

Improving the Power Quality of Independent An UPQC-Based Hydropower Generation System

P.Saisupriya¹, Arpula. Krishnaiah², Maisakshi .Pavan Kumar³

¹Electrical and Electronics Engineering & KLR College Of Engineering and Technology

²Electrical and Electronics Engineering & KLR College Of Engineering and Technology

³Electrical and Electronics Engineering & KLR College Of Engineering and Technology

Abstract - This research lays forth a new approach to adaptive neuro-fuzzy inference systems (ANFIS) and Ant Lion optimisation (ALO) for standalone hydro power devices. Uneven current and voltage profiles occur in a hydropower generation system when it is fed non-linear loads. The important and sensitive loads are greatly affected by these imbalanced power levels, which last for an extended period of time. However, imbalanced load voltage and currents occur when hydro power producers, more often than not, use squirrel cage induction engines (SCIG), which often provide less voltage than needed. From this point of view, a unified electrical performance controller (UPQC) is used in this study to prevent these undesirable power quality concerns. Topologies that compensate for power quality are essential for achieving it. Voltage sag/swell is compensated for by the series regulator of UPQC, while harmonics of current & reactive power compensation are handled by the shunt controller. In this study, a hybrid ALO-ANFIS controller is used to effectively operate the series controller and shunt regulator of UPQC. As a hybrid smart system, ANFIS uses fuzzy logic to make accurate estimations of the compensation voltage. Optimising the ANFIS tuning settings, the ALO algorithm keeps a constant eye on the system's performance to make sure it's running at peak efficiency. This research examines hydropower production in relation to non-linear loads in order to verify the suggested control framework simulation.

Key Words: Battery, fundamental estimation, harmonics elimination, power quality (PQ), unified power quality conditioner (UPQC).

1.INTRODUCTION

Distributed generation systems (DGSs) which employ renewable energy sources (RESs) are becoming more popular as concerns about climate change, pollution, and fossil fuel depletion mount. The viability of standalone RES systems is significantly affected by regulations and stimulation strategies. These renewable energy sources [1] include a wide variety of renewable energy sources that are not depletable, such as solar, geothermal, biomass, wind, and small hydropower. Customers in remote areas or those without access to the grid may find stand-alone DGSs to be an attractive alternative, especially if connecting to the grid would be costly or time-consuming. Squirrel cages induction generators

(SCIGs) [2] are chosen as practical choices for energy delivery in remote areas and rural communities because of their beneficial characteristics. Diesel engines or renewable energy sources (RES) like wind or micro hydropower are suitable options for powering these generators and meeting the energy demands of these locations. The SCIG produces more torque in response to an increase in the load's power requirement and a quick rise in the rotor frequency. As the flux grows, the core loss of the SCIG increases, which further reduces the system frequency. Also, although the prime mover speed remains constant, changes to the load's active power consumption need adjustments to the system's frequency in order to change the rotor's slip frequency. That is why controlling the SCIG's output voltage and frequency is so important. A shunt power active filter (SHPAF) and an appropriate control strategy are presented in the existing literature as tools for effectively implementing this regulation [3, 4]. By eliminating harmonics and providing reactive power locally, the SHPAF improves current quality at the SCIG terminals while simultaneously increasing the power factor of the SHPAF. Another way to reduce core loss and excitation demand is to generate voltages that are 10%-20% below their rated value.

When the predicted voltages across the load are lower than the magnitude of the produced voltages, the sensitive load stops working. The implementation and discussion of a series-connected power active filter (SEPAF) in [5] and [6] aims to solve this problem. A sliding-mode control (SMC) for the four-leg SEPAF, or dynamic voltage restorer, was introduced by Nalla et al. [5] via the determination of the appropriate sliding coefficient to maximise the sliding existence area. In addition, SEPAF voltage adjustment using bipolar direct ac-dc converters has been covered by Yibo et al. [6]. In order to generate switching pulses for the ac-dc converter (SEPAF), this paper presents an instantaneous reactive electrical power theory, also known as $\alpha\beta$ theory, which utilises the pulse length modulation (PWM) approach. A series transformer is used to incorporate this SEPAF at the generator's terminals. Resolving the voltage quality problem mentioned before is the primary goal of the SEPAF.

2. Proposed System

A DRASOGI-based control is used to operate a standalone DGS in this work. The system consists of a hydro-prime-mover-coupled SCIG with a battery-integrated UPQC. The following are a few of the objectives of this project.

1) In contrast to the systems described in [3] and [4], the SEPAF, and not the SHPAF, regulates the voltage amplitude at the load terminals regardless of the generating voltage. As a result, the system operates at the electrical terminals with a power factor of one. Less magnetising current also means less losses and less need for external stimulation.

2) This study discusses the use of DRASOGI—modified frequency-locked loop (mFLL)—for the extraction of the fundamental signals and the positive sequence of fundamental signals from voltages produced by SCIG. A power factor around unity at the source terminals, together with balanced and harmonic-free currents, is the target.

3) By reducing the impact of imbalanced and nonlinear reactive loads, the total harmonic distortions (THDs) of the produced currents are kept within the parameters laid forth by IEEE Standard 519. To maintain balance sine source currents with minimal distortion and to reduce current harmonics, the SHPAF synthesises and injects suitable compensation currents under balanced or unbalanced linear reactive load situations.

improve the quality of the voltage at the load terminals and the current at the generator terminals. The SCIG-based standalone DGS integrated with the UPQC is shown in Fig. 1 as a block structure. An imbalanced and nonlinear load is primarily powered in this situation by the hydro-prime-mover-driven SCIG. More harmonics are extracted from the source when this load is integrated. The power factor drops and the rms currents of the linked loads rise as a consequence. A UPQC is used to improve the voltage and current quality. In order to do this, it improves the power factor by controlling the amplitude and harmonics of the voltage at the load terminals and keeping the current at the generator terminals balanced and sinusoidal. Two separate VSCs are combined to form a UPQC, as shown in Fig. 1. Both VSCs share a dc bus; one is linked in series (SEPAF) while the other is linked in parallel (SHPAF). When combined, they may improve PQ as a whole.

All of the phases of the SHPAF are coupled at the load side via inductors. To mitigate switching harmonics, a passive RC filter is included at the load point. Coupling transformers and inductors link the SCIG stator's terminals to the SEPAF. Next, a battery is connected to the UPQC's dc bus, and we'll talk about how to size it based on its capacity. In times of limited supply, this battery produces actual electricity; in times of low demand, it stores actual electricity. The values and parameters of the system are detailed in Table II. Attached to the shaft of the SCIG generator is a primary mover, sometimes known as a hydro turbine. Because it is effective at catching energy from flowing water and can be constructed in smaller quantities, the usage of an impulsive variant of the Pelton wheel being investigated. If the value of the gate valve is changeable, then the outflow water rate is constant. It follows that the input power to the turbine remains unchanged after the adjustment of the valve.

The distribution system of the hydropower plant with a UPQC based on ALO-ANFIS is shown in Fig. 1. The use of a UPQC improves power quality and voltage and current profiles of non-linear loads connected to the power system network. Voltage source converters (VSCs) in both series and shunt configurations make up the UPQC. Both the series VSC (SeVSC) and the shunt VSC (ShVSC) work together to reduce the impact of the deformed source voltage and harmonic amplitude, respectively, on the system. In order to keep the DC connection voltage at a level that is steady and ensure that the SeVSC and ShVSC run smoothly, this study presents an ALO-ANFIS technique. An interface inductor and an inductive transformer link the Se VSC to the power network network, while ripple filters link the Sh VSC to the same network.

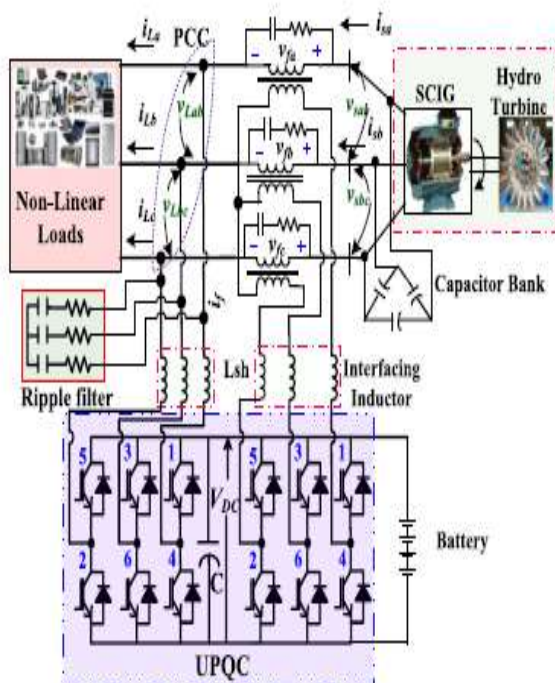


Fig. 1. Schematic diagram of the stand-alone DGS-integrated UPQC system.

Here is an example of a distributed generation system (DGS) that uses a pico-hydro turbine to power a three-phase SCIG, with the battery serving as a secondary source. This standalone DGS has a UPQC built in to

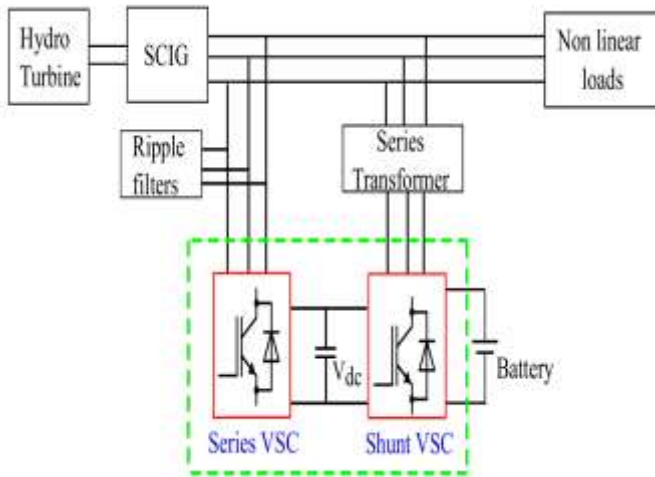


Fig.2 ALO-ANFIS based UPQC for hydro power plant

Control methodology:

With ANFIS, the nonlinearities and uncertainties of UPQC are handled by combining fuzzy logic with neural networks. With proper operation of the VSC converters, it is possible to optimise energy flow and improve grid stability. Typically, an ANFIS will have five levels, and each of those layers will do a different job: The first layer, "fuzzification," works similarly to fuzzy logic control in that it uses membership functions to transform clean input signals (such as voltage error or current) into fuzzy sets.

- **Layer 2 (Rule Base):** The neural network modifies the parameters of the membership function in this layer, which differs from conventional fuzzy logic. This layer reflects the fuzzy rules. In the third layer, called normalisation, the firing intensities of every rule are adjusted such that they add up to 1.
- The fourth layer, known as defuzzification, transforms the fuzzy input into a clear control signal by averaging the rule consequents using the normalised firing strengths.

- Layer 5 (Output): This part of the hierarchy signifies the last output signal that regulates the output voltage by controlling the VSC switching devices (such as transistors). In contrast to conventional fuzzy logic, ANFIS may use training data to fine-tune the functions used for membership in the rule foundation (Layer 2). Past operational circumstances and intended control actions may be included in this training data. As it learns to adjust to new system dynamics and disturbances, the ANFIS improves its control approach in real time. Modelling the ALO control technique allows for optimum tuning of the ANFIS controller and quick convergence. The ALO algorithm receives as input the discrepancy between the target voltage and the measured value. By monitoring system performance in real-time, the ALO algorithm fine-tunes the settings of the ANFIS controller. It is possible that the ant lion's proactive and adaptable pit-trapping behaviour served as inspiration for the creation of a VSC converter PI controller that is more resilient and efficient.

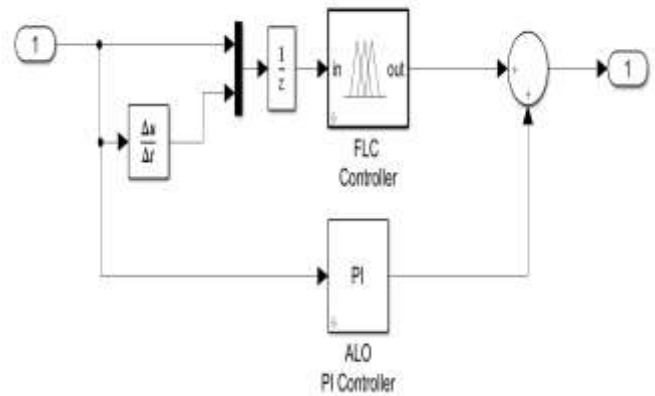
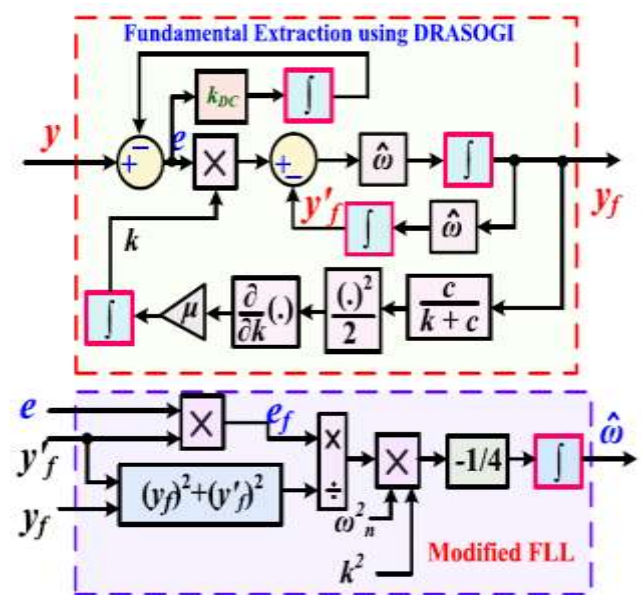
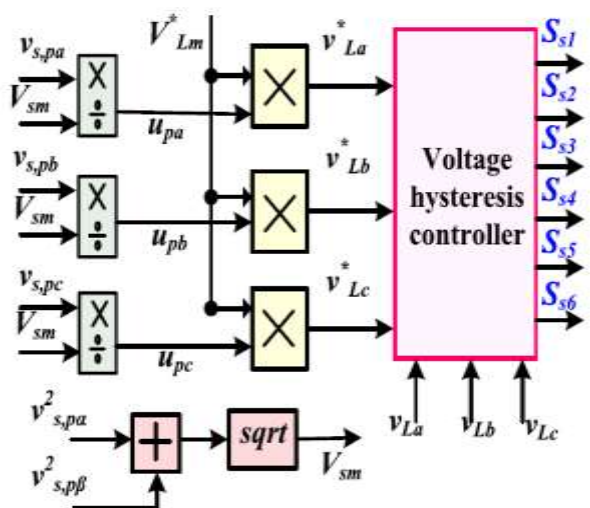


Fig.3 Proposed ALO-ANFIS control scheme



(a)



(b)

Fig. 4. Block representation of the control method of SEPAF. (a) Estimation of fundamental signals using DRASOGImFLL. (b) SEPAF control structure

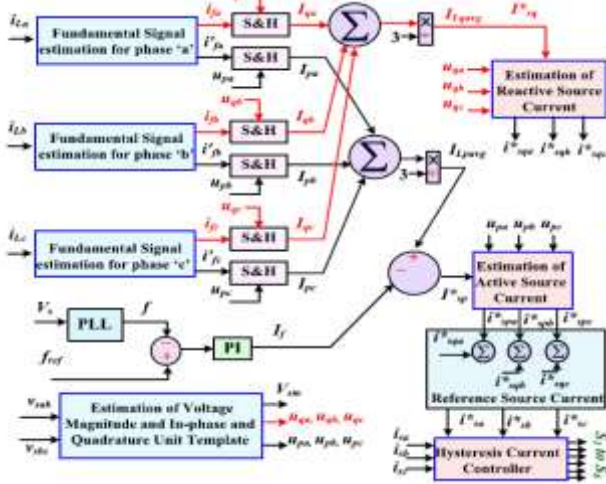


Fig. 5. Block representation for the control technique of SHPAF

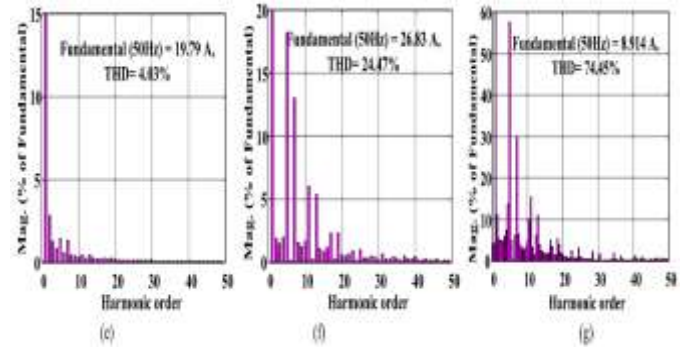


Fig. 6. Simulated performance of the presented DGS for operation in the steady state. (a) v_s , v_f , v_L , i_s , i_L , and i_f . (b) i_{sref} , V_{DC} , P_s , Q_s , PL , QL , and P_{Bat} . (c) THD depiction for v_{Sa} . (d) THD depiction for v_{La} . (e) THD depiction for i_{sa} . (f) THD depiction for i_{La} . (g) THD depiction for i_{fa} .

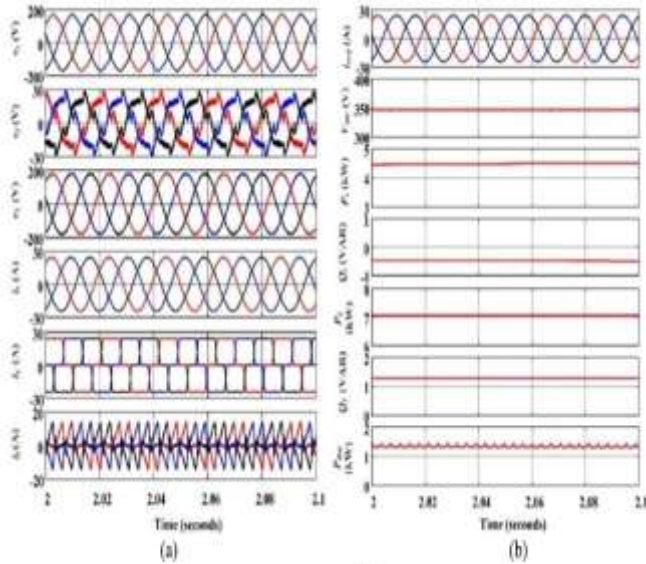


Fig. 7. Simulated performance of the stand-alone DGS for unbalancing of load. (a) v_s , v_f , v_L , i_s , i_L , and i_f . (b) i_{sref} , V_{DC} , P_s , Q_s , PL , QL , and P_{Bat} .

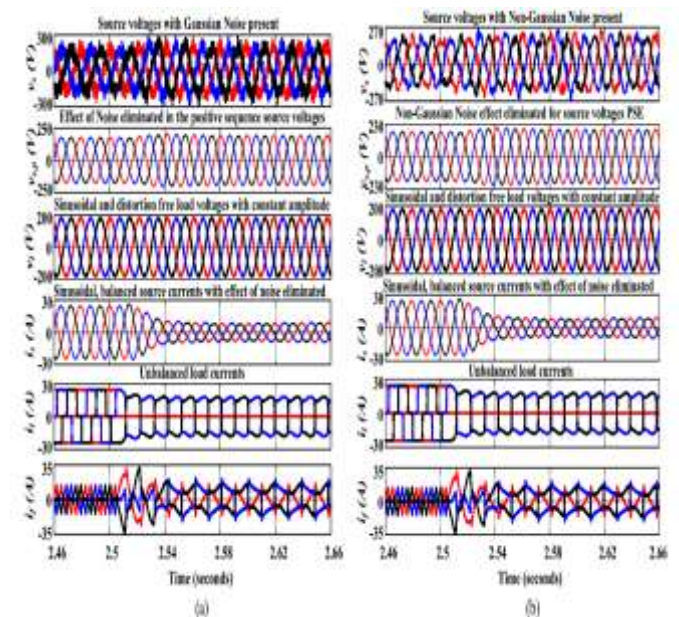
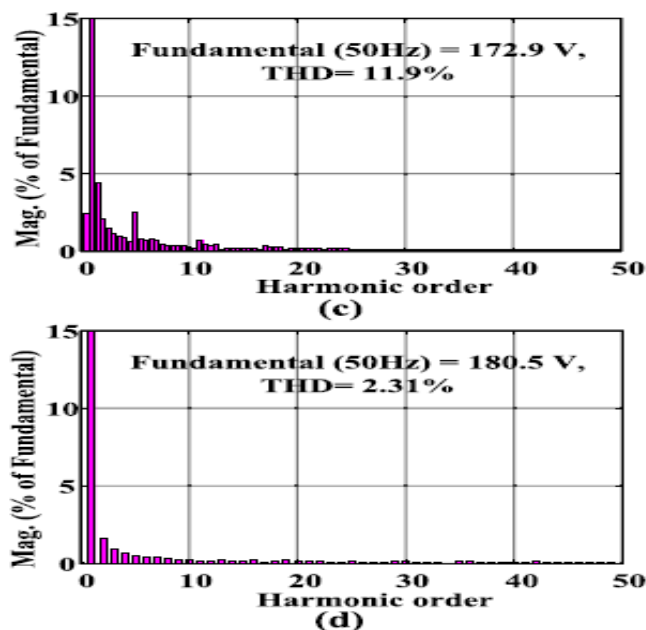


Fig. 8. Effectiveness of the presented DRASOGI technique for noise elimination in the measurement of voltages. (a) Gaussian noise. (b) Non- Gaussian noise.

3. CONCLUSIONS

In this study, a new ALO-ANFIS method is used to improve the electrical performance of independent hydropower systems, which is essential for the efficient running of a UPQC. Hydropower producing systems encounter voltage and current imbalances when irregular loads are linked to them. In order to correct the distorted voltages, the SeVSC of the UPQC injects the required voltage in the power supply network. To maintain peak performance, the ALO algorithm keeps tabs on the system and tweaks the ANFIS settings as needed. Then the ShVSC reduces the current's harmonics. Moving forward, the overall quality of the electricity is enhanced. The simulation results show that the UPQC based on ALO-ANFIS successfully controls the DC-link voltage and keeps the load current and voltage constant. Sustainable and dependable power production is within reach with the help of the suggested control method.

REFERENCES

- [1] L. Xiu, J. He, M. Li, and H. Song, "Fast and stable detection scheme of point of common coupling voltage for renewable energy systems tied to distortion grids," *IEEE Trans. Ind. Informat.*, vol. 19, no. 7, pp. 7876–7884, Jul. 2023.
- [2] M. Bubalo, M. Bašić, D. Vukadinović, and I. Grgić, "Wind energy conversion system using advanced speed control and model-based loss minimization," *IEEE Trans. Energy Convers.*, vol. 38, no. 2, pp. 869–878, Jun. 2023.
- [3] S. Kumar, D. Jaraniya, and B. Singh, "Microgrid integrated charging infrastructure with PV array and seamless grid-hydro generator synchronization for rural and hilly areas," in *Proc. IEEE Int. Power Renewable Energy Conf.*, 2021, pp. 1–6.
- [4] M. K. Behera and L. C. Saikia, "A seamless control of grid-connected PV system for alleviating PV penetration in rural grid using supercapacitor accompanying with DSTATCOM and improved CTF control," *IEEE Trans. Ind. Appl.*, vol. 60, no. 2, pp. 3588–3602, Mar./Apr. 2024.
- [5] L. Nalla, M. K. Mishra, and A. Ghosh, "Sliding mode control of a four-leg dynamic voltage restorer in a natural reference frame," *IEEE J. Emerg. Sel. Topics Ind. Electron.*, vol. 4, no. 3, pp. 919–927, Jul. 2023.
- [6] W. Yibo et al., "A three phase voltage restorer based on bipolar direct AC/AC converters," *IEEE Access*, vol. 11, pp. 74112–74120, 2023.
- [7] A. Chakrabarti, N. Sharma, P. R. Kasari, B. Das, and S. K. Biswas, "A fault tolerant control scheme of grid connected VSI for balanced power injection," *IEEE*

Trans. Ind. Informat., vol. 20, no. 2, pp. 1997–2006, Feb. 2024.



P. Saisupriya, Received B.Tech and from JNTU Hyderabad, pursuing M.Tech in Electrical Power Systems. In KLR College Of Engineering and Technology



Arpula Krishnaiah Received the B.Tech and M.Tech from JNTU Hyderabad, working as Assistant professor and Head of the Electrical and Electronics engineering department in KLR Engineering College, he has Teaching in 17 years of experience in various institutions, published in 11 International Publications.



Maisakshi Pavan Kumar, Received the B.Tech and M.Tech from JNTU Hyderabad, He is currently working as an Assistant Professor in the Department of Electrical and Electronics Engineering at KLR College of Engineering and Technology, where he has been serving for the past five years. He has published in 11 International Publications.