power Generation at No Extra Cost)

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Abstract

Energy conservation has emerged as one of the major issues in the recent years due to the increasing gap between the ever rising demand & the limited supply of energy. On one hand, Energy requirement in our country is increasing in a very rapid rate. On the other hand due to this, the available Energy resources are depleting very fast. So, conservation and efficient utilization of energy resources is the first and most important step towards narrowing down this gap. The need of the hour is to utilize the available energy resources efficiently, wisely & judiciously and at the same time minimize the wastage and unnecessary utilization of the resources. We need to discover the hidden and untapped areas which have good potential of energy and thus reduce the rate of consumption of available non-renewable sources and fossil fuels. The other very important and undeniable fact of the today's world is that the rate of emission of Greenhouse gases is increasing day-by-day leading to Global Warming and various undesirable changes in the environment we are living in today. If we do not take necessary corrective actions today then it would be too late for tomorrow and our Future generation would suffer Keeping in view the importance of the future generation and with an objective of Energy conservation and to reduce some part of the Global Warming by reduction in harmful Green-house gas emission; an innovative and novel concept was devised in our Numaligarh Refinery Plant (NRL) in it's post expansion scenario.

Also an icing on the cake is that while brainstorming this ideas and thought, this very simple and innovative could be also conceptualized in the present Refinery configuration also. Putting this beautiful though in both the existing and post expansion set of the Refinery would indeed result into a great positive changes …….. **Let's see the beauty of this innovative idea …….. which harnesses the untapped & hidden potential through green energy recovery …….**

The above idea could also be conceptualized and applied in other areas or plants as a proactive measures to counter and minimize the ill effects of the so called the burning problem of "Global Warming".

This complete paper is subdivided into

- Brief introduction of existing Numaligarh Refinery Limited (NRL) & would-be Post Expansion scenario in case of NG
- Detail description of the schemes
- Advantages and Profits of the scheme
- Data analysis and Calculation
- Conclusion

Brief introduction of Present & Post Expansion Numaligarh Refinery Limited (NRL):

Nestling in the sylvan environs of the Brahmaputra valley where the beautiful rendezvous of water and land throws up myriad colours, **Numaligarh Refinery Limited (NRL),** which was set up at Numaligarh in the district of Golaghat (Assam) in accordance with the provisions made in the historic Assam Accord signed on 15th August 1985, has been conceived as a vehicle for speedy industrial and economic development of the region.

The **3 MMTPA** Numaligarh Refinery Limited was dedicated to the nation by the erstwhile **Hon'ble Prime Minister Shri A. B. Vajpayee on 9th July, 1999.** NRL has been able to display creditable performance since commencement of commercial production in October, 2000. It is located at Morangi, Golaghat district, Assam in India is a refinery owned by Numaligarh Refinery Limited, a joint venture between Bharat Petroleum (61.65%),

Oil India (26%) and Govt of Assam (12.35%). With its concern, commitment and contribution to socio-economic development of the state combined with a track record of continuous growth, NRL has been conferred the status of Mini Ratna PSU.

Product Range: Our product range includes LPG, Naphtha, Motor Spirit (MS), Aviation Turbine Fuel (ATF) Superior Kerosene Oil (SKO) High Speed Diesel (HSD), Raw Petroleum Coke (RPC) Calcined Petroleum Coke (CPC), Sulphur, Wax, Nitrogen, Mineral Turpentine Oil (MTO), Special Boiling Point Spirit (SBPS) and Liquid Sulphur.

In view of the projected demand growth of petroleum products in the country and also to retain its profitability and competitiveness in the long run. NRL intends to install a parallel new train for imported sour crude processing capacity of 6.0 MMTPA. So the Refinery configuration would be doubled. Many new Refinery plants like Residue Up-gradation Units and Auxiliary Units would come up in the post expansion configuration along with the Primary Processing Units, Light Ends Processing Units and Secondary Processing Units which are briefly given as below:

Primary processing Option
- 6.0 MMTPA of crude to CDU/VDU

Light ends Processing options
- Naphtha Hydro-treater/ Continuous Catalytic Reformer Unit (CCR)/
Naphtha Isomerisation Units (NHT/ISOM)

Secondary Processing options
- Full Conversion Hydrocracker Unit (HCU)

Residue Up-gradation options
- Solvent De-asphalting Unit (SDA)
- Delayed Coking Unit (DCU)
- Bitumen Blowing Unit (BBU)

Auxiliary Units
- Hydrogen generation Unit (HGU)
- SRU/SWS/ARU/TGTU
- LPG treating Unit

In the present NRL configuration of 3 MMTPA, an average power of approx. 35 MWHr is required. In view of the projected demand growth of petroleum products in the country and also to retain its profitability and competitiveness in the long run. NRL intends to install a parallel new train for imported sour crude processing capacity of 6.0 MMTPA. So, in the post expansion Refinery configuration and with the coming of many new additional units, the power demand of the Refinery in the post NRL expansion would increase manifold which is roughly about 74 MWHr. This means we would be increasing our fuel consumption to meet this huge power or we need to get it from the grid. In both the cases, a lot of fossil fuels would be burnt which would result an emission of a large amount of Greenhouse gases in the process. Now with this problem, how to fulfil our main objective of Energy conservation and to reduce some part of the Global Warming by reduction in harmful Greenhouse gas emission…….

Birth of an Innovative Idea of Green Energy Recovery

As we have seen just above that the power demand in the post NRL expansion is almost doubled 74 MWHr in addition to the present 35 MWHr. Now how to reduce some part of the power demand from that big demand of 74 MWHr without burning any fossil fuels …..??? We need to satisfy our two main objectives: reduce power demand & reduce Greenhouse gas emission. How to accomplish that very hard cracking mission …..??? We started thinking and thinking…… started brainstorming ourselves…… search into different angles and possible …… Finally we discovered a very simple and innovative solution to this problem which would help to meet both our objectives….. which gave birth to a beautiful innovative idea of "**Green Energy Recovery**". Now what's this idea about….. Let's see…..

In the post expansion configuration, our NRL would be needing huge amount of Natural Gas (NG>2 MMSCD, approximate **2.3 MMSCD**; MMSCD: Million Metric Standard Cubic Metre Per Day) which will be used for production of Hydrogen Gas (H2) and as a feed and fuel to the H2U generation plant. This NG will be received at around 40 kg/cm2 and supplied at around 32 kg/cm2. This NG pressure will be let down by a NG Pressure Control Valve (PCV). This will be a huge Pressure energy loss in the control valve as a huge amount of NG would be let suddenly down from 40 to 32 kg/cm2. So, we would lose a lot of mechanical energy in the form of PCV where high pressure NG is reduced through PCV to a low pressure without doing any useful work output in the NG PCVs. This gave us an idea …… why not this huge loss of pressure energy in NG CV be converted into useful output. Thus we have discovered the beauty and it's enormous hidden energy recoverable in the Natural Gas (NG) Pressure Control Valves (PCV). We have thought off of installing **NG Turbo-Expander-Generators** in parallel to NG PCVs and convert the huge mechanical energy loss into useful electrical power energy through the NG expander.

While calculating, we were awestruck to discover that we could recover a great amount of energy in the form of Electrical Power of an approx. **7.601 MWHr and that too without burning any single fossil fuel**. In the process, we saw that **an enormous amount of Reduction in Greenhouse Gas (CO2) emission of approx. 32969.715 Tonne per Year. This is the beauty of this beautiful innovative idea.**

Also an icing on the cake is that if we put this idea in the existing NRL NG network, we could extract another great amount of approx. **6.8 MWHr** with an added advantage of **29398.30718 Tonne of CO2** reduced annually. Let's see it in details …….

Description of Schemes in Details

- NG (>2 MMSCD, approximate 2.3 MMSCD) will be used for production of H2 in the post Refinery scenario and as a feed.
- This NG will be received at around 40 ksc and supplied at around 32 ksc.
- This NG pressure will be let down by a NG Pressure control valve.
- This will be a huge Pressure energy loss in the control valve.
- Now in parallel to this control valve, if we install one NG

Turbo Expander, then the huge Pressure loss will be converted into a very useful Electrical Power Energy through this NG Turbo expander.

- Normally this NG Turbo Expander will be in service. If it is out of service, we would switch over to the NG pressure control valve.
- Approximate huge Power of 7.601 MWHr would be generated without burning any Extra fossil fuel just through the Turbo Expander.
- Huge Amount of Reduction in Greenhouse Gas (CO2) emission of 32969.715 Tonne Per Year.

This scheme is shown in the figures below

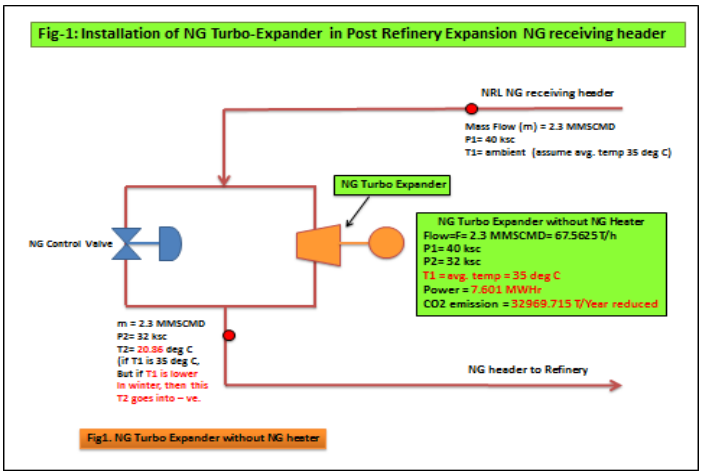

Figure 1: Installtion of NG Turbo Expander in post Refinery Expansion NG receiving header.

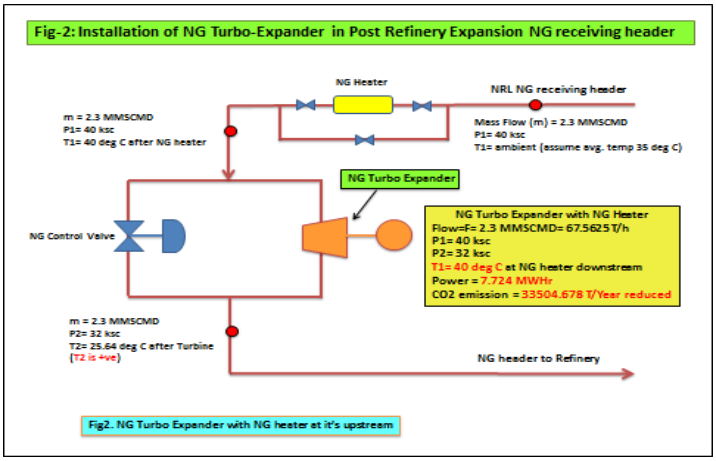

Figure 2: Installtion of NG Turbo Expander in post Refinery Expansion NG receiving header.

Calculation details

(a)Power Generation:

Following formulae are used:

$$Hs = ZRT1\left(\frac{k}{k-1}\right)\left(1-\frac{p2}{p1}\right)^{1-\frac{1}{k}} \text{ ------ equation-1}$$

***P=Hs*m*ys* ---- equation-2**

Where:

Isentropic head (Hs) developed in the NG Turbo Expander is calculated by the above equation-1,

Electrical Power (P) generated by the equation-2, and

Z = Compressibility Factor of NG = **0.92675**

R = Individual Gas Constant of NG = Cp - Cv = (2.35 -1.85) kJ/kgK = **0.5 kJ/kgK**

T1 = NG Temperature at Expander inlet (deg Kelvin, K)

k = ratio of Specific Heat = (Cp/Cv) = 2.35/1.85 = **1.27**

p1 = NG Pressure at Expander inlet (ksc) = **40 ksc**

p2 = NG Pressure at Expander inlet (ksc) =**32 ksc**

m = NG mass flow rate (kg/s) = **2.3 MMSCD = 67.5625 Tonne/hour**

Taking NG inlet temp as avg. **T1= 35 deg C = 308.15 deg Kelvin**

Putting all the values in the above formulae, we get

We get Power generated in the NG Turbo Expander is, P = 7601.473 MWHr

(b) NG Temperature at the outlet of NG Turbo Expander (T2):

$$T2 = T1\left(\frac{p2}{p1}\right)^{1-\frac{1}{k}} \text{-------equation-3}$$

T1 = NG Temperature at Expander inlet (deg Kelvin, K) = = **35 deg C = 308.15 K,**

k = ratio of Specific Heat = (Cp/Cv) = 2.35/1.85 = **1.27**

p1 = NG Pressure at Expander inlet (ksc) = **40 ksc**

p2 = NG Pressure at Expander inlet (ksc) =**32 ksc**,

Putting all the above values, we get,

T2 = 293.862 K = 20.86 deg C.

However, during winter seasons, NG inlet temp goes to lower sides approx.

T1= 13 to 15 deg C, then T2 is 272.88 K = -0.118 deg C (at T1 = 13 deg C)

So, to prevent this problem, we can **install one NG Heater at the inlet of the Turbo Expander** which will maintain the NG inlet Temp, **T1 at 40 deg C** (in all seasons). ----- This is shown in *above fig-2*

If T1=40 deg C, then T2= 298.63 K = 25.64 deg C.

This will also slightly increase Power output to 7.724 MWHr instead of 7.601 MWHr

(b) CO2 reduction

Reduction in CO2 emission (NG)
NG emits 0.502 kg of CO2 per kWh

So, reduction in CO2 emission is:

Reduction in CO2 Emission	
3815.939322	kg/h
91582.54372	kg/day
32969715.74	kg/year
32969.71574	Tonne/year
0.032969716	Million Tonne/ year

Cost Savings

Power = 7724.82 kWh (with heater in service, considering max. power)
Unit Cost of power = 2.68 rupees/KWh
So, Per Day Savings = 7724.81 * 2.68 = 24 = 496859.986 rupees / day

Per Day Saving (max)	**496859.986**	**rupees**
Per Month Saving (max)	**14905799.58**	**rupees**
Per Year saving (max)	**178869595**	**rupees**

Applying the same idea in the existing NRL NG network

We shall **install NG Turbo-Expander-Generators** in parallel to the existing NG Pressure Control Valves (PCVs) at 3 locations to recover lost mechanical energy in PCVs and convert it into useful electrical power energy through the expanders. During normal running conditions, they would be producing electrical power through normal NG flow. Again, there would be a **Huge Green Energy Recovery at no Extra Cost.**

(i) **1st NG Turbo-Expander-Generator** at Duliajan Numaligarh Pipeline (DNPL) NG receiving station at Numaligarh Refinery Limited (NRL).

- Here PCV reduces NG pressure from 40 ksc into 32 ksc; (ksc – kg/cm2).
- Maximum NG flow = 40 TPH
- Minimum NG Flow = 15 TPH
- If NG Turbo-Expander-Generator is installed in parallel to this NG PCV, then
- We would get approx. Minimum Power = **1687.65 kWh** (Pmin)
- Max Power = **4500.41 kWh** (Pmax)
- NG temperature at Expander outlet = **20.86 deg C** (T2)

(ii) 2nd NG Turbo-Expander-Generator at NRL NG KOD area

- Here PCV reduces NG pressure from 31 ksc into 4 ksc.
- Maximum NG flow = 7 TPH
- Minimum NG flow = 5 TPH
- If NG Turbo-Expander-Generator is installed in parallel to this NG PCV, then
- We would get approx. Minimum Power = **769.33 kWh** (Pmin)
- Max Power = **1077.06 kWh** (Pmax)
- But here, we may have one issue. The outlet NG Temperature after expansion would be in the negative side (**-73.68 deg C = T2**). To solve this issue, there are two probable solutions:
- **1st Solution: Reduce pressure ratio to 31:22** from 31:4, then NG temperature at Expander outlet would be 13.5 deg C, after this NG **pressure would be reduced to 4 ksc by PCV** ; or else
- **2nd Solution: Install pre-heater** and increase NG inlet Temperature to about 160 deg C, then NG temperature at Expander outlet would be **7.17 deg C**
- **1st Solution would be feasible.**

(iii) 3rd NG Turbo-Expander-Generator at NRL GTG NG conditioning skid

- Here PCV reduces NG pressure from 31 ksc into 22 ksc.
- Maximum NG flow = 9.7 TPH
- Minimum NG flow = 2.433 TPH
- If NG Turbo-Expander-Generator is installed in parallel to this NG PCV, then
- We would get approx. Minimum Power = **301.135 kWh** (Pmin)
- Maximum Power = **1200.578 kWh** (Pmax)
- NG temperature at Expander outlet = **18.114 deg C** (T2)

(iv) So, through 3 nos. of NG Turbo-Expander-Generators, we would have:

- **Total Pmin = 2758.120 kWH**
- **Total Pmax = 6778.051 kWh**
- **Thus Huge Green Energy at No Extra Cost…….**

The above schemes are shown in the diagrams as mentioned in fig-3 below:

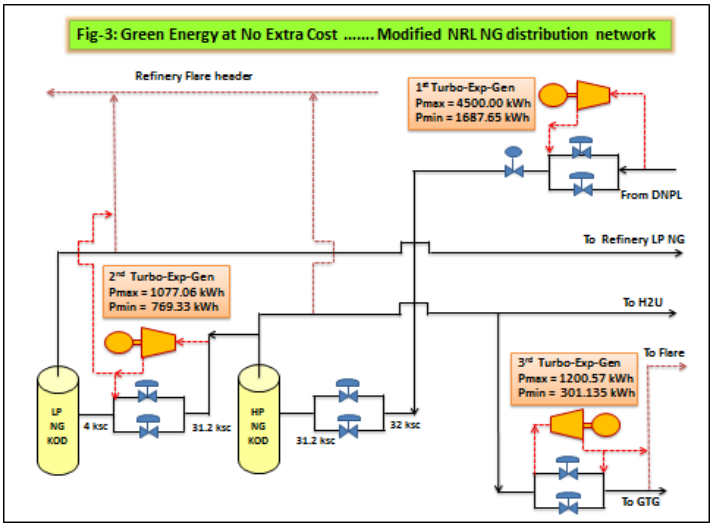

Figure 3: Green Enregy at No Extra Cost….. Modified NRL NG distribution network

So, net Total Electrical Power generated by all the 3 nos. of NG Turbo-Expander-Generator is:

Total P(max)	**6778.051**	kWhr
Total P(min)	**2758.120**	kWhr

Projected Savings through the schemes:

Per Day Saving (min)	1,77,402.2605	rupees
Per Month Saving (min)	53,22,067.814	rupees
Per Year saving (min)	6,38,64,813.77	rupees

Per Day Saving (max)	43,59,64.2721	rupees
Per Month Saving (max)	1,30,78,928.16	rupees
Per Year saving (max)	15,69,47,137.90	rupees

Reduction in CO2 emission (NG)		
NG emits 0.502 kg of CO2 per kWh		
So, CO2 reduced (min)	1384.5761	kg/h
	33229.8264	kg/day
	11962737.5	kg/year
	11962.7375	Tonne/year
CO2 reduced (max)	3402.58185	kg/h
	81661.96439	kg/day
	29398307.18	kg/year
	29398.30718	Tonne/year

Advantages of the scheme

- Huge Green Energy Recovery from the Pressure Energy which is lost in the NG Pressure

Control Valve.

- Brings into reliability, flexibility and redundancy of the operation point of view.
- Reduces overall Power Load of the Refinery.
- Power generation at Free of Cost.
- Thus produce Power without burning any extra Fossil fuels, Saves Fossil Fuels.
- Reduce Consumption Fuels cost.
- Reduce Fuel & Loss of the Refinery.
- Easy to set up.
- Only initial set up cost. No more running cost. Power generated at the expense of Energy recovered which otherwise was lost in the existing PCVs.
- It would be be a CDM Project (Clean Development Mechanism Project).
- It could be replicated in the other Refinery units also.

Conclusion

Thus, we could harness the untapped & hidden potential through green energy recovery by this simple and innovative scheme. It led to the discovery and utilization of huge untapped potential of lost energy in the NG PCVs by installing of NG Turbo-Expander-Generator in parallel to the NG PCVs. It would bring reduction in fossil fuel consumption and overall specific energy consumption of the Refinery. Finally it would result in the reduction of the emission of greenhouse gases (CO2) and thus contributes towards an Eco-friendly Environment (one of the means to reduce air pollution). Thus finally we could successfully fulfil both of our main objectives: reduce power demand & reduce Greenhouse gas emission.

Finally, the above idea could also be conceptualized and applied in other areas or plants as a proactive measures to counter and minimize the ill effects of the so called the burning problem of "Global Warming".

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