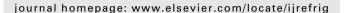




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Performance evaluation of a variable speed DC compressor

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ABSTRACT

Direct current compressors are strong candidates to be employed in energy-efficient refrigeration systems, especially for renewable energy powered units, as these compressors do not require additional components such as a power inverter that an alternative current compressor would require. This study represents experimental performance analysis of a direct current type refrigeration compressor implemented in a 79 L refrigerator. Energy usage reduction and operational improvement potential of the direct current compressor via variable speed operation were investigated. Experiments were carried out at variable speed operation and four different constant speed operation modes of the compressor. Temperature, pressure, and power input measurements were obtained every 30 s. The experimental data were analyzed in terms of energy and exergy efficiencies. The comparison showed that variable speed operation of the direct current compressor can be much more efficient than constant speed operation of the direct current compressors, especially at higher speeds.

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Evaluation de la performance d'un compresseur à courant continu à vitesse variable

Mots clés : Courant continu ; Froid ; Vitesse variable ; Économies d'énergie ; Exergie

1. Introduction

Improvements and reduction in the energy consumption of refrigerator compressors is crucial for the refrigeration industry. Domestic refrigeration systems have the opportunity to be powered by green technologies such as solar energy. Solar energy can be used in the absorption refrigeration systems or vapor compression refrigeration systems, but in the present study, only vapor compression refrigeration systems have been investigated. Green technologies have

been focusing on either decreasing energy usage, or creating environmentally friendly systems worldwide. In the case of refrigeration, there are two different options for powering the compressor which are alternative current (AC) or direct current (DC). A compressor is combination of a mechanical compression part and an electrical motor. An electrical motor converts electrical energy to mechanical energy in a refrigeration compressor. An AC current compressor is powered by alternative voltage such as 120 or 220 V and 50 Hz. Electrical motor of the AC compressor is an AC induction type. On the

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Nomenclature Gre				
		ϵ	absolute wall roughness [-]	
Roman		ho	density [kg m ⁻³]	
Α	surface area [m²]	ψ	exergy efficiency [–]	
B_i	bias error [-]	τ	transmittance	
B_R	bias uncertainty [-]	α	absorptance	
С	command [-]	γ	efficiency correction coefficient	
D	pipe diameter [m]	η	electrical efficiency	
Ėx	exergy rate [W]	Subscrint	Subscripts	
ex	specific exergy [J kg ⁻¹]	-	actual	
f	friction factor [-]	act	ambient	
h	specific enthalpy [J kg ⁻¹]	amb	cabinet	
I	solar irradiance [W m ⁻²]	cab	Carnot cycle	
I _m	maximum power point current [A]	Carnot	photovoltaic cell	
I_{oc}	open circuit current [A]	cell	cold side	
I_{sc}	short circuit current [A]	COLD	compressor	
K_{L}	loss coefficient [-]	comp	condenser	
Kp	proportional gain [-]	con	condensing	
L	pipe length [m]	cond	capillary	
ṁ	mass flow rate [kg s $^{-1}$]	cap	destruction	
N	number of bits of resolution [-]	des	evaporator destruction	
Of	offset [–]	des_evp	external destruction	
P_i	precision error [–]	des_ext	internal destruction	
P_R	precision uncertainty [–]	des_int	desired	
P_{major}	major pressure losses [Pa]	desr	evaporating	
P _{minor}	minor pressure losses [Pa]	evap	evaporator	
Q	heat flow rate [W]	evp	hot side	
Q _{pv_loss}	heat flow rate from the PV surface [W]	HOT	inlet	
Q _{cooling}	total cooling load [W]	in	photovoltaic inlet	
R	experimental results [–]	in_pv	loss	
R_k	kth number of resistance [ohm]	L	maximum	
Re	Reynolds number [-]	max	minimum	
S	specific entropy [J kg ⁻¹ K ⁻¹]	min	reference state	
S _{gen}	entropy generation [W K ⁻¹]	0	outlet	
U_R	uncertainty in the experimental result [–]	out	photovoltaic panel surface	
U	total heat transfer coefficient [W m ⁻² K ⁻¹]	pv_srf	reference conditions	
V_n	nth number of variable [–]	ref	sun	
$V_{\rm w}$	wind velocity [m s ⁻¹]	sun	system	
$V_{\rm m}$	maximum power point voltage [V]	sys tot_des,pv		
V_{oc}	open circuit voltage [V]	-		
T	temperature [K]	Superscri	-	
Ŵ	power transferred out from the system [W]	Q	heat transfer into the system	
\dot{W}_{comp}	compressor power input [W]	W	power transferred out of the system	
и	refrigerant velocity [m s ⁻¹]			

other hand, DC compressor requires low voltage and direct current supply such as 12–24 V. Even though, DC compressor has similar mechanical compression part with AC compressor, it has a brushless electrical motor. Green energy technologies can be used to power a DC compressor directly while an AC compressor requires a power inverter. Energy usage reduction through improved efficiency and use of renewable energy employing DC compressors is an advantage of such systems. There are other uses of small-sized refrigeration systems besides household use. Many vehicles such as trucks, caravans, boats, cars, etc. are often equipped with portable cooling appliances. To improve compressor and refrigeration system efficiency, modulation methods are used.

Cooling capacity and cooling demand of a refrigeration system is equalized by using refrigeration capacity modulation methods. According to Qureshi and Tassou (1996), the most efficient method is variable speed capacity modulation. Different studies have been conducted on variable speed refrigeration systems but most of these are related to AC compressors. Qureshi and Tassou (1996) investigated variable speed capacity modulation of domestic size heat pumps. The study focused on different topics with AC compressors such as energy conservation by using capacity modulation, performance comparison with conventional systems, and mathematical modeling of variable speed systems. Results showed that a variable speed capacity modulation method

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