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Review of Power Efficient Smart Ventilator

Mr. Sanket V. Bhonde[1], Mr. Sahil J. Meshram[2], Mr. Pradyumna Y. Deshmukh[3],
Dr. Sanket A. Nirmal[4]
[1, 2 ,3] Student, Electronics and Telecommunication Engineering, Prof. Ram Meghe Institute of Technology and Research, Badnera-Amravati., Maharashtra, India
[4] Assistant Professor, Electronics and Telecommunication Engineering, Prof. Ram Meghe Institute of Technology and Research, Badnera–Amravati., Maharashtra, India

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ABSTRACT

The COVID-19 pandemic created unprecedented pressure on healthcare systems worldwide, highlighting the urgent need for innovative and affordable medical technologies, especially for respiratory support. This abstract presents the design and development of a ventilator system intended to address critical respiratory requirements during emergency situations. By utilizing Internet of Things (IoT) technology, the system enables automated and responsive mechanical ventilation through the coordinated operation of multiple hardware components. The proposed design is based on an IoT-enabled platform that allows seamless integration of essential peripherals for patient monitoring and control. An Ambu Bag mechanism forms the core of the system and is configured to deliver controlled tidal volumes according to patient requirements. The ventilator system is built around a NodeMCU ESP32 module and employs an L293D motor driver to manage DC motor operation for respiratory assistance during the COVID-19 pandemic. An oximeter continuously monitors the patient's oxygen saturation levels in real time, and a manual push-button interface allows immediate user intervention when oxygen levels fall below a safe threshold. Upon activation, the DC motors compress and release the Ambu Bag to generate positive pressure ventilation, thereby supplying oxygen to the patient. This manual control approach ensures rapid response in critical conditions and enhances system reliability during emergencies. Overall, the integrated system demonstrates a practical and cost-effective solution for emergency ventilation while also providing a foundation for future improvements in critical care and medical automation technologies.

Keywords: - IoT Technology, Real-time monitoring, Mechanical ventilation.

1. INTRODUCTION

The COVID-19 pandemic created unprecedented pressure on healthcare systems worldwide, leading to an urgent need for practical and effective medical solutions. One of the most critical challenges during this period has been the rapid increase in patients suffering from severe respiratory distress. Hospitals faced shortages of respiratory support equipment, making it essential to develop alternative ventilation systems that could reduce the burden on medical infrastructure while ensuring patient safety. To address this challenge, this paper presents the design and development of an automated ventilator system capable of providing controlled mechanical ventilation by combining IoT technology with accurate blood oxygen monitoring. The proposed ventilator system is developed using a Node-MCU ESP32 microcontroller and an L293D motor driver to control mechanical motion. An oximeter is integrated to continuously monitor the patient's blood oxygen saturation in real time. The system operates through manual activation using a push button, which drives two DC motors to compress and release an Ambu Bag, thereby enabling positive pressure ventilation. An oxygen mask ensures effective oxygen delivery, while a power jack provides uninterrupted operation. This system aims to offer a reliable and accessible respiratory support solution, improve patient care during emergency conditions, and reduce the workload on healthcare professionals during the COVID-19 pandemic.

2. LITERATURE SURVEY

Mondal, Aruna, et al. Their work describes how the team created an intelligent pulsed-flow breathing device, called RESPI-Pulse, that delivers oxygen bursts by automatically detecting when a user inhales or exhales through body-worn sEMG sensors, working entirely on its own without requiring any manual adjustments or settings. at all [1].

Rout, Amruta, Golak Bihari Mahanta, et al. the author's purpose of this study is to plan and develop a cost-effective health-care robot for assisting and observing the patients in an accurate and effective way during pandemic situations like COVID-19. The proposed research work can help in better management of pandemic situations in rural areas as well as developing countries where medical facilities are not easily available [2].

Kamble, Shrutika, and Rupali Shekokar, et al. the model is introduced which will monitor body temperature, oxygen level, and face mask detection. The proposed model can be used in any purchase of a shopping mall, hotel, apartment entrance, office entrance, lab entrance etc. As a result, it is an inexpensive and reliable way to build a healthy environment. The test of the proposed framework was performed with the Face Mask Detection algorithm, monitoring the human body temperature using a temperature sensor and monitoring the oxygen level using the pulse oximeter method. As well as providing the count for persons [3].

Rajasekar, Sakthi Jaya Sundar, Swarnalingam Thangavelu, et al. the author proposes a novel AI-powered IoMT model for Continuous Remote Patient Monitoring using COVID Early Warning Score (Co-EWS). Various sensors like temperature sensors, BP sensors, and breath rate sensors record the patients' vital parameters who undergo home quarantine and these are communicated to a dedicated application. This data is then transmitted to the cloud server where further 40processing takes place. The concerned physician will be able to track the patient's health status round the clock. The proposed COVID Early Warning Score (Co-EWS) will be computed automatically using various AI regression models, and the Co-EWS would be predicted [4].

Lopes, Sérgio Ivan, Pedro Pinho, et al. the author presents three key contributions: (i) vital signs characterization in the elderly population; (ii) a state-of-the-art review of the most prominent techniques and methods for Contactless Health Monitoring (CHM); (iii) the design, specification, and evaluation of a low-cost proof-of-concept CHM system for nursing homes, incorporating an IoT Edge Device. This facilitates real-time monitoring of vital signs (cardio-respiratory rates and elevated body temperature) using a multimodal approach based on Doppler radar and IR thermal imaging sensors, generating health indicators without any form of contact or invasiveness. Direct comparisons with reference instruments have revealed an error rate below 10%, in 74%, 52%, and 96% of cases for Heart Rate, Respiratory Rate, and Body Temperature measurements, respectively [5].

Jebaseeli, T. Jemima, Daegeon Kim, et al. the author proposed a model that provides a mechanism for monitoring air pollution in indoor and outdoor environments. The system consists of an IoT-based device. The Arduino IDE connects the Temperature and Humidity sensor, Grove light sensor, and air quality sensor to measure the air pollutants such as Carbon dioxide CO_2, Nitrogen oxide (NO_x), and Particulate Matter PM2.5. The sensors work efficiently and provide qualitative findings from the environment when they are exposed to CO_2, gasoline, solvents, thinner, formaldehyde, and other harmful chemicals. The Wi-Fi module of the Blues Wireless Note-hub is used for secure data routing to the IoT cloud. The Air Quality Index (AQI) measures provide information on whether there is something unsafe in indoor and outdoor environments. For collecting and analyzing the device data, the Notecard is intended to be used with a cloud storage service. Also, the indoor fire detector identifies the incident of fire, intimates the users through the alarm, and measures the indoor pollutant at that time [6].

Bhagat, Shrikant Anil, and Sumit R. Narwade. They portray the outline of different examinations done. The human lungs are utilized for breaths. They use a push system in every breath, motivation and exhalation process happens. The DIY ventilator here they configured is to help individuals during Covid pandemic. Stepper Motor component is utilized to push the Ambu sack. While breathing heartbeat level identified are low this component can be performed. The LED screen is utilized to show the breathing heartbeat levels. Likewise, in a patient's basic condition or breathing issue, a ringer is fitted in the framework to sound ready when any irregularities are identified [7].

Balamurugan, C. R., A. Kasthuri, et al. the author designed a ventilator to help people during Covid situation. It is very cheap and affordable. When people suffer from lungs or breathing problems this can be used for emergency situation. Motor mechanism is used to push the air bag. When oxygen level counts are low this mechanism can be performed. Small screen is used to display the oxygen levels. The entire system is driven by an Arduino microcontroller. And a buzzer is fitted to detect any low levels of oxygen count [8].

Kale, Rameshwar Bhaginath, et al. they portray outline of different examination done. The DIY ventilator here they configuration is to help individuals during Covid pandemic. It is exceptionally modest and reasonable. At the point when patients experience the ill effects of lung or breathing issue this can be utilized in a patient basic condition. Stepper Motor component is utilized to push the ambu sack. While breathing heartbeat level identified are low this component can be performed. The LED screen is utilized to show the breathing heartbeat levels [9].

Bhagat, Shrikant Anil, and Sumit R. Narwade. They use a push system in every breath, motivation and exhalation process happens. The ventilator here plan and foster utilizing Arduino envelopes this large number of necessities to create a dependable yet cheap DIY ventilator to help in the midst of pandemic. Stepper Motor component is utilized to push the Ambu sack. While breathing heartbeat level identified are low this component can be performed. The LED screen is utilized to show the breathing heartbeat levels [10].

Eldeib et al. (2017) designed a home ventilator that was controlled remotely by a wireless camera. It worked on taking pictures and recording videos of the patient and sending them to the system's web page. The camera relied on infrared radiation. The patient's respiratory signals were transmittimg to the doctor remotely via communicate on networks, where the doctor, using a program installed on his computer, controls the settings of the home ventilator [11].

Restuccia et al. (2022) proposed a developed ventilator that could be remotely controlled by a smartphone and communication networks such as Wi-Fi and Bluetooth, and this had led to the improvement of health care by reducing the economic cost where one doctor can monitor a number of patients at the same time It also reduced the need for personal protective equipment and to support the health situation in remote areas. Its disadvantage was controlling the proposed ventilation due to the limited number of doctors [12].

Alhammadi et al. (2022), the proposed device consisted of several sensors represented by the pressure sensor, body temperature, and pulse oxidation sensor, in addition to containing a stepper motor that was controlled by the microcontroller (Arduino). The most important feature of this device was that it supported self-pressure on the inflatable bag by using a lever, so it does not need human intervention, in addition to that, it contains stimuli for abnormal conditions. However, Carbon dioxide buildup in the air tube because the pressure valve was located away from the patient [13].

Kiruthika, et al. (2022), the adoption of IoT technology in the ventilator has greatly improved its work. Where the patient's condition was monitored remotely by smart phone devices. The ventilator is also able to send patient data to doctors in real-time. This helped keep patients at home as well as keep them safe during outbreaks of infectious viruses. The device provides the measurement of oxygen saturation, heart rate and temperature [14].

Radogna et al. (2020), an advanced respirator with multiple sensors such as oxygen, carbon dioxide, temperature and humidity sensors was proposed. It was inexpensive, easy to use, and monitors COPD patients. It relies on the Arduino microcontroller and supported telemedicine, so it could be used in homes [15].

Jawad et al. (2020) presented a mechanical ventilation device that relies on artificial intelligence in its work by using a model with multiple layers of nerve in order to know the level of oxygen coming from the ventilator during the breathing period, and this helps support health care. The neural model is programmed using an open-source programming language (Python). This device provides the measurement of PEEP, FiO2, and SpO2 patterns. However, the air pressure inside the device was manually controlled by doctors or observers during the day 3-4 times [16].

3. METHODOLOGY

The proposed system is designed to assist in managing respiratory distress by combining a Node-MCU ESP32 module with an L293D motor driver to control two DC motors. An oximeter continuously monitors the patient's blood oxygen saturation levels, and the collected data is displayed in real time on the Blynk mobile application for easy observation. When a drop in oxygen saturation is detected, the user can manually activate the system through a control button. Once activated, the DC motors rotate in clockwise and counterclockwise directions to compress and release the Ambu bag, thereby delivering positive pressure ventilation to the patient. The supplied oxygen is administered through an oxygen mask, ensuring effective respiratory support. Manual control allows for immediate human intervention during critical conditions, enhancing safety and responsiveness. The entire system is powered by a power jack that provides a stable and continuous power supply, ensuring reliable operation. Overall, this integrated setup offers a practical and responsive solution for emergency ventilation, where timely manual activation plays a crucial role in patient care.

4. BLOCK DIAGRAM

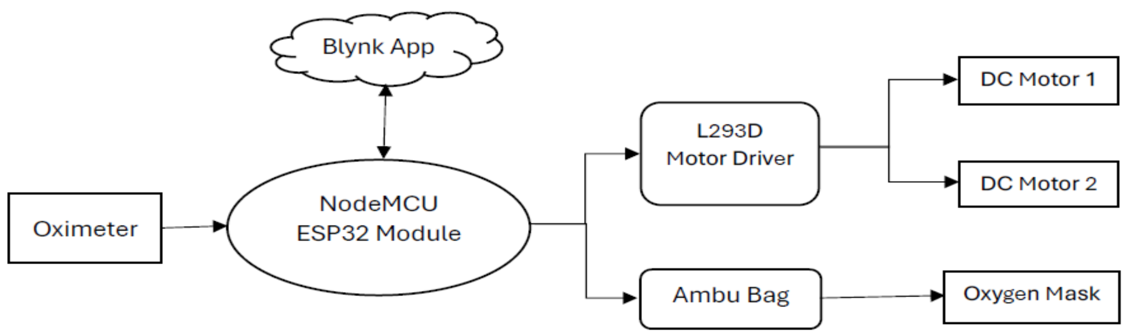

Fig 1: The Block Diagram of the System

4.1 Working of the Proposed Diagram

In this Block diagram we have used the Node-MCU ESP32 Module as a microcontroller. In the input device we have used the Oximeter and in the output device we have used two DC motors, L293D motor driver, Ambu bag and Oxygen mask connected to the microcontroller. Also, we have used the Blynk app to show all the notifications. The operation of the proposed system starts when power is supplied through the power jack, allowing all components to function continuously. The oximeter sensor constantly measures the patient's oxygen saturation level and sends this data to the Blynk App, where it is displayed in real time. If the oxygen level falls below the safe limit, the user takes manual action by pressing the manual control button. This input signals the Node-MCU ESP32 to activate the L293D motor driver, which operates two DC motors. The motors rotate alternately in clockwise and counterclockwise directions, leading to the compression and release of the Ambu Bag. This movement provides positive pressure ventilation to assist the patient's breathing. An oxygen mask connected to the Ambu Bag ensures proper oxygen delivery during each compression cycle. The manual control approach allows quick intervention during low oxygen conditions and offers a reliable method to support patients suffering from respiratory distress.

5. FLOW CHART

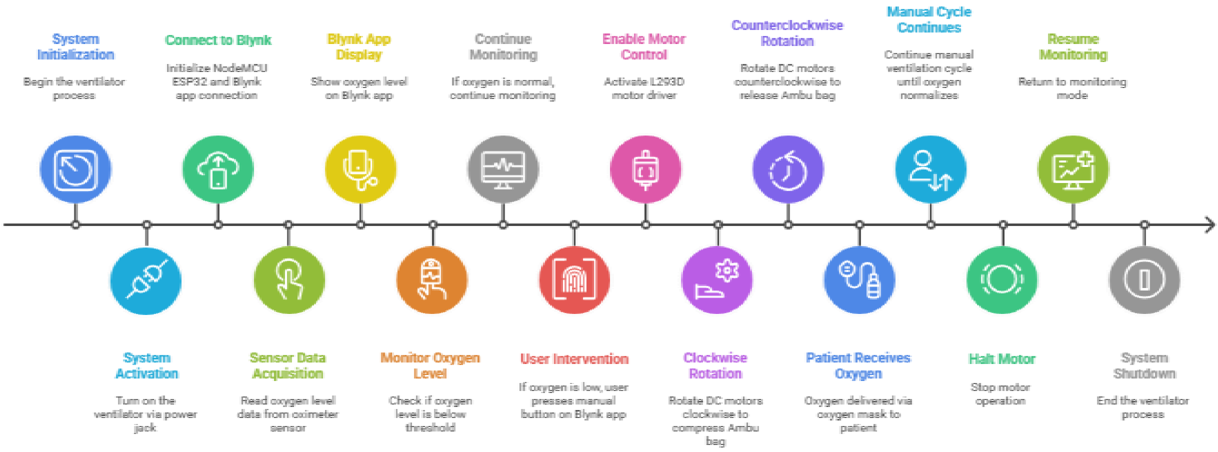

Fig.2: The flow chart of the system

5.1 Flow Chart Description

Step 1: System Initialization
The ventilator system is started, and all parts such as the ESP32, sensors, and motors are made ready to work.

Step 2: System Activation
The system is switched ON using a power jack that provides continuous power for smooth operation.

Step 3: Connect to Blynk
The Node-MCU ESP32 connects to the Blynk application through a Wi-Fi network for remote access.

Step 4: Sensor Data Collection
The oximeter sensor begins measuring the patient's oxygen saturation (SpO_2) in real time.

Step 5: Display on Blynk App
The measured oxygen levels are shown on the Blynk mobile app for easy monitoring.

Step 6: Oxygen Level Monitoring
The system regularly checks whether the oxygen level is normal or falling below the set limit.

Step 7: Detect Oxygen Drop
If the oxygen level drops below the safe range, the system notifies the user.

Step 8: User Action
The user presses a button on the Blynk app to start the ventilation process manually.

Step 9: Motor Activation
After receiving the command, the ESP32 turns ON the L293D motor driver.

Step 10: Clockwise Motor Movement
The motors rotate clockwise and compress the Ambu bag to push oxygen.

Step 11: Oxygen Delivery
Oxygen is supplied to the patient through a mask to support breathing.

Step 12: Reverse Motor Movement
The motors rotate in the opposite direction, releasing the Ambu bag so it can refill.

Step 13: Continuous Operation
This compression and release action continues as long as ventilation support is needed.

Step 14: Stop Ventilation
The user stops the motors using the Blynk app once the patient's condition improves.

Step 15: Return to Monitoring
After stopping ventilation, the system goes back to monitoring oxygen levels.

Step 16: System Shutdown
The system is safely turned OFF when it is no longer required.

6. SYSTEM REQUIREMENT

6.1 Hardware Requirement

1.NodeMCU ESP32 Module
2.L293D Motor Driver
3.DC Motors* 2
4.Ambu Bag
5.Oximeter (SPO2 sensor)
6.Power Jack
7.Manual Button
8.Oxygen Mask

6.2 Software Requirement

1.ESP IDE
2.Blynk App

7. PROJECT ANALYSIS

Table -1: Project Analysis

Project Type	Technology Used	Power Efficiency Method	Key Features	Advantages & Limitations
Arduino-Based Smart Ventilator	Arduino Uno, Temperature & Humidity Sensors	Automatic fan speed control based on sensor input	Real-time monitoring, LCD display, basic automation	Low cost, easy to build. Limited processing power.
IoT-Based Smart Ventilator	ESP8266 / ESP32, Cloud Platform	Remote monitoring reduces unnecessary runtime	Mobile app control, cloud data logging	Remote access, energy tracking. Requires internet connection.
Solar-Powered Smart Ventilator	Solar Panel, Battery Backup, DC Motor	Uses renewable solar energy	Works during power cuts, eco-friendly	No grid dependency. Higher initial cost.
AI-Based Smart Ventilator	Raspberry Pi, Machine Learning Model	Predictive ventilation control based on usage patterns	Smart decision-making, adaptive airflow	High efficiency, intelligent control. Complex implementation.
Industrial Smart Ventilator	PLC System, Industrial Sensors	Variable Frequency Drive (VFD) motor control	Heavy-duty usage, automated airflow control	Suitable for factories. Expensive setup.

8. CONCLUSION

In conclusion, this work takes an important step toward meeting the urgent demand for simple and responsive ventilator systems during the difficulties created by the Covid-19 pandemic. By using IoT technology and combining key parts such as an oximeter, DC motors, and an Ambu Bag, the proposed system provides a dependable way to deliver life saving positive pressure ventilation to patients. The manual control option allows quick action when oxygen saturation levels change, offering vital support in critical moments where fast response is essential. In addition, the use of an Oxygen Mask along with a continuous power supply improves the overall performance and dependability of the system, ensuring steady respiratory assistance for patients. As the world continues to face the effects of the pandemic, this work highlights the value of innovation and teamwork in creating practical solutions that can help save lives and reduce the severity of respiratory distress in emergency situations.

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