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A Hybrid Artificial Intelligence and Internet of Things Model for Generation of Renewable Resource of Energy

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ABSTRACT The world is consuming large amounts of energy in various forms like electric energy and mechanical energy. Since the electrical energy is an important factor for the development of the world, many researchers tried to generate electricity from renewable energy sources collected by sensors in order to overcome the shortage of electrical energy for household appliances and industrial areas. In this paper, we develop Internet-of-Things (IoT) based system to generate electrical energy from multiple sensors for household appliances and industrial areas. Different sensors namely piezoelectric sensor, body heat to electric converter and solar panel are utilized and connected to the power storage circuit for generation of electrical energy. Two different Artificial Intelligence (AI) models such as Artificial Neural Network (ANN), Adaptive Network based Fuzzy Inference System (ANFIS) are utilized for the total power generated from renewable energy resources. Validation is done through the statistical parameters such as Root Mean Square Error (RMSE) and R2 coefficient of correlation. Result outcome from the models shows that ANN performance is better than ANFIS.

INDEX TERMS Internet of Things, artificial intelligence, piezoelectricity, sensors, energy types, human body heat dissipation, optimization of renewal and non-renewal energies.

I. INTRODUCTION

Currently, renewable source of energy plays a vital role to fulfil the demand of electricity energy generation [1]. Demand of electricity is the crucial factor in respect of industrialization, urbanization as well as financial [2], [3]. Increasing demand of electricity and disclosure of smart grid systems attracted home energy management system (HEMS) to reduce the consumption of electricity [4]. Electric power plants are undergoing significant reform generation shift from large centralized electric power plants to small renewable decentralized power stations [5].

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Renewable energy is a sustainable power source gathered from inexhaustible assets, which are normally renewed on a human timescale, for example, daylight, wind, rain, tides, waves, and geothermal warmth [6]. Non-renewable energy originates from sources that are not recharged in our lifetimes [7]. More than 50% of the total energy is produced by non-renewable energy sources; therefore, it was estimated that the world will soon face the shortage of petroleum energy [8]. The generation of electricity from renewable energy sources like solar and wind is costly [9]. In 2016, about 10% of the total energy was produced from renewable energy sources [10]. As the demand of electrical energy is increasing, there is a need of clean-energy sources [11]. Every possible sources of energy (small or large) are used to fulfil demand of electrical energy [12]. The shortage in non-renewable energy sources alters the developments of the world; thus, many researchers tried to generate of electricity from renewable energy sources collected by sensors in order to overcome the shortage of electrical energy for household appliances and industrial areas [13], [14]. The following depicts some of these efforts.

Chakrabarti and Chakrabarti [6] studied about sun arranged influence. Ihn and Chang [15] proposed a model including piezoelectric sensors/actuator settle and electronic gear. Two average sorts of flying machine portion were decided to check the proposed technique: blasted fuselage joints and composite braced repair patches with split aircraft parts. Poulin *et al.* [16] discussed the comprehensive study for the generation of electricity between the electromagnetic and piezoelectric system and proposed analytical model to check the duality of signal on both cases. Khan and Iqbal [17] presented a feasible power source based on low-surge cream centrality structures with hydrogen storing up being not brought centered against standard non-sensible power source. A breeze diesel-battery framework is the most appropriate answer for remain solitary applications. Zhao *et al.* [18] proposed a combined piezoelectric-based embedded sensor with a flying machine for essential uprightness checking. An indirect insufficient group of 8-segment PZT circles was completed on the interior surface of the wing.

Kholkin *et al.* [19] discussed the piezoelectric effect in crystalline materials. Dayou *et al.* [20] discussed the piezoelectric material for the generation of electricity as well as proposed mathematical modelling of mechanism of electric power generation and also optimized this modelling. Leonov [21] proposed a thermoelectric energy harvesting technique for generation of electric power. In the testing phase, sensor integrated on the office shirt and generated power between 5-0.5 mW. The symmetry thoughts are keys for understanding the piezoelectric properties of single valuable stones, earthenware, and thin motion pictures [22]. Cost of vitality for such a framework conveying w25 kW h/d, top w5 kW is around 0.497$/kWh [23]. In such the case, net present cost and cost of vitality would be around $29,475, $41,425 and $0.427/kWh. Instead of utilizing single remain solitary units, the scale degrades down to the cost of vitality towards the present utility power cost (0.07$/kWh). Effective headway in little breeze turbine innovation and energy unit investigate are required [24]. Esmaeeli *et al.* [25] designed and developed a piezoelectric mounted in the inner layer of the pneumatic tire to supply power for devices for the intelligent monitoring of tyre. The results showed that piezoelectric sensor provide enough power for the system. Theoretical approach for the body energy harvesting has been proposed in [26]. The main target for this proposed system is wearable health care sensor and assembled directly into sensor for the power supply of sensors.

Nowadays, machine learning [27] plays a vital role to solve various problems in various fields in real-world applications. Artificial Neural Network (ANN), Adaptive neuro fuzzy inference system (ANFIS), Support Vector Machine (SVM), Linear Regression are some machine learning techniques that support to determine renewable source of energy generation and integration. Over the last few decades, applications of Artificial Intelligence (AI) methods has rapidly expanded in various renewable energy generation problem such as upfront cost, geographic limitations and limited storage capabilities. In terms of renewable energy generation, the authors [28] discussed a comprehensive survey of hybrid renewable energy system which integrates two different energy sources such as solar energy and wind turbine. Mabel and Fernandez [29] employed artificial neural network on the data collected from the seven-wind farm from the 2002 to 2005 year. This dataset includes three input variable such as wind speed, atmospheric humidity, power generation hour and one output variable such as variable energy. The predicted output comes through the ANN model shows that model is accurate and beneficial for the future energy planning.

Azadeh *et al.* [30] presented an ANN approach for forecasting energy consumption of renewable source in the environmental and economical point of view. This approach is mostly used for the remote location where availability of the measuring equipment's is very less. The result outcomes from this model are better as compare to fuzzy regression and conventional models. Kassa *et al.* [31] proposed an ANFIS based approach to predict the wind power generation and tested on dataset collected from the wind turbine which is based on practical case study. The proposed model is more accurate than the BP neural network and hybrid neural network. Mellit *et al.* [32] employed ANFIS model for simulation of photovoltaic power supply under variable climatic conditions. The dataset including climate and electrical data was measured from the 1992 to 1997 years. The result outcomes show than ANFIS performance is better as compare to ANN. Kanaga Sakthivel *et al.* [33] presented ANFIS based hybrid renewable energy scheme which is the combination of wind and solar photovoltaic power with the higher power point tracking. Using ANFIS, it helps to select the power requirement according to the demand and available velocity of wind and amount of sunlight.

It has been observed from those studies that single sensors were used to generate electrical energy for household appliances and industrial areas [34]. This can be improved by using multiple different sensors in the Internet-of-Things (IoT) technology [35]. Internet-of-things (IoT) is defined as the network of physical devices, vehicles, home appliances and other items embedded with electronics, software, sensors, actuators, and connectivity, which enable these objects to connect and exchange data [36]. Things can be devices, vehicles, home appliances and other embedded electronics devices [37]–[39]. This makes IoT exclusive to other available network infrastructure [40]. IoT allows objects to be sensed or controlled remotely across existing network infrastructure. For this, Internet is required [41]. This enables in developing and integrating the physical world into computer-based systems, and resulting in improved

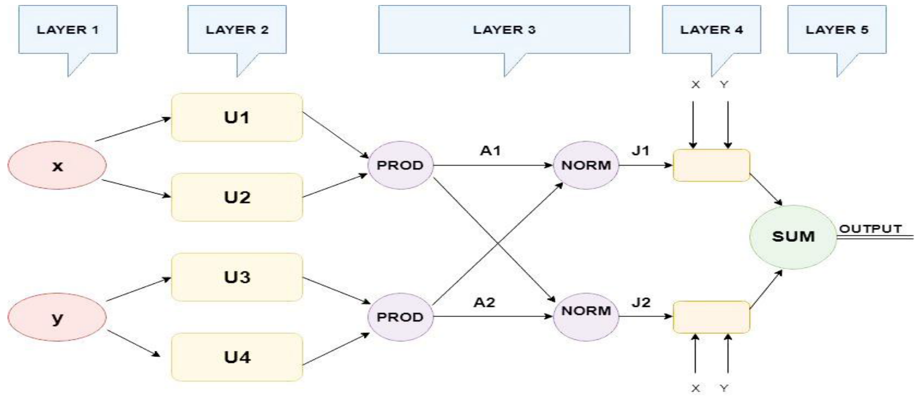

FIGURE 1. ANFIS architecture.

efficiency [42]–[44]. In general, above mentioned work have focused on AI modes for predicting the renewable source energy.

In this paper, we **develop an IoT based system to generate electricity from three different modules** namely piezoelectric sensor, body to heat convertor, and solar panels are utilized and connected to the power storage circuit for generation of electrical energy. We also constructed and validate the data generated from these modules through the ANFIS and ANN for the prediction of power output generated. Validation of these models done using Root mean Square (RMSE) and Correlation Coefficient (R2). The rest of the paper is organized as follows: Section 2 presents the background and the proposed method respectively. Section 4 shows the experiments with Conclusions in the last section.

II. BACKGROUND

A. ARTIFICIAL INTELLIGENCE TECHNIQUE

1) ANFI

ANFIS [45] is a network structure that consists of nodes and guiding links through which nodes are interfaced to each other. In addition, nodes are adaptive in nature; learning rules and output dependency parameter illustrate that change of these parameters able to reduce the prescribed error measure. ANFIS is a manifold feed-forward network that performs a specific function (node function) on the input messages as well as bunch of parameters concern to this node. The mathematical formula for the node function fluctuates from node to node and dainty of each node function rely on input-output which is important for the ANFIS to carry out. Guiding links are totally depending on the flow direction of node to node link and no weight is coupled with them.

There are two types of nodes used in the adaptive network: 1) Circle node 2) Square Node. A Square node is also termed as "Adaptive node" which have parameters. Circle is a static or fixed node not contains any parameters. For the initial membership function, training of ANFIS is done with the training data and adjusting this membership function with the use of back-propagation algorithm [46] or hybrid-learning algorithm [47]. Improved in Decision making of Fuzzy logic and capability of neural network training are done by the ANFIS together. The Layers of the ANFIS architecture is categorized into 5 layers (Figure 1):

Layer 1: With the use of membership function, each node presents at this layer make a new membership grade according to its belong fuzzy set.

Layer 2: This layer worked as multiplier that multiply number of input signals and denoted by PROD.

Layer 3: Every node placed in this layer is static node and denoted by NORM. The j^{th} node calculated as ratio j^{th} firing strength to the sum of all rule strength.

Layer 4: At this layer, prediction of contribution j^{th} node toward total output of the model

Layer 5: This Layer contributes the overall result of the ANFIS model.

2) ANN

ANN [48] is a collection of many artificial neurons which act as simple processing elements and their working functionality is mostly similar with neuron in animal's species. Process of adjustment to link between parameter element and processing element is used for learning ANN. ANN architecture is based on the weight directed graph between neuron input and neuron outputs in which artificial neurons are the nodes and directed edges. Based on the architecture, ANN is categorized into two parts (Figure 2):

- *Feed-forward network*: No loop in ANN Graph
- *Feedback network:* loops due to feedback connection

Feed-forward connection is also called as multilayer perception; neurons are placed into the multiple layers with one side link between them. It is static, memory-less links in the network means response from the network is not dependent on the previous state. Feedback network is dynamic in nature. Due to feedback path, output response relies on the previous response and modify according to the need.

B. VALIDATION METHOD

In this study, to evaluate and predict the power output with the use of different models. In addition, RMSE (Root mean square error), R2 (Coefficient of Correlation) are also

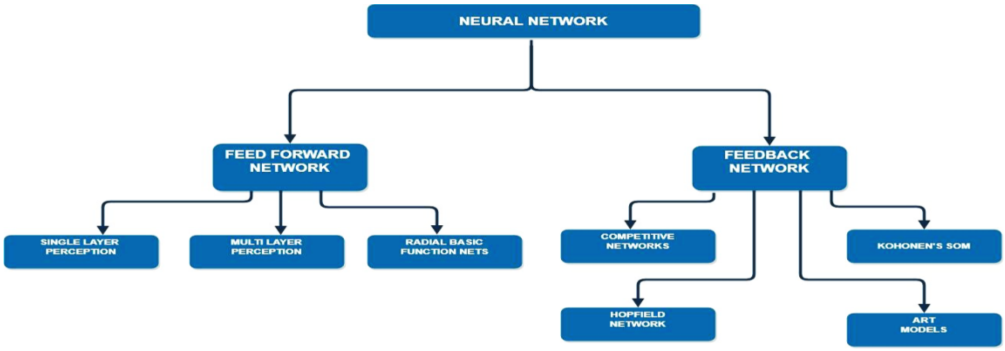

FIGURE 2. **ANN architecture.**

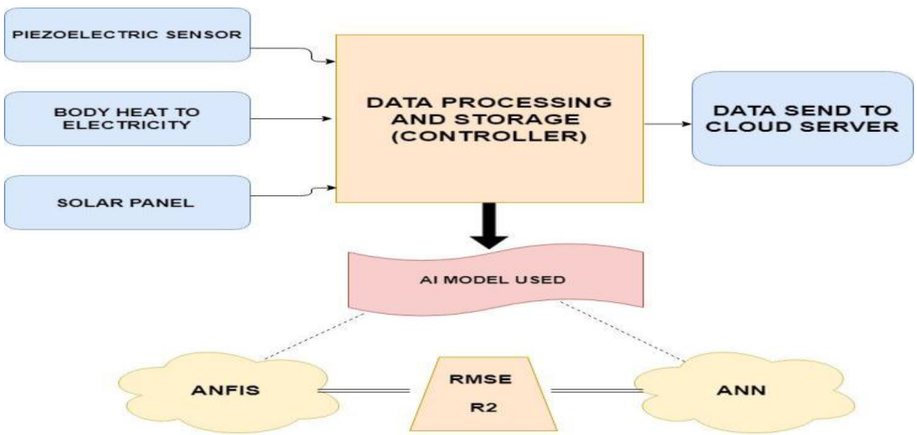

FIGURE 3. **Proposed IoT model.**

engaged to identify the efficient model. The following equations are used to quantify performance metrics parameters as follows:

$$R^2 = \left\{ \left(\frac{1}{N}\right) X \sum\nolimits_{i=1}^{N} \frac{[(p_i - p_{mean})\,(a_i - a_{mean})]}{v_a * v_p} \right\} \tag{1}$$

$$\mathrm{RMSE} = \sqrt{\sum\nolimits_{i=1}^{N} \frac{(p_i - a_i)^2}{a_i}} \tag{2}$$

where a and p are the actual and predicted values respectively. Average values are denoted by the p_{mean} and a_{mean}, v_a and v_p are the standard deviation for actual and predicted values respectively.

III. PROPOSED METHODOLOGY

In this study, our methodology is carried out in four different steps: 1) fetch and processed data, 2) send data to the cloud server, 3) building the models, 4) validating model through the ANFIS and ANN. Figure 3 represents the proposed IoT model.

A. FETCH AND PROCESSING DATA

Three modules include the piezoelectric module, body heats to electricity, solar panels are used for generating renewable source of energy. For the first component (Figure 3), sensors can be installed in shoes welt. When a person starts walking or running, the weight of whole body causes the pressure applied on the piezoelectric sensors. The mechanical stress is converted in to electrical energy by the piezoelectric sensor. As shown in Figure 4, the input to the sensor is pressure or stress by human body and output is electrical energy.

FIGURE 4. **Block diagram of piezoelectric sensors while running / semi walkin.**

For the second component (Figure 3), the heat generated by the human body is used to generate electricity. It is observed by the sensors i.e. body heat to electricity converter and produces the electricity. The sensor is connected with the power storage device that stores the electric energy produced by the sensor. The electricity is stored in the storage device and used for various purposes like for mobile charging, headlight (Figure 5). The equation for this component is as follows:

$$\ddot{O} = \sigma A T^4$$

FIGURE 5. Block diagram for the body heat.

where $\ddot{O}$ is Heat transfer rate (Btu/hr), σ is Stefan-Boltzman constant (0.174 Btu/hr-ft^2-^{o}R^4), A is Surface Area (ft^2), and T is Temperature (^{o}R).

For the third component (Figure 3), solar are made from the photovoltaic cells. When photons from the sunlight hits photovoltaic cells, electron immediately lose their atom and conductor also attached positive and negative side of the photovoltaic cell that's make a medium to flow the electron through it and generation of the electricity (Figure 6). Solar panels are only able to generate the DC power supply. With the use of circuitry consist of diode and regulator, DC power supply directly stores into battery. For AC, Invertor is mandatory for conversion of the DC power supply into the AC power supply. Solar Panel mostly generates nearly 12 volt and current varies according to the size of solar panel. Equation 3 represents the solar power energy calculation

$$EG = Area \times n \times Av \times PR \tag{3}$$

EG	=	Energy (kWh)
Area	=	Total solar panel Area (m2)
n	=	solar panel yield
Av	=	Annual average solar radiation on tilted panels
PR	=	Performance ratio, coefficient for losses

FIGURE 6. Block diagram for the solar pane.

B. SEND DATA TO CLOUD SERVER

ESP8266 module is used to make a gap bridge between data and cloud server. ESP8266 access through AT Commands and equipped with onboard antennas as well as support TCP/IP protocol for the better connectivity. It also makes a suitable connection between backend terminal and processes sensor data.

C. BUILDING MODELS

Collected dataset from 3 different modules were used for the training, and testing of the models. At the time of train model, training and validation dataset are used. Validation dataset work as tuner to tune the model hyper parameters for training dataset to fit on model. After the completion of training, testing dataset employed to evaluate the final model fit of training dataset. ANFIS and ANN are used to test and train different models to check accuracy of model which model is more suitable for power output. Validation models through ANN and ANFIS: ANN and ANFIS are used to validate the different models and statistical methods such as RMSE, R2 are making a medium to test the validity of the models.

D. CIRCUIT DIAGRAM

The proposed system for IoT (Figure 7) based renewable energy generation is primarily composed of an Arduino Uno board equipped with ATmega328, piezoelectric sensor, solar panel, body to heat convertor and ESP8266 based Wi-Fi module. In the category of piezoelectric sensor, piezoelectric plate is used.

Dimension of the plate is directly proportional to the power generation, wider of the disc means more power generation. The dimensions of the piezoelectric plate in open and short circuit conditions are represented. During the interfacing of piezoelectric sensor, one of two conditions is being employed 1) pull-up resistor 2) pull-down resistor. Pull-up and Pull-down resistors are the resistor that helps to achieve the properly-defined logic level at the microcontroller pins. Figure 8 shows the pull-up and pull-down resistor. With this condition, microcontroller worked as measuring instrument to measure the voltage and current. Resistor value varies according to the sensitivity of measurement required.

Omega HFS series heat flux sensor is used as body to heat sensor based on the thin film and also attached on the curved surface. To measure the output of sensors, similar pull-up and pull–down resistors are deployed. Solar panel is connected to microcontroller through the aid of diodes. These diodes are named as bypass diode which make a bridge between the positive and negative terminal of solar panel and also avoid the short circuit condition between positive and negative condition.

In the proposed study, microcontroller directly measure DC power supply through the pull-up and pull-down resistor. Invertor for the conversion of DC power supply to AC is not required in the study. The microcontroller plays a main role to gather data from the different modules, formatting and send the encrypted collected data to the Cloud server through ESP8266. Arduino Uno [49] based on ATmega328 microcontroller. ATmega is a RISC (Reduced Instruction set controller) based microcontroller which support 8-bit data. It has equipped with 8kb of internal memory and 1kb of EEPROM. The purpose behind EEPROM is to save the data inside the chip in the absence or presence of the power supply. Some technical parameters in the ATmega328 is as follows. It supports UART (universal asynchronous receiver transmitter), SPI (serial peripheral interface) for the making the connectivity with the different modules such as Wi-Fi, Bluetooth, Xbee and GSM module. ATmega328 [50] worked as measurement instrument to measure the voltage and current. The voltage measurement range lies between 0-100V and current range lies between 0-500mA. Power calculated using equation (4).

$$\begin{aligned} Total\ Power &= Voltage \times Current \\ TotalPower &= 5v \times 2A = 10W \end{aligned} \tag{4}$$

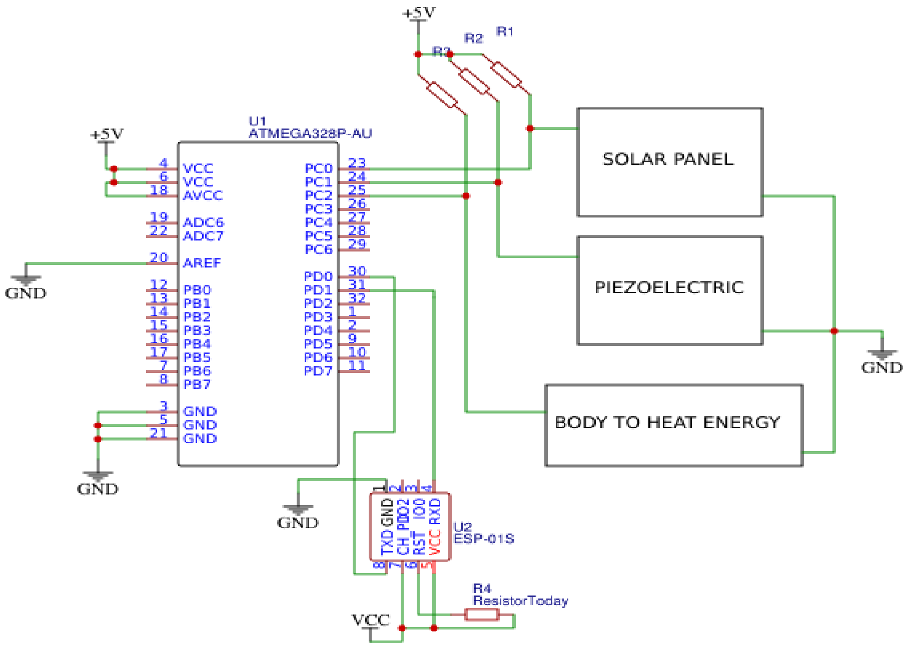

FIGURE 7. Circuit diagram of proposed work.

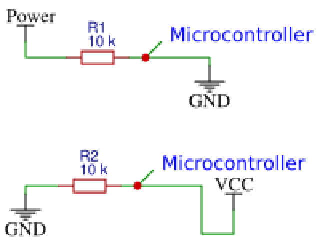

FIGURE 8. Pull up and pull-down resistor condition.

In our proposed work, ESP8266 modules used to make a bridge between the microcontroller and cloud server Blynk (Figure 9). ESP8266 is a small, low cost WiFi module chip embeds with the full TCP/IP stack. It uses AT commands to setup device and transmitting/receiving data with other sensor and modules. In addition, it also encrypts and decrypts data and sharing with main server. Table 1 represents the AT commands for the ESP8266 module.

Three different modules such as piezoelectric sensor, renewable energy and solar cell are connected to the micro-controller through analogue pins. The measuring concept of this module is based on the change in voltage according to their measurement parameters. Table 2 represents measurement of open-circuit and short-circuit voltage and current of piezoelectric sensor with different dimensions.

It has been found that the voltage generated by short-circuit (~0.15V) is less than the voltage generated by open-circuit which is ~80V. The voltage generated increases in dimension of the materials. Thus, to get the maximum voltage, the dimension of materials should be chosen accordingly. The

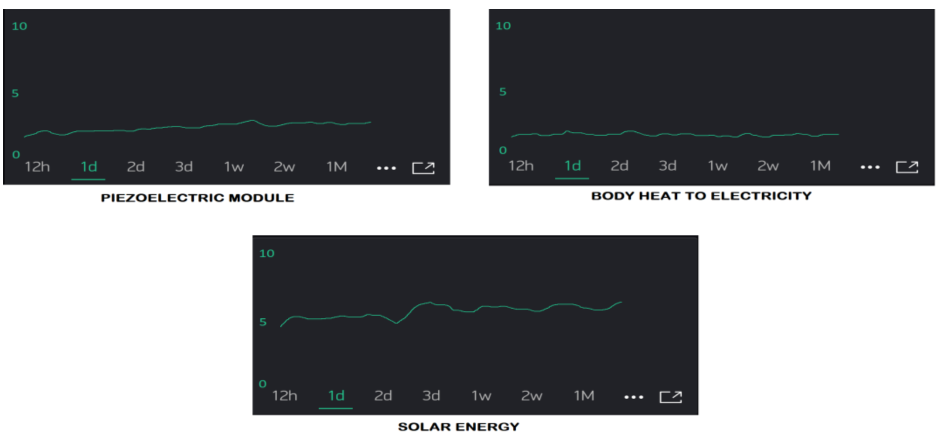

FIGURE 9. Data collected at blynk server.

TABLE 1. AT commands for the ESP module.

No.	AT Commands	Description
1.	AT + RST	Reset the module
2.	AT +GMR	check the firmware version
3.	AT + GSLP	Enter module into deep sleep mode
4.	ATE	Enable/ Disable ECHO
5.	AT+CWMODE	Enter ESP into test, query or execute mode
6.	AT+CWJAP	Setup ssid and password
7.	AT+CWLAP	check the list of available Wi-Fi
8.	AT+CWQAP	Disconnect the Wi-Fi module
9.	AT+ CWSAP	configure softAP mode
10.	AT+CWLIF	list of connected devices
11.	AT+CIPAP	To check the information about connected device

results of the proposed system by different data collection times (Datasets 1 to 4) are shown in Table 3.

When dimension is about 7 × 3 cm3, it produces ∼0.2 V voltage and 0.8 μA. But when the dimension increases to 20×7 cm3, it produces ∼0.8V voltage and 2 μA in short-circuit connection. Table 4 shows how the voltage (V) and current (μA) changes by the human body with respect to time (s). It has been observed that after a certain time period, voltage becomes constant. The production of heat increases when a human body starts walking or running (Table 4). As the heat increases, there is an increasing in production of electrical energy as shown in the Voltage and Current [51], [52].

E. SOLAR PANEL

When a light energy falls on the solar panel, it is converted into electrical energy. Each time it falls, a dataset is recorded.

The algorithm above shows how our proposed work flow and done in two tiers. In the first tier, Microcontroller fetched data from three modules through analog pins. After fetched data, ATmega328 processed, encrypted data and send to the cloud server. In the second tier, collected data is saved in the .csv file. In the .csv file, 3 inputs such as piezoelectric sensors, solar panels and body to heat sensor and one output total power generated. Four models are developed from collected data and trained through the ANFIS and ANN. Compare these models with the statistical parameters such as RMSE and R2 for selecting which model is suitable for our proposed work.

TABLE 2. Open-circuit voltage and Short-circuit current of the Piezoelectric sensor.

Materials	Dimension	Voltage Generated	Current Generated
Piezoelectric sensor (Short-circuit)	7×3 cm^3	~ 0.15 V	0.7 µA
Piezoelectric sensor (Open-circuit)	7×3 cm^3	~ 80 V	7.65 µA

TABLE 3. Data collected by piezoelectric sensors in the proposed model.

Datasets	Materials	Dimension	Voltage Generated	Current Generated
Dataset 1	Piezoelectric sensor (Short-circuit)	7×3 cm^3	~ 0.2 V	0.8 µA
	Piezoelectric sensor (Open-circuit)	7×3 cm^3	~ 100 V	8.5 µA
Dataset 2	Piezoelectric sensor (Short-circuit)	10×3 cm^3	~ 0.3 V	1.0 µA
	Piezoelectric sensor (Open-circuit)	10×3 cm^3	~110V	9.0 µA
Dataset 3	Piezoelectric sensor (Short-circuit)	15×5 cm^3	~0.5 V	1.5 µA
	Piezoelectric sensor (Open-circuit)	15×5 cm^3	~130V	12 µA
Dataset 4	Piezoelectric sensor (Short-circuit)	20×7 cm^3	~0.8V	2 µA
	Piezoelectric sensor (Open-circuit)	20×7 cm^3	~140V	15 µA

Algorithm 1 Proposed Work

fetching the power generated from three modules;
while *Checking the power values from this modules* **do**
  Send data to cloud serve;
  Collected data and generate .csv file from this data;
  Design different models from the generated data;
  Apply ANFIS and ANN on this models;
  Root mean square and Regression;
  if *Root means square and Regression(ANFIS > ANN)* **then**
    ANFIS is Best;
  else
    ANN is Best;
  end
end

TABLE 4. Datasets for the electricity generated by human body heatin the proposed model.

	Time (s)	Voltage (V)	Current(μA)
Human Body Heat over time period	0	0 V	0
	20	0.58	2.5
	40	0.7	2.5
	60	0.75	3
	80	0.8	3.2
	100	0.83	3.5

TABLE 5. Categorized models.

Models	Parameter Considered
Model 1	• Piezoelectric • Solar Energy
Model 2	• Solar Energy • Body to Heat Energy
Model 3	• Piezoelectric • Solar Energy • Body to Heat Energy
Model 4	• Piezoelectric • Body to Heat Energy

TABLE 6. RMSE value of different values with ANN and ANFIS.

	Model 1	Model 2	Model 3	Model 4
ANFIS	0.122	0.133	0.047	0.715
ANN	0.153	0.152	0.117	0.776

TABLE 7. Coefficient of correlation with ANN and ANFIS.

	Model 1	Model 2	Model 3	Model 4
ANFIS	0.983	0.974	0.983	0.965
ANN	0.992	0.987	0.997	0.972

IV. RESULTS AND DISCUSSION

To evaluate the performance of our proposed work, Root mean square error (RMSE) and Correlation Coefficient (R2) are employed in this study and validated through the aid of MATLAB. Consider 366 input samples include piezoelectric, body to heat energy and solar panel energy and 122 output sample of total output power and categorized these samples into 4 different models to check the RMSE and R2 for these models. For the training and validation, MATLAB is used for ANFIS and ANN modelling to verify which techniques is more suitable for our proposed work. Table 5 represents categorized models.

In order to determine the total power generation of renewable energy module, a machine learning model is developed and implemented on the base of ANFIS and ANN. Performance of these models are tested with the use of RMSE and R^2 (Table 6 and 7). Table 5 represents the categorized of dataset into 4 different models.

Validation of ANN and ANFIS model completed through the training and testing of data and the results of RMSE and R^2 of all models are shown in Table 6 and Table 7. Results pointed that predicted value of total power generation values acquired from the training, validation and testing of ANN and ANFIS model are properly mutuality with the experimental values. Out of 4 models, ANN model results and performance is better than ANFIS.

Validation outcome of R^2 of model 3 are shown in Figure 10. The calculated R^2 of ANFIS for model 1, model 2, model 3 and model 4 are 0.983, 0.974, 0.983 and 0.965 respectively. Similar, R^2 of ANN for model 1, model 2, model 3 and model 4 are 0.992, 0.987, 0.997 and 0.972 respectively. The experimental results of observed and predicted value of employed models in ANFIS RMSE and R^2 as follows: Model 1: 0.122; 0.983, Model 2: 0.133; 0.974, Model 3: 0.047; 0.987, Model 4: 0.715; 0.965 and ANN RMSE and R^2 as follows: Model 1: 0.153;0.992, Model 2: 0.152; 0.987, Model 3: 0.117;0.997, Model 4: 0.776;0.972. In addition, 80% of dataset is used for model development and rest of the dataset is used for testing values.

The results shown in Tables 6 and 7 revealed that there is a close relationship between expected and predicted values but performance point of view ANN is better than ANFIS. Table 8 discusses about the comparative analysis between the existing work and proposed work. It clearly indicated that the proposed work is more effective as compare to the existing works.

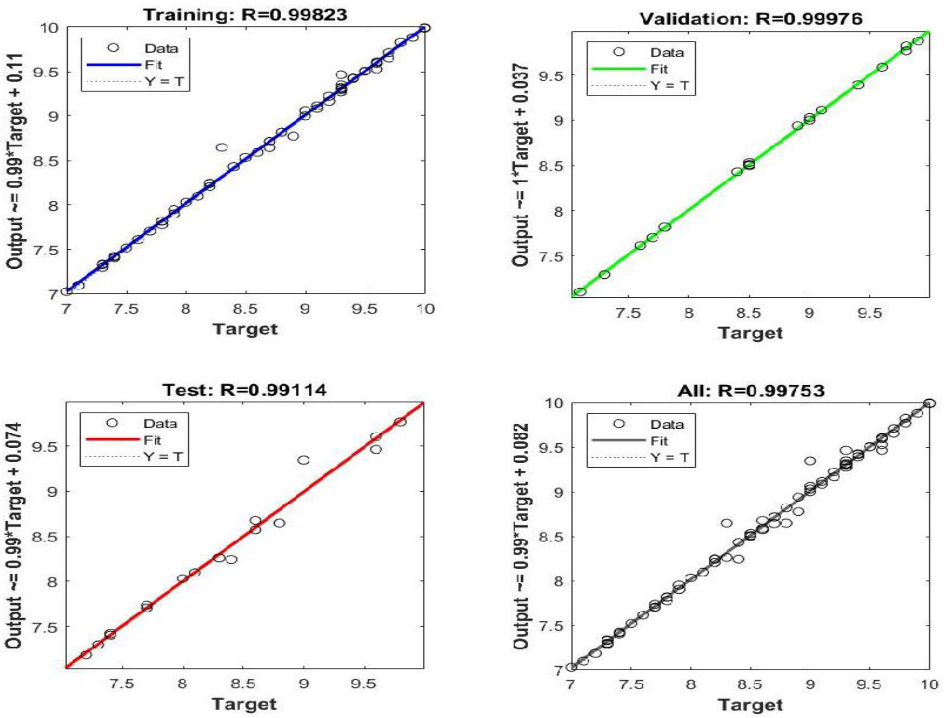

FIGURE 10. Regression of ANN mode.

TABLE 8. Comparative analysis.

Authors	Descriptions	Results
Stojčić et al. [53]	Developed a model based on the Fuzzy Logic and ANFIS for predicting maximum energy generating from the photovoltaic modules	RMSE = 0.209 R2 = 90.78
Dixit et al. [54]	Comparison of two different models such as ANN and ANFIS for power extraction from the photovoltaic modules.	The comparison on the basis of efficient of photovoltaic cells. ANFIS = 98.90 ANN = 96.76
	Developed a model for the weather forecasting prediction and used two step modelling process to connect unheralded weather variables to heralded variables	R2 = 70.5
Proposed Work	Developed model to predict total power generation from four different modules. Compare the performance between the ANN and ANFIS	RMSE = 0.117 R2 = 0.997

V. CONCLUSION

In this paper, we developed a new IoT based system to generate electrical energy from multiple sensors for household appliances and industrial areas and validated the renewable sources through the AI models namely ANN and ANFIS. Different sensors namely piezoelectric sensor, body heat to electric converter and solar panel are utilized and connected to the power storage circuit for generation of electrical energy and after processing data sent to the cloud processor. Electricity from renewable energy sources such as stress generated by the body weight, heat generated by the human body, and movements of the body can be measured by different sensors and transferred to the control system for storing.

For the validation purpose, 4 models are developed from the real time collected dataset and tested and trained through

ANFIS and ANN through statistical parameters namely RMSE and R2. In total 3 input modules such as piezoelectric, solar energy and body to heat energy are considered to predict the total output power generation as output in the AI models. Results outcome from these model shows that training and testing of all models through ANFIS and ANN are good but ANN performance is better than ANN. The proposed study might be beneficial for predicting power generation from renewable resources.

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