DR. A. D. SHINDE COLLEGE OF ENGINEERING

DinkarraoK. ShindeSmarakTrust's

Dr. A.D. Shinde College of Engineering

Guddai, Bhadgaon, Tal: - Gadhinglaj, Dist: -Kolhapur

3.3.2 Number of books and chapters in edited volumes/books published and papers published in National/International conference

Sr.No	Name of Published Book	Name of Authors	ISBN Number
1	Theory and Applications of Engineering Research Vol.5	Dr. Dinkar V. Ghevade	Print ISBN: 978-81-970064-8-7
2	Investigation of Strength Variation in Composite Material with MWCNT Dispersion in Bio-Based Epoxy	Dr . Dinkar V. Ghevade , Prof . Kishor S. Joshi	-
3	Strength Variation in Composite Material with MWCNT Dispersion in Bio-Based Epoxy	Dr . Dinkar V. Ghevade , Prof . Kishor S. Joshi	-
4	Dynamic Power Factor Correction using FC TCR – A Case Study of Academic Campus Distribution Network	Dr . VireshKumar Mathad	979-8-3503-6456-9 -
5	Role of renewable energy in sustainable development	Prof. Kishor S. Joshi , Dr. Sachin A. Mehta	-

Dr.A.D.Shinde College of Engineering Bhadgaon • Tal.Gadhinglaj •

Certificate No: PUB. 2023/BP/7132E

Certificate of Publication

Title: Energy Savings through Retrofitting Waste Heat Recovery System on Bulk Milk Cooler

Authored by:

S. M. Pise, D. V. Ghewade, S. N. Sapali, P. S. Pise

Published in the International Book

Theory and Applications of Engineering Research Vol. 5

Print ISBN: 978-81-970064-8-7
E-ISBN: 978-81-970064-6-3
DOI: https://doi.org/10.9734/bpi/taer/v5/7132E

B P INTERNATIONAL India UK

Dr. M. Basu
Chief Managing Editor

B P International

India: B P International, Guest House Road, Street no - 1/6, Hooghly, West Bengal, India (Reg. Address), Diamond Heritage Building, 16, Strand Road, Kolkata, 700001 West Bengal, India (Corporate Address), Tele: +91 7439016438 | +91 9748770553 | WhatsApp: +91 7439016438
UK: B P International, 27 Old Gloucester Street London WC1N 3AX, UK, Fax: +44 20-3031-1429

Dr. A. D. Shinde College of Engineering, Bhadgaon • Tal. Gadhinglaj •

Investigation of Strength Variation in Composite Material with MWCNT Dispersion in Bio-Based Epoxy

Kishor S. Joshi[1,2], Pavan Hiremath[1], Dinkar V. Ghewade[2], Shivashankarayya Hiremath[3], Vishwanatha H. M[1]

[1]Department of Mechanical and Industrial Engineering, Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal, Karnataka, India, 576104
[2]Department of Mechanical Engineering, Dr. A.D. Shinde College of Engineering, Bhadgaon, Maharashtra, India, 416502
[3]Department of Mechatronics, Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal, Karnataka, India, 576104

Abstract. Sustainable technology is essential in the current era of the industrial revolution, where environmental impact and resource efficiency are critical concerns. Natural fibers, which are recyclable, reusable, and possess high strength, offer a promising solution for various industrial and automotive applications. In this study, natural fibers extracted from sisal plants were investigated for their tensile performance when reinforced with multi-walled carbon nanotubes (MWCNTs) and combined with a bio-based epoxy resin, a naturally sourced matrix material. The hybrid composite, consisting of sisal fibers and MWCNTs, was prepared with varying concentrations of filler content using the hand layup method. The composite samples were then cut according to American Society for Testing and Materials (ASTM) standards and subjected to tensile testing. The results showed a significant improvement in the tensile properties of the natural fiber composite when filled with MWCNTs.
Additionally, the comparison between regular epoxy and bio-based epoxy matrices revealed that the performance of the bio-based epoxy was nearly on par with the regular epoxy. These findings highlight that bio-based epoxy combined with hybrid filler materials, such as MWCNTs and natural fibers, significantly contribute to the development of sustainable materials. This approach not only enhances material properties but also aligns with sustainability goals by utilizing renewable resources and reducing environmental impact.

Keywords: *Sustainable material, Natural fiber, MWCNT, Bio-based epoxy, Tensile properties.*

1. Introduction

For millennia, people have extensively employed composites in various applications. The ancient Egyptians and Iraqis pioneered the creation of composites around 2180 to 3400 B.C., crafting plywood in their distinctive style by joining strips of wood. As their civilizations thrived, they integrated fibers into their building materials such as mud, ceramics, bricks, and wild crafts, enhancing the strength and durability of their structures. This tradition of innovation persisted, culminating in the development of highly effective composite materials around 1200 A.D (Drira, 2019). Where in this study, Natural fiber which is extracted from the leaf is used i.e. sisal fiber is used with this epoxy and cashew nutshell liquid-based bio-based epoxy and multiwalled carbon nanotubes are used. As per the reviewing different papers sisal fiber is a good alternative and has good mechanical properties like tensile and flexural strength compared to jute, banana, pineapple and other fibers(Kiruthika, 2024) ("Front Matter," 2020). Regular epoxy is used which has good binding properties, but these are synthetic and CNSL is one of the natural bio-based epoxy resin which can help to degrade the material, which is environmentally eco-friendly compared to regular epoxy. MWCNT is a filler which can enhance mechanical characteristics (Chen et al., 2024). The composite is prepared with ratio of 1:2 fiber to resin, two sets of samples were prepared with regular epoxy and bio-based epoxy with a hand layup process with varying MWCNT percentages of 0.25 to 0.50. Some recent works show positive results in the use of sisal fiber which enhances mechanical properties and the use of bio-based epoxy which is environmentally eco-friendly and cost-effective which enhances mechanical properties. Also, MWCNT enhances mechanical properties with increasing interfacial bonding between molecules (Liu et al., 2017).

2. Selection and procurement of materials:

Fabrication of bio-based composites using natural fiber (sisal fiber), biobased epoxy resin (FORMULITE) and regular epoxy and MWCNT as filler by varying filler percentage using hand layup techniques and analysing mechanical characteristic tensile strength of both composites.

2.1 Materials

Natural fiber like sisal fiber mat purchased from Hayael Aerospace India Ltd. Poonamalle Chennai, which is easily decomposable, epoxy art ultra clear resin, and epoxy art hardener is used in the mix ratio 2:1 which is purchased from Prashva Infotech Mumbai, Maharashtra, MWCNT with 99% purity, average diameter 10-20 nm, Length- 6 µm Brand- Shilpent from Nagpur and bio-based epoxy FormuLITE 2500A resin and FormuLITE 2401 B was purchased from cardo-lite corporations, USA Table 1, Table 2 and Table 3 shows characteristics of the regular epoxy, FormuLITE (CNSL) and MWNT. Hand layup technique is used to prepare composite with 250mm long 25mm wide and 3-5 mm thickness samples are prepared ASTM D3039 as shown in Figure .

Figure 1(a) Regular epoxy resin

Figure 1(b). Bio epoxy FormuLITE resin

Table 1. Properties of regular epoxy (Kumari & Kumar, 2018)

Thermoset resins	Density (g/cm³)	Tensile strength (MPa)	Young's modulus (GPa)	Elongation (%)
Phenolic	1.2	40-50	3	1-2
Polyester	1.2	50-65	3	2-3
Epoxy	1.1 - 1.4	50-90	3	2-8
Vinyl ester	1.15	70-80	3.5	4-6
Polyimide	1.42	70-150	2.5	8-70
Silicon	2.33	-	-	-

Table 2. Bio epoxy FormuLITE resin (Hiremath et al., 2023).

Parameters	FORMULITE 2500A
Key advantages	Good Tg , pot life, bio-content and mechanical properties
Calculated bio-content	36.6
Mix ratio by weight	100:30:00
Mix ratio by volume	100:36:00
Mix viscosity 25°C (CPs)	700
Pot life at 25°C (min)	105
Pot life at 40°C (min)	57
Suggested cure cycles	4-8 h at RT + 2-4 h at 50-70°C + 2-3 h at 80-100°C
Tg (°C)	92
Tensile strength (MPa)	62
Tensile modulus (MPa)	2615
Elongation at Fmax (%) Elongation at break (%)	4.8/6.4
Flexural strength (MPa)	92
Flexural modulus (MPa)	2262
Recommended processes	Infusion, RTM, VARTM, lamination, wet lay-up

Table 3. Characteristics between SWCNT, MWCNT, and conventional steel at room temperature (Al-Bahrani, 2020.)

Properties	CNT with MW	CTN with SW	Other (Steel)
Density (g.cm^{-3})	1.4-2.1	~1	7.8
Melting point (C)	3550	3550	1538
Thermal conductivity	~3000	~3500	80
Electrical resistivity (Ω m)	10	10	100
Tensile strength (GPa)	11-150	13-53	0.4-1.5
Elongation to break (%)	~10	16	15-50
Young's modulus (GPa)	1000	1000	200

3. Preparation of composite and testing

In this study, we prepared three composite specimens with varying matrix compositions. The first specimen comprised sisal fiber, epoxy resin, and hardener. The second specimen incorporated Multi-Walled Carbon Nanotubes (MWCNT) into sisal Fiber at a concentration of 0.25 % by weight, along with epoxy resin. The third specimen utilized MWCNT at a higher concentration of 0.5 % wt. with sisal Fiber, epoxy resin, and hardener. Additionally, a set of samples was prepared using bio-based epoxy resin FormuLITE combined with sisal fiber, excluding MWCNT, while other samples incorporated varying percentages of MWCNT (0.25% and 0.50%). Mechanical properties are studied with the help of universal testing machine (UTM), and the results were compared between epoxy and bio-based epoxy resin matrices with different MWCNT filler materials and Figure 2 illustrates Specimen prepared as per ASTM D3039 and tensile test carried out on specimens.

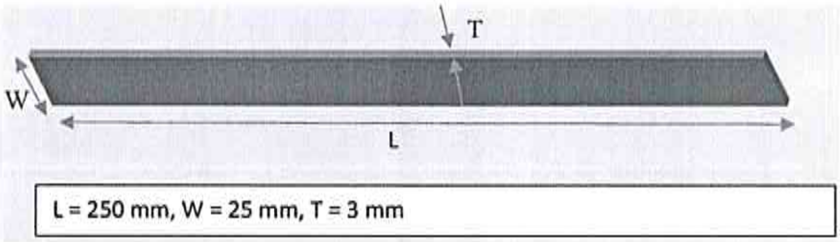


Figure 2 (a). ASTM D3039 specimen for tensile test

Figure 2(b). Specimens prepared using hand layup

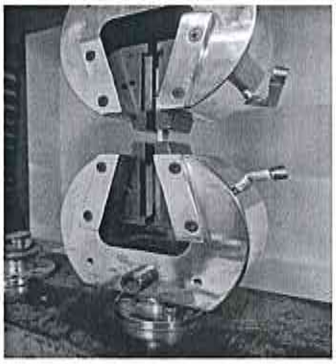


Figure 2(c) Specimens test on UTM

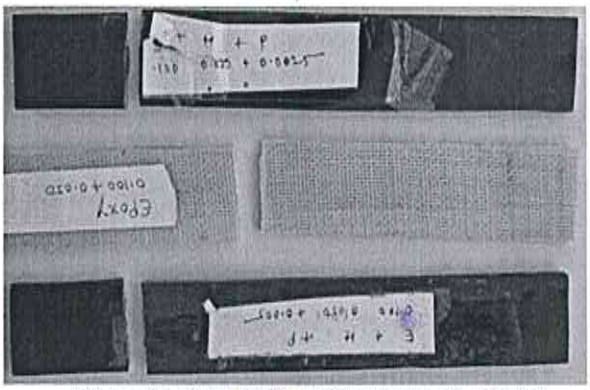


Figure2(d). Fractured specimens after tensile test

4. Results and discussion

After conducting experiments we found that the addition of MWCNT with Sisal fiber , bio-based epoxy as well epoxy increases mechanical properties like tensile strength because Multi-Walled Carbon Nanotubes (MWCNTs), being both lightweight and robust filler agents, strengthen the bonding between bio-based epoxy and sisal fiber. This augmentation facilitates efficient load transfer and stress distribution within the material. Additionally, MWCNTs serve as bridges across microcracks and defects in the component, thereby impeding crack propagation and consequently enhancing tensile strength. Furthermore, as per the literature survey MWCNTs possess the capability to absorb energy during deformation, thereby improving toughness and resistance to failure under tensile testing conditions. Experiments show that the composites consisting of sisal fiber and regular epoxy, as well as sisal fiber with bio-based epoxy resin show a tensile strength of 135 MPa and 94 MPa, respectively without Multi-Walled Carbon Nanotubes (MWCNT) as in Figure 3(a). Furthermore, it is observed that the addition of 0.25% MWCNT to both composite *types* results in tensile strengths of 151 MPa for regular epoxy and 138 MPa for bio-based epoxy resin. Additionally, the tensile strength for the addition of 0.50% MWCNT in both regular epoxy and bio epoxy resin is 178 MPa and 168 MPa, respectively. The subsequent Figure 3(a), (b) and (c) graphs illustrate displacement and stress values for the tensile tests of composites with varying MWCNT concentrations in regular epoxy and bio-based epoxy.

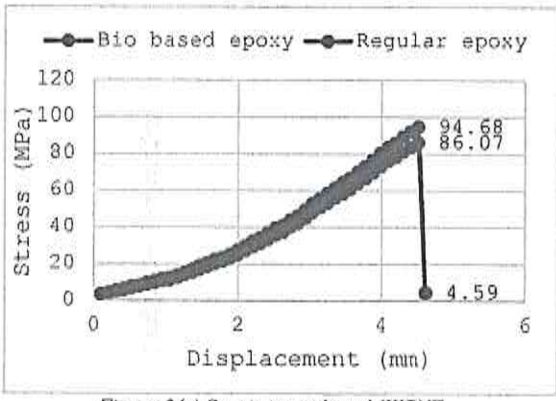


Figure 3(a) Specimen without MWCNT

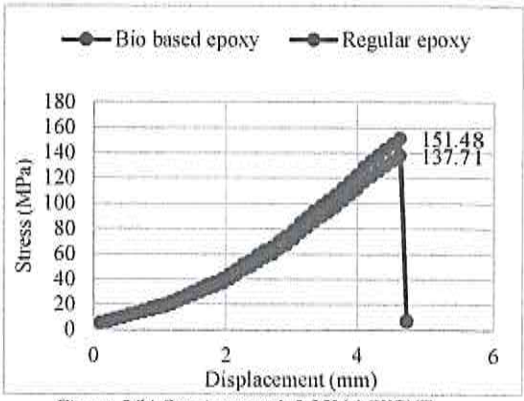


Figure 3(b) Specimen with 0.25% MWCNT

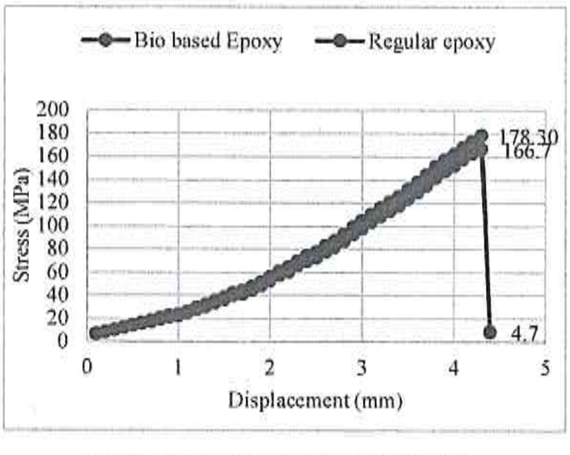


Figure 3(c) Specimen with 0.50% MWCNT

5. References

Al-Bahrani, M. (n.d.). *The Manufacture and Testing of Self-Sensing CNT Nanocomposites for Damage Detecting Applications.* https://doi.org/10.24382/559

Chen, Y., Ren, B., Li, X., Rao, S., Guo, Z., Li, Y., Huang, Y., Kang, M., & Li, X. (2024). A fully bio-based epoxy resin with excellent mechanical properties combines flame retardancy and degradability. *Polymers for Advanced Technologies*, *35*(6). https://doi.org/10.1002/pat.6481

Drira, D. (2019). *Study of the mechanical and comfort properties of a ballistic Kevlar/epoxy composite manufactured with different methods Ministry of Higher Education and Scientific Research University of Monastir National Engineering School of Monastir Graduation Project Specialty: Textile Engineering.*

Front Matter. (2020). In *Hybrid Fiber Composites*. Wiley. https://doi.org/10.1002/9783527824571.fmatter

Hiremath, P., Ranjan, R., DeSouza, V., Bhat, R., Patil, S., Maddodi, B., Shivamurthy, B., Perez, T. C., & Naik, N. (2023). Enhanced Wear Resistance in Carbon Nanotube-Filled Bio-Epoxy Composites: A Comprehensive Analysis via Scanning Electron Microscopy and Atomic Force Microscopy. *Journal of Composites Science*, *7*(11). https://doi.org/10.3390/jcs7110478

Kiruthika, A. V. (2024). A review of leaf fiber reinforced polymer composites. In *Journal of Engineering and Applied Science* (Vol. 71, Issue 1). Institute for Ionics. https://doi.org/10.1186/s44147-024-00365-2

Kumari, N., & Kumar, K. (2018). Mechanical behaviour of graphene and carbon fibre reinforced epoxy-based hybrid nanocomposites for orthotic callipers. *Journal of Experimental Nanoscience*, *13*, S14–S23. https://doi.org/10.1080/17458080.2018.1431847

Liu, F., Hu, N., Ning, H., Atobe, S., Yan, C., Liu, Y., Wu, L., Liu, X., Fu, S., Xu, C., Li, Y., Zhang, J., Wang, Y., & Li, W. (2017). Investigation on the interfacial mechanical properties of hybrid graphene-carbon nanotube/polymer nanocomposites. *Carbon*, *115*, 694–700. https://doi.org/10.1016/j.carbon.2017.01.039

Kolhapur Institute of Technology's College of Engineering Kolhapur
(Empowered Autonomous)

International Conference on

Innovative Engineering Technologies (ICIET – 2025)

CERTIFICATE

This is to certify that, **Dr. Dinkar V. Ghewade**

is a co-author of the research Paper entitled "*Investigation of Strength Variation in Composite Material with MWCNT Dispersion*"

at Joint International Conference on Innovative Engineering Technologies (ICIET – 2025) organized by KITCoE, Kolhapur, India, Ningxia University, China, SJTU, China and AGH University, Poland on 11 - 12 September, 2025.

Prof. Mingxu Xia	**Prof. Jun Li**	**Prof. Mohan Vanarotti**
Ningxia University, China	Shanghai Jiao Tong Unv., China	KITCoEK, India

Kolhapur Institute of Technology's College of Engineering Kolhapur ★ Since 1983 ★ (Empowered Autonomous)

Dr. A. D. Shinde College of Engineering Bhadgaon • Tal Gadhinglaj •

Strength Variation in Composite Material with MWCNT Dispersion in Bio-Based Epoxy

Kishor S. Joshi[1,2], Pavan Hiremath[1], Dinkar V. Ghewade[2], Shivashankarayya Hiremath[3], Vishwanatha H. M[1]

[1]Department of Mechanical and Industrial Engineering, Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal, Karnataka, India, 576104
[2]Department of Mechanical Engineering, Dr. A.D. Shinde College of Engineering, Bhadgaon, Maharashtra, India, 416502
[3]Department of Mechatronics, Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal, Karnataka, India, 576104

Abstract. During this period of industrial development, the shift to sustainable technology is crucial for addressing environmental concerns and improving resource efficiency. This paper examines the tensile performance of hybrid composites reinforced using sisal plant natural fibers, bio-based epoxy resin, and multi-walled carbon nanotubes (MWCNTs). The goal was to evaluate the possibility of bio-based epoxy as a sustainable alternative to conventional epoxy while enhancing the mechanical properties of composites. The hybrid composites with varying MWCNT concentrations (0%, 0.25%, and 0.5%) were made by hand layup. Specimens developed in compliance with ASTM criteria underwent tensile testing.

The findings demonstrated that the tensile strength and elastic modulus considerably improved with increasing MWCNT content. In the era of the industrial revolution, improving resource efficiency and addressing environmental problems need a shift to sustainable technology. The bio-based epoxy demonstrated mechanical properties comparable to those of conventional epoxy, with a 93.57% increase in tensile strength for bio-based composites. Additionally, the bio-based matrix showed a higher improvement in elastic modulus than traditional epoxy. These findings demonstrate the potential of bio-based epoxy reinforced with MWCNTs and sisal fibers to provide high-performing, eco-friendly materials for industrial and automotive applications. This approach is consistent with sustainability goals as it makes use of renewable resources and reduces its environmental impact.

Keywords: *Sustainable material, Natural fiber, MWCNT, Bio-based epoxy, Tensile properties*

1. Introduction

Composites have been used for thousands of years in a variety of applications. Between 2180 and 3400 B.C., the ancient Egyptians and Mesopotamians were among the first to create composite materials by inventing new techniques to arrange wood strips to create plywood. They began adding fibers to building materials like bricks, clay, pottery, and weaving crafts as their society grew, which significantly increased the durability and endurance of their structures. Around 1200 A.D., this legacy of invention had continued to produce increasingly sophisticated composite materials.[1]. In this work, epoxy, cashew nutshell liquid-based bio-epoxy, and multi-walled carbon nanotubes (MWCNTs) are mixed with sisal fiber, a natural fiber that is collected from leaves, to produce hybrid composites. Natural, synthetic, glass, carbon, aramid, ceramic, and polymeric fibers are the broad categories into which fibers may be divided. Among them, natural fibers are clearly superior to synthetic ones due to their affordability, availability, light weight, and environmental friendliness. Xiong claims that natural fibers are ideal for creating composites because of their superior qualities, which include macro-shape deformation, heat stability, and micromechanical performance [2]. After reviewing a number of studies, sisal fiber was shown to be a good alternative with superior mechanical properties including tensile and flexural strength when compared to other natural fibers like jute, bananas, and pineapple[3] [4]. Figure 1 shows the sisal plant, its fibers extracted from the plant, and the sisal fiber mat used in the current study.

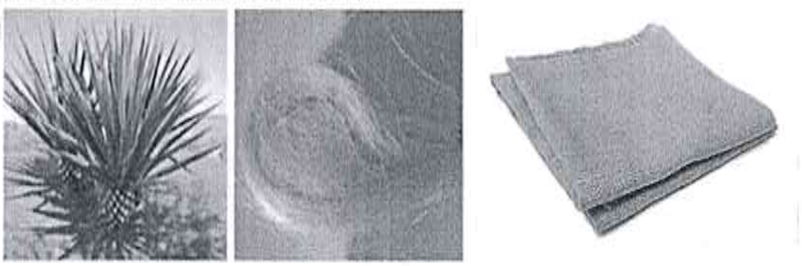


Figure 1: Sisal plant, its fibers, and Sisal fiber mat [5]

By combining natural fibers with conventional and bio-based epoxy resins, polymer matrix composites are being utilized more and more to produce innovative materials. Typically, co-reactants like phenols and other chemicals are added to create regular epoxy resins, which are reactive polymers with epoxide groups. In contrast to other resin types, these epoxies react during curing to generate a network structure that provides outstanding mechanical qualities as well as remarkable resistance to heat and chemicals. Regular epoxies are used in many different fields because of their adaptability, such as attaching structural elements and covering construction materials [6].

Eco-friendly epoxy, also known as bio-based epoxy, is made from sustainable and renewable resources rather than fossil fuels. Natural resources like sugars and oils from plants are used in its production[7]. Epoxy resins made from biomaterials are a great substitute for conventional epoxy resins made from petroleum. When cured with certain hardeners, plant-based epoxidized polymers can create a three-dimensional network because of their structure, which consists of both an epoxide functional group and a polymer backbone. These bio-based epoxies are distinguished by their non-toxic properties, stiffness, and accessibility. [8]. The composites in this study were made using bio-based Cashew Nut Shell Liquid (CNSL) epoxy resin, which has better biodegradability and eco-friendly qualities than traditional epoxies. Different kinds of fillers, such as biological, polymeric, and mineral fillers, were used throughout the preparation process to improve the composites' performance properties. Multi-Walled Carbon Nanotubes (MWCNTs) were employed as fillers in both conventional and bio-based epoxy systems in this investigation at different concentrations of 0.5% and 0.25%. The mechanical qualities of the resultant composites were greatly enhanced by the inclusion of MWCNTs.[9].

Several techniques, such as open molding, closed molding, cast polymer molding, and additive manufacturing, can be used to fabricate composites. The open molding hand layup method was used for this investigation. Using sisal fiber in combination with normal epoxy and bio-based epoxy (CNSL), specimens were made in compliance with ASTM standard D3039. A Universal Testing Machine (UTM) was used to test the prepared specimens for tensile strength. Because MWCNTs are included alongside sisal fiber, researchers have observed that the hybrid composition of these materials improves mechanical qualities, including improved tensile strength. [10]

In this work, hybrid composite materials reinforced with different percentages of multi-walled carbon nanotubes (MWCNTs) were created using both conventional epoxy resins and bio-based epoxy resins. The hybrid composites were created using the hand layup process, and their performance was assessed using tensile testing. Important characteristics including elastic modulus and ultimate tensile strength were recorded in order to assess the mechanical behavior of both bio-based and conventional epoxy hybrid composites. These materials have the potential to provide high-strength materials appropriate for a range of industrial and automotive applications, as well as sustainable green solutions.

2. Materials and Methods

MWCNT, conventional epoxy, bio-based epoxy resin (FORMULATE), and natural fiber (sisal fiber) were used as fillers in different percentages to fabricate bio-based composites. The composites were prepared using the hand layup technique, and their mechanical characteristics—particularly their tensile strength—were examined. The readily decomposable sisal fiber was utilized in a 2:1 mix ratio with Epoxy Art Ultra Clear Resin and Epoxy Art Hardener, which were acquired from Prashva Infotech in Mumbai, Maharashtra. The MWCNTs were obtained from Shilpent, Nagpur, and had an average diameter of 10–20 nm, a length of 6 μm, and 99% purity. Additionally, Cardolite Corporations in the USA provided the bio-based epoxy FormuLITE 2500A resin and FormuLITE 2401B hardener.

Table 1 displays the properties of normal epoxy, FormuLITE (CNSL), and MWCNT. Composites were prepared using the hand layup process; as illustrated in Figure 3, samples were 250 mm long, 25 mm wide, and 3-5 mm thick, in accordance with ASTM D3039 requirements.

(a) (b)

Figure 2 The image shows the (a). Regular epoxy resin and (b) Bio epoxy FormuLITE resin

Table 1. Basic properties of the material used in this process [10][11][12]

Thermoset resins	Density (g/cm³)	Tensile strength (MPa)	Young's modulus (GPa)	Elongation (%)
Epoxy	1.1 - 1.4	50-90	3	2-8
Bio epoxy		62	2615(MPa)	4.8/6.4
MWCNT	1.4-2.1	11-150(GPa)	1000	~10

3. Fabrication Method

As shown in Figure 4, this investigation includes three composite specimens that were made in compliance with ASTM D3039 requirements. The matrix makeup varies among specimens. A bi-directional sisal fiber mat, epoxy resin, and a hardener made up the first specimen. In addition to the epoxy resin, the second specimen added Multi-Walled Carbon Nanotubes (MWCNTs) to the sisal fiber bi-directional mat at a concentration of 0.25% by weight. In the third specimen, MWCNTs were combined with sisal fiber, epoxy resin, and hardener at a greater concentration of 0.5% by weight. Furthermore, a different set of samples was made without MWCNTs utilizing sisal fiber and the bio-based epoxy resin FormuLITE. MWCNTs in different amounts (0.25% and 0.50%) were present in other samples.

These examples were prepared using the hand layup process, which is frequently utilized in composite manufacturing because it requires less equipment. This method involves applying a gel coat to an open mold first, then stacking fiber reinforcement and resin (binder and filler). After that, air bubbles are removed and the resin is completely impregnated into the fiber fabric using brushes and rollers. Without the use of external heat sources, the laminates are left to cure naturally at ambient temperature. [13].

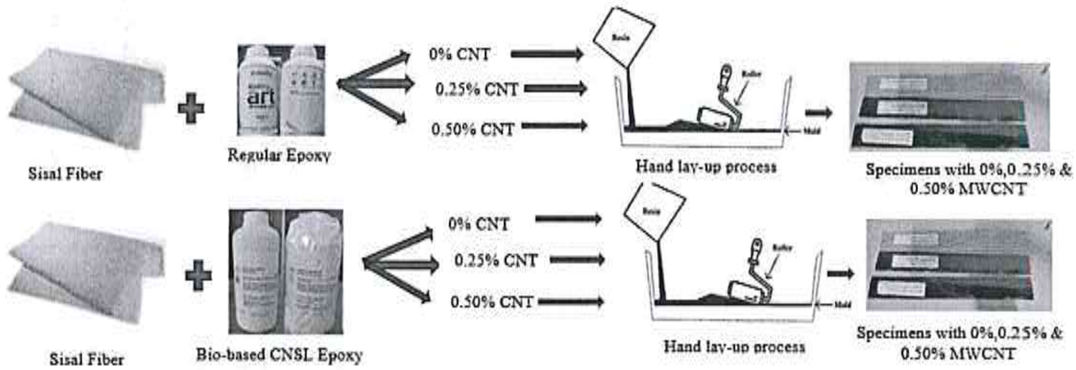


Figure 3: Fabrication of test samples with hand layup process

4. Material Testing

As shown in Figure 5, the test specimens were meticulously made in compliance with ASTM D3039 guidelines, and they had exact measurements of 250 mm in length, 25 mm in breadth, and 3 mm in thickness. Two sets of specimens were created: one with bio-based epoxy and one with ordinary epoxy. As illustrated in Figure 6, each set had three specimens with different concentrations of Multi-Walled Carbon Nanotubes (MWCNTs)—0%, 0.25%, and 0.50%—all reinforced with sisal fiber. A Universal Testing Machine (UTM) was then used to mechanically test the specimens by applying a regulated point load to each one. With a gauge length of 150 mm and a loading rate of 1 kN/sec, the tensile characteristics of the composites were precisely evaluated. With a particular focus on how the addition of MWCNTs affects the strength and durability of both conventional and bio-based epoxy composites, this testing protocol was created to assess each specimen's mechanical performance.

The outcomes of these tensile tests offer vital information on how the concentration of MWCNT affects the tensile strength, elasticity, and general mechanical behavior of the composites.These results are crucial for comprehending how these composites will function in practical settings where material strength and endurance are crucial, such as in industrial, automotive, and structural components.

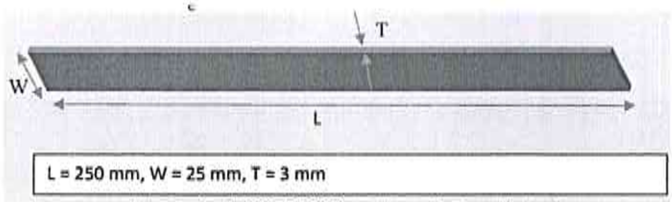


Figure 4: ASTM D3039 specimen for tensile test

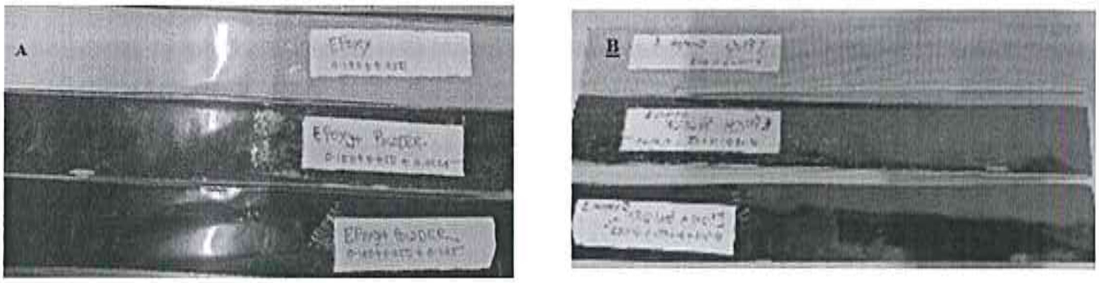


Figure 5: Specimens a). Bio-based epoxy with 0%,0.25% & 0.50% MWCNT b). Regular epoxy with 0%,0.25% & 0.50% MWCNT

(a) *(b)*

Figure 6. (a)Sample Testing under UTM (b) Cut specimens after UTM tested

The test configuration is shown in Figure 7, which also shows the appropriate cross-sectional image of the sample following the test. The composite specimen is placed in the Universal Testing Machine (UTM) before testing. The method used to evaluate the mechanical characteristics of the composite specimens is highlighted by this graphic representation, which focuses on the impact of the applied load during the tensile testing technique. By displaying any deformations, fractures, or failures that might have happened under load, the cross-sectional image offers important information into the internal structure of the composite. Such observations are essential for assessing the integrity and performance of the composite materials under real-world conditions as well as for comprehending how the material reacts to stress.

5. Result and discussion

We examined and discussed the tensile characteristics of ordinary epoxy composites and bio-based epoxy with different filler concentrations. Figures 8(a) and 8(b) show stress-strain curves for varying concentrations of Multi-Walled Carbon Nanotubes (MWCNTs) after both types of epoxy were first combined with sisal fiber. In contrast to the MWCNT-reinforced sisal fiber composites, neat bio-based epoxy and ordinary epoxy composites reinforced with sisal fiber were shown to have lower stress values. Notably, out of all the hybrid composites, the one with 0.50% MWCNTs showed the best outcomes. Compared to the conventional epoxy composite, the bio-based epoxy composite containing sisal fiber and MWCNTs showed less strain, most likely as a result of the bio-epoxy resins elastic properties. Additionally, the composite's overall mechanical performance was improved by the addition of MWCNTs, which allowed for a smoother load transfer between the materials and a more even distribution of stress[14]. The incorporation of MWCNT significantly enhanced the tensile performance of the hybrid composite [15] [16].

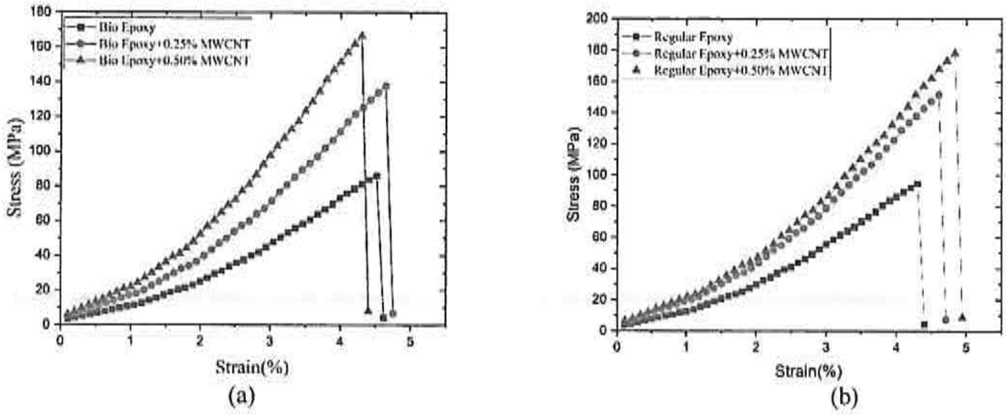


Figure 8. Tensile test results of (a) Bio Epoxy and (b)Regular epoxy with varied MWCNT

Figure 9(a) and (b) illustrate the bio epoxy and conventional epoxy hybrid composites' elastic modulus performance. With different MWCNT concentrations, the elastic modulus increased in both situations. The conventional epoxy with MWCNT showed a 67.17% increase in elastic modulus, whereas the bio epoxy with MWCNT showed a 106.2% improvement over its basic material. This suggests that bioepoxy considerably raises the composite's overall stiffness and load-bearing capability, which raises the elastic modulus. Furthermore, a robust interfacial bond is created by the interaction of MWCNTs, sisal fibers, and the epoxy matrix, which improves stress tolerance.

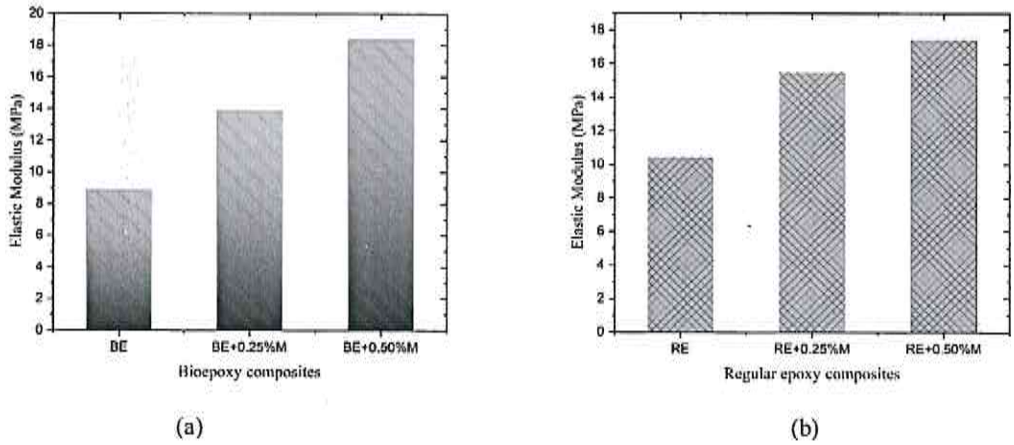
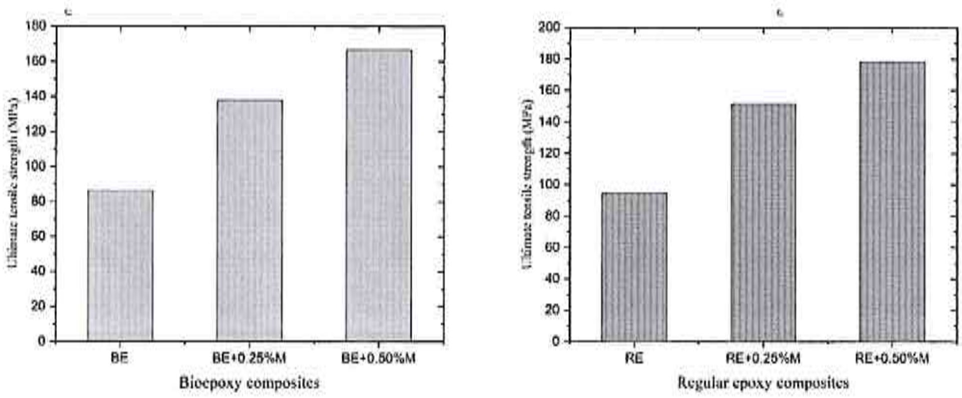


Figure 9. Elastic modulus of (a) Bio epoxy and (b) Regular epoxy with MWCNT

Furthermore, a crucial factor in evaluating the mechanical performance of hybrid composites is ultimate tensile strength (UTS). The UTS of bio and conventional epoxy with different MWCNT concentrations is shown in Figure 10(a) and (b). With varying MWCNT concentrations, the bio-epoxy composite was shown to have UTS values of 86.07 MPa, 137.71 MPa, and 166.63 MPa, respectively. Similarly, with equal variations in MWCNT concentrations, the standard epoxy composite showed UTS values of 94.68 MPa, 151.48 MPa, and 178.3 MPa. The UTS was found to be more than double that of the base material in both situations. The outstanding tensile strength and stiffness that the MWCNTs and sisal fibers offered, which raised the composites' UTS, was responsible for this notable gain. Comparatively, the composite was able to sustain higher tensile stresses before failing because normal epoxy with MWCNTs demonstrated a larger increase in UTS than bio epoxy.



(a) (b)

Figure 10: Ultimate tensile strength of (a) Bio Epoxy and (b)Regular epoxy with varied

Therefore, the performance of sisal fiber and MWCNT-reinforced normal epoxy and bio-epoxy shows great promise for use in lightweight, high-strength materials, especially in fields like protective gear, automotive parts, and aerospace structures.

6. Conclusion:

- The tensile characteristics of bio and conventional epoxy composites reinforced with sisal fiber and different concentrations of Multi-Walled Carbon Nanotubes (MWCNTs) were the main focus of the investigation.
- A universal testing machine was used to evaluate the mechanical performance of hybrid composites, including their tensile strength and elastic modulus, after they were created with varying quantities of MWCNT.
- The findings showed that, in comparison to bio-epoxy composites, conventional epoxy containing sisal fiber and MWCNTs performed better overall. Nonetheless, the bio-epoxy composite's elastic modulus was greater than that of conventional epoxy.The bio and conventional epoxy composites' ultimate tensile strengths improved by 93.57% and 88.31%, respectively. This suggests that the inclusion of natural fibers and high-strength materials has a greater impact on bio-epoxy.
- The results show that bio-epoxy, which has benefits including biodegradability, environmental friendliness, and reduced production costs, may eventually replace conventional epoxy.
- More investigation is required to better understand the mechanical and physical characteristics of bio-based epoxy composites made of a variety of components.

References

[1] D. Drira, "Study of the mechanical and comfort properties of a ballistic Kevlar/epoxy composite manufactured with different methods Ministry of Higher Education and Scientific Research University of Monastir National Engineering School of Monastir Graduation Project Specialty: Textile Engineering," 2019.

[2] X. Xiong et al., "Finite element models of natural fibers and their composites: A review," Journal of Reinforced Plastics and Composites, vol. 37, no. 9, pp. 617–635, May 2018, doi: 10.1177/0731684418755552.

[3] A. V. Kiruthika, "A review of leaf fiber reinforced polymer composites," Dec. 01, 2024, Institute for Ionics. doi: 10.1186/s44147-024-00365-2.

[4] "Dr. Anish Khan. et.al Front Matter," in Hybrid Fiber Composites, Wiley, 2020. doi: 10.1002/9783527824571.fmatter.

[5] M. Puttegowda, S. M. Rangappa, M. Jawaid, P. Shivanna, Y. Basavegowda, and N. Saba, "Potential of natural/synthetic hybrid composites for aerospace applications," in Sustainable Composites for Aerospace Applications, Elsevier, 2018, pp. 315–351. doi: 10.1016/B978-0-08-102131-6.00021-9.

[6] R. Auvergne, S. Caillol, G. David, B. Boutevin, and J. P. Pascault, "Biobased thermosetting epoxy: Present and future," Jan. 22, 2014. doi: 10.1021/cr3001274.

[7] D. Chandramohan and & K. Marimuthu, "A REVIEW ON NATURAL FIBERS," 2011. [Online]. Available: www.arpapress.com/Volumes/Vol8Issue2/IJRRAS_8_2_09.pdf

[8] M. Kumaresan, S. Sathish, and N. Karthi, "Effect of fiber orientation on mechanical properties of sisal fiber reinforced epoxy composites," Journal of Applied Science and Engineering, vol. 18, no. 3, pp. 289–294, 2015, doi: 10.6180/jase.2015.18.3.09.

[9] P. Y. Chen, H. Y. Lian, Y. F. Shih, S. M. Chen-Wei, and R. J. Jeng, "Preparation, characterization and crystallization kinetics of Kenaf fiber/multi-walled carbon nanotube/polylactic acid (PLA) green composites," Mater Chem Phys, vol. 196, pp. 249–255, Aug. 2017, doi: 10.1016/j.matchemphys.2017.05.006.

[10] N. Kumari and K. Kumar, "Mechanical behavior of graphene and carbon fibre reinforced epoxy-based hybrid nanocomposites for orthotic caliper's," J Exp Nano sci, vol. 13, pp. S14–S23, Feb. 2018, doi: 10.1080/17458080.2018.1431847.

[11] P. Hiremath et al., "Enhanced Wear Resistance in Carbon Nanotube-Filled Bio-Epoxy Composites: A Comprehensive Analysis via Scanning Electron Microscopy and Atomic Force Microscopy," Journal of Composites Science, vol. 7, no. 11, Nov. 2023, doi: 10.3390/jcs7110478.

[12] M. Al-Bahrani, "The Manufacture and Testing of Self-Sensing CNTs Nanocomposites for Damage Detecting Applications", doi: 10.24382/559.

[13] D. K. Rajak, P. H. Wagh, and E. Linul, "A Review on Synthetic Fibers for Polymer Matrix Composites: Performance, Failure Modes and Applications," Materials, vol. 15, no. 14, p. 4790, Jul. 2022, doi: 10.3390/ma15144790.

[14] Y. Yi Xuan et al., "Influence of multi-walled carbon nanotubes on thermal behaviour and mechanical properties of pineapple leaf fibre-based natural rubber composites," Journal of Materials Research and Technology, vol. 30, pp. 8608–8619, May 2024, doi: 10.1016/j.jmrt.2024.05.239.

[15] M. Genedy, S. Daghash, E. Soliman, and M. M. Reda Taha, "Improving fatigue performance of GFRP composite using Carbon Nanotubes," Fibers, vol. 3, no. 1, pp. 13–29, Mar. 2015, doi: 10.3390/fib3010013.

[16] H. Li, Y. Peng, Z. Li, Z. Jiang, Q. Zhang, and L. Wu, "Plasma actuating modified multiwalled carbon nanotubes (MWCNTs) to strengthen interface of MWCNTs/Polylactic acid composites by constructing interlaminar stress-transfer bridge," Polym Test, vol. 129, Dec. 2023, doi: 10.1016/j.polymertesting.2023.108261.

Techno-Societal 2024

Patron:
Hon. Dr. P. A. Mahanwar
Hon. Dr. B. P. Ronge

Plenary Speakers:
Dr. Prahlad Vadakkepat
Prof. Dr. R. Logeswaran

Keynote Speakers:
Dr. Botir Usmonov
Dr. Sapna Gambhir
Dr. Vishal Dhamgaye
Dr. Venkata Reddy Poluru
Mr. Lou Simon Catimbang
Mr. Vinoy Vishnu Vadakkepat
Dr. Yeap Kim Ho
Dr. Parmeshwar Udmale
Dr. Vinayak Kulkarni
Dr. Saakshi Dhanekar
Dr. Sunil Gorantiwar
Dr. Gaurav Bartarya
Dr. Vijay Kumar Pal
Dr. Veerendra Dakulagi
Dr. Narendra Shah
Prof. Laxmikant Dama

SVERI

Funding Support

5th International Conference
on
Advanced Technologies for Societal Applications

Certificate

This is to certify that Prof./Dr./Mr./Ms. Kishor S. Joshi

of Manipal Institute of Technology, Manipal has

presented a research paper entitled Strength Variation in Composite Material with MWCNT Dispersion in Bio-Based Epoxy in the 5th International Conference on "Advanced Technologies for Societal Applications: Techno-Societal 2024", held at Shri Vithal Education & Research Institute (SVERI), Pandharpur, India during 13th-14th December 2024

Dr. A. P. Kene Coordinator	Prof. V. B. Patil Co-convener	Prof. P. M. Pawar Co-convener	Prof. B. P. Ronge Convener

Jointly organized by
SHRI VITHAL EDUCATION & RESEARCH INSTITUTE, PANDHARPUR
(P.B. No. 54, Gopalpur-Ranjani Road, Gopalpur, Pandharpur Maharashtra 413304 website: www.sveri.ac.in)
and
SCHOOL OF LIFE SCIENCES, P.A.H. SOLAPUR ...

Dr. A. D. Shinde College of Engineering, Bhadgaon, Tal. Gadhinglaj

Dynamic Power Factor Correction using FC TCR – A Case Study of Academic Campus Distribution Network

Basanagouda Ronad
Department of E&EE
Basaveshwar Engineering College, Bagalkote
Karnataka, India
basugouda.ronad@gmail.com

Mallikarjun Bhirade
Department of E&EE
Basaveshwar Engineering College, Bagalkote
Karnataka, India
mallikarjun.bhirade@gmail.com

Vireshkumar Mathad
Department of E&EE
Dr. A D Shinde College of Engineering, Bhadgaon
Gadhinglaj, Maharashtra
vireshmathad@gmail.com

Mukta Bannur
Department of E&EE
BLDEA's CET
Vijayapura
Karnataka, India
mukta.m.bannur@gmail.com

Shivappa Sobarad
Assistant Engineer, O&M
GESCOM-Gulburga Electricity Supply Company Ltd, Munirabad
Karnataka, India
shivappa.kptcl@gmail.com

Suresh H. Jangamshetti
Vice Chancellor
Haveri University
Haveri
Karnataka, India
suresh718@gmail.com

***Abstract*— This paper presents development of MATLAB simulation model for power factor improvement using fixed capacitor thyristor controlled reactor (FC-TCR). Electrical and Electronics Department, Basaveshwar Engineering College, Bagalkot laboratories include inductive loads which consume reactive power and run at low power factor about 0.6 lagging. Operation of these loads reduce power factor below unity. This will cause excessive losses i.e. for distribution of electrical power at same voltage conductor has to carry heavy currents. This issue is addressed by improving power factor to unity with proposed employment of FC-TCR circuit. Presently a 10 kVAr fixed capacitor bank is used to correct power factor of inductive loads. With loaded condition during the working hours of college, operating power factor is corrected and found to be 0.95 lagging. However, during offloaded condition in the evening and night hour's power factor is found to be 0.3 leading. It is impossible to monitor unity power factor for the both cases. This is addressed and achieved in simulation by employing FC-TCR in the said load network. FC-TCR arrangement is achieved by connecting FC in parallel with TCR. The Simulation is carried out with EEE department 24 hours load data. Results indicate that, developed simulation model for power factor correction by FC-TCR has an effective task in monitoring unity power factor with and without loads.**

Keywords*— *FACTS, FC-TCR, Power Factor Correction, Reactive Power Compensation, Academic Campus Load

I. Introduction

The concept of Flexible AC Transmission technology was first time introduced by Narain. G. Hingorani, in 1988. FACTS controllers are capable of maintaining the voltage regulation, power factor improvement, power system transient stability. They are used for resolving various transient and steady-state problems. These are having capacity to control active and reactive power in transmission line by controlling series and shunt parameters. FACTS devices are used as either series or shunt controllers. These are mainly classified as, UPFC, TCSC, SVC, SSSC. Due to advancement in technology, the FACTS controllers are used with semiconductor devices to obtain faster controllability of network [1]. Features of controllers include improvement of steady-state & transient stability along with voltage stability of complex power system network [2]. FACTS devices are employed for dynamic control of voltage, impedance and phase angle of high voltage AC transmission lines. The main demerit of FACTS controllers is expensive cost in providing flat response to secure power system during normal and steady state operating conditions. The employment of TCR and FC-TCR in power factor improvement and regulation at unity power factor is an effective approach. Distribution side of power system has various resistive and inductive loads connected. Majority of operating loads are inductive in nature and power system network suffers with low power factor due to these inductive loads such as arc furnace, transformer, single phase & three phase induction motors, choke of tube lights and many more [3], [4]. Induction motors require both real power and reactive power (maintain electro-magnetic fields) to perform the actual work When electrical distribution company supplies power with loads having unity power factor, large amount of electric power can be delivered for the identical capability of distribution systems. But most induction motors, operating at lower power factor of 0.6 lagging. Due to this, electrical distribution network may be stressed out for the same amount of power transfer capacity. Reduced power factor increases loss on both transmission and

979-8-3503-6456-9/24/$31.00 ©2024 IEEE

distribution networks. Therefore it is necessity to monitor system power factor at unity [5], [6].

Reactive power generation and absorption is very important since, it plays an important role in maintaining power system stability. But with application of capacitors only, power factor is improved but reactive power compensation is not provided i.e. unable maintain stability of power system network. The reactive power compensation and power factor improvement of inductive loads is achieved by means of FC-TCR device[7]. As shown in the Figure 1. FC-TCR arrangement consists of a fixed capacitor (FC) connected in parallel with thyristor controlled reactor (TCR). In general, FC is used to improve power factor of inductive loads. Further, during under load conditions, fixed capacitors leads to leading power factor, which is again an issue to handle. This is addressed by TCR through optimally compensating leading component by adding the required inductive component [8], [9].

FC-TCR is often simpler in design compared to other FACTS devices, such as STATCOM, which requires more complex power electronics circuit and control strategies. This assures lesser cost for initial investment and for continued maintenance. FC-TCR possess mature and reliable technology, which is proven in large scale industry applications. It provides a relatively fast response to changes in system conditions, making it effective for dynamic voltage control and reactive power compensation. Unlike switched capacitors or reactors, FC-TCR provide continuous and smooth control of reactive power by adjusting the firing angle of thyristors. It is particularly effective in providing shunt compensation, which is crucial for maintaining voltage stability in power systems with varying loads. FC-TCR can be easily integrated into existing power systems without the need for significant modifications, making it a practical choice for system upgrades. The thermal performance of FC-TCR is typically robust due to the use of fixed capacitors and thyristor-controlled reactors, which are less susceptible to overheating compared to more complex power electronics used in other controllers.

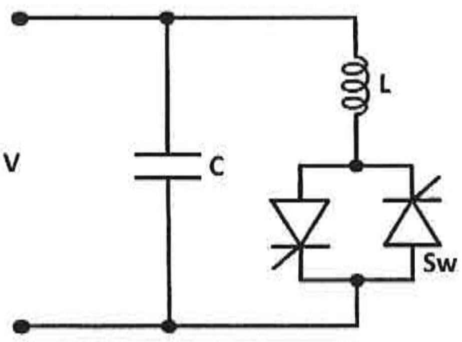


Fig. 1. Schematic diagram of FC –TCR [1]

In this paper, one of the important FACTS device like static VAr compensator (SVC) representing fixed capacitor thyristor controlled reactor (FC-TCR) is developed and implemented using MATLAB Simulation model for the power factor improvement. The developed model is employed for testing with load data of Electrical and Electronics Department, Basaveshwar Engineering College, Bagalkote.

II. METHODOLOGY

In the proposed simulation study, assessment of fixed capacitor and inductance employed in TCR is carried out. For the design process 50 Hz three phase source Voltage 440V is considered with source Resistance 0.01Ω and source Inductance 0.01 H. Further, 3 phase dynamic load details are considered with real & reactive power of Electrical and Electronics Engineering Department.

A. Design of Fixed Capacitance

In EEE department, 10 kVAr fixed capacitor is used for power factor correction of loads. Capacitance per phase value is assessed using the bus voltage available from the system:

$$X_C = \frac{V_{bus}^2}{Q_c} \;........ (1)$$

Where, X_c= Reactance of Fixed Capacitor

Q_c= Reactive power of Fixed Capacitor

With delta connected FC bank, $V_{bus} = V_{ph} = 440V$

and $X_C = \frac{1}{2\pi fC}$

$$X_C = \frac{440^2}{10\times10^3} = 19.36\,\Omega \quad \text{with,} \quad C = \frac{1}{2\pi f X_C}$$

$$C = \frac{1}{100\pi \times 19.36} = 164.416\ \mu F$$

Since 3-Φ FC bank is having capacitance per phase connected in delta structure is calculated as,

Per phase capacitance is,

$$C_{ph} = \frac{164.416\times10^{-6}}{3} = 54.805\ \mu F$$

B. Design of Compensating TCR Inductance

To design TCR circuit, its compensating inductance is assessed. This is taken up by compensated capacitance value QSVC with bus voltage V_{bus}.

$$X_{SVC} = \frac{(V_{bus}^2)}{Q_{VSC}} \;.......... (2)$$

But, $X_{SVC} = X_{TCR}$ and $Q_{VSC} = Q_c$

Where, X_{TCR} = Reactance of TCR

Q_C = Capacitive reactive power

With star connected TCR,

$$V_{bus} = \frac{V}{\sqrt{3}} = 254\ V$$

$$Q_{VSC} = Q_c = 10\ kVAr$$

$$X_{TCR} = \frac{254^2}{10\times10^3} = 6.4516\,\Omega$$

But, $X_{TCR} = 2\pi fL$ and

$$L = \frac{X_{TCR}}{2\pi f} = \frac{6.4516}{100\times\pi} = 0.0205\ H$$

III. SIMULATION BLOCK DIAGRAM

Simulation block diagram of the proposed model is shown in Figure 2. Power factor correction of 3-phase dynamic load with FC-TCR is presented in the model. 440V, 50 Hz, 3-Phase voltage source with constant impedance is employed in simulation. A dynamic load block of 440V, 50 Hz is connected in series with the programmable voltage source. In between source and load fixed capacitor thyristor controlled reactor (FC-

TCR) block is connected. To measure reactive VAr, scopes and displays are used for each subsystem block. A main block called powergui is used to simulate simulink model containing Sim-Power Systems tool by setting required parameters- sample time, frequency, solver configuration and simulation type. Electrical parameters of EEED load data is collected from SCADA Research Centre and one day load profile is created in MS excel sheet. This is assigned as input to dynamic load via look-up table. Using this code, look-up table is able to read 24 hours load data from excel file. Simulation time is set for 24 seconds where, each hour load data is considered for each second.

Once simulation begin, will end at 24 seconds. During simulation process, a difference of load and fixed capacitive reactive power data is applied as input to firing angle generator. It computes compensating reactance and with designed value of TCR reactance, conduction angle is assessed. This is carried out through Newton Raphson Solver. It is an iterative technique used to obtain solutions for complex equations. Finally with conduction angle, delay or firing angle in degree is determined corresponding to each load hour data.

Generated firing angle is again applied as an input to the firing pulse generator where TCR triggering pulses were generated by taking different bus voltage magnitudes for 3 phases. TCR with total 3 branches contains 6 thyristors. There are 2 anti-paralleled thyristor configurations per TCR branch in series with reactor end to end. Triggering pulses are applied to thyristor per each half cycle of input supply and reactive power is generated. This represents total TCR VAr output. FC, total TCR and Load VAr is applied as input to "Net VAr Output" block where it is connected to power factor measurement block.

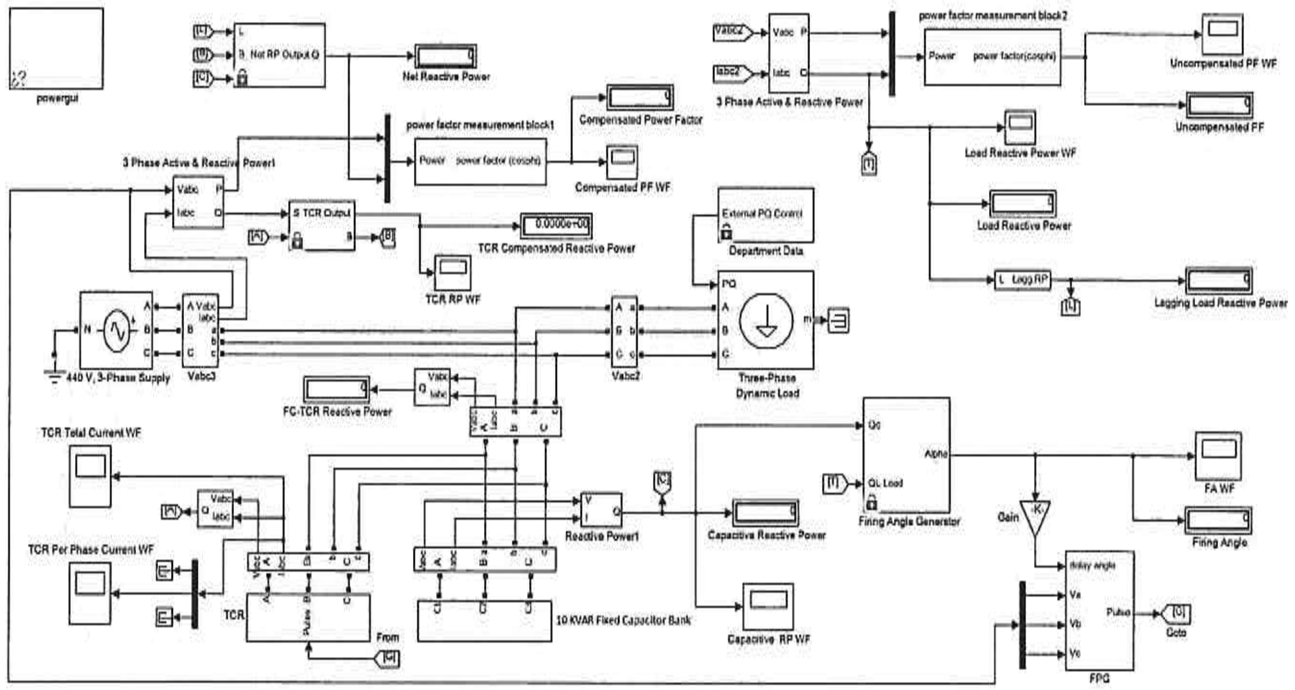


Fig. 2. Simulink model of power factor correction of 3-phase dynamic load with FC-TCR

IV. Simulated Model Subsystem Blocks Diagrams

To design whole simulation model for power factor correction method, subsystem block containing other blocks are constructed. The subsystem blocks will largely reduce complexity of model and make it easier to analyze.

A. Power Factor Measurement

Subsystem of power factor measurement block shown in Figure 3. It is used to measure power factor at load side. Initially complex power is given as an input. Complex power contains 3-phase instantaneous active and reactive power measured from the said block. In MATLAB simulation this subsystem block is used to measure power factor for three phase AC systems.

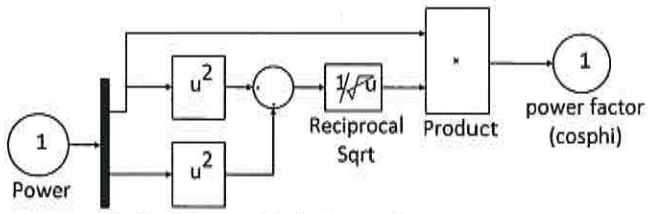


Fig. 3. Subsystem block of power factor measurement

B. Fixed Capacitor (FC)

Subsystem block of delta connected fixed capacitor bank is shown in the Figure 4. It is having 10 kVAr capacity used for power factor correction of inductive loads. Since each capacitor is connected in delta structure, per phase capacitance value is designed with respect to total kVAr rating of capacitor bank. The size of capacitance is chosen such that its value should not be too low or high. Capacitor used for power factor correction of inductive loads is also referred to as synchronous condenser. For 10 kVAr capacitor bank with system voltage 440 V value of each capacitance is found to be 54.805μF. Total equivalent capacitance is found to be 164.415μF.

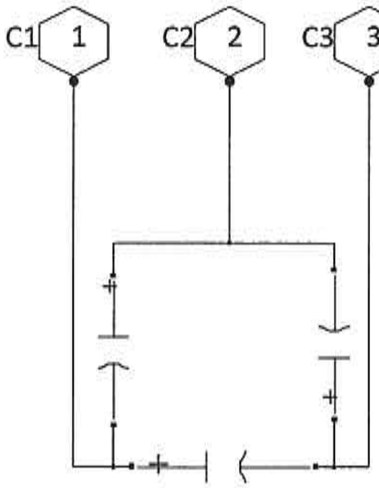


Fig. 4. Subsystem block of delta connected FC bank

C. Thyristor Controlled Reactor (TCR)

Subsystem block of star connected thyristor controlled reactor is shown in Figure 5. This TCR block is connected in between source and load across bus, used for 3 phase AC system. Thyristor controlled reactor branch is created by connecting anti-paralleled thyristors end to end represents a triac structure. This structure or thyristor branch is connected in series with a reactor. Finally three TCR branches are connected across each phase with respect their neutral points forming a complete TCR circuit for total 3 phases. Each branch of TCR containing thyristor is triggered by means of triggering pulses generated and supplied from firing pulse generator. Structure of triggering pulses is square in nature. Further, input to firing pulse generator is supplied from firing angle generator. TCR is used for reactive power compensation of inductive loads.

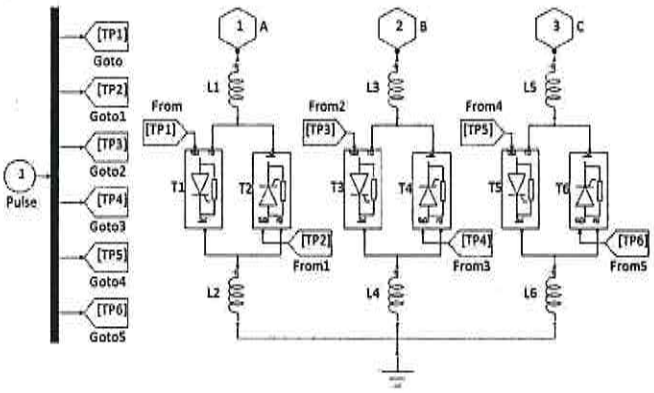


Fig. 5. Subsystem block of thyristor controlled reactor

D. Firing Angle Generator

Subsystem block of firing angle generator is shown in the Figure 6. It is used to generate delay angle α required to generate triggering pulses which are needed to turn on thyristors. Initially difference of capacitive reactive power QC and inductive or load reactive power QL is given as input, where QC represents leading reactive power (positive) and QL represents lagging reactive power (negative). With this difference and a line voltage of 440 V, the compensating reactance is calculated. This reactance is directly proportional to phi times the TCR reactance and inversely proportional to conduction angle minus sine of conduction angle where, conduction angle is measured in radians or degrees. Using this relation with known values of compensating and TCR reactance, conduction angle σ is calculated with the help of Newton Raphson (NR) method. It is an iterative technique used to solve complex trigonometric equations by approximate solution method. In this subsystem block NR Solver block is designed to make calculations up to 3 iterations. At 3rd iteration required value of conduction angle in radian is obtained. Finally with known value of conduction angle σ, the delay angle α is calculated in radians and is converted into degrees. Generated delay angle is given as input to firing pulse generator to generate thyristor triggering pulse [16].

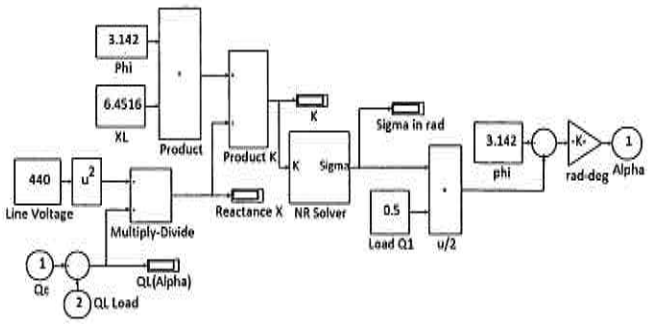


Fig. 6. Subsystem block of firing angle generator

Mathematical expressions used in designing of delay or firing angle generator subsystem block are given by,

$$X_L(\alpha) = \frac{\pi X_L}{\sigma - \sin\sigma} \quad \ldots\ldots\ldots (3)$$

Where, $X_L(\alpha)$ is Compensating Reactance in ohms
X_L is TCR Reactance in ohms
σ is Conduction angle in radians

$X_L(\alpha)$ is calculated from the mathematical expression,

$$X_L(\alpha) = \frac{V^2\,bus}{(Q_c - Q_{Load})} \quad \ldots\ldots\ldots (4)$$

Where, Q_C is Capacitive Reactive Power
Q_{Load} is Inductive Load Reactive Power

With known value of conduction angle, the delay angle α in radians is calculated by using equation,

$$\alpha = \pi - \left(\frac{\sigma}{2}\right) \quad \ldots\ldots\ldots (5)$$

In degrees, delay angle α is calculated using the expression,

$$\alpha = \left(\frac{\alpha\ rad \times 180^\circ}{\pi}\right) \quad \ldots\ldots\ldots (6)$$

E. *Firing Pulse Generator*

Subsystem block of firing pulse generator is shown in Figure 7. This block is used for 3 phase AC systems to generate firing pulses with periodic variation of 3 different voltage magnitudes where, square output is generated and is made difference with firing angle, in which firing angle is generated and supplied from firing angle generator. Generated triggering pulses are applied to each cycle of thyristor controlled reactor block containing total thyristors. TCR contains two thyristor connected in anti-parallel mode in each branch. For each half cycle only one thyristor gets triggered per TCR branch and vice versa. Delay or firing angle is provided from firing angle generator as input to gate pulse generator.

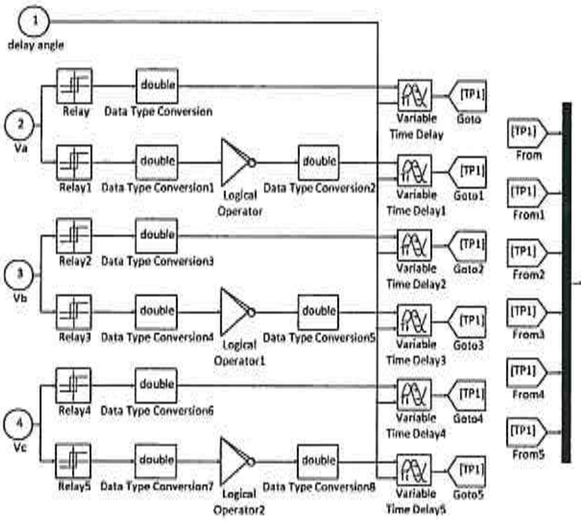


Fig. 7. Subsystem block of firing pulse generator

V. RESULTS AND DISCUSSIONS

MATLAB Simulink model is developed for power factor improvement using FC-TCR and results are obtained before and after reactive power compensation of inductive loads.

A. *Power Factor Results Before Compensation*

Table-1. shows the variation of power factor before reactive power compensation. Load data is collected for 24 hours from SCADA research laboratory on November 28, 2023 is fed into dynamic load via look-up table and simulation is carried out. With fixed capacitor, power factor results of an uncompensated inductive load are obtained.

B. *Power Factor Results After Compensation*

Table-2 shows the constant unity power factor after compensation for inductive loads. From 10 kVAr fixed capacitor, excess uncompensated leading reactive power flows into loads. To compensate this, additional lagging reactive power is supplied by connecting thyristor controlled reactor (TCR) parallel to the fixed capacitor (FC) which cancels out excess leading reactive power. Thus resultant of TCR and uncompensated VArs become zero. Finally with zero VAr output power factor becomes unity. In this case also load data is taken for total 24 hours on November 28, 2023.

TABLE I. Power Factor before compensation for the load data on November 28, 2023

Time	P Watts	Q_{Load} VArs	Power Factor
0:00	606.26	207.69	0.94
1:00	431.26	172.88	0.92
2:00	300.35	111.52	0.93
3:00	294.32	91.65	0.95
4:00	397.60	122.08	0.95
5:00	454.11	137.52	0.95
6:00	511.85	150.94	0.95
7:00	506.07	139.83	0.96
8:00	465.54	115.26	0.97
9:00	365.77	346.85	0.72
10:00	252.55	498.32	0.45
11:00	217.91	659.26	0.31
12:00	776.27	2318.98	0.31
13:00	386.26	1230.91	0.29
14:00	325.20	1259.61	0.25
15:00	440.56	1329.98	0.31
16:00	1000.51	1400.84	0.51
17:00	1301.45	1318.50	0.70
18:00	1195.25	3875.50	0.29
19:00	1233.47	1666.63	0.59
20:00	1227.93	1056.06	0.75
21:00	1173.39	743.70	0.84
22:00	1049.90	592.96	0.87
23:00	885.98	295.48	0.94

TABLE II. Power factor after compensation for the load data on November 28, 2023

Time	Q_{Load} VArs	Power Factor BC	Q_c VArs	$Q_L(\alpha)$ Vars	Power Factor AC
0:00	207.69	0.94	10000	9792.31	1
1:00	172.88	0.92	10000	9827.12	1
2:00	111.52	0.93	10000	9888.47	1
3:00	91.65	0.95	10000	9908.35	1
4:00	122.08	0.95	10000	9877.91	1
5:00	137.52	0.95	10000	9862.48	1
6:00	150.94	0.95	10000	9849.05	1
7:00	139.83	0.96	10000	9860.16	1
8:00	115.26	0.97	10000	9884.73	1
9:00	346.85	0.72	10000	9653.15	1
10:00	498.32	0.45	10000	9501.68	1
11:00	659.26	0.31	10000	9340.74	1
12:00	2318.98	0.31	10000	7681.01	1
13:00	1230.91	0.29	10000	8729.09	1
14:00	1259.61	0.25	10000	8740.38	1
15:00	1329.98	0.31	10000	8670.01	1
16:00	1400.84	0.51	10000	8599.15	1
17:00	1318.50	0.70	10000	8681.50	1
18:00	3875.50	0.29	10000	6124.50	1
19:00	1666.63	0.59	10000	8333.37	1
20:00	1056.06	0.75	10000	8943.94	1
21:00	743.70	0.84	10000	9256.30	1
22:00	592.96	0.87	10000	9407.04	1
23:00	295.48	0.94	10000	9704.52	1

Figure 8. shows variation of uncompensated load curve for total 24 hours of reactive power data, which is collected and fed in to dynamic load through look-up table and simulation is carried out. Total reactive power data is considered from

morning 12.00 AM to till night 12.00 PM. During MATLAB Simulation, load data is applied to 3-phase instantaneous active and reactive power measurement block. This is connected to power factor measurement subsystems block which shows uncompensated load reactive power curve.

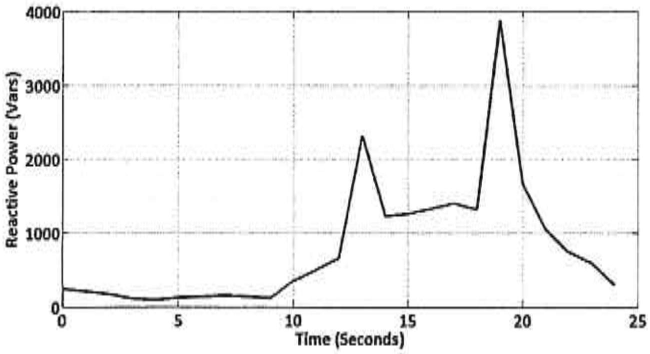


Fig. 8. Uncompensated load reactive power

Figure 9. shows power factor variation curve for the uncompensated load. Data is collected and from this, load profile is created for 24 hours of time on November 28, 2023. Power factor of applied load is calculated by considering reactive power data corresponding to the real power. Obtained results indicate that, in the morning at 12.00 AM, measured power factor is found to 0.94 lagging and at 3.00 PM an induction motor is started in which power factor of load is reduced to 0.314 lagging. This is illustrated in Table-1.

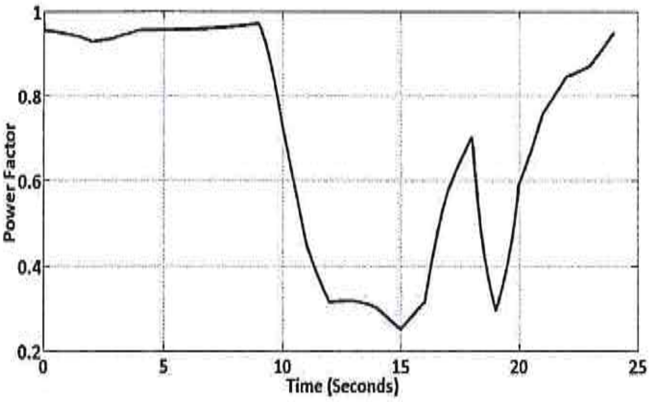


Fig. 9. Uncompensated load power factor

Figure 10. shows the capacitive reactive power curve. From this it is observed that, capacitive reactive power is constant throughout the day. Fixed Capacitor (FC) bank is connected at three phase load ends (in between source and load) to improve power factor. Required value of load reactive power demand (lagging) is supplied from 10 kVAr fixed capacitor (leading). This contains 3 delta connected capacitors in each phase which are designed with respect to total rating of fixed capacitor bank. The designed capacitance value is found to be 55μF each. Even though fixed capacitor is connected to improve load power factor, it is unable to achieve unity power factor with and without connected load. With suitable reactive power compensation by TCR, it is possible to monitor system power factor at unity in both the cases.

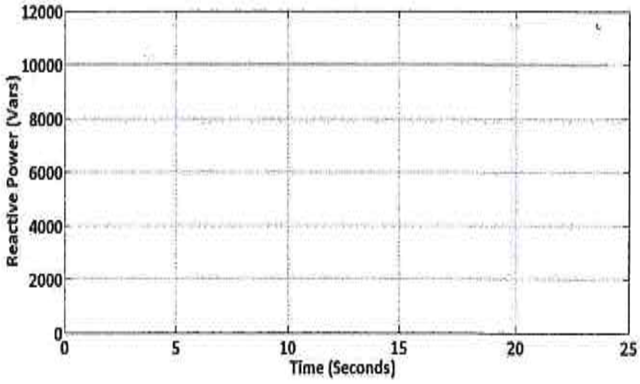


Fig. 10. Capacitive reactive power

Figure 11. shows the firing angle characteristics curve obtained from firing or delay angle generator. These are mainly required to generate firing pulses in order to trigger thyristor circuit for particular instant at each positive and negative half cycles of applied system voltage. Difference of load (lagging) and capacitive reactive power (leading) is given as input to firing angle generator. From collected load data with the designed value of TCR reactance, the firing angle generator is able to generate firing angles. These are measured in degrees.

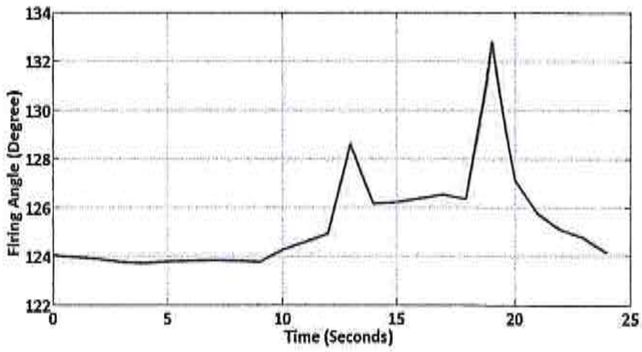


Fig. 11. Firing angle characteristics

Figure 12. shows graph for variation of TCR currents. This represents TCR current alone without connecting to fixed capacitor bank. The variation of this current represents all three phases of operation. TCR currents flow due to thyristor triggering pulses supplied from firing pulse generator. These are able to generate lagging reactive power required to compensate inductive loads. Figure 13. presents variation of TCR reactive power curve for compensating load. TCR is a VAr generator, provides lagging reactive power to compensate inductive loads. With 10 kVAr fixed capacitor, load reactive power demand is supplied and also at this time excess reactive power is supplied to operating load. This makes flow of heavy current in the system and power factor is reduced below unity. To correct system power factor to unity, load reactive power must be compensated using TCR by connecting in parallel with FC. The results reveal that, in morning at 8.00 AM with load of 115.269 VAr the TCR supplies reactive power demand of 9884.731 VAr with the fixed capacitor (FC).

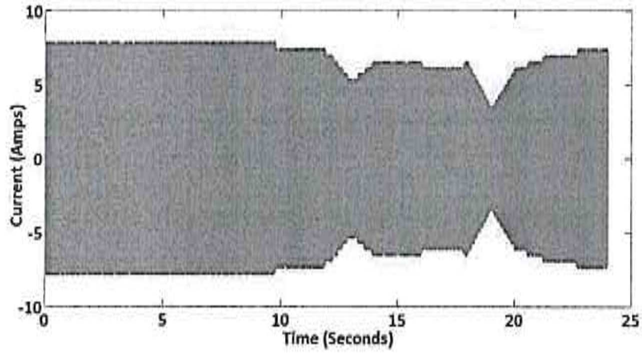


Fig. 12. TCR Per phase current

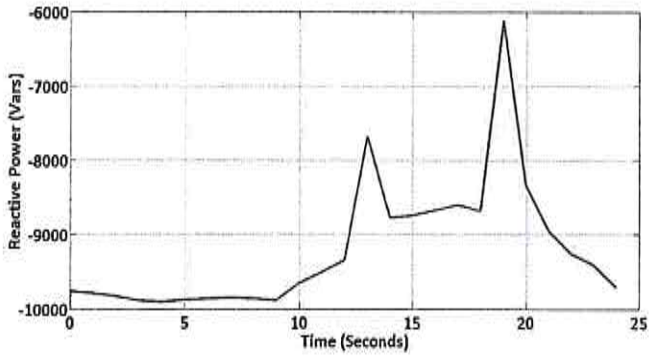


Fig. 13. TCR reactive power

Figure 14. shows that, unity power factor curve obtained through out 24 hours. In MATLAB simulation, load profile data is fed to dynamic load through look-up table. After simulation, power factor results for both cases are observed i.e. before and after reactive power compensation of inductive load. The comparison of results with and without compensation, at afternoon 12.00 noon power factor of 0.317 lagging is obtained and corresponding to this unity power factor is achieved.

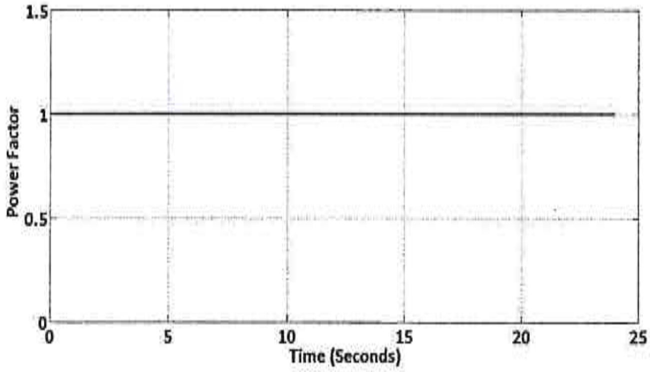


Fig. 14. Compensated power factor

VI. Conclusion

Power factor correction of inductive loads using fixed capacitor thyristor controlled reactor (FC-TCR) is developed and MATLAB Simulation model is presented in this paper. Simulation is carried out by considering the load data of Electrical and Electronics department, Basaveshwar Engineering College, Bagalkote for 24 hours on 28th Nov. 2023. Simulations are conducted with and without compensation in the system. The results are compared and comparative analysis is conducted. Results revealed that unity power factor is analytically achieved through the time span of the day. It is concluded that, for EEE Department of BEC, the proposed power factor improvement model is viable and a suitable choice in an adopting with hardware circuitry.

References

[1] N. G. Hingorani and L. Gyugyi, "Understanding FACTS Concepts and Technology of Flexible AC Transmission Systems," 1st Indian Edition, IEEE Press, New York and Standard Publishers Distributors, Delhi, 2000.

[2] Sandeep Sharma, Saket Gupta, Mohd Zuhaib, Vijay Bhuria, Hasmat Malik, Abdulaziz Almutairi, Asyraf Afthanorhan and Mohammad Asef Hossaini, "A Comprehensive Review on STATCOM: Paradigm of Modeling, Control, Stability, Optimal Location, Integration, Application, and Installation" IEEE Access, VOLUME 12, pp- 2701-2729, 2024.

[3] C. Roy, D. Chatterjee, and T. Bhattacharya, "Control of a hybrid shunt FACTS compensator for voltage collapse prevention in interconnected EHV power transmission systems", IEEE J. Emerg. Sel. Topics Ind. Electron. vol. 4, no. 2, pp. 538–548, Apr. 2023.

[4] C. Roy, D. Chatterjee, and T. Bhattacharya, "An economic hybrid shunt compensator for power factor correction and mitigation of large unbalance as in HV traction distribution system", IEEE Trans. Ind. Appl., vol. 59, no. 5, pp. 5989–5999, Sep. 2023.

[5] Basanagouda Patil, Jagadish S. Jakati, Mallikarjun B. P., Vireshkumar G. Mathad, "Enhancement of Power System and Control by Implementation of FACTS devices", Journal of Data Acquisition and Processing Vol. 38 (2), pp- 4048-4049, 2023.

[6] Urbanus MwanziaNgei and Peter Musau Moses, "Optimization of FACTS Devices for Power System Performance Improvement: A Review", IEEE PES/IAS Power Africa, 2023.

[7] Vireskumar Mathad, Gururaj Kulkarni, "Artificial-Neural-Network based Unified Power Flow Controller (UPFC) for Mitigation of Power Oscillations", Indonesian Journal of Electrical Engineering and Computer Science, Vol. 24, No. 3 December, pp. 1323 to 1331, 2021.

[8] M. A. Kamarposhti, Hassan Shokouhandeh, Ilhami Colak, Shahab S. Band and Kei eguchi, "Optimal Location of FACTS Devices in Order to Simultaneously Improving Transmission Losses and Stability Margin Using Artificial Bee Colony Algorithm", IEEE Access, VOLUME 9, pp- 125920- 125929, 2021.

[9] M. K. Zarkani, A. S. Tukkee, and M. J. Alali, "Optimal placement of facts devices to reduce power system losses using evolutionary algorithm," vol. 21, no. 3, 2021, pp. 1271–1278.

[10] YacineTerriche, Chun-Lien Su, AbderezakLashab, Muhammad UmairMutarraf, MojtabaMehrzadi, Josep M. Guerrero and Juan Carlos Vasquez, "Effective Controls of Fixed Capacitor-Thyristor Controlled Reactors for Power Quality Improvement in Shipboard Microgrids", IEEE Transactions on Industry Applications, Vol. 57, NO. 3, May/June, pp- 2838-2849, 2021.

[11] M.Rajalakshmi, Molla Addisu, N.Jeyakkannan , G. Renuka Devi and C.Karthik, "Optimal Placement of Voltage Regulator and Capacitor for Distribution System", nternational Conference on System, Computation, Automation and Networking, ISBN 978-1-6654-3986-2, 2021

[12] A. A. Shehata and N. V Korovkin, "Efficient Utilization of the Power Grid using FACTS devices based on a new Metaheuristic Optimizer", 3rd International Youth Conference on Radio Electronics, Electrical and Power Engineering, 2021.

[13] Imdadullah, S. M. Amrr, M. S. J. Asghar, I. Ashraf and M. Meraj, "A Comprehensive Review of Power Flow Controllers in Interconnected Power System Networks," IEEE Access, vol. 8, pp. 18036-18063, 2020.

[14] Y. Terriche, Chun-Lien Su, Muhammad. U. M., Mojtaba M., Abderezak L., Josep M. Guerrero and Juan C. Vasquez, "Harmonics Mitigation in Hybrid AC/DC Shipboard Microgrids Using Fixed Capacitor-Thyristor Controlled Reactors", International Conference on Environment and Electrical Engineering and Industrial and Commercial Power Systems Europe, 2020

[15] A. R. Jordehi, "Optimal allocation of FACTS devices for static security enhancement in power systems via imperialistic competitive algorithm (ICA)," Appl. Soft Comput. J., pp. 1–13, 2016

[16] Vireshkumar G. M, Ronad.B.F, Jangamshetti. S. H, "Voltage Control and Stability Enhancement using UPFC", International Conference on Renewable Energy and Power Quality-14, Renewable Energy & Power Quality Journal, ISSN: 2172-038X, No.12, April 2014, ISBN:978-84-616-8196-9, Spain, pp-.671-675.

[17] Vireshkumar G. Mathad, Basangouda F. Ronad, Suresh H. Jangamshetti, "Review on Comparison of FACTS Controllers for Power System Stability Enhancement", International Journal of Scientific and Research Publications, Volume 3, Issue 3, ISSN 2250-3153, March 2013

[18] Shunfu Lin, DiogoSalles, WalmirFreitas and WilsunXu, "An Intelligent Control Strategy for Power Factor Compensation on Distorted Low Voltage Power Systems", IEEE Transactions on Smart Grid, VOL. 3, NO. 3, September, pp- 1562-1570, 2012

[19] Dean G. Duffy, "Advanced Engineering Mathematics with MATLAB," CRC Press, 3rd Edition, ISBN-13: 978-1439816240, 2010.

[20] M. A. Abdel-Moamen and N. P. Padhy, "Optimal Power Flow Incorporating FACTS Devices Bibliography and Survey", IEEE PES Transmission and Distribution Conference and Exposition, vol. 2, pp. 669 – 676, 7–12 September 2003.

Role of renewable energy in sustainable development

Dr.Sachin A Mehta[1],Dr.Samira J Bagewadi[2],Prof.Kishor S. Joshi[3]

[1*]*Associate Professor, Dr.A.D.Shinde College of Engineering, Gadhinglaj.*

[2]*Principal Vidya Samvardhak Mandal, CBSE School Nipani.*

[3]*Vice-Principal, Dr.A.D.Shinde College of Engineering , Gadhinglaj.*

sachi21.sm@gmail.com[1], samirabagewadi@gmail.com[2] kishorjoshinds@gmail.com[3]

Abstract

Non-conventional energy sources are essential for good sustainable development and no environmental pollution. While the high growth enhances human well-being, it also has environmental repercussions. In an around world transitioning from conventional to non conventional can help alleviate environmental change, it will hinder progress towards achieving sustainable development. This study employs role of renewable energy for sustainable development for providing a roadmap for solar and wind energy along with hybrid energy systems for anticipating and improving the impact of a low-carbon transition while ensuring climate objectives. Our multidisciplinary approach started with evaluating public investments in renewable energy. After implementing renewable energy source projects into the environment maximum CDM benefits will be earned to respective organizations.

Our research identified gaps in our understanding of renewable energy toward sustainable development. This led to the creation of a good roadmap for a future of renewable energy that aligns with both climate global change and sustainable environment. Our findings provide a role of renewable energy for the good sustainable development. It will achieve good human, animal health towards green, healthy environment.

Keywords :- Sustainable development, solar and wind energy, climate change, renewable Energy.

I. INTRODUCTION

Renewable energy plays a vital role for the development of country in such way that it's overall susitanable development toward earth, green energy. In the world various countries mainly focus on non-conventional energy projects. Non-conventional energy project after implementation certain countries give CDM benefits (Clean Development Mechanisms). It will reduce the carbon emission into the environment and green sustainable climate change within the country. In various countries (state /central govt.) agencies mostly gives subsidy for the installation of non-conventional energy projects.

In the society increasing the public awareness towards sustainability and reducing the environmental impact towards green energy implementation. One of the major concern reducing the impact towards non-conventional sources for good efforts to achieve sustainability achievement. For achieving towards the renewable energy goals into the environment it is decided that there is great need for the roadmap for renewable energy project implemented towards society. Most of the industry stakeholders showing interest in investing in renewable energy technologies.

II. LITERATURE REVIEW

Non-conventional energy plays a vital role in the environmental development. Some researchers studies [1] had mainly planned wind energy programme in India. They argued that wind energy was an alternative energy option for sustainable growth of society, whereas [2] they studied waste management technologies in India. Their conclusion mainly shows that there are wide range of opportunities through waste to energy technology. [3] mainly studied wind energy development and policy in India. As per their reports mainly indicate wind energy potential approximately 10-12 % in India. [4] et.al had mainly studied renewable sources of energy in south asian countries. He mainly focus on challenges and policy for non-conventional energy sources.

[5] had mainly studied status of solar and renewable energy in India. He argued that there has a huge potential in India. Whereas [6] mainly studied for non-conventional energy sources for rural community in Maharashtra. Their results mainly shows that solar and wind are wide options for Maharashtra state in India. [7] Mainly studied renewable energy current status and future potential in India, whereas [8] had studied wind power status and achievements towords renewable power development in the countries (India). [9] The author mainly studied renewable energy potential and status in Tamilnadu. They clearly mentioned that wind energy maximum potential obtained in Tamilnadu state. [10] had mainly studied small hydro energy potential in India. They had to be mentioned current trends & future aspect for hydro energy whereas [11] are studied off-grid solar lighting system which was sustainable way for society. [12] Mainly focus on repowering for the next India i.e. non-conventional energy soucres are better option for future India whereas [13] et al. had mainly studied recent development of solar energy in India. Their conclusion mainly shows that solar thermal and solar PV application in India has bigger opportunities in market. [14] mainly

focus on evaluation of non-conventional energy sources based on rural development. Their results mainly shows that solar and wind has huge potential across India. [15,16] had mainly focus on solar desalination system. They mainly design and develop hybrid solar desalination system; He mainly argued that single effect boiling approach is better option for solar desalination system in non-conventional energy sources. The author [17] mainly focus of non-conventional energy for sustainable development in India, It's review outcome to be provided researchers, scientists, industries for future development in India.

After most of the studies from literature review, it was clear that most of the researchers had studied analytical, numerical and experimental investigations on the non-renewable projects, green environment and less carbon emission projects. Some of the authors they argued that renewable energy plays a vital role for financial economy of the country. In the literature review it was not observed for clear roadmap regarding renewable energy for the climate change and sustainable development. In this article author mainly focus role of renewable energy for green sustainable development.

III. RENEWABLE ENENRGY TO SUSTAINABLITY

Renewable energy power generation :-

Renewable energy plays a vital role towards sustainability. It will undoubtedly become more important in a world where energy consumption will be 60 % higher than other countries energy consumption. Although it has already attracted a large number of investors. According to the data, provided through renewables generated barely 21 % of global energy demand in 2013. It has seen that non conventional energy fastest growing sector. In the current decades there is a huge potential for non-conventional energy sources for the power generation application. The following graph shows that various renewable energy sources with different percentages for annual growth rate installed capacity.

The figure 1 mainly describes the annual growth rate for installed capacity in non conventional energy sources. It was shows that solar thermal / PV sources maximum 40 % as compared to the other renewable energy sources. Hence it was shows that there is more vital scope towords renewable energy for sustainability. It also reduces the pollution into the environment which will helps for better climate change.

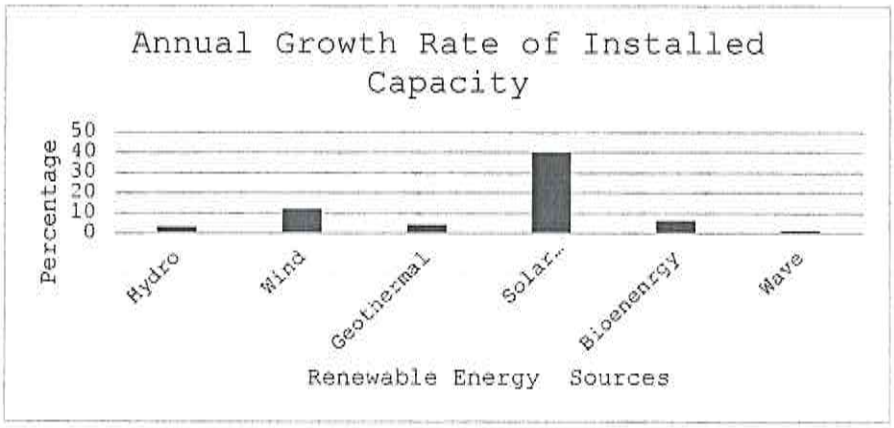


Figure 1. Renewable Energy Technology – Annual Growth Rate in Percentage

Energy Cost

Renewable energy systems are often seen as having high starting costs, which is the primary impediment to their widespread growth. The energy cost plays a vital role in the non-conventional energy. Initial capital investment cost is the crucial parameter for energy cost calculations towards entire project. As comparing the various non-conventional energy sources it is clearly indicated that solar thermal / PV initial capital investment cost in the range of (1200 – 3800 $ /kW).

Electricity generated by non-renewable energy is highly reliant for the different parameters such as site selection and environmental and climatic condition resulting in a different variety of costs across systems. It is argued that after implementation of such project gives longer financial benefit up to the maturity stage. In addition to that increasing their reliability and monitoring of the entire system to avoid as minimum as carbon emission into the environment.

Sr. No.	Renewable Energy Technology	Capital cost ($/kW)
1	Hydro	750 – 6000
2	Wind	925 - 6040
3	Geothermal	1900 - 5000
4	Solar Thermal / PV	1200 – 3800
5	Bioenergy	500 – 6500

6	Wave	5290 -5870

Table 1 :- Renewable energy technology with initial capital cost ($ / kW)

Table 1 shows that renewable energy technology with capital cost in ($/kW). It has shown that some of the renewable energy sources are costlier whereas some as cheaper. While selecting sources it is kept in mind according to availability, less cost and more output to be selected for implementation. It has been recognised that solar PV / thermal and hydropower are the primary energy sources for energy generation and some of other sources under development category obtained.

Social Impacts towards sustainability

It is true that measuring the social consequences of non conventional energy is equally important as examining their society and financial impact towards sustainability. To estimate social implications, social approval of various technologies must be determined. It is great social impact after non-conventional energy projects towards sustainability. Through direct benefit for green energy to the society and less (air/water/noise/soil) pollution to be achieved. For the other hand some of the researchers showing public supports for such renewable energy projects. It is good indicator for social acceptance for renewable energy projects for implementation towards society.

IV. CONCLUSION AND FUTURE SCOPE

Non-conventional energy sources are plays key role for achieving goal of sustainable development. In and around world many companies, stakeholders interested in non-conventional energy sources not only gaining financial advantages but also mainly contributing towards overall worldwide sustainability efforts. Hence non-conventional energy plays a significant role for mentioning good sustainability towards green environment.

The rising carbon footprint is a significant concern that is being addressed in developed nations through various strategies. Additionally, ongoing development and research in these technologies are contributing to a reduction in initial costs. Such factors render renewable energy systems an appealing investment option. Regarding social acceptance and impacts, each technology presents its own set of challenges and advantages that warrant careful consideration. It is essential to devise solutions that enhance the perceived benefits of renewable technologies for local communities while mitigating any negative effects they may experience. Furthermore, it is crucial to enhance public understanding of the potential benefits of renewable energy technologies and the necessity of taking bold actions to address pressing global issues, such as CO_2 emissions. These initiatives can significantly shift public perception of these technologies in a favorable direction.

For future investigations, it is advisable to conduct multi-criteria analyses to evaluate and compare the sustainability of various non-conventional energy sources. This approach can yield optimal solutions for selecting the appropriate technology for a specific location. Additionally, it may be beneficial to consider concentrated solar power technology, which is regarded as a novel and promising renewable energy option for electricity generation. In summary, renewable energy technologies are gaining increasing popularity on a daily basis. Nevertheless, their contribution to global energy production remains relatively minimal. In future renewable energy plays a vital role for sustaining human-animal towards green, cleaner environment.

References

1) Charles Rajesh Kumar. J, Vinod Kumar. D, M.A. Majid (2019) Wind energy programme in India: emerging energy alternatives for sustainable growth. 'Energy & Environment' 30(7), pp.1135-1189.

2) Charles Rajesh Kumar. J, Mary Arunsi. B, Jenova. R, M.A.Majid (2019) Sustainable waste management through waste to energy technologies in India—opportunities and environmental impacts .'International journal of renewable energy research' 9(1), pp.309-342.

3) Sholapurkar RB, Mahajan YS (2015) Review of wind energy development and policy in India. 'Energy Technology & Policy' 2, pp.122–132

4) Akash Kumar Shukl (2017) Renewable energy resources in South Asian countries: challenges, policy and recommendations. 'Resource-Efficient Technologies' 3, pp.342-346.

5) Vikas Khare, Savita Nema, Prashant Bareda (2013) Status of solar wind renewable energy in India, 'Renewable and Sustainable Energy Reviews' 27, pp.1-10

6) T.Blenkinsopp, S.RColes ,K.Kirwan (2013) Renewable energy for rural communities in Maharashtra, India, 'Energy Policy'.60, pp.192-199

7) Ashwani Kumar,Kapil Kumar, Naresh Kaushik, Satyawati Sharma,Saroj Mishra, Renewable energy in India:Current status and future potentials,'Journal of renewable and sustainable energy reviews',14(2010),2434-2442

8) Subhojit Dawn, Prashant Kumar Tiwari, Arup Kumar Goswami, Ankit Kumar, Singh Rajesh Panda (2019) Wind power: Existing status, achievements and government's initiative towards renewable power dominating India.'Energy Strategy Reviews' 23.pp.178-199.

9) J. Jeslin Drusila Nesamalar, P. Venkatesh, S. Charles Raja (2017) The drive of renewable energy in Tamilnadu: Status, barriers and future prospect. 'Renewable and Sustainable Energy Reviews'.73.pp 115-124.

10) Mukesh Kumar Mishra, Nilay Khare,Alka Bani Agrawa (2015) Small hydro power in India: Current status and future perspectives. 'Renewable and Sustainable Energy Reviews'.51, pp.101-115.

11) Sravanthi Choragudi (2013) Off-grid solar lighting systems: a way align India's sustainable and inclusive development goals. 'Renewable and Sustainable Energy Reviews'.28, pp.890-899.

12) Mohit Goyal (2010) Repowering - next big thing in India. 'Renewable and Sustainable Energy Reviews'.1 4(5). pp.1400-1409.

13) Dawn,Subhojit Dawn, Prashant Tiwari, Arup Kumar Goswami, Manash Kumar Mishra.(2016). Recent developments of solar energy in India: perspectives, strategies and future goals. 'Renewable and Sustainable Energy Reviews'.62. pp. 215-235.

14) Jozsef Benedek, Tihamer-Tibor Sebestyen, Blanka Bartok (2018) Evaluation of renewable energy sources in peripheral areas and renewable energy-based rural development. 'Renewable and Sustainable Energy Reviews'.90,pp.516-535.

15) Kedar Shridhar, Kumaravel A.R., Bewoor, A.K. (2019). Experimental investigation of solar desalination system using evacuated tube collector. International Journal of Heat and Technology, Vol. 37, No. 2, pp. 527-532.

16) Kedar Shridhar, Kumaravel A.R., Bewoor, A.K.(2019) Performance analysis of hybrid solar desalination system using ETC and CPC. SN Applied Science 1,965.

17) Kumar. J, C.R., Majid, M.A.(2020) Renewable energy for sustainable development in India: current status, future prospects, challenges, employment, and investment opportunities. Energy Sustainability and society. 10, 2.pp. 1-36.

CERTIFICATE

INTERNATIONAL CONFERENCE on INNOVATION AND SUSTAINABILITY Reimagining and Repositioning (Business, Information Technology, Environment & Society)

Organized by

CHHATRAPATI SHAHU INSTITUTE OF BUSINESS EDUCATION AND RESEARCH (CSIBER), KOLHAPUR, MAHARASHTRA, INDIA.

(An Autonomous Institute Under UGC, Government of India), Accredited by NAAC with 'A+' Grade
RUSA 2.0 Quality Enhancement and Excellence of Higher Education,
College with Potential For Excellence (CPE III), Government of India

In Association With

University of Vavuniya, Sri Lanka, University of Technology, Mauritius & Anton De Kom University of Suriname

This is to Certify that Dr. Sachin A Mehta of Dr.A.D.Shinde College of Engineering, Gadhinglaj has presented a paper titled Role of renewable energy in sustainable development at the International Conference on "Innovation and Sustainability Reimagining and Repositioning (Business, Information Technology, Environment & Society)" organized by CHHATRAPATI SHAHU INSTITUTE OF BUSINESS EDUCATION AND RESEARCH (CSIBER), KOLHAPUR, India on 14th & 15th March, 2025.

Dr. B. N. Menon
I/c. Director, CSIBER

Prof. Dr. R. A. Shinde
PRESIDENT & MANAGING TRUSTEE

Dr. A. D. Shinde College of Engineering • Tal. Gadhinglaj • Bhadgaon

CERTIFICATE

INTERNATIONAL CONFERENCE on INNOVATION AND SUSTAINABILITY Reimagining and Repositioning (Business, Information Technology, Environment & Society)

Organized by

CHHATRAPATI SHAHU INSTITUTE OF BUSINESS EDUCATION AND RESEARCH (CSIBER), KOLHAPUR, MAHARASHTRA, INDIA.

(An Autonomous Institute Under UGC, Government of India), Accredited by NAAC with 'A+' Grade
RUSA 2.0 Quality Enhancement and Excellence of Higher Education,
College with Potential For Excellence (CPE III), Government of India

In Association With

University of Vavuniya, Sri Lanka, University of Technology, Mauritius & Anton De Kom University of Suriname

This is to Certify that Prof. Kishor S. Joshi of Dr.A. D. Shinde College of Engineering,Gadhinglaj has participated in International Conference on "Innovation and Sustainability Reimagining and Repositioning (Business, Information Technology, Environment & Society)"organized by CHHATRAPATI SHAHU INSTITUTE OF BUSINESS EDUCATION AND RESEARCH (CSIBER), KOLHAPUR, India on 14th & 15th March, 2025.

Dr. B. N. Menon
I/c. Director, CSIBER

Prof. Dr. R. A. Shinde
PRESIDENT & MANAGING TRUSTEE

Dr.A.D.Shinde College of Engineering Bhadgaon Tal.Gadhinglaj