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Iot Based Platform for Smart Electric Fans

Mahesh Kumar Reddy Vennapusa, Suchart Yammen

Abstract: ***Existing speed control systems on conventional electric fans operate in only three speed modes: Low, Medium and High. Changing the speed of the fan is a manual action which may be problematic for many users, such as senior citizens ordisabled users or any user with mobility problems. Using Internet of Things (IoT) technology solves this problem by allowing variation in fan speed from very low speed to the maximum speed as a linearly increasing speed function. This paper clearly explains the functioning of the IoT, and how to use IoT applications for automatic fan speed adjustments in this way, resulting in the SmartFan. A smart mobile phone with a mobile app is used as the remote controller. A control algorithm was developed to control the interactive communications between the smartphone and the electric fan. This control approach has proven to be a useful and convenient method for the remote control of electric fan speeds.***

Keywords: ***Internet of Things; MQTT mobile application; Linear speed control; Smart electric fan***

I. INTRODUCTION

Usability and ease of use are essential design criteria for designing and manufacturing new products. Electric fans are a ubiquitous device in households and places of residence in almost hot countries. They are cheap to purchase with low power consumption with their operation based on simple electric circuitry. Controlling the speed of the fan is a necessary but simple operation, allowing the manual change in speed from the simple three speed range, Low, Medium and High.

In modern society, however, the electric fan is probably the only electric device that is still controlled manually which may cause difficulties for many domestic users, particularly those with mobility problems due to old age or physical disability, as well as many industrial uses of electric fans. Therefore, changing the speed of the electric fan either from remote control devices or automatically in response to changing environmental circumstances is an interesting research activity with many potential benefits to both individuals and organizations, in the latter case with potentially significant reductions in power consumption and therefore lower costs. Using automated and devices with or without remote control abilities is at least useful and at best essential for multiple reasons ranging from safety to ease of handling [1]. Initially, automation systems were limited to industry as they required significant investment.

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***** Correspondence Author
Mahesh Kumar Reddy Vennapusa*, Department of Electrical and Computer Engineering, Faculty of Engineering, Naresuan University, Phitsanulok, Thailand.
Suchart Yammen, Department of Electrical and Computer Engineering, Faculty of Engineering, Naresuan University, Phitsanulok, Thailand.

With the development F communication technology, especially now IoT technologies, automation and remote controlling is available to everyone.

The imaginative development and application of technology in every aspect has brought many benefits to individuals and organizations, large and small. Devices such as smartphones and tab computers, smart watches, fitness measurement devices and a host of other "gadgets" now means that people trust technology and rely on it to connect to and communicate with their friends and to find, download and store information. An important evolution of communication technology, following the Internet, is the technology called the Internet of Things (IoT) which has enabled the control of home automation devices more simply and indeed more cheaply, almost to the point of being ubiquitous and unremarkable [2]. Furthermore, other various wireless technologies like Wi-Fi, Bluetooth, LAN, and Cellular networks have enabled remote connectivity in the fullest extent [3]: viewing the visitor at your front door on your smartphone from across the world, for example, would now be considered unremarkable and merely convenient. Our concept of the Smart operational performance characteristics are defined and determined in an on-board control system. Controlling the speed of a fan motor, both AC or DC motors, to satisfy user's expectations has been the subject of prior research [4]. Internet application development demand is at an all-time high with becoming a major technology which can be used in many and various useful internet applications [5]. A mobile application was developed and applied IoT technology to the Smart Fan. Basically, IoT is defined as a network in which all physical objects are connected to the Internet through network devices or routers and exchanged at a between them. IoT allows objects to be remotely controlled, and to remotely control other devices, across the existing Internet network infrastructure, fully automatically. This has resulted in the availability and widespread ownership and use of intelligent refrigerators, intelligent TV, and, potentially more sinister, intelligent surveillance devices. These devices gather useful data with the help of various existing technologies and share that data between other devices. Home Automation Systems and Home Security Systems have become consumer products, using Wi-Fi or Bluetooth for exchange data between various devices in the home [6] and outside the home. The unexciting but very useful device, the electric fan, has up to now been neglected in this whirlwind of IoT enabled sophisticated electronic advances. This Smart Fan fills that gap [7]. This paper clearly explains about the functionality of an IoT based smart speed control system implemented for electric fans: The Smart Fan.

Statement of the Problem

The main problem associated with the existing speed control systems in case of conventional fan motors is that the fan speed is varied only in three modes i.e. Low, Medium and High. In a traditional fan the tapped winding method is used to control the speed of the fan with a simple mechanical switch. This winding may be the Auxiliary or the main winding. By varying the tapping points, the voltage/turn changes and subsequently the number of turns between the main and auxiliary windings also changes. In this method, the number of turns must be increased by about 40% in order to decrease the volts per turn [8]. This makes the initial cost of the motor high. Also for any speed value some amount of tapped winding may not be used completely resulting in power loss, so the full load power is not applied to the motor. This design means that changing the fan speed is a manual activity which may present serious physical difficulties especially to senior citizens, or the disabled and persons with restricted mobility [4]. Also, this is an inefficient operational design in regard to power consumption.

Who has never left the premises without ensuring that all electric devices, including fans, have been turned off or immobilized? The continued operation of electric fans overnight or over weekends clearly is a waste of power. Home automation systems that include features such a movement detection will certainly assist, as will the ability to control devices via a simple mobile application on a smart phone [6]. Existing remote-control methods could be applied to control fan speed in the three steps of Low, Medium, and High but this is an unnecessarily simple application of the technology. Hand-held remote controllers that use infra-red (IR) sensors have an effective detection range of up to 4 meters beyond which they cannot work, and, to add to the inconvenience, and indeed the cost, frequent change of batteries is needed for any remote control. In case of manual speed operation of the fan. Inductive Auxiliary winding changes the speed levels of the motor, which produces a voltage drop at the main winding resulting in reduced power at the Motor terminals there by flux is also reduced correspondingly which reduces torque while simultaneously reducing speed [9]. This results in some transient power loss applied to the motor terminals. Also, there is wastage of airflow/energy whenever a table fan or a tower fan is allowed to swing. This is because most of the fan air flow is delivered to a region with no human presence [10] meaning the system is consuming power to produce while air flow experienced by the person is lowered. Overall, this accumulation of small operational and power consumption problems can be alleviated and overcome in order to increase the comfort level of the user by applying IoT thinking to the device design.

II. ARCHITECTURE DESIGN

Any Operation of an IoT device practically depends on the architecture of the hardware and the design of the software. The hardware architecture includes any physical IoT client that are connected to the Cloud, and network servers, micro controllers and other devices providing load. Software architecture includes client management, operations of hardware devices and also communication between each and every device in the system. Eventhough there are many components used in this architecture design, attention is given to the core important elements of IoT applications [11].

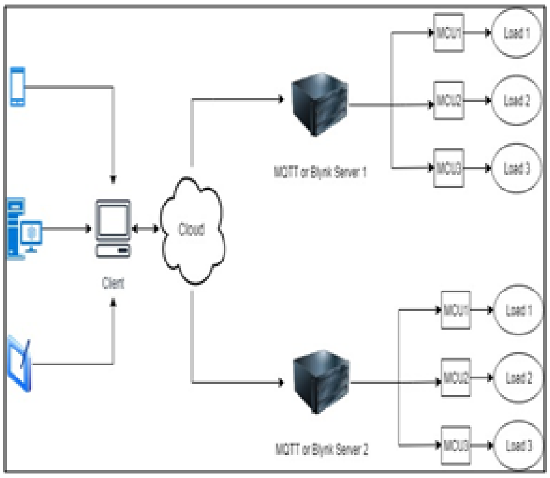

Fig. 1 Architecture Design of the IoT Application

The architecture design shown in Figure 1 has physical devices, Microcontroller Unit (MCU), client, Cloud, Server and Load.

Physical IoT Client Devices or Controllers

These physical devices are the main components of IoT applications. These devices could be smartphones, computing devices, hardware controllers, even common household appliances, or Webpages. Most, if not all, of these physical devices can be controlled devices or controllers, or both, with in-built programmed operations that can monitor other devices, or be monitored by other devices. Application of these devices can include temperature sensing, movement detection, motor speed controlling, image capture, vision capturing and transmitting, and so forth.

Client

A client is nothing but a gate way which acts as an intermediate station between IoT physical devices and the Cloud, using the Internet or other communication protocol as a carrier to the Cloud infrastructure. The main function of a client depends on the individual system application and its requirements. These devices also can be used for device management and communication processing.

Cloud Infrastructure

This will store and process the data for/from the IoT devices in the IoT network [1]. The Cloud could include hosting of a database based on the needs of an application.

Server

A server acts as a mediator between the Cloud and MCU's. Servers subscribe to and publish all communication messages between the server and Cloud and also between the MCU's and the server.

For IoT-based motor control, either the Message Queuing Telemetry Transport (MQTT) proto color Blynk is used as a server. The main function of the MQTT or Blynk server is to receive commands from clients, process the command and then send it to a microcontroller (board) via Internet [12]. The Internet can be used for any type of communication such as Wi-Fi direct, Hotspot, LAN etc.

A mobile application was developed for Android-based devices and for iPhone Operating System (IOS)-based, which is either an MQTT dashboard app, or a Blynk application, both of which can be downloaded to the smartphone. These apps are then used to send control signals to the target device. These control signals include temperature controls, and motor speed controls, etc. A control algorithm for microcontrollers written in the C++ program was also developed by using the Arduino Integrated Development Environment (IDE) software. This software is stored in the microcontroller embedded on a control board. An incoming signal originated from our Android or IOS device, containing coded instructions, is converted by the Control Algorithm to electrical signals to control the speed of the motor.

III. MQTT/BLYNK APPLICATION

The MQTT app is a free downloadable app, but the Blynk app requires payment of a fee.

For creating a new server [13] first sign up and login to the control panel of "CloudMQTT" web page as shown in Figure 2.

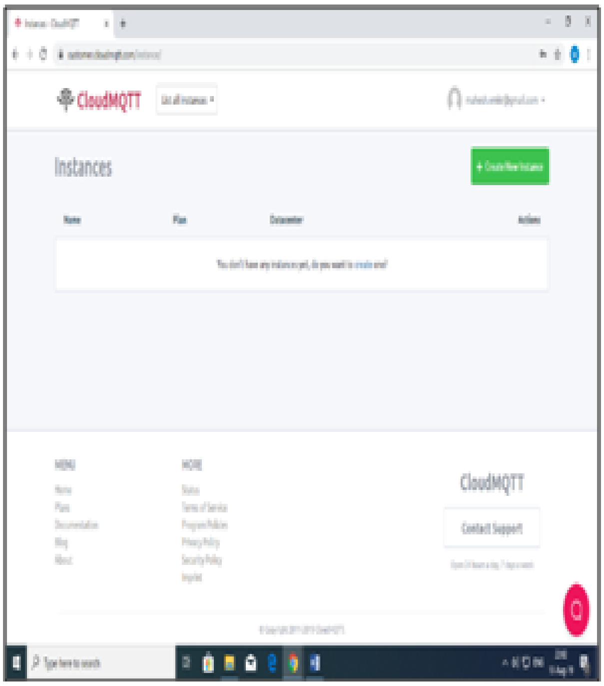

Fig. 2CloudMQTT panel after login

Click on + *Create New Instance*(Server) and select a plan and the name of server (Instance) and tags, then click on "*select region" to go to next step* as shown in Figure 3.

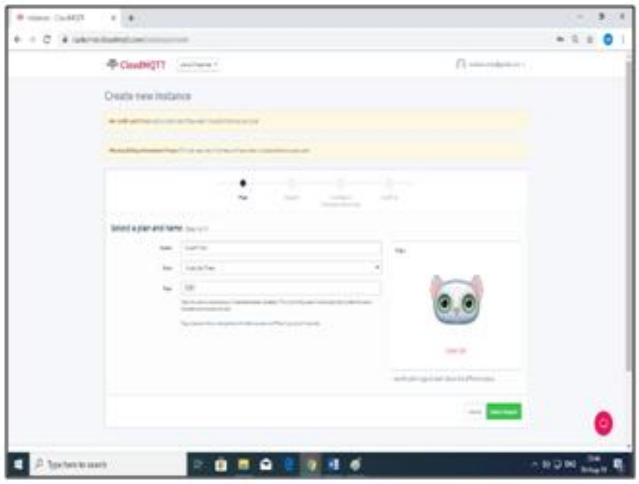

Fig. 3 CloudMQTT panel after selecting a plan type and name of the server

Now, select a region and data center that the server should be in and click on the "*Review"* button to go step 3 as shown in Figure 4.

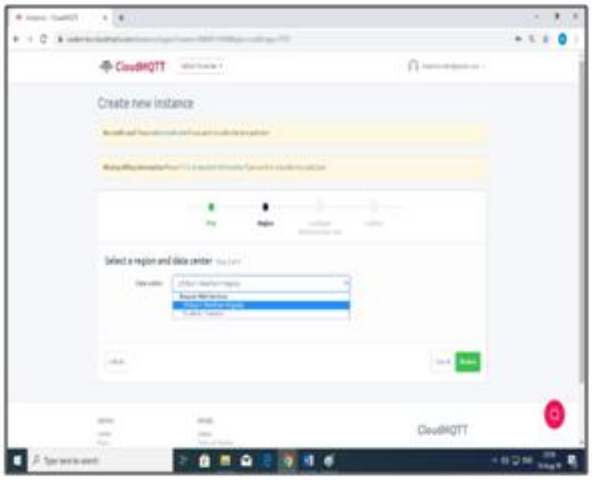

Fig. 4 CloudMQTT panel to select region and data center of the server

Next, a page is opened with the plan name, server name, provider name, region name and tags. Ensure all the details and press "*Create Instance"* as shown in Figure 5.

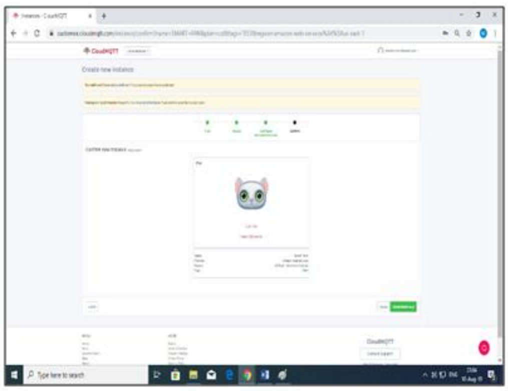

Fig. 5 CloudMQTT pre-check page

Finally, the server is created successfully on the "CloudMQTT" panel as shown in Figure 6.

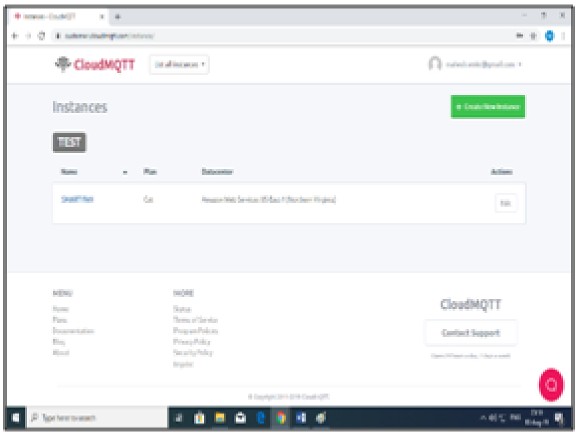

Fig. 6 CloudMQTT server confirmation page

Steps to build connection between MQTT mobile application and the CloudMQTT server.

Step 1: After creating the server, the MQTT mobile app (Free) need to be downloaded on the user's smart phone from Play store.

Step 2: Open the MQTT mobile app, a page is opened as shown in Figure 7. Click "+" symbol to open the next page as shown in Figure 8, where the connection details like Client ID, Server name, Port number, User name and Password needs to be entered. These connection details are available on the "CloudMQTT" panel as shown in Figure 9.

Fig. 7 MQTT app. page 1

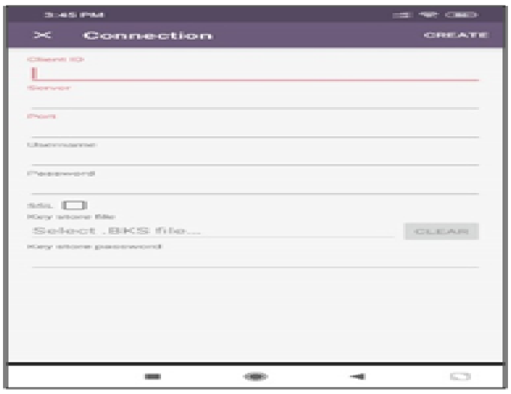

Fig. 8 MQTT app. Page 2

Step 3: Now enter the connection details as shown in Figure 9 and click on "Create" to build a successful connection between the MQTT mobile application and the "CloudMQTT" server as shown in Figure 10.

Step 4: Now Click "SMART FAN" on mobile app as shown in Figure 10, an empty page is opened as shown in Figure 11.This shows that the mobile app is connected to the "*soldier.cloudmqtt.com*" server.

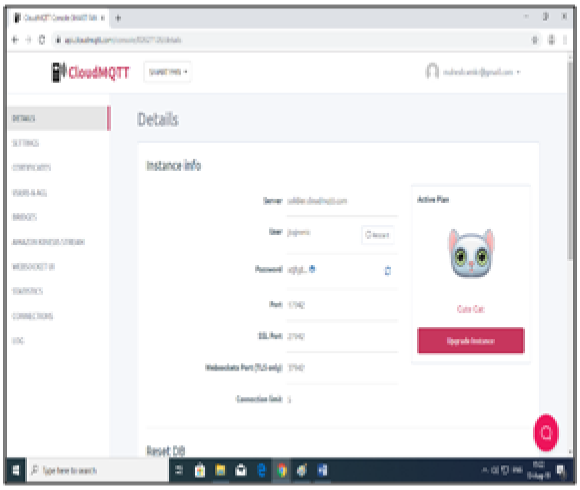

Fig. 9 CloudMQTT panel page with connections details

Fig. 10 MQTT app. Page 3 Fig. 11 MQTT app. Page 4

Also there are two options "Subscribe and Publish". If the MQTT client or MQTT mobile app has subscribed to a specific topic it means that it will keep on listening to that till either it is unsubscribed or the connection is dismissed. If the MQTT client or MQTT mobile app is publishing, it publishes the MQTT message to the Broker (CloudMQTT Server) and all the clients who are subscribed i.e. listening will receive the message [14]. So ensure the connection all the time to keep the messages subscribed and published as shown in Figure 12 [13].

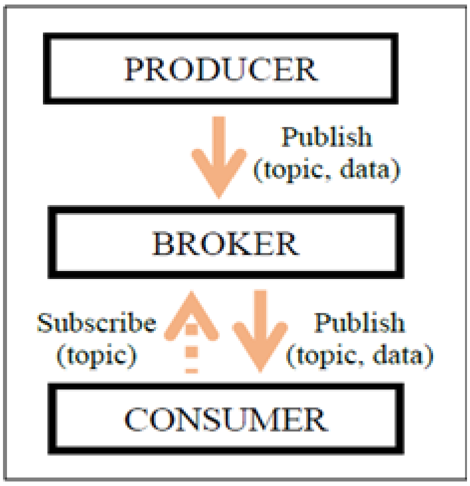

Fig. 12 Block diagram of the Subscribe/Publish message

Step 5: For Subscribing a data or a message, enter Friendly name (Example: Temperature & Humidity) and Topic name as shown in the Figure 13.

Step 6: For Publish a data or a message first select component type (chosen Seek bar) by clicking "+" symbol as shown in Figure 14 and enter Friendly name, Topic, Min value and Max value as shown in Figure 15 and click "CREATE", then the Topic/path is successfully created to perform the operations from mobile app as shown in Figure 16.


Fig. 13 MQTT app Page 5Fig. 14 MQTT app. Page 6


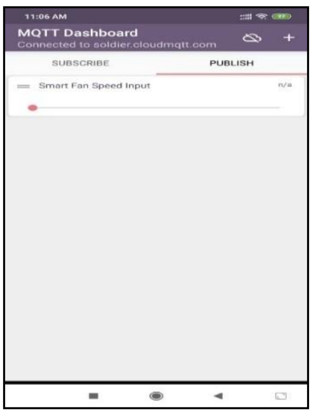

Fig. 15 MQTT app. Page 7 Fig. 16 MQTT app. Page 8

For Installing the Blynk App., Paid server

Step 1: Initially Download the Blynk application in Smart Phone from Play store.


(a) (b)


(c) (d)

Fig. 17 Stepwise installation of Blynk app

Step 2: Open Blynk application and Create new project using project name and device as shown in Figure 17 (a).

Step 3: Next follow the instructions and the fee need to be paid for buying tokens in order to develop and use the control panel on the mobile application by clicking "Add" as shown in Figure 17 (b).

Step 4: Using the widgets as seen in Figure 17(b) the specific control panel is designed as shown in Figure 17 (d). Necessary changes could be done using the project settings as shown in Figure 17 (c). After successful registration an Authenticated (called as Auth) token is generated and is sent to the specified registered email as seen in Figure 17 (c).

Step 5: Copy and paste the auth token in the respective code to control the devices

Step 6: Now login using the registered email id and password and start using the blynk application.

IV. PROPOSED METHOD IN TECHNICAL LINE

The Schematic diagram of the proposed new system model is shown in Figure18. A new controller was designed and developed to process incoming instructions. There may be a difference between the current processing parameter (speed) and the new processing parameter indicated in the incoming command (the set point). This difference is referred to as an error, and an Error Signal is generated and sent as input to the Induction Motor (IM) controller. To achieve a smooth linear change in motor speed, which is our research objective, this error must be minimized such that the increment, or decrement, in speed is small. The MCU processes the set point to change the output voltage wave form by changing the triggering pulses to the triac. The output voltage changes whenever there is change in the pulses to the triac [15].The fan motor can then to run at the number of revolutions per minute (RPM) value for that set point.

The feedback circuit continuously calculates the current operational value – the number of rotations – from the fan motor, measured using a speed encoder sensor that is part of the feedback circuit. The speed encoder sensor converts the number of rotations, measured in the form of pulses, to the RPM value which is transmitted back to the smartphone. The RPM value is then displayed on the smartphone. The cycle repeats whenever there is an error detected which generates an Error Signal. Where no Error signal is detected the fan motor continues to run at a constant speed. Changes in motor speed will depend on the size if the error. Where this is reduced to a very small incremental value, speed changes approach being linear.

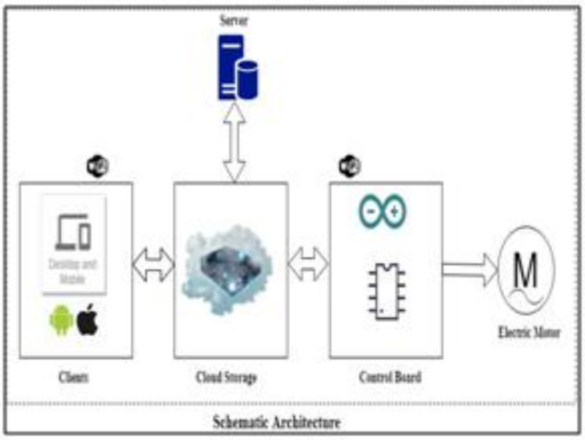

Fig. 18 Schematic Architecture of the complete system

IoT based Control

In an IoT-based control system, all configuration details are stored in the Cloud; In the case of MQTT these include Client ID, Servername, Portnumber, username, password and topic and the defined speed levels of the fan motor. For a Blynk Application these configuration details include Login Credentials and an Authentication Token. The connection between the smartphone app controlling the fan speed and the microcontroller in the fan is by Wi-Fi. [16]. The actual current operating parameters (motor speed, temperature, humidity, movements: rotation, vertical and horizontal oscillation) are also stored in the Cloud in real time, and the MQTT software can display these data for operators to check. For the Blynk application, all current values of temperature, humidity, motor speed set point value, Encoder value, Error, step input value are shown on the smart phone screen, together with a graph over time of the Encoder and Set point speed value. [17].

By using the app on a smartphone, the user has Anytime / Anywhere / Any Device control of the fan with an easy-to-use, informative display on the smartphone.

V. RESULTS AND DISCUSSIONS

Initially the test fan was analyzed to understand dits features and its control mechanism. Both inner and outer views of the old control board are shown in Figure 19. As can be seen there are control buttons for motor speed; three selectable speed levels, for time; 1 hr., 2 hr., 4 hr. and 8 hr., arotation control button (180^{o}), and Auto-mode button, together with temperature display. There is also are mote-control device to control the fan.

Figure 20 illustrates testing the fan for speed values. A tachometer was used to measure RPMs for each of the three speed levels; Low, Medium, High.

Fig. 19 Old control board

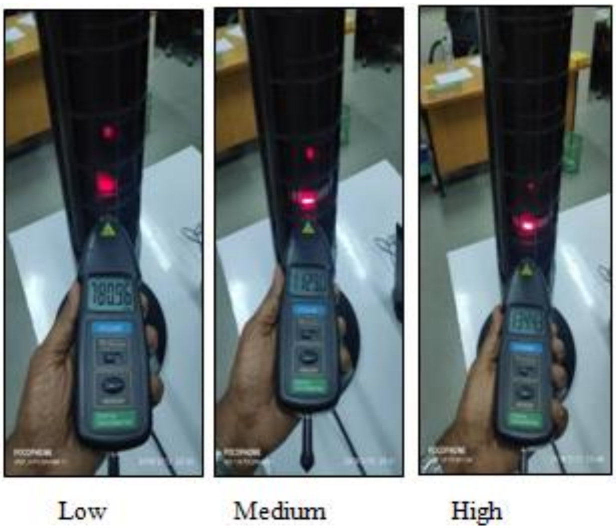

Fig. 20 Speed Values of the Original Fan

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To ensure correct conversions, the fan speeds were measured five times with the tachometer and the average values of the readings were accepted as the working test values (Table1).

Table. 1 Average speed values of the fan using remote control

S.No.	Mode of Original Fan	Tachometer reading (RPM)
1.	Low	780
2.	Medium	1129
3.	High	1344

Problems Identified

1. The remote control has a maximum of 4 m range beyond which the remote signals are not able to be detected by the IR sensor in the fan.
2. The fan speed is limited to three modes.
3. Usage of the remote puts responsibility for running cost on to the user.
4. The remote signals are only detectable within a certain angle of arc over the fan's face. Outside that angle of arc, the signals are not detected by the fan.

Results of the Proposed Control Method

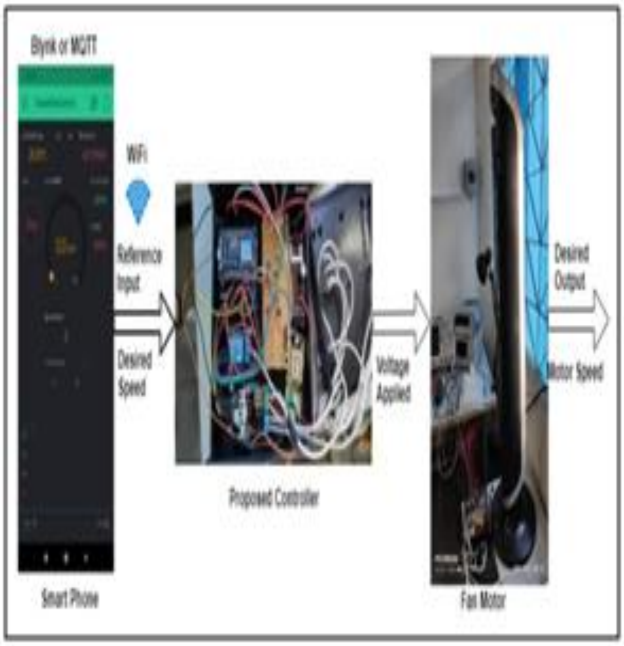
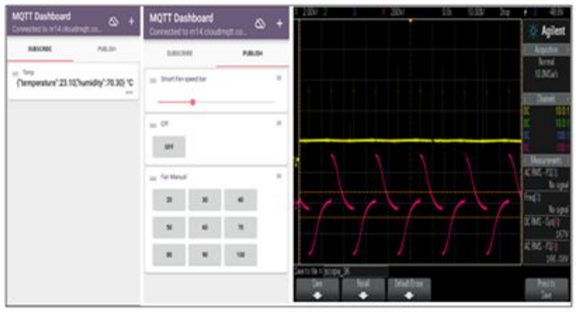


Fig. 21 Overview of new proposed control method

Figure 21 illustrates the overview of our proposed control system. The importance of the proposed IoT based smart control is emphasized by the results of our performance analysis of the fan motor. These are shown in Figures 22, 23.



(a) (b) (c)

Fig. 22 Motor at 30% Speed input from Smart Phone using MQTT. (a) MQTT app. screenshot displaying temperature and humidity values. (b) MQTT app. screenshot displaying speed input button pressed. (c) Oscilloscope screenshot displaying the waveforms of the TRIAC and output voltage.

The used fan was a tower fan from a well-known supplier, with an ESPINO microcontroller installed. The experimental results for input and output voltage (variac), Zero Crossing Detector (ZCD), TRIAC and Feedback control were obtained for different motor speed values using a mobile application for a smartphone that hasbeen developed for this purpose. The total time period of the output voltage wave form when motor running at full speed is 20ms which is equal to 360 degrees. To process this procedure, the connection between the MQTT dashboard on the smartphone and the MQTT server is established. Using the mobile app's MQTT dashboard, the speed input for the fan motor is manually entered and the fan motor starts rotating at the desired speed. The speed input from the MQTT dashboard is sent to the MQTT server via the Cloud, and the ESPINO microcontroller on the fan receives this input command from the MQTT server via the Cloud. The ESPINO microcontroller converts this input command to RPMs and sends a command to the fan motor terminals. The microcontroller generates a triggering signal including a phase angle, this turns ontheTRIAC, and the motor then starts rotating at a speed based on the retriggering signal [18].

(a) (b)

Fig. 23 Motor at 100 % Speed Input from Smart Phone using Blynk(a): Blynk app. screenshot displaying the values of temperature, humidity, set point RPM value, Encoder value, Error etc. (b): Oscilloscope screenshot displaying the waveforms of the TRIAC and output voltage.

Results Discussion

Explaining Figure 22, if the seek bar or speed input button indicating 30 RPMs is pressed on the MQTT Dashboard on the smartphone app, wave forms are produced on the Oscilloscope illustrated in Figures 22. The yellow signals (Vertical Lines) as shown in the figure 22 represents the triggering pulses of the TRIAC. At this point the TRIAC is turned ON by applying the regulated voltage to the motor terminals to change its speed. The pink signal is the terminal voltage wave form of the motor. The area under the chopped sine wave represents the magnitude of the voltage applied to the motor terminals. Thus the Terminal RMS voltage is measured at 30 speed input is 166.08V. The fan motor speed is measured using the tachometer which is 750RPM. The fan operated at this stage is assumed to be low speed mode. The temperature and humidity values from DHT 22 sensor is displayed on MQTT dashboard as shown in Figure 22.

Figure 23 shows the temperature value (23.2^{o}C) and the humidity value (57.8% RH). The Fan motor speed is detected as 1340 RPM from the Encoder attached to the fan motor: shown on the mobile screen Figure 23 (a). The wave forms shown in Figure 23 (b) represents the magnitude of the output voltage (Pink lines) and the triggering pulses (Yellow Lines) to the TRIAC. The Error in this case is Zero which means that the set point speed value and the Encoder value match. This makes the motor to run with constant speed which is the maximum speed of the motor: the indicated speed was 100, the maximum.

Average Speed Values of Proposed Control Method

Table.2 explains the comparison between the average speed values of the fan, with our proposed control methodology using both the MQTT app and the Blynk app. The results prove thatinboth of the applications the speed values are approximately equal.

Table. 2 Average speed values of proposed fan control method

S. No.	Speed Input from Smart Fan(%)	Tachometer reading (RPM) MQTT mobile Application	Tachometer Reading (RPM) Blynk mobile Application
1	10	650	218
2	20	704	293
3	30	759	740
4	40	1040	1034
5	50	1290	1240
6	60	1296	1294
7	70	1300	1309
8	80	1311	1326
9	90	1318	1339
10	100	1341	1344

Summary of the results

The above results prove that this new proposed control method overcome the drawbacks of the old control method. Combining the phase angle control method with IoT application enables a much simpler speed control ability. Also, by comparing the results in Table 1 and Table 2, it is clear that the fan motor speed can be controlled precisely from 1% to 100% of the motor rated speed. This allows the user to choose fan speed levels according to their own choice. This new method will be most helpful for senior citizens, disabled persons and otherwise those with limited mobility, being able to operate the fan using their smart phones. Though the performance of the fan motor in both cases are nearly equal, this new method will control the fan speed more efficiently.

While the emphasis in this specific research project was on ensuring the convenience of people in the domestic situation, the same mobile app could be readily applied to industrial situations for monitoring the operations of fans in any situation, and indeed for monitoring electric motors of any kind. In this research work, the efficacy of having a control system app on any Android or IOS device has been proven.

VI. CONCLUSION& FUTURE WORK

A smartphone app to control the speed of a fan via the IoT was successfully developed, tested and subsequently implemented. The purpose was to enable the remote control of a fan motor and to allow the speed of the fan motor to be increased or decreased in an essentially linear manner, rather than the usual 'Low', 'Medium', 'High" speed controls found on most fans.

Above mentioned smartphone app is proved to be 100% successful in its purpose. The user can operate the fan over the Internet on an Anytime / Anywhere / Any Device basis. This app could be used for electric motor control where motor speeds need to increase or decrease linearly which would result in significantly better operational life for the motor, and better control of power costs.

Usage of Internet of Things has become an interesting topic and by integrating these IoT concepts with Artificial Intelligence, Neural networks and Fuzzy makes this technology as Smart and the applications of this technology will be the near future.

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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.

He is 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.