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ScienceDirect

Energy Procedia 117 (2017) 567–574

Energy Procedia

www.elsevier.com/locate/procedia

1st International Conference on Power Engineering, Computing and CONtrol, PECCON-2017, 2-4 March 2017, VIT University, Chennai Campus

Profit maximization of hybrid system under availability based tariff in deregulated environment

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Abstract

This paper proposes an idea for the profit maximization of hybrid system. Wind plant and pumped storage hydro plant acts as a hybrid system. Profit calculation is mainly based on frequency. Contract is signed between hybrid system and grid. Deviations from contract make unscheduled interchange flow between hybrid system and grid. Load scheduling is implemented in the utility connected load to maximize their profit and to minimize unscheduled interchange flow. The effect of load scheduling on the profit of hybrid system for different wind power is analyzed and compared with the case without load scheduling.

Peer-review under responsibility of the scientific committee of the 1st International Conference on Power Engineering, Computing and CONtrol.

Keywords: Availability Based Tariff; Frequency; Unscheduled Interchange; Load scheduling; Pumped storage hydro plant

1. Introduction

Due to eco-friendly nature, usage of renewable energy resources is continuously increasing. One of the most widely used renewable resources is wind resource. But the wind power is not available at all times so usually an energy storage device is used along with the wind plant. One of such commonly used energy storage device is pumped storage hydro (PSH) plant. PSH plant operation has been reported in [1]. The usage of wind plant along

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1876-6102
Peer-review under responsibility of the scientific committee of the 1st International Conference on Power Engineering, Computing and CONtrol.
10.1016/j.egypro.2017.05.149

with PSH plant has been discussed in [2-4]. When the wind power availability is more, PSH plant acts as a pump by pumping the water to the upper reservoir. During low wind power period the PSH plant acts as a generator, at that time water flows from upper reservoir to the lower reservoir for compensating the low wind power. In deregulated market power delivery is scheduled in advance and contract is usually signed for the delivery of power. The frequency based pricing promotes competition in electricity market [5]. The frequency based pricing that came into existence from 2002 is Availability Based Tariff (ABT). The ABT structure and unscheduled interchange reported in [6]. The ABT consists of three cost components namely capacity charge, energy charge and unscheduled interchange charge. The third cost component arises when the actual power delivered is more or less than the scheduled. Unscheduled Interchange (UI) is the difference between actual value and scheduled value. The unscheduled interchange rate is inversely proportional to frequency. UI charge is more for low frequency and UI charge is almost zero for high frequency. Therefore ABT avoids excess consumption, excess generation and helps to maintain the frequency of the grid. The UI rate for different frequency will be decided by Central Electricity Regulatory Commission (CERC). The pricing of hybrid system under ABT method is discussed in [7-8].

Nomenclature

h	hour
R	percentage of residential load
C	percentage of commercial load
I	percentage of industrial load
C_{SP}^{h}	hourly cost of scheduled power delivery in rupees
C_{PUI}^{h}	hourly cost for positive unscheduled interchange in rupees
C_{NUI}^{h}	hourly cost for negative unscheduled interchange in rupees
P_{HS}^{h}	hourly real power delivered by the hybrid system to grid in MW
P_{w}^{h}	hourly real power from wind power plant in MW
P_{H}^{h}	hourly real power available from pumped storage hydro plant in MW
P_{M}^{h}	hourly active power of main load in MW
P_{0}^{h}	hourly real power of utility load or local load at nominal voltage in MW
P_{L}^{h}	hourly actual real power of utility load or local load in MW
Q_{M}^{h}	hourly reactive power of main load in MVAR
Q_{0}^{h}	hourly reactive power of utility load or local load at nominal voltage in MVAR
Q_{L}^{h}	hourly actual reactive power of utility load or local load in MVAR
MP^{h}	hourly market price in Rs/MWh
P_{CG}^{h}	hourly power generation from grid generator in MW
P_{aw}^{h}	hourly available wind power in MW
P_{C}^{h}	hourly contract power in MW
f^{h}	frequency for each hour in Hz
n	number of buses
B	line susceptance
G	line conductance
$\|V_i\|$	magnitude of voltage at ith bus
θ_j	phase angle of voltage at ith bus
$\alpha r, \alpha c, \alpha i, \beta r, \beta c, \beta i$	exponents for residential, commercial and industrial load

2. Problem description

A contract was signed between the hybrid system and the grid. Hybrid system has its own local load. After satisfying its own load hybrid system supplies power to the grid load or main load. Grid load receives power from both grid generator and from hybrid system. Hybrid system must deliver power to the grid load as per the pre-