JOURNAL OF ENGINEERING AND EARTH SCIENCES
JEES ISSN: 1897-8680
JEES 2022
VOLUME 15 ISSUE NO 1
PAGE 129 - 139

DEVELOPMENT AND IMPLEMENTATION OF DC SMART VENTILATOR USING SOLAR SYSTEM

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ABSTRACT

Small and portable Direct Current (DC) smart fans with solar power are utilized in different rooms of the house or business. It provides office workers with a variety of services, including energy conservation, the removal of heat from indoor spaces, and outdoor space ventilation. For a nation like Nigeria, which benefits from an average of eight hours of sunlight each day, the concept of a solar DC driven fan employing a smart ventilator has been demonstrated to be highly important. In this work, a standing-three-blade DC fan powered by a 40 watt photovoltaic (PV) module uses a programmable controller to adjust its speed in response to the ambient temperature Additionally, this work's goal is to achieve the rate of about 85% efficiency after subjected this ventilator to an intensive testing. In order to maintain constant operation during the night and when the sun is not at its peak, a 18Ah, 12V battery has been considered suitable to serve as power supply.

KEYWORDS: DC Smart Ventilator; Photo-Voltaic module; Controller; Temperature sensor

INTRODUCTION

The Department of Energy Efficiency and renewable Energy (2003) pointed that It is obvious that solar energy might play a significant role in tackling the present energy and climate change challenges, as the availability of fossil fuels is declining due to overuse, notwithstanding its effects on ozone layer depletion. There is an obvious growing need for countries to reduce their emissions and achieve greater energy independence while coping with rising volatility in the price of fossil fuels, a significant increase in energy demand and CO_2 emissions in emerging nations, and a decline in nuclear generation in the energy mix of developed and developing nations. Hydroelectricity makes up 16% of the entire amount of renewable energy used to produce electricity, while new renewable makes up 3% of this total. One of the most exciting advances in the field of renewable energy in recent years has been the decline in the price of photovoltaic (PV) cells (Renewable energy policy network for the 21st century, 2011). Osman et al., (2014) conducted research on the design and implementation of an infrared remote controlled fan regulator. Shigley and Mischke (2003) mentioned that A ventilator or fan is used to ventilate a house's cabin; it brings in outside air while also expelling hot air outside. This novel device employs solar electricity combined with the ventilation system to control the temperature inside the house on sunny days. A ventilation system comprising a ventilator or fan to inhale fresh air from environment surrounding enters the cabin of a house where at the same time exhale the hot air to the outside. This invention system is using solar power integrate with the ventilation system in order to stabilize the thermal condition inside the house during sunny day. The solar power is chosen as it is reasonable due to its limitless and environmental friendly source. In addition, a rechargeable battery is used to power the ventilator in the absence of the alternative energy during cloudy day or has obstacle like being shaded by buildings, trees and others (Al Husseini et al., 2010; Ankit et al., 2021). Solar electricity is the chosen source due to its abundant supply and ecologically friendly nature, as well as its affordability (Kreider & Kreith, 1981; Nasir, 2004). In addition, a rechargeable battery is utilized to power the ventilator when there is no alternative energy source available, it is foggy outside, or it faces other challenges such being shaded by structures like buildings or trees. It functions much like a backup supply in an emergency. This might stop the system from running out of power. In order to identify targeted (high temperature) and desired (lower temperature) temperatures inside the house, a heat sensor is utilized. Surabhi & Vivek (2015) proposed temperature based DC fan ventilator by designing circuit using microcontroller and pulse width modulation technique. The controller uses a device that can detect environmental condition to enable the power supply to activate or deactivate the ventilator. It is operationally coupled to a logic circuit with considerable environmental factor. In another development, Sikiru et al., (2014) provided their research on a portable solar-DC Powered Fan, which can be used in offices.

Hence, our main contribution is to develop and implement a solar powered standing D.C. fan with controller that can be used for both urban and rural areas. This is followed by having critically observations on the duration of usage, the effect of temperature changes on the speed of DC smart ventilator.

MATERIALS AND METHODS

Materials

The solar power system consists of the battery and the solar PV system, which is used to power the fan and controller. The voltage acquired from the solar system is being regulated with a voltage regulator that is connected to the micro controller. The microcontroller works like a processor that connects the temperature sensors, battery monitor and other ICs (Integrated Circuit such as LCD (Liquid crystal display). The LCD displays the temperature changes. The Amplifier boost the signals from the micro controller, which is then used to power the DC (direct current) fan. The battery also can be charged through 230V house hold supply. This charge circuit uses regulated 12V, 750mA power supply of full wave rectification and an Integrated circuit (7812) three terminal voltage regulator is used for voltage regulation.

Analysis of the required airflow for cooling

After the equipment specifications and conditions of the system have been determined, there is need to calculate required airflow to meet the conditions (Hudson Product Consideration, 2000). The equation (1) shows that it can only be applicable when the heat radiation is performed only by cooling air from the fan.

Let Q = Motion airflow (m^3/min)

$$Q^1 = \frac{V}{20\Delta T} = \frac{40\ (W)}{20x18\ (K)} = 0.11\ (m^3/\min) \quad (1)$$

Before a fan can be specified for a particular system, there are a few parameters that are important to understand regarding airflow and heat transfer. Moving air is effective in cooling objects by absorbing heat from the object and then transferring hat heat elsewhere to be dissipated (Budynas & Nisbett, 2006; Khurmi & Gupta, 2005). The amount of energy transferred in equation (2) is dependent upon the mass of the moving air (m), the specific heat of the moving air (c), and the temperature change (θ) imparted to the moving air.

$$Energy\ transferred = m \times c \times \theta \qquad (2)$$

The mass of the moving air can be calculated from the volume of air (V) being moved and the density of the moving air (ρ).

$$m = V \times \rho$$

Therefore,

$$Energy\ transferred = V \times \rho \times c \times \theta$$

$$Power = \frac{V \times \rho \times c \times \theta}{t} \qquad (3)$$

In most applications the excess power (inefficiency of the system) is known, which is indicated in equation (3) and the airflow rate (volume/time) is unknown. Thus, the equation can be arranged as shown in equation (4).

$$Airflow = \frac{Power}{\rho \times c \times \theta} \qquad (4)$$

Ventilator is a driver of both (i) Indoor Air Quality (IAQ) considerations in residential building and (ii) Energy use in residential building (conditioning ventilation air and fan power requirement). In order to provide both improved IAQ and energy performance in residential building, ventilation must become aware of what is happing in the space and its own impact; that is, it must become smarter. Smarter ventilation provides higher performance whether that performance is more energy-efficient, conducive to improved IAQ, or it also takes into consideration the needs of the power grid and potential future variable costs of electricity (BASF Corporation, 2003). The block diagram for the implementation of the smart ventilator and the electronic circuit of the system are show in Figures 1.and 2 respectively.

RESULTS AND DISCUSSION

For this research work, correlation method was adopted to know the effect of temperature on ventilator speed level when the temperature is increasing (hot) and when the temperature is decreasing. Correlation is a test procedure used for testing whether two metric variables are linearly related in some population. Here, the temperature (^oC) and the speed level (%) are the two performance metrics used. The correlation coefficient (a value between -1 and +1) depicts how strongly two variables are related to each other. A correlation coefficient of +1 indicates a perfect positive correlation.

Temperature is recognized as the primary parameter for quantifying comfort because of its impact on relative humidity and on indoor pollutant concentration such as formaldehyde, temperature is clearly a parameter of interest when considering ventilation (Khurmi & Gupta, 2006; Sharma & Aggarwal, 2006). Researchers have investigated temperature as a suitable variable for controlling ventilation homes. The performance of natural and hybrid ventilation systems controlled by indoor temperature and predicted mean (PMV). By turning off the air conditioning when it is not needed, 24 hour cooling needs were reduced at least 8% in the cross-flow strategy and at least 28% in the optimized hybrid strategy (Ezeilo, 1998). Nevertheless, indoor temperature-controlled ventilation is not further investigation here. The Effect of Temperature on Ventilator when the temperature is increasing is as shown in Table 1. The correlation is 0.935 as shown in Table 2. It is an indication that a strong (positive) linear relationship exist between temperature and speed level of the ventilator. The p-value is denoted by "Sig. (2-tailed)" and it is equal to 0.000. N is the number of samples which is 11 in this case. If the correlation is 0 in the population, then there is a 0% chance of finding the correlation we found in our sample. If p-value is less than 0.05, the null hypothesis is typically rejected. We can infer that the population's correlation is not zero (we now expect it to be somewhere near 0.935). As a result, the significance test shows that a strong linear relationship between temperature and ventilator's speed level was found. The level also rises when the temperature rises. The effect of temperature on the ventilation speed level when temperature is changing is as shown in Figure 3. It can be observed that the increase with the level which the ventilation is changing in the same direction. Then, the graphical illustration of the system shows incomplete linear relationship from which there is irregular airflow of temperature. In Table 3, the value of correlation is 0.998, which indicates a strong (positive) linear relationship between temperature and speed level of the ventilator. The p-value is denoted by "Sig. (2-tailed)" and it is equal to 0.000. N is the number of samples which is 13 in this case. If the correlation is 0 in the population, then there is a 0% chance of finding the correlation in our sample.

The null hypothesis is normally rejected if p-value < 0.05. We can conclude that the correlation is not 0 in the population (we now expect it to be somewhere near 0.998). Hence, the significance test indicates that a strong linear relation was observed between temperature and speed level of the ventilator. Figure 4 shows the negative effect of temperature on the speed level. It can be seen that there is sharp decrease with the speed level, in which the ventilation is changing in opposite direction. Further to this observation, is a partial sloppy portion with irregular airflow temperature.

Battery charging with level

Depending on the time of day and weather, measurement will probably be lower than the maximum listed, but it should be close to the value that is appropriate for the size of your solar panel. When the panel is in the sun, if the measurement of the current from the solar panel is close to the maximum output current, but the 12V on the terminals from step is less than 13 .6 – 13.8V, then the power supply should be returned for repair.

It was concluded that passive infrared activity sensors had a poor short-term correlation with CO_2 but an excellent long-term correlation (BASF Corporation, 2003). Indoor Air Quality (IAQ) has been described by the World Health Organization (WHO) as acceptable if:

- Not more than 50% of the occupant can detect any odour,
- Not more than 20% experience discomfort,
- Not more than 10% suffer from mucosal irritation,
- Not more than 5% experience annoyance,
- Not more than 2% of the time

Effects of Fan Speed

The speed of the fan (rev/min) can be determined by the initial selection of the fan or by a fan control signal. Changing the speed of the fan will affect the air volume, the air pressure, the power consumed, and the acoustic noise produced by the fan. These relationships are described as the "fan affinity laws"

The fan laws would indicate that doubling the flow rate of a fan will increase the required shaft power by about eight times. For example, if flow was (472 L/s) at 10 Watts shaft power, the power expected to reach (944 L/s) would be 4 x 10 = 40 watts. In the data obtained from the test reports, velocity at 9 volts is reduced to 46.4 percent of the velocity at 12 volts. 46.4 percent cubed is 10 percent, so by the fan laws, shaft power is expected drop to 10 percent. Shaft power was not measured but electrical power dropped to 13 percent. Electric power is not expected to drop quite as much as shaft power because motor efficiency is reduced at very low loads (Hudson Product Consideration, 2000).

CONCLUSIONS AND RECOMMENDATIONS

In summary, a ventilator fan powered with 12V battery and charged with a 40 watt PV module of solar panel using designed controller had been developed. This work necessitated for the need to have a fan that could facilitate ventilation in both outdoor and indoor with a renewable energy for use as a source of power backup when there is no sunlight in the night. At the end of this research work, the variation of the speed with temperature rise could be observed clearly on the display unit. The system would work perfectly at fully charged battery regardless little temperature variable. Further research can be conducted in future to compare the effect of temperature on speed level in both outdoor and indoor within specified period of time.

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Table 1: Effect of Temperature on Ventilator when the temperature is increasing

S/No	**Temperature (^0C)**	**Level (% of the total speed)**
1.	29	55
2.	30	60
3.	31	63
4.	32	67
5.	33	75
6.	35	80
7.	34	75
8.	36	83
9.	41	100
10.	48	100
11	49	100

Table 2: Correlations

		Temperature	Level
Temperature	Pearson Correlation	1	.935**
	Sig. (2-tailed)		.000
	N	11	11
Level	Pearson Correlation	.935**	1
	Sig. (2-tailed)	.000	
	N	11	11

Table 3: Effect of Temperature on Ventilator when the temperature is decreasing

S/N	Temperature (^{0}C)	Level (% of the total speed)
1.	32	67
2.	31	63
3.	30	60
4.	29	51
5.	26	43
6.	25	40
7.	24	35
8.	23	31
9.	22	27
10.	21	23
11	20	20
12.	19	15
13.	18	11

Table 4: Correlations

		Temperature	Level
Temperature	Pearson Correlation	1	.998**
	Sig. (2-tailed)		.000
	N	13	13
Level	Pearson Correlation	.998**	1
	Sig. (2-tailed)	.000	
	N	13	13

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5: Battery usage with speed level

S/N	Battery Voltage (V)	Level (% of the total speed)
1	12.98	71
2	12.75	73
3	12.78	76
4	12.67	81
5	12.58	86
6	12.48	91

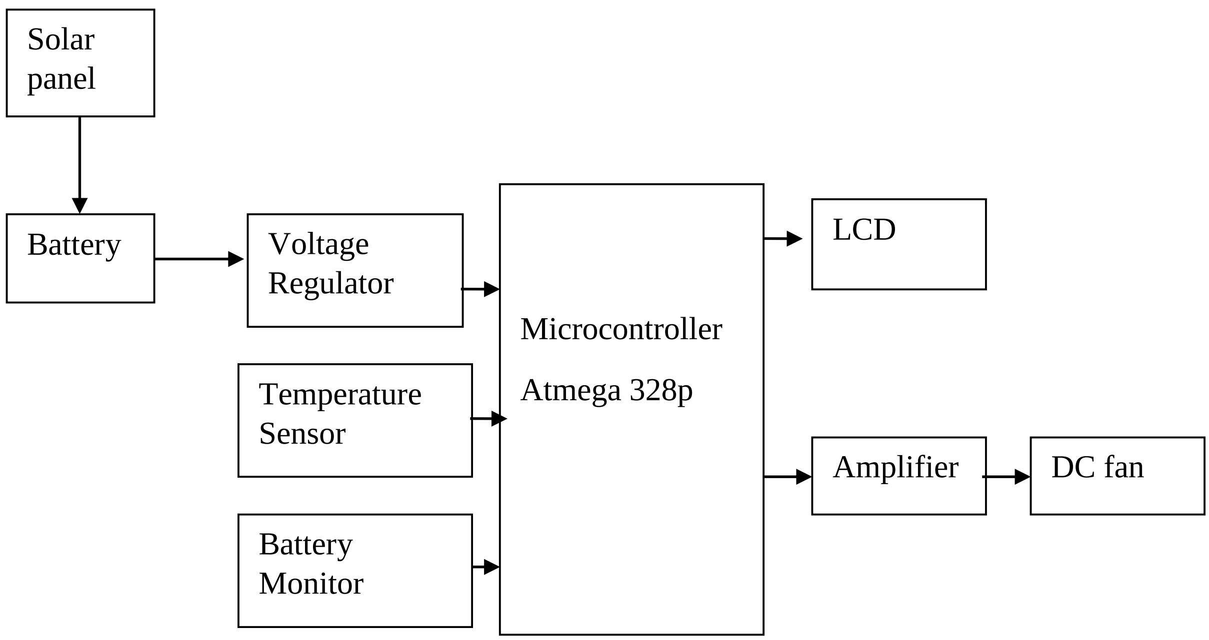

Figure 1: Electronic circuit of the implemented system

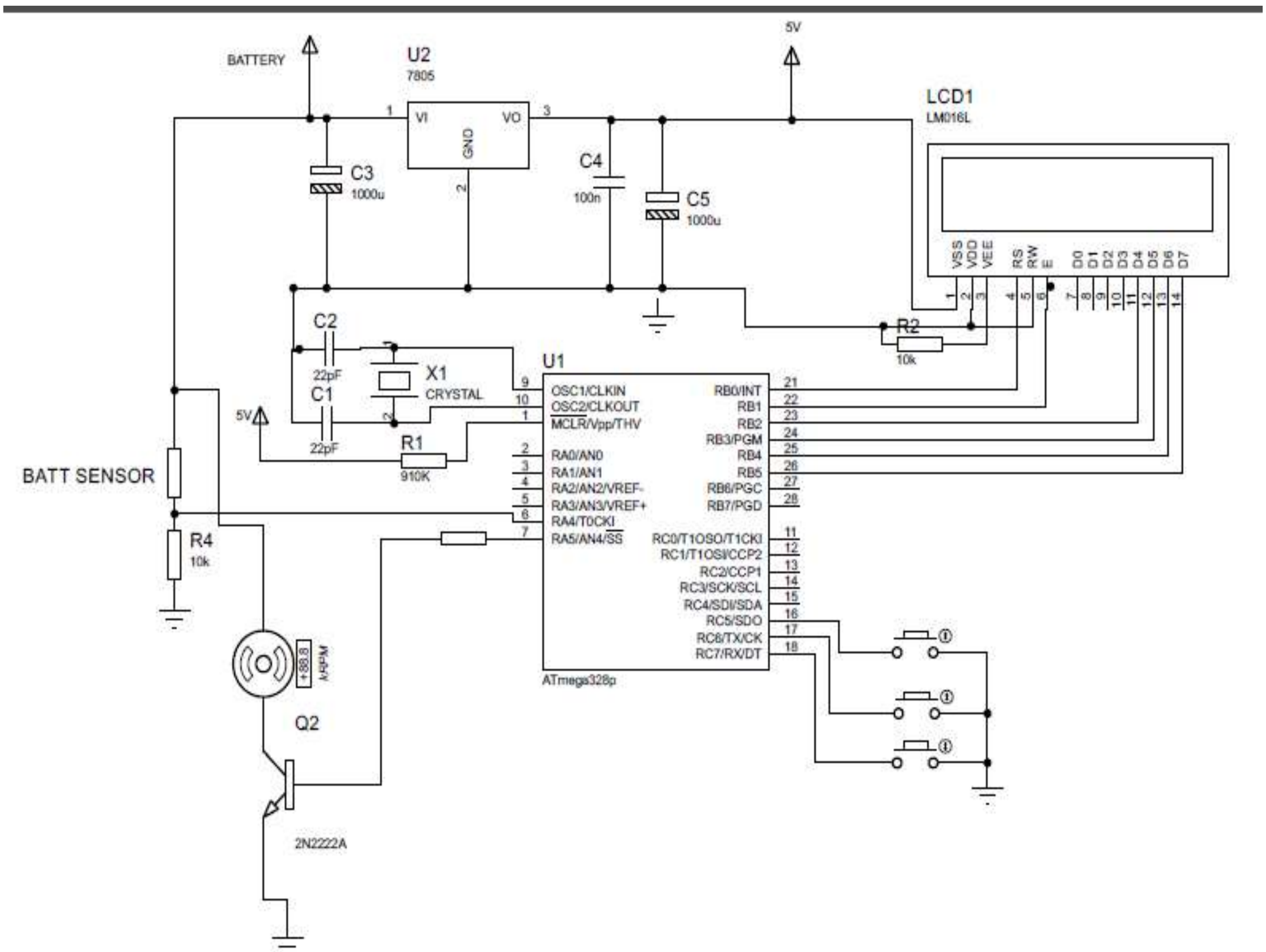

Figure 2: Electronic circuit of the implemented system

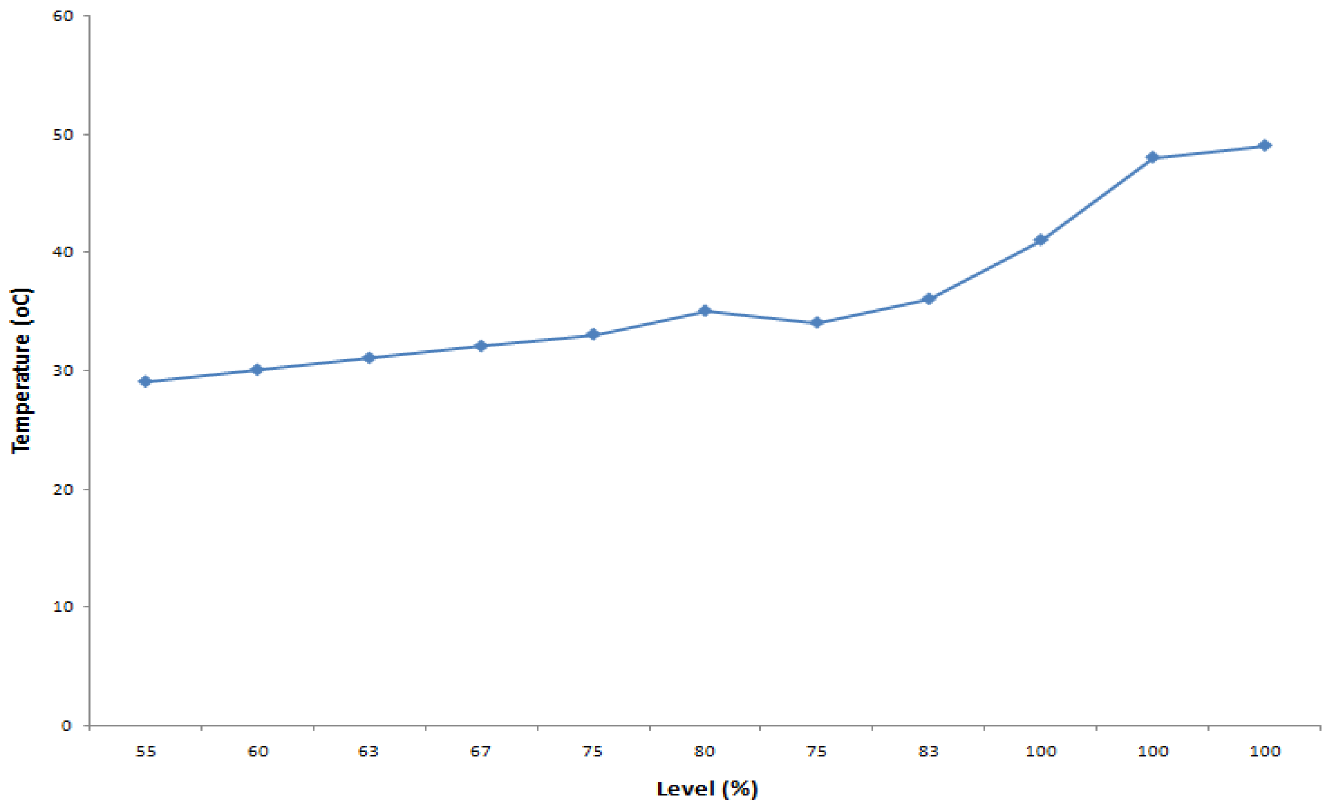

Figure 3: Effect of temperature on speed level when the temperature is increasing

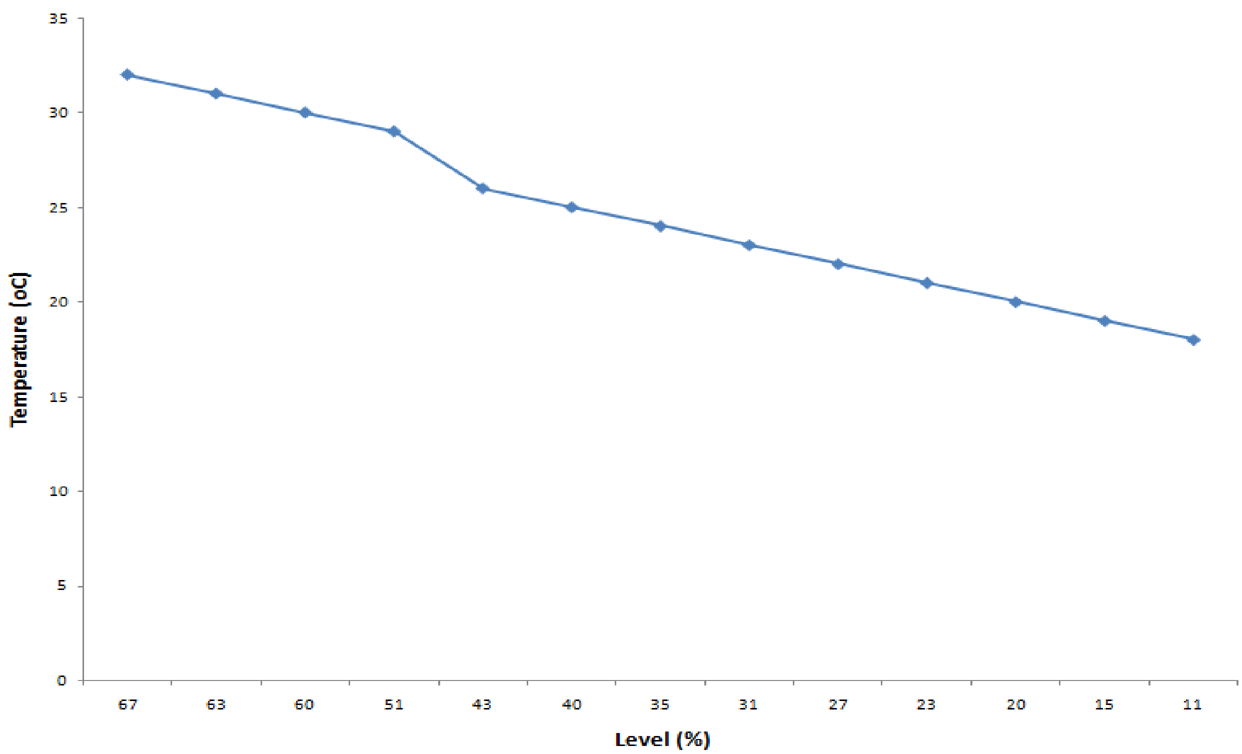

Figure 4: Effect of temperature on speed level when the temperature is decreasing

Figure 5: Complete Solar DC Fan with Controller (Smart Ventilator)