Economic evaluation of seawater desalination by using SMART in the MENA

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1. Introduction

Fresh water is a fundamental necessity for human's life and sustainable socio-economic development. But it's a limited resource and only 2.5% of the world's water is fresh water, of which the majority is glaciers and ice caps. Especially, the Middle East and North Africa (MENA) region is the most water scarce region of the world and in recent years the amount of water available per person has declined dramatically. So the governments of this region have adopted the seawater desalination as the solution of water scarcity, and have plans to construct the more desalination plant, which use fossil fuel, nuclear, renewable energy as energy source for desalination process.[1] At this point, this paper show the economic evaluation of seawater desalination in the MENA(Middle East & North Africa) by using nuclear source. Especially the evaluation of economics is performed based on comparing the SMART(System integrated Modular Advanced Reactor) developed in Korea with general Combined Cycle Gas Turbine

2. The main body

2.1 Potential market for SMART

SMART is suitable for developing countries with a small electrical grid capacity, insufficient infrastructure and limited investment capability. And it is a complex facility for generating electricity and fresh water by using seawater desalination. Finally, the SMART has a characteristic for nuclear power plant. So the market which area is possible to introduce nuclear can be the potential market for SMART. It can be summarized as country or regions that want to solve the water shortage problem by using small nuclear plant. The Middle East and North Africa region is the most water scarce region of the world. And reflecting the growing interest for the introduction of nuclear power, this region can be the optimum site for SMART.

2.2 Economics Analysis

This paper attempts to estimate the economic impact of the SMART nuclear power and desalination construction in MENA by using DEEP(Desalination Economic Evaluation Program). And Electricity generation cost, Desalinated-water production cost, and Equivalent electricity generation cost were evaluated by assuming the CCGT(Combined Cycle Gas Turbine) to alternative source of SMART. Table 1 shows basic parameters of the power plant and desalination plant for evaluating the levelized cost.[2]

Table I: Input data [2]

		SMART	CCGT
Power cost data	Capacity(Mwe)	330	600
	Net thermal efficiency(%)	33	53
	Construction lead time(m)	36	24
	overnight cost($/kWe)	3,000 - 5,000	850
	O&M cost($/MWh)	6.81	4.09
	Fuel cost	15.43($/MWh) *	7.3/Mbtu
	Fuel escalation(%/a)	0	0.5
	Economic plant life	60	30
	Capacity factor(%)	90	85
	Discount Rate(%)	7	7
Desalination cost data	Unit size (m3/day)	40,000	40,000
	Base unit cost [$/(m3/day)]	900	900
	Plant availability (%)	94	94
	Water plant lead time	12	12

KEPCO Research Institute, Market demand forecast and economic analysis of SMART, 2007

* The value is calculated by assuming that the market price of uranium ore will stabilize at the level of USD36.29/lb (USD80/kg) to supply the uranium by 2030.

2.3 Result from DEEP run

The cost of electricity and fresh water production in combined cycle power plant is respectively 68.1$/MWh and 0.9$/m3/d. On the other hand, SMART has the cost 67.5~98$/MWh for the electricity production costs and 0.87~1.06$/m3/d for fresh water production cost according to the construction cost. CCGT using the natural gas is analyzed to have a more competitive edge. In order to have a competitive at market SMART needs to have scale at least 3,000$/kWe levels for the construction cost.

Table Ⅱ: Result from DEEP

Current model run : Outputs Summary		CCGT	SMART (3.0k$/kWe)	SMART (4.0k$/kWe)	SMART (5.0k$/kWe)
Levelized Capital Costs	$/m3	0.34	0.32	0.32	0.32
Base plant overnight EPC	$/m3	0.28	0.27	0.27	0.27
Other	$/m3	0.05	0.05	0.05	0.05
Levelized operating costs	$/m3	0.56	0.56	0.65	0.74
Heat	$/m3	0.32	0.32	0.39	0.46
Electricity	$/m3	0.10	0.10	0.12	0.14
O&M	$/m3	0.14	0.14	0.14	0.14
Transport	$/m3	0.00	0.00	0.00	0.00
Lifecycle Emissions	Mtn/yr	923	38	38	38
Thermal Utilization		62%	41%	41%	41%
Power lost	MWe	8	8	8	8
Power used for desalination	MWe	2	2	2	2
Power cost	$/MWh	68.1	67.5	82.8	98.0
Inputs Summary					
Power Plant Type		Combined Cycle	Steam Cycle	Steam Cycle	Steam Cycle
Fuel		Oil/Gas	Nuclear	Nuclear	Nuclear
Reference thermal output	MWth	660	660	660	660
Reference electricity output	Mwe	351	211	211	211
Electricity Production	GWh/y	2307	1317	1317	1317
Desalination Type		MED	MED	MED	MED
Total Capacity	m3/d	40000	40000	40000	40000
Feed Salinity	ppm	43000	35000	35000	35000
Combined Availability		80%	85%	85%	85%
Water Production	10^6 m3/d	11.67	12.35	12.35	12.35

And equivalent electricity generation cost method is applied to compare plants with the same potable output and to make a fair comparison with similar base power plant capacities. The equivalent electricity generation cost of CCGT is 7.87$/MWh and SMART has the cost of 7.77~11.22$/MWh according to the construction cost.

Thus, Smart construction cost should be the level of 3,000$/kWe to ensure a competitive like a case of electricity and water production costs.

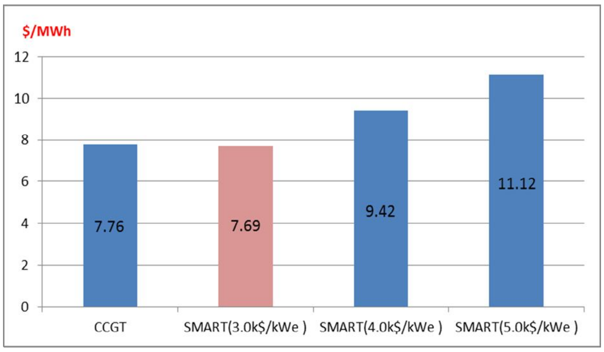

Fig. 1. Equivalent electricity cost for alternatives

2. Sensitivity Analysis

The major parameters, which have great effects on the economic, are identified to be discount rate, the escalation of gas price, uncertainties in the costs of new design of plants and equipment, and construction lead time. In this paper, a sensitivity analysis was performed with respect to the fuel cost escalation of CCGT, discount rate, and construction cost for SMART.

Table Ⅲ: Electricity cost ($/MWh) for various discount rate & fuel cost escalation

Power option	Fuel escalation(%/year)	Disconut Rate		
	%/year	5%	7%	9%
CCGT	0	63.1	65	67.1
	0.5	66.6	68.1	69.9
	1	70.3	71.5	72.9
	2	78.9	79.2	79.8
SMART(3.0k$/kWe)	0	55.7	67.5	79.9
SMART(4.0k$/kWe)	0	67	82.8	99.3
SMART(5.0k$/kWe)	0	78.3	98	118.6

Table Ⅳ: Water cost ($/m^3) for various discount rate & fuel cost escalation

Power option	Fuel escalation(%/year)	Disconut Rate		
	%/year	5%	7%	9%
CCGT	0	0.81	0.88	0.96
	0.5	0.83	0.9	0.97
	1	0.85	0.92	0.99
	2	0.91	0.97	1.03
SMART(3.0k$/kWe)	0	0.74	0.87	1.01
SMART(4.0k$/kWe)	0	0.81	0.97	1.13
SMART(5.0k$/kWe)	0	0.88	1.06	1.25

The effects of 5% discount rates show that SMART which construction cost is below 4.0k$/kWe has competitiveness in comparison with combined cycle power plant of 0.5% fuel escalation. On the other hand, the case of 9% discount rates show that SMART isn't competitive regardless fuel cost escalation.

3. Conclusions

Taken the economic analysis together, the most important issues for economic feasibility are the management of the construction cost. SMART have a competitive when the construction cost is 3,000$/kWe . Thus plan for the management of the target construction cost will be reflected in the design process like a notion of modularity and mass production methods. Another way is the design optimization of SMART and facility of desalination in a view of the mechanical properties. In other words, it is a way to design improvements for eliminating or sharing of duplicate functions between SMART and desalination facility and maximization the efficiency of energy use. Finally, construction cost can be rationalized by reduce the construction lead time. The potential weakness of SMART is the long construction lead time as compared with alternative. Moreover considering the smart is suitable for the country which is expected to have the most rapid economic growth in the near future, the construction lead time should be shorten. Managing these concepts to reduce the construction cost is enough to compensate for a disadvantage in power cost and water cost comparing with combined cycle.

4. Limitation of this study

Up to now, there is no experience of SMART construction or test site. For this reason, this paper cannot consider the actual economical cost for construction, O&M, and fuel. The result from this study needs more research to get actual input data for economic analysis and these issues remains as the further study.

REFERENCES

[1] Centre for environment and development for the Arab region and Europe(CEDARE), Water Conflicts and Conflict Management Mechanisms in the Middle East and North Africa Region, 2006.
[2] KEPCO Research Institute, Market demand forecast and economic analysis of System Integrated Modular Advanced Reactor, 2007.