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DESIGN AND DEVELOPMENT OF THREE - PHASE TRANSFORMER

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Abstract: Three-phase Transformers are the backbone of electrical power distribution this research paper presents a comprehensive analysis of key insights gleaned in centered on the construction and design of 3-phase transformers within industrial electrical systems and equipment. It delves into various facets including the intricacies of 3-phase transformer design, component identification and testing, and the significance of material analysis in transformer manufacturing. By amalgamating theoretical understanding with practical applications, the report paper aims to furnish readers with a thorough comprehension of vital concepts and methodologies crucial for proficient management and enhancement of industrial electrical infrastructures.

I. INTRODUCTION

In the realm of industrial electrical systems and equipment, the construction and design of 3-phase transformers stand as pivotal components, orchestrating the efficient transmission and distribution of electrical power. This report paper embarks on a journey through the insights garnered from delving deep into the intricacies of 3-phase transformer construction and design.

The primary aim of this report paper is to offer a comprehensive overview of the key learnings and observations derived from our immersive exploration. Central to this endeavor is a meticulous analysis of various aspects surrounding 3-phase transformers. We began by dissecting the nuances of transformer design, shedding light on the critical considerations and methodologies that underpin its construction.

Moreover, this project work extends to the identification and testing of diverse components integral to transformer functionality. By scrutinizing these components, valuable insights were gained about their roles and interactions within the broader context of industrial electrical systems. Crucially, this report paper underscores the paramount importance of analyzing appropriate materials in transformer fabrication. Through meticulous material selection and evaluation, we elucidate how the performance and reliability of transformers are profoundly influenced, thereby emphasizing the significance of this aspect in ensuring optimal functionality.

The complexities inherent in 3-phase transformer engineering are aimed to be unraveled through the realm of design, fabrication, implementation, and quality assurance, with our objective remaining steadfast. By synthesizing theoretical knowledge with practical applications gleaned from our industrial visit, we endeavor to equip readers with a robust understanding of the essential concepts and methodologies indispensable for the effective management and optimization of industrial electrical infrastructure.

Through this holistic approach,it has been aspired not only to enrich our understanding of 3-phase transformers but also to empower stakeholders with the requisite knowledge and insights to navigate the intricate landscape of industrial electrical systems with confidence and proficiency.

II. LITERATURE REVIEW

1. 3-Phase transformer:Connection and configuration
The research paper focuses on three-phase transformers in electrical power distribution, discussing their construction, advantages over single-phase transformers, and their essential role in power generation, transmission, and industrial applications. It explains how three single-phase transformers can be connected for use on a three-phase supply and highlights the electrical advantages and unique characteristics of three-phase systems for efficient power distribution.

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2. 3-Phase Transformer Used on single phase:
This paper investigates using a three-phase transformer with a single-phase power source and load. It discusses different methods of utilizing the transformer and loading techniques, validating theoretical assumptions through measurements. The research focuses on determining the most effective approach for power supply and load configuration to maximize transformer performance.

3. A survey of transformers
Study by Tianyang Lin offers a comprehensive review of various Transformer variants (referred to as X-formers) across different artificial intelligence fields such as natural language processing, computer vision, and audio processing.

III. METHODOLOGY

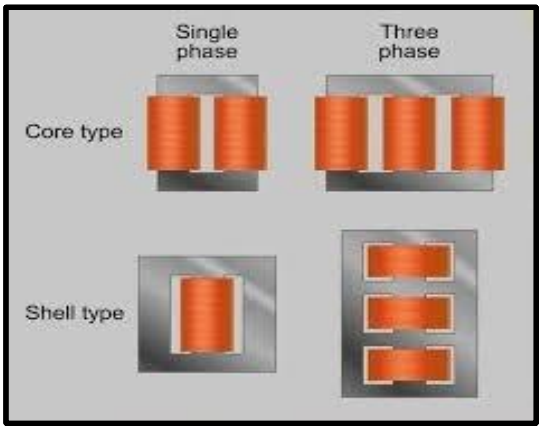
The methodology outlined in the introduction encompasses several key components. It begins with a focused industrial visit, providing firsthand experience and observation of 3-phase transformers in operational settings. This visit likely involved studying schematics, blueprints, and technical documentation to understand the design principles of these transformers. Additionally, researchers likely engaged in hands-on activities, such as identifying and rigorously testing various components integral to transformer functionality, including cores, windings, and insulation materials.

A crucial aspect of the methodology involves meticulous material selection and evaluation for transformer fabrication. This includes studying the properties of different materials and assessing their suitability based on factors like electrical and thermal conductivity, mechanical strength, and cost-effectiveness. By synthesizing theoretical knowledge with practical insights gained from the industrial visit, the methodology aims to provide a comprehensive understanding of 3-phase transformer engineering.

1. Types of Transformers[1]:

Core-Type Transformer:
1.Core Material: High permeability materials like silicon steel laminations.
2.Windings: Primary and secondary windings wound around the core limbs.
3.Magnetic Flux: Alternating current in primary winding induces alternating magnetic flux in the core, inducing voltage in secondary winding.
4.Iron Losses: Hysteresis loss and eddy current loss due to core material properties.
5.Advantages: Better mechanical strength, lower leakage flux, and reduced losses compared to core-type transformers.
6.Operation: Primary winding receives electrical power, inducing a magnetic field in the core, resulting in voltage induction in the secondary winding.Refer diagram 1(a).

Shell-Type Transformer:
1.Core Structure: Consists of two separate cylindrical limbs, with windings around the central limb.
2.Windings: Primary and secondary windings wound concentrically on the central limb.
3.Magnetic Circuit: Flux travels through both limbs of the core, providing a shorter magnetic path, reducing losses.
4.Advantages: Better mechanical strength, lower leakage flux, and reduced losses compared to core-type transformers.
5.Operation: Similar to core-type transformers, primary winding induces a magnetic field, resulting in voltage induction in the secondary winding.



1(a): Types of transformers

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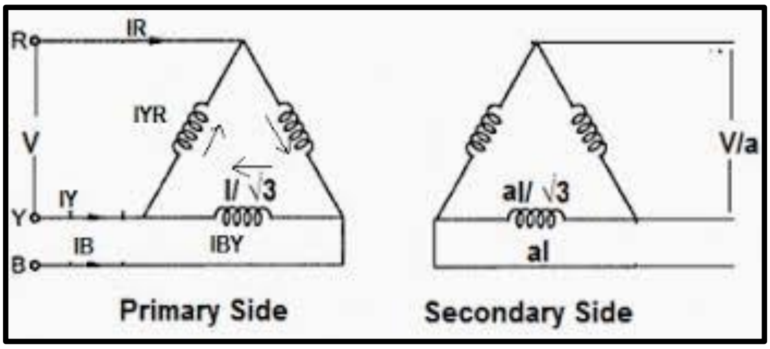
2. Types of Connections[1]

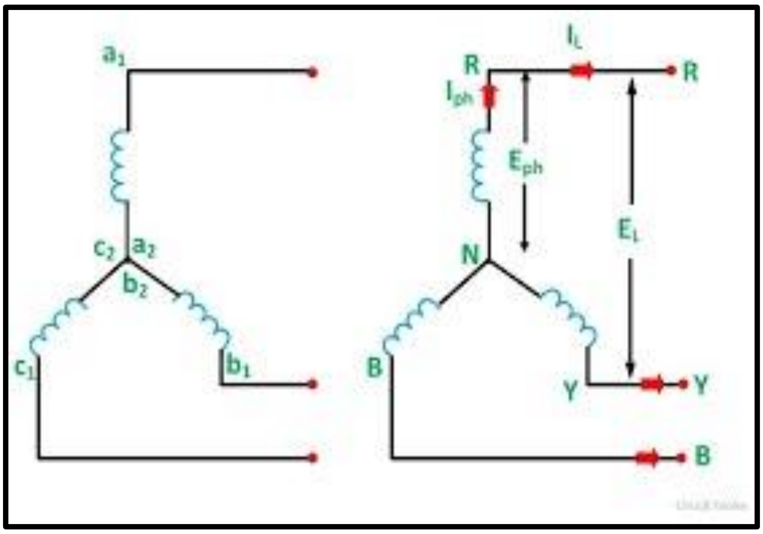
A] Delta-Delta Connection:
1.In a Delta-Delta connection, the primary and secondary windings of each transformer are connected in a delta configuration.
2.This connection is commonly used in industrial applications where loads are balanced and phase shifts are not critical. It provides isolation between the primary and secondary systems.Refer 2(a).



2(a):Delta-Delta connection

B] Star-Star Connection:

1.In a Star-Star connection, both the primary and secondary windings of each transformer are connected in a star or wye configuration.
2.This connection is widely used in distribution systems where balanced loads and neutral grounding are necessary.
3. It offers good voltage regulation and is suitable for both balanced and unbalanced loads. Refer 2(b).



2(b):Star-Star connection

C] Delta-Star Connection:

1.In a Delta-Star connection, the primary winding is connected in a delta configuration, while the secondary winding is connected in a star configuration.
2. This connection is often employed when the primary voltage is higher than the secondary voltage, providing a step-down transformation.
3.It is commonly used in distribution systems to supply lower voltage to consumers.Refer 2(c).

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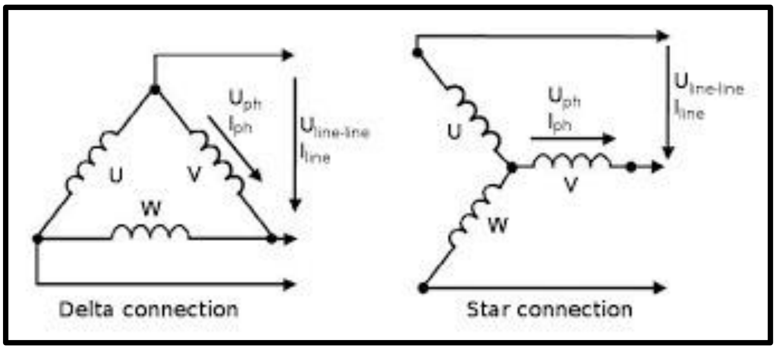
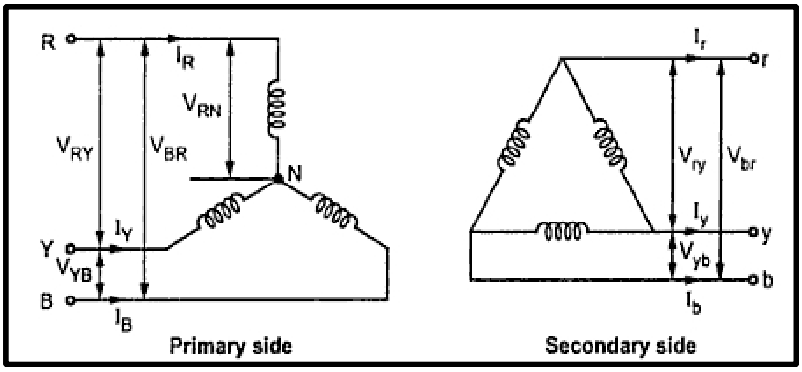


2(c): Delta-Star connection

D] Star-Delta Connection:

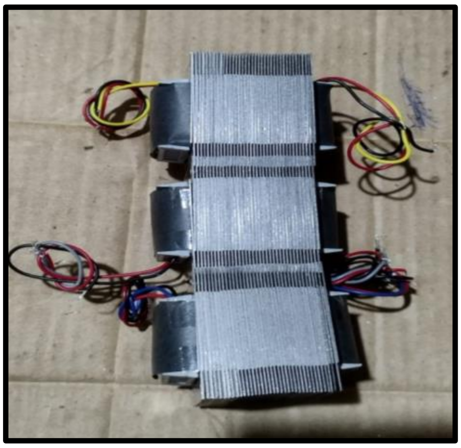
1.In a Star-Delta connection, the primary winding is connected in a star configuration, while the secondary winding is connected in a delta configuration.
2. This connection is utilized when the primary voltage is lower than the secondary voltage, offering a step-up transformation.
3.It is commonly found in industrial applications where high starting torque is required for motors.Refer 2(d).



2(d):Star-Delta connection

3.Components for building 3-phase transformer

A] Core:
1. The core is typically made of laminated steel sheets or amorphous metal, providing a low reluctance path for magnetic flux.
2.It serves to concentrate the magnetic field generated by the primary winding, facilitating efficient energy transfer between windings.Refer 3(a).



3(a): Laminated steel core

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B] Transformer Windings:
1.The primary and secondary windings are coils of insulated copper or aluminum wire wound around the core.
2.The primary winding receives electrical energy from the source, while the secondary winding delivers energy to the load.
3.In 3-phase transformers, there are three sets of primary and secondary windings, one for each phase.Refer 3(b).

3(b): Copper windings

C] Laminations:
1.They are composed of insulated silicon steel or amorphous metal sheets, from the core of 3-phase transformers.
2.They minimize eddy current losses, improving efficiency by reducing circulating currents induced by magnetic flux.
3.Additionally, laminations facilitate efficient energy transfer between windings, mitigating core losses like hysteresis and ensuring optimal performance.
4.Through careful selection of thickness and material properties,laminations help control magnetic saturation within the core, maintaining stability across varying loads.
5.Mechanically, laminations offer structural support, ensuring the core's integrity under operational stresses. In essence, laminations are pivotal components that enhance efficiency, reduce losses, and provide stability in 3-phase transformer construction.Refer 3(c).

3(c): Steel laminations

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D] PVC Thermistor Strips:
1.PVC thermistor strips: they are sometimes used in 3-phase transformers, serve as temperature sensors for monitoring and controlling the operating temperature of the transformer.
2.These strips contain thermistors(temperature sensitive resistors) embedded within PVC insulation.
3.As the temperature changes, the resistance of the thermistor changes accordingly, providing an electrical signal proportional to the temperature.
4. This signal is then used by temperature monitoring systems to regulate cooling mechanisms or activate alarms in case of overheating.

E] Bakelite Sheets:
1.These sheets are made up of Bakelite,which is a type of phenolic resin and is known for its electrical insulation properties and mechanical strength.
2.When used in conjunction with PVC thermistor strips, bakelite sheets provide additional insulation and mechanical support, ensuring that the thermistors are securely embedded and protected within the transformer assembly.Refer3(f)

3(f): Bakelite Sheets

F] Varnish:
1.Varnish coats winding coils, preventing short circuits and ensuring safe operation.
2.Shields coils from moisture, dust, and contaminants, prolonging transformer lifespan.
3.Enhances insulation's ability to withstand high voltages, reducing electrical faults.
4.Dampens noise and vibration, contributing to quieter operation.
5.Overall, varnish is crucial for insulating, protecting, and improving the performance of three-phase transformers in electrical systems.Refer 3(g).

3(g): Varnish

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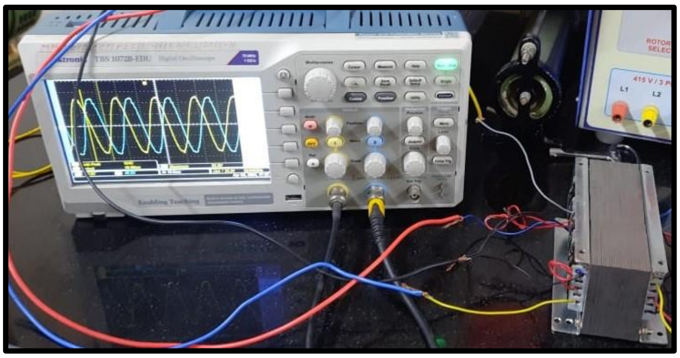
IV. TESTING AND OBSERVATIONS

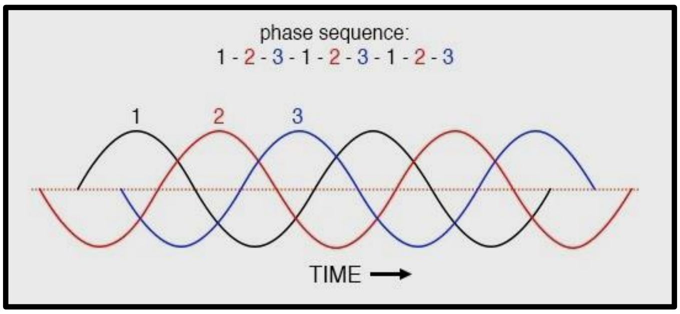
Performance characteristics:

1.Testing phase sequence of a 3- phase transformer :

Testing the phase sequence of a 3-phase transformer is fundamental for ensuring correct alignment of primary and secondary windings. In a balanced 3-phase system, each phase is typically offset by 120 degrees from the others. The phase sequence indicates the order in which these phases reach their peak voltages, crucial for the proper operation of electrical equipment. Incorrect phase sequence can lead to reversed rotation in motors, malfunctioning of equipment, and potential damage to electrical components.

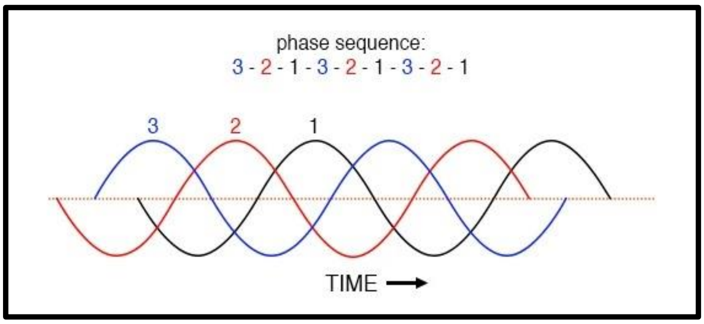


1: Phase sequence testing



(CLOCKWISE ROTATION)

To conduct the test, a low-voltage source is applied to the primary winding, generating a signal with a known sequence, such as ABC or ACB. The resulting voltages on the secondary side are observed and compared to the expected sequence. Technicians measure the voltages across the secondary windings to determine the sequence in which they rise and fall. If the observed sequence matches the expected one, the phase sequence of the transformer is correct. Any discrepancy indicates an incorrect phase sequence, requiring corrective action to reconfigure the primary side connections.



(COUNTER CLOCKWISE ROTATION)

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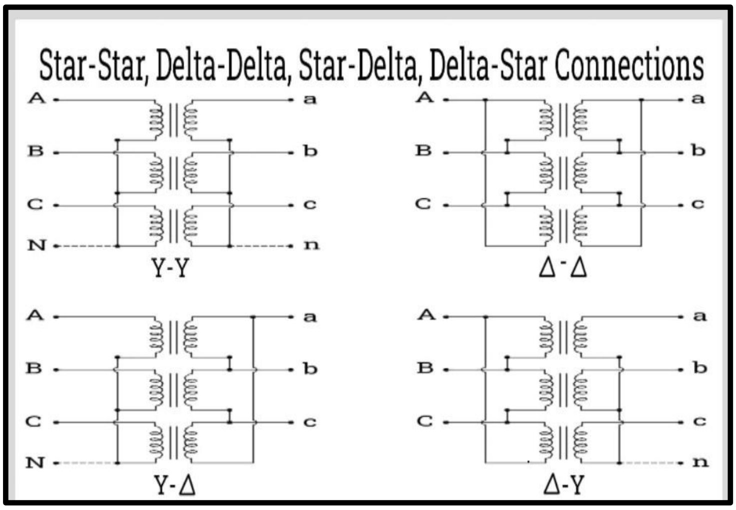
V. CIRCUIT DIAGRAM OF 3-PHASE TRANSFORMER FOR VARIOUS CONNECTIONS



2.Transformer connections

A)Delta-Delta (Δ-Δ) Transformer:
1.Primary and secondary windings connected in delta (Δ) configuration.
2.No neutral connection.
3.Three phases labeled A, B, and C for both primary and secondary windings.
4.Closed delta loops in the circuit diagram.

B)Delta-STAR (Δ-Y) Transformer:
1.Primary winding connected in delta (Δ) configuration.
2.Secondary winding connected in STAR(Y) configuration.
3.Provides neutral connection on the secondary side.
4.Delta connection for primary winding, wye connection for secondary winding.
5.Neutral terminal on the secondary side.

C)Star-Delta (Y-Δ) Transformer:
1.Primary winding connected in STAR (Y) configuration.
2.Secondary winding connected in delta (Δ) configuration.
3.Provides neutral connection on the primary side.
4.Wye connection for primary winding, delta connection for secondary winding.
5.Neutral terminal on the primary side.

D) Star - Star(Y-Y) Transformer:
1.Both primary and secondary windings connected in STAR (Y) configuration.
2.Provides neutral connection on both primary and secondary sides.
3.Star connection for both primary and secondary windings.
4.Neutral terminals on both sides.

VI. CONCLUSION

Understanding the theory behind various 3-phase transformer circuit diagrams is essential in electrical engineering. These transformers are integral to power distribution, transferring electrical energy efficiently across different voltage levels. Each configuration offers specific advantages tailored to different applications. For instance, delta-delta transformers are valued for their simplicity and suitability in applications where neutral connections are unnecessary. Conversely, delta-star and star-delta configurations provide versatile neutral connections, accommodating grounding and single-phase load requirements. The star-star configuration ensures balanced power distribution and enhanced reliability, crucial for sensitive environments like data centers and hospitals. Additionally, auto-transformers offer efficient voltage adjustment with reduced size and cost, leveraging a single winding with tap points.

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A comprehensive understanding of these configurations empowers engineers and technicians to optimize system performance, reliability, and safety in diverse industrial, commercial, and residential applications. Through ongoing research and innovation, the electrical engineering field continues to advance, driving efficiency and sustainability in modern power systems.

VII. ACKNOWLEDGEMENT

This design, development and study project was carried out under guidance of **Mr. MADHAV GOKHALE SIR** proprietor of, “**GOKHALE TRANSFORMERS**” who provided us all the required resources for the successful completion of the project.

REFERENCES

[1] Saif Aldeen Saad Alkadhim(2020). "Three phase Transformer:Connection and Configuration" Research Gate,1-6.
[2] Michaela Vachtlova (2011)."3-phase transformer used on single phase"IEEE Xplore.
[3] Tianyang Lin,Yuxin Wang,Xiangyang Liu,Xipeng Qiu(2022)."A survey of transformers"ScienceDirect
[4] Parasnath, Pushpanjali Singh Bisht, Saubhagya Kumar Moharana, Anjali Kumari(2018)."Testing of transformer for its reliability" IJERT
[5] Manohar Singh, Meera KS, Vishnuvarddhan Telukatna(2019)."An Innovative Solution for Type Testing of Power Transformers, International Journal of Emerging Electric Power Systems 20(1)