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Assessment of Wind Energy Use to Store the Water for Generation Power with Two Stage Optimization Method

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ABSTRACT

In recent years, energy predicament and environmental problems in the world caused by fossil fuels combustion make us to pay serious attention to optimizing energy consumption and using renewable energies. One of the potential renewable energies which can be helpful in electricity generation is harness wind and water energy or using these two kinds of energy simultaneously. In this study, to provide a part of electricity in Azadi complex, 2 wind turbines with 12 different scenarios are used. In addition to provide some parts of the consumed electricity, they provide consumed electricity for water pumps which pump the sport complex lake water to a reservoir with 30000 cubic meters capacity and 20 meters height which provides remainder the consumed electricity. In this model, with regard to the uncertain amount of electricity consumption, 3consumption scenarios with three probabilities are pumped every day into a pool and a few of it is used for electricity consumption and the surplus is sold to the agricultural sector and irrigation of green spaces. The GAMS software and two stage optimization methods in two states, with and without considering the risk for optimization are used and in both states, profit and net profit in each scenario are computed.

1. INTRODUCTION

One of the most important cases which nowadays has a great effect on the international relations and development of countries, is providing the needed energy. At the present time, the most important resources of energy preparation which provide about 90% of the world needed energy are fossil energy sources [1]. These resources known as irreplaceable resources are running out and their prices are affected by the world political and economic situations.

Using Pumped Hydroelectric Energy Storage (PHES) started as early 1890 in Italy and Switzerland. The majority of plants were built from 1960s to the late 1980s. This was due to rushing in to nuclear energy after the oil crises in the early 1970s. In the United States and European countries PHES development closely correlated to the nuclear development. PHES was used as a system tool to supply energy at times of high load demand and to allow base load nuclear units to operate in their base load mode during low load demand period. However, in countries with rich hydro energy and no nuclear, PHES was developed primarily to enhance the operation and efficiency of large scale hydro power plants. In addition PHES provided power system management capabilities such as balancing, frequency stability and black starts [2].

The benefits of adding wind power to the power system can be summarized as in the following: 1. Reduction in overall generation cost as less fuel is consumed in conventional power plants and 2. Reduction in carbon emission as less fossil fuel is burned. However, due to the inherent variability of wind, increasing wind power integration may create negative impacts on the power system reliability. These negative impacts may demand an increase in the cost of maintaining the same level of power system reliability, also known as wind integration cost. In addition, such negative impacts may offset the benefits of wind power and become significant as more wind power is integrated into the power system [3].

Moreover, using these energy resources due to issues such as lacking of security in providing energy and the worthiness of these kinds of fuels including peripheral industries of oil and after all environmental issues caused by useing these fuels has made a lot of problems on earth ecosystem and as a result attentions are focused on the other resources [4]. Regarding the population

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growth and increasing demand for energy, finding the alternative energy resources is necessary and attention centers on energy resources that are renewable and interminable with no problems caused by fossil resources such as global warming and contamination of the harmful gases and most importantly its different kinds to be available free in the most regions of the world and because of this different usages of renewable energies at global level is grown.

Supporting private sector, the government buys the guaranteed electricity with tariff of 18.5 cents in return for each kWh. Last year, 44% of the power plant's consumed fuel has been liquid fuel that worth in average 10 cents in a liter. About 6.3 kWh electricity is produced in power plants that in exchange for a liter fuel and for every kWh cost about 20 cents without considering the transferring and distributing expenses. This statistics show that using renewable energies is quite justifiable [5].

In this research to provide electricity, two types of renewable energies including hydroelectric and wind energies are used. The wind energy is gained by construction of two wind turbines and hydroelectric energy is gained by an artificial pool that is constructed upward of the Azadi sport complex lake. In addition these two energies are renewable and are utility to make maximum use of the potentiality with optimization of two stage method in GAMS software [6] of the produced energy.

2. STUDY OF WIND STATUS IN AZADI SPORT

Like other renewable energy resources, the wind energy is geographically extensive and at the same time scattered, non-concentrated and almost always available. Naturally, wind energy is fluctuant, intermittent and doesn't blow permanently. When the sun light reaches the rugged levels of the earth, the temperature and pressure changes and this leads to the creation of wind , also transferring the heat from tropical to polar regions by atmosphere, caused by the earth diurnal movement, creates wind too. By studding the wind potential energy in any place solutions of energy production in vast scale is examined and personal goals in relation to wind energy utilization in future would be determined. To assess the potentiality, economic, technical and organizational factors as well as factors related to weather would be considered.

To measure the potentiality of the wind energy in Azadi sport complex, wind information of the Eshtehard's anemometer station is used. Eshtehard station is placed in the right direction with the chosen region, both of them are influenced by the same streams of wind and this is why choosing this station seems rational [7]. Inserting wind information from Eshtehard station in excel wind analysis software [8], following results are obtained:

2. 1. Average Speed

Since in most anemometer stations the data shows variable wind speed, it is recorded every 3 seconds and the average of 10 minutes is calculated and used [9].

2. 2. Weibull Function

Weibull distribution is one of the bound probableones, represents the probability of high and low speeds [10]. The curve should not be close to the vertical axis, but if it happens the low speeds possibility willbe ascended and if the curve is far from the vertical axis, the probability of high speeds will be ascended. But, for very high speeds the probability decreases sharply. Usually for Weibull function a numerical definition named K is assigned and usually K=2 is favorable. Distribution of the wind speed data using weibull function is shown in the following equation. To calculate the power output important parameters such as K and A parameters are calculated and wind share evaluated.

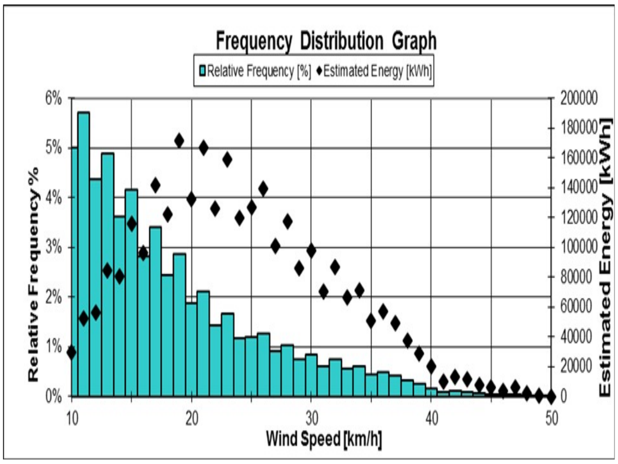

Figure 1. Weibull function of Eshtehard station.

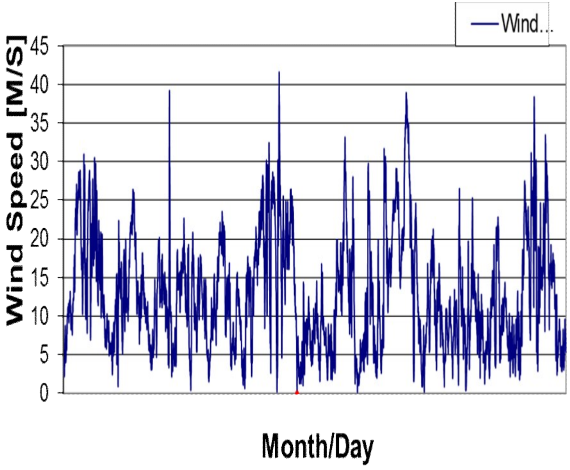

Figure 2. Wind speed changes in eshtehard station in February.

2. 3. Turbines Generative Power Curve

To utilize the wind energy in the region, turbines of the vertical axis are used. Tree important points of choosing wind turbines are turbines starting speed, maximum generation power of turbines and failing speed. Regarding the average speed of the wind and these points, GE 1.5 SL, 77m rotor turbine [11] has been used. Turbine's generation power curve is shown below.

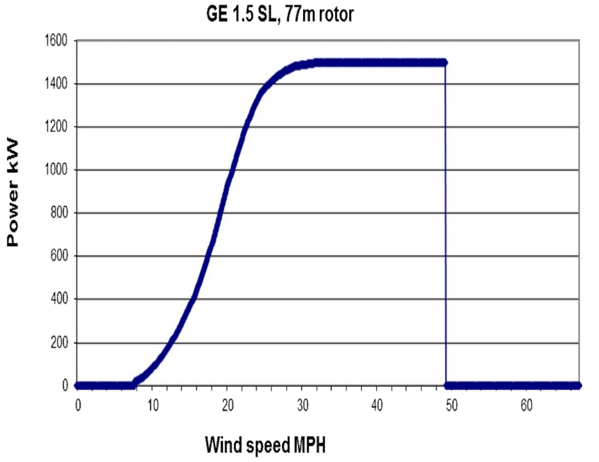

Figure 3. Wind production power turbine, GE 1.5 SL, 77m rotor model.

2. 4. Wind Blow Direction

One of the most important points of installing wind turbines in the region is the direction of dominant wind blow. Such a diagnosis causes direction of the first row of turbines to be done well and be in the same direction with the wind blowing in order to get maximum output. On this basis and using Eshtehard's anemometer data and WINDr software, direction of dominant wind blow in region has more density from west to the east.

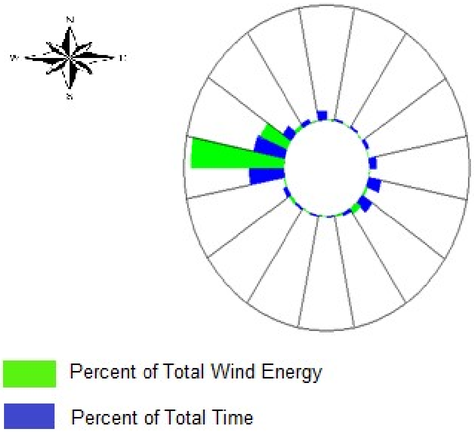

Figure 4. Wind rose graph

According to the mentioned points, results show the capacity factor (cf) is 0.25 and 0.3 in 40 meters height and in the height of Hob turbine respectively .The amount of output power in Azadi sports complex for a turbine in a year would be 3937982 kWh. This quantity shows that using wind turbines in the region is justifiable.

3. PROPOSED MODEL

The goal of this project is providing part of the Azadi sport complex electricity by using hydroelectric and wind renewable energies. The done computations to measure the probability of wind energy show that using wind turbines in this region technically and economically is justifiable. The existence of natural lake and a poo in the stadium and make it feasible to generate electricity by using water turbines.

In this model by using some pumps, the lake water would be pumped into a reservoir with 30000 cubic meters capacity and 20 meters height above the lake level with 100 meters distance from it for 12 hours. The reservoir dimensionsis 100, 50, 6. The stored water is used for generating hydroelectric power. In order to provide consumed electricity, two 1.5MW turbines are used. The additional amount of produced electricity would be connected to the network and would be sold as renewable electricity.

The amount of water pumped and stored every day in the reservoir is a function of the next day consumption and is dependent on it. The remarkable point is that the amount of electricity used in the next day is not clear completely but, it can be considered with 3 scenarios as Low with 40000 kWh, Normal with 50000 kWh and High with 60000 kWh and probabilities are 0.25, 0.5 and 0.25 respectively .Now regarding this point, the amount of pumped water in a day is considered X_1 cubic meter. Pumping expenses for water per cubic meter is P_w and computed in the next section.

TABLE 1. Set, parameters and variable of model

SET	S: scenarios for wind turbine K: scenarios for demand
PARAMETER	h(s): Probability of each scenario for wind turbine. P(k): Probability of each scenario for demand. d(k): Demand under each scenario [kWh]. pwd(s): power of wind turbines under each scenario [kWh]. Pe: Electricity price per kWh in USD [0.18]. Pt: Price to wind turbine for pump up water per m^3 in USD [0.13]. Pr: Price per m^3 when sold back to locale beverage company [0.03]. e: coefficient of converting cubic meter to kWh considered 2.5 [13].
VARIABLE	X_1: First stage decision: How much water to pump [m^3]. X_2: Second stage decision: How much water to release [m^3]. Profit(k,s): Profit under each scenario Exp_profit: Expected Profit of the whole day

Of the X_1 quantity of pumped water, X_2 cubic meters of it with regard to the different demand scenarios for generating hydroelectric power is used and the price of each kWh generated power is Pe. The other point in this model is that, it's not necessary to generate the whole consumed electricity. At the end of every night for repairing and inspection of different parts of the power plant, extra amount of water remained from differences between quantities X_1 and X_2 is evacuated and sold at the price of Pr for agricultural affairs and irrigation of green spaces.

Another point in this model is related to electricity generating by wind turbines. Regarding turbines generating power, 3 areas with 12 different scenarios and probabilities that are resulted from integrating of zero speed to V_{in} of one scenario, in to Vr of 10 scenarios and V_r to V_{out} of one scenario are obtained.

If (K) equals the number of demand scenarios, the amount of demand in each scenario is shown as d (k), S is the number of wind generation scenario, h(s) is the occurrence probability of each scenario and pw(s) is the amount of generated wind in each scenario. According to these points required conditions are as follows:

$$\begin{aligned} &X_2(k) \le X_1 \\ &X_2(k)*e \le d(k) \end{aligned} \tag{1}$$

Considering wind probabilities and generating power of GE, 1.5 SL turbine, results can be seen as in Table 2:

TABLE 2. Parameters h(s) probability of each scenario for wind turbines

S_1	0.07843
S_2	0.02500
S_3	0.03265
S_4	0.04509
S_5	0.05011
S_6	0.07728
S_7	0.09121
S_8	0.11222
S_9	0.10365
S_{10}	0.11233
S_{11}	0.06610
S_{12}	0. 20594

Regarding the occurrence probability of each scenario, generating power of wind turbines that is dependent on the percent of generation power of each scenario is calculated according to the Table 3[12]:

TABLE 3. Wind power generation scenarios

scenario	wp_s	π_s
S_1	100.00	0.07843
S_2	94.97	0.02500
S_3	84.97	0.03265
S_4	74.98	0.4509
S_5	64.98	0.05011
S_6	54.98	0.07728
S_7	44.99	0.09121
S_8	34.99	0.11222
S_9	19.99	0.10365
S_{10}	15.00	0.11233
S_{11}	5.00	0.06610
S_{12}	00	0.20594

In this project 2 similar wind turbines for utilizing the wind energy are used. Because of this and considering the probability of each scenario, the output power of wind turbines is calculated in the Table 4:

TABLE 4. Power of wind turbine under each scenario [kWh]

S_1	1000
S_2	949.7
S_3	849.7
S_4	749.8
S_5	649.8
S_6	549.8
S_7	449.9
S_8	349.9
S_9	199.9
S_{10}	150
S_{11}	50
S_{12}	0

According to the mentioned points and assigned parameters, profit that is the result of resulted from the differences between selling wind and hydroelectric power and expenses of pumping and power plant is as follows:

$$\begin{aligned} profit &= x_2(k)*e*pe + (x_2 - x_1)*pr \\ &+ \left[pw(s) - \frac{9.81*x_1*25}{0.8*43200} \right] - x_1*pt \end{aligned} \tag{2}$$

The price of pumping water per cubic meter included constructive and pumping expenses. This quantity involves expenses such as purchasing wind and water pumps, excavation, putting, plumbing, laying pipes and lagging.

Regarding the capacity of reservoir and daily pumping of 30000 cubic meters, the asset refunds during 5 years, it can be concluded expenses in this project in average, costs 40000 Rials.

Net profit is the sum of the product of the probability of wind generating power, demand probability and the net profit in each scenario [14].

$$Exp_{profit} = \sum_{s=1}^{S} \sum_{k=1}^{K} h(s)*p(k)*profit \tag{3}$$

In this model for more correct conclusion and more reliable computation it's better to use the risk function. To this mean risk function is defined as:

$$\begin{aligned} Risk &= \sum_{s=1}^{S} \sum_{k=1}^{K} h(s)*p(k)* \\ &(profit - Exp_{profit})^2 \end{aligned} \tag{4}$$

$$Objective = (1-\beta)*Exp_{profit} - \beta*Risk \tag{5}$$

Where β is the gap between final profit and the one with considering the risk function. Accordingly β can be ranged from 0 to 1[15].

At the end, to obtain the maximum profit Two Stages Optimization in GAMS software are used.

3. 1. Without Considering Risk Function

If the risk functions not to be considered in software results would be as in Table 5:

TABLE 5. Results with risk function

Consumed electricity scenario	X_1	X_2	Evacuated water for agriculture & green spaces
Low	24000m^3	16000m^3	8000m^3
Normal	24000m^3	20000m^3	4000m^3
High	24000m^3	24000m^3	0m^3

As for the amount of pumped water in each demand scenario and produced electricity by water turbine and soled surplus water of the pool for agriculture and irrigation of green spaces utilizations, the profit would be the same as the Table 6.

TABLE 6. Profit under each scenario for wind turbine

Demand scenario	Low	Normal	High
S_1	4289	5969	7649
S_2	4316	5996	7676
S_3	4370	6050	7730
S_4	4397	6077	7757
S_5	4478	6158	7838
S_6	4532	6212	7892
S_7	4586	6266	7946
S_8	4640	6320	8000
S_9	4694	6374	8054
S_{10}	4748	6428	8108
S_{11}	4802	6482	8162
S_{12}	4829	6509	8189

Considering total probabilities of the wind and electricity consumption and its product in each scenario, the net profit in a day will be 6163$.

3. 2. Considering Risk Function

Now if the risk function is considered and included in the software in this model, the conclusion and profit computation will be more logical. results of this model can be seen in the Table 7:

TABLE 7. Results with risk function

Consumed electricity scenario	X_1	X_2	Evacuated water for agriculture & green spaces
Low	16000m^3	16000m^3	16000m^3
Normal	16000m^3	16000m^3	16000m^3
High	16000m^3	16000m^3	16000m^3

As it is seen, when risk function is being considered the amount of pumped water in each scenario and the amount of water evacuated for generating hydroelectric power are equals. In this model the whole pumped water for generating hydroelectric power is evacuated and there is not water to sell to farmers and irrigate green spaces.

Regarding various β in this model, the net profit is different. The more β is, the more risk probability and consequently the less profit. Determining the exact quantity of β depends on the employer and the extent of risk in the model. With regard to this point, for different β the net profit will be specified as in the Table 8:

TABLE 8. Daily net profit for different β

β	Net profit
0	6163
0.1	5979
0.2	5582
0.3	5429
0.4	5340
0.5	5278
0.6	5234
0.7	5198
0.8	5162
0.9	5131
1	5096

Regarding the fact that the net profit is being calculated in the worst conditions e.i β=1 in the software, it is concluded that the daily net profit in this method will be 5096$.

4. CONCLUSION

Today, in the modern industrial societies energy consumption in addition to having the risk of fossil resources ending has faced the world with irrevocable and threatening environmental changes. As a result international programs and policies for the world sustainable development pay a particular attention to renewable resources. For example, EU has defined 12 percent of its needed electrical energy by new energies in its energy producing programs as a goal. In our country "Iran New Energies Organization" following the ministry of electricity policy making in energy affairs, is responsible for dealing with this important issue since 1995.For the purpose of achieving the world's newest information and technology using of renewable energy resources, measuring capacity, implementation of various solar plans, wind and earth heat as well as hydrogen and bio copper has been included in the agenda.

Now considering this important issue in the country, models and projects should be presented that in addition to be profitable and refundable in a logical time can allocate an important part of generating renewable energies to itself. One of these projects is the model that is described in details. In this model to provide renewable water and wind electricity jointly, in addition to two wind turbines a pool for storing and generating water electricity are used.

Regarding the presented model, it is clear that without considering the risk of the net daily profit causes investment refunds more quickly in about 3 years. In the second method when the risk function is considered, investment will be refundable in less than 4 years. It should be noted that in the second method determination of β can be changeable dependent on the employer diagnosis and the type of project.

Observing the fact that the government supports investing in the field of generating renewable energy, in addition to the gained profit in this model because of high efficiency, private sector to invest in this industry promotes.

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REFERENCES

1. Dincer, I., "Renewable energy and sustainable development: a crucial review", ***Renewable and Sustainable Energy Reviews,*** Vol. 4, No. 2, (2000), 157-175.
2. Deane, J.P., Gallachóir, B.P.Ó. and McKeogh, E.J., "Techno-economic review of existing and new pumped hydro energy storage plant", ***Renewable and Sustainable Energy Reviews,*** Vol. 14, No. 4, (2010), 1293-1302.
3. Holttinen, H., "Estimating the Impacts of Wind Power on Power Systems Summary of International Energy Agency (IEA) Wind Collaboration", ***Environmental Research Letters,*** Vol. 3, (2008), 1-6.
4. Kleindorfer, P., "Risk management for energy efficiency projects in developing countries",(2010).
5. www.moe.org.ir.
6. GAMS Distribution (23.8.2).
7. Renewable Energy Organization of Iran, Website: www.suna.org.ir
8. Excel Wind Analysis. Prepared by, "Matthew West--Idaho National Engineering and Environmental", Laboratory, 2003, 2004; Idaho National Laboratory, 2005-Summer Fellowship Programs
9. Archer, C.L. and Jacobson, M.Z., "Spatial and temporal distributions of US winds and wind power at 80 m derived from measurements", ***Journal of Geophysical Research: Atmospheres***, Vol. 108, (2003).
10. Morgan, E.C., Lackner, M., Richard M.R. and Baise, L.g., "Probability distributions for offshore wind speeds", ***Energy Conversion and Management,*** Vol. 52, No. 1, (2011), 15-26.
11. www.thewindpower.net
12. Rabiee, A. and Soroudi, A.R., "Stochastic multiperiod OPF model of power systems with HVDC-connected intermittent wind power generation", ***Power Delivery, IEEE Transactions,*** Vol. 29, No. 1, (2014), 336-344.
13. Kali, P. and Wallace, S.W., "Stochastic programming", Wiley, Chichester, (1994).
14. Albers, Y.C., "Stochastic programming tools with application to hydropower production scheduling", Diss. Bachelor's Thesis, ETH Zurich, 1 (1): 102, 2011.
15. Eichhorn, A., Heitsch, H. and Römisch, W., "Stochastic optimization of electricity portfolios: Scenario tree modeling and risk management", ***Handbook of Power Systems: Part of the Series Energy Systems,*** (2010). 405-432.