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Techno economic and environmental assessment of using gasification process in order to mitigate the emission in the available steam power cycle

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A B S T R A C T

As a result of the gas pressure drop in natural grid pipelines in the cold seasons, the feedstock of steam power plant is changed from the natural gas into the heavy fuel oil. Sometimes this change happens for the whole winter and causes lots of environmental problems for the cities near the big power plant. Gasification is a technologically advanced and environmentally friendly process of disposing the heavy fuel oil and the coal by converting them into the usable gas products named Syngas which mainly consists of CO and H_2. In this article, the feasibility study of gasification process application in the available steam power plant is considered. The 1000 MW steam power cycle is simulated and the natural gas, heavy oil, and generated syngas from gasification process of heavy fuel oil are selected as the feedstock. Results of economic analysis illustrate that in current economic conditions, the application of gasification process is not feasible in the available steam power cycle. It also shows that in the higher market prices of electrical energy, the revenue of system is much more than the emission penalty cost. So the difference between two types of calculation (considering emission penalty cost) is not noticeable.

1. Introduction

Iran has an area of 1,648,195 km^2, with a population of about 77 million based on the latest census in 2011 [1]. The country is a member of OPEC (Organization of Petroleum Exporting Countries) that controls about 78% of the world oil reserves and produces about 45% of the world oil production. Iran is one of the major exporters of energy such as crude oil and natural gas with approximately 9.39% of world oil reserves (154.58 billion barrels). It has the second largest reserves of natural gas in the world with approximately 17.42% of the world proven natural gas reserves which are about 1193 Trillion Cubic Feet [2]. The electrical energy generation capacity (New power plant construction) of the country increases with the rate of 5.2 percent per year during the last decade in the country. The total energy generation capacity of the country during 2005–2012 is shown in Fig. 1 [3].

Fig. 2 shows the different fuel consumptions in power plants section during 2005–2012 in the equivalent energy unit (TJ = 10^9 J) [3]. More investigations show that the natural gas consumption increases dramatically in the country during this period of time especially after 2010 but this increment mostly happens in the household application (for heating purpose) not the power plant section. The government investment for distributing the natural gas pipeline through the country and the usage of inefficient local heating instruments are the main reasons for this increment. In this condition and by rising the capacity of installed power plant, the heavy fuel oil and gasoil consumption increase to cover the lack of natural gas. So, the fuel oil and diesel consumptions increase in this period of time.

As a result of the gas pressure drop in the natural grid pipeline in the cold seasons, the feedstock of steam power plant is changed from natural gas into heavy fuel oil. Sometimes this change occurs for the whole winter and causes lots of environmental problems for the cities near the big power plant in the country same as Arak (Arak is a name of industrial and polluted city which is located in

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Nomenclature

A,B,C,D	components of equation
A	area, m^2
C	component cost
C_P	heat specific capacity, J/g.K
E	reaction activation energy
f	annual inflation rate
h	specific enthalpy, kJ/kg
i	annual interested rate
j and j_0	the real and nominal interest rate
k	kinetics constant of the forward reaction
k_{-}	backward constant of the forward reaction
k_0	pre-exponential factor
LHV	low heating value, kJ/kg
m	exponent for the dependence on the temperature
$\dot{m}$	mass flow rate, kg/s
P	pressure, Pa
Q	heat transfer, J
R	universal gas constant, kJ/kmol.K
r	net reaction rate
T	temperature, K
$\dot{W}$	power, W
W	work, J
X	molar concentration
x	coefficients in cooling tower equation
Y	lifetime, year

Subscripts

a	air
acap	annualized capital cost
act	actual
actv	activation
amin	annualized maintenance cost
aope	annualized operating cost
arep	annualized replacement cost
B	burner
c	cold
cap	initial capital cost
cond	condenser
f	fuel
g	gas
h	hot
i	number of reaction
in	inlet
is	isentropic
j	specie
nom	nominal
o	outlet
proj	project
rep	replacement
s	steam
ST	steam turbine
w	water

Greek letter

$\alpha, \beta, \gamma, \delta$	mole, kmol
η	efficiency
Δ	difference of inlet and outlet

Abbreviations

AB	annual benefit
ACS	annualized cost of system, US$
AV	additive value
CC	capital Cost Of Instrument
CRF	the capital recovery factor
LCOP	levelized cost of product
NAB	net annual benefit
NPV	net present value
OFC	operating flow cost
PC	prime cost
POR	period of return
SOPC	summation of product cost
ROR	rate of return
SFF	the sinking fund factor
VOP	volume of product

the central area of the country and 240 km far from Tehran). Fig. 3 shows the monthly average fuel consumption of power plant during the last five years. For the better comparison, all the fuel consumptions are converted into the equivalent magnitude of the energy content (TJ = 10^9 J) [3].

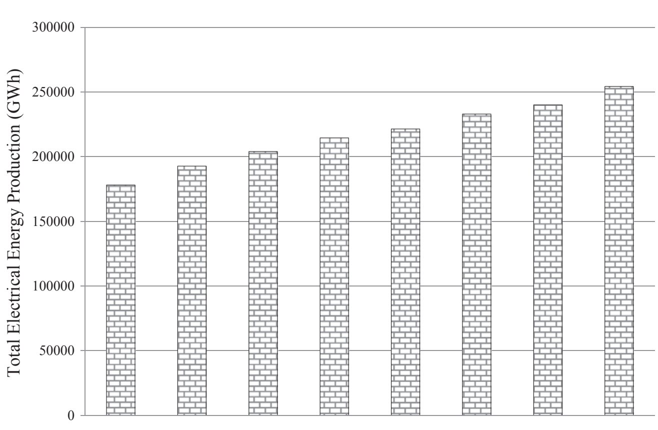

Fig. 1. The total energy generation of the country during 2005–2012.

As illustrated in Fig. 3, the greatest fuel oil consumption happens in December, January and February (the coldest seasons in the country). In this condition, the gas consumption of power plants decreases dramatically because it is used for the heating in household applications. In contrast to natural gas consumption, the electrical energy consumption is maximum in the summer. In this condition, the heavy fuel oil consumption increases to cover the need of fossil fuel for power generation. During the last five years, using the fuel oil instead of the natural gas in the winter has imposed financial and environmental pressures on the government. In some cases, this trend gives rise to the shutdown in some of steam power plant units in the country. That way, one of the government priorities is to decrease the environmental effect of fuel oil consumption during the cold season. It should be noted that the inversion phenomenon (Which is led to pollution such as smog being trapped close to the ground, with possible adverse infects on health) in the cold seasons makes the condition worse. Fig. 4 shows the emission production during 2008–2012 in electrical power generation sectors. It is illustrated that the rate of SO_X, NO_X, CO and CO_2 increases during this period of time [3]. The incremental trend of emission production during this period of time shows the growth in the fossil fuel power generation capacity. As mentioned before, after 2010 this increment occurs with the sharp incline. The main

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