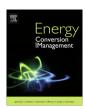


Contents lists available at ScienceDirect

Energy Conversion and Management

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



Review

Review of tri-generation technologies: Design evaluation, optimization, decision-making, and selection approach



Houssein Al Moussawi a,b, Farouk Fardoun a,*, Hasna Louahlia-Gualous b

ARTICLE INFO

Article history: Received 3 October 2015 Received in revised form 29 March 2016 Accepted 24 April 2016

Keywords:
Tri-generation
Prime mover
Heat recovery
Thermal storage
Evaluation criteria

ABSTRACT

Electricity, heating, and cooling are the three main components constituting the tripod of energy consumption in residential, commercial, and public buildings all around the world. Their separate generation causes higher fuel consumption, at a time where energy demands and fuel costs are continuously rising. Combined cooling, heating, and power (CCHP) or trigeneration could be a solution for such challenge yielding an efficient, reliable, flexible, competitive, and less pollutant alternative. A variety of trigeneration technologies are available and their proper choice is influenced by the employed energy system conditions and preferences. In this paper, different types of trigeneration systems are classified according to the prime mover, size and energy sequence usage. A leveled selection procedure is subsequently listed in the consecutive sections. The first level contains the applied prime mover technologies which are considered to be the heart of any CCHP system. The second level comprises the heat recovery equipment (heating and cooling) of which suitable selection should be compatible with the used prime mover. The third level includes the thermal energy storage system and heat transfer fluid to be employed. For each section of the paper, a survey of conducted studies with CHP/CCHP implementation is presented. A comprehensive table of evaluation criteria for such systems based on energy, exergy, economy, and environment measures is performed, along with a survey of the methods used in their design, optimization, and decision-making. Moreover, a classification diagram of the main CHP/CCHP system components is summarized. A general selection approach of the appropriate CCHP system according to specific needs is finally suggested. In almost all reviewed works, CCHP systems are found to have positive technical and performance impacts.

© 2016 Elsevier Ltd. All rights reserved.

Contents

1.	Introd	luction	159
2.	Trigeneration technology		160
	2.1.	Definition and principle	160
	2.2.	Advantages	160
3.	Trigen	neration classifications	161
	3.1.	According to prime mover	161
	3.2.	According to energy sequence	161
	3.3.	According to plant size	161
4.	Trigen	neration prime movers	161
	4.1.	Steam turbines	161
	4.2.	Gas turbines.	162
	4.3.	Microturbines	162
	4.4.	Combined cycle gas turbines	164
	4.5.	Reciprocating internal combustion engines.	165

E-mail addresses: houssein.almoussawi@etu.unicaen.fr (H. Al Moussawi), ffardoun@ul.edu.lb (F. Fardoun), hasna.gualous@unicaen.fr (H. Louahlia-Gualous).

^a University Institute of Technology, Department GIM, Lebanese University, Saida, Lebanon

^b Université de Caen Base Normandie, LUSAC, IUT de Cherbourg Manche, 50000 Saint Lô, France

^{*} Corresponding author.

Nomenclature surface area PEMFC proton exchange membrane fuel cell AbC absorption chiller PER primary energy rate AdC adsorption chiller PES primary energy savings performance fraction indicator AFC alkaline fuel cell PFI power to heat ratio PHR **CAPEX** capital expenditure PHX plate heat exchanger capital cost CCPM prime mover combined cycle gas turbine ppb, ppm, ppmv parts per billion, million, by volume CCGT combined cooling, heating, and power pinch point temperature **CCHP** PPT CCP combined cooling and power Pr pressure PVT CHP combined heating and power photovoltaic-thermal CHS chemical heat storage thermal power Q CI compression ignition Rec recuperator commercial Com Reg regenerator Con condenser Res residential COP coefficient of performance RICE reciprocating internal combustion engine domestic hot water DHW rotations per minute rpm desiccant dehumidifier S&THX shell and tube heat exchanger DD **EPC** exergetic production cost SE stirling engine specific cooling power SCP FS emissions savings **EUF** sensible heat storage energy utilization factor SHS Eva evaporator **SOFC** solid oxide fuel cell **FCS** fuel consumption/cost savings stainless steel SS **FESR** fuel energy saving ratio ST steam turbine **FUE** fuel utilization efficiency T temperature feed water temperature thermal energy storage **FWT TES** overall heat transfer coefficient U gega **GHG** greenhouse gas U_f fuel utilization factor v gas turbine GT volume **GWP** global warming potential width w WHRB height waste heat recovery boiler HHV higher heating value HP high pressure Greek letters **HRSG** heat recovery steam generator h energy efficiency **HST** heat storage tank exergy efficiency 3 HTF heat transfer fluid ϕ diameter HX heat exchanger difference Δ IC internal combustion w rotational speed ICE internal combustion engine micro Ind industrial IRR internal return rate **Subscripts** L length ambient LHS latent heat storage h boiler LHV lower heating value cooling LNG liquefied natural gas chilled water chw liquefied petroleum gas LPG cold water cw flow rate m electrical mass mg equivalent eq M million/mega eqm equipment molten carbonate fuel cell MCFC exhaust ex MP middle pressure fuel metric standard cubic meters **MSCM** h heating micro-turbine MT hot water hw NG natural gas Investment Inv NPV net present value in input OCS operating cost savings maximum max ODP ozone depletion potential minimum min **OPEX** operational expenditure overall ORC organic Rankine cycle operating OD electric power optimum opt **PAFC** phosphoric acid fuel cell out output **PBP** pay back period power generation unit pgu **PCM** phase change material recovery PEC primary energy costs

Download English Version:

https://daneshyari.com/en/article/7160405

Download Persian Version:

https://daneshyari.com/article/7160405

<u>Daneshyari.com</u>