Underground Coal Gasification – Experience of ONGC

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Abstract. Underground Coal Gasification (UCG) is expected to be game changer for nation like ours that requires large amounts of energy but have few natural resources other than coal. ONGC, being an integrated energy company and due to synergy between E & P operations and UCG, envisaged opportunities in UCG business. Its first campaign on UCG started in 1980s. With its initiative, a National Committee for UCG was constituted with representatives from Ministry of Petroleum, Dept. of Coal, CSIR, CMPDIL, State of Gujarat and ONGC for experimenting a pilot. It was decided in mid-1986 to carry out a UCG pilot in Sobhasan area of Mehsana district which was to be funded by OIDB. Two information wells were drilled to generate geological, geophysical, geo-hydrological data and core/coal samples. 3-D seismic survey data of Mehsana area was processed and interpreted and geological model was prepared. Basic designing of pilot project, drilling and completion, strategy of process wells and designing of surface facilities were carried out. The project could not be pursued further due to escalation in cost and contractual difficulty with design consultant. ONGC second UCG campaign commenced with signing of an agreement of collaboration (AOC) with Skochinsky Institute of Mining (SIM), Russia on 25th November 2004 for Underground Coal Gasification (UCG). In parallel, MOUs were signed with major coal and power companies, namely, Gujarat Industries Power Company Ltd (GIPCL), Gujarat Mineral Development Corporation Ltd (GMDC),Coal India Ltd (CIL), Singareni Colliery Company Ltd (SCCL) and NLC India Ltd. Under the AOC, suitability study was carried out for different sites belonging to MOU companies. Only Vastan mine block, Nani Naroli, Surat, Gujarat was found to be suitable for UCG. Therefore, subsequent stages of detailed characterization & pilot layout, detailed engineering design were taken up for Vastan site. After enormous efforts for quite long since 2006, in the absence of UCG policy with Ministry of Coal (MoC), MoC finally allotted in-principle Vastan Lignite block to GIPCL in Aug. 2015. The project was to be carried out through a joint venture between ONGC and GIPCL. Unfortunately, efforts lacking sincerity were made by GIPCL for JV. MoC also did not bother adequately to monitor development of JV between ONGC and GIPCL. And finally, GIPCL citing the company to be small sized and it being without any experience on UCG, withdrew from the project in Dec. 2016. Now the block allocation process for the Vastan will have to be initiated afresh by MoC. The future of ONGC yet another UCG campaign seems to have once again hanged in balance. In view of the association with UCG for the decade and based on the feedback from the world-wide status of the technology, the author tries to make important suggestions in the paper for expeditious and efficient implementation of UCG technology in the country.

1. Introduction to UCG Process
Underground Coal Gasification (UCG) is a method for exploitation of energy from coal resources which are otherwise regarded as either uneconomical to work on by conventional underground coal extraction methods or are inaccessible due to depth, geology or other mining and safety
considerations. Through UCG, coal is converted into combustible gas which can be used for industrial heating (Figure 1), power generation or the manufacture of hydrogen, synthetic gas or fuel [1]. The gas can be processed to remove its CO$_2$ content thereby providing a source of clean energy with minimal greenhouse gas emissions.

Figure 1 Schematic of UCG process [2]

The basic UCG process involves drilling a combination of two wells into coal, one for injection of the oxidants (water/air or water/oxygen) and the other, some distance away, for bringing the product gas to the surface. The end product is a combustible syngas containing hydrogen, carbon monoxide and methane along with few other gases produced as result of thermo-chemical reactions. Major reactions are as follows:

**Pyrolysis**

\[
\text{Coal + Heating (in absence of oxygen)} \rightarrow \text{Char} + \text{CO}_2 + \text{CO} + \text{H}_2\text{O} + \text{H}_2 + \text{CH}_4
\]

**Char Oxidation**

\[
\text{Char + Oxygen} \rightarrow \text{CO}_2 + \text{H}_2\text{O}
\]

**Steam Gasification**

\[
\text{Char + H}_2\text{O} \rightarrow \text{CO} + \text{H}_2
\]

**Water Gas Shift Reaction**

\[
\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2
\]

Since the combustible components in syngas are mainly carbon mono-oxide (CO) and hydrogen (H$_2$), its calorific value (CV) is usually low (nearly 1/10$^{th}$ of natural gas, NG) (with air as oxidant) and around 1/5$^{th}$ of NG when only oxygen as oxidant is used.

2. Potential for UCG development in India

In India, almost 40% of the available coal resources are deep seated that is beyond 300 meters depth and mining these deposits in many cases through conventional mining techniques is difficult as well as capital intensive. The exploration activity carried out by agencies like GSI, CMPDI, MECL & NLC
etc. has established a coal resource inventory of 306 billion tonnes and lignite inventory of about 44 billion tonnes. However, only less than 1/6th of the coal is economically accessible through open cast mining. Out of total coal, nearly 66% could be potential candidate for UCG. Similar is the case for lignite as well. It is pertinent to mention here ONGC has encountered vast reserves of coal during oil & gas operation in Cambay basin. Estimated reserves in north Gujarat are of the order of 63 Billion tonnes of which 37 billion tonnes were estimated to be recoverable through UCG. In addition, the discoveries in the course of oil drilling in some basins have further, revealed existence of coal/lignite deposits at greater depths. The energy from such deposits may be harnessed through UCG technology for present day use.

Most of the activities related to underground coal mining like coal stockpiling, coal washing and waste disposal and activities at user end like ash handling and disposal are eliminated in UCG. UCG has lower overall capital and operating costs. The effect of UCG on environment is not significant as the main product coming out of the process is gas and the by products are either left in the ground, or re injected into the seam. It is therefore beneficial from health and safety point of view. UCG is considered clean coal technology as it offers separation of CO$_2$ from syngas and its disposal is possible [2].

3. ONGC's 1st UCG Campaign

ONGC, while drilling in search of hydrocarbons, has discovered large resources of coal in the state of Gujarat. The exploitation of these coal resources was not possible due to prevailing sub-surface conditions such as depths, geology, geo-hydrology, in-situ temperature and high gas content in the coal seam, etc. Underground Coal Gasification is the only method to exploit these un-mineable coal resources. Way back in 1981, an expert committee was constituted in relevance to UCG, with the approval of inter-ministerial meeting consisting of CMRS, CFRI, Govt. of Gujarat and ONGC. The committee visited a number of countries having UCG experience viz. France, Belgium, West Germany and erstwhile USSR and recommended that UCG is the only technology for exploiting deeper coal.

Subsequently, with the initiative of ONGC, a National Committee for UCG was constituted with the representatives from Ministry of Petroleum, Dept. of Coal, CSIR, CMPDIL, State of Gujarat and ONGC for experimenting a pilot at Mehsana in North Gujarat at a depth of 700 – 1100 m. Estimated reserves in North Gujarat are of the order of 63 Billion tonnes of which 37 Billion tonnes were estimated to be recoverable through UCG. With the concerted efforts of the Committee members it was decided in mid-1986 to carry out a UCG pilot experiment in Sobhasan area of Mehsana district which was to be funded by OIDB.

Major works carried out were:

a) Drilled two information wells UCG-1 and UCG-3.
b) All geological, geophysical, geo-hydrological data and core/coal samples collected.
c) Detailed lab studies on core and coal samples of well UCG-1, was carried out.
d) 3-D seismic survey data of Mehsana area was processed and interpreted.
e) Geological Model prepared.
f) Basic designing of pilot project, drilling and completion, strategy of process wells and designing of surface facilities.

The stumbling block for the progress was non finalization of the contract with M/s PDIL for surface engineering and design and finalization of the foreign back up consultant M/s BME through M/s PDIL. M/s BME had refused to accept the task of back up consultancy. The revised estimates were prepared under the guidelines from National committee by the UCG subcommittee. Depending on the year of completion (1992 – 1996) of the project the estimated cost of the pilot can vary in the range Rs.40 – Rs. 62 crores of which the foreign exchange components will be of the order of Rs. 16 to Rs. 26 crores (Rupees equivalent). This is against an initial estimate of the project cost of Rs. 9.6 crores. The committee decided that this R&D project should appropriately be funded by OIDB and hence OIDB was approached to provide the grant- in-aid to meet the cost of the project. The case was
processed for the approval of OIDB for funding this project by the OIDB’s grant-in-aid. The OIDB funding was not forthcoming due to the escalation of costs. For these reasons this project was discontinued in 1992.

4. **ONGC’s 2nd UCG Campaign**

ONGC signed an Agreement of Collaboration (AOC) with Skochinsky Institute of Mining (SIM), Russia in November 2004 for Underground Coal Gasification (UCG). MoUs were signed with companies like CIL, SCCL, NLC, Gujarat Mineral Development Corporation (GMD) and Gujarat Industries Power Corporation Ltd (GIPCL). Eleven sites were evaluated for suitability to UCG and out of those, only Vastan mine block, Nani Naroli, Surat, Gujarat was found to be suitable. Subsequent stages of detailed characterization & pilot layout, detailed engineering design were taken up for Vastan. Additional geological and hydro-geological data was generated for the design and execution of UCG pilot. High Resolution Shallow Seismic Survey was carried out for detailed characterization of the field. The data was analyzed and location and layout of UCG Pilot finalized. The detailed engineering design for construction of UCG pilot module is available. Ministry of Environment and Forest, Government of India has given the Environmental clearance for testing of pilot. AOC with SIM and MOUs with GIPCL, GMD and NLC are valid at present also.

Allocation of Vastan block for UCG had consistently been followed up with Ministry of Coal (MoC) for years since 2006. Finally, MoC allotted in-principle Vastan Lignite Block to GIPCL in August 2015. The project was to be carried out through a joint venture between ONGC and GIPCL. Allottee (GIPCL) was required to enter into an agreement containing the terms & agreement of allotment namely, Coal Mine Development & Production Agreement (CMDPA) with the Central Government.

Unfortunately, efforts lacking sincerity were made by GIPCL for JV. MOC also did not bother adequately to monitor development of JV between ONGC and GIPCL. And finally, GIPCL citing the company to be small sized and it being without any experience on UCG, withdrew from the project in Dec. 2016. They are in the process of intimating MoC in this direction. Now the block allocation process for the Vastan will have to be initiated afresh by MOC. The future of ONGC yet another UCG campaign seems to have once again hanged in balance. After the block allocation, the activities required before ground work at site includes mine plan approval, grant of mining lease by state govt., land acquisition followed by approach road and site preparation.

The very casual approach on UCG by stakeholders may be attributed to (i) much delayed approval of the UCG policy framework by Govt. of India and absence of model agreement which is to be signed between government and Allottee. A policy framework has been approved by the government in Dec. 2015. According to this, a model agreement similar to CBM, i.e. revenue sharing will be followed for UCG. CMPDIL has been made nodal agency for UCG implementation. (ii) Also not available is the bid documents and evaluation criteria for allotment of UCG blocks by MoC. Both the documents; model agreement and bid-documents, are under development at present by CMPDIL, Ranchi by hiring consultant through international bidding. CRISIL is the consultant which has been awarded this work. (iii) Worldwide sluggishness on UCG commercialization. However, the countries with huge resources of un-mineable or un-economically mineable coal/lignite need to be pro-active on usage of UCG.

5. **Recommendations for effective UCG deployment in India**

In view of the association with UCG for the decade and based on the feedback from the world-wide status of the technology, the author tries to make important suggestions in the paper for expeditious and efficient implementation of UCG technology in the country.

5.1. **Pilot trials are necessary for gaining confidence**

In the present scenario, the process of moving ahead for promotion of the technology has turned very slow. ONGC has already carried out major works on the Vastan UCG project. Site suitability, detailed
site characterization including seismic survey of the lignite seams and surface facilities design have already been completed by 2009 with consultancy of Russian Expert Skochinsky Institute of Mining (SIM) [3].

The whole process as detailed above is likely to take very long time and work already done by ONGC may go waste. In view of this, it is pertinent for MoC to permit ONGC or any other collaboration to carry out only the pilot at Vastan lignite block as soon as possible without waiting for any long term policy framework and CMDPA etc.

The UCG technology is site specific and its technical success need to be first established in the country through pilots only. The economics of an UCG project are clearly dependent upon the characteristics of the location. Additionally, the concept apparently does not lend itself to a once and for all solution. The solutions must be tailored to match the site. UCG undoubtedly will not be economical for all coal resources that are slated for development. R & D is needed, in fact, to define the resources, whose UCG would be cost effective. The technology requires detailed investigation, pilot experimentation and data evaluation before embarking on full scale commercial projects. The successful R & D program in UCG would be considered viable commercialization of clean fuels from coal at prices which would be competitive with existing energy sources. The countries: South Africa, Canada, China, Australia, New Zealand have gained rich experience through pilots/ demo usage of UCG syngas during 2007-13 [4].

‘Road Map to Develop UCG Technology in India’, prepared by the Working Group and the R & D Committee on UCG, under the auspices of the Office of the Principal Scientific Adviser To the Government of India, (PSA, GoI), Nov, 2008, has also recommended on the above lines: The Working Group to prepare the Roadmap was constituted by R & D Committee on UCG under the Chairmanship of Shri A.K.Hazarika, Director (Onshore), ONGC Ltd. Other members of the Group were CIL, GAIL, NLC, BHEL, CMRI, ISM, ONGC, Scientist E, Office PSA-GoI, MoC, CMPDIL, RIL, Essar Oil Ltd.

As per the Road-map, ‘there is an urgent need to carry out at least one UCG pilot scale study each in coal and lignite deposits, so that efficacy of the suitable technology under Indian conditions can be established [5]. This will give confidence to the Indian operators to adopt that technology and speed up the start of commercial operations. The committee was set-up to give appropriate recommendations regarding regulatory framework and related issues also. It proposed a framework to facilitate operations by various interested parties. Based on the data generated from the pilot scale studies/ commercial stage operations, this interim regulatory framework would be reviewed periodically by a committee appointed by MoC with representation from MoPNG. For this purpose, a facilitating and monitoring mechanism or committee was proposed to be set up at MoC, which was suggested as administrative ministry for UCG. A very important observation on applicability of existing act/ rules was made by the committee: Since syngas produced from UCG operations neither fall under the definition of ‘Coal’ nor by the definition of ‘Petroleum’ as per the existing regulations, a separate set of Regulations will have to be developed in due course of time for UCG operations.

As per the reports available in the public domain, China, Indonesia, Hungary, Canada and South Africa are in the process of preparing regulations on UCG in their respective countries to promote UCG. One Australian Pvt. Company, namely Carbon Energy, is participating in UCG research center in China in conjunction with China University of Mining and Technology (CUMT), one of the largest mining universities in the world.

5.2. Core Group needs to be developed

UCG operations are quite different than normal E&P operations. There is need for development of core group on UCG in any organization to take up the operational challenges. It is prudent to be technically conversant with intricacies of the UCG process. The major issues which need exposures are as follows:

- Drilling of UCG Gasifier [6]
- Cementation /Metallurgy for higher temperature – The expected temperature down hole in the cavity may vary 1000 to 1300 °C depending upon moisture contain in the lignite seam. The
completions are to be suitable for this temperature range. Additionally the cement has to be high temperature resistant.

- Suitability of site for UCG, estimation of gasifiable coal reserves and techno-commercial evaluation.
- Design of process layout
- Processing of UCG raw syngas – The syngas may contain suspended solids, H$_2$S, moisture nitrogen & condensate. This gas needs to be processed to make it suitable for sale.
- Handling of UCG syngas and condensate – As the constituents of the both are toxic in nature.
- Processing of condensate to extract valuable components such as phenols etc.
- Safety guideline to be observed at UCG Installation.
- Carbon capture and Disposal – UCG syngas is expected to contain lot of CO$_2$ which needs to be separated and disposed of. One has to be acquainted with latest development on carbon capture and sequestration (CCS) [7].

5.3. Integration with some end-usage
It is now established that well drilling and completion cost take more than 65-80% of the total cost in UCG, efforts need to make to get steady syngas volume maximizing volume with minimum number of wells. Syngas production alone may not be economically viable, it needs to be integrated with some end usage such as methanol, SNG, power, GTL, fuel cell, etc [8].

5.4. Formation of UCG Association
To promote UCG in the country, some sort of association by the energy PSUs may be formed which carryout advanced R&D in the area of UCG on the lines of South Africa and China. Recognizing the potential of UCG, Exxaro, Eskom, Sasol and Africary in South Africa have founded the South African UCG Association to champion the technology and create industry standards and training schemes.

It is with this objective that this project and the association thus formed will propel our energy starved country to the forefront of a global industry based on an unconventional technology.

6. Conclusion
The utilization of UCG technology in Indian scenario can be materialized in harnessing the energy from un-minable / uneconomically minable coal / lignite. ONGC has made two serious campaigns for the implementation of technology in the country, first in 1980’s and second in first decade of current century. The implementation did not reach logical conclusion because of absence of UCG policy for so long. Now after the approval of policy frame work in December 2015 and proactive approach of the central government in developing related documents, one can hope for change in mindset of stake holders towards UCG technology and visible UCG implementation on ground.

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