Experimental Investigation of Energy Recovery from Industrial Exhaust Fan Airflow

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Abstract
Industrial exhaust fans are widely used in factories, warehouses, and commercial buildings for ventilation and removal of heat and harmful gases. These exhaust fans continuously discharge high-velocity air into the atmosphere. The kinetic energy present in this airflow is generally wasted and remains unutilized. This paper presents an experimental study on generating electrical power by utilizing waste airflow from industrial exhaust fans.
In the proposed system, the exhaust air is directed through a duct to drive a horizontal axis micro wind turbine coupled with a DC generator. The generated electrical power is regulated using a charge controller and stored in a battery. The stored energy can be used for low-power applications through an inverter. The system is economical, eco-friendly, and easy to install without disturbing existing industrial setups. Experimental observations confirm that usable electrical power can be generated from exhaust fan airflow, making this method a promising solution for energy recovery and conservation in industrial environments.

Keywords: Exhaust fan, Waste energy recovery, Micro wind turbine, Renewable energy, Industrial airflow

1. Introduction
The rapid growth of industrialization and urbanization has led to a significant increase in electrical energy demand. Conventional energy sources such as coal, petroleum, and natural gas are limited and cause serious environmental problems including air pollution and global warming. Due to these issues, there is an urgent need to explore renewable energy sources and improve energy efficiency by utilizing waste energy.
Industries widely use exhaust fans for ventilation, cooling, and removal of dust, fumes, and harmful gases. These exhaust fans operate continuously and expel air at considerable velocity. The expelled air possesses kinetic energy, which is usually wasted into the atmosphere without any useful application.
If this waste airflow is properly utilized, it can be converted into electrical energy using a suitable energy conversion system. This research focuses on designing and experimentally analysing a system that converts the kinetic energy of exhaust fan airflow into electrical energy using a micro wind turbine. The main objective of this study is to reduce energy wastage, improve energy efficiency, and promote sustainable and eco-friendly industrial practices.

2. Literature Review

Research has been conducted into both waste energy recovery systems and small-scale renewable energy generation systems. Artificial airflow sources including (but not limited to) ventilation ducts, cooling systems and exhaust fans, have been identified as possible sources for the generation of micro power.
Studies have demonstrated the feasibility of generating electricity from the exhaust fans in buildings through the use of small turbines, specifically for low-power applications (Harshad Papadkar et al.). Industrial exhaust fans were also identified as an additional potential source of power generation (Archit Patnaik & S. M. Ali), with consideration being given to airflow velocity and turbine design.
Md. Abir Hasan et al., also identified that while small quantities of electrical energy can be produced from the waste wind created from exhaust fans for auxiliary applications, the majority of prior research are either theoretical in nature or relate to laboratory-based models. As such there remains a need for practical experimental data concerning industrial exhaust fan-based power generation.
Therefore, this paper will address the existing knowledge gap by providing a simple experimental model, and analyzing the performance parameters under practical working conditions.

3. Methodology

The methodology of this study is based on capturing waste airflow from an industrial exhaust fan and converting that airflow into electrical energy via a micro wind energy conversion system.

3.1 System Components

The primary system components are:
Industrial exhaust fan
Air duct
Horizontal axis micro wind turbine
DC generator
Charge controller
Rechargeable battery
Inverter

3.2 Working Principle

The exhaust fan produces continuous airflow at a specific velocity. That airflow is then routed through an air duct to reduce loss and improve the efficiency of the air flow. The high-velocity airflow impacts the turbine blades, resulting in the rotation of the turbine.
The rotation of the turbine transfers the kinetic energy associated with airflow to mechanical energy. That mechanical energy drives a DC generator to convert it into electrical energy. The produced DC voltage changes with airflow speed.
A charge controller will be utilized to control the amount of produced energy and to safely charge the battery. The stored energy may be used to supply DC loads or be converted into AC power utilizing an inverter to make the energy suitable for use in actual applications.

4. Experimental Setup

Experimental Design

A prototype of a horizontal-axis micro-wind turbine and a standard industrial exhaust fan was created. The turbine was positioned at the most favourable distance downstream of the fan to reduce turbulence and increase the airflow's energy transfer.

The wind turbine and generator assembly was held in place by a fixed support frame. A digital multimeter (voltmeter) and ammeter were utilized to monitor the electrical power generated by the turbine and its speed in various operational states.

Data regarding speed and power generation of the turbine was collected in multiple airflow velocities to assess the effects of velocity changes upon the turbine's performance. Additionally, the system was operated continuously to assess both reliability and stability of the system.

5. Results and Discussion

Experimental Results and Analysis

Experimental data collected by this study has demonstrated the feasibility of producing electrical energy using industrial exhaust fan air flow. Experimental data indicate that both the magnitude of the electrical output (i.e., voltage and current) increases when the velocity of the exhaust fan air flow increases.

There are many different variables which affect how a given energy generation device will perform. Examples include the geometry and design of turbine blades, the uniformity of the airflow through the turbine blades, the cross-sectional area and shape of the ducting used to transfer the air from the turbine to the generator, and the efficiency of the generator itself. Additionally, losses caused by friction between the moving parts, turbulent flows within the turbine or generator, and resistance to the flow of electricity also contribute to loss of overall power production capability.

While the amount of power generated is low compared to commercial electric power sources, it is sufficient to charge battery banks and power small, low-power electronic devices such as LEDs, emergency lighting, sensors, and small electronic circuits. Because the generator is continuously operational so long as the exhaust fan continues to operate, the system is well-suited for use in an industrial environment.

6. Applications

- It is used inindustries.
- It is used in big shopping malls.
- It is used in godowns.
- Factory & Manufacturing Plants
- Chemical & Process Industries
- Thermal Power Plants & Boilers
- HVAC Systems in Large Buildings
- Cement, Steel & Mining Industries
- Textile & Paper Industries
- Warehouses & Cold Storage Facilities
- Tunnels & Underground Facilities
- Waste Treatment & Recycling Plants
- Educational & Research Projects

7. Conclusion

Summary

This experimental research demonstrated an industrial waste airflow from exhaust fan(s) can be converted

into electricity through a new proposed system. This proposed system represents a relatively inexpensive, environmentally friendly and practical means to utilize waste heat in various forms to produce electricity in industrial settings.
The low power output is somewhat offset by the continuous and renewable nature of this type of system which makes it beneficial for energy conservation. As such, with additional development and optimization, this process will contribute to the growing number of sustainable energy alternatives available to industry.

8. Future Scope

Potential Future Development

There are a number of ways in which the above system can be enhanced or otherwise expanded in the future. Optimizing and improving turbine blade design (for example by using high-performance turbine blades that are designed to have an optimal aerodynamic configuration) could potentially allow greater amounts of energy to be generated than is currently possible from low air velocity exhausts. Designing better duct configurations to minimize turbulence and optimize airflow concentrations at the turbine intake may also allow for additional improvements to overall system efficiency.
Additional power electronic components (such as maximum power point tracking [MPPT] charge controllers) can be incorporated into the system to maximize energy harvesting from the exhaust fan. Similarly, using higher efficiency generators and/or newer types of batteries may improve system performance.
As part of its future expansion, multiple small wind turbines can be installed together near large industrial exhaust fans to produce a larger amount of power than would be produced individually. Real-time performance and fault diagnosis can be achieved through integration of the system with internet-of-things (IoT)-based monitoring capabilities.
Additionally, hybrid energy generating systems utilizing both exhaust fan generated electricity and solar generated electricity can be created to provide electrical power to commercial and industrial buildings. If properly scaled and optimized, this type of technology can lead to reductions in energy waste, greenhouse gas emissions, and dependence on conventional forms of energy.

9.Block diagram

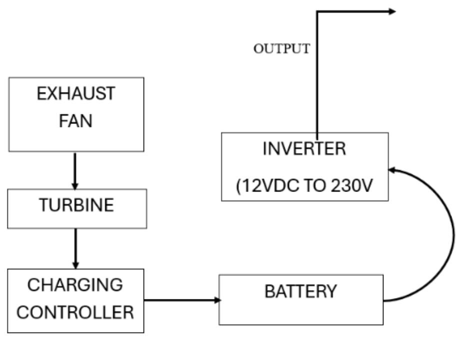

FIG. A Block Diagram

Description

FIG. A Block Diagram of Power Generation Using Exhaust Fan
Description of FIG. A:

The above figure “a” represents a block diagram of a power generation system utilizing an exhaust fan. The components of the system include an exhaust fan; a turbine; a charge controller; a battery; and an inverter.

Innovative System Design of Energy Recovery System:

The primary objective of designing this innovative system of an energy recovery system is to utilize the expelled air from an exhaust fan’s outlet to generate electricity. This is accomplished by integrating a Horizontal Axis Wind Turbine (HAWT) with an enclosure directly in front of an exhaust fan's outlet. This illustrates the configuration of the developed system. In order to capture the wind generated by the axial fan (which has a horizontal lying axis), a turbine was mounted vertically atop a tower in front of an axial fan. The exhaust air produced by the fan was directed to pass through a circular duct of the same diameter as the fan outlet. The duct configuration and shape were specifically designed to provide guidance, correction of the velocity profile and create a Venturi Effect to increase the airflow velocity to optimize the system performance. Therefore, the duct was intended to be cylindrical at the initial section just at the fan outlet, and partially conical along the flow direction for the Venturi Effect.

Wind Turbine Converts Wind Energy into Electrical Energy:

The turbine converts the kinetic energy of the wind into electrical energy, providing output to the Charging Controller Circuitry, which provides output to compare the battery voltage. If the battery is full, then it will automatically switch off the charging voltage to the battery and if the battery is discharged, then it will continue to provide output voltage to the battery. The battery supplies output voltage to the Inverter Circuitry, which converts the 12v DC supply into 230 V AC supply. Thus, power can be generated from the exhaust fan.

Circuit Diagram

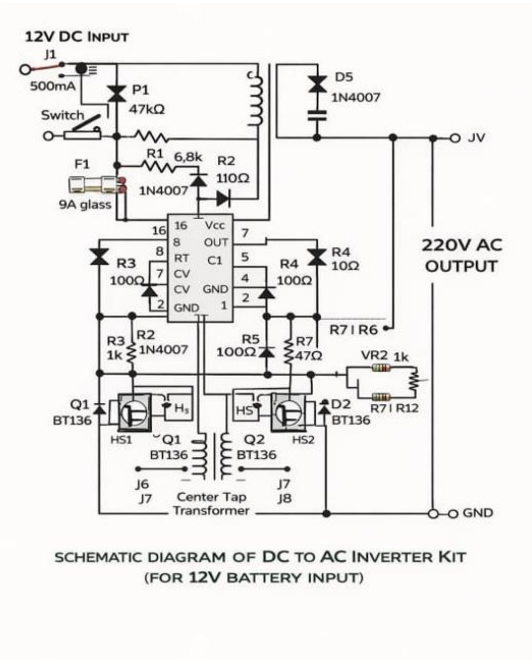

FIG. B Circuit Diagram

working

The 12V DC to 230V AC inverter has the ability to convert low-voltage DC from a battery into high-voltage AC for use with household appliances. The conversion occurs via rapid electronic switching of power devices (BT136) under control of a pulse-width modulated (PWM) oscillator IC (SG3524 or SG3525). The IC produces square waveforms that are out-of-phase (complementary), causing the switching devices to alternate in their switching action, thereby creating a pulsating DC waveform across the primary of a center tapped transformer. The center tap secondary of the transformer then induces an electromotive force on the secondary winding of sufficient amplitude to produce an output AC waveform of approximately 230V AC from the input 12V DC. The inverter contains additional circuitry that provides reverse polarity protection to the load via the use of two diodes; a fuse for overload protection; and a potentiometer for minor adjustments to the output voltage. The output waveform produced by this type of inverter is generally a square waveform (modified by the inductance and capacitance in the system) that can be used to supply a wide variety of standard household loads including lighting, fans, and charging devices. Due to its simplicity and low cost, this type of inverter is well suited for small scale backup power applications.

References

1. HARSHAD PAPADKAR, HARSHAL SONEKAR, VRUSHABH KUMBHARE, SHRAWAN DHURVE, PROF.FIROZ AKHTAR5, PROF. GAYATRI PADOLE6, “Generation of Electricity from Exhaust Fan”, A review, “IJIRT” Volume 9, Issue 2, July 2022
2. ARCHIT PATNAIK, 2S.M.ALI, “INDUSTRIAL EXHAUST FANS AS SOURCE OF POWER”, A review, “International Journal of Electrical, Electronics and Data Communication”, Volume-1, Issue-9, Nov-2013
3. Er. R.K. Rajput. Non-conventional energy sources and utilization.2013 Edition.
4. Anon (2010). "What is wind?”. Renewable UK: Education and careers. Renewable UK. Retrieved 9 April 2012.
5. Md. Abir Hasan, Mohammad Tanvir Hossain, Ratul Paul, Nilufer Akter, Producing Electrical Energy by using wastage wind energy from exhaust fans of industries, International Journal of Scientific & Engineering Research, Volume 4, Issue 8, August-2013
6. B.H. Khan (2013). Non-conventional Energy resources.2ND Edition.
7. S. Triantafyllou and G. S. Triantafyllou, “An efficient swimming vehicle”. Guo, T. Fukuda, and K. Asaka, “A new type of fish-like underwater microrobot,” IEEE/ASME Trans. Mechatronic, vol. 8, no. 1, pp. 136–141, Mar. 2003.
8. S. N. Trimmer and K. J. Gabriel, “Design considerations for a practical electrostatic micro-motor,” Sens. Actuators, vol. 11, no. 2, pp. 126– 173, Jan. 1987.
9. Schaub, “Spread frequency shift keying”, IEEE Trans. Commun., vol. 42, no. 4, pp. 182–296, Aug. 1993.
10. Brown J. A., “vacuum tanker for cleaning storage tanks,” Process Engineering, vol. 21, no. 5, pp.138–180, Sep. 1989.
11. R. K. Bansal, “Kinematics of machine”, Laxmi Publications (P) Ltd., vol. 1, no. 4, pp. 23–287, Nov. 2011.
12. Shubham Shrivastav, Hari Om Kumar, “Design and Development of Cylindrical Water tank cleaner”, IEEE Trans. Commun., vol. 6, no. 1, pp. 1–7, Feb. 2016.
13. Prayosha innovative, “Sedimclean water tank cleaning machine”, Prayosha innovative, vol. 1 no. 1, pp.1–177, Feb. 2017.

14. Shubham Shrivastav, Hari Om Kumar, “Design and Development of Cylindrical Water tank cleaner”, IEEE Trans. Commun., vol. 4, no. 8, pp. 1–7, Nov. 2016.Mr. Sankaran Nampoothiri, Dhanya G2, A Review on Flying Electric Generator as an Alternate Source of Energy Harvester, IRJET, Volume: 03 pp 143-214,04 Apr-2016