Wind for Irrigation Application

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***Abstract*—The remarkably high and unstable fuel cost due to the international situation could impact the local agricultural operating cost and significantly affect rural development.**

Regular water wheels require fuel to run the motor pumps in them to supply water during the irrigation season. A wind generation system that is connected to the irrigation system and electric grid is proposed here. This involves electric power generated from the wind turbine being used to drive a water pump to fill a storage tank and the excess being sold to the electric grid. Water storage allows for optimization of both wind resources over time with respect to irrigation needs and electricity sell back rates at during the day/night and season times.

The new scheme helps in decreasing carbon emission, generates electricity from renewable sources connected to the grid and reduces the dependence on foreign oil.

***Index Terms*—Economic evaluation, irrigation, rural development, Water pumping, wind power.**

I. Introduction

THE majority of irrigation pumping in Nebraska uses fossil fuels such as diesel, nature gas, and propane. An increasing percentage of irrigation pumping is however done by using electrical energy (42% at present). High fuel cost is helping to drive the installed pumping systems to become electric. Wind power as a source for irrigation load becomes attractive [1] due to the large resource of wind available in the state and the decreasing costs of wind energy. This analysis envisions using wind energy to pump water and deliver it to a storage tank connected with pivot-type irrigation system. First goal is to satisfy agriculture needs during irrigation season (spring and summer) and the second goal is to sell back excess electricity to the utility, particularly during the fall and winter months. The electrical power production cost offset and reduce the payback time of the turbine investment.

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II. Wind for Water and Electricity

The diagram of the water pumping system is shown in fig1. The wind turbine(s) (1) is(are) used to produce electrical energy. They are connected to the pump (2) and to the grid (3). During irrigation season most of the energy is used to supply the pumping system while during the winter all the energy is sold to the grid.

There are times when the wind turbine supplies energy to both the pumping system and the electric grid. The pump is used to fill the water storage tank (4) with underground water (5).

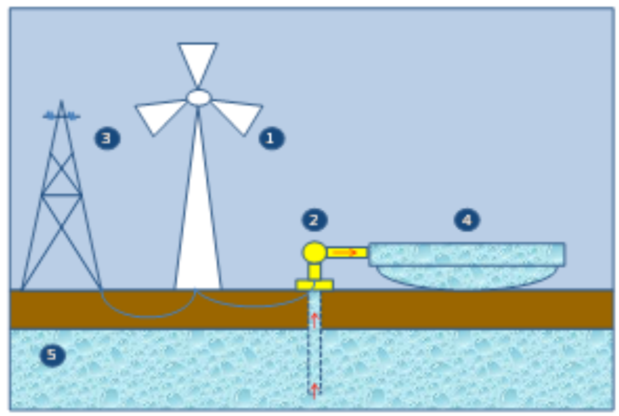

Fig. 1. Diagram of the water pumping system: 1 - wind turbine; 2 - pump; 3 - transmission line; 4 – water storage tank; 5 – underground water.

A. Simulation

Wind data from central Nebraska has been used for simulation and analysis. In Fig. 2 is presented hourly data of wind speed in m/s on monthly base [2]. The wind velocity values are monthly averages at 50 m height above the ground.

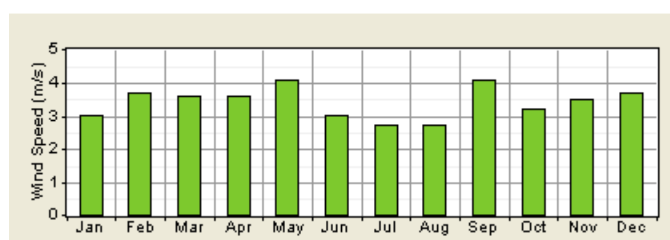

Fig. 2. Wind resources from central Nebraska.

Fig. 3 represents the irrigation data referred to corn in silt Loam Soil in central Nebraska [3]. Ordinate shows the amount of water required for irrigation (inches) and abscissa shows the time in months. The crop requires most irrigation water during summer time (June, July and August) and needs an average of 11 inches per year of irrigation water.

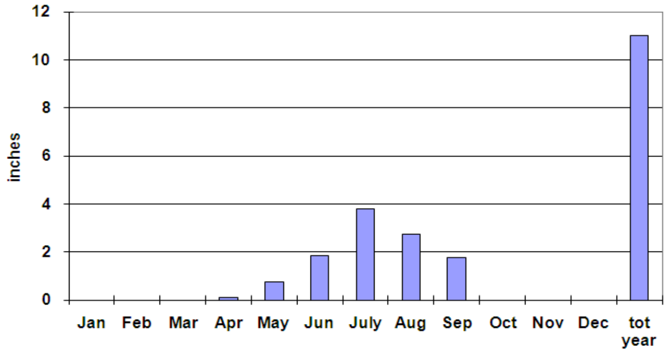

Fig. 3. Water required for corn in silt loam soil.

To determine the optimum solution, different net metering policies have been considered. The electric energy rates purchased from cogenerating and small power producing facilities from three different company LES [4] (Lincoln Electric System), OPPD [5] (Omaha Public Power District) and NPPD [6] (Norris Public Power District) have been evaluated. It was concluded that NPPD provide the most beneficial rate for irrigation purpose. NPPD has different rates for different levels of consumption of energy, the charge for the first level up to 2400 kWh is $0.128/kWh, between 2400 and 7600 kWh it is $0.079/kWh and for all additional kWh it is $0.065/kWh. This work assumes a 1:1 rate (buy/sell).

For the simulation of the wind system three different set up have been used. The first system include an 30 kW robust start-up turbine (FL 30 , Waigandshain, Germany). The second system include three 30 kW (FL 30 , Waigandshain, Germany) turbines and the third system include one 100 kW turbine (FL 100 , Waigandshain, Germany). The grid rate is 115 kV, and a water storage tank 93×10^{3} m^{3}.

To implement the simulation of the data the optimization model for distribution power - Homer [7] (National Renewable Energy Laboratory, Washington, DC) was used. Homer is a computer model that helps to evaluate options for both off-grid and grid-connected power systems for different type of generation applications: distributed generation (DG), stand-alone, and remote systems. Homer's sensitivity analysis algorithms allowed evaluating the technical and economic feasibility of systems [2].

B. Simulation results

Cost summary

The overall system cost includes the wind turbine cost, grid connection cost, all federal and state credits, incentives and financial facilities. For the 30 kW system the overall cost is around hundred thousand dollars, for the three 30 kW system is approximately three hundred thousand dollars and for the 100 kW system is approximately three hundred thousand dollars. All the economic and financial calculations have been based on the available data at December 2008.

In table I is presented the data of the total net present cost in dollars, the levelized cost of energy in dollars per kW/h and operating cost in dollars per year for the three systems. From the simulation results it can be concluded that higher total cost is the 3x30 kW system and the lowest is the 30 kW system while for the operation cost the 100 kW system present the best solution with -13,544 dollars per year and the 30 kW has an operating cost of -1,989 dollars per year. Although the 100 kW system has the highest initial cost but it has the lowest levelized cost of energy. The highest levelized cost of energy was calculated for the 30 kW system but from the economical point of view the best solution is the system using 100 kW wind turbine.

TABLE I
COST SUMMARY OF THE THREE SYSTEMS

Power of the system [kW]	30	3x30	100
Total net present cost [$]	70,512	117,014	80,174
Levelized cost of energy [$/kWh]	0.084	0.112	0.076
Operating cost [$/yr]	-1,989	-12,340	-13,544

The data of the simulation of the monthly average electric production is presented in Fig. 4. From the simulation results it was deduced that the annual energy productions for the three systems 30, 3x30 and 100 kW was approximately 33, 99 and 111 MWh/yr. For regular operation of the three systems only 100 kW does not need grid support during irrigation season while 30 and 3x30 kW systems need additional 32 and 2.5 MWh/y. The 30 kW system provide only 51% of the required power for irrigation and sell about 13% of the produced energy. The 3x30 system provide almost all the necessary energy for irrigation, covering 98% of the load with turbine production and sell 30% of the energy production. The 100 kW system provide all the energy required for pumping and sell 37% to the grid.

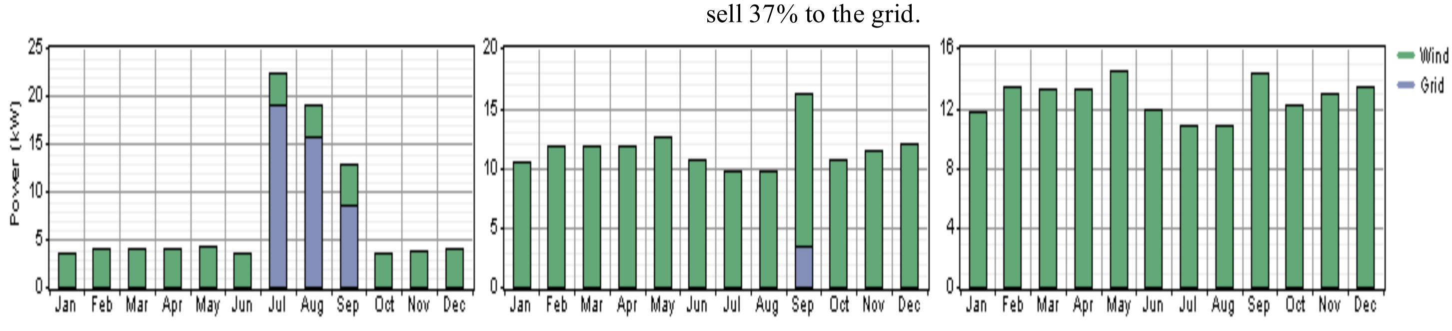

Fig. 4. Monthly average electric production: a) 30 kW; b) 3x30 kW and c) 100 kW systems.

AC Wind Turbine: Fuhrländer 30, 3x30 and 100 kW

The results of the simulation of the electricity production during the year, using the central Nebraska region wind data and the parameters of the turbine, are presented in table II. The mean outputs of 30, 3x30 and 100 kW are 3.77, 11.3 and 12.7 kW correspondingly. The maximum outputs for the three systems were calculated to be 30.8, 92.5 and 117 kW respectively. The operation hours during the year are 3,132 for 30 and 3X30 systems while 3,172 hours for the 100 kW system.

TABLE II
CALCULATED WIND TURBINE PARAMETERS FOR CENTRAL NEBRASKA REGION

Power of the system [kW]	30	3x30	100
Total rated capacity [kW]	30	90	100
Mean output [kW]	3.77	11.3	12.7
Total production [MWh/yr]	33	99	111
Maximum output [kW]	30.8	92.5	117
Hours of operation [hr/yr]	3,132	3,132	3,172

In Table III is presented the data of the produced and sold energy during the year for the three systems. In Fig. 5 is presented the simulated data of the trend of the volume of the water in the tank during the year. The simulation results for the 3x30 and 100 kW systems coincide with our expectations that during the winter the electricity produced is sold and during the summer is used to pump the water. April will be the first month when the produced electricity from the three systems will not be sold to the grid. In May not all the produced energy of the 100 kW system will be used for irrigation but also will be sold to the grid. Between June and October all the produced electricity of the three systems will be used to supply the pump. The tank of the 30 kW system becomes empty at the beginning of July because the energy supplied from the wind turbine is not enough for replacing the water use for irrigation and by the end of the year the tank is approximately 1/3 full. The 30 kW system is not appropriate for usage as it does not produce sufficient energy to fill the whole tank. The 3x30 and 100 kW systems both have similar distribution of volume during the year. Some of the energy of the 100 kW system can be sold after October while the whole energy of the 3x30 kW system is used for pumping the water and can be sold after November. The 100 kW system sells approximately 25% more energy to the grid compared to the 3x30 kW system. The lowest levilized cost and the highest percent of the sell energy makes the 100 kW system an attractive system for irrigation usage.

TABLE III
WIND TURBINE ENERGY PRODUCED AND SOLD

	Energy Produced			Energy Sold		
Power of the system [kW]	30	30x3	100	30	30x3	100
January	2569	7706	8564	2569	7706	8564
February	2681	8043	9124	2681	8043	9124
March	2937	8812	9911	2937	8812	9911
April	2853	8559	9539	0	0	0
May	3123	9368	10761	0	0	2385
June	2554	7662	8506	0	0	0
July	2407	7220	8186	0	0	0
August	2379	7136	7961	0	0	0
September	3078	9235	10436	0	0	0
October	2663	7989	9029	0	0	0
November	2757	8271	9326	0	0	677
December	2986	8959	10013	0	6190	10013
Total	33016	98959	111457	8217	30751	40773

Fig. 5. The water level in the tank along the year.

It is well known that using renewable energy sources leads to reductions in Carbon dioxide emissions and consequently decreased contributions to global warming. Thus a 100 kW system produces clean energy and saves 25.7 ton/year in Carbon dioxide emissions to the atmosphere. Similarly a 3X30 kW and 30 kW system saves 17.8 ton/year and 15.1 ton/year in Carbon dioxide emissions respectively.

III. CONCLUSION

This paper presents the technical and economical feasibility to use wind resource to pump water for irrigation and electricity production in rural area connected to the grid.

For the central Nebraska the 100 kW system has an attractive usage for irrigation due to the lowest levilized cost, the highest percent of the sell energy and the highest reduction of Carbon dioxide emission compared to the 30 and 3x30 kW systems.

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