Impact of plasma arc reforming deployment on economic performance of a commercial coal to liquids process

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ABSTRACT

Coal is integral to the supply of energy in many parts of the world despite the associated negative effects on the environment. Plasma arc reforming has the potential of making coal to liquids processes cleaner by reducing their greenhouse gas footprint. However, the chances of adoption without a clear understanding of how the process modification would affect economic performance are slim. In this study, financial models were built using an existing commercial coal to liquids process as a reference case. Economic analyses were done to evaluate the impact of deploying a plasma arc reformer on financial performance of a coal to liquids process. In building the financial models, the possibility of the introduction of a carbon tax was taken into consideration. The results show that deploying plasma arc reforming reduces the oil price required for break-even from $89/bbl. to $82/bbl., achieves a positive project NPV and exceeds the hurdle rate for similar projects. In the process, it reduces vulnerability to the introduction of a carbon tax. The requirement for extra low carbon electricity can be a hurdle to implementation, however the alternative carbon tax related charges are less desirable. Overall, it was concluded that the deployment of plasma arc reforming to coal to liquids processes is value adding. The project demonstrates that by implementing a cleaner production initiative it is possible to reduce greenhouse gas emissions of coal to liquids without significantly losing shareholder value.

1. Introduction

South Africa meets up to 30% of its fuel requirements through the use of coal derived liquid fuels and petrochemicals produced by a coal-to-liquid (CTL) plant. The CTL plant is sustained by the availability of cheap and abundant coal resources (Dry, 2002). Replacing this supply option with a cleaner alternative that gives the same level of economic benefit is difficult because of the scale of the coal to liquid contribution. The coal derived fuels sector contributes significantly through provision of jobs and tax revenue (Nkomo, 2009). In terms of making use of local resources to provide energy security, South Africa’s success with CTL is exemplary (Goldstein et al., 2006; Qi et al., 2012). However, CTL plant operation has significant negative environmental impacts. Hence, the South African CTL industry presents an important case for the evaluation of the impact of applying cleaner production.

Conventional CTL plants are some of the biggest point source emitters of carbon dioxide (Stoker and Conradie, 2015). Increased use of CTL would result in significant growth of greenhouse gas emissions, which would defeat climate change mitigation goals. However, given the significance of CTL contribution where it is being used, it is necessary to make existing and planned plants greener. The introduction of plasma arc reforming (PAR) technology into the CTL process has the potential of reducing coal usage, water requirements and greenhouse gas emissions from CTL plants. This would reduce the negative environmental impact of CTL (Mapamba et al., 2015). While it is acknowledged that just lowering the carbon footprint is not an ideal solution in the long term, it is a potentially helpful transitory solution. It is presented as a transitory solution because it would serve to bridge the current scenario where the sectors are fully on fossil fuels and the ideal scenario where decarbonisation has been achieved to a full extent. However, PAR can only have an impact if CTL operators adopt PAR modified plants. PAR modified plants can only be adopted if it can be

Abbreviations: ATR, Auto thermal reforming; CAPEX, Capital expenditure; CEPCI, Chemical equipment Plant Cost Index; CTL, Coal to liquids; HTFT, High temperature Fischer-Tropsch; IRR, Internal rate of return; NPV, Net present value; OPEX, Operating expenditure; PAR, Plasma arc reforming; PAT, Profit after Tax; SARS, South African Revenue Services; USD, United States Dollar; WACC, Weighted average cost of capital; WGS, Water gas Shift; ZAR, South African Rand.

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demonstrated that they meet technical and economic criteria of CTL operators. Mapamba et al. (2015) showed that when developed fully, PAR could meet the key technical criteria for integration in a CTL plant. However, whether a PAR modified plant could meet economic expectations of a CTL operator has not been ascertained. This paper seeks to reduce this knowledge gap by evaluating impact of PAR on CTL economic performance with the hope of addressing operator concerns that might stand in the way of PAR adoption. As a starting point, the authors focus on addressing three issues: 1) Evaluating how the economic performance of a PAR modified CTL plant compares to the performance of a conventional CTL plant? 2) Identifying conditions where the performance of a PAR modified plant is more attractive to a CTL operator? 3) Estimating how likely these conditions are?

Improving the understanding of the impact of PAR on economic performance of a CTL plant is important for two reasons. The first is that it provides a guide to PAR developers on performance targets that would give CTL operators an economic incentive to adopt PAR. CTL operators tend to be cost sensitive, as is common for commodity chemical producers, and are more likely to adopt technologies that help improve economic performance. This is supported by data from conventional oil producers who preferentially deploy lower cost rigs (Hughes, 2015; Williams, 2015). Since CTL operators are on the high cost end of oil production infrastructure spectrum, economic performance is a high priority for CTL operators (Aguilera, 2014). The second reason is that economic performance is an important aspect of sustainability. Understanding the economic performance of a PAR modified CTL plant gives an indication of the sustainability of use, which helps developers make configuration decisions that improve adoption of the PAR modification of CTL as a cleaner production initiative.

The remainder of this article presents an overview of the plant configurations in Section 2.1, financial modelling and economic analyses in Sections 2.2 and 2.3. Finally, Sections 3 and 4 present the results, discussion and conclusions of the study.

2. Approach

Using a South African CTL plant as a case study, a comparative approach was used in this study to evaluate the impact of deploying PAR on CTL economic performance. The economic data of a commercial CTL plant was used as the baseline plant and configuration changes were made to the baseline to predict the performance of a PAR modified plant. Financial models of the conventional and PAR modified plants were used to evaluate the impact of deploying PAR to CTL. Fig. 1 shows the anatomy of the evaluation process used in the study.

As shown in Fig. 1, the study has three aspects; 1) Definition of plant configurations, 2) financial modelling and 3) economic impact evaluation. Plant configurations are discussed briefly in Section 2.1, financial modelling in Section 2.2 and the approach to economic impact analysis in Section 2.3.

2.1. Configuration of coal to liquids simulation model

Two plant configurations were modelled to evaluate the economic effect of deploying PAR to CTL. A model of the Sasol Secunda plant was used as a representative conventional commercial CTL plant. The same model was modified to introduce PAR and that model was the technical basis of the plasma arc modified CTL plant. Brief descriptions of both plant configurations follow.

2.1.1. Conventional coal to liquids plant

Fig. 2 illustrates a simplified block flow diagram of a conventional CTL process. In the process, Coal is prepared to a size range that is suitable for gasification taking into consideration the gasifier type being used (Bell et al., 2011b). The gasifier uses oxygen and steam under high temperature and pressure to convert coal to synthesis gas (Zennaro et al., 2013). The specific conditions in the gasifier influence the amount of CO2 present in the raw synthesis gas stream (Bell et al., 2011a). If necessary, the ratio of hydrogen to carbon monoxide in the syngas is adjusted through the water gas shift (WGS) process (Zennaro et al., 2013). The use of the WGS process to produce hydrogen comes at the cost of producing carbon dioxide, which reduces the net benefit associated with the use of PAR. As part of the conditioning process, syngas, sulphur based compounds and carbon dioxide are removed by the rectisol process (Sun and Smith, 2013) or the selexol process (Mohammed et al., 2014). Purified syngas is then used to produce synthetic hydrocarbons, which are also known as syncrude, under high pressure with the help of a cobalt or iron catalyst (De Klerk, 2011). The syncrude is processed in the product work-up section in preparation for refining, upgrading or shipping to different product markets (De Klerk, 2011). Methane produced in gasification and Fischer-Tropsch synthesis is recovered in cold separation and recycled to produce more syngas by auto thermal reforming (ATR) (De Klerk, 2008).

2.1.2. PAR modified coal to liquid plant

The plasma modified CTL plant is similar to the conventional plant in many respects with the exception that the ATR in the synthol loop was replaced by a PAR system as shown in Fig. 3.

**Fig. 1.** Schematic of the approach to the evaluation of impact of PAR on CTL economic performance.
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