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PRELIMINARY EXAMINATION

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ELECTRICAL ENGINEERING

ESE TOPICWISE OBJECTIVE SOLVED PAPER-II

Detailed Solution | Topicwise Description | Fully Revised & Updated

UPSC Engineering Service Examination 2018

ELECTRICAL ENGINEERING

ESE TOPIC WISE OBJECTIVE
SOLVED PAPER-II

From (1992 – 2017)

IES MASTER PUBLICATION

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PREFACE

It is an immense pleasure to present topic wise previous years solved paper of Engineering Services Exam. This booklet has come out after long observation and detailed interaction with the students preparing for Engineering Services Exam and includes detailed explanation to all questions. The approach has been to provide explanation in such a way that just by going through the solutions, students will be able to understand the basic concepts and will apply these concepts in solving other questions that might be asked in future exams.

Engineering Services Exam is a gateway to a immensly satisfying and high exposure job in engineering sector. The exposure to challenges and opportunities of leading the diverse field of engineering has been the main reason for students opting for this service as compared to others. To facilitate selection into these services, availability of arithmetic solution to previous year paper is the need of the day. Towards this end this book becomes indispensable.

Mr. Kanchan Kumar Thakur
Director–IES Master

Note: Direction of all **Assertion Reasoning (A–R)** type of questions covered in this booklet is as follows:

DIRECTIONS:

The following four items consist of two statements, one labelled as **'Assertion A'** and the other labelled as **'Reason R'.** You are to examine these two statements carefully and select the answer to these two statements carefully and select the answer to these items using the codes given below:

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is not the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true.

Note: Direction of all **Statement-I** and **Statement-II** type of questions covered in this booklet is as follows:

DIRECTION:

Following items consists of two statements, one labelled as 'Statement (I)' and the other as 'Statement (II)'. You are to examine these two statements carefully and select the answers to these items using the code given below:

(a) Both Statement : (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).

(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).

(c) Statement (I) is true but Statement (II) is false

(d) Statement (I) is false but Statement (II) is true.

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Unit 1 Electrical Machines and Power Transformers

SYLLABUS

Magnetic Circuits-Analysis and Design of Power transformers. Construction and testing. Equivalent circuits. Losses and efficiency. Regulation. Auto-transformer, 3-phase transformer. Parallel operation.

Basic concepts in rotating machines. EMF, torque, basic machine types. Construction and operation, leakage losses and efficiency.

D.C. Machines. Construction, Excitation methods. Circuit models. Armature reaction and commutation. Characteristics and performance analysis. Generators and motors. Starting and speed control. Testing, Losses and efficiency.

Synchronous Machines. Construction. Circuit model. Operating characteristics and performance analysis. Synchronous reactance. Efficiency. Voltage regulation. Salient-pole machine, Parallel operation. Hunting. Short circuit transients.

Induction Machines. Construction. Principle of operation. Rotating fields. Characteristics and performance analysis. Determination of circuit model. Circle diagram. Starting and speed control.

Fractional KW motors. Single-phase synchronous and induction motors.

Contents

CHAPTER 1

Transformers

IES – 1992

1. The desirable properties of transformer core material are

(a) low permeability and low hyteresis loss

(b) high permeability and high hysteresis loss

(c) high permeability and low hysteresis loss

(d) low permeability and high hysteresis loss

2. Which of the following acts as a protection against high voltage surges due to lightening and switching?

(a) Breather

(b) Conservator

(c) Horn gaps

(d) Thermal overload relays

3. The efficiency of two identical transformers under load conditions can be determined by

(a) back to back test

(b) open circuit test

(c) short circuit test

(d) any of the above

4. For an ideal transformer the windings should have

(a) maximum resistance on primary side and least resistance on secondary side

(b) least resistance on primary and secondary side

(c) equal resistance on primary and secondary side

(d) no ohmic resistance on either side

5. Two single phase 100 kVA transformers, each having different leakage impedance are connected in parallel. When a load of 150 kVA at 0.8 p.f. lagging is applied

(a) both transformer will operate at power factor more than 0.8 lagging

(b) both transformer will operate at power factor less than 0.8 lagging

(c) one of the transformers will operate at p.f. more than 0.8 lagging and other will operate at p.f. less than 0.8 lagging

(d) both transformers will operate at identical power factors

6. Scott connections are used for

(a) single phase to three phase transformation

(b) three phase to single phase transformation

(c) three phase to two phase transformation

(d) any of the above

7. Two single phase transformers with equal turns have impedance of (0.5 + j0.3) ohms and (0.6 + j1) ohms with respect to the secondary. If they operate in parallel, how will they share a load of 100 kw at 0.8 p.f. lagging?

(a) 50 kW, 50 kW

(b) 62 kW, 38 kW

(c) 78.2 kW, 21.8 kW

(d) 85.5 kW, 14.5 kW

8. The losses on a transformer are

I. Copper losses

II. Eddy current losses

III. Hysteresis losses

The constant power loss of a transformer loss is given by

(a) I only (b) I and II only

(c) II and III only (d) I, II and III

9. Which of the following will improve the mutual coupling between primary and secondary circuits?

(a) Transformer oil of high break down voltage

(b) High reluctance magnetic core

(c) Winding material of high resistivity

(d) Low reluctance magnetic core

10. The secondary of a current transformer under operating conditions is short-circuited to avoid

(a) break in primary winding

(b) insulation break-down

(c) core saturation and high voltage induction

(d) high voltage surge

11. The inductive reactance of a transformer depends on

(a) electromotive force

(b) magneto motive force

(c) magnetic flux

(d) leakage flux

12. Which of the following connection of transformer will give the highest secondary voltage?

(a) Delta primary, delta secondary

(b) Delta primary, star secondary

(c) Star primary, star secondary

(d) Star primary, delta secondary

IES – 1993

13. In a transformer, if the iron losses and copper losses are 40.5 kW and 50 kW respectively, then at what fraction of load will the efficiency be maximum?

(a) 0.8 (b) 0.57

(c) 0.70 (d) 0.9

14. Can a 50Hz transformer be used as 25Hz, if the input voltage is maintained constant at the rated value corresponding to 50Hz?

(a) Yes since the voltage is constant, current levels will not change

(b) No, flux will be doubled which will drive the core to execessive saturation

(c) No, owing to decreased reactance of transformer, input current will be doubled at load

(d) Yes, at constant voltage, insulation will not be overstressed

15. Short-circuit test is performed on a transformer with a certain impressed voltage at rated frequency. If the short-circuit test is now performed with the same magnitude impressed voltage, but at a frequency higher than the rated frequency, then

(a) the magnitude of current and power factor will both increase

(b) the magnitude of current will decrease but the power factor will increase

(c) the magnitude of current will increase but the power factor will decrease

(d) the magnitude of current as well as the power factor will decrease

16. While performing the open-circuit and short-circuit tests on a transformer to determine its parameters, the status of the low voltage (L.V) and high voltage (H.V) winding will be such that

(a) in O.C., L.V. is open and in S.C., H.V. is shorted

(b) in O.C., H.V. is open and in S.C., L.V. is shorted

(c) in O.C., L.V. is open and in S.C., L.V. is shorted

(d) in O.C., H.V. is open and in S.C., H.V. is shorted

IES – 1994

17. A 2kVA transformer has iron loss of 150 watts and full-load copper loss of 250 watts. The maximum efficiency of the transformer would occur when the total loss is

(a) 500 W (b) 400 W
(c) 300 W (d) 275 W

18. If the frequency of input voltage of a transformer is increased keeping the magnitude of voltage unchanged, then
(a) both hysteresis loss and eddy current loss in the core will increase
(b) hysteresis loss will increase but eddy current loss in the core will decrease
(c) hysteresis loss will decrease but eddy current loss will increase
(d) hysteresis loss will decrease but eddy current loss will remain unchanged.

19. The voltage regulation of a transformer at full load and 0.8 power factor lagging is 2.5%. The voltage regulation at full load 0.8 power factor leading will be
(a) –2.5% (b) zero
(c) –0.9% (d) 2.5%

20. For successful parallel operation of two single-phase transformers, the most essential condition is that their
(a) percentage impedances are equal
(b) polarities are properly connected
(c) turns ratios are exactly equal
(d) kVA ratings are equal

IES – 1995

21. "In all cases of electromagnetic induction, an induced voltage will cause a current to flow in a closed circuit in such a direction that the magnetic field which is caused by that current will oppose the change that produces the current" is the original statement of
(a) Lenz's law
(b) Faraday's law of magnetic induction
(c) Fleming's law of induction
(d) Ampere's law

22. If rated voltage from the power lines is applied to the primary of a single-phase transformer which is operated on load, then
(a) both input voltage and current are sinusoidal
(b) both input voltage and current are non-sinusoidal
(c) input voltage is non sinusoidal and the input current is sinusoidal
(d) input voltage is sinusoidal and input current is non-sinusoidal

23. Two 3-phase transformers are to be connected for parallel operation. Which one of the following arrangements is impossible?
(a) Transformer A : primary Y; secondary Y
Transformer B : primary Δ; secondary Δ
(b) Transformer A : primary Δ; secondary Y
Transformer B : primary Δ; secondary Δ
(c) Transformer A : primary Y; secondary Δ
Transformer B : primary Δ; secondary Y
(d) Transformer A : primary Δ; secondary Δ
Transformer B : primary Δ; secondary Δ

24. For the purpose of analysis, exact equivalent circuit of a transformer is usually replaced by an approximate equivalent circuit. In doing so errors introduced due to winding copper loss and core loss are of differential nature. Due to this, the analysis by approximate equivalent circuit gives fairly satisfactory results. Under the circumstances, which one of the following statements is correct respect of losses referred to approximate equivalent circuit as compared to exact equivalent circuit?
(a) This accounts for somewhat greater primary winding copper loss and less core loss
(b) This accounts for somewhat lesser primary winding copper loss and more core loss
(c) This accounts for somewhat greater secondary winding copper loss and less core loss
(d) This accounts for somewhat lesser secondary winding copper loss and more core loss

25. If the waveform of the voltage impressed on the primary of a Y-Δ bank contains a 5th harmonic, the wave-forms of the resultant voltages of primary and the secondary would be

101.	**(c)**	**122.**	**(b)**	**143.**	**(a)**	**164.**	**(d)**
102.	**(a)**	**123.**	**(b)**	**144.**	**(b)**	**165.**	**(c)**
103.	**(d)**	**124.**	**(none)**	**145.**	**(b)**	**166.**	**(c)**
104.	**(d)**	**125.**	**(b)**	**146.**	**(c)**	**167.**	**(a)**
105.	**(b)**	**126.**	**(b)**	**147.**	**(a)**	**168.**	**(c)**
106.	**(d)**	**127.**	**(c)**	**148.**	**(c)**	**169.**	**(d)**
107.	**(b)**	**128.**	**(b)**	**149.**	**(c)**	**170.**	**(c)**
108.	**(a)**	**129.**	**(c)**	**150.**	**(b)**	**171.**	**(a)**
109.	**(c)**	**130.**	**(c)**	**151.**	**(d)**	**172.**	**(a)**
110.	**(d)**	**131.**	**(a)**	**152.**	**(d)**	**173.**	**(a)**
111.	**(b)**	**132.**	**(b)**	**153.**	**(d)**	**174.**	**(none)**
112.	**(a)**	**133.**	**(a)**	**154.**	**(d)**	**175.**	**(a)**
113.	**(b)**	**134.**	**(a)**	**155.**	**(d)**	**176.**	**(b)**
114.	**(a)**	**135.**	**(a)**	**156.**	**(a)**	**177.**	**(d)**
115.	**(a)**	**136.**	**(d)**	**157.**	**(a)**	**178.**	**(c)**
116.	**(c)**	**137.**	**(b)**	**158.**	**(d)**	**179.**	**(a)**
117.	**(b)**	**138.**	**(d)**	**159.**	**(b)**	**180.**	**(a)**
118.	**(b)**	**139.**	**(d)**	**160.**	**(c)**	**181.**	**(c)**
119.	**(c)**	**140.**	**(d)**	**161.**	**(a)**	**182.**	**(b)**
120.	**(b)**	**141.**	**(d)**	**162.**	**(b)**		
121.	**(d)**	**142.**	**(d)**	**163.**	**(b)**		

SOLUTION...

Sol–1: **(c)**

The desirable properties of transformer core material are:

(i) High permeability, so that a very small magnetising current is needed to establish the required flux in the core.

(ii) The core-loss should be low i.e. hysteresis loss and eddy-current loss should be low. For low hysteresis loss, hysteresis loop of the material should be small and for low eddy-current loss, material should have high electrical resistivity.

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Sol–2: (c)

Horn gap is used as a protection against high voltage surges due to lightening and switching. For utmost protection to the terminal apparatus, the horn gap should be located as close to the apparatus.

Horn gap consists of two horn-shaped pieces of metal seperated by a small air gap and connected in shunt between each conductor and earth. The distance between the two electrodes is such that the normal voltage between the line and earth is insufficient to jump the gap, but abnormally high voltages will breakdown the gap and so, find a path to earth.

Sol–3: (a)

In back-to-back test or Sumpner's test, two identical transformers are used to determine the ohmic loss and core loss both, occuring in the transformers. Considering, ohmic loss and iron-loss are the major losses occuring in the transformer, the efficiency can be determined.

Open-circuit test is used to determine the core-loss only.

Short-circuit test is used to determine the ohmic loss only.

Sol–4: (d)

For an ideal transformer

(i) no ohmic resistance on either side of the transformer, so that there is no ohmic loss.

(ii) no leakage reactance on either side, so that all the flux is confined to the core and links both windings (i.e. leakage flux is assumed neglegible)

(iii) no losses in the core.

(iv) permeability of the core is infinite i.e. negligible exciting mmf is required to establish the flux

Sol–5: (c)

For parallel operation of single phase transformer,

$$\bar{I}_a \bar{Z}_a = \bar{I}_b \bar{Z}_b$$

If $|\bar{Z}_a| \neq |Z_b|$ and $\frac{X_{ea}}{R_{ea}} \neq \frac{X_{eb}}{R_{eb}}$

then both transformer will not share the load, proportionally to their kVA rating. The transformer whose impedance is larger, will share less kVA and the transformer which has smaller impedance will share large kVA of load.

Also, both transformer will operate at different power factor i.e. one will operate at power factor greater than the load pf and other at lesser pf of the load.

If $|\bar{Z}_a| \neq |Z_b|$ but $\frac{X_{ea}}{R_{ea}} = \frac{X_{eb}}{R_{eb}}$

Both transformer will operate at same power factor and it will be equal to load power factor.

Sol–6: (c)

Scott connection is used to convert three phase to two phase transformation. In scott conection, there are two single phase transformers : one having turns ratio N_1/N_2; called main transformer and other having turns ratio $\frac{\sqrt{3}}{2}(N_1/N_2)$; called Teaser transformer. This type of connection is required in arc furnace.

Sol–7: (c)

Given, load = 100 kW at 0.8 pf lagging

i.e. S_L = 125 kVA at ϕ = –36.87°

Let $Z_1 = (0.5 + j0.3)\Omega = 0.58\angle 30.96^o \Omega$

and $Z_2 = (0.6 + j1)\Omega = 1.16\angle 59^o \Omega$

Now, load sharing of transformer-1,

$$S_1 = \frac{Z_2}{Z_1 + Z_2} \times S_L^*$$

$$= \frac{1.16\angle 59^o}{0.58\angle 30.96 + 1.16\angle 59^o} \times (125\angle +36.87^o)$$

$$= 85.6\angle +27.6^o \text{kVA}$$

= 85.6 × cos(+27.6°) kW = 75.85 kW

i.e. 75.85kW at 0.886 pf lagging

and, load sharing of transformer-2,

$$S_2 = \frac{Z_1}{Z_1+Z_2}\times S_L^*$$

$$= \frac{(0.58\angle 30.96)}{(0.58\angle 30.96)+(1.16\angle 59^o)}$$

$$\times(125\angle +36.87^o)$$

$$= 42.8\angle +55.64^o\,\text{kVA}$$

i.e. 42.8 × cos(+55.64^o) kW

= 24.15kW at 0.564pf lagging.

Sol–8: **(c)**

For electrical machines, the constant loss means the losses which do not vary with load. Copper losses are directly proportional to the square of the current and hence depend on loading condition. But core losses which comprises eddy current losses and hysteresis losses depends on voltage, frequency and magnetic field density but not on the load. Hence, core losses are called constant losses.

Sol–9: **(d)**

Mutual coupling between primary and secondary winding of the transformer depends on what amount of flux produced by primary winding is linking with the secondary winding. Higher the flux linking, higher will be mutual coupling. Hence, to improve the mutual coupling, the reluctance of the core (i.e. the path for magnetic flux) should be low so that there is less leakage flux and there is maximum flux linkage between windings.

Sol–10: **(c)**

Current transformer is always connected in the series of the line. Hence, its primary winding current is equal to the current flowing in the line.

For the transformer,

$$I_1 = I_2^{0'} + I_0$$

If secondary of the C.T. is left open; $I_2^{0'}$ will be zero.

then, $I_0 = I_1$

i.e. the excitation current will be equal to the line current which is very high. It leads the core into deep saturation and may damage the core of the transformer permanently.

Sol–11: **(d)**

Inductive reactance of transformers depends on leakage flux. For simplicity, the primary winding and secondary winding are considered to be wound seperately on the two legs of the core. Then, leakage flux caused by the primary mmf links primary winding itself and leakage flux caused by secondary mmf links secondary winding itself. By keeping this assumptions and accounting these leakage fluxes, we assume two inductive reactances, one in series with of the primary winding and other in series with secondary winding.

Sol–12: **(b)**

Let consider a bank of three single-phase transformer, each having turns ratio, N_1/N_2, forming a three-phase transformer.

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} \Rightarrow V_2 = \left(\frac{N_2}{N_1}\right)V_1$$

where, V_1 and V_2 are phase voltage for 3ϕ transformer. Now, output voltage V_2 will be maximum if V_1 will be maximum. So, for same primary line voltage, delta connection has maximum phase voltage (Since, $V_{ph} = V_L$). So, input connection should be in delta.

Now, for same secondary phase voltage V_2, star connection has maximum line voltage (since, $V_L = \sqrt{3}\,V_{ph}$).

So, the transformer having delta primary and star secondary gives the highest secondary voltage.

Sol–13: **(d)**

If x is the fraction of load at which the efficiency of a transformer is maximum,

Then,

Ohmic losses at that load = Core-loss

$$\Rightarrow x^2 \times P_{cuf\,l} = P_i$$

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$$\Rightarrow \ x = \sqrt{\frac{P_i}{P_{cufl}}} = \sqrt{\frac{40.5}{50}}$$

$$= \sqrt{\frac{81}{100}} = \frac{9}{10} = 0.9$$

Sol–14: (b)

Since, $V = \sqrt{2}\pi f\phi N$

i.e. for the constant input voltage V,

$$f \cdot \phi = \text{constant}$$

i.e. $f_1 \cdot \phi_1 = f_2 \cdot \phi_2$

$$\Rightarrow \ f_1 \cdot \phi_1 = \frac{f_1}{2} \cdot \phi_2$$

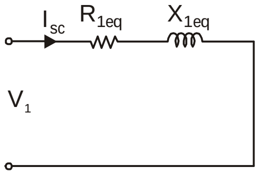
[since f_1 = 50Hz, f_2 = 25Hz]

$$\Rightarrow \ \phi_2 = 2\phi_1$$

i.e. if the frequency of supply voltage is reduced from 50Hz to 25Hz, the flux will be doubled which will drive the core of the transformer into deep saturation.

Sol–15: (d)

Since, during short-circuit test, only a fraction of input voltage is required, the excitation current can be neglected. Hence, during short-circuit test, transformer circuit may be represented as,



then, $$I_{sc} = \frac{V_1}{\sqrt{(R_{1eq})^2 + (X_{1eq})^2}}$$

$$= \frac{V_1}{\sqrt{(R_{1eq})^2 + (2\pi f\, L_{eq})^2}}$$

and, power factor, $\cos\phi$

$$= \frac{R_{1eq}}{\sqrt{(R_{1eq})^2 + (2\pi f\, L_{eq})^2}}$$

Since, current and power factor, both having frequency 'f' in denominator, which causes decrease in current and power factor with increase in frequency.

Sol–16: (b)

In O.C. test, HV side is kept open and supply is usually performed from the LV side because of availability and convenience in supply of low voltage.

In S.C. test, LV side is kept shorted and measurment is taken on hv side because the rated current can be safely measured with the available laboratory ammeters. Also, since the voltage required to circulate full load current i.e. only 5% of the rated voltage, hence, accuracy in the reading of voltmeter is possible when the hv side is used as the primary.

Sol–17: (c)

At the maximum efficiency condition, the copper loss or, ohmic loss of transformer is equal to the iron loss or, core loss of transformer.

So, Copper loss occuring at maximum efficiency = Iron loss = 150W

Then, total loss

= Copper loss + Iron loss

= 150 + 150 = 300W

Sol–18: (d)

The emf equation of transformer is

$$V = \sqrt{2}\pi f\phi N = \sqrt{2}\pi f\, B_m A\, N$$

i.e. $V \propto B_m f$

At constant input voltage,

$$B_m f = \text{constant}$$

Now, the hysteresis loss, $P_h \propto {B_m}^{1.6} \cdot f$

$$\propto \left(\frac{1}{f}\right)^{1.6} \cdot f$$

$$\propto \frac{1}{(f)^{0.6}}$$

i.e. with increase in frequency hysteresis loss will decrease.

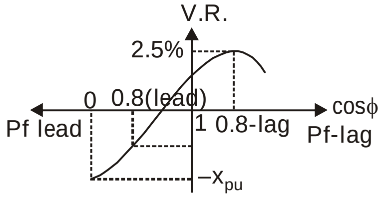
Now, the eddy current loss, $P_e \propto B_m^2 f^2$

$$\propto (B_m f)^2$$

$$\propto \text{constant}$$

i.e. with increase or decrease in frequency, eddy current loss will remain same.

Sol–19: (c)



From the figure, at lead power factor, voltage regulation will be –ve. Hence either of ‘a’ and ‘c’ options are feasible. Since 0.8 is very near to 1. Hence, voltage regulation will be close to 1 with –ve sign which is clearly option ‘c’.

Sol–20: (b)

For successful parallel operation of two single phase transformers, the most essential condition is that their polarities are properly connected. A wrong polarity connection results in a dead short-circuit.

If their turns ratios are different, there will be a circulating current on both primary and secondary sides which leads to extra ohmic losses. So, we can compromise with this condition.

If their pu impedances are not same on its own rating, then the load carried by the transformer will not be proportional to their rating.

If the ratio of equivalent leakage reactance to equivalent resistance of transformers are not same, the one transformer will be operating with higher and other with a lower power factor than that of load. So, the active load is not proportionally shared by them.

Sol–21: (a)

Lenz’s law: In electromagnetic induction, an induced voltage will cause a current to flow in a closed circuit in such a direction that the magnetic field which is caused by that current will oppose the change that produces the current.

Hence, $E = -\frac{d\phi}{dt}$

Here, negative sign appears due to Lenz’s law.

Sol–22: (d)

Since, the voltage applied is taken from the power lines, it can be treated as sinusoidal. Now, as the ohmic drop in the primary winding is assumed negligible as compared to the magnitude of the applied voltage, the induced emf which balances the applied voltage must also be sinusoidal and hence flux established in the core will be also sinusoidal. But due to the hysteresis and saturation non-linearities of the core material, the current required to produce the sinusoidal flux will be non-sinusoidal and peaky.

Sol–23: (b)

— For parallel operation of 3ϕ transformers, the relative phase difference on the secondary sides of transformers must be zero to avoid un-intended short-circuit between phases of two windings.

— Only the transformers of the same phase group can be paralleled.

There are four groups, in which three phase windings connection are classified:

(1) Group 1 : 0^o phase displacement (Y_{y0}, D_{d0}, D_{z0})

(2) Group 2 : 180^o phase displacement (Y_{y6}, D_{d6}, D_{z6})

(3) Group 3 : -30^o phase displacement (Y_{d1}, D_{y1}, Y_{z1})

(4) Group 4 : $+30^o$ phase displacement (Y_{d11}, D_{y11}, Y_{z11})

In order to have zero phase displacement of secondary side line voltages, the transformer belonging to the same group can be paralleled, eg. Y_{d1} and D_{y1}. The transformers of group-1 and group-2 can also be paralleled but with their own group where as the transformer of group-3 and group-4 can be paralleled by reversing the phase sequence of both primary and secondary terminals of one of the transformers.

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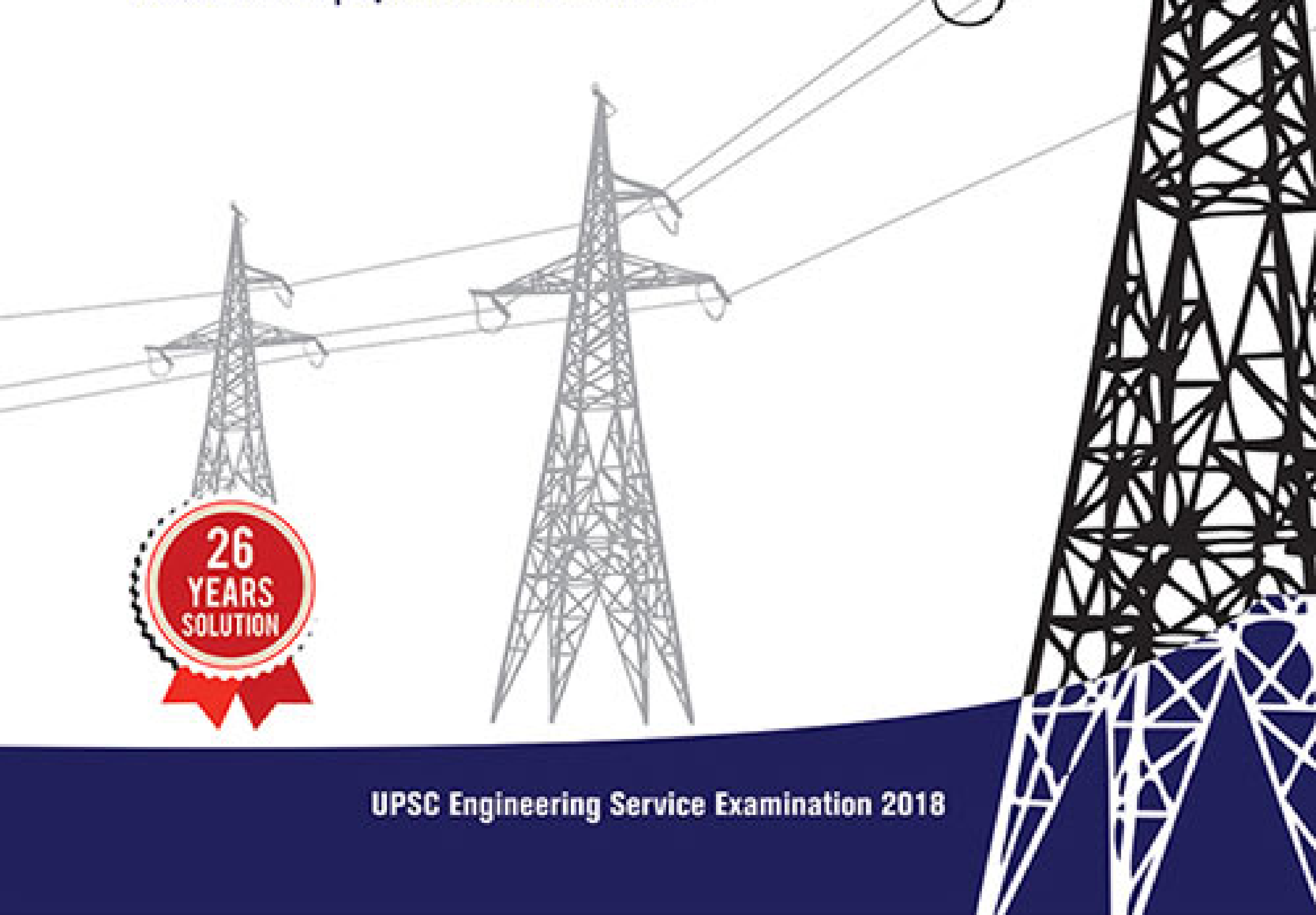

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