## 1. Learning Specification Details

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| ***Title:*** | **Power Transformers** | |
| ***Code:*** | **LSEGG540A** | |
| ***Training Package(s) Title and code:*** | Electrotechnology Training Package<br>UEE06<br>Version 1 | |
| ***Applicable EKAS Clause Number(s) and title(s) applicable to this LS*** | 2.6.8.3<br>2.18.1<br>2.18.2 | Power transformer diagnostic<br>Occupational Health and Safety principles<br>Electrical Safe working practices |
| ***Competency standard units aligned to this Learning Specification*** | The principles and concepts covered in this part are aligned to all competency standard units in the above referenced Training Package(s) and also to:<br>**UEENEEG040A - Develop engineering solutions for energy supply power transformer problems**<br>Note: Refer to Training Package(s) Volume 2 - 2.2 Essential Knowledge and Associated Skills (EKAS) to competency standard units (CSU) to assist in confirming specific mapping information. | |

## 2. Intention of the Learning Specification

<table>
<tr><td>Purpose</td><td colspan="6">This specification defines the depth and breath of knowledge and skills relating to the principles involved in the use and operation of large single and three phase transformers and auxiliary equipment</td></tr>
<tr><td>Suggested duration</td><td colspan="6">It is anticipated 60 hours of structured/supervised learning will be required to impart this part.<br><br>Note: This duration includes the time taken to impart and assess the learning content areas. It does not include the necessary workplace assessment and experience that augments learning in this part and before competence is determined.</td></tr>
<tr><td>Learning sequence</td><td colspan="6">Before undertaking this specification a learner is to have completed the following learning specification(s) or equivalent:<br>LSEGG315A Electricity Supply and Reticulation</td></tr>
<tr><td rowspan="2">Language, Literacy and Numeracy advice</td><td colspan="6">Learners are best equipped to achieve outcome in this LS if they have reading, writing, and numeracy skills indicated by the following scales. (Refer to Training Package Vol 2 Part 3 for scale definitions)</td></tr>
<tr><td>Reading</td><td>5</td><td>Writing</td><td>5</td><td>Numeracy</td><td>5</td></tr>
<tr><td>Intended use of this specification</td><td colspan="6">Learning specifications have been designed:<br>1. for learners who undertake an approved and prescribed competency development program/plan (e.g. apprenticeship, traineeship, cadetship, approved and accredited course/programs), and/or<br>2. to augment a Work Performance Specification (WPS) for the requisite competency standard unit.<br>Note: Learning specifications may stand alone for delivery purposes. However, where it is used to support competency development against competency standard units such learning specifications will be augmented by a Work Performance Specification. For detailed information refer to the industry approved competency development training model applicable for the respective Training Package – visit EE-Oz website: www.ee-oz.com.au</td></tr>
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## 3. Learning Specification Content Areas

| *Content title* | *Content topics* | *Learning objectives:* Learners should be able to meet the following learning objectives: |
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| **1. The single phase transformer** | • The transformer.<br>• Principle of transformer.<br>• Elementary theory of ideal transformer.<br>• Differences between ideal and actual transformer.<br>• Transformer with losses but without magnetic leakage.<br>• Magnetic leakage.<br>• Leakage reactance.<br>• Phasor diagram of transformer with losses and magnetic leakage.<br>• Simplified or approximate phasor diagram. | a) Describe the basic construction of transformers in terms of the material and structure of the core and the windings.<br>b) State the essential fundamentals of the theory of transformer action.<br>c) Draw a simplified phasor diagram showing primary and secondary induced voltages and impedance drop voltages in relation to the different components of the primary and secondary currents.<br>d) Perform calculations relating the turns per coil, core flux, and frequency for sinusoidal supplies with one factor unknown. |
| **2. Equivalent circuits** | • Equivalent resistance and leakage reactances<br>• Approximate relative magnitude of primary and secondary resistances and leakage reactance.<br>• Equivalent Circuits<br>• Equivalent circuit parameters<br>• Determination of Equivalent Resistance and Reactance | a) Determine the transformer equivalent circuit parameters either; from data provided by the manufacturer relating to winding and core details or from the short circuit and open circuit tests<br>b) Describe the effects of voltage regulation under varying power factor loads.<br>c) Determine the voltage regulation under a stated set of load conditions by calculations based on the<br>• equivalent circuit<br>• use of on appropriate expression. |

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| | • Core loss and magnetizing current<br>• Voltage Regulation and its predetermination<br>• Kapp Diagram<br>• Calculation of Voltage Regulation | d) Draw and interpret a Kapp diagram |
| **3. Auto-transformers** | • Operation<br>• Comparison of VA ratings of windings of auto-transformer and ordinary transformer.<br>• Application and uses of the auto-transformer.<br>• The equivalent circuit. | a) Describe the differences between double wound and auto-transformers.<br>b) Derive the relationship between the va ratings of a transformer operating as a double wound and an auto-transformer.<br>c) List some applications of auto-transformers<br>d) Compare the losses of a transformer operating as both a double wound and an auto-transformer. |
| **4. Principle of operation and construction of three-phase transformers** | • Shell or core type iron circuits and disc coils,<br>• Sandwich or helix windings<br>• Transposition of windings.<br>• Transportation of large transformers.<br>• Single phase transformers<br>• Three-phase transformers<br>• Phasor diagrams no load<br>• Phasor diagrams full load | a) Describe the construction, the winding and iron configurations and the common winding connections.<br>b) Describe methods of moving and transporting large transformers.<br>c) Describe the operation of a three phase transformer.<br>d) Sketch no-load and phasor diagrams.<br>e) Identify flux, magnetising and core loss components.<br>f) Sketch on-load phasor diagram.<br>g) Identify currents, voltages and voltage drop components for a balanced three phase load.<br>h) Describe the construction of core and shell type iron circuits including the cutting, stacking, shaping and clamping of the stack.<br>i) Identify winding types including disc, helix and transposition windings. |

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| | | j) Describe the effects of insulation and voltage level on the winding constructions. |
| **5. Tests applied to transformers** | • Losses and efficiency<br>• Maximum efficiency.<br>• All day efficiency.<br>• Heating and temperature rise.<br>• Tests to establish<br>  o losses (open and short circuit tests)<br>  o per unit or percentage impedance (voltage).<br>• Efficiency<br>• Regulation<br>• High voltage tests<br>• Polarity tests | a) State the losses that occur in a transformer on no-load and full load.<br>b) Describe open circuit and short circuit tests applied to transformers.<br>c) Describe the metering connections and calculations involved in open circuit and short circuit tests.<br>d) Describe the errors introduced if using values of current and voltage other than rated<br>e) Describe the test equipment used and how the results are obtained.<br>f) Use typical results for calculation purposes<br>g) Describe other tests required by Australian Standards**.**<br>h) Calculate the p.u. value of impedance.<br>i) Develop and sketch the approximate equivalent circuit.<br>j) Calculate referred values of impedances.<br>k) Calculate the losses and efficiency at a given load<br>l) Determine the load at which maximum efficiency occurs..<br>m) Calculate all day efficiency<br>n) Describe high voltage and polarity tests applied to transformers. |
| **6. Methods of connection of three-phase transformers** | • Windings<br>• Polarity and the markings of the terminals of transformer<br>• Interconnection of Windings<br>• Star<br>• Delta<br>• Zigzag<br>• Open delta.<br>• Grouping (on the basis of phase shift) and precautions to be taken for parallel | a) Describe common winding connections and phasor groups as detailed in Australian Standards<br>b) Sketch windings connected in star, delta and zig-zag (or inter-star).<br>c) List the symbols and meanings used in phasor groupings.<br>d) Describe the standard method of terminal marking. Classify (for parallel operation) the different transformer connections into Group I, II, III or IV.<br>e) Describe the necessary conditions for the parallel operation of transformer |

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| | operation.<br>• Forward and backward roll.<br>• Load sharing. | f) Calculate the load share for each transformer in parallel group<br>g) Classify the likely connection used for a range of transformer applications.<br>h) Calculate the phase voltage and the line voltage given the voltage of a phase section for the interconnected-star connection.<br>i) Identify the high tension and the low tension winding terminals from their markings;<br>j) Describe the relationship between the induced e.m.f. in the windings and the terminal marking suffixes;<br>k) Explain the significance of the terms "subtractive polarity" and "additive polarity" with respect to the terminal markings and the induced voltages.<br>l) Explain the significance of the "o'clock" references to the phase displacement of the voltages of three-phase transformers.<br>m) Define the voltages referred to in the o'clock references<br>n) Draw the related voltage vector diagrams, given the transformer connections in symbolic form.<br>o) Define, given the voltage vector diagram for any one of the sixteen standard connections, the connection in symbolic form. |
| **7. Tap changers** | • Use of off-load and on-load tap changing to compensate for voltage variation.<br>• Comparison of fault current levels and voltage regulation requirements. | a) Detail how load and transformer impedance produce<br>b) conditions requiring tap-changers.<br>c) Describe different types of tap-changers and how they are used.<br>d) Detail principles of voltage control using tap changing.<br>e) Define the conflict produced by the need for fault current limitation and adequate load regulation.<br>f) List electrical requirements for, and disadvantages of, off-load tap-changing. |

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| | | g) List the advantages of, and sketch the sequence of<br>h) operation for, an on-load tap-changer as specified by Australian Standards |
| **8. Auxiliary equipment** | • Transformer temperature limitation<br>• Equipment required and the means of cooling transformers.<br>• Cooling nomenclature.<br>• Changes of rating based on cooling and multi-rating transformers.<br>• Oil testing and maintenance.<br>• Conservator,<br>• Desication,<br>• Buchholz relay operation. | Describe the means of cooling large, oil filled, 3 phase transformer.<br>a) State the symbols used to define the cooling system in use as detailed in Australian Standards.<br>b) Relate cooling with transformer rating.<br>c) Describe the reasons for and the principle methods used to cool large three phase transformers.<br>d) Identify the symbols used to describe transformer cooling.<br>e) Describe the various means used to measure temperatures.<br>f) Describe multiple rating transformers and the reasons for temperature controlled cooling.<br>g) Describe "dry-type" power transformers complying with Australian Standards<br>h) Describe the types of oils and tests used to determine the efficacy of the oil.<br>i) Describe the operation of the Buchholz relay, the conservator and desication equipment. |
| **9. Winding connections** | • Choice and use of multi-winding, auto transformers and neutral earthing compensators.<br>• Types of harmonics produced and methods of attenuation.<br>• Use of tertiary windings to suppress harmonics. | a) State the reasons for selection of particular transformers based on output, voltage and importance.<br>b) Detail the type of harmonics produced in transformers.<br>c) Explain the reason for their production and methods of reduction.<br>d) Detail the uses for star/star, star/delta and delta/star transformers.<br>e) Explain the reasons for the use of auto transformers and neutral earthing compensators.<br>f) Explain the reason for the production of harmonics in |

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| | | transformers<br>g) Explain why a third harmonic voltage may exist in the phase voltages of a star-connected winding but not in the line voltages<br>h) Explain how the interconnected star connection eliminates third harmonic voltages from the phase voltages<br>i) Explain how third and higher harmonic voltages are produced in three-phase transformer windings<br>j) Explain the effect on the third harmonic voltages and currents for:<br>• three wire star,<br>• four wire star,<br>• delta, connections<br>k) Explain the reduction of harmonics based on selection of core materials, iron circuit design and types of winding connection.<br>l) Explain the effect on the third harmonic flux and the voltage induced in the windings of a three-phase transformer by the following types of cores:<br>• three single phase transformers<br>• three limbed three-phase transformers<br>• five limbed three-phase transformers<br>m) Explain the effect of connecting single phase loads to three phase transformers. |
| **10. Instrument Transformers** | • Current transformers<br>o construction<br>o ratios<br>o accuracy<br>o connections<br>o dangers<br>• Potential transformers | a) State why instrument transformers are to be preferred to shunts and multipliers for extending the range of ammeters and volt-meters on a.c. circuits.<br>b) List the standard ratings of C.T.s and P.T.s.<br>c) Correctly describe the method of connection and construction of instrument transformers.<br>d) Describe the techniques employed to minimize transformation |

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| | o construction<br>o ratios<br>o accuracy | errors.<br>e) Describe the essential differences between C.T.s used for protection and for measurement purposes. |