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Design and integration of solar-biomass hybrid energy system for drip irrigation pumping

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ABSTRACT

Pump irrigation used in the agriculture farms account 25% of grid electricity consumption and 12% of diesel power. In India, electrical and diesel-powered water pumping systems are in practice for irrigation applications. Increasing cost and depleting conventional energy sources and grid availability at the site has created an interest in renewable energy sources. Hybrid renewable energy system in pumping is relatively new. Hybrid systems depend on more than one energy source therefore it increases flexibility and reliability of the system. Kota region of Rajasthan is having high abundance of solar, biomass and hydro renewable energy sources and moderate to low wind energy source. A small scale solar-biomass hybrid energy system can make a significant contribution for pumping operation in agriculture. Water use efficiency in Indian agriculture at 30.40%, is one of the lowest in the world, against the 55% in China. Therefore Drip irrigation is the best method for irrigation having 90% or higher efficiency. In this study an attempt has been made for designing of drip irrigation system for horticulture crops in two ha. land of Rajasthan technical university campus Kota. It involves the climatological and meteorological survey, the process of selection of drippers, sub main and main line pipe size and determination of pump capacity. According to peak water requirement and total head losses the designed pump size is 5hp which consumes 15kWh of electric energy per day to irrigate 2ha Guava crop. The approximate cost is ₹ 2, 46,000 for 4kW solar - biomass hybrid system.

Keywords: Drip irrigation system, solar biomass hybrid energy system, peak water requirement, head losses, renewable energy sources.

INTRODUCTION

The renewable energy sources are freely available, environment friendly and decentralize the electric power. Different renewable energy sources have different characteristics and the energy available from these energy sources is not constant but varies widely depending on the location and climatic conditions. Thus integration of two or more renewable/conventional energy systems also known as hybrid systems such as solar-biomass, wind-biomass, wind-solar, solar/wind/biomass and solar/wind/diesel etc. is useful in practice. In this paper theoretical investigation for applicability of solar biomass hybrid system for agriculture pumping is presented.

Drip irrigation: Drip irrigation is a method of applying uniform and precise amount of water directly to the root zone of the plants as per the requirement through emitters at frequent intervals over a long period of time via a low pressure pipe network comprising of mains, sub-mains, and laterals. In this system water is applied drop by drop, on the soil surface or below it at a rate lower than the infiltration rate of the soil. The main components of solar-biomass hybrids system are as follows.

1. A biomass gasifier based electricity generation system included biomass preparation unit, biomass gasifier, gas cooling and cleaning system, internal combustion engine suitable for operation in dual fuel mode, and electric generator.
2. PV electricity: Solar photovoltaic (SPV) technology involves the direct conversion of sunlight into electricity through the use of photovoltaic modules. Panels joined together form a PV array.
3. Inverter or dc to ac converter.

MATERIALS AND METHODS

Drip irrigation system design: Here the system is designed in Rajasthan technical university campus for guava crop in 2ha area. Rajasthan technical university Kota situated near Chambal River having large area of rocky and black soil.

Table.1.Engineering Survey

For drip irrigation system		For hybrid system	
Measurement of field	2 ha (200m × 100 m)	Annual mean daily duration of sunshine hours	9.3 hr
Elevation	304 m amsl	Daily Solar Radiation horizontal (kWh/m2/day)	5.68kWh/m2/day
Ground slope	level land	Latitude	25º08'27.3" N
Water source	Tanka	Longitude	75º48'35.1" E
Soil analysis	black clay	Altitude	0 m agl

Table.2.Agricultural and climatological details:

Agricultural data		Climatological data:	
Vegetables:	lady finger, garlic, chilly, locky, tomato	Temperature	25 ºC - 45 ºC
Horticulture crop:	guava, mango, papaya, onion, cotton	Average annual rainfall	660.6mm
Agriculture crop:	mustered, wheat, barlay, soya been	Evapotranspiration	6mm

Table.3.Drip irrigation system design

Designed parameters	Determination
Peak Water Requirement of the Crop	$\frac{A \times B \times C \times D}{E}$ A = Evapotranspiration rate, B = Crop Factor, C = canopy factor, D = area per plant, E = efficiency
Selection of Emitting Device	Online dripper having discharge of 8lph
Selection of Laterals	SDR of laterals = $\frac{\text{Dripper Q} \times \text{no.of dripper per plant}}{plant\ to\ plant\ spacing}$ (16mmϕ and 100m length)
Selection of submain	SDR = $\frac{\text{No.of plant covered} \times \text{dripper Q} \times \text{no.of dripper}}{length\ of\ submain}$ (75mmϕ ,100m length)
Number of plants	Area / area per plant
Total head(H)	(suction head + delivery head) {10m} + filter losses (5m) + Main line losses(1.3) + operating pressure (10m) + fitting loss (5m) + Ventury head loss (2m) + elevation differences
Flow in submain(Q)	$\frac{no.of\ plant\ covered\ X\ dripper\ Q\ X\ no.of\ dripper\ per\ plant}{3600}$
Required pump size(Hp)	$\frac{Q\ X\ H}{75\ \eta a\ \eta b}$ (Q=flow rate $\eta a\ and\ \eta b$ motor and pump efficiency respectively)

***SDR- Specific discharge rate**.

Design and configuration of hybrid system: The present investigation includes design of an integrated and sustainable renewable energy system that supply electricity to pumping system that irrigates the land of 2 hectares of horticulture crops in Kota, Rajasthan, India.

Table.4. hybrid system specifications

Drip system specifications		Pump system specifications		Solar-biomass system components	
Dripper capacity	8 lph	Total head H	35.3m	Size of biomass gasifier	3000 W
Number of drippers	3188	Discharge Q l/sec	7.08lit/sec	Solar array	1000 W
Drip system operation hours	4 hrs	Irrigated area	2 ha.	Inverter size	4.0kVA
Water Required per day	25504 lit	The size of pump	4.90hp/5hp	Motor- pump set	Submersible pump

Cost analysis of hybrid energy system: Approximate cost of multicrystalline solar panel is ₹ 60/watt (JNNSM report) and biomass gasifier is ₹ 60,000/kW (Ankur gasifier Pvt. Ltd.) and cost of 4kVA dc to ac converter is ₹ 6,000.

RESULTS AND DISCUSSION

Solar-biomass hybrid Systems is the feasible economic solution for lowering electricity bills; also they help in avoiding the high costs of extending utility power lines to remote locations, prevent power interruptions, and provide a non-polluting source of electricity. There is a definite need of the designed hybrid Systems based on the various operating and design parameters. In this paper, solar-biomass hybrid system is designed for the given requirement of drip irrigation pumping. The designed system does not require any battery storage thus eliminates battery storage unit in the system. In agriculture application like pumping biomass in the form of crop residue is easily available and affordable by the farmers. Hence it is suggested to use 3kW biomass gasifier and 1kW solar panel. As cost of solar panel and biomass gasifier is same (₹ 60,000/kW) total cost of the system comes out to be ₹ 1, 80,000 and ₹ 60,000 and cost of inverter ₹ 6,000 is ₹ 2,46,000. Alternatively for the same cost, 2kW biomass gasifier and 2kW solar panel can be installed.

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