International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-2, December, 2019

Air Flow Control of a Smart Electric Fan using IoT Solutions

Mahesh Kumar Reddy Vennapusa, Suchart Yammen

Abstract: ***Remote control of electric fans by the application of IoT technology addresses the restrictions of "push button" controls that are usual in conventional fans. This paper explains a new control method for air flow control of a Smart Electric Fan (SEF), in this case fans mainly used in the household. In this new method the supply voltage that is applied to the motor terminals of the SEF is precisely changed with the mobile application developed by using IoT solutions. As this proposed method integrates with the conventional control methods referred to as the Firing Angle Control method or Phase Angle Control method with a new IoT-based solution, the controlling of any device becomes simpler. We developed a mobile application that enables the fan to be remotely controlled using a smartphone or tablet computer. The phase or delay angle of the voltage waveform is changed by giving as an input from the smart phone mobile application, and this results in minimizing the power loss caused due to switching in case of push button system. We demonstrated that by using this app, implementing the IoT-based solution, the air flow rate of the SEF was increased and the performance of the SEF exceeded the air flow rate of the original, conventionally controlled fan with the speed of the fan being significantly increased. Applying this control method has thus been verified to be advantageous and appropriate for the remote control of the air flow and fan speed, resulting in the efficient Smart Electric Fan. The main focus of this research was to implement the integrated control method in the residential fans.***

Keywords: ***Air Flow Control, Internet of Things, Blynk/MQTT Mobile application, Smart Fan Control***

I. INTRODUCTION

The Internet of Things (IoT) enabled the connectivity of physical devices over the Internet. These devices, referred to as "connected devices" and "smart devices", may be in buildings, thus the term that has been coined; the Smart Building, and a vast array of electronic devices embedded in machinery, equipment controlling sensors and actuators, even domestic devices such as refrigerators, television sets, home security and other home control systems. The network connectivity enabled by IoT technology also enables these objects to gather, communicate and give-and-take data [1]. The IoT identifies entities to be detected or controlled remotely through the existing, now global, network infrastructure, scope for building direct incorporation of the physical domain into computer grounded systems, then resulting in better accuracy, efficiency and financial subsidy and also to minimize human involvement [2].

While IOT is improved with sensors and actuators, the technology has developed an example of cyber physical systems, which also includes technologies such as smart grids, smart homes and smart cities. Usually, IoT is likely to offer innovative device connectivity, systems, and services that drives away from device to device communications and organizes various protocols, domains, and applications. The interconnection of these implanted devices (together with smart objects), is anticipated to guide in automation in all fields, whereas allowing these innovative applications such as a smart grid, and growing to areas such as smart cities [3]. The present market cases comprise home automation in another way smart home devices such as the control and automation of lighting, heating, drying, air conditioning, High Voltage Alternating Current systems, and also machines such as washing machines and/or dryers, vacuum cleaners, air filters, microwave ovens and freezers that use internet or Wi-Fi for monitoring from remote areas. Also by expanding the Internet-connected automation devices into a surplus of new application areas, IoT is likely to share large information or data from various localities, through the subsequent need for fast accumulation of such data, the necessity to stock, numbering and development such data has increased more successfully [4].

II. IOT SOLUTION FOR AIR FLOW CONTROL

Internet of Things (IoT) supported devices usage is being increased linearly and has shaped a large scope for the technology which enlarges its boundaries almost exponentially. From beginning, IoT has more flexibility and efficiency in many industries by connecting a growing set of dissimilar devices and equipment.

Creating a smart electric fans (SEF), users can benefit by being able to operate such devices remotely. SEF's are created by the combining of hardware (an IoT supported microcontroller board) and software (IoT based mobile applications). Continuous integration between SEFs and a mobile app permits for perfect exchange of data and management for the appliance to control accurately, thereby enabling the highly efficient operation of the SEF.

Figure 1 illustrates the complete architecture and assembling of devices enabled by the network architecture including IoT technologies, specifically, in this case, the operating of a SEF. The particular fan used in the development and testing was a tower fan, as illustrated in Figure 1.

Revised Manuscript Received on December 30, 2019.
* Correspondence Author
Mahesh Kumar Reddy Vennapusa, Faculty, Department of Electrical and Computer Engineering, Naresuan University, Phitsanulok, Thailand. E-mail: maheshkumarr59@email.nu.ac.th
Suchart Yammen*, Faculty, Department of Electrical and Computer Engineering, Naresuan University, Phitsanulok, Thailand.
E-mail: sucharty@nu.ac.th*

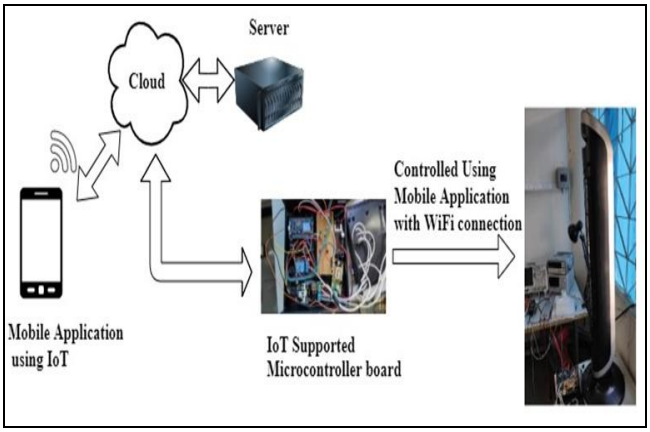


Figure1. System architecture with IoT solution

The test fan is connected to an IoT-supported microcontroller board by Wi-Fi. At the source, the mobile app, signals are transmitted to the microcontroller via the Cloud.

Automated speed control of SEF was possible by integrating GPS options, including defining the geographical range of your smartphone. Every time the device come into the well-defined geographical limit there is immediate interaction with the SEF via Wi-Fi to control the device. On exit from that geographical range, the connection will be lost. By this means, the users can manage the settings of the target SEF from the mobile phone using the application that we developed [5], [6].

The following features explain the benefits of this control mechanism and the reasons to choose this SEF.

A. Distant Governing

Users can turn the SEF On and Off and also can adjust the settings of the SEF remotely with the help of IoT solution. The SEF settings that could be changed consist of temperature (the tower fan has an in-built thermostat), humidity, fan speed of the fan, and speed input from mobile application through the user's smartphone.

B. Extreme Comfort

By being able to control the SEF remotely, the householder can set the fan's operating parameters remotely and arrive home to enjoy the comfortable temperature achieved during his journey home. As well, by using these features, the app enables the automatic switching of the SEF On and Off as the smartphone enters into or exits from the home, presumably in the possession of the householder. By using these associated devices and IoT solutions, the level of personal comfort can increase or decrease by this ability to remotely control the SEF.

C. Smart Planning

Revised planning of different temperatures at different times of the day, according to personal requirements, is a feature of the mobile app.

D. Cost Effectiveness

By aiding automated On and Off facilities in addition to smart planning, 40% savings of power consumption is achievable, with the associated savings in cost.

E. Multi-zone Maintenance

Multi-zone programming of cooling facilities, including the SEF and other air conditioning equipment is possible using the mobile app.

F. Mobile Application Development

The mobile application designed in our project uses Message Queuing Telemetry Transport (MQTT) or Blynk protocols. The main purpose of this application is to send the necessary control commands and receive output from the SEF and display this information on the smart phone screen. This includes all of the appropriate operating parameters of the SEF of ambient temperature and humidity, and fan speed. By receiving these parameter values in real-time, appropriate commands can be directed to the microcontroller [7]. A C++ based control program was written using Arduino Integrated Development Environment (IDE) software and integrated with all the microcontrollers and sensors in the circuit. The following steps explains how to develop a mobile application in the user's smart phone.

Step 1: Login to the web page of CloudMQTT, follow the instructions, register and create the new server. The screen shot of the created server "Smart Fan" is shown in Figure 2.

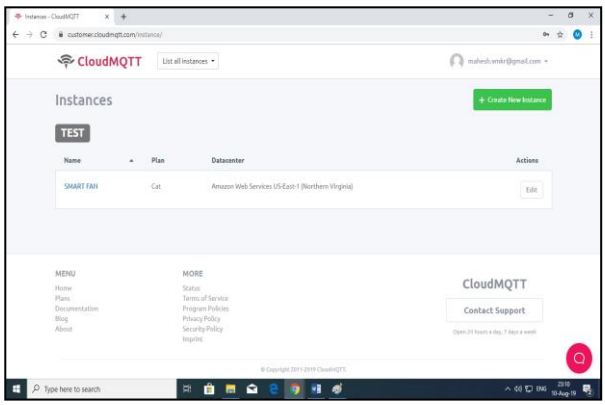


Figure 2. Screen shot of the new server page created

Step 2: Next, download the MQTT application from the mobile play store on to the smart phone.

Step 3: Follow the instructions carefully lead to create a path between the mobile application and the server using URL, username and password etc.

Step 4: Subsequently create connections for/from the server by entering the details of Client ID, port number, URL of the server, username and password.

Step 5: Once confirmation is done successfully, the dashboard or mobile application page is connected to the server.

Step 6: To subscribe/publish the commands the MQTT mobile app has to be subscribed to a particular topic, i.e. the task is continuous until the connection is disconnected or it is unsubscribed. Similarly, the same process is applicable in case of publishing the commands.

Step 7: The topic/payload i.e., /ESP32_1/DIMMER acts as a path to communicate the instructions between mobile application and the server. Also using the same payload, the MCU receives the commands from the server [8].

The screen shot of completely designed MQTT mobile application on the smart phone is shown in Figure 3.

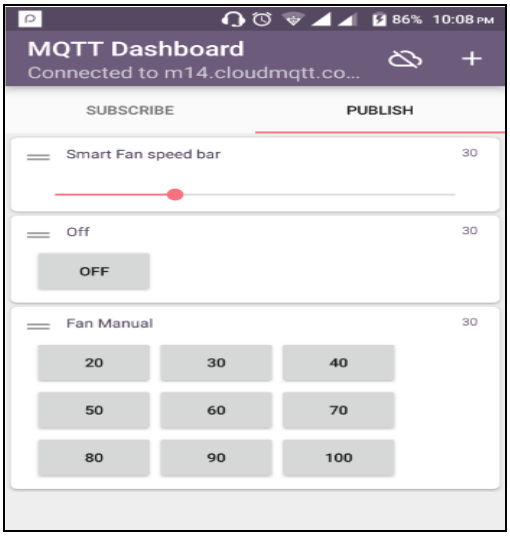


Figure 3. Screen shot of the MQTT mobile application

III. METHODOLOGY

A simple method of Voltage control of an Induction Motor (IM) is used to control the phase angle or the voltage applied to the motor terminals of the IM. This is a simple and economical method that can be integrated and implemented easily. The idea of integrating the IoT solutions with this voltage control method makes it feasible to control the fan speed [9]. The microcontroller ESP8266 acts as the heart of the system as it performs and controls all the operations. The motor used in the tower fan in our development was a single phase induction motor with the type Permanent Split Capacitor (PSC) Motor. The development method used the EasyEDA software tool to design the circuit which was then printed onto the circuit board (PCB), The PCB control board was then designed with all the necessary components. The schematic diagram of the proposed method is shown in Figure 4.

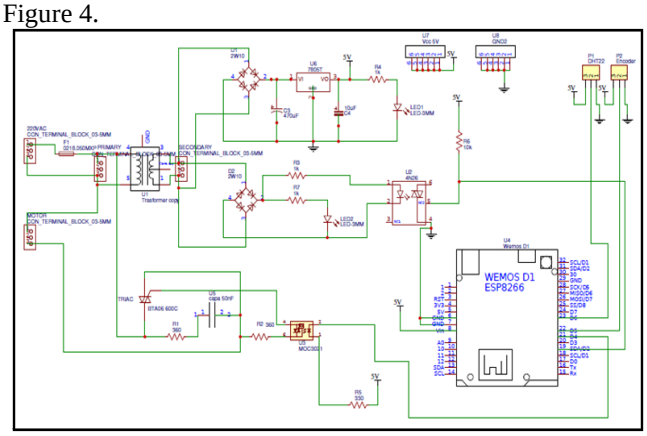


Figure4. Schematic diagram of the proposed method

Initially the circuit in Figure 4 was tested for Zero Crossing Detection and to change the firing angle of the applied voltage. The stepped down voltage 6V was given to the diode bridge to change the negative half cycle of the voltage waveform to the positive. The optocoupler 4N26 generates the pulse whenever the sinusoidal voltage waveform crosses the zero point as shown in Figure 5. The root mean square (RMS) value of the voltage was applied to the 4N26. When the base to emitter voltage is greater than 0.7 V, the transistor in 4N26 is "ON" and the output voltage applied across the transistor is 0V. Similarly, if the base to emitter voltage is less than 0.7 V, the transistor is "OFF", and the output voltage is equal to $+V_{cc}$ volts.

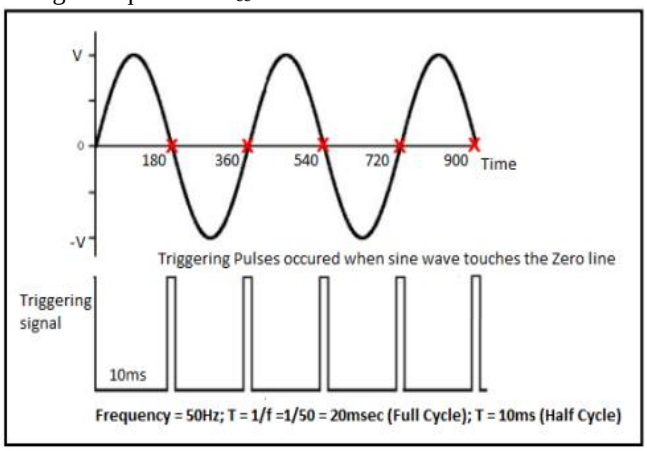


Figure 5: Zero Crossing Detection of a Sine Wave

The phase angle control is used to chop an AC sine wave with a low frequency switch i.e. TRIAC. The firing angle of the TRIAC is varied so that the rms output voltage is also varied [10]. The average voltage applied to the motor load terminals will be proportional to the area under the sine wave as shown in Figure 6 [11]. Therefore, the average voltage is defined as the integral of the firing angle to the zero crossing, the cosine of the firing angle. Once the MCU identifies the zero crossing point then it will process the triggering pulses and is fed to the Opto Diac (MOC3021) which is an interface between the microcontroller and the high-powered TRIAC circuit for AC load control. When the voltage +5V Vcc is applied to the Opto Diac MOC3021, a Small pulse from pin GPIO2 of microcontroller is applied to pins 1 and 2 of the MOC3021 [12]. The light produced by the LED flashes the diodes so that TRIAC gets triggered and the regulated power is applied to the motor terminals to achieve the desired speed of the fan.

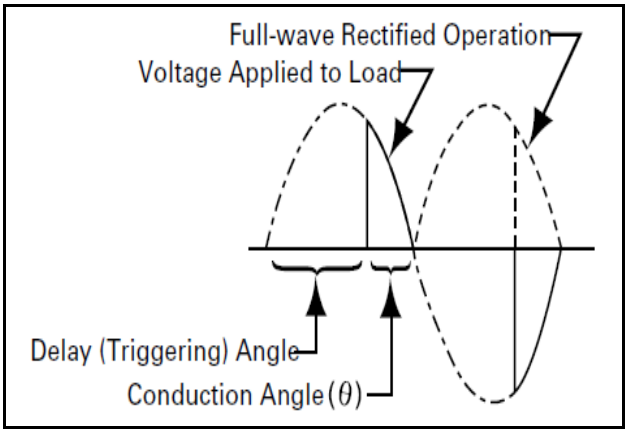
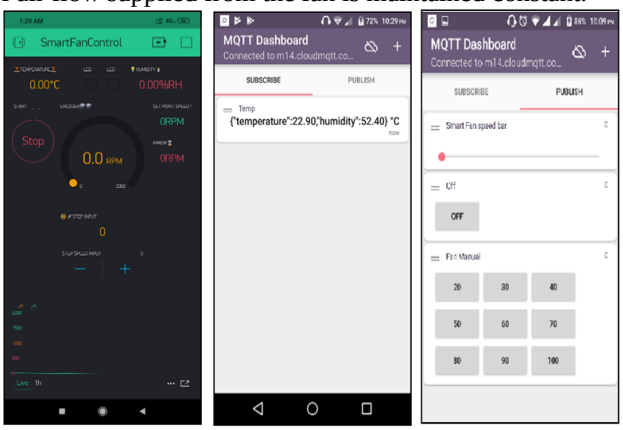


Figure 6: Phase Angle Control of Sine wave

The main advantage of this method is that changes in the output voltage waveform is smooth and easy to control. The Microcontroller compares the reference speed (set point) and the speed value from the feedback sensor [13]. If the set point is greater than the calculated speed, then the Microcontroller unit (MCU) changes the delay time and the triggering pulses are given to TRIAC such that the motor speed is increased [14].

Now, the feedback sensor calculates the number of revolutions of the motor per second and is given to the MCU which converts this pulses per second to revolutions per minutes (rpm). This calculated speed is again compared with the set point given by the Esp8266 microcontroller. If there is a difference between the set point and the calculated values the motor will change its speed, otherwise, the motor will run with constant speed. The delay angle is the time during which the TRIAC blocks the line voltage and the Conduction angle is the time during which the TRIAC is on [15].

This topic focuses on the automatic control of a fan by using Wi-Fi direct and by providing all the configuration particulars such as Client ID, name of the server, Port number, user name, password and topic and the speed levels of fan in case of MQTT and Login Credentials, Authentication Token in case of Blynk Application. The control algorithm helps to interface all the connections between the physical devices like Sensors, Microcontroller, Relays, fan motor etc. once the code is uploaded and connected to the server then the fan is ready to control using smart phone. The ambient temperature and humidity, the set point value, speed sensor (Encoder) values, and error with respect to the step input, are displayed on the smart phone screen. Examples of the developed Blynk application and MQTT application control page are shown in Figure 7. The motor speed is controlled by using the Wi-Fi direct, and the data is stored in the cloud storage [16]. All the values related to temperature, humidity and speed of the motor is stored in the cloud, and this information is shown on the MQTT or Blynk mobile application for reference. In case of Blynk application various values of Temperature and Humidity, set point value, Encoder value, Error, step input value and the graph between Encoder and Set point speed value were organized and shown on the smart phone screen as shown in Figure 7 (a). There is no need for a remote to control this fan. The smart phone takes over the place of the remote thereby this option reduces the additional cost of the fan and increases the ease of controlling. Any number of devices can be interfaced and communicate with other devices with simple programs [17]. In addition to the work done so far by many researchers, this new method of speed control is proposed where the fan adjust its swing automatically and delivers the air flow at the place where human is located. Also the density of air flow supplied from the fan is maintained constant.



(a) (b)

Figure 7: (a) Blynk and (b) MQTT mobile application pages

The main advantage of this method is that the user can control the speed of the fan by giving the set point via the smart phone. Also the user can rotate the fan up to 180^0 by using the mobile application in smart phone. Therefore, the motor can be efficiently controlled by using the Wi-Fi direct from anywhere and anytime in this world with proper internet connection. The performance of the fan can be monitored and operated through smartphones, tablets and laptops as well. The proposed method has a unique feature to control a fan using multiple smart devices [18].

IV. RESULTS & DISCUSSION

At first the test fan was examined to identify the features and its control mechanism. The test fan was operated and the speed of the fan measured in Low, Medium and High mode using a Tachometer as shown in Figure 8. The air flow rate w.r.t. speed at different distances from the fan were measured and tabulated as shown in the Table 1. A Thermo-Anemometer DIGICON DA-40 was used for measuring air flow. As per the data sheet the accuracy of this anemometer is 1% to 5% under normal operating conditions [19].

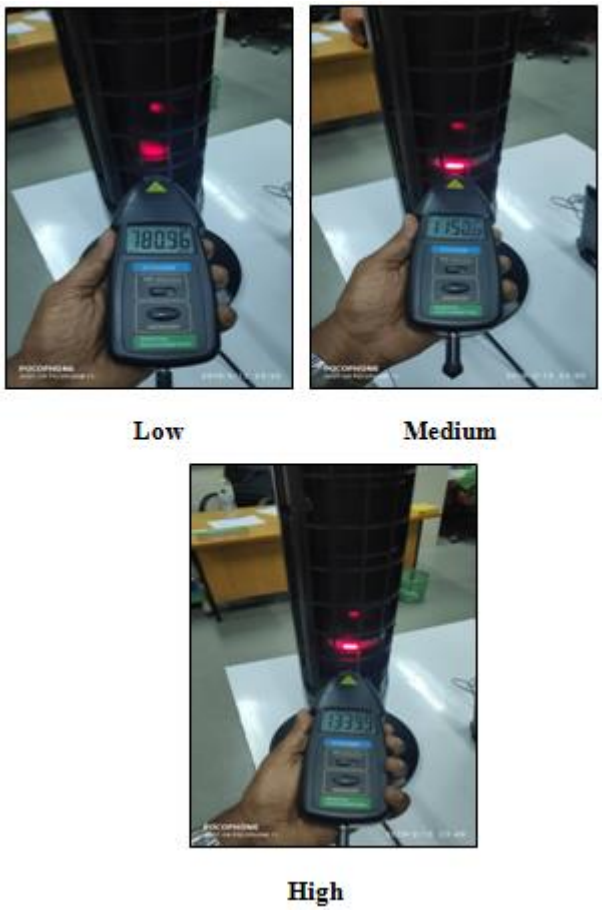


Figure 8: Modes of Test fan

Figure 9 shows the control board of the test fan and Figure 10 shows our proposed new control board with IoT solutions.

Figure 9: Test fan Control board

Figure 10: New designed Control board

Table I illustrates the air flow rate at various distances from the test fan (which was explained in section III).

Table I: Average speed and Air flow values of the original fan

S.No.	Mode of Test fan	Speed (RPM)	Air Flow measurement (m/s) at different distance from the SEF							
			1cm	50cm	100cm	150cm	200cm	250cm	300cm	350cm
1.	Low	780	2.3	1.4	0.8	0.5	0.3	0.1	0.0	0.0
2.	Medium	1150	4.2	2.8	1.9	1.2	0.8	0.5	0.2	0.0
3.	High	1340	4.9	3.5	2.4	1.8	1.5	1.2	0.8	0.5

A new control board was designed (Figure 10) with a new control mechanism as explained in section III and experiments on the test fan were conducted. The input from the smart phone is given using either MQTT or Blynk mobile application as shown in Figure 7. By using a Tachometer, the speed of the fan was measured and tabulated, as was the air flow rate as measured using an Anemometer (Table II).

Table II: Average speed and Air flow values of the new control board fan

S.No	Smart Fan Input %	Speed (RPM)	Air Flow measurement (m/s) at different distance from the SEF							
			1cm	50cm	100cm	150cm	200cm	250cm	300cm	350cm
1.	10	679	2.8	1.6	1.0	0.7	0.4	0.3	0.1	0.0
2.	20	989	3.9	2.5	1.6	1.2	0.7	0.5	0.4	0.3
3.	30	1185	4.4	2.9	1.8	1.3	0.8	0.6	0.5	0.4
4.	40	1233	4.6	3.2	1.9	1.4	0.9	0.7	0.6	0.5
5.	50	1264	4.7	3.3	2.0	1.5	1.0	0.8	0.7	0.6
6.	60	1288	4.8	3.4	2.1	1.6	1.1	0.9	0.8	0.7
7.	70	1303	4.9	3.5	2.2	1.7	1.2	1.0	0.9	0.8
8.	80	1315	5.0	3.6	2.3	1.8	1.3	1.1	1.0	0.9
9.	90	1329	5.1	3.7	2.4	1.9	1.4	1.2	1.1	1.0
10.	100	1345	5.2	3.8	2.5	2.0	1.5	1.3	1.2	1.1

It can be clearly seen from Tables I and II that the speed of the test fan was increased, together the air flow rate from the fan, when using our new designed control board. The experimental results in both tables and the Figure 11 show that our new control board minimizes the power loss and delivers more voltage to the motor terminals. This makes the motor to run with increased speed and results in the increased air flow from the fan.

Figure 11: Speed measurement at 10, 40, 70 and 100 reference smart fan input from mobile app.

V. CONCLUSION

An IoT-based solution using a mobile application increase the speed of a fan was developed and tested as being successful. The determination was to facilitate the smart control of SEF and to increase the air flow delivered from SEF at multiple speed levels rather than the standard Low, Medium and High speed control options seen on maximum fans. The experimental results prove that the developed mobile application is working successfully. The mobile application developed could be installed and used in any type of Android or iOS smart phone and the user can control this SEF from anywhere with proper internet connection. This application could be further upgraded by using other methods such as Fuzzy Logic, Artificial Intelligence, Neural Networks and Machine Learning., etc. The uses of this technology also may be more interesting in the future.

ACKNOWLEDGMENT

At first, the authors would like to thank Dr. Sureerat Tang, Managing Director of TJ Supply Limited Partnership, Bangkok, Thailand for providing financial support for this research, together with necessary materials including the test fan. A special thanks to Mr. Roy I. Morien of the Naresuan University Graduate School for his assistance in editing the grammar and English expression in this paper. Also the authors are happy to thank Mr. Tanee Ton Kosum, Lab Instructor, for his complete support in providing the Anemometer, Tachometer and other electrical components and for his cooperation.

REFERENCES

1. Li, H., et al., *Strategic Power Infrastructure Defense.* Proceedings of the IEEE, 2005. **93**: p. 918-933.
2. Gungor, V.C. and F. Lambert, *A Survey on Communication Networks for Electric System Automation.* Computer Networks, 2006. **50**: p. 877-897.
3. Ramalingam, N., et al., *Implementation of PV - Based Boost Converter Using PI Controller with PSO Algorithm.* International Journal Of Engineering And Computer Science, 2017.
4. Hemalatha, M., et al., *Brushless DC Motor Controlled by using Internet of Things.* 2017. **3**: p. 2349-784.
5. Soliman, M., et al., *Smart Home: Integrating Internet of Things with Web Services and Cloud Computing*. Vol. 2. 2013. 317-320.
6. Central, I. *IOT Transforms the Way Users Interact with Smart Air Conditioners*. 2019; Available from: https://www.iotcentral.io/blog/iot-transforms-the-way-users-interact-with-smart-air-conditioners.
7. Yammen, S., S. Tang, and M.K.R. Vennapusa. *IoT based speed control of Smart Fan*. in *2019 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunications Engineering (ECTI DAMT-NCON)*. 2019.
8. Vennapusa, M.K.R. and S. Yammen, *Iot based platform for smart electric fans.* International Journal of Innovative Technology and Exploring Engineering, 2019. **8**(12): p. 5720-5728.
9. Metwally, H., *New Method For Speed Control of Single-Phase Induction Motor With Improved Motor Performance.* Engineering Research Journal, 2001. **Shebin El-Kom, Egypt**: p. 41-51.
10. Oluwasogo, E., *PERFORMANCE ANALYSIS OF A SINGLE-PHASE AC VOLTAGE CONTROLLER UNDER INDUCTION MOTOR LOAD*. Vol. 03. 2014. 184-191.
11. Littelfuse. *Phase Control Using Thyristors*. 2013 09/23/13; Available from: https://www.littelfuse.com/~/media/electronics/application_notes/switching_thyristors/littelfuse_thyristor_phase_control_using_thyristors_application_note.pdf.pdf.
12. Semiconductor, F., *6-PIN DIP Random-Phase Optoisolators Triac Driver Output*. 2003.
13. Rahman, M.M., M.F.R.B. Zakaria, and S.N.i. Sidek, *Sensory and Control System for Smart Fan.* INTERNATIONAL JOURNAL OF CONTROL, AUTOMATION AND SYSTEMS, July 2015. **VOL.4 NO.3**.
14. Kalbande, P.A. and S. Rathod, *TRIAC AS INDUCTION MOTOR SPEED CONTROLLER* International Journal of Innovative and Emerging Research in Engineering 2016 **Volume 3**(Issue 3).
15. Hanafi, D., et al., *Time base firing pulse delay control for improving single phase induction motor speed performance using fuzzy logic control.* ARPN Journal of Engineering and Applied Sciences, 2016. **11**(12): p. 7515-7521.
16. Kodali, R., S. Soratkal, and L. Boppana, *IOT based control of appliances*. 2016. 1293-1297.
17. Bethapudi, D.P., et al., *IOT Based Monitoring and Control System for Home Automation.* International Journal of Research, 2018. **5**.
18. Sharma, K., et al., *Speed Control of Single Phase Induction Motor Using TRIAC & Reversal of Direction* Journal of Emerging Technologies and Innovative Research (JETIR), April 2016. **Volume 3**(Issue 4).
19. *Anemometer, Digicon DA-40*. 2019; Available from: http://www.visethsiri.com/product-th-1121136-6902253-%E0%B9%80%E0%B8%84%E0%B8%A3%E0%B8%B7%E0%B9%88%E0%B8%AD%E0%B8%87%E0%B8%A1%E0%B8%B7%E0%B8%AD%E0%B8%A7%E0%B8%B1%E0%B8%94%E0%B8%84%E0%B8%A7%E0%B8%B2%E0%B8%A1%E0%B9%80%E0%B8%A3%E0%B9%87%E0%B8%A7%E0%B8%A5%E0%B8%A1+%E0%B9%81%E0%B8%A5%E0%B8%B0+%E0%B8%AD%E0%B8%B8%E0%B8%93%E0%B8%A0%E0%B8%B9%E0%B8%A1%E0%B8%B4+Digicon+%E0%B8%A3%E0%B8%B8%E0%B9%88%E0%B8%99+DA+40.html.

AUTHORS PROFILE

Mahesh Kumar Reddy Vennapusa received the B.Tech degree from Jawaharlal Nehru Technological University Hyderabad, India in the year 2009. Also received M.E. degree in Power Electronics and Drives from Hindustan University, Chennai, India in the year 2012. He is currently working as an Assistant Professor in the Department of Electrical and Electronics Engineering at Hindustan Institute of Technology and Science (HITS), Chennai, India. His areas of interests are Electrical machines and Drives, Power electronics and control systems. Mahesh is currently a Research Scholar in Department of Electrical and Computer Engineering, Faculty of Engineering, Naresuan University, Phitsanulok, Thailand.

Suchart Yammen received the Bachelor of Electrical Engineering (Hons) degree from Chiang Mai University, Thailand in 1988, and the M.S. and Ph.D.degrees from Vanderbilt University, TN, USA in 1998 and 2001, respectively. In 1988, he worked with the Colgate-Palmolive (Thailand) Co., Limited and served as a Supervisor in the powder plant. From 1989 to 1993, he had ever joined with the Siam Cement (Public) Co., Limited, Thailand, as a production engineer, a maintenance engineer and a project engineer. Since 1994, he has served Naresuan University where he is currently an Associate Professor of Electrical Engineering. He has coauthored of The Era of Interactive Media (New York, NY, USA: Springer Publisher, 2012), Principles of Communications (Bangkok, Thailand: Chulalongkorn University Press, 2011) and Visual Inspection Technology in the Hard Disk Drive Industry (Hoboken, NJ, USA: John Wiley& Sons Publisher, 2015). His current research interests include internet of things, smart technology, communication and control theory, signal processing, medical image processing, system identification, and modeling. Dr.SUCHART is currently a registered professional engineer associated with the Council of Engineers in Thailand as a Fellow Member in Electrical Engineering (Power) and an Associate Member in Electrical Engineering (Telecommunications/Electronics). He is also a Senior IEEE Member.