1. One circuit of a single-phase transmission line is composed of three solid 0.5-cm radius wires. The return circuit is composed of two solid 2.5-cm radius wires. The arrangement of conductors is as shown in Figure 1. Applying the concept of the \( GMD \) and \( GMR \), find the inductance of the complete line in milli-henry per kilometer. (15%)

![Figure 1](image)

2. Figure 2 shows the one-line diagram of a simple three-bus power system with generation at buses 1 and 3. The voltage at bus 1 is \( V_1 = 1.025\angle 0^\circ \) per unit. Voltage magnitude at bus 3 is fixed at 1.03 pu with a real power generation of 300 MW. A load consisting of 400MW and 200Mvar is taken from bus 2. Line impedances are marked in per unit on a 100 MVA base. For the purpose of hand calculations, line resistances and line charging susceptances are neglected.

(a) Using Gauss-Seidel method and initial estimates of \( V_2^{(0)} = 1.0 + j0 \) pu
and \( V_3^{(0)} = 1.03 + j0 \) pu and keeping \( |V_b| = 1.03 \) pu, determine the phasor values of \( V_2 \) and \( V_3 \). Perform one iteration. (15%)

(b) If after several iterations the bus voltages converge to
\[
V_2 = 1.001243\angle -2.1^\circ = 1.000571 - j0.0366898 \text{ pu}
\]
\[
V_3 = 1.03\angle 1.36851^\circ = 1.029706 + j0.0246 \text{ pu}
\]
Determine the real and reactive power of the slack bus. (5%)

![Figure 2](image)
3. Two impedances, $Z_1 = 0.8 + j5.6 \, \Omega$ and $Z_2 = 0.8 - j16 \, \Omega$, and a single-phase motor are connected in parallel across a 200 Vrms, 60 Hz supply as shown in Figure 3. The motor draws 5 kVA at 0.8 power factor lagging.

(a) Find the complex powers $S_1$, $S_2$ for the two impedances, and $S_M$ for the motor. (5 %)

(b) Determine total power taken from the supply, the supply current, and the overall power factor. (5 %)

(c) An extra capacitor is connected in parallel with the loads. Find the kvar and the capacitance in $\mu$F to improve the overall power factor to unity.

What is the new line current? (5 %)

![Figure 3](image)

4. A single-line diagram of the power system is shown in Fig. 4. A 13.8 kV generator $G_1$ voltage is stepped up to 138 kV. At the consumer end, the voltage is stepped down to 13.8 kV, and generator $G_2$ operates in synchronism with the supply system. Bus B has 10000 hp motor load. A line-to-ground (LG) fault occurs at bus B. Calculate the fault current (in per unit) in each phase in the motor M. (20 %)

![Figure 4](image)
5. An area of an interconnected power system has four fossil-fuel units operating on economic dispatch. The fuel cost function of these units are given by

\[ C_1(P_1) = 200 + 15P_1 + 0.2P_1^2 \text{ $$/h$$} \; ; \text{Maximum of } P_1 = 100 \text{ MW} \]
\[ C_2(P_2) = 300 + 17.0P_2 + 0.1P_2^2 \text{ $$/h$$} \; ; \text{Maximum of } P_2 = 120 \text{ MW} \]
\[ C_3(P_3) = 150 + 12.0P_3 + 0.15P_3^2 \text{ $$/h$$} \; ; \text{Maximum of } P_3 = 160 \text{ MW} \]
\[ C_4(P_4) = 500 + 2.0P_4 + 0.07P_4^2 \text{ $$/h$$} \; ; \text{Maximum of } P_4 = 200 \text{ MW} \]

\( P_1, P_2, P_3 \) and \( P_4 \) are in megawatts.

Determine the power output of each unit as the total load demand is 505 MW.
Transmission losses are neglected. (20 %)

6. A 60 Hz generator, connected directly to infinite bus operating at a voltage of 1.0 p.u., has a synchronous reactance of 1.35 per unit. The generator no-load voltage is 1.1 p.u., and its inertia constant \( H \) is 4 M/J/MVA. The generator is suddenly loaded to 60 percent of its maximum power limit; determine the frequency of the resulting natural oscillations of the generator rotor. (10 %)