Star/Delta Three Phase System : Educational Trainer

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Abstract
The 3-Phase Star/Delta connection system is a method used for connection purposes for a 3-phase electrical system. The use of trainers for the 3-phase system is widely used in educational institutions as one of the applicable learning method to meet the requirements of the syllabus that has been prepared in accordance with the requirements of accreditation certification recognition for each program offered in the institution. Comparison study between existing trainers in the market found out few elements that need to be improve to fulfil the objective of syllabus in polytechnic and suitable for use in teaching and learning (TnL) sessions. These Three Phase Star/Delta System Learning Trainer capable to introduces students to the basic methods of Star/Delta connections by combining teaching methods that require higher level thinking. This trainer has been equipped with multimeter and load connection terminals that can be tested by students. This trainer has been built to be flexible to use either by using a 3-phase supply or a 1-phase supply socket. So that students can still practice the 3-phase connection method according to the objective target in the lecturer's TnL session despite the constraints of the 3-phase supply facility. The use of a 3-phase trainer produces results that are different from the existing trainers and this is able to increase the level of understanding of the students which in turn helps the lecturer during the TnL session.

Keywords: three phase, trainer, star/delta connection

1.0 Introduction

Like most foreign countries, Malaysia is a country that uses single phase and three phase supply sources to supply domestic and industrial consumers. The connection of three phase supply source will be connected using Star and Delta method. Based on this requirement, every institution that offers its own electrical engineering program will ensure that its syllabus also includes three phase wiring systems. One of the institutions that offer electrical engineering programs is Polytechnic Malaysia.

Three phase Star/Delta Connection System is one of the topics for subject DET20033 Electrical Circuit course which must be taken by all second semester students of the Department of Electrical Engineering throughout the Polytechnic (Ghazali, N.H et al., 2021**)**. This topic includes theoretical and practical knowledge where students need to know the basics of using a three phase system, connection types, and basic calculations

involving voltage, current, and power values (Department of Polytechnic and Community College Education [DPCC], 2019). Several approaches have been taken by the lecturer to ensure the objectives of this course are achieved and subsequently produce students who are skilled in the basic knowledge requirements of three phase connection.

This study involves the use of teaching aids that are compatible with the requirements of the Malaysian polytechnic syllabus. TnL used to enhance student understanding for three phase system topic is three phase system education trainer. These trainers used as the teaching aids during practical work in order to increase the student understanding on the topic since the real three phase system wiring not suitable to install among the student during practical due to safety issues.

2.0 Literature review

2.1 Problem statement

Trainer in Electrical Engineering Department, Politeknik Sultan Haji Ahmad Shah (EED, POLISAS) laboratory was built by limiting use to star connections only. This trainer also built without providing students with high-level thinking skills because it has been visually connected to be used by students. Students only need to connect this trainer with a three-phase supply source without having to think about the connection method they need to do.

This existing trainer is also limited to light bulbs as a load to be used as an example for students. Students also cannot apply other loads to be used as test for the 3-phase system as an exercise for them. In addition, this trainer can only be used in laboratories equipped with a 3-phase supply source. This situation makes the TnL session quite difficult considering that the three-phase supply source is only provided in two laboratories. Figure 1 shows the three phase Star Trainer used during the practical session for the DET20033 Electrical Circuit course at POLISAS.

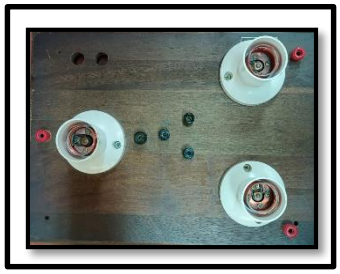

Figure 1: *Three phase star trainer*

2.2 Three phase system comparison

Three phase education trainer's sold in the market offer three-phase system learning and come in various purposes, shapes and specifications. However, there are various constraints on the trainers offered in the market,

for example in terms of cost, size and specifications that are less or more than the learning objectives to be achieved. Figure 2 shows several types of three-phase trainers that can be obtained in the market.

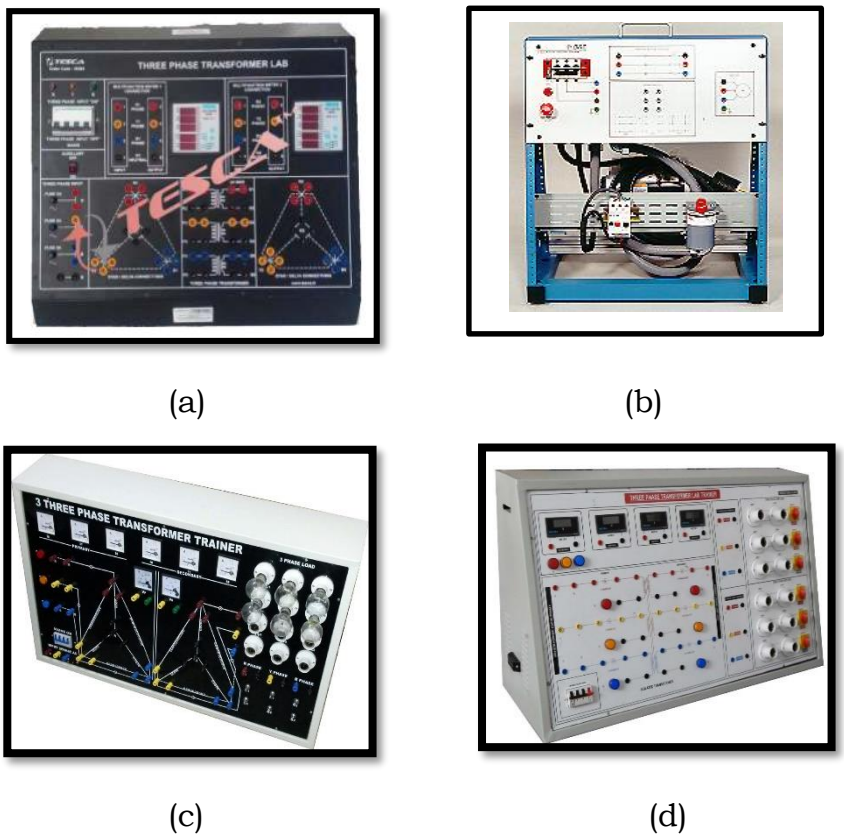

Figure 2: a) Three phase motor control training system, b) Three Phase Transformer Lab, c) Three phase Star Connection Trainer Scope of Learning, d) Three phase Transformer Trainer

Three phase Motor Control Training System is a trainer that is limited to testing Three phase connections for motor loads. Meanwhile, Three Phase Transformer Lab was produced by the TESCA company for a training system in an electrical laboratory with a large and non-mobile size. The construction is very complex and the scope offered is too much and unnecessary as the syllabus developed by the polytechnic for the DET20033 Electrical Circuit course. While, three phase Star Connection Trainer Scope of Learning is limited to Three Phase Star Connections and The Three Phase Transformer Trainer is specialized for transformer testing. In general, all these trainers can only work with a three-phase supply source.

Apart from the trainers in the industrial market, the Three Phase Star Delta Trainer (3 SPDT) was also produced as one of the innovations in the TnL for this course. 3 SPDTs are produced by changing the supply of one phase to three phases, and it can be used in other places other than the laboratory. Zahidi et al. al produced a three-phase waveform display from 3 SPDTs to give students an understanding of the three-phase system being studied. While the Star/Delta connection has been prepared for use by students to measure

the desired voltage, current or power values. This situation causes students to not be able to practice the connections they have learned. Figure 3 shows a Three Phase Star Delta Trainer (3 SPDT).

Figure 3: *Three phase star delta trainer (3 SPDT)*

Based on this study, a Three phase Star/Delta Connection System Educational Trainer was built and tested to meet the syllabus requirements for DET2033 Electrical Circuit. The trainer that was built focuses on both types of Star and Delta connections that can be used by students. It is also built with more compact and light size so that it can be used anywhere without the need for a three-phase supply source. Table 1 shows the summary of comparison between the other trainer available on the market and Three Phase Star Trainer at EED, POLISAS. According to table 1, this study needs to be done to achieve all the objectives and the beneficial goes among student, lecturers and institutions itself.

Table 1: Comparison of trainer features

Features	Three phase Star Trainer, EED POLISAS	Trainers on the market
Small size	/	x
Compact	x	/
Low cost	/	x
Stars	/	/ (Star only)
Delta	x	/ (delta only)
Three phase supply source	/	/
1 phase supply source	x	x
3-phase connection skills	x	/

3.0 Research Objective

There are several objectives for this study, one of them is to obtain data on the needs of a three-phase system trainer that is more effective and

suitable according to the syllabus. The syllabus and practical requirements provided for the Electrical Circuit DET20033 course at the Polytechnic are the main reference in this study. This is to provide teaching aids for TnL sessions for electrical engineering students and teaching staff involving three phase systems.

The comparison between trainers is to produce the construction of a Three Phase Star/Delta Connection System Educational Trainer. Based on this study, the next objective is to produce a flexible trainer that can be used without a three phase supply system, built in multimeter and compact size. This trainer construction study also focuses on students' abilities in using high-level thinking skills. In relation to that, every objective that is targeted can give advantages either to students, teaching staff and institutions involved.

4.0 Research methadology

The construction of a Three Phase Star/Delta Connection System Educational Trainer was carried out to achieve the desired objectives in the TnL of Electrical Engineering students, Polytechnic. Figure 4 shows the process carried out during the construction of this trainer

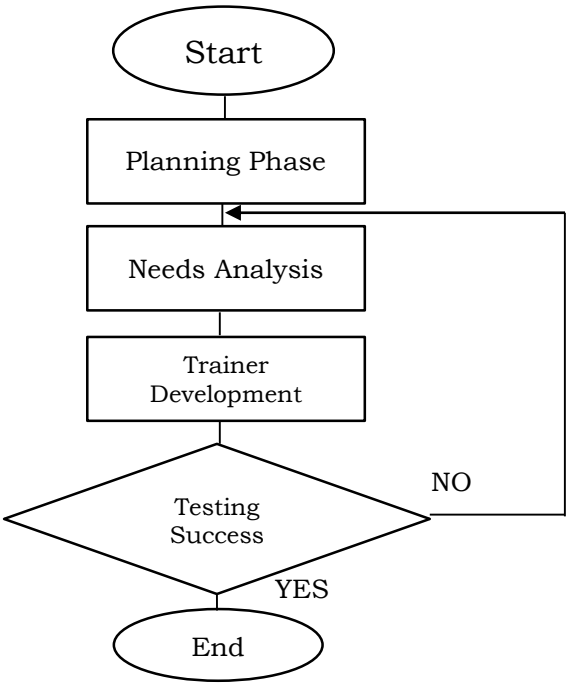

Figure 4: Construction Process of Three phase Star/Delta Connection System Educational Trainer

3.1 Planning phase: construction of three phase system trainer

Research on the objective of trainer construction has been done to meet the practical needs of the three phase system that will be implemented by

students. Bakar, B.H et al. states that the three phase system consists of three lines and one neutral conductor, which is usually known as Red (R), Yellow (Y), Blue (B) and Neutral (Black). The phase sequence for the national standard is R,Y, and B.

The three phase circuit connection method consists of a Star connection system and a Delta connection system. The study of this connection needs to be done to ensure that both of these connections can be done in the same trainer. Figure 5 and figure 6 show schematic circuits for Star and Delta connections.

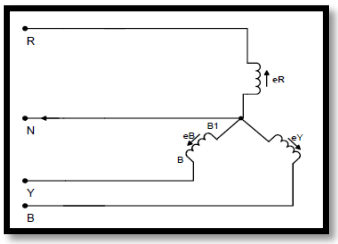

Figure 5: Star Connection

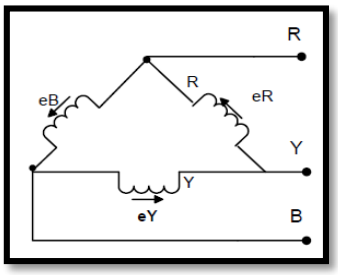

Figure 6: Delta Connection

3.2 Needs analysis phase: Three phase system trainer

This trainer is arranged so that users can take readings for voltage (V) and current (I) for each connection. This measurement is necessary to ensure the accuracy of the actual reading value compared to the theoretical value. The formula for both connections of this three-phase system is as follows:

a) Star Connection:

$$IL = IPH \quad (1)$$
$$VL = \sqrt{3}VPH \quad (2)$$
$$P3\emptyset = \sqrt{3}\ VL\ IL\ cos\ \theta^{o} \quad (3)$$
$$P3\emptyset = 3VPHIPHcos\theta^{\circ} \quad (4)$$

b) Delta Connection:

$$IL = \sqrt{3}\ IPH \quad (5)$$
$$VL = VPH \quad (6)$$

$$P3\emptyset = \sqrt{3}\ VL\ IL\ cos\ \theta^{o} \quad (7)$$

$$P3\emptyset = 3VPHIPHcos\theta° \quad (8)$$

This trainer is also equipped with a built in multimeter to make it easier for users to get voltage and current readings for any desired line. The measurement of voltage and current readings for both lines and phases for R, Y and B can be done simultaneously. Students or lecturers can connect an AC voltmeter and an AC ammeter while performing the desired connection.

Based on the requirements that have been stated, the schematic circuit of the Three Phase Star/Delta Connection System Educational Trainer has been drawn as in Figure 7. This schematic is drawn so that students can learn the actual connection method based on the schematic circuit of the Star and delta connection. This circuit is also designed so that this trainer is flexible to be used in other places even without a three phase supply source.

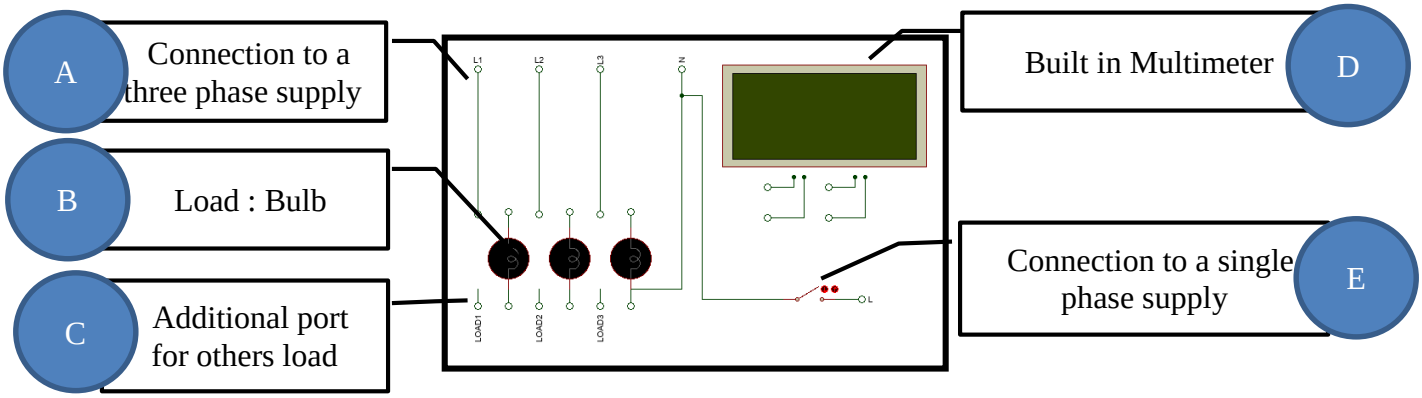

Figure 7: Schematic circuit for three phase star/delta connection system educational trainer

Refer to Figure 7, banana clip will be use to implement the star or delta connection using Three phase Star/Delta Connection System Educational Trainer. The three phase supply will be connected thru “A” and it will be connected to “B” if bulb was chosen as the load in the experiment. While “C” is an optional load for student that can be connected on this trainer. All connection on this trainer can be measured if student connect their circuit with “D” (built in multimeter). Student can refer their lab sheet given by the lecturer to build their own circuit using Star/Delta connection and find the desired value for three phase system. “E” was an alternative method can be use by student if there is no three phase supply provide in the laboratory.

3.3 Construction phase: Three phase system trainer

The design of this trainer uses light wood and plastic materials. Each line is separated to facilitate the inspection of the circuit connections built by

students. Figure 8 shows the trainer that has been developed and is ready to be used by students and lecturers. While figure 9 shows the Three phase Star/Delta Connection System Educational Trainer from the side view.

(a) (b)

Figure 8: Three phase Star/Delta Connection System Educational Trainer: (a) Top view, (b) Side view

3.4 Testing phase

Testing for the trainer is done to ensure that it works and coincides with the objectives that have been targeted. The usability study of this trainer involves both connection and testing of voltage and current readings. This testing phase also involves lecturers who teach the DET20033 Electrical circuit course.

Improvements to the accuracy of various meter values are also done at this stage of testing. The actual voltage and current values are also compared with the values obtained theoretically. Figure 9 shows the trainer being tested using a bulb load with a 3-phase supply source used.

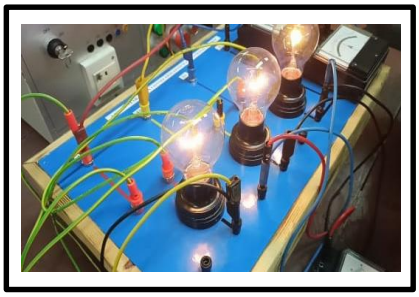

Figure 9: Test run of Three Phase Star/Delta Connection System Educational Trainer

In addition, this trainer is also improved by providing a storage space for cables and also small hand tools such as test pens, pliers and also circuit connecting cables.

4. Result & Discussion

The construction of the Three Phase Star/Delta Connection System Educational Trainer has met the requirements that have been set. The comparison between the new trainer, existing trainers in the EED, POLISAS and also the trainers in the market is as in Table 2 below.

Table 2: Comparison of available Trainer Features and Three phase Star/Delta Connection System Educational Trainer

Features	Three phase Star Trainer, JKE POLISAS	Trainers on the market	Three phase Star/Delta Connection System Educational Trainer
Small size	/	x	/
Compact	x	/	/
Low cost	/	x	/
Stars	/	/ (Star only)	/
Delta	x	/ (delta only)	/
Three phase supply source	/	/	/
1 phase supply source	x	x	/
3-phase connection skills	x	/	/

Based on Table 2, the Three phase Star/Delta Connection System Educational Trainer is built with a smaller and compact size. Star or delta connection can also be used with only 1 trainer without having to use a separate trainer. Even this trainer is also flexible because it is light and portable and can be used even without a three phase supply. The advantage of this trainer is that the construction cost is very cheap compared to the three phase trainer in the market.

Students can test their understanding by connecting a star or delta circuit themselves because the built trainer does not provide a direct connection. High-level thinking skills can be tested by lecturers on students during practical. The use of this trainer is one of the ways to expose students to the real application of connecting a three phase system. Lecturers can also test student's understanding based on the connections made during the practical session.

5.0 Conclusion

The study of the use and construction of a trainer for the three phase wiring system is an alternative teaching aid in TnL sessions. The existing trainer in the Electrical Engineering Department POLISAS laboratory is also very suitable to be replaced with a Three Phase Star/Delta Connection System Educational Trainer based on the comparison results that have been done.

A three phase system connected in star or delta can also be practiced by students and lecturers by only using the same trainer without the need to connect another circuit or use a separate trainer. In fact, the use of this trainer is not limited to laboratory facilities with a 3-phase supply source only where for TnL purposes, a 3-pin socket is also equipped on this trainer and can be used anywhere.

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