5. CASO PRACTICO DE COMPENSACION SERIE

5.1. Planteamiento del problema

REPOTENCIACIÓN DE LT´S PITIRERA-DONATO GUERRA 1 Y 2

Para las LT´s Pitirera-Donato Guerra 1 y 2, actualmente tienen capacitores serie de 96.9 MVAR y pueden transmitir hasta 658 MVAS, se propuso incrementar la capacidad de los capacitores serie a 228 MVAR y poder transmitir hasta 1003 MVA lo cuál es posible si se transmite a factores de potencia cercanos a la unidad (en S.E. Donato Guerra ≥ -0.99), para FP´s menores a –0.99 no es posible transmitir los 1003 MVA ya que se rebasa la clase de voltaje de los equipos primarios (420 KV) en la S.E. Pitirera. Desde el punto de vista operativo del sistema de potencia sólo se podrán transmitir 900 MVA a un FP en Donato Guerra de –0.98 y así sucesivamente se disminuye la potencia de transmisión a medida que el FP de transmisión también es menor. Para la toma de decisión sobre la repotenciación de los capacitores serie, es muy importante evaluar su costo ya que involucra adquirir por capacitor serie: 588 unidades capacitoras, 21 racks para alojar 28 unidades, 3 reactores de amortiguamiento, 3 varistores y puentes de conexión para los 7 racks por fase, además de considerar al mismo proveedor de los capacitores serie.

5.2 Análisis de parámetros

RESUMEN DEL ANÁLISIS DE LA OPERACIÓN DE LAS LÍNEAS DE TRANSMISIÓN PITIRERA–DONATO GUERRA, L1 Y L2.

Caso	Transmisión de:	Parámetros en S.E. Pitirera					Parámetros en S.E. Donato Guerra					Observaciones
		Voltaje (kV)	Corriente (Amp´s)	Potencia Real (P) (MW)	Potencia Reactiva (Q) (VAR)	Factor de Potencia	Voltaje (kV)	Corriente (Amp´s)	Potencia Real (P) (MW)	Potencia Reactiva (Q) (VAR)	Factor de Potencia	
5.1	603 MVA, FP = 1.0	406.8	871	613.7	-3.5	1.0	400	870	603	0	1.0	LT sin Compensación
5.2	658 MVA, FP = 1.0	396.7	980	671	-54	+ 0.997	400	950	658	0	1.0	Capacitor Serie a 96.9 MVAR, Cap. Nominal
5.3	658 MVA, FP = -0.98	410.5	929	658	64	- 0.99	400	950	645	130	- 0.98	Capacitor Serie a 96.9 MVAR, Cap. Nominal
5.4	811 MVA, FP = 1.0	402	1193	831	8	1.0	400	1170	811	0	1.0	Transmisión de la potencia natural de la LT.
5.5	811 MVA, FP = -0.98	418.7	1142	814	153	- 0.98	400	1170	795	160	- 0.98	Transmisión de la potencia natural de la LT.
5.6	1003 MVA,	409	1463	1033	104	- 0.99	400	1447	1003	0	1.0	Capacitor Serie a su Capacidad nominal 228

	FP = 1.0											MVAR
5.7	1003 MVA, FP = -0.99	424	1427	1022	231	- 0.975	400	1447	993	141	- 0.99	Capacitor Serie a su Capacidad nominal 228 MVAR
5.8	1003 MVA, FP = -0.98	430	1412	1012	284	- 0.96	400	1447	983	199	- 0.98	Capacitor Serie a su Capacidad nominal 228 MVAR
5.9	900 MVA, FP = -0.98	423.8	1267	905	211	- 0.97	400	1299	882	179	- 0.98	Capacitor Serie a 184 MVAR
5.10	603 MVA, FP = -0.99	422	835	607	66	- 0.99	400	870	597	85	- 0.99	LT sin compensación
5.11	900 MVA, FP = -0.98	420	1283	906	221	- 0.97	395	1315	882	179	- 0.98	Capacitor Serie a 188 MVAR

ANÁLISIS – REPOTENCIACIÓN LÍNEAS DE TRANSMISIÓN PITIRERA-DONATO GUERRA (LT's PIT – DG 1 Y 2).

Situación actual de los capacitores serie de líneas Pitirera – Donato Guerra 1 y 2, S.E. Donato Guerra.

Diagrama unifilar fase "A"

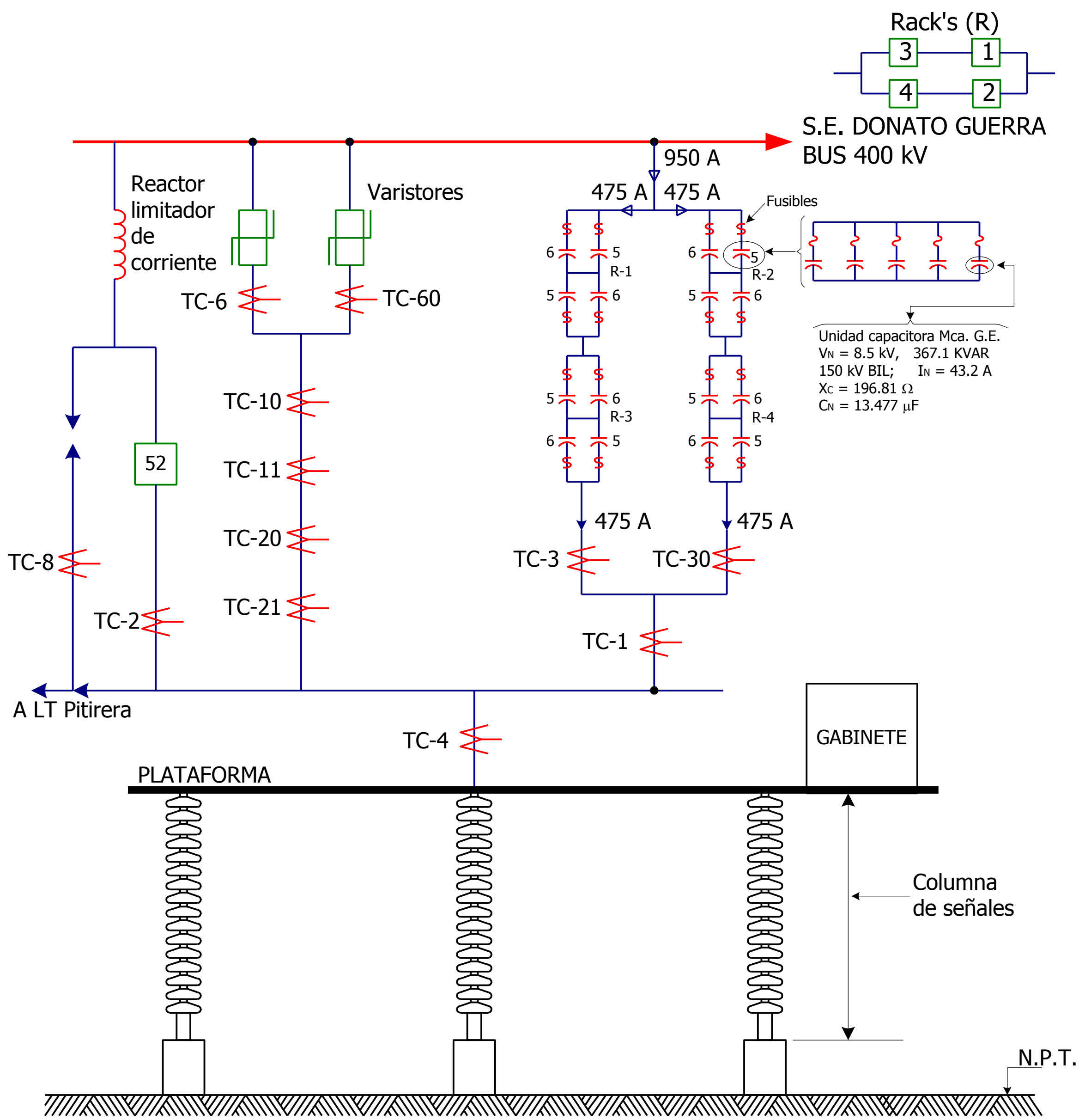


Fig. 5.1 Conexión del Capacitor serie Diagrama Unifilar Fase A

Unidad Capacitora Mca G.E.

$V_N = 8.5\ kV$ $Q_C = 367.1\ KVAR$

$150\ kV\ BIL$ $I_N = 43.2\ A$

$X_C = 196.81\ \Omega$

$C_N = 13.447\ \mu F$

Número de unidades capacitoras por fase:

4 Racks con 22 unidades capacitoras = 88 unidades capacitoras

Capacidad de potencia reactiva por fase:

$KVAR_{1\phi}$ = 88 (367.1) = 32300 KVAR ⇔ 32.3 MVAR.

Reactancia capacitiva por fase:

Reactancia capacitiva de unidad capacitora:

$$X_C = \frac{V_N^2}{Q_C}$$

$$X_{C_{(U.C.)}} = \frac{8.5^2}{.3671} = 196.81\Omega$$

Reactancia capacitiva de 11 u.c. en paralelo.

$$X_{C11U.C.} = \frac{X_{C(U.C.)}}{\#\ U.C.}$$

$$X_{C_{11\,U.C.}} = \frac{196.81}{11} = 17.892\,\Omega$$

Reactancia capacitiva por pierna de fase:

$$X_{C_{PIERNA}} = (\#\, arreglos\ en\ la\ pierna)(X_{C11U.C.})$$

$$X_{C_{PIERNA}} = 4\,(17.892) = 71.568\,\Omega$$

Reactancia capacitiva por fase:

$$X_{C_{\phi}} = \frac{X_{C_{PIERNA}}}{\#\, PIERNAS}$$

$$X_{C_{\phi}} = \frac{71.568\Omega}{2} = 35.784\,\Omega$$

Corriente del capacitor serie a su potencia nominal:

$$I_C = (\#\, U.C\ por\ RACK)(I_N)$$

$$I_C = 11\ (43.188)\ (2) = 950\ A$$

Diferencia de potencial del capacitor serie a su potencia nominal:

$$V_{C_{\phi}} = X_{C_{\phi}} I_C$$

$$V_{C_{\phi}} = (35.784)\ (950) = 34000\ V \Leftrightarrow 34\ kV$$

Potencia reactiva nominal trifásica:

$$Q_{3\phi} = 3X_C I_C^2$$

$$Q_{3\phi} = (35.784)\ (950)^2\ (3) = 96.9\ MVAR$$

Capacitancia por Fase:

$$\boldsymbol{C_1 = 5(13.477) = 67.38\ \mu F}$$

$$C_2 = 2(67.38) = 134.76\ \mu F$$

$$\boldsymbol{C_R = \frac{134.76}{2} = 67.38\ \mu F}$$

$$\boldsymbol{C_P = \frac{67.38}{2} = 33.69\ \mu F}$$

$$\boldsymbol{C_\phi = 33.69 + 33.69 = 67.38\ \mu F}$$

REPOTENCIACIÓN DE LÍNEAS DE TRANSMISIÓN PITIRERA – DONATO GUERRA L1 y L2 (PROPUESTA 258.72 MVAR).

Cada fase contará con 2 piernas formadas por 7 grupos serie con 14 unidades capacitoras en paralelo por grupo. (Ver diagrama unifilar)

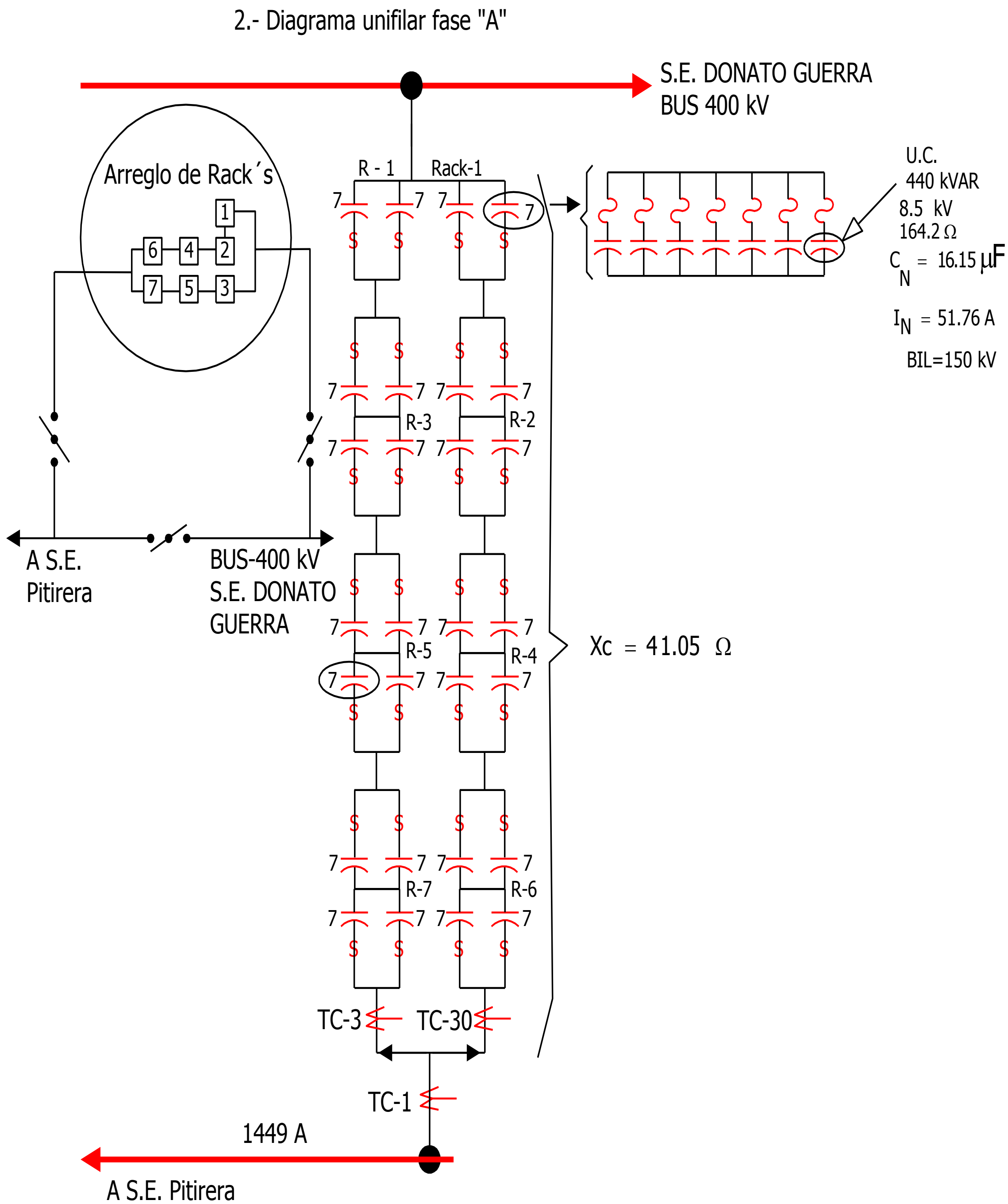


Fig. 5.2. Diagrama Unifilar Fase A Propuesta

Potencia reactiva nominal de unidades capacitoras (u.c.) para tener una Q trifásica de 258.72 MVAR.

Potencia reactiva nominal por fase:

$$\frac{258.72}{3} = 86.24 \text{ MVAR}$$

Total de u.c. por fase:

$$2\ (14)\ (7) = 196 \text{ u.c.}$$

Capacidad de u.c. $Q_{\phi} = \frac{86240 \text{ KVAR}}{196} = 440 \text{ KVAR}$

Voltaje nominal de u.c.:

$$V_N = 8.5 \text{ kV}$$

El voltaje nominal del interruptor de bypass es de 63 kV; por tanto se selecciona el voltaje de u.c. de tal manera que la suma de los 7 grupos serie sea menor a 63 kV.

$$7\ (8.5) < 63 \text{ kV}; \qquad 59.5 \text{ kV} < 63 \text{ kV}$$

Datos nominales de las unidades capacitoras (u.c):

$V_N = 8.5$ kV;	$Q_N = 440$ KVAR;	$X_C = 164.2\ \Omega$
$C_N = 16.1537$□ μF;	$I_N = 51.76$ A;	150 kV – BIL

Reactancia capacitiva por fase:

Reactancia capacitiva de 14 u.c. en paralelo.

$$X_{C14U.C.} = \frac{X_{C(U.C.)}}{\# U.C.}$$

$$X_{C_{14\,U.C.}} = \frac{164.2}{14} = 11.72\,\Omega$$

Reactancia capacitiva por pierna de fase:

$$X_{C_{PIERNA}} = (\# \, arreglos \, en \, la \, pierna)(X_{C14U.C.})$$

$$X_{C_{PIERNA}} = 7\,(11.72) = 82.10\,\Omega$$

Reactancia capacitiva por fase:

$$X_{C_{\phi}} = \frac{X_{C_{PIERNA}}}{\# \, PIERNAS}$$

$$X_{C_{\phi}} = \frac{82.10\,\Omega}{2} = 41.05\,\Omega$$

Corriente nominal por fase a potencia nominal del capacitor serie:

$$I_{N_{\phi}} = (14)(51.76)(2)$$

$$I_{N_{\phi}} = 1449.4 \;\; AMP$$

Capacidad de corriente máxima de emergencia por 30 min.

$$I_{MÁX.} = 1.15\ (1449.4) \doteq 1667\ A \Leftrightarrow 1155\ MVA$$

Diferencia de potencial en el capacitor serie:

$$V_{C_\phi} = X_{C_\phi} I_C$$

$$V_{C_\phi} = (41.05)\ (1449.4) \doteq 59498\ V \Leftrightarrow 59.5\ kV$$

Potencia reactiva nominal por fase:

$$Q_\phi = X_C I_C^2$$

$$Q_{1\phi} = (41.05)\ (1449.4)^2 \doteq 86.24\ MVAR$$

Potencia reactiva trifásica del capacitor serie:

$$Q_{3\phi} = 3\ (86.24) = 258.72\ MVAR$$

Capacitancia por Fase:

$$\boldsymbol{C_1 = 7(16.15) = 113.05\ \mu F}$$

$$C_2 = 2(113.05) = 226.1\ \mu F$$

$$\boldsymbol{C_R = \frac{226.1}{2} = 113.05\ \mu F}$$

$$\boldsymbol{C_{3R} = \frac{113.05}{3} = 37.683\ \mu F}$$

$$\boldsymbol{C_{PIERNA} = \frac{(37.683)(226.1)}{(37.683) + (226.1)} = 32.30\ \mu F}$$

$$C_\phi = 32.30 + 32.30 = 64.6\ \mu F$$

Unidades capacitoras por capacitor serie:

V_N = 8.5 kV; Q_N = 440 KVAR; X_C = 164.2 Ω

C_N = 16.1537 μF; I_N = 51.76 A; 150 kV – BIL.

Total de Unidades: 3 X 196 = 588

Para cada capacitor serie adquirir 21 Rack's tipo G7 para alojar hasta 28 unidades capacitoras máx.

Por capacitor serie, adquirir 588 listones fusibles para protección de u.c. (capacidad determinada por proveedor), tipo 31F2804G3 – G.E., V = 25 kV_{pico}

Las u.c. deberán ser de las dimensiones especificadas, compatibles con rack's tipo G7.

Por capacitor serie, adquirir 3 reactores de amortiguamiento para 1500 Amps.

Por capacitor serie, adquirir 3 varistores para 65.5 kV.

Por capacitor serie, adquirir las conexiones necesarias para tener 7 racks por fase con 28 unidades capacitoras.

Adquirir 5% adicional de unidades capacitoras y fusibles como reserva.

Los TC´S existentes son funcionales para la repotenciación del capacitor serie.

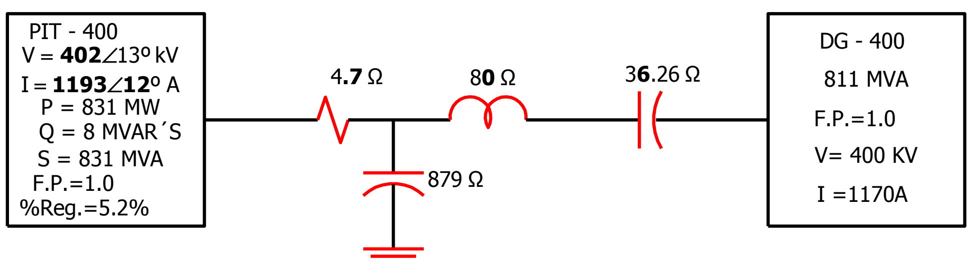
TC	FUNCIÓN	RELACIÓN
TC-9	Interfase plataforma – fibra óptica	1000/2000:1A
TC-2	Corriente de interruptor	2000:1ª
TC-3 TC-30	Desbalance del capacitor	1500:5ª
TC-1	Corriente del banco de capacitores	2000:1ª
TC-4	Falla a plataforma	2000:1ª
TC-6 TC-60	Desbalance de varistor	2000:1ª
TC-8	Corriente de gap (aire)	2000:1ª
TC-10 TC-11	Varistor analógico	2000:1ª
TC-20 TC-21	Varistor analógico	2000:1ª

OPERACIÓN DE LA LÍNEA DE TRANSMISIÓN PITIRERA – DONATO GUERRA.

LT SIN COMPENSACIÓN, IMPEDANCIA CARACTERÍSTICA ZC = 265Ω, SIL = 603 MW

LT CON UN GRADO DE COMPENSACIÓN DEL 45%, (SITUACIÓN ACTUAL)

(I) LT- COMPENSADA (SITUACIÓN PROPUESTA, 228 MVAR, TRANSMISIÓN DE 811 MVA, F.P.=1.0, EN S.E. DONATO GUERRA (POTENCIA NATURAL DE LA LT).



$$V_z = I_R\left[\frac{R}{2}+\frac{jX_L}{2}-jX_S\right]$$

$$\tilde{V}_T = \tilde{V}_R + \tilde{I}_R\left[\frac{R}{2}+\frac{jX_L}{2}-jX_S\right] = \left(\frac{400[KV]}{\sqrt{3}}\right)+(1170[A])\left(\frac{4.7}{2}+\frac{j80}{2}-j36.26\right)$$

$$\tilde{V}_T = [233.6895 + j4.3758][KV]$$

$$\tilde{V}_T = 233.73[KV]\angle 1.07°$$

$$\tilde{I}_c = \frac{\tilde{V}_T}{-jX_c} = \frac{233.73[KV]\angle 1.08}{879[\Omega]\angle -90} = 265.9049[A]\angle 91.07°$$

$$\tilde{I}_c = [-4.9781 + j265.8583][A]$$

$$\tilde{I}_G = \tilde{I}_R + \tilde{I}_c = 1170[A] - 4.9781 + j265.8583[A]$$

$$\tilde{I}_G = [1165.0218 + j265.8583][A]$$

$$\mathbf{1194.9713}[A]\angle\mathbf{12.85}°$$

$$\tilde{V}_G = \tilde{V}_T + \tilde{I}_G \left[\frac{R}{2} + j\frac{X_L}{2}\right]$$

$$= 233.6895 + j4.3758[KV] + [1165.0218 + j265.8583]\left[\frac{4.7}{2} + j\frac{80}{2}\right]$$

$$[225.792 + j51.601][KV]$$

$$231.614[KV]\angle 12.87$$

$$\sqrt{3} * [231.614[KV]\angle 12.87]$$

$$\mathbf{401.167[KV]\angle 12.87° + 30°}$$

$$S_G = P_G + jQ_G = V_G I_G^*$$

$$S_G = (225.792 + j51.601)[KV](1165.0218 - j265.8583)[A]$$

$$S_G = 276.7711[MW] - j87.612[KVAR]$$

$$S_G = 276.7711[MVA]$$

$$\boldsymbol{S_{G3\emptyset} = 3(276.7711) = 830[MVA]}$$

$$\boldsymbol{P_{G3\emptyset} = 3(276.7711)[MW] = 830.3133[MW]}$$

$$\boldsymbol{Q_{G3\emptyset} = 3(87.612)[KVAR] = 262.836[KVAR]}$$

$$\boldsymbol{F.P = \cos\theta = \cos(12.87 - 12.85)}$$

$$\boldsymbol{= 1}$$

$$I_0 = \frac{\tilde{V}_G}{\frac{R}{2} + j\frac{X_L}{2} - jX_C}$$

$$I_0 = \frac{[225.792 + j51.601][KV]}{\left[\frac{4.7}{2} + j\frac{80}{2} - j879\right][\Omega]}$$

$$I_0 = (-60.7487 + j269.2905)[A]$$

$$V_{R_0} = -jX_C\tilde{I}_0$$

$$V_{R_0} = -j879(-60.7487 + j269.2905)$$

$$= [236.706 + j53.398][KV]$$

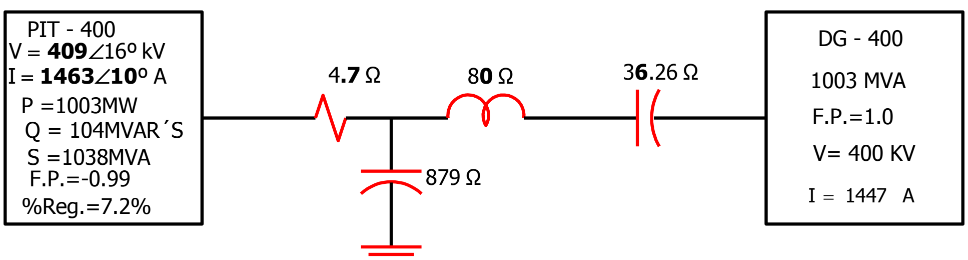
$$= 242.6546[KV]$$

$$\%\boldsymbol{Reg} = \frac{\boldsymbol{V_{R_0} - V_R}}{\boldsymbol{V_R}} \times \mathbf{100}$$

$$= \frac{\mathbf{242.6546[KV] - 230.9401[KV]}}{\mathbf{230.9401[KV]}} \times \mathbf{100}$$

$$= \mathbf{5.07}\%$$

(II) TRANSMISIÓN DE 1003 MVA, F.P.= 1.0 EN S.E. DONATO GUERRA (CAPACITOR SERIE A SU CAPACIDAD NOMINAL 228 MVAR, V=52.5KV, I=1447A).



$$V_z = I_R\left[\frac{R}{2} + \frac{jX_L}{2} - jX_S\right]$$

$$\tilde{V}_T = \tilde{V}_R + \tilde{I}_R\left[\frac{R}{2} + \frac{jX_L}{2} - jX_S\right] = \left(\frac{400[KV]}{\sqrt{3}}\right) + (1447[A])\left(\frac{4.7}{2} + \frac{j80}{2} - j36.26\right)$$

$$\tilde{V}_T = [234.3405 + j5.4117][KV]$$

$$\tilde{V}_T = 234.403[KV]\angle 1.32°$$

$$\tilde{I}_c = \frac{\tilde{V}_T}{-jX_c} = \frac{234.403[KV]\angle 1.32}{879[\Omega]\angle -90} = 266.6701[A]\angle 91.32°$$

$$\tilde{I}_c = [-6.1567 + j266.5990][A]$$

$$\tilde{I}_G = \tilde{I}_R + \tilde{I}_c = 1147[A] - 6.1567 + j266.5990[A]$$

$$\tilde{I}_G = [1440.8433 + j266.5990][A]$$

$$\mathbf{1465.3001[A]\angle 10.48°}$$

$$\tilde{V}_G = \tilde{V}_T + \tilde{I}_G\left[\frac{R}{2} + j\frac{X_L}{2}\right]$$

$$= [234.3405 + j5.4117][KV] + [1440.8433 + j266.599]\left[\frac{4.7}{2} + j\frac{80}{2}\right]$$

$$[227.0625 + j63.7619][KV]$$

$$235.8209[KV]\angle 15.66$$

$$\sqrt{3} * [235.8209[KV]\angle 15.66]$$

$$\mathbf{408.4538[\mathit{KV}]\angle 15.66° + 30°}$$

$$S_G = P_G + jQ_G = V_G I_G^*$$

$$S_G = (227.0625 + j63.6719)[KV](1440.8433 - j266.5990)[A]$$

$$S_G = 344.1363[MW] - j31.2065[MVAR]$$

$$S_G = 345.5483[MVA]$$

$$\boldsymbol{S_{G3\emptyset} = 3(345.5483) = 1036.645[MVA]}$$

$$\boldsymbol{P_{G3\emptyset} = 3(344.1363)[MW] = 1032.40889[MW]}$$

$$\boldsymbol{Q_{G3\emptyset} = 3(31.2065)[MVAR] = 93.6195[MVAR]}$$

$$\boldsymbol{F.P = \cos\theta = \cos(15.66 - 10.48)}$$

$$\mathbf{= 0.99}$$

$$I_0 = \frac{\tilde{V}_G}{\frac{R}{2} + j\frac{X_L}{2} - jX_C}$$

$$I_0 = \frac{[227.0625 + j63.6719][KV]}{\left[\frac{4.7}{2} + j\frac{80}{2} - j879\right][\Omega]}$$

$$I_0 = (-75.1316 + j270.8451)[A]$$

$$V_{R_0} = -jX_C\tilde{I}_0$$

$$V_{R_0} = -j879(-75.1316 + j270.8451)$$

$$= [238.0728 + j66.0406][KV]$$

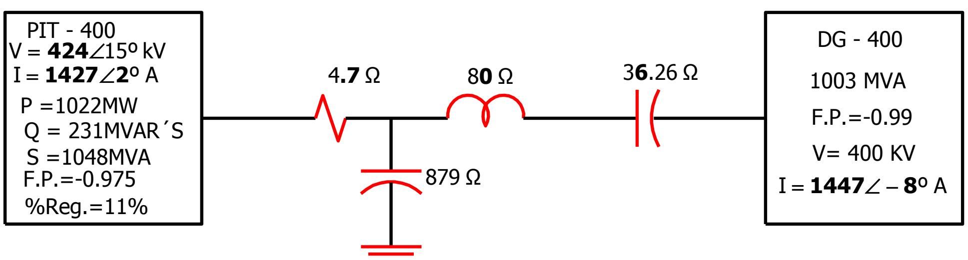
$$= 247.0628[KV]$$

$$\%\boldsymbol{Reg} = \frac{\boldsymbol{V_{R_0} - V_R}}{\boldsymbol{V_R}} \times \mathbf{100}$$

$$= \frac{\mathbf{247.0628[KV] - 230.9401[KV]}}{\mathbf{230.9401[KV]}} \times \mathbf{100}$$

$$= \mathbf{6.98}\%$$

(III) TRANSMISIÓN DE 1003 MVA, F.P.=-.99 EN S.E. DONATO GUERRA (CAPACITOR SERIE A SU CAPACIDAD NOMINAL 228 MVAR, V=52.5KV, I=1447 A).



$$V_z = I_R\left[\frac{R}{2} + \frac{jX_L}{2} - jX_S\right]$$

$$\tilde{V}_T = \tilde{V}_R + \tilde{I}_R\left[\frac{R}{2} + \frac{jX_L}{2} - jX_S\right] = \left(\frac{400[KV]}{\sqrt{3}}\right) + (1432 - j201.3834)[A]\left(\frac{4.7}{2} + \frac{j80}{2} - j36.26\right)$$

$$\tilde{V}_T = [235.0606 + j4.8858][KV]$$

$$\tilde{V}_T = 235.1114[KV]\angle 1.19°$$

$$\tilde{I}_c = \frac{\tilde{V}_T}{-jX_c} = \frac{235.1114[KV]\angle 1.19}{879[\Omega]\angle -90} = 267.4759[A]\angle 91.19°$$

$$\tilde{I}_c = [-5.5584 + j267.4182][A]$$

$$\tilde{I}_G = \tilde{I}_R + \tilde{I}_c = 1432.9178 - j201.38 - 5.5584 + j267.4182[A]$$

$$\tilde{I}_G = [1427.3593 + j66.0382][A]$$

$$\mathbf{1428.8862}[A]\angle \mathbf{2.64}°$$

$$\tilde{V}_G = \tilde{V}_T + \tilde{I}_G\left[\frac{R}{2} + j\frac{X_L}{2}\right]$$

$$= [235.0606 + j4.8858][KV] + [1427.3593 + j66.038]\left[\frac{4.7}{2} + j\frac{80}{2}\right]$$

$$[235.773 + j62.1353][KV]$$

$$243.8234[KV]\angle 14.76$$

$$\sqrt{3} * [243.8283[KV]\angle 14.76]$$

$$\mathbf{422.3146[KV]\angle 14.76° + 30°}$$

$$S_G = P_G + jQ_G = V_G I_G^*$$

$$S_G = ([235.773 + j62.1353])[KV](1427.3593 - j66.0382)[A]$$

$$S_G = 340.6366[MW] - j73.1194[MVAR]$$

$$S_G = 348.3959[MVA]$$

$$\boldsymbol{S_{G3\emptyset}} = \mathbf{3}(348.3959) = \mathbf{1045.1879[MVA]}$$

$$\boldsymbol{P_{G3\emptyset}} = \mathbf{3}(340.6366)[\boldsymbol{MW}] = \mathbf{1021.9098[MW]}$$

$$\boldsymbol{Q_{G3\emptyset}} = \mathbf{3}(73.1194)[\boldsymbol{MVAR}] = \mathbf{219.3582[MVAR]}$$

$$\boldsymbol{F.P} = \mathbf{\cos\theta} = \mathbf{\cos(14.76 - 2.64)}$$

$$= \mathbf{0.97}$$

$$I_0 = \frac{\tilde{V}_G}{\frac{R}{2} + j\frac{X_L}{2} - jX_C}$$

$$I_0 = \frac{[235.773 + j62.1353][KV]}{\left[\frac{4.7}{2} + j\frac{80}{2} - j879\right][\Omega]}$$

$$I_0 = (-73.2710 + j281.2219)[A]$$

$$V_{R_0} = -jX_C\tilde{I}_0$$

$$V_{R_0} = -j879(-73.2710 + j281.2219)$$

$$= [247.194 + j64.4052][KV]$$

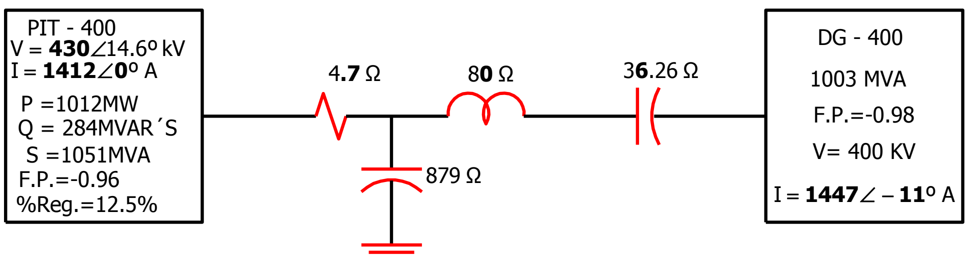
$$= 255.4465[KV]$$

$$\%\boldsymbol{Reg} = \frac{\boldsymbol{V_{R_0}} - \boldsymbol{V_R}}{\boldsymbol{V_R}} \times \mathbf{100}$$

$$= \frac{\mathbf{255.4465}[\boldsymbol{KV}] - \mathbf{230.9401}[\boldsymbol{KV}]}{\mathbf{230.9401}[\boldsymbol{KV}]} \times \mathbf{100}$$

$$= \mathbf{10.61}\%$$

(IV) TRANSMISIÓN DE 1003 MVA, F.P.=-0.98 EN S.E. DONATO GUERRA (CAPACITOR SERIE A SU CAPACIDAD NOMINAL 228 MVAR, V=52.5KV, I=1447 A).



$$V_z = I_R\left[\frac{R}{2} + \frac{jX_L}{2} - jX_S\right]$$

$$\tilde{V}_T = \tilde{V}_R + \tilde{I}_R\left[\frac{R}{2} + \frac{jX_L}{2} - jX_S\right] = \left(\frac{400[KV]}{\sqrt{3}}\right) + (1420 - j276.10)[A]\left(\frac{4.7}{2} + \frac{j80}{2} - j36.26\right)$$

$$\tilde{V}_T = [235.3106 + j4.663][KV]$$

$$\tilde{V}_T = 235.3568[KV]\angle 1.13°$$

$$\tilde{I}_c = \frac{\tilde{V}_T}{-jX_c} = \frac{235.356[KV]\angle 1.13}{879[\Omega]\angle - 90} = 267.66[A]\angle 91.13°$$

$$\tilde{I}_c = [-5.3054 + j267.7027][A]$$

$$\tilde{I}_G = \tilde{I}_R + \tilde{I}_c = 1420.41 - j276.10 - 5.3054 + j267.7027[A]$$

$$\tilde{I}_G = [1415.1046 - j8.3973][A]$$

$$\mathbf{1415.1295}[\boldsymbol{A}]\angle - \mathbf{0.33}°$$

$$\tilde{V}_G = \tilde{V}_T + \tilde{I}_G\left[\frac{R}{2} + j\frac{X_L}{2}\right]$$

$$= [235.3106 + j4.663][KV] + [1415.1046 + j8.3973]\left[\frac{4.7}{2} + j\frac{80}{2}\right]$$

$$[238.9719 + j61.2474][KV]$$

$$246.6958[KV]\angle 14.37$$

$$\sqrt{3} * \left[246.6958[KV]\right]$$

$$\mathbf{427.2898}[\boldsymbol{KV}]\angle\mathbf{14.37}° + \mathbf{30}°$$

$$S_G = P_G + jQ_G = V_G I_G^*$$

$$S_G = ([238.9719 + j61.2474])[KV](1415.1046 + j8.3973)[A]$$

$$S_G = 337.6559[MW] - j88.6718[MVAR]$$

$$S_G = 349.1064[MVA]$$

$$\boldsymbol{S_{G3\emptyset}} = \mathbf{3}(349.1064) = \mathbf{1047.3199}[\boldsymbol{MVA}]$$

$$\boldsymbol{P_{G3\emptyset}} = \mathbf{3}(337.6559)[\boldsymbol{MW}] = \mathbf{1012.96}[\boldsymbol{MW}]$$

$$\boldsymbol{Q_{G3\emptyset}} = \mathbf{3}(88.6718)[\boldsymbol{MVAR}] = \mathbf{266.0344}[\boldsymbol{MVAR}]$$

$$\boldsymbol{F.P} = \mathbf{cos}\,\boldsymbol{\theta} = \mathbf{cos}(\mathbf{14.37} + \mathbf{0.33})$$

$$= \mathbf{0.96}$$

$$I_0 = \frac{\tilde{V}_G}{\frac{R}{2} + j\frac{X_L}{2} - jX_C}$$

$$I_0 = \frac{[238.9719 + j61.2474][KV]}{\left[\frac{4.7}{2} + j\frac{80}{2} - j879\right][\Omega]}$$

$$I_0 = (-72.202 + j285.031)[A]$$

$$V_{R_0} = -jX_C\tilde{I}_0$$

$$V_{R_0} = -j879(-72.202 + j285.031)$$

$$= [250.542 + j63.465][KV]$$

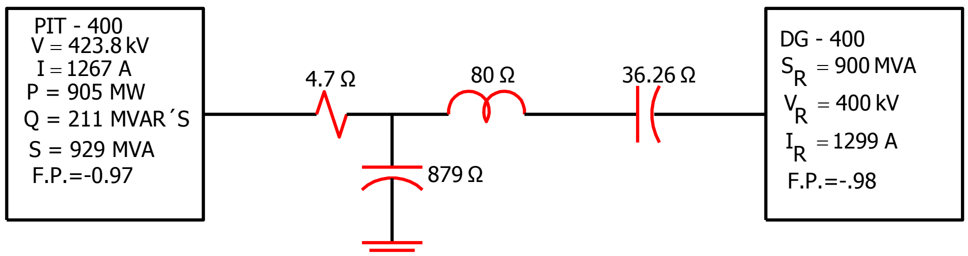
$$= 258.4561[KV]$$

$$\%\boldsymbol{Reg} = \frac{\boldsymbol{V_{R_0}} - \boldsymbol{V_R}}{\boldsymbol{V_R}} \times \mathbf{100}$$

$$= \frac{\mathbf{258.4561}[\boldsymbol{KV}] - \mathbf{230.9401}[\boldsymbol{KV}]}{\mathbf{230.9401}[\boldsymbol{KV}]} \times \mathbf{100}$$

$$= \mathbf{11.91}\%$$

(V) TRANSMISIÓN DE 900 MVA, F.P.=-0.98 EN S.E. DONATO GUERRA.



$$V_z = I_R\left[\frac{R}{2} + \frac{jX_L}{2} - jX_S\right]$$

$$\tilde{V}_T = \tilde{V}_R + \tilde{I}_R\left[\frac{R}{2} + \frac{jX_L}{2} - jX_S\right] = \left(\frac{400[KV]}{\sqrt{3}}\right) + (1275.13 - j247.86)[A]\left(\frac{4.7}{2} + \frac{j80}{2} - j36.26\right)$$

$$\tilde{V}_T = [234.86 + j4.186][KV]$$

$$\tilde{V}_T = 234.9[KV]\angle 1.02°$$

$$\tilde{I}_c = \frac{\tilde{V}_T}{-jX_c} = \frac{234.9[KV]\angle 1.02}{879[\Omega]\angle -90} = 267.236[A]\angle 91.02°$$

$$\tilde{I}_c = [-4.7628 + j267.1941][A]$$

$$\tilde{I}_G = \tilde{I}_R + \tilde{I}_c = 1275.13 - j247.86 - 4.7628 + j267.1941[A]$$

$$\tilde{I}_G = [1270.3672 + j19.3341][A]$$

$$\mathbf{1270.5143}[\boldsymbol{A}]\angle\mathbf{0.87}°$$

$$\tilde{V}_G = \tilde{V}_T + \tilde{I}_G\left[\frac{R}{2} + j\frac{X_L}{2}\right]$$

$$= [234.86 + j4.186][KV] + [1270.3672 + j19.3341]\left[\frac{4.7}{2} + j\frac{80}{2}\right]$$

$$[237.071 + j55.046][KV]$$

$$243.3787[KV]\angle 13.07$$

$$\sqrt{3} * \left[243.3787[KV]\right]$$

$$\mathbf{421.544}[\boldsymbol{KV}]\angle\mathbf{13.07}° + \mathbf{30}°$$

$$S_G = P_G + jQ_G = V_G I_G^*$$

$$S_G = ([237.071 + j55.046])[KV](1270.3672 - j19.3341)[A]$$

$$S_G = 302.231[MW] + j65.345[MVAR]$$

$$S_G = 309.214[MVA]$$

$$\boldsymbol{S_{G3\emptyset}} = \mathbf{3}(309.214) = \mathbf{927.6445}[\boldsymbol{MVA}]$$

$$\boldsymbol{P_{G3\emptyset}} = \mathbf{3}(302.231)[\boldsymbol{MW}] = \mathbf{906.693}[\boldsymbol{MW}]$$

$$\boldsymbol{Q_{G3\emptyset}} = \mathbf{3}(65.345)[\boldsymbol{MVAR}] = \mathbf{196.345}[\boldsymbol{MVAR}]$$

$$\boldsymbol{F.P} = \mathbf{cos}\,\boldsymbol{\theta} = \mathbf{cos}(\mathbf{13.07} + \mathbf{0.87})$$

$$= \mathbf{0.97}$$

$$I_0 = \frac{\tilde{V}_G}{\frac{R}{2} + j\frac{X_L}{2} - jX_C}$$

$$I_0 = \frac{[237.071 + j55.046][KV]}{\left[\frac{4.7}{2} + j\frac{80}{2} - j879\right][\Omega]}$$

$$I_0 = (-64.817 + j282.745)[A]$$

$$V_{R_0} = -jX_C\tilde{I}_0$$

$$V_{R_0} = -j879(-64.817 + j282.745)$$

$$= [248.533 + j56.974][KV]$$

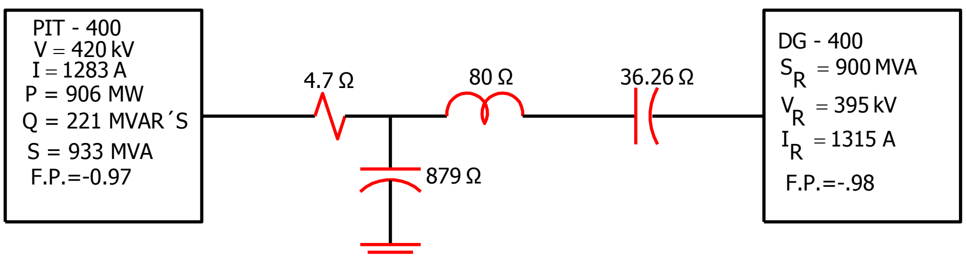
$$= 254.979[KV]$$

$$\%\boldsymbol{Reg} = \frac{\boldsymbol{V_{R_0} - V_R}}{\boldsymbol{V_R}} \times \mathbf{100}$$

$$= \frac{\mathbf{254.979}[\boldsymbol{KV}] - \mathbf{230.9401}[\boldsymbol{KV}]}{\mathbf{230.9401}[\boldsymbol{KV}]} \times \mathbf{100}$$

$$= \mathbf{10.40}\%$$

(VI) TRANSMISIÓN DE 900 MVA, F.P.=-0.98 EN DONATO GUERRA.



$$V_z = I_R\left[\frac{R}{2} + \frac{jX_L}{2} - jX_S\right]$$

$$\tilde{V}_T = \tilde{V}_R + \tilde{I}_R\left[\frac{R}{2} + \frac{jX_L}{2} - jX_S\right] = \left(\frac{395[KV]}{\sqrt{3}}\right) + (1290.83 - j250.91)[A]\left(\frac{4.7}{2} + \frac{j80}{2} - j36.26\right)$$

$$\tilde{V}_T = [232.0251 + j4.238][KV]$$

$$\tilde{V}_T = 232.063[KV]\angle 1.04°$$

$$\tilde{I}_c = \frac{\tilde{V}_T}{-jX_c} = \frac{232.063[KV]\angle 1.04°}{879[\Omega]\angle -90} = 264.008[A]\angle 91.04°$$

$$\tilde{I}_c = [-4.821 + j263.9649][A]$$

$$\tilde{I}_G = \tilde{I}_R + \tilde{I}_c = 1290.83 - j250.91 - 4.821 + j263.9649[A]$$

$$\tilde{I}_G = [1286.009 + j13.054][A]$$

$$\mathbf{1286.0752}[\boldsymbol{A}]\angle\mathbf{0.58}°$$

$$\tilde{V}_G = \tilde{V}_T + \tilde{I}_G\left[\frac{R}{2} + j\frac{X_L}{2}\right]$$

$$= [232.0251 + j4.238][KV] + [1286.009 + j13.054]\left[\frac{4.7}{2} + j\frac{80}{2}\right]$$

$$[234.562 + j55.709][KV]$$

$$241.087[KV]\angle 13.36$$

$$\sqrt{3} * [241.087[KV]]$$

$$\mathbf{417.576[KV]\angle 13.36° + 30°}$$

$$S_G = P_G + jQ_G = V_G I_G^*$$

$$S_G = ([234.562 + j55.709])[KV](1286.009 - j13.054)[A]$$

$$S_G = 298.5868[MW] + j70.915[MVAR]$$

$$S_G = 306.8925[MVA]$$

$$\boldsymbol{S_{G3\emptyset}} = \mathbf{3}(306.8925) = \mathbf{920.6777}[\boldsymbol{MVA}]$$

$$\boldsymbol{P_{G3\emptyset}} = \mathbf{3}(298.5868)[\boldsymbol{MW}] = \mathbf{895.7604}[\boldsymbol{MW}]$$

$$\boldsymbol{Q_{G3\emptyset}} = \mathbf{3}(70.915)[\boldsymbol{MVAR}] = \mathbf{212.745}[\boldsymbol{MVAR}]$$

$$\boldsymbol{F.P} = \mathbf{cos}\,\boldsymbol{\theta} = \mathbf{cos(13.36 - 0.58)}$$

$$= \mathbf{0.97}$$

$$I_0 = \frac{\tilde{V}_G}{\frac{R}{2} + j\frac{X_L}{2} - jX_C}$$

$$I_0 = \frac{[234.562 + j55.709][KV]}{\left[\frac{4.7}{2} + j\frac{80}{2} - j879\right][\Omega]}$$

$$I_0 = (-65.6156 + j279.757)[A]$$

$$V_{R_0} = -jX_C\tilde{I}_0$$

$$V_{R_0} = -j879(-65.6156 + j279.757)$$

$$= [245.9064 + j57.6761][KV]$$

$$= 252.579[KV]$$

$$\%\boldsymbol{Reg} = \frac{\boldsymbol{V_{R_0}} - \boldsymbol{V_R}}{\boldsymbol{V_R}} \times \mathbf{100}$$

$$= \frac{\mathbf{252.579}[\boldsymbol{KV}] - \mathbf{228.05}[\boldsymbol{KV}]}{\mathbf{228.05}[\boldsymbol{KV}]} \times \mathbf{100}$$

$$= \mathbf{10.75}\%$$