The Economic Importance in Developing of the Electrical Storage Systems: A case study of Iran, Kerman

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In Iran, due to low electricity price, the development of electrical energy storage systems (EESS) is not economic, currently. This paper presents new economic indicators based on the value of EESS in the electricity network. The economic value of the battery is tested for three different applications: capacity benefit, avoidance of carbon emitting and loss reduction. In doing so, a comprehensive economic analysis is performed to explore the real benefit of the spreading EESS. In addition, a new economic term, opportunity cost, is established to show the importance of EESS which is calculated by comparison levelized value of energy (LVOE) and levelized cost of energy (LCOE). The proposed model is applied to investigate the techno-economic analysis in the electricity grid of Kerman, Iran. Such analysis introduces the importance of EESS in investment from national and regional electricity network viewpoints. These results also show that at the current retail rate, the EESS developing is not beneficial but from the viewpoint of national saving, the EESS developing is very attractive. In all scenarios, the LVOE of the battery is more than its LCOE. It can be shown that via the proposed economic platform of EESS, the efficiency in the electricity network could be increased by reducing losses and capacity requirements.

keywords: *Battery storage, value of storage, cost of energy, national viewpoint*

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NOMENCLATURE

Indices

C Distribution capacity investment cost (\$/KW)

$\mathbf{CB}_1$ Generation capacity benefit (\$)

CB_2 Distribution capacity benefit (\$)

CRF Capital recovery factor (%)

CP Carbone price (\$/gram. CO2)

DF Delivery factor (%)

d Discount rate (%)

EB_1 carbon reduction benefit in winter (\$)

EB_2 carbon reduction benefit in summer (\$)

HR^T Heat rate of thermal power plant (Litter/kWh)

HR^C Heat rate of combined cycle power plant (BTU/kWh)

h Index of hours

IC Investment cost of battery(\$/kWh)

i Index of years

LRB Loss reduction benefit (\$)

$LCOE$ Levelized cost of energy (\$/kWh)

$LVOE$ Levelized cost of energy (\$/kWh)

M operational expenditure (\$/kWh)

n_{yr} Battery lifetime (year)

$E_{disch\arg e}$ discharged energy in each year (KWh)

E_{gas} carbon production of natural gas (gram CO2/British thermal unit) or (g CO2/BTU)

$E_{gasoline}$ carbon production of gasoline (g CO2/BTU)

E_{mazut} carbon production of mazut (g CO2/BTU)

FP Fuel price ($/BTU)

n Peaking plant lifetime (year)

ON Overnight cost of peaking plant ($/KW)

OP Opportunity cost ($/KWh)

TV_{ES} Total value of battery storage ($)

1. INTRODUCTION

Nowadays, due to the increasing importance of variable renewable generation, capacity shortage, in parallel with the increasing demand for electrical energy, using electrical energy storage systems (EESS) is inevitable. EESS play a crucial role in the future electricity grid and their capability in storing electrical energy can be facilitating the traditional power system's challenges. The development of the EESS is driven by falling costs [1], high round trip efficiency, and various supportive policies that allowed investors to recover their investment costs [2]. The EESS can provide economic benefits to the electricity grid including improved reliability, peak smoothing, avoiding the capacity cost and ancillary services. The promotion of intermittent renewable technologies, such as wind and solar technologies lead to a higher value of EESS increases, because EESS can provide more flexibility and avoid curtailment of renewable output. In hot and dry areas of Iran, the cooling load is relatively high at midday as well as afternoon. Based on the Ministry of Energy (MOE) report in 2017, the summer peak load was 55443 megawatts which happened in the early hours of the afternoon [3]. Fig.1 shows the annual peak demand for electricity from 2010 until 2017. As it shows during the first four years; the peak occurred at night while is moving to midday since 2014. The electricity consumption in the peak time is increased by nearly 62 percent between the years 2010 and 2017, with regard to the fact that increasing residential and commercial demands were the main causes of this growing energy use. Also, in summer peak times, the old and low-efficient power plants enter the electricity network to compensate capacity shortage. Under these circumstances, the government spends a considerable budget for constructing power plants and new interconnected grids. Therefore EESS can provide capacity requirements and energy arbitrage in summer peak times. On the other hand, in winter, gas demand for household and commercial sectors is nearly six times more than summer. In this situation, the marginal electricity generators at night (peak periods of electricity in winter) are often liquid fuel plants and the marginal generators at day are natural gas plants. Therefore, EESS can provide a carbon arbitrage, meaning that storage can effectively replace liquid fuel generated electricity with cleaner natural gas-generated electricity. Therefore, there is a need to propose a business model to promote EESS based on economic benefits. Nevertheless, the main barriers in the penetration of battery systems into the electricity grid are their high cost of energy production [4].There is no complete market for electricity grid in Iran, and implementation of storages based on electricity tariff is not profitable due to the price gap between subsidized retail electricity rate and storage energy cost. Therefore, there is a need for new economic mechanisms to show the importance of EESS and to offer an attractive incentive to investment.

A number of studies have investigated the techno-economic analysis of batteries with a different objective in deep. The economic market benefit of battery storage for electric-utility-related applications is investigated in [5]. These benefits are categorized in different viewpoints, including: electric supply, renewable integration, ancillary service, and end-user customer. In [6] authors analyzed battery storage from aspects of residential photovoltaic self-consumption, by considering optimal size and charge rate Also, PV self-consumption in the presence of battery with considering the behavior of consumer has been investigated in [7]. A new method for determining the optimum capacity of wind generators and energy storage system is expressed in [8] with aim of investment deferral in distribution network. In [9] stochastic security constraint unit commitment problem is solved considering wind farm and storage system, where the storage system is modeled via benders decomposition method. A new application of storage systems is presented in [10] for increasing power quality in a microgrid with high penetration of renewable energy sources. Storage capacity, Technology costs, storage dispatch, revenues of the local use and selling to the grid can affect the profitability of residential storage [11, 12]. The authors in [13] analyzed the importance of EESS in providing flexibility at the high promotion of renewable energy sources. In [14] battery and combined heat and power, are modeled to obtain optimum participation in the day-ahead market considering hub concept. The peak shaving potential of battery storage with considering charging and discharging rate is evaluated in [15, 16]. The optimal location and energy capacity of storages with the aim of justifying investment costs in the distribution network are determined in [17]. Optimal size and scheduling of storage in the presence of high photovoltaic penetration are investigated in [18]. Optimal location and capacity of EESS and wind turbine considering three objectives and uncertainties are determined in [19]. The profitability of EESS under different incentives and a new electricity tariff is discussed in [20]. Energy arbitrage trading as revenue for EESS is discussed in [21].In this arbitrage, a storage operator buys electricity to charge at low prices and then it sells electricity at high prices. Usually, energy arbitrage is more economic if energy is traded close to real-time [22]. Some recent works [11, 12] measured economic benefits of EESS based on real electricity tariff, but tariff-based method for EESS is not attractive considerably in Iran. The present paper proposes a new incentive mechanism based on economic analysis for developing EESS in countries with high energy subsidies such as Iran. In doing so, first, an analysis is proposed to evaluate the economic benefit of EESS, including three main parameters: capacity benefit, carbon re-

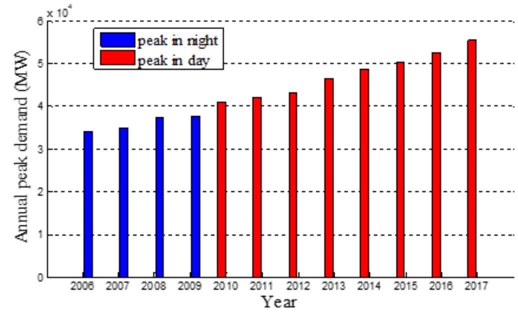

Fig. 1. Annual peak demand in the 12-year periods between 2006 and 2017

duction benefit and power loss reduction with help of avoided cost-based method. Then, a new effective incentive mechanism is designed for the promotion of EESS. A comprehensive Techno-economic analysis of EESS is performed, which quantifies the profitability of the project under both the current electricity price and the proposed incentive; accordingly, the novelties of this paper can be mentioned as follows:

- A new economic model is proposed to evaluate the economic benefit of EESS projects in different time periods
- An economic analysis is introduced to illustrate the importance of EESS from the perspective of national saving
- A new scheme of incentive based-on value of energy is presented for developing EESS

The rest of this paper is organized as follows: the economic values of EESS are presented in Section 2. Section 3 defines the economic analysis of EESS under the proposed incentive. Section 4 illustrates the simulation results and finally, Section 5 provides concluding remarks.

2. ECONOMIC BENEFITS OF EESS

This section discusses the calculation of main economic values of EESS in the electricity network, including: capacity value in peak periods, loss reduction and the ability to providing clean energy. EESS can provide additional values including the benefit from ancillary services, increasing penetration level of renewable energy sources, and helping to improve electric system reliability and power quality. There is a wide range of battery technologies in the electricity grid, including: lead-acid, high-temperature, flow and lithium-ion [23]. A comprehensive comparison of technical indicators of electricity storage systems is presented in Table 1.As can be seen, battery technologies differ in many techno-economic parameters including: depth of discharge, round trip efficiency, power density, energy density, cycle life, calendar life and investment cost. The cost reduction potential for storage technologies is significant for instance, the cost of lithium-ion batteries has fallen by as much as 73% between 2010 and 2016 [24]. In this section, the benefit of storage is taken from avoided cost- based method, because the tariff-based method may fail to represent real benefits especially in the case of subsidized electricity price.

A. Carbon reduction

One recognized revenue of EESS is carbon arbitrage – storing electricity when it is cleaner and selling it back to the electricity market when the carbon is embedded in the supply is high. In Iran, natural gas is the preferred fuel for residential heating and cooking. In winter, the gas demand for household and commercial sectors is nearly six times more than summer. In this situation, exports have been interrupted and the industry and the power generation gas utilization are switched to liquid fuel. In winter a storage device capture value by storing low-emission fuel (natural gas) and then injecting it during liquid fuel utilization in power plants. Carbon emissions cost reduction caused by a power plant with two fuels in winter has been calculated as follows:

$$EB_1\,(\$) = \sum_{i=1}^{n_{yr}} \frac{HR_i^c \times CP_i\left(\$/_{tco2}\right) \times \left(E_{gas}\left(^{gco2}/_{BTU}\right) - E_{gasoline}\left(^{gco2}/_{BTU}\right)\right)}{(1+d)^i} \quad (1)$$

Where, EB_1 is carbon reduction benefit in winter, i is the index of years, n_{yr} is battery lifetime, HR^c is heat rate of the combined cycle power plant, CP is carbon price, E_{gas} is carbon production of natural gas, $E_{gasoline}$ is carbon production of gasoline fuel and d is discount rate. Also in summer peak times, the old and low-efficient power plants enter in the electricity network to compensate capacity shortage. There is an old thermal power plant with mazut fuel in Kerman, which is only used during summer peak times. Therefore, there is a potential for storage in the reduction of carbon emissions from electricity generation. A battery can be charged with combined cycle power plant (efficient power plant) and discharged in peak times to decrease the use of a less efficient power plant. Carbon reduction due to the installation of battery in winter is calculated as follows:

$$EB_2\,(\$) = \sum_{i=1}^{n_{yr}} \frac{CP_i\left(\$/_{tco2}\right) \times \left(HR_i^T \times E_{mazut}\left(^{gco2}/_{BTU}\right) - HR_i^C \times E_{gas}\left(^{gco2}/_{BTU}\right)\right)}{(1+d)^i} \quad (2)$$

Where EB_2 is carbon reduction benefit in summer, HR^T is heat rate of the thermal power plant and E_{mazut} is the carbon production of mazut fuel.

B. Capacity benefit

Battery capacity benefit is related to a reduced need of generation units, transmission and distribution equipment. Here, the cost of postponing power plants entering at peak times and the avoided cost of distribution equipment are indicative of the capacity value of the EESS.

Generation capacity benefit

The EESS, which inject electricity in higher demand periods, can avoid/reduce investments associated with generation capacity. If the demand could be supplied in peak periods locally by EESS, the need for new capacities to supply the peak load would decrease. From a government point of view, it is more attractive to reduce the capacity shortage. Key drivers of capacity benefit include generation capacity cost, battery lifetime and discount rate. The capacity benefit of EESS is calculated as follows:

$$CB_1\,(\$) = \sum_{i=1}^{n_{yr}} \frac{ON \times CRF}{(1+d)^i} \quad (3)$$

Where CB_1 is generation capacity benefit due to the installation 1kWh battery and ON is the overnight cost of peaking plant. The capital recovery factor, CRF can be further defined as [25]:

$$CRF = \frac{d}{1-(1+d)^{-n}} \quad (4)$$

Distribution capacity benefit

The peak demand occurs in only a few hours per year. The load reduction on peak demands by EESS free assets to serve other services. Storages may be useful in deferring network upgrades, during peak demand when the distribution equipment may be at their rated capacity and it is unable to service the peak load. Fig.5 shows the load duration curve with and without storage. As can be seen, the distribution capacity benefit of EESS depends on feeder capacity, annual peak increasing and round trip efficiency of EESS. Deferral value equals to the difference between the present value of the expansion plan and the present

Table 1. comparison of technical properties of electricity storage systems [24]

	Pumped hydro storage	Compressed air energy storage	Flywheel energy storage	Lithium-ion battery	Lead-acid battery	Flow battery	High-temperature battery
Energy density range (watt-hour/liter)	[0.1-2]	[2-6]	[10-200]	[200-600]	[50-100]	[15-70]	[150-300]
Energy installation cost range ($/kWh)	[2-100]	[1-80]	[2000-6000]	[150-650]	[100-500]	[300-1000]	[300-600]
Cycle life range (full cycles)	[20000-100000]	[20000-100000]	[200000-1000000]	[1000-4000]	[500-2500]	[12000-15000]	[1000-10000]
Calendar life range (years)	[30-100]	[20-100]	[15-25]	[5-15]	[2-15]	[5-20]	[10-20]
Depth of discharge range (%)	[80-100]	[35-50]	[75-90]	[85-100]	[50-60]	[95-100]	[95-100]
Round trip efficiency range (%)	[80-90]	[55-60]	[80-85]	[90-95]	[80-85]	[65-70]	[75-80]

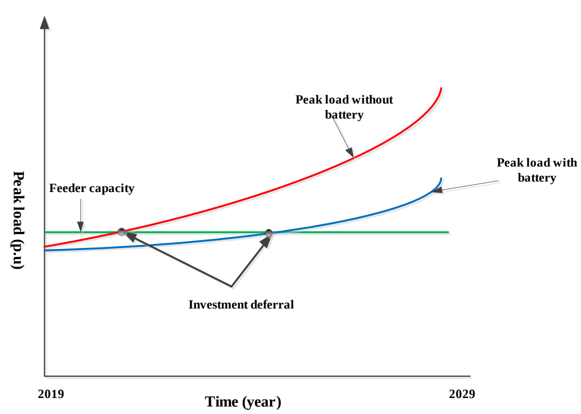

Fig. 2. Investment deferral in presence of the battery storage

value of the same plan with the battery. The net present value of investment deferral is presented as follows:

$$CB_2\,(\$) = \sum_{i=1}^{n_{yr}} \frac{C_i(\$/KW)}{(1+d)^i}\bigg|_{no\ battery} - \sum_{i=1}^{n_{yr}} \frac{C_i(\$/KW)}{(1+d)^i}\bigg|_{battery} \tag{5}$$

Where C is distribution capacity investment.

C. Loss reduction

Energy losses as the difference between the energy entering the electricity network and the energy consumed occur in the process of transmission and distribution. Energy losses usually are low during winter days and are higher at the early hour of nights. In the summer, the energy losses are high at midday as well as afternoon because of entering the cooling load. To reduce electricity losses, the utilities can be charged during low demand periods for its discharge when electricity demand is higher. The benefit of EESS is based on the difference between energy losses during peak times and off-peak hours. Local EESS avoid the need to transmit power over an electricity network. If the total energy discharged from EESS in a given distribution grid does not exceed the local demand, losses will be reduced. Losses act as a magnifier of value for capacity and environmental benefits since avoided energy losses result in lower required capacity and lower emissions. The economic benefit from loss reduction can be achieved by multiplying the reduction of energy losses due to deploying EESS in the system by the electricity price. The price of electricity is considered as fuel cost and heat rate of a power plant. Sometimes loss reduction benefit of the 1kWh battery may be expressed by the following equation:

$$LRB\,(\$) = \sum_{i=1}^{n_{yr}} \frac{\sum_{h=1}^{8760} \left[\left(\frac{1-DF^{di}_{i,h}}{DF^{di}_{i,h}} \right) - \left(\frac{1-DF^{ch}_{i,h}}{DF^{ch}_{i,h}} \right) \right] \times FP_i \times HR^c_i}{(1+d)^i} \tag{6}$$

Where LRB is loss reduction benefit, DFdi and DFch are the delivery factors of the electricity grid in discharge and charge modes of battery. DF is different in time periods and is low when demand is high. For example, when the loss factor of the electricity grid is 20% or DF is 80%, it means that to supply 1kWh electricity should be 1.25kWh is generated.

3. COST-BENEFIT ANALYSIS

The total revenue of battery created by combining all dierent applications is derived by:

$$TV_{ES} = EB_1 + EB_2 + CB_1 + CB_2 + LRB \tag{7}$$

Where TV_{ES} is the total value of battery storage, EB1 is according to emission reduction in winter times, EB2 is related to carbon saving in summer times. CB1 and CB2 are capacity related, that is, the extent to which battery is able to reduce peak load on the national grid and the distribution network, respectively. LRB is related to the loss reduction, which has various values at different times. Here, the concept of LCOE, LVOE and opportunity cost from the lithium-ion battery investment is presented.

LCOE

The concept of LCOE is used to compare the present value of the unit-cost of electricity for all main electricity technologies. The LCOE due to relative the simplicity and the ease of comparison is valuable for policy makers [26]. Here, the concept of LCOE has been transferred to the battery technology, which is calculated as follows:

$$LCOE = \frac{IC + \sum_{i=1}^{n_{yr}} \frac{M_i}{(1+d)^i}}{\sum_{i=1}^{n_{yr}} \frac{E_{discharge}}{(1+d)^i}} \quad \textbf{(8)}$$

Where IC is the investment cost of a battery, M is operational expenditure and $E_{discharge}$ is discharged energy in each year.

LVOE

Levelized value of energy storage is an economic assessment of the benefits of the storage system during its lifetime. LVOE could be defined as premium price per kilowatt-hour [27]. As long as the cost of a technology is less than its value, the government should support this technology.

$$LVOE = \frac{EB_1 + EB_2 + CB_1 + CB_2 + LRB}{\sum_{i=1}^{n_{yr}} \frac{E_{discharge}}{(1+d)^i}} \quad \textbf{(9)}$$

Opportunity cost:

Demand profile of electricity in Iran presenting a significant opportunity for storage integration. There are major opportunity costs if storage not deployed, including: high capacity investment, lower energy security, higher carbon emission, higher losses and congestion and higher other operational costs. Storage provides opportunities to meet demand requirement with lower cost. Here, opportunity cost is defined as the difference between LVOE and LCOE. Projects with a positive opportunity cost are deemed acceptable, while those that exhibit a negative opportunity cost are considered unacceptable [28].

$$OP = LVOE - LCOE \quad \textbf{(10)}$$

Where OP is opportunity cost.

4. NUMERICAL STUDY AND RESULT ANALYSIS

The proposed methodology has been tested on the Kerman electricity grid with a peak of 2265 MW. In this paper, lithium-ion battery technology considered for simulation. The round trip efficiency of the battery is the amount of energy which can be injected after being charged. The economic, financial and technical data used in this case study are provided in Table 9.

Table 2. the parameters used in this study

	parameters	value	Reference
Battery round trip efficiency	η($/kWh)	0.85	[24]
Discount rate	d%	10	[29]
Battery investment cost	IC ($/kWh)	400	[24]
Distribution capacity investment cost	C($/kW)	2000	[30]
Oil price	($/barrel)	40	[31]
Calendar life of battery	n_{yr}(years)	10	[24]

Table 3. Economic analysis of avoided carbon emission cost in winter

Carbon price ($/tCO2)	20			50		
Annual carbon price increasing (%)	0	5	10	0	5	10
EB1	0.55	0.89	3.375	1.375	2.225	8.44

A. Economic benefits of EESS

Carbon reduction

The Fuel type and heat rate of the power plant are two key factors in carbon reduction due to battery installation. Heat rate is a common measure of power plant efficiency, and it is energy input divided by electricity generated. In Kerman, there are several power plants; here, two main power plants with different technologies and fuels are selected to assess the carbon arbitrage, namely, combined cycle and thermal cycle. The amount of fuel consumed and the generated electricity from 2011 to 2016 are used for heat rate prediction. The ratio (BTU/KWh) of the fuel consumption to the total energy generated for Kerman combined cycle is depicted in Fig. 3, where the least square method is employed for the curve fitting Based on historical data, there are many times per year that combined cycle power plants consumed gasoline instead of natural gas. Fig. 4 illustrates the plotted record data of thermal power plant against each corresponding year, where the slope of this line represents the estimated incremental heat rate (Lit gasoline/Kwh). Here, carbon reduction is evaluated in two periods, including: summer times and winter times. Economic results regarding carbon emission reduction in Kerman's combined cycle power plant due to the installation of 1kWh storage in winter times are given in Table 10, according to different carbon price increase (0, 5 and 10%) and two carbon price scenarios. Carbon reduction benefit in the combined cycle power plant in all scenarios ranges from 0.55$ to 8.44. High carbon price leads to more avoided carbon cost.

In summer peak times, the thermal power plant (low-efficient power plant with mazut fuel) produces electricity. Carbon emit-

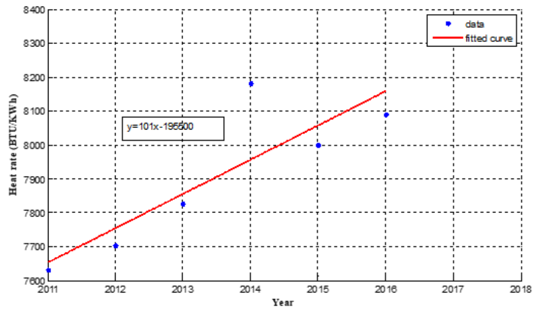

Fig. 3. Incremental heat rate for combined cycle power plant

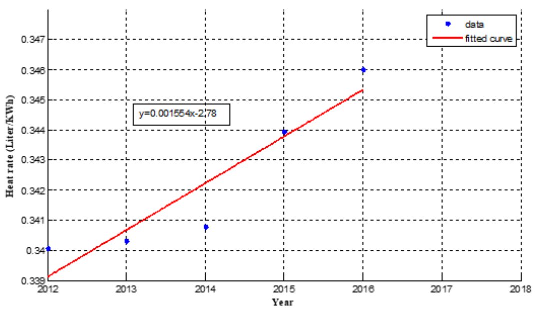

Fig. 4. Incremental heat rate for thermal power plant

Table 4. Economic analysis of avoided carbon emission cost in summer

Carbon price ($/tCO2)	20			50		
Annual carbon price increasing (%)	0	5	10	0	5	10
EB2 ($/Kw)	0.98	1.6	6	2.45	4	15

ted of liquid fuels is more than natural gas; therefore battery can lead to reducing emission. The stored energy from the combined cycle power plant can offset the use of the low-efficient thermal plant. Summer Economic results during battery lifetime are summarized in Table 4. According to the results of all scenarios, it is obvious that by increasing the carbon price, an enhancement occurs in the carbon benefit.

Generation Capacity benefit

In peak times, where electric generation capacity is limited, EESS could be used to offset the need to purchase and install a new generation in the electricity network. Economic peak demand occurs in hot, summer afternoons when air conditioners are on, so storage in such circumstances is able to reduce investment on peaking plants. These plants run during June, July, August and September from noon to 4 p.m., which are critical hours for the operator. Table 5 summarizes the value of 1kWh storage in avoiding the need for more peak generation in different scenarios. The annual capital cost of a peaking plant is determined by multiplying this cost through a capital recovery factor. The lifecycle benefit of EESS in all scenarios ranges from 338$ to 675$.

Table 5. Economic analysis of avoided generation capacity cost

Capital cost ($/KW)	500	750	1000
Annualized capital cost ($/kw-year)	55	82.5	110
CB ($)	338	507	675

Table 6. Economic analysis of distribution deferral capacity cost

Annual Investment cost increasing (%)	0			5		
Annual peak load increasing (%)	2	5	10	2	5	10
CB2 ($/Kw)	124	181	302	158	182	344

Distribution capacity benefit

The investment deferral in the distribution network is assessed as a benefit brought by subtracting the present value of the total investment required by a given storage system from that of the original (no given storage system). Feeder maximum load, peak demand increasing rate, EESS round trip efficiency, affect the benefit of storage. Battery systems can defer investment in distribution equipment since these reduce peak load. Table 6 displays the capacity benefit of EESS, computed in different annual peak increases. It can be seen that with an increase in deployment rate and annual peak, the total value of deferral increases. Furthermore, Table 6 illustrates the sensitivity of capacity benefit to different annual scenarios.

Loss reduction benefit

In Iran, the electricity grid suffers from lack of perfect power market and subsidized electricity price, thus the effect of loss in locational marginal price is not visible. Here cost of loss is considered as a portion of fuel cost (in combined cycle power plant). There is a role of thumb for relating natural gas prices to global oil prices [32]. This is the 10-to-1 rule, in which the natural gas price is one-tenth of the crude oil price. The variations in DF according to both season and time of day are tabulated in Table 7.

Economic results regarding loss reduction due to the installation of 1kWh battery in different scenarios are given in Table 8, considering the natural gas price at 4$/MBTU. As can be seen, the benefit of battery in the summer is higher than the winter. Also, the total benefit of 1kWh storage is 2.5$.

B. Cost-effectiveness of EESS

In order to investigate the cost-effectiveness of 1kWh battery, two distinct scenarios were conducted as follows:

scenario #A:

In this scenario, the benefit of battery is calculated by considering carbon price of 20$/tCO2, Annual carbon price increase of 5%,

Table 7. Variations of electricity network conditions in different periods

Season*	Periods	Hours	Delivery factor (%)
Summer	Peak.	12p.m.-5p.m	82
	Part-peak	7p.m.-12p.m. 5p.m.-23p.m.	88
	Off-peak	23p.m.-7a.m.	92
Winter	Peak	6p.m.-9p.m.	88
	Off-peak	9p.m.-6a.m.	94
	Part-peak	6a.m.-6p.m.	92

Table 8. Economic analysis of avoided fuel cost

	Summer peak	Winter peak
ALC ($/kWh)	1.6	0.9

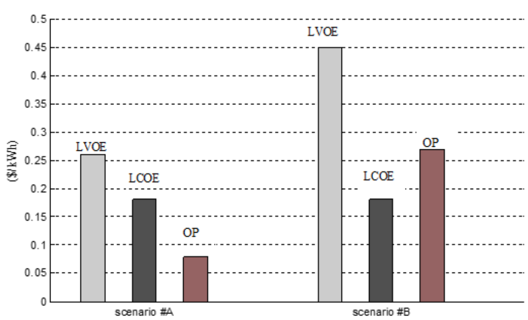

Fig. 5. value and cost of EESS in two different scenarios

peak plants capital cost of 750$/KW, annual peak load increase of 5% and annual Investment cost increase of 0%.

scenario #B:

In this scenario, the benefit of battery is calculated by considering carbon price of 50$/tCO2, annual carbon price increase of 5%, peak plants capital cost of 1000$/KW, annual peak load increase of 10% and annual investment cost increase of 5%. Fig. 5 shows graphically the LCOE, the LVOE and the opportunity cost of 1kWh battery in two scenarios. In scenario #A, the LVOE is 44% more than the LCOE and the opportunity cost is 0.08$/kWh. In scenario B, the LVOE is 150

5. CONCLUSION AND DISCUSSION

An economic profitability analysis of electrical battery storage has been presented in this paper in countries with subsidized electricity prices such as Iran. Current retail rates in Iran do not represent the marginal value of the battery; therefore, the implementation based on the tariff model is not economical. In this paper, a benefit analysis based on avoided cost method is given, which is achieved from carbon arbitrage, avoiding generation capacity, deferring distribution system upgrade reducing loss. The simulation results have been modeled with data measured from two real power plants in Kerman. The results have led to the following potentially useful conclusions:

- From a national viewpoint, the implementation of a residential battery is an attractive option.
- The benefit of the battery is high in some cases where there is a power plant with low efficiency.
- According to the avoided cost method, Battery provides a high capacity benefit, which is not clear in Current retail electricity rates
- According to the economic analysis, the value of the battery is more important than the cost of the battery, which is a fundamental solution for policymakers and government.
- Viewed from the techno-economic perspective, not promoting the battery is a burning opportunity.

The study is useful for government, operator of the electricity grid and investor in several ways. The results of capacity saving and carbon reduction will create a solution for the government to implement support policies for developing battery storage. Investigating the complementary model of battery benefit based reliability improvement and asset management is worth studying in future research.

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