Final Written Examination.

10/1/2016

Time all: 3 hrs.

Answer the following questions

Question One: **Complete:** **[15 Marks]**

a) The requirements of a distribution System are Proper voltage , Reliability& Availability of power on demand.

b) The power loss in an overhead transmission line is mainly due to resistance, if the length of a transmission line increases, its inductance is increased

c) The skin effect is less for stranded conductor than the solid conductor, If the supply frequency increases, then skin effect is increased

d) Corona effect is more in stormy weather as compared to fair weather & If the conductor size is increased, the corona effect is decreased.

e) The types of power plants according fuel are nuclear power plants, thermal power plants &solar power plants & according prime mover are turbine, gas turbine & combined cycle.

Question Two: **[25 Marks]**

a) Discuss briefly the design considerations in distribution system.

(i) Feeders. A feeder is designed from the point of view of its current carrying capacity while the voltage drop consideration is relatively unimportant. It is because voltage drop in a feeder can be compensated by means of voltage regulating equipment at the substation.

(ii) Distributors. A distributor is designed from the point of view of the voltage drop in it. It is because a distributor supplies power to the consumers and there is a statutory limit of voltage variations at the consumer's terminals (± 6% of rated value). The size and length of the distributor should be such that voltage at the consumer's terminals is within the permissible limits.

b) What is a sag in overhead lines? Discuss the disadvantages of providing too small or too large sag on a line

Sag is the difference in level between points of supports and the lowest point on the conductor.

- The conductor sag should be kept to a minimum in order to reduce the conductor material required and to avoid extra pole height for sufficient clearance above ground level.
- The tension in the conductor should be low to avoid the mechanical failure of conductor and to permit the use of less strong supports.
- whereas a low tension means a loose wire and increased sag. Therefore, in actual practice, a compromise in made between the two.

b) What is the effect of load power factor on regulation and efficiency of a transmission line?

1. Effect on regulation.

$$\%\text{age Voltage regulation} = \frac{I\,R\cos\phi_R + I\,X_L\sin\phi_R}{V_R}\times 100 \qquad (\textit{for lagging p.f.})$$

$$\%\text{age Voltage regulation} = \frac{I\,R\cos\phi_R - I\,X_L\sin\phi_R}{V_R}\times 100 \qquad (\textit{for leading p.f.})$$

(i) When the load p.f. is lagging or unity or such leading that I R cos ϕR > I XL sin ϕR, then voltage regulation is positive i.e., receiving end voltage VR will be less than the sending end voltage VS.

(ii) For a given VR and I, the voltage regulation of the line increases with the decrease in p.f. for lagging loads.

(iii) When the load p.f. is leading to this extent that I XL sin ϕR > I R cos ϕR, then voltage regulation is negative i.e. the receiving end voltage VR is more than the sending end voltage VS.

(iv) For a given VR and I, the voltage regulation of the line decreases with the decrease in p.f. for leading loads.

2. Effect on transmission efficiency.

$$P = V_R * I\cos\phi_R \quad \text{(For 1-phase line)}$$

$$\therefore \quad I = \frac{P}{V_R\cos\phi_R}$$

$$P = 3\,V_R\,I\cos\phi_R \quad \text{(For 3-phase line)}$$

$$\therefore \quad I = \frac{P}{3V_R\cos\phi_R}$$

It is clear that in each case, for a given amount of power to be transmitted (P) and receiving end voltage (VR), the load current I is inversely proportional to the load p.f. cos ϕR.

Consequently, with the decrease in load p.f., the load current and hence the line losses are increased. This leads to the conclusion that transmission efficiency of a line decreases with the decrease in load p.f. and vice-versa,

c) Why are nuclear power stations becoming very popular?

Because a nuclear power station is that huge amount of electrical energy can be produced from a relatively small amount of nuclear fuel as compared to other conventional types of power stations.

Advantages

(i) The amount of fuel required is quite small. Therefore, there is a considerable saving in the cost of fuel transportation.

(ii) A nuclear power plant requires less space as compared to any other type of the same size.

(iii) It has low running charges as a small amount of fuel is used for producing bulk electrical energy.

(iv) This type of plant is very economical for producing bulk electric power.

(v) It can be located near the load centers because it does not require large quantities of water and need not be near coal mines. Therefore, the cost of primary distribution is reduced.

(vi)There are large deposits of nuclear fuels available all over the world. Therefore, such plants can ensure continued supply of electrical energy for thousands of years.

(vii) It ensures reliability of operation.

d) Derive an expression for the inductance per phase for a 3-phase overhead transmission line when conductors are symmetrically placed.

Flux linkages with conductor A due to its own current $= \frac{\mu_0 I_A}{2\pi}\left(\frac{1}{4} + \int_r^{\infty} \frac{dx}{x}\right)$

Flux linkages with conductor A due to current IB $= \frac{\mu_0 I_B}{2\pi} \int_{d_3}^{\infty} \frac{dx}{x}$

AND ……

$$= \frac{\mu_0 I_A}{2\pi}\left(\frac{1}{4} + \int_r^{\infty} \frac{dx}{x}\right) + \frac{\mu_0 I_B}{2\pi}\int_{d_3}^{\infty}\frac{dx}{x} + \frac{\mu_0 I_C}{2\pi}\int_{d_2}^{\infty}\frac{dx}{x}$$

$$= \frac{\mu_0}{2\pi}\left[\left(\frac{1}{4} + \int_r^{\infty}\frac{dx}{x}\right) I_A + I_B \int_{d_3}^{\infty}\frac{dx}{x} + I_C \int_{d_2}^{\infty}\frac{dx}{x}\right]$$

$$= \frac{\mu_0}{2\pi}\left[\left(\frac{1}{4} - \log_e r\right) I_A - I_B \log_e d_3 - I_C \log_e d_2 + \log_e \infty \left(I_A + I_B + I_C\right)\right]$$

As $I_A + I_B + I_C = 0,$

$$\therefore \quad \psi_A = \frac{\mu_0}{2\pi}\left[\left(\frac{1}{4} - \log_e r\right) I_A - I_B \log_e d_3 - I_C \log_e d_2\right]$$

$$\psi_A = \frac{\mu_0}{2\pi}\left[\left(\frac{1}{4} - \log_e r\right) I_A - I_B \log_e d - I_C \log_e d\right]$$

$$= \frac{\mu_0}{2\pi}\left[\left(\frac{1}{4} - \log_e r\right) I_A - (I_B + I_C)\log_e d\right]$$

$$= \frac{\mu_0}{2\pi}\left[\left(\frac{1}{4} - \log_e r\right) I_A + I_A \log_e d\right] \qquad (\because I_B + I_C = -I_A)$$

$$= \frac{\mu_0 I_A}{2\pi}\left[\frac{1}{4} + \log_e \frac{d}{r}\right] \text{ werber-turns/m}$$

$$L_A = \frac{\psi_A}{I_A} \text{ H/m} = \frac{\mu_0}{2\pi}\left[\frac{1}{4} + \log_e \frac{d}{r}\right] \text{ H/m}$$

$$= \frac{4\pi \times 10^{-7}}{2\pi}\left[\frac{1}{4} + \log_e \frac{d}{r}\right] \text{ H/m}$$

$$L_A = 10^{-7}\left[0 \cdot 5 + 2\log_e \frac{d}{r}\right] \text{ H/m}$$

Question Three: ***Answer Briefly*** **[16 Marks]**

a) Overhead system can be operated at 400 kV or above but underground system offers problems at such voltages Why?.

Underground have greater installation cost and introduce insulation problems at high voltages compared with the equivalent overhead system.

b) The present trend is towards a.c for generation and distribution and d.c. for transmission. Discuss the reasons for it.

a.c for generation and distribution

-Electric power cannot be generated at high d.c. voltage due to commutation problems.

- The d.c. voltage cannot be stepped up for transmission of power at high voltages

But in ac

The power can be generated at high voltages.

(ii) The maintenance of a.c. sub-stations is easy and cheaper.

The a.c. voltage can be stepped up or stepped down by transformers with ease and efficiency. This permits to transmit power at high voltages and distribute it at safe potential

D.C. transmission.

(i) It requires only two conductors as compared to three for a.c. transmission.

(ii) There is no inductance, capacitance.

(iii) Due to the absence of inductance, the voltage drop in a d.c. transmission line is less than the a.c. line for the same load and sending end voltage. For this reason, a d.c. transmission line has better voltage regulation.

(iv) There is no skin effect in a d.c. system. Therefore, entire cross-section of the line conductor is utilized.

(v) For the same working voltage, the potential stress on the insulation is less in case of d.c. system than that in a.c. system. Therefore, a d.c. line requires less insulation.

c) Why hydro-electric stations have high transmission and distribution costs?

Because the plant is located in hilly areas which are quite away from the consumers

d) What is the effect of unsymmetrical spacing of conductors in a 3phase transmission line?

When 3-phase line conductors are not equidistant from each other, the conductor spacing is said to be unsymmetrical. Under such conditions, the flux linkages and inductance of each phase are not the same. A different inductance in each phase results in unequal voltage drops in the three phases even if the currents in the conductors are balanced. Therefore, the voltage at the receiving end will not be the same for all phases.

Question Four: **Design with Drawing** **[20 Marks]**

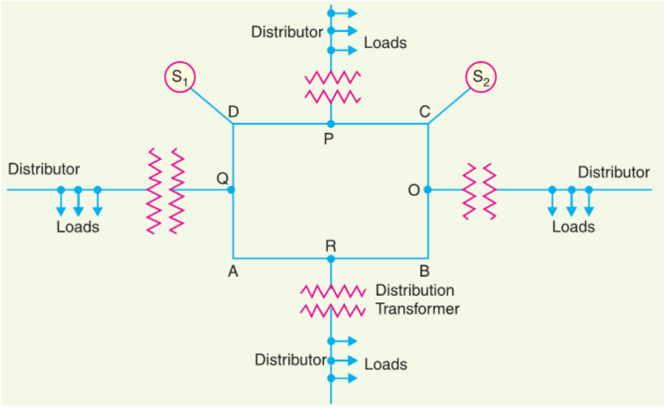
a) Design the distribution system with select type of cables, scheme of connection for feed power from substation 66/11 kV to industrial zone in 6th of october city.

Interconnected system. When the feeder ring is energized by two or more than two generating stations or substations, it is called inter-connected system.

The interconnected system has the following advantages :

(a) It increases the service reliability.

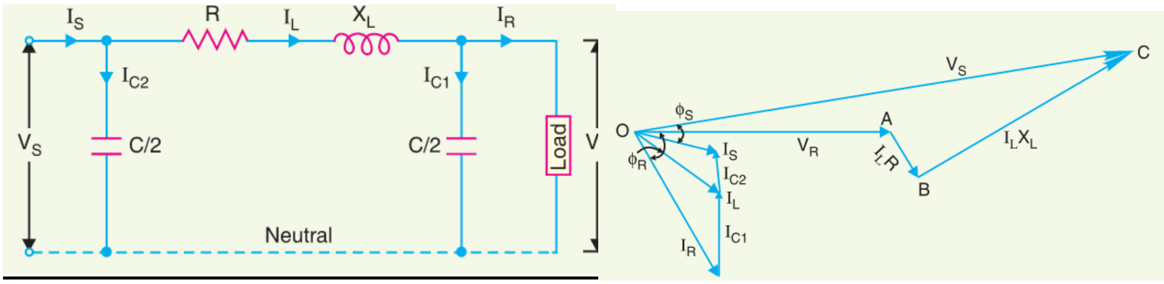
(b) Any area fed from one generating station during peak load hours can be fed from the other generating station. This reduces reserve power capacity and increases efficiency of the system.



With underground cables Belted & screens cables

b) Design The best performance model of overhead transmission line with distance of 150 km &determine regulation and transmission efficiency.

<u>Nominal π method</u>. Capacitance of each conductor (i.e., line to neutral) is divided into two halves; one half being lumped at the sending end and the other half at the receiving end



$$\vec{V_R} = V_R + j0$$

Load current, $\vec{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$

Charging current at load end is

$$\vec{I_{C1}} = j\omega(C/2)\vec{V_R} = j\pi\ fC\vec{V_R}$$

Line current, $\vec{I_L} = \vec{I_R} + \vec{I_{C1}}$

Sending end voltage, $\vec{V_S} = \vec{V_R} + \vec{I_L}\vec{Z} = \vec{V_R} + \vec{I_L}(R + jX_L)$

Charging current at the sending end is

$$\vec{I_{C2}} = j\omega(C/2)\vec{V_S} = j\pi\ fC\vec{V_S}$$

∴ Sending end current, $\vec{I_S} = \vec{I_L} + \vec{I_{C2}}$

c) Design with select all system parts (tower types, cable types, insulation types, substation, cables construction & laying method) to transmit 3000MW by 500 kV from Egypt to Saudi Arabia with some distance via aqaba gulf.

- **Towers type:** suspension, angle ,tension, transposition &end all steel material that Longer life ,**Longer span** ,**Greater mechanical strength For long distance at high voltage**
- **Insulator :** **suspension type &Strain type**
- **Cables types :** **for overhead used Aluminum Conductor Steel Reinforced** for High mechanical strength can be utilized by using spans of larger lengths. ,Tower of smaller height can be used ,A reduction in the number of supports also include reduction in insulators and the risk of lines outage due to flash over or faults is reduced ,losses are reduced due to larger diameter of conductor ,High current carrying capacity.
- **Underground cables :** used Pressure cables :
- When the operating voltages are greater than 66 kV, pressure cables are used. In such cables, holes are eliminated by increasing the pressure of compound and for this reason they are called pressure cables. Two types of pressure :**oil-filled cables & gas pressure cables are commonly used.**
- ***Laying of Under grounding cables:*** ***Draw-in system.***
- ***Substation: AC/DC & DC/AC***

d) The best power station type in area near sea or river and away from heavily populated areas.

Nuclear Power plant

- Energy in nuclear power plants is is a thermal **power** station in which the heat source is a **nuclear** reactor
- In nuclear power station, heavy elements such as Uranium (U235) or Thorium (Th232) are subjected to nuclear fission* in a special apparatus known as a reactor.
- Turbines are rotated by high velocity steam, which is produced as a result of heat generated by **NUCLEAR FISSION** taking place in Reactor Core.
- It has been found that complete fission of 1 kg of Uranium (U235) can produce as much energy as can be produced by the burning of 4,500 tons of high grade coal.

Advantages

(i) The amount of fuel required is quite small. Therefore, there is a considerable saving in the cost of fuel transportation.

(ii) A nuclear power plant requires less space as compared to any other type of the same size.

(iii) It has low running charges as a small amount of fuel is used for producing bulk electrical energy.

- (iv) This type of plant is very economical for producing bulk electric power.
- (vi) There are large deposits of nuclear fuels available all over the world. Therefore, such plants can ensure continued supply of electrical energy for thousands of years.

Disadvantages

(i) The fuel used is expensive and is difficult to recover.

(ii) The capital cost on a nuclear plant is very high as compared to other types of plants.

(iii) The erection and commissioning of the plant requires greater technical know-how.

(iv) The fission by-products are generally radioactive and may cause a dangerous amount of radioactive pollution

Question Five: **[14 Marks]**

a) A diesel power station has the following data , fuel consumption/day = 1000 kg ,units generated/day = 4000 kWh, Calorific value of fuel = 10,000 kcal/kg, Alternator efficiency = 96% ,engine mech. efficiency = 95% ,Estimate

(i) Specific fuel consumption,

(ii) Overall efficiency, and

(iii) Thermal efficiency of engine.

Solution.

(i) Specific fuel consumption = 1000/4000 = **0·25 kg/kWh**

(ii) Heat produced by fuel per day

$$= \text{Coal consumption/day} \times \text{calorific value}$$

$$= 1000 \times 10{,}000 = 10^7 \text{ kcal}$$

Electrical output in heat units per day

$$= 4000 \times 860 = 344 \times 10^4 \text{ kcal}$$

$$\text{Overall efficiency} = \frac{344 \times 10^4}{10^7} \times 100 = \mathbf{34{\cdot}4\%}$$

(iii)
$$\text{Engine efficiency, } \eta_{engine} = \frac{\eta_{overall}}{\eta_{alt.}} = \frac{34 \cdot 4}{0 \cdot 96} = 35{\cdot}83\%$$

$$\text{Thermal efficiency, } \eta_{ther} = \frac{\eta_{engine}}{\text{Mech. } \eta \text{ of engine}} = \frac{35 \cdot 83}{0 \cdot 95} = \mathbf{37{\cdot}71\%}$$

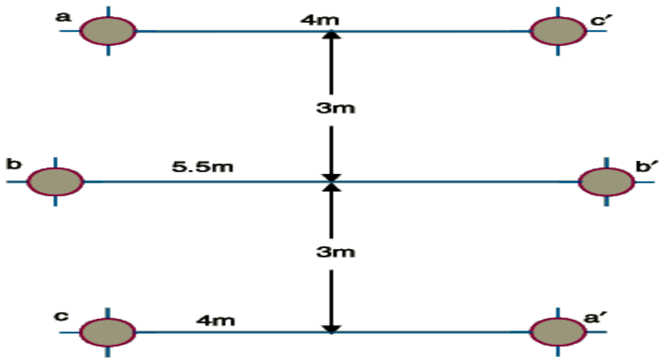
b) A 3-phase, 50 Hz overhead transmission line 100 km long, as shown in Figure below has the following: Resistance/km/phase = 0.1 Ω ,Capacitive Susceptance /km/phase = $0{\cdot}04 \times 10^{-4}$ seamen .The conductors are transposed and are of radius 0·75 cm each. The phase sequence is ABC , Determine:

(i) The sending end current

(ii) Sending end voltage

(iii)Sending end power factor

(iv)Transmission efficiency when supplying a balanced load of 10,000 kW at 66 KV, p.f.0.8 lagging. Use nominal T method.



Solution.

G.M.R. of conductor = $0{\cdot}75 \times 0{\cdot}7788 = 0{\cdot}584$ cm

Distance a to b = $\sqrt{3^2 + (0.75)^2} = 3{\cdot}1$ m

Distance a to b' = $\sqrt{3^2 + (4.75)^2} = 5{\cdot}62$ m

Distance a to a' = $\sqrt{6^2 + 4^2} = 7{\cdot}21$ m

Equivalent self G.M.D. of one phase is

$$D_s = \sqrt[3]{D_{s1} \times D_{s2} \times D_{s3}}$$

where $$D_{s1} = \sqrt[4]{D_{aa} \times D_{aa'} \times D_{a'a'} \times D_{a'a}}$$

$$= \sqrt[4]{\left(0\cdot584\times10^{-2}\right)\times(7\cdot21)\times\left(0\cdot584\times10^{-2}\right)\times(7\cdot21)}$$

$$= 0\cdot205 \text{ m} = D_{s3}$$

$$D_{s2} = \sqrt[4]{\left(D_{bb}\times D_{bb'}\times D_{b'b'}\times D_{b'b}\right)}$$

$$= \sqrt[4]{\left(0\cdot584\times10^{-2}\right)\times(5\cdot5)\times\left(0\cdot584\times10^{-2}\right)\times5\cdot5} = 0\cdot18 \text{ m}$$

$$\therefore \quad D_s = \sqrt[3]{0\cdot205\times0\cdot18\times0\cdot205} = 0\cdot195 \text{ m}$$

Equivalent mutual G.M.D. is

$$D_m = \sqrt[3]{D_{AB}\times D_{BC}\times D_{CA}}$$

where $D_{AB} = \sqrt[4]{D_{ab}\times D_{ab'}\times D_{a'b}\times D_{a'b'}} = \sqrt[4]{3\cdot1\times5\cdot62\times5\cdot62\times3\cdot1}$

$$= 4\cdot17 \text{ m} = D_{BC}$$

$$D_{CA} = \sqrt[4]{D_{ca}\times D_{ca'}\times D_{c'a}\times D_{c'a'}}$$

$$= \sqrt[4]{6\times4\times4\times6} = 4\cdot9 \text{ m}$$

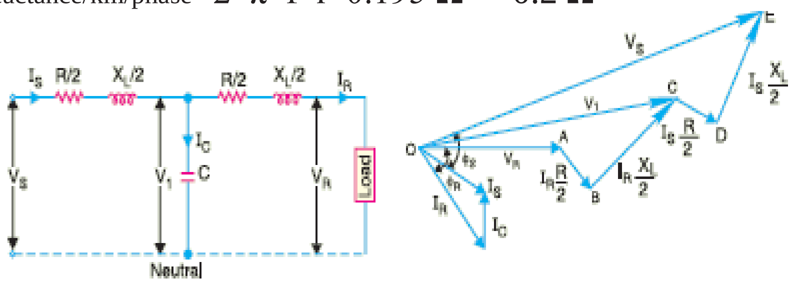
$$\therefore \quad D_m = \sqrt[3]{4\cdot17\times4\cdot17\times4\cdot9} = 4\cdot4 \text{ m}$$

$\therefore$ Inductance/phase/m $= 10^{-7}\times 2\log_e D_m/D_s = 10^{-7}\times2\log_e 4\cdot4/0\cdot195$ H

$= 6\cdot23\times10^{-7}$ H $= 0\cdot623\times10^{-3}$ mH

Inductance/phase/km $= 0\cdot623\times10^{-3}\times1000 = $ **0·623 mH**

Inductive reactance/km/phase=2*π*f*l=0.195 Ω =~0.2 Ω



Total resistance/phase, $R = 0\cdot1\times100 = 10\ \Omega$

Total reactance/phase. $X_L = 0\cdot2\times100 = 20\ \Omega$

Capacitive susceptance, $Y = 0\cdot04\times10^{-4}\times100 = 4\times10^{-4}$ S

Receiving end voltage/phase, $V_R = 66{,}000/\sqrt{3} = 38105\ V$

Load current, $I_R = \dfrac{10{,}000\times10^3}{\sqrt{3}\times66\times10^3\times0\cdot8} = 109$ A

$\cos\phi_R = 0\cdot8\ ;\ \sin\phi_R = 0\cdot6$

Impedance per phase, $\vec{Z} = R + jX_L = 10 + j\,20$

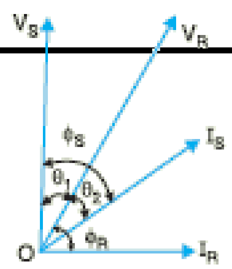
(*i*) Taking receiving end voltage as the reference phasor [see Fig. 10.13 (*ii*)], we have,

Receiving end voltage, $\vec{V_R} = V_R + j\,0 = 38{,}105\ V$

Load current, $\vec{I_R} = I_R(\cos\phi_R - j\sin\phi_R) = 109\,(0\cdot8 - j\,0\cdot6) = 87\cdot2 - j\,65\cdot4$

Voltage across C, $\vec{V_1} = \vec{V_R} + \vec{I_R}\,\vec{Z}/2 = 38{,}105 + (87\cdot2 - j\,65\cdot4)(5 + j\,10)$

$= 38{,}105 + 436 + j\,872 - j\,327 + 654 = 39{,}195 + j\,545$



Charging current, $\vec{I_C} = j\,Y\,\vec{V_1} = j\,4 \times 10^{-4}(39{,}195 + j\,545) = -0{\cdot}218 + j\,15{\cdot}6$

Sending end current, $\vec{I_S} = \vec{I_R} + \vec{I_C} = (87{\cdot}2 - j\,65{\cdot}4) + (-0{\cdot}218 + j\,15{\cdot}6)$

$= 87{\cdot}0 - j\,49{\cdot}8 = 100 \angle -29°47'\text{ A}$

∴ Sending end current $=$ **100 A**

(ii) Sending end voltage, $\vec{V_S} = \vec{V_1} + \vec{I_S}\,\vec{Z}/2 = (39{,}195 + j\,545) + (87{\cdot}0 - j\,49{\cdot}8)\,(5 + j\,10)$

$= 39{,}195 + j\,545 + 434{\cdot}9 + j\,870 - j\,249 + 498$

$= 40128 + j\,1170 = 40145 \angle 1°40'\text{ V}$

∴ Line value of sending end voltage

$= 40145 \times \sqrt{3} = 69\,533\text{ V} =$ **69·533 kV**

(iii) Referring to phasor diagram in Fig. 10.14,

θ_1 = angle between $\vec{V_R}$ and $\vec{V_S} = 1°40'$

θ_2 = angle between $\vec{V_R}$ and $\vec{I_S} = 29°\,47'$

∴ ϕ_S = angle between $\vec{V_S}$ and $\vec{I_S}$

$= \theta_1 + \theta_2 = 1°40' + 29°47' = 31°27'$

∴ Sending end power factor, $\cos\phi_S = \cos 31°27' =$ **0·853 lag**

(iv) Sending end power $= 3\,V_S I_S \cos\phi_S = 3 \times 40{,}145 \times 100 \times 0{\cdot}853$

$= 10273105\text{ W} = 10273{\cdot}105\text{ kW}$

Power delivered $= 10{,}000\text{ kW}$

∴ Transmission efficiency $= \dfrac{10{,}000}{10273{\cdot}105} \times 100 =$ **97·34%**

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With my best wishes