Renewable and Sustainable Energy Reviews 51 (2015) 304–316

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Scope and sustainability of hybrid solar–biomass power plant with cooling, desalination in polygeneration process in India

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ARTICLE INFO

Article history:
Received 14 March 2015
Received in revised form
10 May 2015
Accepted 1 June 2015

Keywords:
Solar energy
Biomass
Power generation
VAR cooling
Water desalination
Polygeneration process
Thermodynamics analysis

ABSTRACT

The term “polygeneration” is referred to as “an energy supply system, which delivers more than one form of energy to the final user”, for example: electricity, heating/cooling, desalination can be delivered from polygeneration process. The polygeneration demonstrates unique integration of energy efficiency and renewable energy. It is the next generation energy production technique with a potential to overcome intermittence of renewable energy, reduce cost of power generation and greenhouse gas emissions. The feasibility study of this paper is divided in three sections: In first section of this study, solar and biomass have been arranged to produce steam for power generation. In the second section, cooling is produced by vapor absorption refrigeration (VAR; LiBr-H_2O) system as per demand load requirement using steam, extracted from pass-out turbine. In the last section of this paper, multi effect dehumidification (MED) water desalination is produced by using limited amount of heat from water vapor (refrigerant; H_2O) through HE1 of VAR cooling system.

Contents

1. Introduction

The energy scene in India is a complex picture of variety of energy sources being used to meet the growing energy needs. However there is a gap in the demand and supply position. It is recognized that decentralize generation based on the various renewable energy technology can, to some extent, help in meeting the growing energy needs. Renewable energy landscape in India, during the last few years, has witnessed tremendous changes in the policy framework with accelerated and ambitious plans to increase the contribution of renewable energy such as solar, wind, bio-power etc. The present installed capacity of power generation in energy sector of India is 272.50 GW as on May 2015. This includes, 189.31 GW (69.4%) from thermal power, 41.63 GW (15.27%) from hydro, 35.77 GW (13.12%) from renewable energy sources and 5.78 GW (2.12%) from nuclear. Out of 35.77 GW renewable energy, wind energy continues to dominate India's

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http://dx.doi.org/10.1016/j.rser.2015.06.004
1364-0321/

Nomenclature

A_{ap}	aperture area of the PTC (m^2)
A_r	aperture area of the receiver (m^2)
COP	coefficient of performance
$C1$, $C2$, $C3$	condenser 1, 2, and 3
DNI	direct normal irradiance ($kWh/m^2/day$)
EV1, EV2	expansion valve 1 and 2
E_{Th}	specific thermal energy (kJ/kg)
F_R	heat removal factor
HTG	high temperature generator
HE1, HE2	heat exchanger 1 and 2
H.V.	heating value of biomass (MJ/kg)
h_a, h_b....h_m and h_1, h_2....h_{17}	enthalpy as state point a to m and 1–17 (kJ/kg)
I_{bm}	beam radiation ($kWh/m^2/day$)
IAM	incident angle modifier
LTG	low temperature generator
m	mass flow rate (kg/s)
PES	primary energy savings
$Q_{biomass}$	heat from biomass (kW)
Q_{boiler}	heat transfer to biomass boiler (kW)
Q_d	heat transfer rate into the saline water of distillation system (kW)
Q	heat transfer (kW)
Q_1	useful heat gain collected from PTC field (kW)
SHE1, SHE2	solution heat exchanger 1 and 2
S.H.	super heater
S	radiation observed by receiver ($kWh/m^2/day$)
T	temperature (°C)
T_x	inlet temperature of heat transfer fluid (°C)
T_y	outlet temperature of heat transfer fluid (°C)
TV	throttle valve
U_L	overall heat loss coefficient (W/m^2 °C)
W	work (kW)
W_{VAR}	equivalent power consumption of cooling load (kW)
W_{DW}	equivalent power consumption for the production of drinking water (kW)
$W_{polygeneration}$	total equivalent power produced from polygeneration process (kW)
W_{net}	net work output (kW)
W_T	turbine work output (kW)
η_{opt}	optical efficiency of the PTC (%)
$\eta_{I,E}$	instantaneous energy efficiency of the PTC collector (%)
$\eta_{I,b}$	energy efficiency of biomass boiler (%)
$\eta_{o,HSB}$	overall energy efficiency of the HSB (%)
η_{heat}	heat efficiency of the polygeneration process (%)
$\eta_{electrical}$	electrical efficiency of the polygeneration process (%)
$\eta_{ref,heat}$	efficiency reference value for heat production (%)
$\eta_{ref,electrical}$	efficiency reference value for electricity production (%)
ΔT	temperature difference between outlet and inlet temperature of heat transfer fluid (°C)
ω	humidity of air (kg/kg dry air)

Greek symbols

ε	effectiveness
η	efficiency
θ	incidence angle

Subscripts

ab	absorber
g	generator
$C1$, $C2$, $C3$	condenser 1, 2 and 3
e	evaporator
$p1$, $p2$, $p3$, $p4$	pump 1,2, 3 and 4
T	turbine
opt	optical
ref	reference heat
spp	simple power plant
d	distilled
a	air
T	turbine
ap	aparature
r	receiver
amb	ambient
m	mean
$SHE1$, $SHE2$	solution heat exchanger 1 and 2
HE	heat extraction
VAR	vapor absorption refrigeration
w	water

renewable energy scene, accounting for 65.52% of installed capacity (23.44 GW), followed by biomass power 12.66% (4.53 GW), small hydropower 11.32% (4.05 GW), and solar power 10.48% (3.75 GW) [1]. The launching of the Jawaharlal Nehru National Solar Mission (JNNSM) symbolizes both and indeed encapsulates the vision and ambition for the future of solar energy. The cost of power produced from concentrated solar power (CSP) is becoming competitive with conventional energy sources with the development of technologies [2]. CSP and biomass power has good potential for thermal power generation and/or process heat in the industrial sector from renewable energy.

Global capacity of CSP is growing rapidly and has reached 3.40 GW and bio-power capacity of 88.00 GW during the year of 2014, including combined power and process heat. India occupies the fourth position in the World with a CSP installed capacity of 0.5 GW and fifth position with a bio-power generation installed capacity of 4.12 GW [3]. As capacity of CSP with heat energy storage is growing rapidly but hybridization with CSP is receiving more attention due to low level of insolation in this country. The demand for biomass is increasing for use as solid fuels including wood pellets. It is the power generation potential of biomass, however, which has recently been attracting greater attention. On the other hand, biomass power plants is a secured supply of required quality and quantity at a competitive price for sustainable operation of the plant. Now the price of biomass resources has slowly increased due to non-availability of feed stock at right price in recent years. So, biomass and solar resources having an importance to hybrid with each other and add seasonally. Many industries use their electricity for their own requirements, like cooling, desalination for drinking water and process heat (preheating or feed water heating) to fulfill the energy demand. Taking in the view, many industries use their application through cogeneration process, but polygeneration process can provide their full energy demand with high efficiency such as power electricity, cooling and desalination and/or process heat. In this paper several aspects are associated for polygeneration process in hybrid solar–biomass power generation such as availability of biomass resources, solar DNI and energy analysis have been investigated.