International Journal on Science and Technology (IJSAT)

E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

Modelling and Analysis of Transformer Winding Configuration for Application to Distribution Network

Darshan P. Potale[1], Deep R. Vaidya[2]

[1,2]UG Students
Department of Electrical Engineering, Government College of Engineering,
Amravati, Maharashtra, India.

Abstract

The development of the multiphase transformation system can be traced back to the early 1950s of the twentieth century.[6] At that time, A general theoretical framework for phase transformation, facilitating the conversion of 'n' phases to 'm' phases in a 'k'-limbed transformer, was proposed. Further elaboration has been provided on the general theories of phase transformation techniques from single-phase to multiphase systems in [7]. This concept has been explored and applied in the development of specialized transformer winding configurations, specifically designed to facilitate nine-phase output at the secondary side of the transformer. By strategically designing the winding arrangement, the transformation process ensures that the desired number of phases is achieved, thereby enhancing the operational flexibility and reliability of the system.

Keywords: Distribution transformer, Distribution network, Configuration, Multiphase, Feeders

1. Introduction

In the current scenario, for a distribution network, three-phase lines are supplied by distribution transformers. A three-phase distribution network is composed of three-phase distribution transformers, purposefully engineered to ensure the seamless and efficient distribution of three-phase electrical poweras it is conventional to use primarily for efficiency and power delivery. In general,towards this objective we chieflyassignthree phase delta star configured transformers incorporatingthreehigh voltage windings and threelow voltage windings connected in star configuration with three phase four wire schemes.Three phases with one neutral is typically employed for distribution grid. But whenever a new residential area needs an electricity supply, a transformer must be installed to adequately meet the area's power demand. To make it feasible by a single one, multi-winding transformers introduce as an optimal choice which is consolidate a total of nine secondaries, by modeling the transformer winding by this configuration we can grant 3 different feeders by assigning one transformer only.By modifying the connection and winding in transformer we can get 3 feeding points from a single distribution transformer. For modification, rather than a single secondary winding corresponding to the primary, multiple secondaries are integrated.

A three-phase system is typically chosen in electrical secondary distribution network in order to successive utilization of power, it is also termed as poly-phase scheme used to supply consumers. On the contrary, interest in multiphase systems has been steadily growing, a system designed with several output phases of distribution transformer exceeding three towards this aim numerous studies have emphasized the benefit and applications of multiphase systems such as variable speed drives to multiphase wind energy generation system. Alongside that the approach comprehensively discussed in the literature for targeted application to integrate three feeders supplied by single transformer instead of three. As usual the distribution transformer is mounted on pole or concrete mount according to their ratings and suitability, the large amount of support is needed if three transformer are being used for three different feeders. Also, the protective device and the length of conductor is also increased. On solution for this problem by this configuration we can get three different distributor line with three phase four wire system. E.g.By this modification we can get, reduced cost, reduced maintenance and lower support cost. Also reducing the need of two extra distributiontransformers.

2. Objective

The primary objective of the literature is to depict optimized configuration of distribution transformer in order to provide a stable power supply to meet consumer demand, by implementing presented configuration the need for three separate distribution transformers to handle large residential or commercial area has been eliminated in option to that a single distribution transformer which can cope with it. As a result, the requirement for additional protective devices is minimized, significantly affecting the cost factor.

3. Literature review

A growing interest in multiphase system, i.e., a transformer consisting of output phases more than three has been observed. There have been a number of research articles that highlight the different applications of multiphase systems over three-phase system by implementing advanced configuration techniques of transformer. This section reviews the existing literature on configuration techniques of transformer winding.

1) Three phase to five phase transformation:To obtain a multiphase output from transformer connections, the general idea of the solutions mentioned [1] and initially done. Two existing solutions from the literature were analyzed. A new connection scheme to achieve this transformation was then proposed.The first connection scheme employs a total of fifteen secondary coils divided equally among the three single magnetic cores.A similar connection scheme proposed which assumes that the three-phase input supply is perfectly balanced.

2) Three phase to six phase transformation:[2] demonstrate the systematic phase transformation technique from three-phase to six-phase (both symmetrical and asymmetrical) for both understanding and teaching purposes. When the phase difference between the two consecutive phases of six phases has a phase difference of 60, it is called a symmetrical six-phase system; while an asymmetrical or quasi, six-phase has two set of three-phase with a phase shift of 30 between the two sets[2].

3) Threephase to seven phase transformation: In this literature the theory of phase transformation is presented by graphical approach using vectors and phasor diagrams of different phases.Three phase to seven phase power converting transformer design is presented [3] with connection scheme, analysis and simulation and experimental results.
4) Three phase to eleven phase transformation: This paper proposes a new complex transformer connection scheme to transform three phase grid power to an Eleven-phase output supply. The new connection scheme and the phasor diagram along with the turn ratios are illustrated. This method required the main data of transformer, the phase shifting and as well as the winding connections of the transformer[4].

4. Proposed System

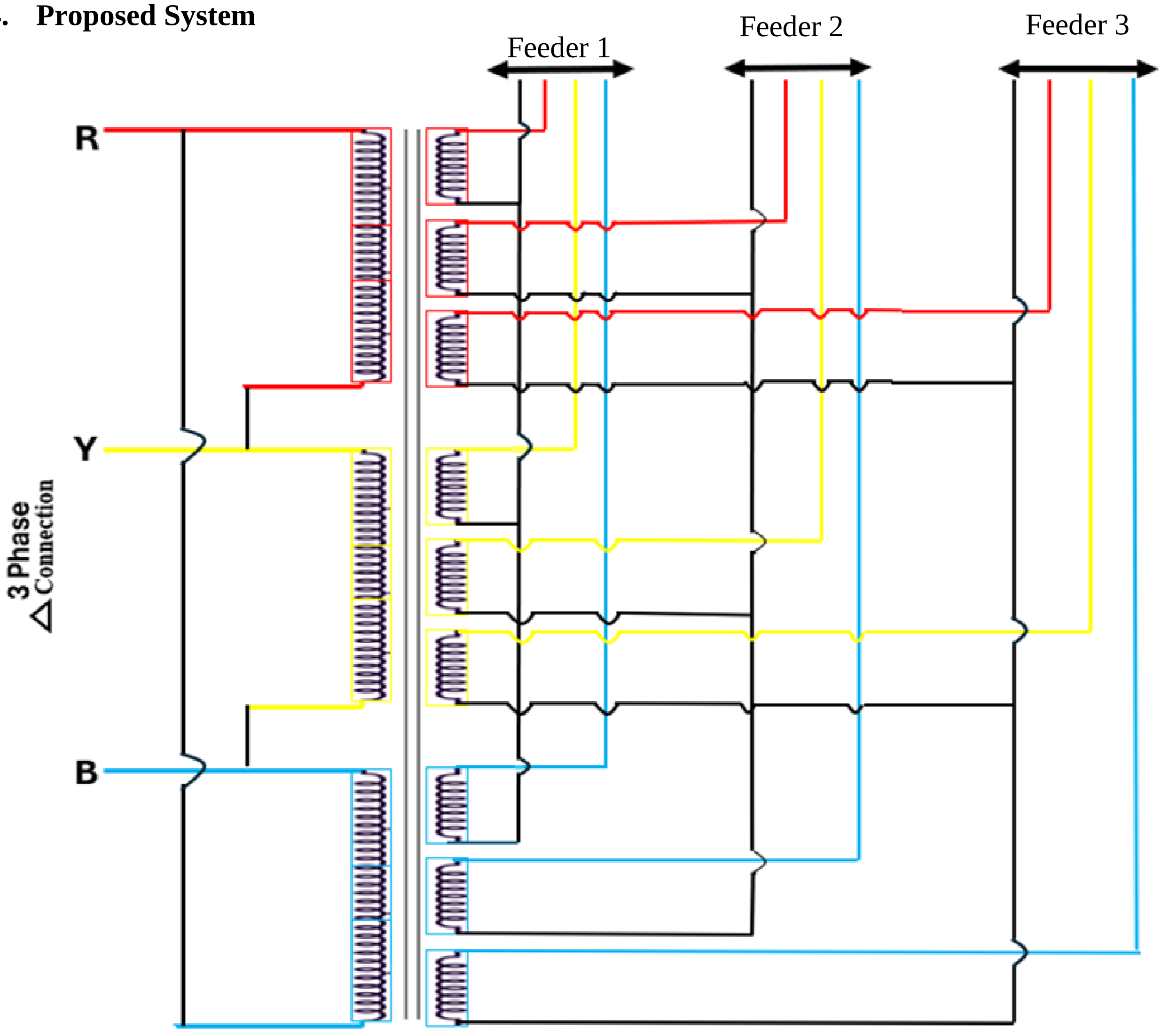

Figure 1: Configuration

When 3 phase distribution transformer fed with three phase electrical power source, flux linkage with secondary winding occurs based on the faradays law of electromagnetic induction. It uses mutual induction between two windings to produce an alternative electromotive force (EMF) in the secondary winding.The system is designed in a star configuration, allowing for a three-phase, four-wire setupensuring efficient power distribution for consumer demands. By implementing the proposed concept,the three phase distribution transformeris capable of providing three multiple feedersinstead ofsupplying a singlefeeder. The working of multiphase transformer which converts three phases of incoming grid to multiple of three phase (3x3=9) for application of distribution network. The transformer input will be in delta configuration as per the standard connections of distribution transformer, transformer will take delta connected three phase supply from the line coming from substation and then will convert three phases into multiple of three phases instead of only three phases and neutral as three windings instead of one is employed in the secondary side of transformer which gives multiple phases of three primary phases.

The proposed concept is similar to that of a distribution transformer with introducing three same turn winding onto secondary side replacing single winding, which facilitate two more distributors in secondary distribution network. Three number of primary windings containing three phases R, Y& B connected in delta configuration, the secondary side consists of nine windings (R1, R2, R3, Y1, Y2, Y3, B1, B2, B3), divided into three groups to form three separate feeders (F1, F2, F3). Each feeder contains three distinct phases; for instance, F1 comprises R1, Y1, and B1. These windings are connected in a star configuration, creating a common neutral point N1, andsimilar configuration is maintained for the other two feeders.

5. Simulation and Results

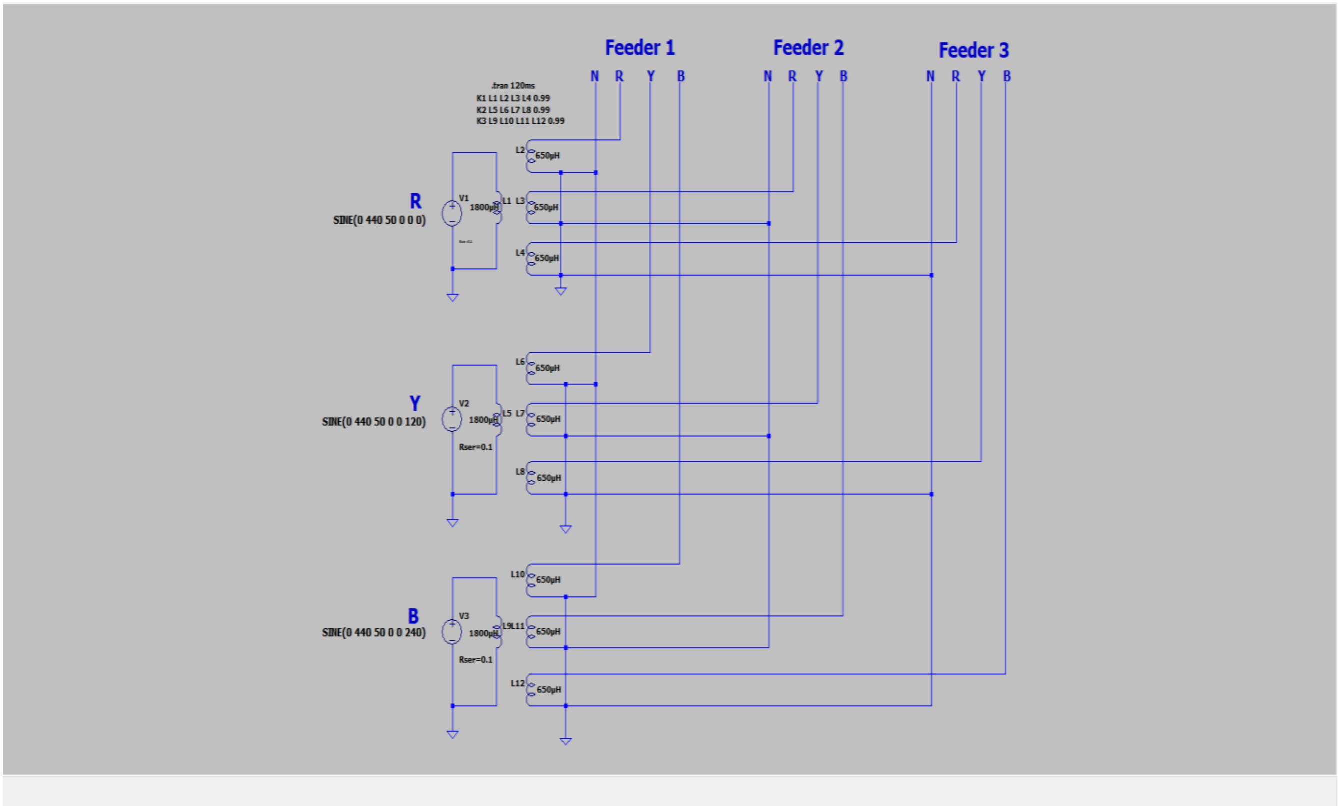

Figure 2: Schematic

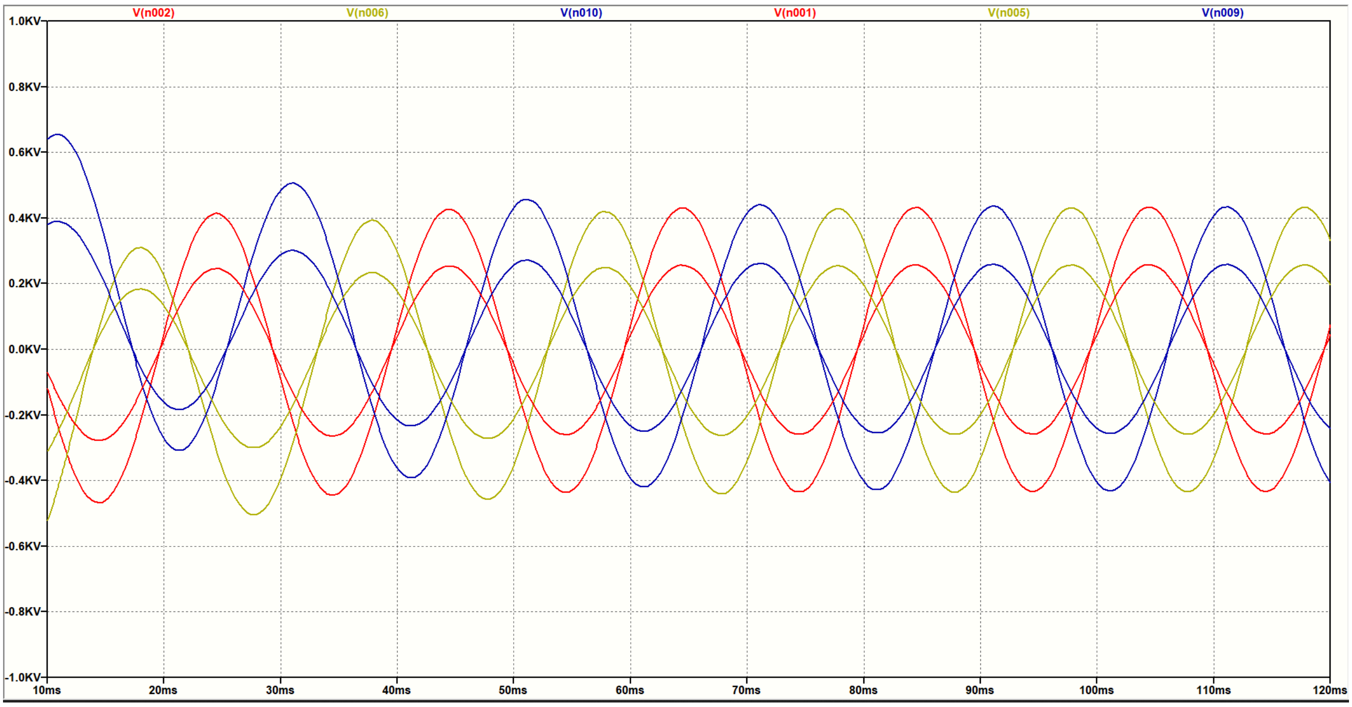

Figure 3: Waveforms of feeder 1

It has been observed that when three separate windings are replaced with a single secondary winding in the transformer, a single feeder is responsible for supplying all three phases R, Y, Balong with the neutral (N). The configuration, as illustrated in Figure 2, demonstrates the presence of three secondary windings for each phase, resulting in a total of nine windings. These windings are systematically arranged and interconnected in a star configuration to ensure balanced phase distribution and proper system operation.Figure 3 portrays the waveforms that illustrate the characteristics of Feeder 1, specifically V(n002), V(n006), and V(n009), each maintaining an approximate voltage of 430V under steady-state conditions, as detailed in Table 1. Similarly, the secondary voltage values are lower, around 250V, further validating that the step-down function of the distribution transformer has been successfully achieved. Additionally, the secondary voltages remain in phase with their respective primary voltages while maintaining the expected 120° phase shift relative to each other.In Figure 4, the transformer's inrush current is illustrated, highlighting the magnetizing inrush current caused by core saturation[8]. This phenomenon lasts for approximately 40ms, after which the transformer reaches its steady-state condition, providing a stable and constant output voltage.

+

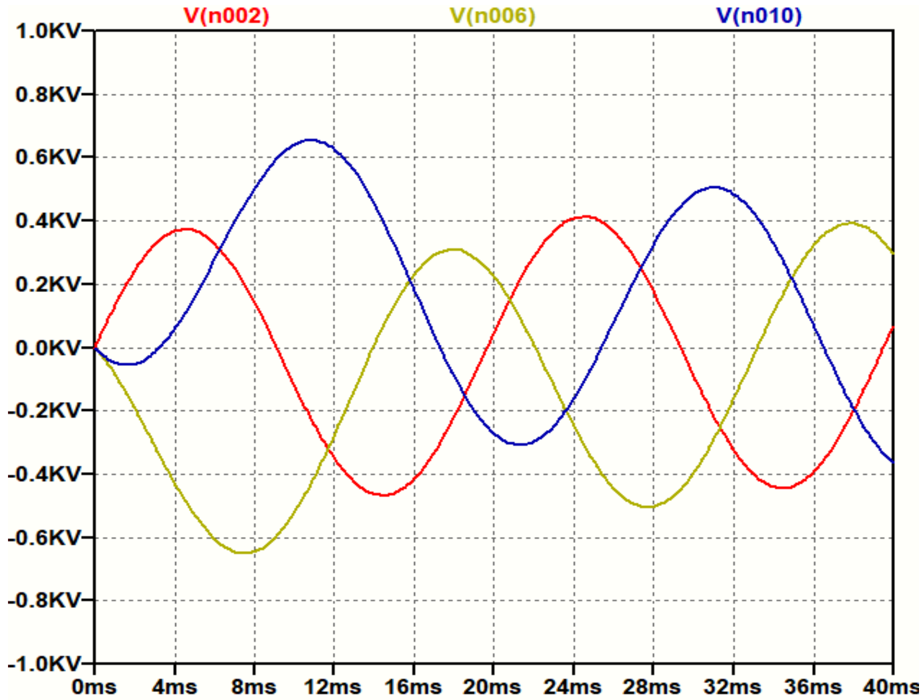

Figure 4: Waveforms of primary voltages (Inrush)

3 phase in delta configuration	**Magnitudeof primary phases**	**Multiple of three phase in star configuration**	**Magnitudeof secondary phases**
V(n002)	429.76 V	**V(n001)** **V(n005)** **V(n009)**	**253.35 V** **255.23 V** **255.23 V**
V(n006)		B1 B3	253.35 V 255.23 V 255.23 V
V(n010)	433.51 V	Y1 Y2 Y3	253.35 V 255.23 V 255.23 V

Table 1: steady state values for all three feeders

6. Future Scope

At the end of the primary distribution system, extra feeders are available to serve a greater number of residential and LT consumers, it eliminates the need for installing an additional distribution transformer in case of future system expansion or uberization, A single distribution transformer is capable of serving the newly increased consumer load.This will lead to a major cost saving in the deployment of pole-mounted transformers. Additionally, it minimizes the total installation cost of incoming power lines, transformer connections, supporting structures, and switchgear.

The entire network can be able tomanage and controlled from a single location where the multiphase transformer is installed, In the event of a fault occurring within the distribution network, engineers can efficiently analyze and pinpoint the exact location of the issue. This is possible because all power distribution lines extending throughout the consumer area are systematically integrated at a central location. By having a single point of convergence, fault detection and troubleshooting become significantly more streamlined, reducing response time and improving overall system reliability.

7. Conclusion

The successful modeling and comprehensive analysis of the transformer winding configuration for its effective application in the distribution network have been carried out. Various performance parameters have been evaluated, ensuring the feasibility of the proposed configuration. The obtained results, represented in the form of graphical illustrations, provide a clear validation of the system's operational effectiveness. Each graph meticulously verifies the expected performance outcomes, demonstrating the accuracy of the proposed model and confirming its suitability for practical implementation in real-world distribution networks.

8. References

[1] Enas Mohammad, Fatima Khan, Hadeel Bassel, Atif Iqbal & Ahmed Riyaz (2018): Comparative analysis of three-phase to five-phase transformer connections, Australian Journal of Electrical and Electronics Engineering, DOI: 10.1080/1448837X.2018.1437678.

[2] Al-Ammari, R.; Iqbal, A.; Khandakar, A.; Rahman, S.; Padmanaban, S. Systematic Implementation of Multi-Phase Power Supply (Three to Six) Conversion System. Electronics 2019, 8, 109. https://doi.org/10.3390/electronics8010109

[3] Tabrez, M., Sadhu, P.K. and Iqbal, A. 2017. A Novel Three Phase to Seven Phase Conversion Technique Using Transformer Winding Connections. Engineering, Technology & Applied Science Research. 7, 5 (Oct. 2017), 1953–1961. DOI:https://doi.org/10.48084/etasr.1190.

[4] Satish Karekar. A Novel Scheme of Three to Eleven Phases Transformer Connection by using MATLAB Software. JOJ Material Sci. 2018; 4(1): 555627. DOI: 10.19080/JOJMS.2018.04.555627

[5] Bronzeado, H. S., and R. Yacamini. "Transformer interaction caused by inrush current." MSc Thesis (1993).

[6] Parton, J.E. A general theory of phase transformation. Proc. IEEE Part. IV Inst. Monogr. 1952, 99, 12–23.

[7] Tabrez, M.; Sadhu, P.K.; Hossain Lipu, M.S.; Iqbal, A.; Husain, M.A.; Ansari, S. Power Conversion Techniques Using Multi-Phase Transformer: Configurations, Applications, Issues and Recommendations. *Machines* **2022**, *10*, 13. https://doi.org/10.3390/machines10010013.

[8] Bronzeado, Herivelto&Yacamini, R. (1997). Transformer interaction caused by inrush current.