Appendix A

Program (Gas s)

```
format short

fprintf('\n                    Voltage (pu)                                    \n')

fprintf('\n Substation Hwata   Gedaref   Showak  El-girba  New-Hlfa   Kassala  Aroma \n')

fprintf('\n Iteration      V2         V3        V4         V5        V6          V7        V8\n')

y12=j*41.1523;

y23=j*30.9598;

y34=j*23.8663;

y45=j*28.4091;

y56=j*38.9105;

y57=j*23.8663;

y78=j*37.2856;

y11=j*40.99234;

y22=j*71.73997;

y33=j*54.53815;

y44=j*52.135955;

y55=j*90.99997;

y66=j*38.864018;

y77=j*61.027612;

y88=j*37.237097;

V1=1.0 +j*0;

iter =0;

S2=.0029+j*0.0021;

S3=0.101+j*0.073;
```

```
S4=0.0+j*0.0;

S5=0.058+j*0.042;

S6=0.052+j*0.03789;

S7=0.055+j*0.03996;

S8=0.0+j*0.0;

V2=1+j*0;

V3=1+j*0;

V4=1+j*0;

V5=1+j*0;

V6=1+j*0;

V7=1+j*0;

V8=1+j*0;

for I=1:13;

iter=iter+1;

V2=(conj (S2)./conj(V2)-(y12*V1+y23*V3))./(-y22);

V3=(conj (S3)./conj(V3)-(y23*V2+y34*V4))./(-y33);

V4=(conj (S4)./conj(V4)-(y34*V3+y45*V5))./(-y44);

V5=(conj (S5)./conj(V5)-(y45*V4+y56*V6+y57*V7))./(-y55);

V6=(conj (S6)./conj(V6)-(y56*V5))./(-y66);

V7=(conj (S7)./conj(V7)-(y57*V5+y78*V8))./(-y77);

V8=(conj (S8)./conj(V8)-(y78*V7))./(-y88);

disp([iter, V2, V3, V4, V5, V6, V7, V8])

end
```

Mat lab code (relationship between V&Qc)

```
clc
Length=391.9;            %transmission line length
F=50.0;                              %frequency
A=4.845e-004;                     %cross secsion ofconductor
W=2*pi*F;
D=3.250;                  %spacing between phase A-B&phase B-c
d=0.4450;                    %spacing between sub-conductors
V=220000:500:224500;
Voltage=V';                       %line voltage
P=10e6:10e6:100e6;                   %active powers
Real=P';
Dab=(D*(D+d)*(D-d)*D)^(1/4);
Dbc=Dab;
Dac=((2*D)*((2*D)-d)*((2*D)+d)*2*D)^ (1/4);
Dia=2*sqrt((A/(2*pi)));
Rad= Dia/2;                              %meter
Ds=sqrt(0.7788*Rad*d);
Dsc= sqrt(Rad*d);
Deq=(Dab*Dbc* Dac)^(1/3);
L=(0.4605* log10(Deq/Ds));
C=0.02412/ log10(Deq/Dsc);
Zc=sqrt((L*1e-3)/(C*1e-6));
Beta=W*sqrt(L*C*1e-9);
BetaL= Beta*Length*(180/(pi));
for i=1:10                              % power counter
for j=1:10                          % voltage counter
Xc=Zc*sind(BetaL);
R=(P(i)*Xc)/V(j)^2;
DELTA=asind(R);
Qc(j)=((V(j))^2/Xc)*(cosd(DELTA)-cosd(BetaL));
end
plot(Qc ,V)
table(:,i)=Qc'/1e6;
ReactiveR=Qc'
voltageR=V'
hold on
grid on
format short
real power=([',num2str(p(i))])
end
```

Mat lab code for no loads or very light loads

```
H=0:19.9: 390.9;
Vs=220000;
Length=H;
H=0:19.6:391.9;
F=50.0;                          %frequency
A=4.845e-004;                    %cross secsion ofconductor
W=2*pi*F;
D=3.250;                 %spacing between phase A-B&phase B-c
d=0.4450;                    %spacing between sub-conductors
V=220000;
P=100;                   %active powers
Dab=(D*(D+d)*(D-d)*D)^(1/4);
Dbc=Dab;
Dac=((2*D)*((2*D)-d)*((2*D)+d)*2*D)^ (1/4);
Dia=2*sqrt((A/(2*pi)));
Rad= Dia/2;                             %meter
Ds=sqrt(0.7788*Rad*d);
Dsc= sqrt(Rad*d);
Deq=(Dab*Dbc* Dac)^(1/3);
L=(0.4605* log10(Deq/Ds));
C=0.02412/ log10(Deq/Dsc);
Zc=sqrt((L*1e-3)/(C*1e-6));
Beta=W*sqrt(L*C*1e-9);
BetaL= Beta*H*(180/(pi));
Vr=Vs./ (cosd(BetaL));
plot(H,Vr)
```

Mat lab code (relationship between voltage no load or light load at receiving end for one and double circuits)

```
Length=H';
H=0:19.9: 390.9;
F=50.0;                          %frequency
A=4.845e-004;                    %cross secsion ofconductor
W=2*pi*F;
D=3.250;                 %spacing between phase A-B&phase B-c
d=0.4450;                    %spacing between sub-conductors
V=220000;
P=100;                   %active powers
Dab=(D*(D+d)*(D-d)*D)^(1/4);
Dbc=Dab;
Dac=((2*D)*((2*D)-d)*((2*D)+d)*2*D)^ (1/4);
Dia=2*sqrt((A/(2*pi)));
Rad= Dia/2;                             %meter
Ds=sqrt(0.7788*Rad*d);
Dsc= sqrt(Rad*d);
```

```
Deq=(Dab*Dbc* Dac)^(1/3);
L=(0.4605* log10(Deq/Ds));
C=0.02412/ log10(Deq/Dsc);
Zc=sqrt((L*1e-3)/(C*1e-6));
Beta=W*sqrt(L*C*1e-9);
BetaL= Beta*H*(180/(pi));
Vr=Vs./ (cosd(BetaL));
GMR=0.0017343;                    %cross secsion ofconductor
Da1b2= sqrt(D^2+(2*D)^2);
Da1a2= sqrt((2*D)^2+(2*D)^2);
Da1b1=D;
Da2b2=D;
Db1c1=D;
Db2c2=D;
Da1c2=2*D;
Da2c1=2*D;
Db1b2=2*D;
Da1c1=2*D;
Da2c2=2*D;
Db2c1=Da1b2;
Da2b1= Da1b2;
Db1c2= Da1b2;
Dc1c2= Da1a2;
Dab=( Da1b1* Da1b2* Da1b2* Da2b2)^(1/4);
Dbc=( Db1c1* Db1c2* Db2c1* Db2c2)^(1/4);
Dca=( Da1c1* Da1c2* Da2c1* Da2c2)^(1/4);
Deq2=(Dab*Dbc* Dca)^(1/3);
Dia=2*sqrt((A/(2*pi)));
Rad= Dia/2;                            %meter
Ds2= sqrt(GMR*d);
Rb= sqrt(Rad*d);
Dsa= sqrt(Ds2*Da1a2);
Dsb= sqrt(Ds2*Db1b2);
Dsc= sqrt(Ds2*Dc1c2);
ra= sqrt(Rb *Da1a2);
rb= sqrt(Rb *Db1b2);
rc= sqrt(Rb *Dc1c2);
GMRL=(Dsa*Dsb*Dsc)^(1/3);
GMRC=(ra*rb*rc)^(1/3);
L2=0.2* log (Deq2/GMRL);
C2=0.0556/ log (Deq2/GMRC);
Beta2=W*sqrt(L2*C2*1e-9);
BetaL2= Beta2*H*57.3;
Vr2=Vs./ (cosd(BetaL2));
plot(H,Vr,H,Vr2),
grid on
```

Appendix B

The different lengths of the line from sub-station to another substation on the line are as follow:

From	To	Length (Km)
Singa	Hawata	76.9
Hawata	Gedaref	102
Gedaref	Shuwak	75
Shuwak	El-ghirba	63
El-girba	New-Halfa	46
El-girba	Kassala	75
Kassala	Aroma	48

Appendix C

Transmission line Data (data from SETC):

Parameter	**Value**
Line Voltage	220KV
Frequency	50Hz
Active Power/ct	I00MW
Reactive Power/ct	72MVAR
Rating current	972A
Power factor	0.809
Conductor type Twin bundle	240/40ACSR
Cross section area of Conductor	484.5mm^2
Diameter of Conductor	17.56 mm
Total Length of the line	391.4Km
Resistance	0.067Ohm/Km
D_{RY}	3.25m
D_{RB}	3.25m
D_{YB}	6.5m
Space between bundle	0.45m
Space between circuit	8 m
Type of Tower	Double circuit

Appendix D

Substation Capacity (data from SETC):

Substation	Capacity		
	Main transformer	Auxiliary transformer	Reactor
Singa	2*100 MVA(220/33KV)	500KVA (220/33KV)	2*15Mvar
Hawata	2*100 MVA(220/33KV)	500KVA (220/33KV)	2*15Mvar
Gedaref	2*100 MVA(220/33KV)	500KVA (220/33KV)	No
Shuwak	2*50 MVA (220/33KV)	500KVA (220/33KV)	2*15Mvar
El-girba	2*100 MVA(220/66KV)	500KVA (220/33KV)	No
New-Halfa	2*100 MVA(220/33KV)	500KVA (220/33KV)	2*15Mvar
Kassala	2*100MVA (220/33KV)	500KVA (220/33KV)	2*15Mvar
Aroma	2*50MVA	500KVA (220/33KV)	No

Appendix E

The numbers of towers are as follow:

From	To	Towers(No)
Singa	Hawata	123
Hawata	Gedaref	210
Gedaref	Shuwak	179
Shuwak	El-ghirba	150
El-girba	New-Halfa	101
El-girba	Kassala	174
Kassala	Aroma	117

Appendix F

Symbols identifying different type of towers are as follow:

Type of towers		Applicable for	Insulator set type	Angle of deviation
AA	Anchor/Angle	Plain area of route and for small angles of the line deviation with their extension	Suspension	0^o – 3^o
BB	Angle	Straight run of the transmission line route and small angles of the line	Tension	0^o – 5^o 3^o – 10^o
		Position of small angles deviation	Tension	10^o – 30^o
		Position of medium angles deviation		30^o – 60^o
		Position of large angles deviation		60^o – 90^o
FF	Terminal	The end of the line	Tension	0^o – 90^o
AAL	Transposition	For Transposition purpose	Tension	25^o – 60^o 0^o – 30^o
AAR	River Crossing (Anchor)	For Crossing Rivers	Tension	0^o – 2^o

Appendix G

Specification of conductor ACSR 240/40 used in Eastern Grid:

Specification	Value
Number and diameter of aluminum wires	26/3.42mm
Number and diameter of steel wires	7/2.66mm
Cross section area of aluminum wires	238.85 mm^2
Cross section area of steel wires	38.9mm^2
Overall Cross section area	277.75 mm^2
Outside diameter	21.66mm
Mass of conductor per unit	964.3 Kg/Km
Ultimate tensile strength of complete conductor	83370 N
Modulus of elasticity conductor	76000N/ mm^2
Coefficient of linear expansion of conductor	$18.9*10^{-6}$(1/C□)