# Investigation and Analysis of Real Time Transformer Oil Images at different Temperatures using Gabor Texture Features

**Maheshan C M[1], H Prasanna Kumar[2]**

[1]*Research scholar, Department of Electrical Engineering, VTU-RRC Mysuru.*
*(Affiliated to VTU, Belagavi). Karnataka State, India*
*And*
*Associate Professor, Department of Electrical Engineering,*
*University Visvesvaraya College of Engineering, Bangalore University city campus,*
*K. R. Circle, Bengaluru-560 001.*
*maheshan.cm@gmail.com*

[2] *Professor, Department of Electrical Engineering,*
*University Visvesvaraya College of Engineering,*
*Bangalore University city campus, K. R. Circle, Bengaluru-560 001.*
*uvcehpk@gmail.com*

## Abstract.

A new technique in the investigation and analysis of real time transformer oil at different temperatures using Gabor image texture features is proposed in this paper. A numerical evaluation performed using Gabor filtering technique to characterize its textural properties of transformer oil test images. Transformer oil characteristics define the performance of power transferring equipment. An experiment conducted to capture test images at different temperatures. These images are enhanced using linear and nonlinear noise eliminating filters. The statistical features extracted for unused or normal as well as enhanced transformer oil image at different temperatures. The results of improved complex shock filtered images indicate the better recognition of significant textures of the test images since they are nearly equivalent to normal oil test images. The experimental results of texture features extracted from the Gabor filter realize a modern method in the analysis of real time transformer oil images operating under different temperatures.

**Keywords**: Transformer oil, image processing, Gabor filter, OSF, ICSF.

## 1. INTRODUCTION

Texture feature extraction is a process of evaluating as well as describing the feature characteristics of an image which numerically describes that texture image properties. Texture features are very helpful and have been used practically in image processing domain. Besides, the texture features can also differentiate between objects with similar colours and shapes [1-2]. Gabor filter is an efficient method to extract texture features from the images. Basically, Gabor filters are collection of wavelets. Each wavelet of the filter captures energy at a specific frequency along with a specific direction. Expanding a signal through this filter presents a localized frequency description, thus capturing local features of the signal. Thus the texture features can be extracted through this group of energy distributions [3-5].

Transformer is an important device which connects generation, transmission and distribution electrical power system. Its performance depends on the cooling as well as insulation efficiency of the working device. Transformer oil provides the insulation along with cooling for the internal parts of the transformer [6-7]. The characteristic electrical, chemical, thermal as well as physical properties of the transformer oil changes with the different operating temperatures in addition to loading conditions [8-10]. Digital image processing methods are used as latest technology to monitor the performance of the transformer instead of time consuming classical methods [11]. This paper proposes an image analysis technique to identify the Gabor texture features of a test image. Transformer oil images acquired through digital camera in specific combined with noise signal due to improper lighting levels in addition to as well movement of oil. The image preprocessing filters used to eliminate the noise in the test images.

In this paper, the weiner filter, Non-Local Means (NLM) filter, Original Shock Filter (OSF), Complex Shock Filter (CSF) and Improved Complex Shock Filters (ICSF) are used for image enhancement of transformer oil images at different temperatures [12-14]. The objective of this paper is to investigate the Gabor texture features of real time transformer oil images at different temperatures. An experiment was conducted to acquire the transformer oil images using digital camera at $30^0$C, $60^0$C, $90^0$C and the maximum temperature limited to $120^0$C [15]. The betterment of test images are achieved using image enhancement filters. Gabor texture features extracted from the original image as well as from the filtered transformer oil images.

## 2. MATERIALS AND METHODS

This section explains the data collection, method adopted to extract textures of test images. In this paper the test images are real time transformer oil images.

### *2.1. Data Collection*

An experiment is conducted on transformer oil to capture the transformer oil images at different temperatures. In this paper the transformer oil images are captured at $30^0$C, $60^0$C, $90^0$C as well as $120^0$C temperatures. These images are enhanced with difference noise eliminating filters. The original images captured as well as filter image considered as test images. Typical test images are presented in figure 1[15].

Figure 1 Typical transformer oil test images captured at different temperatures [15]

### *2.2. Method*

Gabor filter introduced by Gabor [16] and it is applied to extract features by analyzing the frequency domain of the image. Gabor filter is basically a Gaussian function modulated by complex sinusoidal of frequency and orientation. It has the ability to perform both in spatial and frequency domain and can be in any number of dimensions. These filters are more desirable since they provide the finer distinctions of the different textures [17-19]. Figure 2 demonstrates Gabor image texture feature extraction methodology of real time transformer oil images. The real impulse response of two dimensional Gabor filter given as in Equation (1).

$$h(x,y) = \frac{1}{2\pi\sigma_x\sigma_y} \equiv e^{-\frac{x^2}{2\sigma_x^2}-\frac{y^2}{2\sigma_y^2}} cos(2\pi\, u_0 x) \quad (1)$$

Where $u_0$ is radial frequency of Gabor function, $\sigma_x$ and $\sigma_y$ are constants of Gaussian envelope along x and y axis respectively. The Gabor wavelets or filters are generated to cover the two dimensional image planes with arbitrary orientations can be obtained as in equation (2) as

$$x' = x\cos\theta + y\sin\theta \;\text{ And }\; y' = -x\sin\theta + y\cos\theta \quad (2)$$

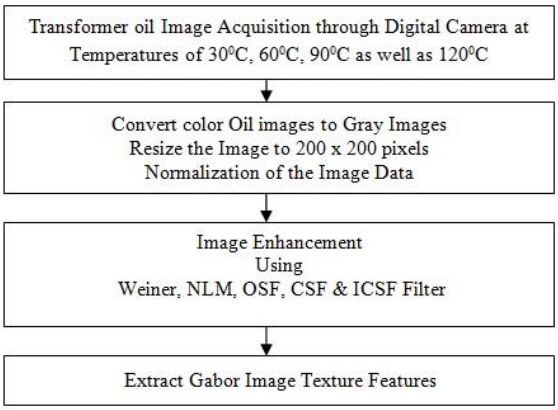


Figure 2. Gabor Image Texture Feature Extraction Methodology

## 3. RESULTS AND DISCUSSION

In this section, the numerical and graphical results of Gabor texture features of transformer oil test images are presented. The acquired transformer oil images at different temperatures are converted into gray images. The gray scale images are resized to 200 x 200 pixels. All images are enhanced through wiener, NLM, OSF, CSF and ICSF. The 25 Gabor image texture features were extracted from transformer oil (normal or unused / with metal nails / with metal nails and conductor coil) $30^0$C, $60^0$C, $90^0$C and $120^0$C images. In this paper, only $30^0$C Gabor feature magnitude values listed in table 1 to table 3, but figure 3, 4 and 5 shows the Gabor texture features for all temperatures using Column plots.

Table 1 Gabor Texture features of Unused/Normal Transformer oil at $30^0$ C

| Sl. No. | Gabor Texture features | $30^0$ C N | $30^0$ C N- Weiner filter | $30^0$C N- NLM filter | $30^0$C N- OSF filter | $30^0$C N- CSF filter | $30^0$C N- ICSF filter |
|---|---|---|---|---|---|---|---|
| 1 | Gabor-1 | 459.16 | 459.13 | 460.97 | 459.16 | 459.20 | 459.35 |
| 2 | Gabor-2 | 3.89 | 3.86 | 3.90 | 3.99 | 3.89 | 3.89 |
| 3 | Gabor-3 | 9.41 | 9.35 | 9.37 | 9.46 | 9.37 | 9.36 |
| 4 | Gabor-4 | 27.61 | 27.42 | 26.99 | 27.67 | 27.47 | 27.26 |
| 5 | Gabor-5 | 352.10 | 352.16 | 353.46 | 352.10 | 352.12 | 352.22 |
| 6 | Gabor-6 | 328.71 | 328.68 | 330.00 | 328.71 | 328.74 | 328.85 |
| 7 | Gabor-7 | 29.96 | 29.95 | 30.08 | 29.97 | 29.97 | 29.98 |
| 8 | Gabor-8 | 8.63 | 8.53 | 8.54 | 8.70 | 8.58 | 8.56 |
| 9 | Gabor-9 | 35.37 | 35.26 | 35.10 | 35.40 | 35.30 | 35.22 |
| 10 | Gabor-10 | 226.54 | 226.62 | 227.39 | 226.55 | 226.55 | 226.61 |
| 11 | Gabor-11 | 378.05 | 378.01 | 379.53 | 378.04 | 378.08 | 378.20 |
| 12 | Gabor-12 | 12.72 | 12.69 | 12.77 | 12.73 | 12.72 | 12.73 |
| 13 | Gabor-13 | 9.28 | 9.06 | 8.99 | 9.41 | 9.16 | 9.11 |
| 14 | Gabor-14 | 26.41 | 25.92 | 24.57 | 26.59 | 26.12 | 25.83 |
| 15 | Gabor-15 | 304.15 | 304.22 | 305.31 | 304.14 | 304.17 | 304.27 |
| 16 | Gabor-16 | 378.05 | 378.01 | 379.53 | 378.04 | 378.08 | 378.20 |
| 17 | Gabor-17 | 12.72 | 12.69 | 12.77 | 12.73 | 12.72 | 12.73 |
| 18 | Gabor-18 | 9.27 | 9.06 | 8.99 | 9.40 | 9.16 | 9.11 |
| 19 | Gabor-19 | 26.38 | 25.88 | 24.58 | 26.54 | 26.09 | 25.80 |
| 20 | Gabor-20 | 304.29 | 304.36 | 305.46 | 304.28 | 304.31 | 304.41 |
| 21 | Gabor-21 | 328.71 | 328.68 | 330.00 | 328.71 | 328.74 | 328.85 |
| 22 | Gabor-22 | 29.96 | 29.95 | 30.08 | 29.97 | 29.97 | 29.97 |
| 23 | Gabor-23 | 8.63 | 8.53 | 8.54 | 8.69 | 8.57 | 8.55 |
| 24 | Gabor-24 | 35.33 | 35.22 | 35.08 | 35.36 | 35.27 | 35.19 |
| 25 | Gabor-25 | 226.70 | 226.78 | 227.55 | 226.70 | 226.71 | 226.77 |

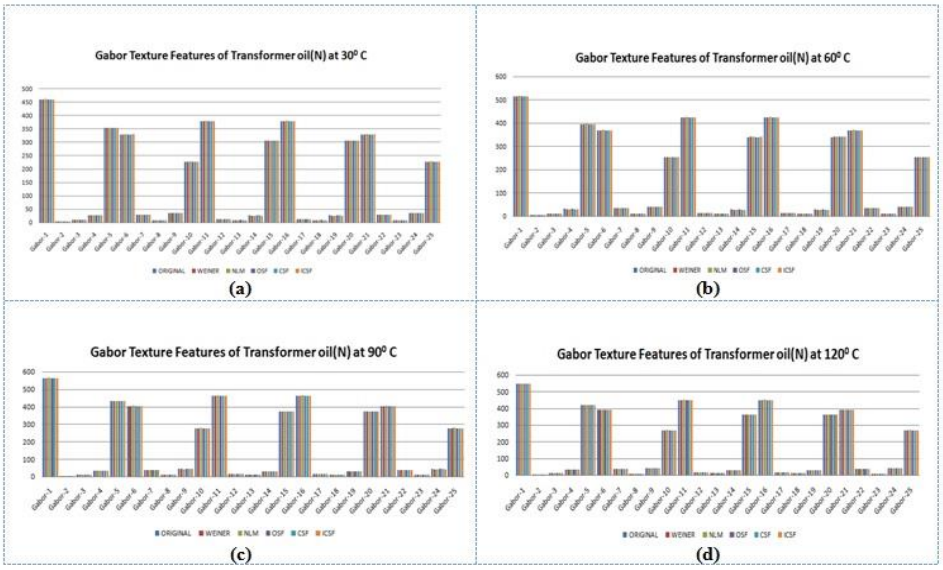


Figure 3 Column plot of Gabor Texture Features of Unused/Normal Transformer oil At (a) $30^0$ C (b) $60^0$ C (c) $90^0$ C (d) $120^0$

Table 2 Gabor Texture features of Transformer oil with metal nails at $30^0$ C

| Sl. No. | Gabor Texture features | $30^0$ C WM | $30^0$ C WM-Weiner filter | $30^0$C WM-NLM filter | $30^0$C WM-OSF filter | $30^0$C WM-CSF filter | $30^0$C WM-ICSF filter |
|---|---|---|---|---|---|---|---|
| 1 | Gabor-1 | 416.73 | 416.68 | 418.35 | 416.74 | 416.75 | 416.83 |
| 2 | Gabor-2 | 3.50 | 3.47 | 3.51 | 3.60 | 3.50 | 3.50 |
| 3 | Gabor-3 | 8.45 | 8.39 | 8.42 | 8.50 | 8.42 | 8.40 |
| 4 | Gabor-4 | 24.72 | 24.55 | 24.11 | 24.80 | 24.59 | 24.39 |
| 5 | Gabor-5 | 318.82 | 318.86 | 319.98 | 318.83 | 318.82 | 318.87 |
| 6 | Gabor-6 | 298.32 | 298.28 | 299.48 | 298.33 | 298.33 | 298.39 |
| 7 | Gabor-7 | 27.18 | 27.17 | 27.29 | 27.19 | 27.18 | 27.19 |
| 8 | Gabor-8 | 7.75 | 7.68 | 7.70 | 7.81 | 7.71 | 7.70 |
| 9 | Gabor-9 | 31.82 | 31.72 | 31.62 | 31.85 | 31.76 | 31.70 |
| 10 | Gabor-10 | 204.96 | 205.03 | 205.66 | 204.98 | 204.96 | 204.98 |
| 11 | Gabor-11 | 343.10 | 343.06 | 344.43 | 343.11 | 343.11 | 343.18 |
| 12 | Gabor-12 | 11.54 | 11.52 | 11.59 | 11.55 | 11.54 | 11.55 |
| 13 | Gabor-13 | 8.31 | 8.19 | 8.16 | 8.39 | 8.24 | 8.22 |
| 14 | Gabor-14 | 24.40 | 23.90 | 22.46 | 24.50 | 24.07 | 23.74 |
| 15 | Gabor-15 | 275.85 | 275.91 | 276.88 | 275.86 | 275.86 | 275.90 |
| 16 | Gabor-16 | 343.10 | 343.06 | 344.43 | 343.11 | 343.11 | 343.18 |
| 17 | Gabor-17 | 11.54 | 11.52 | 11.59 | 11.55 | 11.54 | 11.55 |
| 18 | Gabor-18 | 8.31 | 8.19 | 8.16 | 8.39 | 8.24 | 8.22 |
| 19 | Gabor-19 | 24.38 | 23.88 | 22.44 | 24.47 | 24.06 | 23.72 |
| 20 | Gabor-20 | 275.98 | 276.04 | 277.00 | 275.98 | 275.98 | 276.03 |
| 21 | Gabor-21 | 298.32 | 298.28 | 299.48 | 298.33 | 298.33 | 298.39 |
| 22 | Gabor-22 | 27.18 | 27.17 | 27.29 | 27.19 | 27.18 | 27.19 |
| 23 | Gabor-23 | 7.75 | 7.68 | 7.70 | 7.80 | 7.71 | 7.70 |
| 24 | Gabor-24 | 31.81 | 31.71 | 31.61 | 31.84 | 31.75 | 31.69 |
| 25 | Gabor-25 | 205.11 | 205.17 | 205.80 | 205.11 | 205.10 | 205.12 |

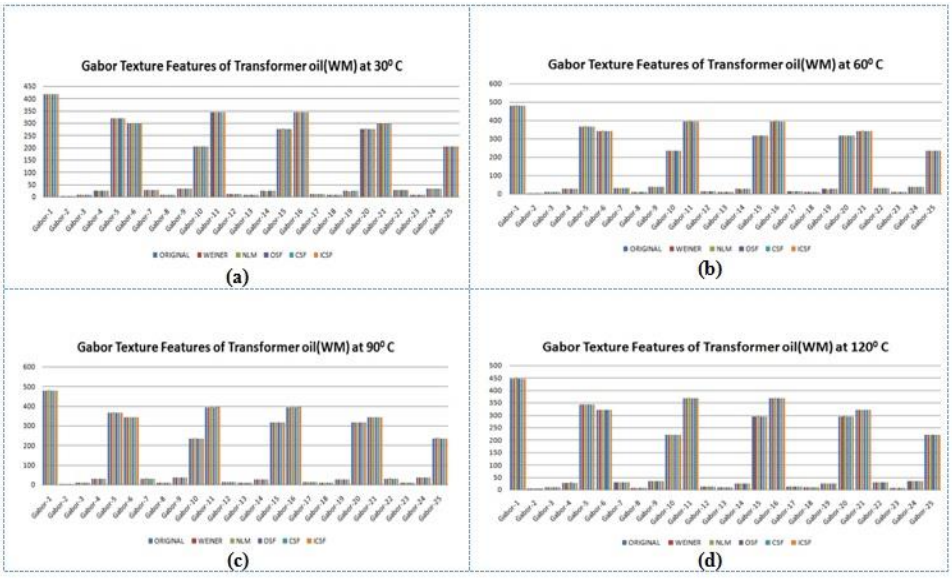


Figure 4 Column plot of Gabor Texture Features of Transformer oil with metal nails At (a) $30^0$ C (b) $60^0$ C (c) $90^0$ C (d) $120^0$ C

Table 3 Gabor Texture features of Transformer oil with metal nails and Conductor coil at $30^0$ C

| Sl. No. | Gabor Texture features | $30^0$ C WMC | $30^0$ C WMC-Weiner filter | $30^0$C WMC-NLM filter | $30^0$C WMC-OSF filter | $30^0$C WMC-CSF filter | $30^0$C WMC-ICSF filter |
|---|---|---|---|---|---|---|---|
| 1 | Gabor-1 | 579.31 | 579.28 | 581.59 | 579.33 | 579.35 | 579.47 |
| 2 | Gabor-2 | 4.88 | 4.84 | 4.89 | 4.95 | 4.87 | 4.87 |
| 3 | Gabor-3 | 11.83 | 11.72 | 11.72 | 11.89 | 11.76 | 11.72 |
| 4 | Gabor-4 | 34.00 | 33.78 | 33.43 | 34.06 | 33.84 | 33.66 |
| 5 | Gabor-5 | 443.59 | 443.65 | 445.30 | 443.61 | 443.62 | 443.69 |
| 6 | Gabor-6 | 414.71 | 414.68 | 416.34 | 414.72 | 414.73 | 414.82 |
| 7 | Gabor-7 | 37.77 | 37.76 | 37.92 | 37.78 | 37.77 | 37.78 |
| 8 | Gabor-8 | 10.74 | 10.63 | 10.65 | 10.81 | 10.68 | 10.65 |
| 9 | Gabor-9 | 43.81 | 43.72 | 43.72 | 43.84 | 43.76 | 43.71 |
| 10 | Gabor-10 | 284.16 | 284.24 | 285.22 | 284.17 | 284.17 | 284.20 |
| 11 | Gabor-11 | 476.97 | 476.94 | 478.84 | 476.99 | 477.00 | 477.10 |
| 12 | Gabor-12 | 15.98 | 15.95 | 16.05 | 15.99 | 15.98 | 15.99 |
| 13 | Gabor-13 | 11.18 | 11.06 | 11.08 | 11.26 | 11.12 | 11.08 |
| 14 | Gabor-14 | 30.28 | 30.00 | 29.51 | 30.38 | 30.10 | 29.90 |
| 15 | Gabor-15 | 381.46 | 381.54 | 382.91 | 381.48 | 381.48 | 381.55 |
| 16 | Gabor-16 | 476.97 | 476.94 | 478.84 | 476.99 | 477.00 | 477.10 |
| 17 | Gabor-17 | 15.98 | 15.95 | 16.05 | 15.99 | 15.98 | 15.99 |
| 18 | Gabor-18 | 11.18 | 11.06 | 11.08 | 11.26 | 11.12 | 11.08 |
| 19 | Gabor-19 | 30.22 | 29.95 | 29.50 | 30.31 | 30.05 | 29.84 |
| 20 | Gabor-20 | 381.08 | 381.15 | 382.53 | 381.10 | 381.10 | 381.17 |
| 21 | Gabor-21 | 414.71 | 414.68 | 416.34 | 414.72 | 414.73 | 414.82 |
| 22 | Gabor-22 | 37.77 | 37.76 | 37.92 | 37.78 | 37.77 | 37.78 |
| 23 | Gabor-23 | 10.74 | 10.63 | 10.65 | 10.80 | 10.68 | 10.64 |
| 24 | Gabor-24 | 43.78 | 43.70 | 43.72 | 43.81 | 43.73 | 43.69 |
| 25 | Gabor-25 | 283.60 | 283.67 | 284.65 | 283.61 | 283.60 | 283.64 |

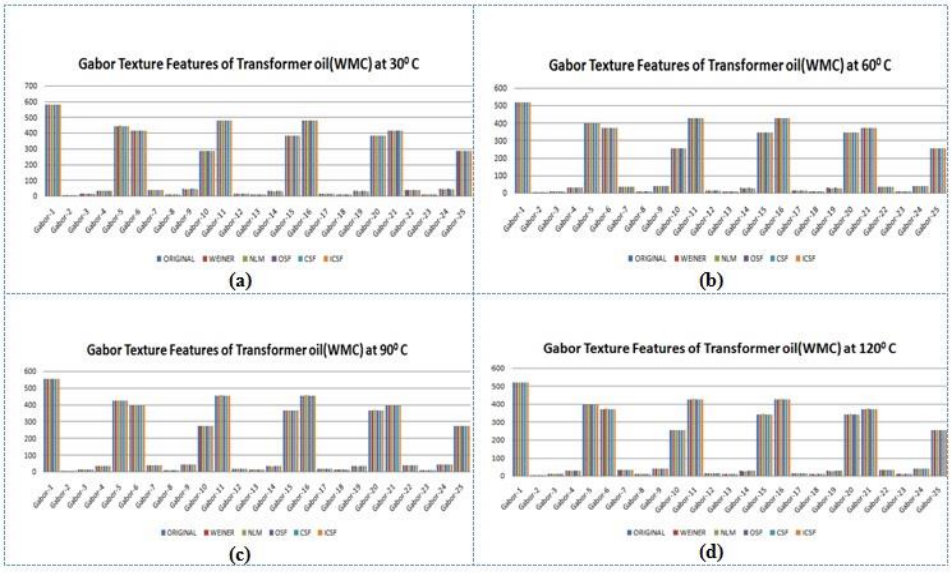


Figure 5 Column plot of Gabor Texture Features of Transformer oil with metal -nails and conductor coils at (a) $30^0$ C (b) $60^0$ C (c) $90^0$ C (d) $120^0$

Gabor texture features explore the spatial and frequency values in terms of magnitude. From tables and figures, it is observed that higher variations of the magnitude values with special frequency relation of Gabor image texture features. Gabor feature envelope controls the frequency magnitude of the image texture feature. For a very large feature envelope approaches a high magnitude, and for a very small feature envelope, the magnitude height stretches across the image.

## 4. CONCLUSIONS

This paper presents an effective method in the investigation and analysis of Gabor texture image features for real time transformer oil images acquired at $30^0$C, $60^0$C, $90^0$C as well as $120^0$C temperatures. This paper demonstrates numerical results of transformer oil for normal as well as enhanced images. Twenty five Gabor image texture features were evaluated for all the test images. The results indicate that the features evaluated were substantially identifying texture features. The ICSF filter texture features provide best results among all filters. This paper concludes that the Gabor texture features extracted through ICSF is best for further analysis of images. The extension of this study can be used for online or offline condition monitoring of transformer oil.

## 5. REFERENCES


[1] D. Zhang, M. M. Islam, G. Lu, and I. J. Sumana, "*Rotation Invariant Curvelet Features for Region Based Image Retrieval"*, International Journal Computer Vision, Vol. 98(2), 2012. pp. 187-201. DOI:10.1007/s11263-011-0503-6

[2] A. Humeau-Heurtier, "*Texture Feature Extraction Methods: A Survey*", IEEE Access, Vol. 7, 2019. pp. 8975-9000. DOI: 10.1109/ACCESS.2018.2890743.

[3] Ajay Kumar and Grantham K. H. Pang., "Defect Detection in Textured Materials Using Gabor Filters", IEEE Transactions on Industry Applications, Vol. 38, 2002. pp. 425-439.

[4] J. Kamarainen, "*Gabor features in image analysis*", 3rd International Conference on Image Processing Theory, Tools and Applications (IPTA), 2012. pp. 13-14. DOI: 10.1109/IPTA.2012.6469502.

[5] Erwin et al., "*The Enhancement of Fingerprint Images using Gabor Filter*", ICONISCSE. IOP Publishing. IOP Conf. Series: Journal of Physics: Conf. Series 1196. 2019. pp. 1-6. DOI:10.1088/1742-6596/1196/1/012045.

[6] Waldemar Ziomek, “Transformer Electrical Insulation”, Editorial, IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 19(6), 2012. pp.1841-42.

[7] Liao, R.J. Hao, J. Chen and G. Yang, “*Quantitative analysis of insulation condition of oil-paper insulation based on frequency domain spectroscopy*”, IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 22(1), 2015. pp. 322-334. DOI:10.1109/TDEI.2012.6215085.

[8] Suwarno and Pasaribu RA., “*Thermal aging of mineral oil-paper composite insulation for high voltage transformer*”, Int J Electr Eng Inf., Vol. 8(4), 2016. pp. 820–835. DOI: 10.15676/ijeei.2016.8.4.9.

[9] R. Siva Sai, J. Rafi, S. Farook, NMG. Kumar, M. Parthasarathy and Ashok B. R., “*Degradation studies of electrical, physical and chemical properties of aged transformer oil”,* First International Conference on Advances in Physical Sciences and Materials. J. Phys.: Conf. Ser. 1706 012056. 2020. DOI:10.1088/1742-6596/1706/1/012056.

[10] Akshatha S Raj and C M Maheshan, “*Artificial bee colony algorithm based interpretation of dissolved gas analysis*”, 4th International Conference on Electrical, Electronics, Communication, Computer Technologies and Optimization Techniques (ICEECCOT), 2019. pp. 106 -110.

[11] C M Maheshan and Prasanna Kumar H, *“A Review of image Processing Applications in Fault Detection of Transformer Oil”,* International Journal of Research in Advent Technology. ICTTSTM, 2018. pp. 433-437.

[12] C M Maheshan and H Prasanna Kumar, “*Image enhancement of Transformer oil images using improved complex shock filter*” IIETA Instrumentation Mesure Metrologie, Vol. 18, issue 4, 2019. pp. 407-412.

[13] C M Maheshan and H Prasanna Kumar, “*Investigation and analysis of real time transformer oil Images using haralick texture features*”, Third International Conference on Multimedia Processing, Communication & Information Technology (MPCIT), 2020. pp. 45-50. DOI: 10.1109/MPCIT51588.2020.9350502.

[14] C M Maheshan and H Prasanna Kumar, “*Intensity-Based Feature Extraction of Real-Time Transformer Oil Images*”, Book chapter in Advances in VLSI, Signal Processing, Power Electronics, IoT, Communication and Embedded Systems, 2021. pp. 379 -396. DOI: 10.1007/978-981-16-0443-0_31.

[15] C M Maheshan and H Prasanna Kumar, “*Performance of image pre-processing filters for noise removal in transformer oil images at different temperatures*”, Research article. SN applied sciences, A Springer Nature Journal. 2:67, 2020.

[16] D. Gabor, “*Theory of Communication. Journal of the Institution of Electrical Engineers*”, Vol. 93(26), 1946. pp. 429-441.

[17] Tadic V, Kiraly Z, Odry P,Trpovski Z and Loncar-Turukalo T, "*Comparison of Gabor Filter Bank and Fuzzified Gabor Filter for License Plate Detection*", Acta Polytech., Hung., Vol.17, 2020; pp. 61–81.

[18] Luan S, Chen C, Zhang B, Han J and Liu J., "*Gabor Convolutional Networks*", IEEE Trans. Image Processing, Vol. 27, 2018. pp. 4357–4366.

[19] Allagwail S, Gedik O.S and Rahebi J, "*Face Recognition with Symmetrical Face Training Samples Based on Local Binary Patterns and the Gabor Filter*", Symmetry, 11, 2019. DOI:10.3390/sym11020157

## Biographies

**Maheshan C M** received the BE and ME from Bangalore University in 1999 and 2003 respectively. He is pursuing his Ph.D. in Electrical Engineering from VTU, Belagavi. He is currently working as an Associate Professor at the Department of Electrical Engineering, UVCE, K.R.Circle, Bangalore University, Bengaluru-01. His research areas include Power systems engineering, Image Processing, and Control systems.

**Dr. H. Prasanna Kumar** received the BE from Karnataka University in 1997, M. Tech from Visvesvaraya Technological University (VTU) in 2005 and received his Ph.D. during 2015 at Anna University, Chennai. He is currently working as Professor in the Department of Electrical Engineering, University Visvesvaraya College Engineering (UVCE), Bangalore University, K.R. Circle, Bengaluru-01. His research interests cover Biomedical Image processing, Instrumentation and Process Control.