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Solar based Air Conditioner with Standalone BLDC, Charger Controller and Battery Backup for Improved Efficiency

***Abstract**. Because of its high efficiency, high power density, and low cost, the synchronous brushless DC (BLDC) motor is increasingly used in industrial settings, particularly in solar DC air conditioning systems and household applications. In this article, we provide a method for measuring the characteristics of BLDC motors used in solar-powered DC air conditioning systems. The main source is solar energy, which is widely available, environmentally friendly, and excellent for the next generation. This essay discusses how changing the brushless DC motor's speed can adjust the air conditioner's output in accordance with the size of the room. Under the guidance of the Matlab program, the identification techniques are being evaluated through simulation.*

Streszczenie. *Ze względu na wysoką wydajność, dużą gęstość mocy i niski koszt, synchroniczny bezszczotkowy silnik prądu stałego (BLDC) jest coraz częściej stosowany w warunkach przemysłowych, szczególnie w systemach klimatyzacji na prąd stały i zastosowaniach domowych. W artykule przedstawiamy metodę pomiaru charakterystyk silników BLDC stosowanych w systemach klimatyzacji prądu stałego zasilanych energią słoneczną. Głównym źródłem jest energia słoneczna, która jest powszechnie dostępna, przyjazna dla środowiska i doskonała dla następnych pokoleń. W tym eseju omówiono, w jaki sposób zmiana prędkości bezszczotkowego silnika prądu stałego może dostosować moc wyjściową klimatyzatora do wielkości pomieszczenia. Pod kierunkiem programu Matlab techniki identyfikacji są oceniane poprzez symulację.* (***Klimatyzator zasilany energią słoneczną z samodzielnym BLDC, kontrolerem ładowarki i baterią rezerwową dla lepszej wydajności***)

Keywords: Brushless DC motor, Parameter Tuning Methods, Batteries, Charger controller.
Słowa kluczowe: klimatyzator, baterie słonecznw

Introduction

Because of their great power density and efficiency, inside permanent magnet brushless DC motors are becoming more popular in industrial applications and electrical machinery [1-3]. Due to developments in motor control electronics, magnet technology, and manufacturing capital expenditure, brushless machines have grown less expensive in recent years. As a result, brushless machines have gained popularity in high-speed applications [4-7].

Appliances, automobiles, airplanes, consumer goods, healthcare, automated industrial equipment, and instrumentation are just a few of the applications for BLDC motors. Power switches are used as the BLDC motor's electrical commutators rather than brushes. In comparison to brushed DC motors and induction motors, the BLDC motor has a number of advantages, including improved efficiency, durability, reduced acoustic noise, smaller and lighter, better dynamic responsiveness, better speed vs torque characteristics, a wider speed range, and longer life. [8-11].

The speed control, as well as the inner hysteresis current controller, will assist in driving the air-cooling system by adjusting the speed of the BLDC motor.

To increase the system's dependability during power outages, a battery and charge controller are provided. As a result, the system is made to function effectively in all solar radiation conditions. [12-15].

The BLDC motor has a substantially higher efficiency than any other motor due to the usage of an electronic switch rather than a mechanical switch. Some advantages of a BLDC motor over a DC motor include improved speed vs torque characteristics, durability, longer life, noiseless operation and higher efficiency, elimination of switching ionizing sparks, and a full EMI trim. Because of the important benefits mentioned above, we decided to develop the SPV fed air cooler with a BLDC motor.

[16-18].

BLDC motors are more suited to produce flat torque characteristics than other motors since they have a relatively high speed range for sustaining torque and no brush fiction to reduce torque. The BLDC motor has been widely utilized in industry due to its outstanding speed control capabilities, despite having higher maintenance costs than an induction motor. [19-20].

In order to charge the battery and stop the electric cells from being overcharged, a solar charge controller essentially functions as a voltage or current controller. Here, the pulse width modulation controller is used. Charge controllers of this type are the norm; examples include anthrax, Blue Sky, and others. They are currently thought to be the norm in the sector. The simplest charge controller regulates the device voltage and opens the circuit to stop charging when the battery voltage reaches a certain threshold.

A mechanical relay was utilized by more charge controllers to open or close the circuit and start or stop electricity to electric storage devices. Sections of the paper are oriented differently.

The article is introduced briefly in Section I. Section III examines the simulation results after Section II details the parameters estimation BDCM. The experimental study is described in Section IV, and the conclusion is covered in Section V.

Parameters Estimation BDCM

Because there are no brushes used in BLDC motors, they should have a long lifespan and operate quietly. Permanent magnets utilized in the rotor produce a high torque-to-motor size ratio. Hall sensors are necessary for BLDC motors to determine the position of the rotor, but they raise the system's cost. The armature leakage reactance has mainly been replaced by the Potier reactance. [1-3].

To get precise armature leakage reactance xs measurements without endangering the equipment under test. Without being loaded or stimulated machine, the (V/I) characteristic is required, as well as the machine's open-circuit characteristic as presented in Fig.1

Although having higher maintenance costs than an induction motor, the BLDC motor has been widely employed in industry due to its outstanding speed control capabilities. As a result, the corresponding and are known for a given stator voltage, yielding the alpha If/I ratio. It is acknowledged that the nonlinear magnetic curve at rated speed can be produced either directly or inverted by activating the field circuit and opening the stator terminals., Fig.2.

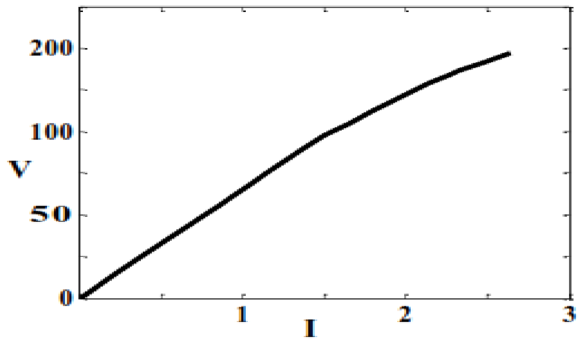

Fig.1: Open Circuit Characteristics

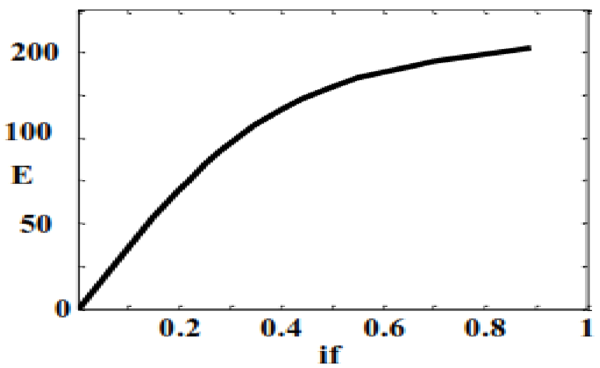

Fig.2: Nonlinear magnetic characteristic

The armature current in V(I) is assumed to be a pure magnetizing component by ignoring copper and core losses. The foundation of the solution for all fluxes in the BLDC motor is the permeability of the bridge, a nonlinear unknown parameter.

For this issue, the iterative approach works well. Here is an example of an iterative process:

- Chose an initial value of the leakage reactance xo.
- Calculate all saturation factors.
- Find E from the open circuit test.
- Calculate the reactance x.
- Compare the obtained leakage reactance xo with x.
- Finally, adjust xs
- Keep doing this until the fault is fixed.

After applying this process in the three applied method (open circuit test, short circuit test and Potier), the characteristics of the field/armature ratio is obtained in figure 3

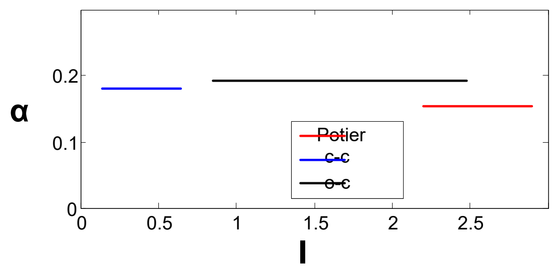

Fig. 3: Leakage reactance characteristic

BLDC Improved Efficiency

The suggested method was tested in a lab setting and at a number of hydroelectric plants on numerous significant synchronous machines of varying rated sizes. Table 1 and 2 summarizes the rated values of the tested machines.

A steady excitation current was maintained while the units were loaded, and voltage, active power, and reactive power measurements were taken. The Potier approach relies on disentangling the effects of an armature's leaking reactance.

Table 1. lists the short circuit test's rated features.

Vs	0	24	48	96	117	130	140	150	170
Is	0	0.25	0.5	1	1.22	1.36	1.47	1.57	1.77
Vs	185	200	218	234	258	274	300	315	325
Is	1.91	2.08	2.3	2.5	2.8	3	3.4	3 .7	4

Table 2. Rated characteristics of the open circuit test.

E_f	0	108	115	140	150	170	185	215	220
J	0	0.15	0.16	0.2	0.22	0.25	0.28	0.32	0.35
E_f	232	245	255	260	270	277	283	289	305
J	0.4	0.44	0.48	0.5	0.55	0.6	0.65	0.7	0.89

It is used to calculate the armature reaction's equivalent of field current and leakage reactance. It is the voltage regulation technique that is most precise.

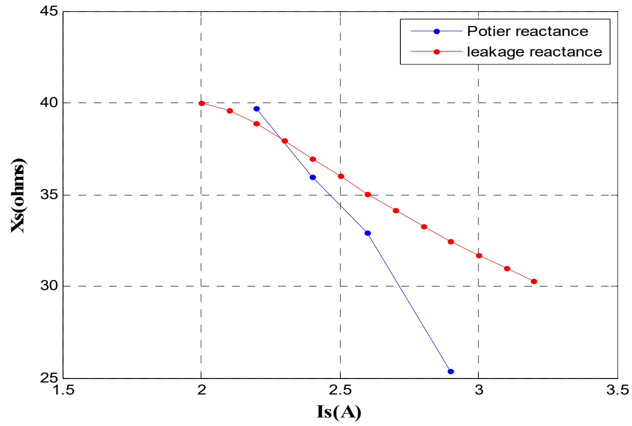

Fig.4. Leakage characteristic impedance comparison

Experimental measurements and investigation of brushless dc air conditioner using solar power

in this section we manage to describe what should be done in practical measurement that aim to calculate efficiency of the system by calculating electric and thermal readings from sensor, ammeter and anemometer. Our focus is on parameters that we want to measure, schematic of the system and parameters that we must find out by calculation.

In this part we aim to give clear image about actual project, performance and measurements. We also brought normal AC air conditioner to compare results and performance between them. Since we are using brushless dc motor inside compressor combined with off grid system, we are expecting better and more efficient performance than normal air conditioner.

Fig.5. Solar panels

Fig.6: Charger controller

Fig. 7: Acid battery

Fig.8: DC & AC air conditioner

First, this part consists of 6 solar panel (figure 5) each three connected in series and thin two row connected in parallel. Each panel 405W total is 2430W.panels are connected into charger controller using DC wires and since panels' output voltage is about 120V then we intuitively can expect that charger controller (figure 9) must reduce that voltage before fed it to 48V air conditioner and 6 volts battery. Now talk about battery, there are 8 ACID deep cycle battery (figure 7) connected in series which make total voltage same or less as rating of air conditioner. Finally, we brushless motor dc air conditioner that is rated 2160W (figure 8),

Then, all we can do from now is to take measurement about input electrical and output thermal energy in order to calculate overall efficiency and compare it to AC air conditioner we got. It is worthy that mechanical energy conversion between electrical and thermal energy is not calculated due to complexity, moreover mechanical losses (frictional losses) inside compressor does not have big effect on overall efficiency.

As we mention before thermal efficiency can be calculated by measuring temperature before and after compressor, condenser and evaporator. Same thing will be done for refrigerant flow rate inside pumps. (figure 9).

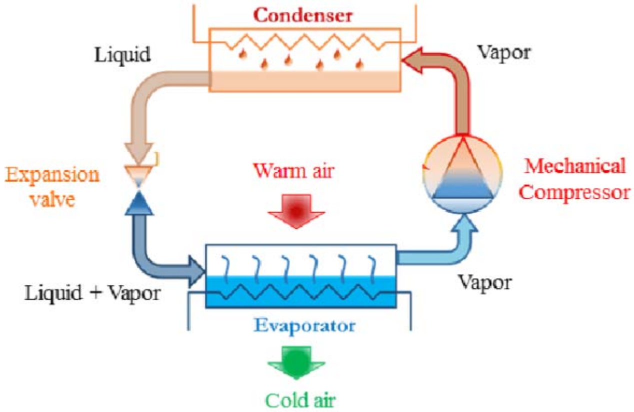

Fig.9: Cooling Cycle

Fig. 14: AC & DC Air Conditioner

We are interested to know what time it takes for each air conditioner in order to reach the desired temperature. The following schedule shows it for different temperature. Keep in mind that assumed desired temperature is 30Co.

Table 3. coefficient of performance test.

	40 Co	35 Co	30 Co
COP	3.35	3.61	3.9

Where COP is the coefficient of performance required for DC air conditioner to reach into desired temperature.

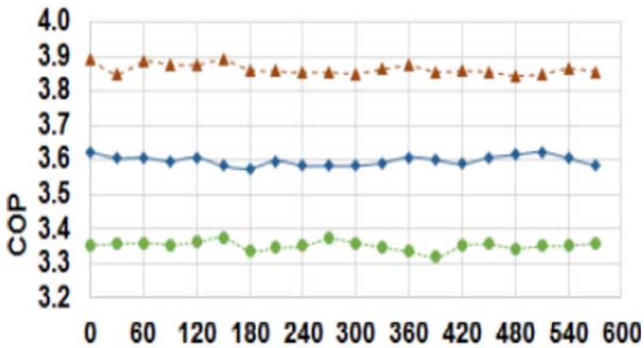

Fig.10: coefficient of performance with time

Now in figure 10 where COP (which describe the useful cooling energy in relation to input power) is inversely proportional to temperature.

In this paper, a DC air-conditioning system with an integrated BLDC motor-rotary compressor is experimentally tested.

The study's findings demonstrated that raising the condenser's air inlet temperature increased condensing temperature, cooling capacity, and compressor work while lowering coefficient of performance (COP).

It may seem desirable to have a greater COP for better efficiency, but on the other hand, we need sufficient cooling capacity because the compressor is tiny due to power consumption. The evaporating temperature rises with the increase in condenser air inlet temperature.

Conclusion

The first component of this work is to offer a novel approach combining the constant excitation test and straightforward calculations over the acquired data to determine the armature leakage reactance of a BLDC motor.

This was done since even for modest changes, the percentage errors seem to be higher due to the small values of the leakage reactance. The idea uses solar-powered brushless DC compression to help reduce or conserve input energy losses. To maintain the system's backup, we require eight 48-volt ACID deep cycle batteries and six 405W PV modules for this reason.

According to the study's results, raising the condenser's air inlet temperature led to an increase in condensing temperature, cooling capacity, and compressor work while lowering the coefficient of performance (COP).

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