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Advanced CtL/CtG technologies for lignite

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ABSTRACT

Conversion of coal into dedicated hydrocarbons has been developed in the beginning of the last century and is still practiced in areas of the world with scarcity or insecure oil and gas supply.

Given the need for carbon in chemistry, possible political disruptions in oil and gas producing regions and the rise of renewable energy, lignite, as a secure domestic raw material, can serve as a chemical feedstock. Furthermore, it can serve as an energy storage using polygeneration, i.e. the ratio between power and hydrocarbon products can follow the fluctuating grid requirements.

In North-Rhine Westphalia (NRW), a committee for inquiry regarding the future of the chemical industry advocates this idea in its final report released in April 2015. This is in line with the position of RWE Generation (RWEG), which has been pursuing an alternative use of lignite besides the generation of electricity and has been expediting the related technology development for decades. So far, economical reasons prevented this option to be realized in commercial scale in Germany during the last 30 years.

Together with partners from science, as well as industry and partly government-funded, RWEG develops innovative plant concepts and technologies for Coal-to-Product concepts. Especially the challenges and chances are taken into consideration resulting from the given circumstances, a changing market situation and shifting political goals.

To meet the challenge of high investment costs, RWEG pursues a so called annex approach to improve the economic viability of the alternative use of lignite. Annex means to use synergies on infrastructure at established power plant or chemical sites, when planning a CtL/CtG plant.

In addition, the process steps are critically questioned, here the gas treatment plant, whether amine-scrubbing can be applied as a less costly alternative to the commonly used Rectisol scrubbing.

To reduce the CO_2 footprint and to use renewable energy for hydrocarbon products, there is, next to the way of integrating electrolytically produced H_2 into the process, another way, to substitute carbon consumption needed for the gasification temperatures by electrical heating.

1. Introduction

For more than 50 years now, lignite-fired power plants have been a guarantor of reliable power supplies in Germany. In addition to electricity generation, lignite is used as a refined product like activated coke used in filter technologies, as a carbon additive for steel production and more.

In the wake of the rapid expansion of renewables, however, alternative applications for lignite utilization outside the power production market will rise in importance and they will have a new role to play in future. A substantial aspect will be the so called chemical use of coal, i.e. the production of energy carriers or basic chemicals.

This has also been recognized by politics. In their report [1] issued in 2015, the Commission of Inquiry (Enquete-Kommission) "Future of chemical Industry in North Rhine-Westphalia" jointly supports this position throughout all political parties. This is in line with RWE's position. Alternative use of lignite will have a future beyond power generation, since it can be applied complementary to power generation to balance the expected increasing fluctuations in the power grid.

Concerning chemical use of coal the situation in Europe – especially in Germany due to its plans for energy transition – differs to that in Asia, MENA-region and North America, where CtL/CtG/GtL processes are already in operation.

In co-operation with partners [2] from science and industry – partially governmentally funded – RWE is investigating in detail the possibilities of chemical use and is developing innovative plant concepts facing future market changes and shift of political boundary conditions. An essential potential of alternative coal use is

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anticipated in coal transformation into basic chemicals and liquid fuels [3].

2. The CtL (Coal-to-Liquids) route and potential

2.1. CtL for lignite

Domestic lignite, as a primary resource, can be considered price stable and independent from price fluctuations induced by the global market. Especially concerning risk aspects, this could become a significant economic advantage for lignite based hydrocarbons.

The chemical industry is also significantly represented in NRW, therefore, from a micro-economic point of view, there is another advantage. The whole value chain - from mining up to chemical products - remains in NRW, respectively Germany.

A typical Coal-to-Liquid (CtL) process chain can be described as follows (Fig. 1):

- In a first step, lignite, typically containing water amounts of 45–60%, is dried. The in-house developed WTA-Technology (fluidized bed drying with heat recuperation) can serve as a highly efficient technology.
- In a second step, the dried coal is gasified, i.e. substoichiometrically burned to create a synthesis gas consisting mainly of carbon monoxide (CO) and hydrogen (H_2). This synthesis gas does not yet have the necessary ratio between CO and H_2, that is required by the synthesis. The missing H_2 is formed by the so called shift-reaction where water vapor and CO react to H_2 and CO_2. After establishing this necessary ratio the acidic gases (H_2S und CO_2) are removed.
- The cleaned synthesis gas can be transformed in the subsequent catalytic synthesis reaction to the desired products, e.g. a mixture consisting of naphtha (as feedstock for petro chemical industry), middle distillate (diesel, kerosene) and wax.

2.2. Potential of CtL processes to tie-in renewable energy

The CtL process already allows for several possibilities to apply renewable energies. On the one hand, next to coal also biomass can serve as a feed to the gasifier. On the other hand, by addition of electrolytically produced hydrogen into the synthesis gas, the necessity to produce hydrogen by the shift reaction lowers, resulting in less formation of CO_2. (Surplus power production by renewables could be usefully transformed into a valuable product, the problematic storage of hydrogen could also been avoided.) In case of sufficient availability of hydrogen, the possibility arises to partly substitute the coal by carbon dioxide as carbon carrier material. In this case, synthesis gas can be produced by a reverse-shift reaction. However, currently the considerably high costs for hydrogen production by electrolysis prevent an economic feasibility.

3. Process optimization and systemic extension

Two issues forming a challenge in designing a CtL plant shall be discussed in the following. These are volume of investment and specific CO_2 emissions of the process. Aim of the work presented is to put two approaches into discussion, reduction of investment costs by an alternative gas scrubbing process and CO_2 reduction by use of electrical surplus energy to put heat into the gasification process. Both approaches have been calculated using ChemCad.

3.1. Reduction of investment costs by application of alternative gas treatment

The main parameters for reduction of capital to be invested can be found in the cost intense process steps. The Rectisol-scrubbing (physical scrubbing by cold methanol), typically used in CtL processes, represents about 20% of the total investment of a CtL plant. This scrubbing is usually chosen, since it is superior to e.g. chemical scrubbing (Selexol, etc.) by means of purity of the synthesis gas.

Advantages of Rectisol-scrubbing are existing experiences with plants already in operation, high synthesis gas purity and the possibility, to directly separate sulfuric and carbonate gases. Disadvantages are the high effort regarding equipment (high amount of plant components) and the need for a refrigerant system with need for refrigerant scrubbing agent.

To remedy the aforementioned disadvantages, a concept of chemical scrubbing is considered which reduces the amount of equipment, avoids requirement of refrigeration processes but delivers synthesis gas of high purity. This alternative scrubbing combines (mainly) technically mature process steps from other technological areas for coal derived synthesis gas cleaning. Aim of the chemical scrubbing is to reduce the sour gases like CO_2 and H_2S to a level $\ll$ 1 ppm. The described process does not contain a CO shift for CO/H_2 ratio adjustment and it has some flexibility disadvantages compared to Rectisol. Furthermore, the discussed cleaning section is not able to handle contaminants like aromatics or higher hydrocarbons.

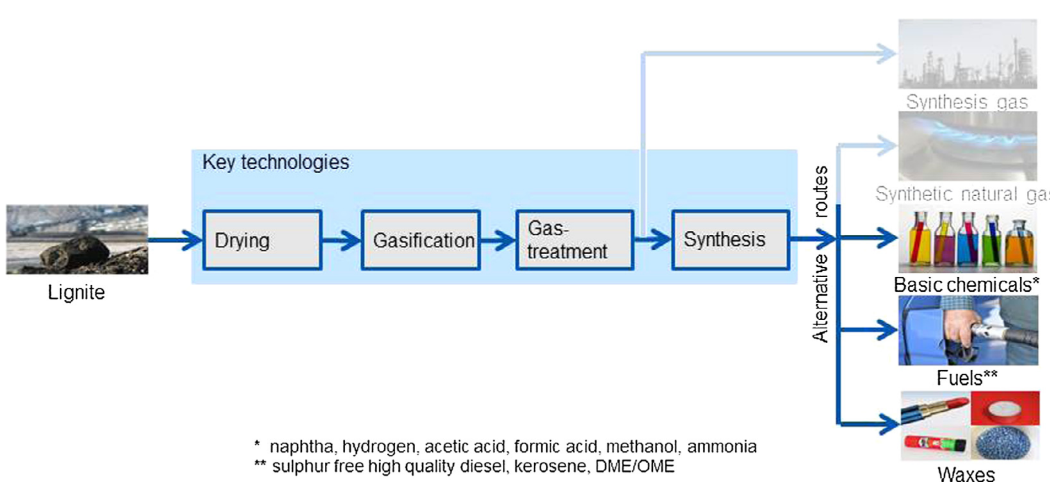

Fig. 1. CtL/CtG process chain with gasification is most promising for high product yield and quality.