Techno-Economic Analysis of a Decarbonised Integrated Power Plant Fired by Syngas from Solid Wastes and Natural Gas: Case for Energy Storage

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Presentation outline

- Introduction
- Research question/Aim
- Methodology
- Results
- Case for energy storage
- Conclusion

Introduction

- Electricity is expected to play a critical role in the energy transition future.
- In Nigeria, there is huge gap between electricity supply and demand.
- At over 80% of total electricity generation in Nigeria, fossil-fuel fired power plants contribute significantly to climate change.
- Energy policies in Nigeria have not adequately considered the mitigation of carbon emissions through carbon capture and storage
- Huge waste generation; municipal solid wastes

Research Question

- Having announced its commitment to net-zero by 2060, how can Nigeria decarbonize it gas power plants with improved energy access

Aim

- To investigate a decarbonized power generation system in Nigeria for improved clean energy access.

Methodology

- ❑ System/ Technological configuration
- ❑ Analytical Method
  - Energy and exergy models
  - Economic models
  - Socio-economics of plant
- ❑ Solution Method
  - Genetic Algorithm
- ❑ Computational Platform
  - Engineering Equation Solver

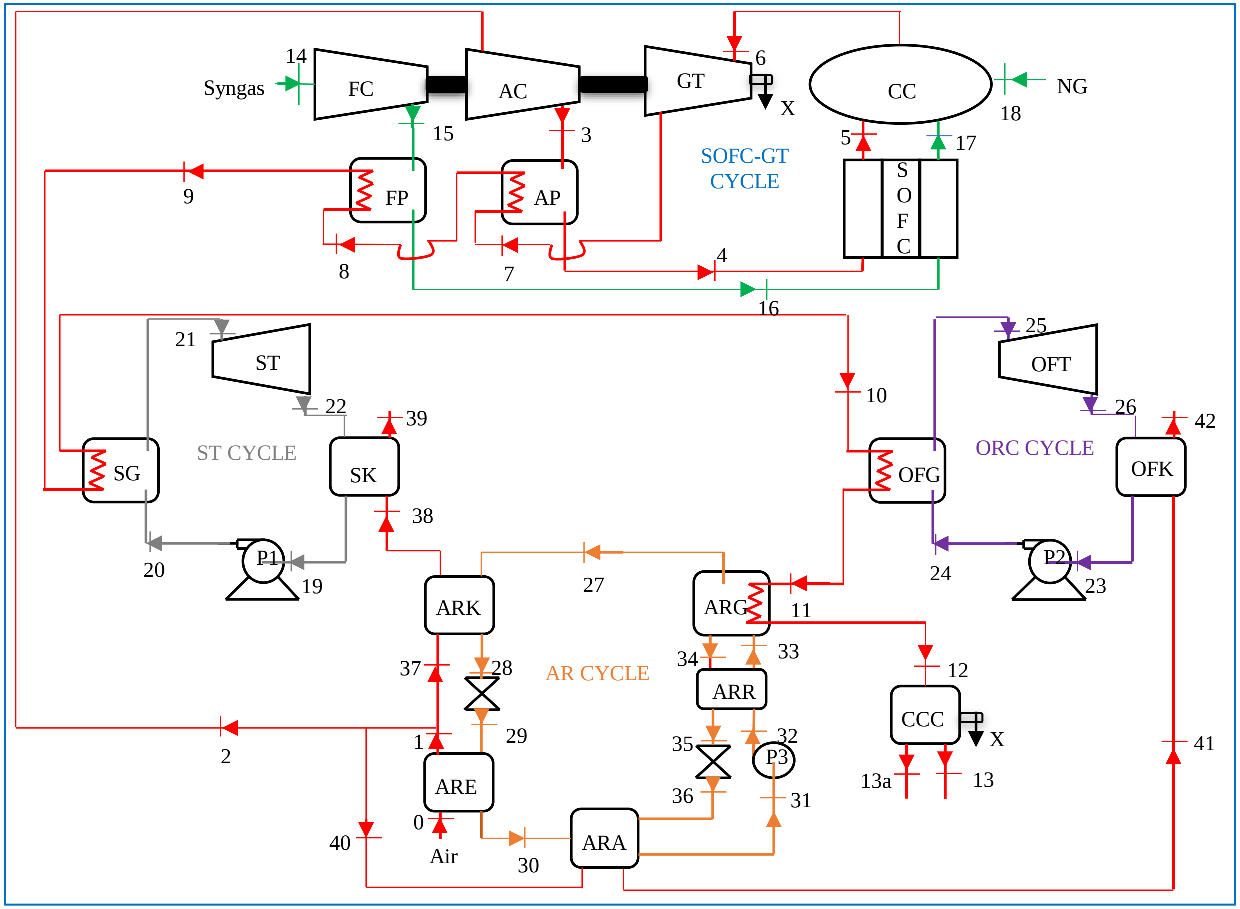

Figure 1: Proposed integrated power system

Results

Table 1: Thermodynamics performance of the power generation plant

Plant	Parameter	Units	Values
SOFC	Power	MW	54.68
GTC	Power	MW	102.2
STC	Power	MW	39.03
ORC	Power	MW	12.93
ARC	Refrigeration capacity	MW	39.2
CCS	CO_2 capture	%	93.5
SOFC-GT-ST-OR-AR-CCS	Power	MW	208.8
	Energy efficiency	%	42.93
	Exergy efficiency	%	42.49
	CO_2 emission factor	tonnes/MWh	0.029
	CO_2 transported	ktonnes/y	612.2
	CO_2 emissions	ktonnes/y	42.56

- At 7.23 kWh of electricity per household, the proposed system is able to provide electricity for 690k households in Nigeria
- At 42.9%, efficiency is lower than integrated power systems because of energy required for carbon capture at, estimates as 60.8 MW
- Transported CO2 is useful for enhanced oil recovery (EOR)
- CO2 emission factor of 0.03 tonnes per MWh is lower than 0.41 in Oyedepo et al. (2015)

Results

Table 2: Economic quantification of power plant

Parameter	Units	Values
Total cost of power plant	Million $	236.7
Unit cost of energy	$/kWh	0.141
Cost of CO_2 avoidance	$/tonne	110
Payback period	Years	5.2

- ❑ The unit cost suggests that the proposed system is more economical than back up gasoline/diesel generators in Nigeria at 0.3-0.6 USD per kWh (NERC, 2020)
- ❑ The cost of CO2 avoidance of the proposed plant put at 110 USD per tonne of CO2 may be justified by the social cost of CO2 emissions at 220 USD per tonne of CO2.

Case for Energy Storage

- ❑Seasonal variability of the primary energy (municipal waste) calls for storage.
- ❑Long period of waste treatment during raining season
- ❑Hydrogen energy storage (HEN) is a clean technology for storing the excess power during the dry season
- ❑Thus, the proposed configuration is retrofitted with a HEN.

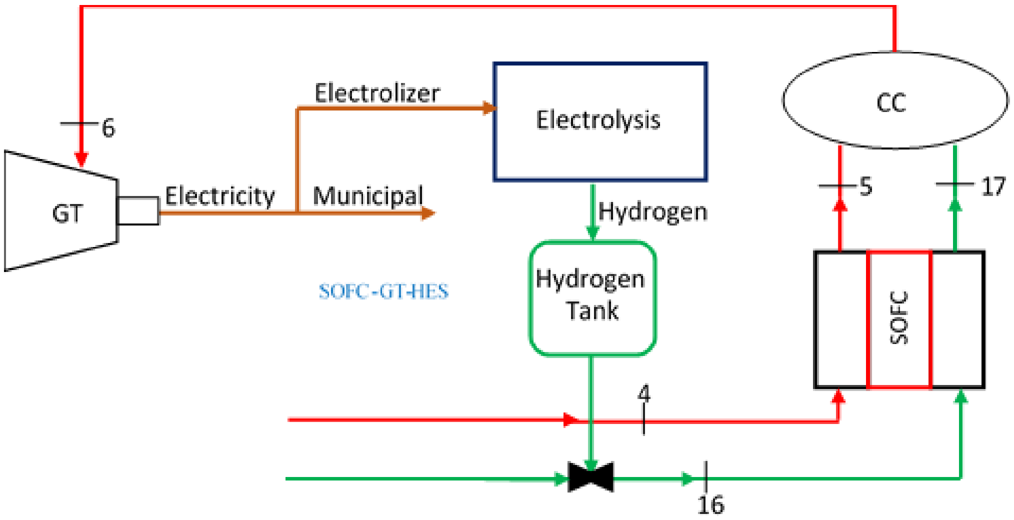

Figure 2: Process diagram to incorporate the hydrogen energy storage

Conclusion

- Developing countries are still struggling to meet the goal of energy access.
- The oil-rich developing countries are very challenged with meeting the Paris Agreement, since majority of their power plants are fossil fuel, Nigeria, for example.
- Carbon capture integrated power plant via cryogenic liquefaction can capture 94% of CO2 from flue gases for EOR.
- Integrated power plant with energy storage is critical for uninterrupted power and attainment of 1.5 ^{o}C energy future.

References

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- ❑Oyedepo, S. O., Fagbenle, R. O., Adefila, S. S., & Alam, M. (2015). Thermoeconomic and thermoenvironomic modeling and analysis of selected gas turbine power plants in Nigeria. *Energy Science & Engineering*, *3*(5), 423–442. https://doi.org/10.1002/ese3.79.

Thank you for listening