International Journal of Scientific & Engineering Research Volume 9, Issue 4, April-2018
ISSN 2229-5518

Wind Hydro Coordination Strategy for Enhancing the Worth of Wind Power

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Abstract— The renewable power generation has gained a lot of prominence in the recent times due to several oblivious contemporary reasons. Wind power is one such major source of bulk renewable energy. But the intermittent nature of wind itself is one of the major hurdles in utilizing it effectively. Among several methods of combating the problem of intermittency Wind Hydro Coordination (WHC) is one such method . in this paper a novel method of WHC is proposed to enhance the worth of wind power by storing it in the form of water and using indirectly during the period of high demand. MATLAB SIMULINK is used for modeling the wind power station and a coordination strategy is proposed. A simple case study is considered to show the scopes for implementation. Economic feasibility analysis is also done for one possible case

Index Terms— Wind power, Wind hydro coordination, Economic feasibility.

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1 INTRODUCTION

Renewable power generation has gained increased importance in the recent times due to its clean and modular nature, advancement in relevant technologies and more importantly the increased awareness among the public. In Indian perspective wind and solar are the two major bulk renewable power generating options. India is blessed with plenty of wind resources and fairly good technology to harvest the power form blowing wind. India stands 4th globally in the production of wind energy. The Fig 1 indicates the share of different sources of generation of electricity in India and the Fig 2 shows the same with renewable energy sources

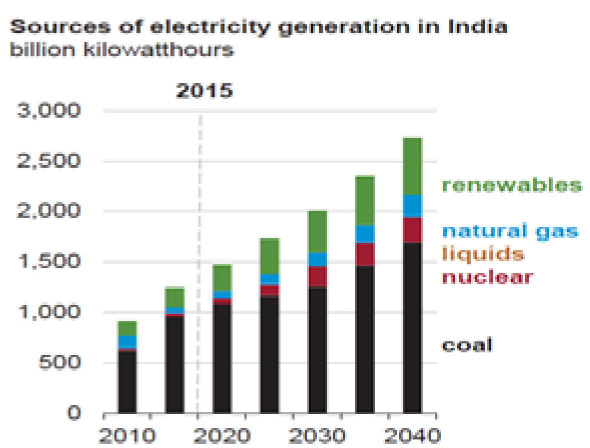

Fig 1: Sources of electricity generation in India

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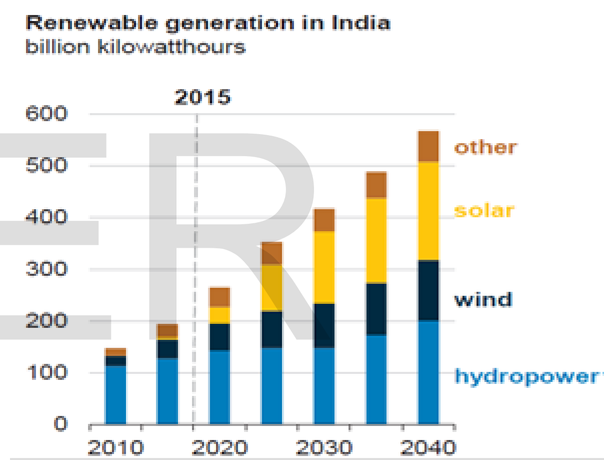

Fig 2: Renewable source based energy generation in India
(Source: U S energy Information Administration)

With such a huge prospects of wind power generation, the effective harvesting of wind power can be made if the constraints of the system are overcome. One of the major bottlenecks of wind power generation is its strong dependency on wind speed as can be seen from the following equation.

$P=(\frac{1}{2})\rho AV3$ ---------------- (1)

where ρ is the air density in Kg/m3.

A is the area of the turbine blades in m2.

V is the wind velocity in m/sec.

When the wind speed is not always accurately predictable the wind power is also not predictable. This leads to several problems as identified by several researchers [1,2].

Emailed and contact number of corresponding author (intermittency of wind power with different dimensions. A comprehensive review can be found in [3] and wind hydro coordination is considered to be one of the prominent methods for enhancing the worth of intermittent wind power. In the proposed method the strategy of operating wind and dispatchable hydro power stations with geographic proximity is considered to store the wind power in the dam during the high wind periods and using it during high demand periods is used.

The section II discusses the modeling of wind power station, section III discusses about the proposed strategy using a case study, section IV discusses about the results of the proposed scheme with an insight of economic feasibility analysis

2 METHODOLOGY

2.1 Proposed system

The proposed schematic is shown in the Fig 3. below.

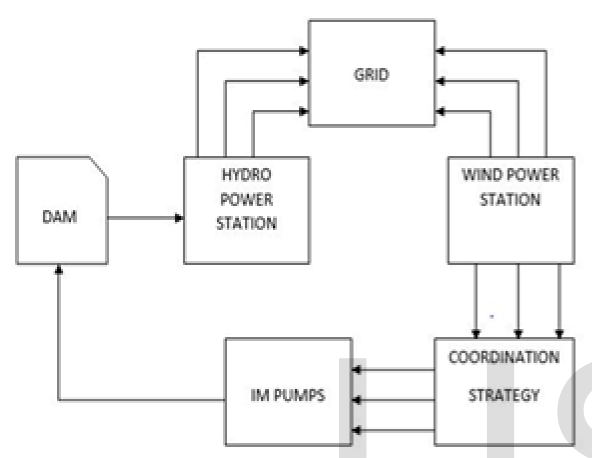

Fig 3: Proposed scheme

In order to perform the WHC the modeling of the wind power station is done using MATLAB. A grid connected wind turbine with synchronous generator is modeled [4] and the average monthly power of the wind power station and harvestable energy is evaluated for the specific conditions of the wind site and specification of the wind power station. The Fig 4 . shows the MATLAB model of the scheme. The detailed specifications are shown in the appendix.

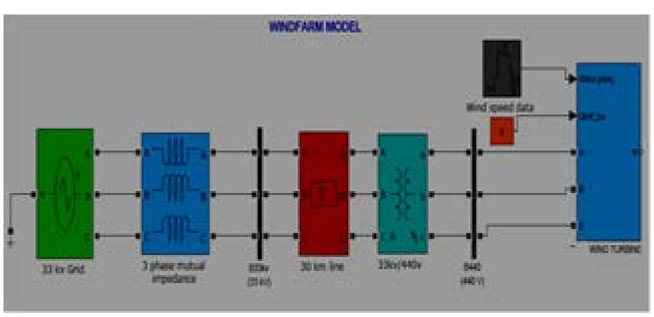

Fig 4: MATLAB model of grid connected wind power station

2.2 Wind hydro coordination

The following flowchart shows the control strategy used for wind hydro coordination

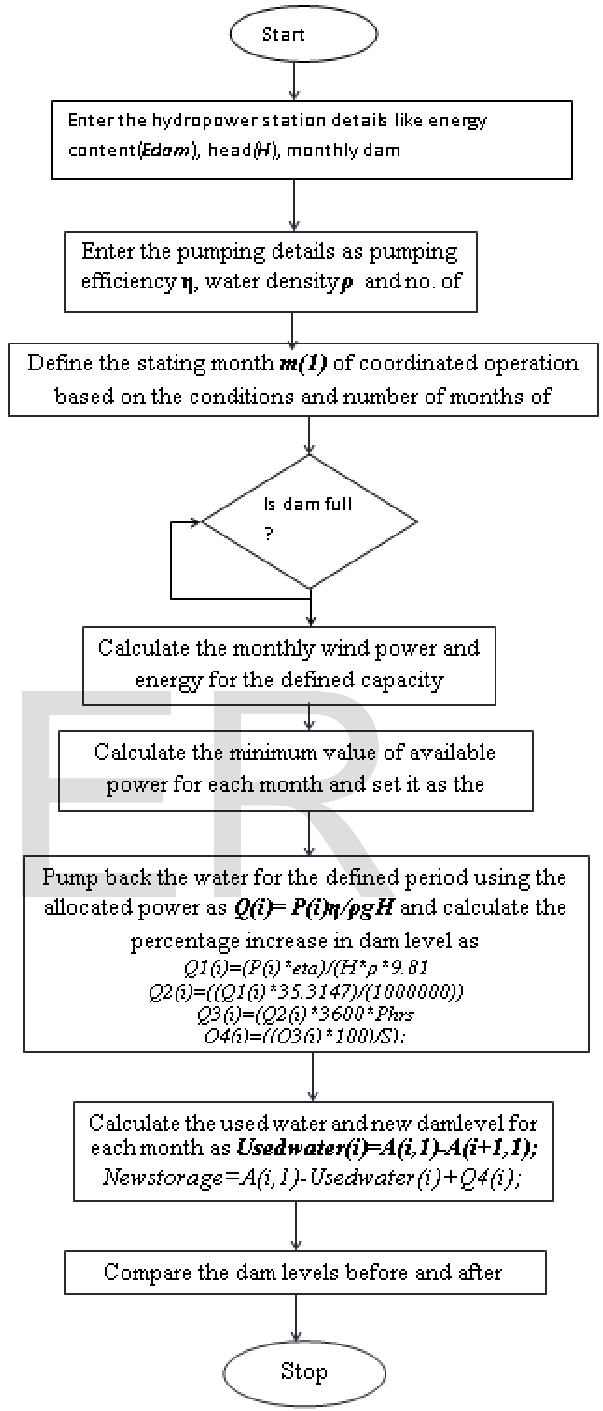

Fig 5: Flowchart for WHC strategy

The WHC operation considers the following.

i)The geographical proximity between the wind and hydro power station is desirable. Otherwise the transmission losses between the two are need to be accounted for.

ii) The details of the hydro power stations in terms of harvestable energy, effective head , monthly water level in the dam are to be obtained.

iii) The stating month of the coordinated operation has to be defined.

2.2 Case study

In order to illustrate the scope of implementing the proposed control strategy the case study of hydro power station at Almatti, Bagalkot is considered. The wind profile of the same location is considered as wind speed input for the wind power station model developed. About 10 % of the hydro power station capacity is considered as the rating of wind power station. The table 1 shows the details of the considered power plant.

TABLE 1
DETAILS OF ALMATTI HYDRO POWER PLANT

Name	Location and year of commissioning	Dam capacity	Power station capacity	Type of turbine, Head	Designed energy capacity	Energy content
Almatti Dam Power House	Almatti, Bagalkot 2005	124 TMC/ 124000 MCFT	290 MW	Vertical Kaplan, 25m	719 MU	172MCFT/MU

3 RESULTS AND DISCUSSION

The monthly average output power and harvestable energy of the wind power station of the capacity 30 MW connected to a 33kV grid are as shown in Fig 6 and 7 respectively.

The base case of the Almatti Dam Power House (ADPH) for the

WHC strategy is considered as follows
1) Water storage capacity:124000MCFT
2) Energy content: 172 MU/MCFT
3) Head: 25m
4) Pumping efficiencies: 70 % and 90%

Considering August as the starting month for applying WHC strategy the percentage water level in the dams are compared before and after coordination in the month of May in which usually the shortage of water in the dams to produce hydro power is felt. The results are as shown in Fig 8.

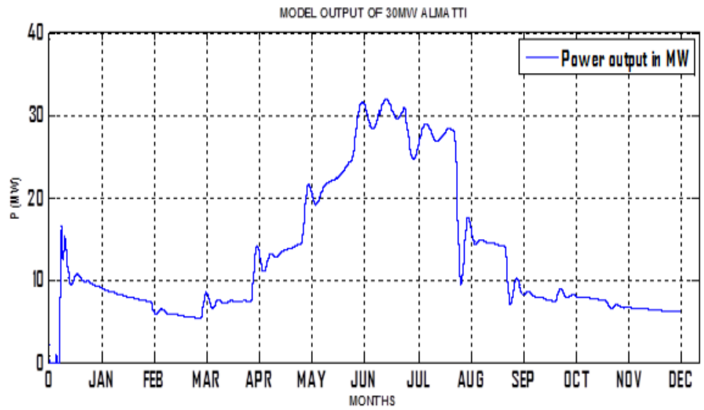

Fig 6: Power output in MW

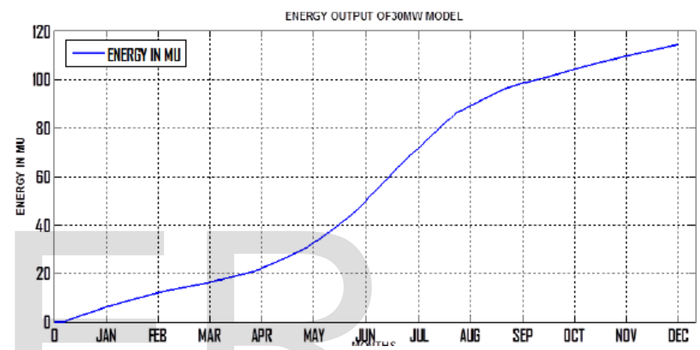

Fig 7: Harvestable energy output in MU

The analysis is made for three different wind power installed capacities with 70% and 90% pumping efficiencies. The table 2 below gives the results of this analysis.

TABLE 1
STORE ENERGY IN THE DAM DUE TO PUMP BACK

Installed wind power capacity (MW)	Pumping efficiency ***(PE)***	Energy	
		Grid fed wind energy ***Egrid*** (MU)	Energy saved due to pump back ***Epb*** (MU)
15	0.7	31.40	46.139
	0.9		59.116
30	0.7	50.67	111.023
	0.9		142.744
45	0.7	63.91	184.558
	0.9		237.906

The validation and feasibility of this method however strongly depends on the consideration of economic aspects.

The details of wind power economics are taken from[5] and assuming the current cost of installation of Rs.65/W in the Indian scenario the economic analysis is carried out. The Fig 8 shows the total expenditure of the scheme and the annual expected revenue from the proposed scheme.

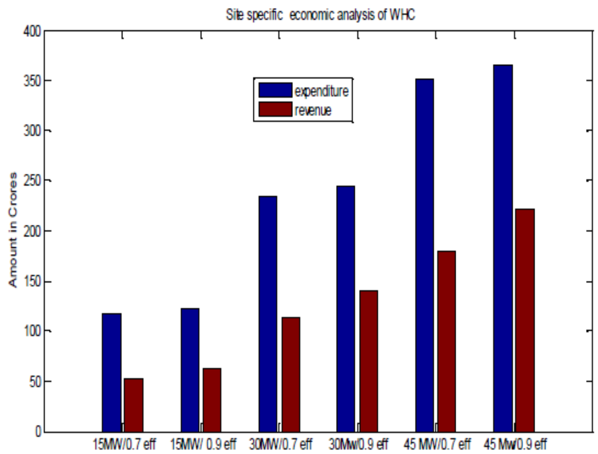

Fig 8: Expenditure and revenue comparison

4 Conclusion

The WHC strategy to enhance the worth of wind power is proposed in the paper. The pump back of the water from the tailrace of the dam is done using certain amount of the generated wind power for a specified duration of time similar to the pumped hydro power plants. Thus the intermittent wind power over a period of time is stored as definite energy in the form of hydro power which will serve as the available power during expected high demand periods. Thus the worth of wind power can be indirectly enhanced. However the implementation of this scheme is mostly site specific and requires a thorough investigation of different economic considerations. In view of the increasing wind power installations this type of approach can definitely be one of the options for the future in view of enhancing the worth of wind power.

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Appendix

A.1. Wind Turbine:

Nominal mechanical output power (W):1.5MW
Wind speed at nominal speed and at Cp max: 11 m/s
Initial wind speed: 5 m/s
Rotor-side converter current regulator gains
[Kp Ki]: 0.6, 8
Q and V regulator gains [Ki_var Ki_volt]: 0.05,20
Pitch controller gain [Kp]: 15
Pitch compensation gains [Kp Ki]: 1.5,6
Field excitation gain: 10, 20
Maximum pitch angle (deg): 27
Maximum rate of change of pitch angle (deg/s):10

A.2. Generator:

Nom. power, L-L volt and frequency: 1.5MW/0.9, 400V, 1975 V, 50 Hz
Reactance [Xd, Xd', Xd'' ,Xq , Xq'' Xl] (p.u.) :1.305, 0.296, 0.252, 0.474, 0.243, 0.18
Time constants [Tdo', Tdo'', Tq''] (s):
4.49 0.0681 0.0513
Resistance Rs (p.u.): 0.006
Inertia constant, friction factor, and pairs of poles:
0.62, 0.01

A.3. Converters:

Grid-side converter maximum current (pu): 1.1
Grid-side coupling inductor [L, R] (p.u.): 0.15,0.15/50
Nominal DC bus voltage (V): 1109
DC bus capacitor (μF):10000
Line filter capacitor (var): 150e3

A.4.Control parameters for wind turbine:

DC bus voltage regulator gains [Kp Ki]: 1.1, 27.5
Grid-side converter current regulator gains [Kp Ki]: 1, 50
Speed regulator gains [Kp Ki]: 3.0.6

A.5. Transmission system parameters:

Type, length and frequency: π model, 30 KM, 50 Hz
Positive- and zero-sequence resistances (Ohms/km)
[R1, R0]: 0.1153, 0.413
Positive- and zero-sequence inductances (H/km)
[L1, L0]:1.05e-3, 3.32e-3
Positive- and zero-sequence capacitances (F/km)
[C1,C0] :11.33e-9, 5.01e9

A.5. Transmission system parameters:

Type, length and frequency: π model, 30 KM, 50 Hz
Positive- and zero-sequence resistances (Ohms/km)
[R1, R0]: 0.1153, 0.413
Positive- and zero-sequence inductances (H/km)
[L1, L0]:1.05e-3, 3.32e-3
Positive- and zero-sequence capacitances (F/km)
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