International Journal of Power Electronics and Drive Systems (IJPEDS)
Vol. 15, No. 1, March 2024, pp. 631~638
ISSN: 2088-8694, DOI: 10.11591/ijpeds.v15.i1.pp631-638

Dual axis solar tracking system for agriculture applications using machine learning

Deepa Somasundaram[1], Lakshmi Dhandapani[2], Jayashree Kathirvel[3], Marlin Sagayaraj[4], Vijay Anand Jagadeesan[5]
[1]Department of Electrical and Electronics Engineering, Panimalar Engineering College, Tamil Nadu, India
[2]Department of Electrical and Electronics Engineering, AMET University, Tamil Nadu, India
[3]Department of Electrical and Electronics Engineering, Rajalakshmi Engineering College, Tamil Nadu, India
[4]Department of Electrical and Electronics Engineering, Agni Engineering College, Tamil Nadu, India
[5]Department of Electronics and Communication Engineering, J.N.N Institute of Engineering, Tamil Nadu, India

Article Info

Article history:

Received Apr 24, 2023
Revised Jul 25, 2023
Accepted Aug 9, 2023

Keywords:

Automated system
Crop recommendation
Energy harvesting
Logistic regression algorithm
Machine learning
Random forest classifier
Solar tracking system

ABSTRACT

The three most basic amenities required for human survival are food, shelter and clothing. In today's tech-savvy generation, these have experienced a great deal of scientific advancement. Unfortunately, agriculture is still more man power-oriented. So they have to rely on the hit and trial method to learn from experience which leads to waste of time. In proposed work includes an automated system using dual axis solar tracking system and gives crop recommendation for different types of soil to yield maximum. The suggested system is a dual-axis solar tracker based on machine learning that is intended to considerably increase the effectiveness of energy harvesting. The approach makes use of the logistic regression algorithm (LR) to do this. This novel strategy tries to maximize the solar panel's ability to produce energy, leading to increased energy yields. The quality of soil is predicted by using suitable sensors for crop recommendation. The data’s are temperature, humidity, pH of soil, nitrogen, phosphorous & potassium in soil and rainfall in soil are considered. For crop recommendation six algorithms- SVM, KNN, Native Bays, Logistic Regression, Decision Tree classifier, Random Forest Classifier are applied and tested. It is found that random forest classifier gave us excellent results.

Corresponding Author:

Deepa Somasundaram
Department of Electrical and Electronics Engineering, Panimalar Engineering College
Tamil Nadu, India
Email: dee_soms123@yahoo.co.in

1. INTRODUCTION

Automation is necessary in India since human irrigation methods are ineffective there, where two thirds of the population depend on agriculture as their primary source of income. Automated irrigation can deliver precise water delivery [1]. Following the path of the sun allows solar panels with tracking systems, controlled by machine learning algorithms, to produce the most power. In comparison to fixed arrays, this dual-axis solar tracker can capture the most sunshine, potentially improving solar panel yields by 30 to 60% and producing up to 40% more electricity annually [2], [3].

According to agriculture, maximum crop production is very important to make agriculture profitable [4]. So, the crop recommendation to a farmer will help them increase their productivity. To know the suitable crop for their field generally need to approach soil testing laboratories to learn about the nature of the soil, its nutrients contents, pH level and moisture level [5]. There may be a delay in the results of these tests because the laboratory will have too many samples to test [6]. Once the results have been obtained, farmers can determine the suitable crop to grow in that soil [7]. To avoid such time delays and complications, this project also has crop recommendation system will be more beneficial because it senses the pH, nutrients, temperature and humidity levels of soil using the necessary sensors and then compares these to dataset values to produce accurate results [8]. By choosing renewable energy for this kind of system, electricity can be saved. They can be easily fixed in agricultural areas so that maximum power is achieved by solar trackers [9]. Usually, the crop recommendation system consumes less power for accurate results, so itis very easy to run any other system connected to it.

The crop selection method (CSM) was put forth to address crop selection issues, maximize net crop production rates over the course of the season, and promote national economic growth [10]–[12]. The software chooses a succession of crops that maximizes daily production throughout the entire season using plantation days and expected yield rate as inputs. The CSM calculates agricultural yield based on input conditions by using machine learning and prediction methods like multiple linear regression. The methodology was tested using data gathered from 1997 to 2014 covering all 640 districts and 5924 sub-districts in India. The use of polynomial regression produced a remarkable overall accuracy rate of 78% [13].

By enhancing the population initialization technique with time-series soil nutrients, Krizhevsky *et al*. [14] provided a novel method for identifying the optimal nutrients for boosting yield output while preserving soil fertility. The suggested method helps to reduce the search space and get rid of any local optimisation parameters that aren't present [15]. The model uses a genetic algorithm to examine the data and offer suggestions for improving the remote environment. The ideal nutrient settings for different crops could be recommended using this study's improved genetic algorithm (IGA). Naive Bayesian, Linear Support, Vector Classification, and K Nearest neighbour algorithms were used to decide the type of fertiliser to use [16] based on the area and crop type. For this project, it is necessary to understand the many types of soil, their health and characteristics, and the relationship between various pesticides and manures and the soil types they should be associated with [17], [18]. In terms of the type of fertiliser to be employed, the findings showed that KNN had the highest accuracy (0.8145), while Naive Bayesian and linear SVC had 0.759 and 0.777 accuracy, respectively [19].

At Plataforma solar de Almera (PSA), a small mockup heliostat whose STS was based on conventional computer vision algorithms was successfully tested [20]. Low-cost open hardware and machine learning (deep learning) methods [21] combined with specialized software (MATLAB [22] and Mathematica [23]) have advanced the computer vision approach. This most recent method, which was tested at (PSA), demonstrated the enormous potential of intelligent STSs. Additionally, the authors of the current study have obtained a patent for a novel method of Sun tracking devices [24]. The major finding of an extensive assessment and preliminary findings concur that the adoption of smart STSs is the most viable approach for the advancement of concentrated solar power and photovoltaic technology.

2. METHODOLOGY

As shown in the block diagram of Figure 1, the Raspberry Pi 3 Model B CPU, which controls the entire system, is used. Let's begin with crop recommendations. The PH sensor, NPK sensor, temperature and humidity sensor, and rainfall values are collected to recommend the most suitable crops based on the data [25]. To produce the needed result, the collected data will be compared to the dataset downloaded from the Kaggle website. The data will be categorized using the Random Forest algorithm, a well-known supervised learning method.

This particular technique produced the highest output out of all the methods we used to train our model. The suitable crop names and sensor values are displayed on the monitor by Putty software and we can hear the results via Bluetooth speaker or head phones. We use this humidity sensor not only for crop recommending system, but also in irrigation process in the field. We are using solar power for the irrigation. This will be carried out by turning on and off the water pump according to the soil water vapor level. This will be done with the help of a motor driver circuit. In order to increase crop productivity and maintain crop health, the sensor could sense the water level and pump water at the right time. Here the panel works by the mechanism of a tracking system which can track sunlight and convert it into electrical energy. This tracker will work without light dependent sensors since the entire tracking system is designed to be controlled through a logistic regression algorithm in machine learning.

The random forest method can swiftly categorize unclassified data records and is very effective at training new models. The orientation of the solar panel in this system is changed by a servo motor in response to the angle of the sun's irradiation and the time of day. The algorithm has been set up to adjust the panel's angle based on the sun's position at various times.

2.1. ML algorithm used in solar tracker

Applying the logistic regression technique allows the dual-axis solar tracking system to rotate the panel to the desired angle. Figure 2 shows the training and testing the sun tracking model. For this model, training and testing will be done based on this logistic regression algorithm. So, it will be easy to position the solar tracker with a servo motor at the desired angle. The testing and training data will be given to input them and it computes the data with regression coefficients using Sigmoid function. After finding a relationship between training and testing data, the object position can be determined. By using this tracking system, power would be provided to the water pump for irrigation process. Once the humidity value reaches below the predetermined value, power is supplied to motor driver circuit for driving the water pump for irrigation.

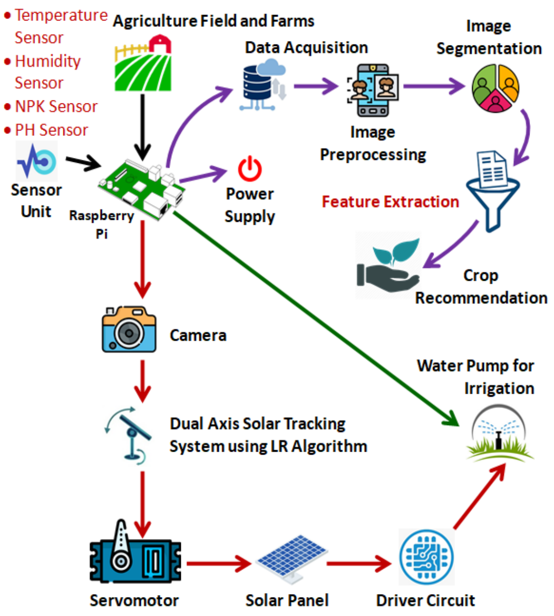

Figure 1. Block diagram of proposed method

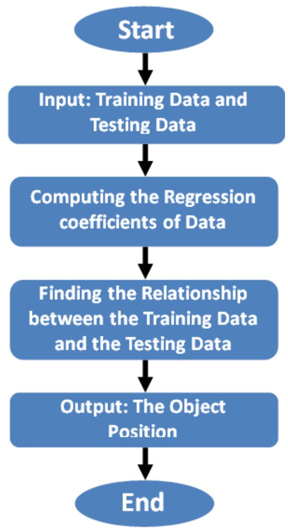

Figure 2. Training and testing the tracking model

2.2. ML algorithms used in crop recommendation

Figure 2 illustrates a random forest, a type of classifier that consists of a collection of trees-organized classifiers where independent random vectors are dispersed indistinguishably and each tree makes a unit decision for the most common class at input x. A random vector that is independent of earlier random vectors with the same dispersion is formed, and a tree is made using the training set. The random forest algorithm's key benefits are improved accuracy, resistance to outliers, speed compared to bagging and boosting, and simplicity and ease of parallelization. First, N decision trees are combined to generate the random forest, and then predictions are made for each tree that was produced in the first phase. Algorithm for random forest in machine learning:

– Step 1: Choose K data points at random from the training set.
– Step 2: Create the decision trees connected to the subsets of data that you have chosen.
– Step 3: For any decision trees you intend to construct, select N.
– Step 4: Repeat Step 1 & 2.
– Step 5: Find each decision tree's forecasts for any new data points, then place them in the category that receives the most votes.

The crop recommendation dataset being used in the presented proposed study principally consists of soil parameters, coupled with information on temperature, humidity, and rainfall. The benchmark repository provides an open-source dataset. The flowchart for the random forest algorithm for crop prediction is shown in Figure 3. In several scenarios for model evaluation, like crop recommendation, accuracy is a commonly used parameter to gauge how well the classifier can recognize the intended variable. The following equation is used to determine a model's accuracy:

$$\text{Accuracy} = \frac{\text{Correctly Classified observation}}{\text{Total number of Input}} * 100$$

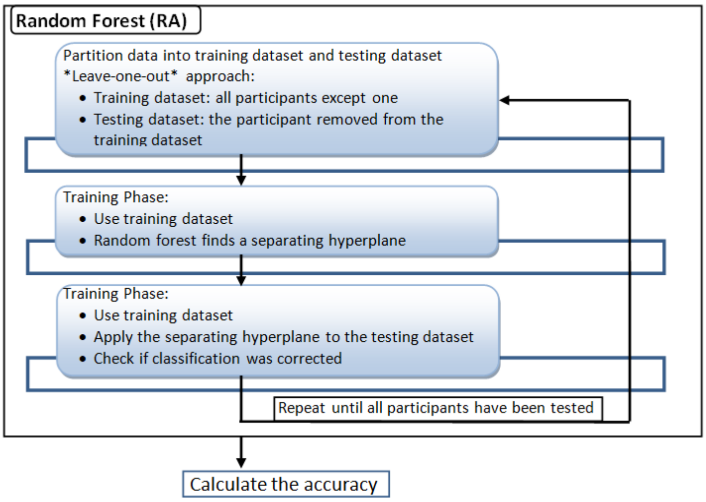

Figure 3. Flowchart for random forest algorithm for crop recommendation

3. RESULTS AND DISCUSSION

The system is structured around a hardware configuration outlined in a block diagram which is shown in Figure 4, effectively gathering sensor data which is then directed towards Raspberry pi for processing. The initial phase of training the model holds significant importance, as it plays a pivotal role in achieving the desired predictive accuracy. By evaluating the accuracy levels, the most appropriate machine learning (ML) algorithm is selected, with random forest emerging as the optimal choice. Upon successful training, the model undergoes testing through the utilization of putty software. During this process, collected data is meticulously cross-referenced with a pre-existing dataset that was employed for training purposes. This comparison forms the foundation for accurate crop prediction, where the model identifies and suggests the most suitable crop for the given conditions.

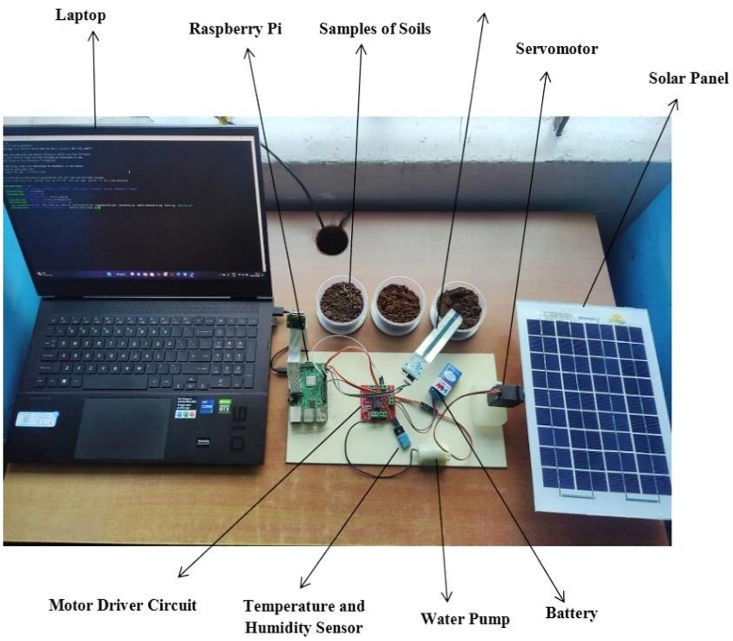

Figure 4. Prototype of the proposed system

Furthermore, the hardware setup encompasses a motor driver circuit that exercises control over the irrigation process, fortified by a reliable battery backup system. The effectiveness of this irrigation is further amplified by a solar tracking mechanism, driven by a logistic regression algorithm. This integration ensures that the irrigation system receives optimal solar energy through the dynamic adjustment of panel positions. Notably, the output derived from logistic regression contributes to expediting predictions made by the neural network component of the system. In its entirety, this study undertakes the task of proposing a novel and refined approach to dual-axis solar tracking systems. The core innovation lies in the integration of supervised logistic regression, with the primary objective being an augmentation of efficiency. Through this integration, the system's overall performance is projected to achieve notable enhancements in terms of accuracy and functionality.

3.1. Solar tracking system

The prototype of the proposed system using a machine learning algorithm is shown in Figure 4. In order to generate a workable model, a logistic regression algorithm (LR) is connected to solar panels. The proposed model's fundamental idea is to rotate the solar panel automatically based on the direction of sunlight, hence removing the requirement for manual rotation, a key problem in this industry. To detect greater sunlight emissions, the suggested model includes a light dependent resistor (LDR), and this data is then submitted to the machine learning algorithm for analysis. The suggested method took into consideration a 12 V, 30 W solar panel for experimental reasons. The study's results and conclusions section compare the effectiveness of the current system with that of the suggested approach. The usefulness and benefits of using machine learning in the solar panel tracking system are illustrated in Table 1 by a comparison of solar power output with and without the LR algorithm.

Numerous factors were taken into account in this study, with solar power generation receiving the most attention. Different scenarios, including time periods, power usage, and waste management, were compared. Solar power generation with and without the logistic regression (LR) algorithm is shown in Table 1 along with a comparison.

Monitoring was done from 9 am to 5 pm every day, with the comparison time interval set at one hour. The average power generated was found to be 17.125 watts per hour using the current methodology. The average power production rose to 23.125 watts per hour with the proposed LR technique, nevertheless. This notable improvement demonstrates how the LR algorithm is excellent at increasing solar power generation and maximizing energy use.

Table 1. Solar power output (with and without LR algorithm)

Time (Hours)	Without LR Algorithm	With LR Algorithm
9-10 am	19 w	21 w
10-11 am	21 w	22 w
11 am-12 pm	23 w	25 w
12-1 pm	22 w	26 w
1-2 pm	19 w	24 w
2-3 pm	14 w	23 w
3-4 pm	10 w	22 w
4-5 pm	09 w	22 w
Average Power	17.125 w	23.125 w

3.2. Crop recommendations

Our proposed model uses a data set from Kaggle that contains various factors that contribute to crop growth. These factors have been thoroughly analyzed. Our predictions were based on various inferences generated from the results. Temperature, humidity, pH of soil, nitrogen in soil, phosphorous in soil, potassium in soil and rainfall in soil are considered. Figure 5 shows the model training results for crop recommendation.

Six methods were used and tested for crop recommendation: SVM, KNN, Naive Bayes, logistic regression, decision tree classifier, and random forest classifier. A comparison of the effectiveness of the various algorithms in this situation is shown in Table 2. Surprisingly, the random forest classifier produced excellent outcomes, obtaining a remarkable accuracy of 99.54%. The Random Forest method builds several decision trees and integrates the outputs of each to produce forecasts, producing suggestions for crops that are very accurate and trustworthy.

Table 2. Comparison of different algorithm for crop recommendation

S. No	Algorithm	Accuracy	S. No	Algorithm	Accuracy
1	Logistic regression (LR)	95%	4	Naive bays	99.3%
2	Decision tree classifier	98.78%	5	Support vector machine (SVM)	31.51%
3	K nearest neighbors (KNN)	97.87%	6	Random Forest Classifier (RF)	99.54%

Different soil samples are considered for crop recommendation. Based on the soil nature (PH value, nitrogen, phosphorus and potassium, temperature and humidity value), proposed system using random forest classifier suggest the suitable crop to cultivate in the respective area. The rainfall data's are also collected to recommend the most suitable crops based on the data experimental results shows that for sample a soil, the recommended crop to cultivate is Muskmelon. F or sample B and Sample C the suggested crop are banana and coffee which are shown in Figures 6-8.

To give farmers more precise and fruitful crop recommendations, the system uses a supervised machine learning algorithm. Table 3 provides information and findings from the framework to help farmers choose appropriate crops based on soil conditions. In the end, it gives farmers more freedom to decide which crops to sow in their land.

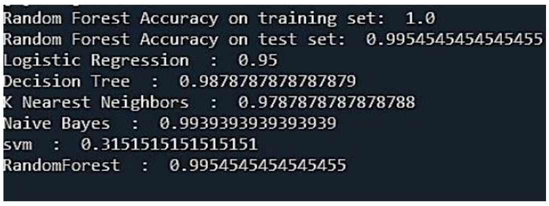

Figure 5. Model training results

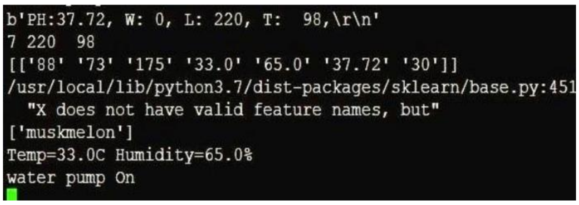

Figure 6. Sample A soil result

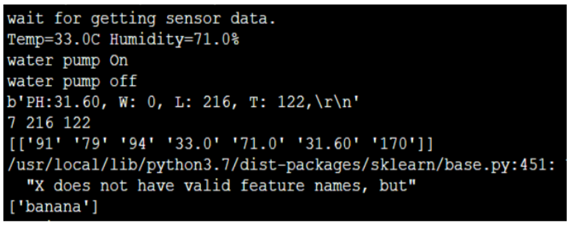

Figure 7. Sample B soil result

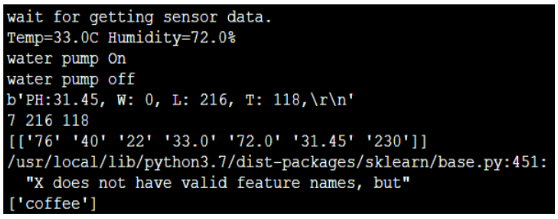

Figure 8. Sample C soil result

Table 3. Output for crop recommendation

Nutrients				Recommended Crop
Nitrogen	Phosphorus	Potassium	pH	
88	73	75	37.72	Muskmelon
91	79	74	31.60	Banana
76	40	22	31.45	Coffee

4. CONCLUSION

We have been successful in creating a smart crop recommendation system that is available to farmers all over India. Using the random forest algorithm, this system helps farmers choose crops wisely depending on important factors including nitrogen, phosphorus, potassium, PH value, humidity, temperature, and rainfall. The system also includes humidity and temperature sensors to track soil water content and automatically control water flow through a water pump. Additionally, using a Dual-axis solar tracking system in conjunction with the LR Algorithm has increased power generation by an astounding more than 25.94%. In addition to helping the environment, the solar-powered farm improves the habitat for plants and animals, addresses recurring drought problems, lowers electricity costs, and raises the farm's total worth. Utilizing a smart irrigation system also has the added benefit of saving water and money on labor. By fusing these cutting-edge technologies, we hope to transform agriculture by giving farmers effective, sustainable solutions while also supporting economic growth and environmental sustainability.

REFERENCES

[1] A. L. Mahmood, A. M. Shakir, and B. A. Numan, "Design and performance analysis of stand-alone PV system at al-nahrain university, Baghdad, Iraq," *International Journal of Power Electronics and Drive Systems*, vol. 11, no. 2, pp. 921–930, 2020, doi: 10.11591/ijpeds.v11.i2.pp921-930.

[2] G. Nguyen *et al.*, "Machine Learning and Deep Learning frameworks and libraries for large-scale data mining: a survey," *Artificial Intelligence Review*, vol. 52, no. 1, pp. 77–124, 2019, doi: 10.1007/s10462-018-09679-z.

[3] I. Etier, S. Nijmeh, M. Shdiefat, and O. Al-Obaidy, "Experimentally evaluating electrical outputs of a pv-t system in jordan," *International Journal of Power Electronics and Drive Systems*, vol. 12, no. 1, pp. 421–430, 2021, doi: 10.11591/ijpeds.v12.i1.pp421-430.

[4] R. Vinayakumar, M. Alazab, K. P. Soman, P. Poornachandran, A. Al-Nemrat, and S. Venkatraman, "Deep Learning Approach for Intelligent Intrusion Detection System," *IEEE Access*, vol. 7, pp. 41525–41550, 2019, doi: 10.1109/ACCESS.2019.2895334.

[5] R. Ayop *et al.*, "The performances of partial shading adjuster for improving photovoltaic emulator," *International Journal of Power Electronics and Drive Systems*, vol. 13, no. 1, pp. 528–536, 2022, doi: 10.11591/ijpeds.v13.i1.pp528-536.

[6] N. Priyadarshi, S. Padmanaban, M. S. Bhaskar, F. Blaabjerg, and J. B. Holm-Nielsen, "An improved hybrid PV-wind power system with MPPT for water pumping applications," *International Transactions on Electrical Energy Systems*, vol. 30, no. 2, Feb. 2020, doi: 10.1002/2050-7038.12210.

[7] H. A. Attia and F. D. Gonzalo, "Stand-alone PV system with MPPT function based on fuzzy logic control for remote building applications," *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 10, no. 2, p. 842, Jun. 2019, doi: 10.11591/ijpeds.v10.i2.pp842-851.

[8] S. Deepa, N. Anipriya, and R. Subbulakshmy, "Design of controllers for continuous stirred tank reactor," *International Journal of Power Electronics and Drive Systems*, vol. 5, no. 4, pp. 576–582, 2015, doi: 10.11591/ijpeds.v5.i4.pp576-582.

[9] E. H. M. Ndiaye, A. Ndiaye, M. Faye, and S. Gueye, "Intelligent Control of a Photovoltaic Generator for Charging and Discharging Battery Using Adaptive Neuro-Fuzzy Inference System," *International Journal of Photoenergy*, vol. 2020, pp. 1–15, Mar. 2020, doi: 10.1155/2020/8649868.

[10] Y. García-Vera, R. Dufo-López, and J. Bernal-Agustín, "Optimization of Isolated Hybrid Microgrids with Renewable Energy Based on Different Battery Models and Technologies," *Energies*, vol. 13, no. 3, p. 581, Jan. 2020, doi: 10.3390/en13030581.

[11] Y. Wu *et al.*, "Large Scale Incremental Learning," in *2019 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, Jun. 2019, pp. 374–382, doi: 10.1109/CVPR.2019.00046.

[12] A. Mosavi, S. Shamshirband, E. Salwana, K. wing Chau, and J. H. M. Tah, "Prediction of multi-inputs bubble column reactor using a novel hybrid model of computational fluid dynamics and machine learning," *Engineering Applications of Computational Fluid Mechanics*, vol. 13, no. 1, pp. 482–492, 2019, doi: 10.1080/19942060.2019.1613448.

[13] Z. Wang, K. Liu, J. Li, Y. Zhu, and Y. Zhang, "Various Frameworks and Libraries of Machine Learning and Deep Learning: A Survey," *Archives of Computational Methods in Engineering*, Feb. 2019, doi: 10.1007/s11831-018-09312-w.

[14] A. Krizhevsky, I. Sutskever, and G. E. Hinton, "ImageNet classification with deep convolutional neural networks," *Communications of the ACM*, vol. 60, no. 6, pp. 84–90, May 2017, doi: 10.1145/3065386.

[15] J. R. Saura, B. R. Herraez, and A. Reyes-Menendez, "Comparing a Traditional Approach for Financial Brand Communication Analysis With a Big Data Analytics Technique," *IEEE Access*, vol. 7, pp. 37100–37108, 2019, doi: 10.1109/ACCESS.2019.2905301.

[16] S. Deepa, S. Praba, V. Deepalakshmi, L. Jayaprakash, and M. Manimurugan, "A Fuzzy Ga Based STATCOM for Power Quality Improvement," *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 8, no. 1, p. 483, Mar. 2017, doi: 10.11591/ijpeds.v8.i1.pp483-491.

[17] A. Awasthi *et al.*, "Review on sun tracking technology in solar PV system," *Energy Reports*, vol. 6, pp. 392–405, Nov. 2020, doi: 10.1016/j.egyr.2020.02.004.

[18] N. AL-Rousan, N. A. Mat Isa, and M. K. Mat Desa, "Efficient single and dual axis solar tracking system controllers based on adaptive neural fuzzy inference system," *Journal of King Saud University - Engineering Sciences*, vol. 32, no. 7, pp. 459–469, Nov. 2020, doi: 10.1016/j.jksues.2020.04.004.

[19] M. Kharrich *et al.*, "Optimal Design of an Isolated Hybrid Microgrid for Enhanced Deployment of Renewable Energy Sources in Saudi Arabia," *Sustainability*, vol. 13, no. 9, p. 4708, Apr. 2021, doi: 10.3390/su13094708.

[20] J. A. Carballo, J. Bonilla, L. Roca, and M. Berenguel, "New low-cost solar tracking system based on open source hardware for educational purposes," *Solar Energy*, vol. 174, pp. 826–836, 2018, doi: 10.1016/j.solener.2018.09.064.

[21] J. A. Carballo, J. Bonilla, M. Berenguel, J. Fernández-Reche, and G. García, "New approach for solar tracking systems based on computer vision, low cost hardware and deep learning," *Renewable Energy*, pp. 1158–1166, 2019, doi: 10.1016/j.renene.2018.08.101.

[22] The MathWorks Inc, "MATLAB R2018a." 2018, [Online]. Available: http://www.mathworks.es/products/matlab.

[23] Wolfram, "Mathematica 11." 2018, [Online]. Available: http://www.wolfram.com/mathematica.

[24] W. Abitha Memala, C. Bhuvaneswari, S. M. Shyni, G. Merlin Sheeba, M. S. Mahendra, and V. Jaishree, "DC-DC converter based power management for go green applications," *International Journal of Power Electronics and Drive Systems*, vol. 10, no. 4, pp. 2046–2054, 2019, doi: 10.11591/ijpeds.v10.i4.pp2046-2054.

[25] M. Aqib, R. Mehmood, A. Alzahrani, I. Katib, A. Albeshri, and S. M. Altowaijri, "Smarter Traffic Prediction Using Big Data, In-Memory Computing, Deep Learning and GPUs," *Sensors*, vol. 19, no. 9, p. 2206, May 2019, doi: 10.3390/s19092206.

BIOGRAPHIES OF AUTHORS

Deepa Somasundaram received her B.E. from K.S.R college of Technology, affiliated to Periyar University, in 2003, M.E. from Annamalai University in 2005. She completed her Ph.D. degree form Sathyabama university in 2013. Presently, she is working as an Professor in the Department of EEE at Panimalar Engineering College, Chennai. She has published a more than 30 papers in International and National Journals. Her area of interest is. Power system, optimisation technique. She has more than 15 years of experience in teaching field. She can be contacted at email: dee_soms123@yahoo.co.in.

Lakshmi Dhandapani received B.E (Electrical and Electronics Engineering) from University of Madras in 1999, M.E (Power Systems Engineering) from B.S.A. Crescent Engineering College, Anna University, Chennai in 2006 and the Doctoral degree from Anna University in March 2018. She has 21 years of teaching experience. She has published over 40 national, international journals and nearly 35 national and international conferences proceedings. Her areas of interest are load frequency control, deregulated power system, power quality, power system dynamics, renewable energy systems, microgrid. She can be contacted at email: lakshmid1980@gmail.com.

Jayashree Kathirvel completed her bachelor degree (2002) in Sona College of Technology, Salem and completed her master degree (2010) in Indian Institute of Technology, Madras. She is currently working as assistant professor (senior grade), in electrical and electronics engineering department at Rajalakshmi Engineering College, Chennai. She is currently pursuing her Ph.D. at Anna University, Chennai. Her current research area includes hybrid renewable energy systems, investigation on converter topologies for electric vehicles, FACTS devices and power system stability and control. She can be contacted at email: jayasree@rajalakshmi.edu.in.

Marlin Sagayaraj received her Bachelor of Engineering degree in Electrical and Electronics Engineering in the year 2014 from Sathyabama University, Chennai, Tamil Nadu and Master of Engineering degree in Power Systems in the year 2016. She is currently working as an assistant professor in the Department of Electrical and Electronics Engineering, Agni College of Technology, Chennai and a research scholar in the Department of Electrical and Electronics Engineering, Sathyabama University, Chennai. Her current research interest includes optimization technique in FACTS Devices, Smart Grid, Renewable Energy Source. She can be contacted at email: sagayarajmarlin@gmail.com.

Vijay Anand Jagadeesan is working as an assistant professor in J.N.N Institute of Engineering, Chennai, India. He has completed his UG in EEE from Thirumalai Engineering College, Kanchipuram and PG in Control and Instrumentation from Thiagarajar College of Engineering, Madurai and Received Ph.D. degree from Anna University, Chennai, India. He has published 7 papers in International and UGC care Journals and 9 International and National Conferences. His research interests include solar energy, DCS, and Artificial Intelligence techniques. He can be contacted at email: jvanandan@gmail.com.