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Enhanced Electric Power Transmission by Hybrid Compensation Technique

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Abstract. In today's competitive environment, new power system engineers are likely to contribute immediately to the task, without years of seasoning via on-the-job training, mentoring, and rotation assignments. At the same time it is becoming obligatory to train power system engineering graduates for an increasingly quality-minded corporate environment. In order to achieve this, there is a need to make available better-quality tools for educating and training power system engineering students and in-service system engineers too. As a result of the swift advances in computer hardware and software, many windows-based computer software packages were developed for the purpose of educating and training. In line with those packages, a simulation package called Hybrid Series-Shunt Compensators (HSSC) has been developed and presented in this paper for educational purposes.

1. Introduction

The increasing load demand has necessitated the development of new generating facilities, transmission and distribution networks. However the construction of new transmission lines [1, 2] has been limited due to economic and environmental constraints. Therefore, in a competitive market milieu due to the challenges associated with the construction of new transmission lines, it is desirable to apply the existing transmission systems to the fullest possible extent without compromising quality and reliability [3-6]. Moreover, growth of different commercial schemes for the electric power industry, particularly deregulation of market, has made this requirement even stronger [7-9]. In developing countries, the optimized use of transmission system investments is also important to support industry, create employment, and employ efficiently the scarce economic resources [10-12].

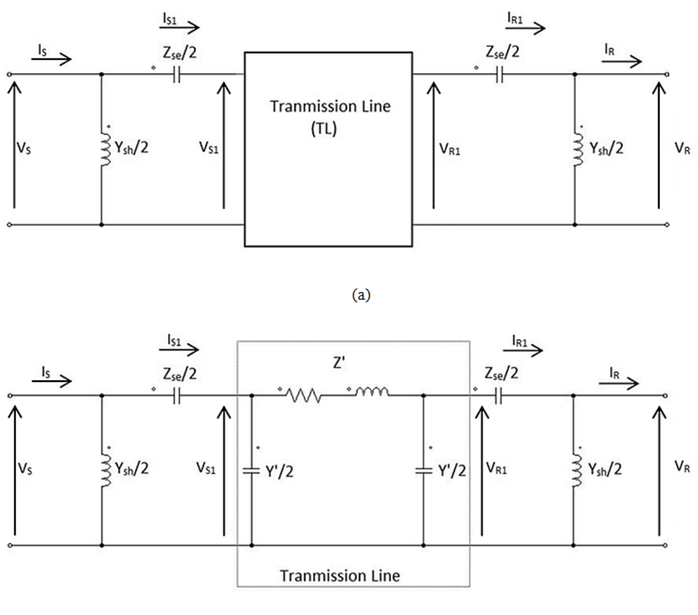
The use of series and shunt compensation schemes [5, 6, 13-16] to increase the power transfer capability of long transmission line is well-known. The advent and development of power electronics resulted in the introduction of Flexible AC Transmission System (FACTS) controllers such as Thyristor Controlled Series Compensators (TCSC), Unified Power Flow Controllers (UPFC) and Static Var Compensators (SVC) for transmission line compensation [17-19]. The TCSC is a series connected device used to regulate the reactance of a transmission line thereby controls the real and reactive power flow and redistributes power flow even under highly loaded conditions. Hence FACTS controllers can be used to increase system load ability and the available transfer capacity as situation demands. Steady state and transient stability is also improved with the help of FACTS controller. SVC is a shunt connected device which regulates the transmission system voltage by reactive power injections. UPFC is a combination of static synchronous compensators (STATCOM) and static synchronous series compensators (SSSC) coupled through a common DC voltage link used for controlling active and reactive power flow through the transmission lines.

In recent years, computer-aided instruction has been extensively used in electrical and power engineering education [20]. Computer simulation models have been employed to support and improve power engineering courses [21-23]. In this paper, an educational software package called Hybrid Series-Shunt Compensators (HSSC) for enhanced electric power transmission has been developed. The design and simulations of HSSC are proposed by using the Matlab R2013b and Matlab GUI. Windows based Graphical User Interface (GUI) concept is used, which gives the advantages of interactive visual communication between users and computer processes and quick interpretation of test results.

2. Compensated Transmission Line

Transmitted real and reactive power of the transmission line, which is shown in Fig. 1, can be derived in terms of the ABCD parameters of the line using the following notations:

l = *length of transmission line*
Z_0 = *characteristic impedance of transmission line*
V_S = *sending end voltage*
I_S = *sending end current*
V_R = *receiving end voltage*
I_R = *receiving end current*
Z_{se} = *series capacitor compensation*
Y_{sh} = *shunt reactor/capacitor compensation*
P_S = *sending end real power/operating power*
P_{S-max} = *maximum sending end real power*
Q_S= *sending end reactive power*
S_S = *sending end apparent power*
α = *argument of TL parameter A*
β = *argument of TL parameter B*
δ = *power angle*



(b)

Figure 1. Compensated transmission line.

For the compensated lines, the degree of series (K_{se}) and shunt (K_{sh}) compensation, respectively, is defined by

$$K_{se} = \frac{Total\ capacitive\ reactance\ of\ series\ compensators}{Total\ inductive\ reactance\ of\ the\ line}$$

And

$$K_{sh} = \frac{Total\ inductive\ susceptance\ of\ shunt\ compensators}{Total\ charging\ susceptance\ of\ the\ line}$$

Following the notations defined above, the ABCD constants of the two port network representation of the compensated transmission line as depicted in Fig.2 are derived as

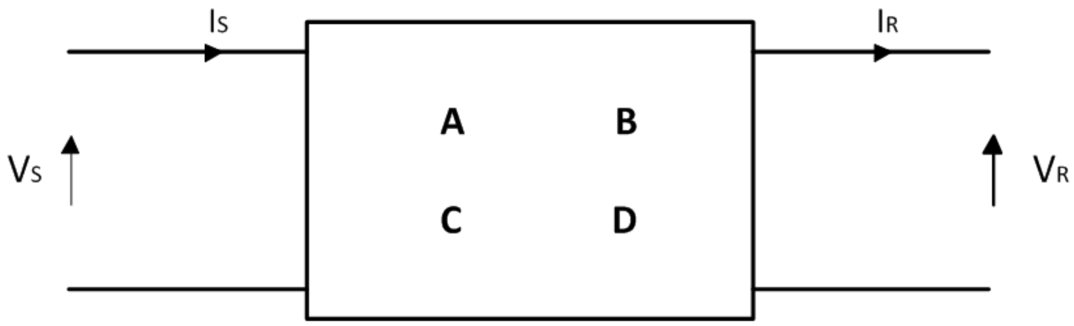


Figure 2. Two port network.

$$V_{S1} = (\cosh\gamma l)V_{R1} + (Z_0\sinh\gamma l)I_{R1} \tag{1}$$

$$I_{S1} = \left(\frac{1}{Z_0}\sinh\gamma l\right)V_{R1} + (\cosh\gamma l)I_{R1} \tag{2}$$

$$\begin{aligned} V_S &= (\cosh\gamma l)V_{R1} + (Z_0\sinh\gamma l)I_{R1} + \left(\frac{Z_{se}}{2}\right)I_{S1} \\ &= (\cosh\gamma l)V_{R1} + (Z_0\sinh\gamma l)I_{R1} + \left(\frac{Z_{se}}{2}\right)\left(\left(\frac{1}{Z_0}\sinh\gamma l\right)V_{R1} + (\cosh\gamma l)I_{R1}\right) \\ &= (\cosh\gamma l)V_{R1} + (Z_0\sinh\gamma l)I_{R1} + \left(\frac{Z_{se}}{2Z_0}\sinh\gamma l\right)V_{R1} + \left(\frac{Z_{se}}{2}\cosh\gamma l\right)I_{R1} \\ &= \left(\frac{Z_{se}}{2Z_0}\sinh\gamma l + \cosh\gamma l\right)V_{R1} + \left(\frac{Z_{se}}{2}\cosh\gamma l + Z_0\sinh\gamma l\right)I_{R1} \end{aligned} \tag{3}$$

$$\begin{aligned} I_S &= \frac{Y_{sh}}{2}V_S + I_{S1} \\ &= \frac{Y_{sh}}{2}V_S + \left(\frac{1}{Z_0}\sinh\gamma l\right)V_{R1} + (\cosh\gamma l)I_{R1} \\ &= \frac{Y_{sh}}{2}\left(\left(\frac{Z_{se}}{2Z_0}\sinh\gamma l + \cosh\gamma l\right)V_{R1} + \left(\frac{Z_{se}}{2}\cosh\gamma l + Z_0\sinh\gamma l\right)I_{R1}\right) + \left(\frac{1}{Z_0}\sinh\gamma l\right)V_{R1} + (\cosh\gamma l)I_{R1} \\ &= \left(\frac{Y_{sh}Z_{se}}{4Z_0}\sinh\gamma l + \frac{Y_{sh}}{2}\cosh\gamma l\right)V_{R1} + \left(\frac{Y_{sh}Z_{se}}{4}\cosh\gamma l + \frac{Y_{sh}Z_0}{2}\sinh\gamma l\right)I_{R1} + \left(\frac{1}{Z_0}\sinh\gamma l\right)V_{R1} + (\cosh\gamma l)I_{R1} \\ &= \left(\frac{Y_{sh}Z_{se}}{4Z_0}\sinh\gamma l + \frac{Y_{sh}}{2}\cosh\gamma l + \frac{1}{Z_0}\sinh\gamma l\right)V_{R1} + \left(\frac{Y_{sh}Z_{se}}{4}\cosh\gamma l + \frac{Y_{sh}Z_0}{2}\sinh\gamma l + \cosh\gamma l\right)I_{R1} \end{aligned} \tag{4}$$

$$\begin{aligned} I_R &= I_{R1} - \frac{Y_{sh}}{2}V_R \\ I_{R1} &= I_R + \frac{Y_{sh}}{2}V_R \end{aligned} \tag{5}$$

$$\begin{aligned} V_R &= V_{R1} - \frac{Z_{se}}{2} I_{R1} \\ &= V_{R1} - \frac{Z_{se}}{2}\left(I_R + \frac{Y_{sh}}{2} V_R\right) \\ V_{R1} &= V_R + \frac{Z_{se}Y_{sh}}{4} V_R + \frac{Z_{se}}{2} I_R \end{aligned} \tag{6}$$

$$\begin{aligned} V_S &= \left(\frac{Z_{se}}{2Z_0}\sinh\gamma l + \cosh\gamma l\right)\left(V_R + \frac{Z_{se}Y_{sh}}{4}V_R + \frac{Z_{se}}{2}I_R\right) + \left(\frac{Z_{se}}{2}\cosh\gamma l + Z_0\sinh\gamma l\right)\left(I_R + \frac{Y_{sh}}{2}V_R\right) \\ &= \left(\frac{Z_{se}}{2Z_0}\sinh\gamma l + \frac{{Z_{se}}^2 Y_{sh}}{8Z_0}\sinh\gamma l + \frac{Z_0 Y_{sh}}{2}\sinh\gamma l + \cosh\gamma l + \frac{Z_{se}Y_{sh}}{2}\cosh\gamma l\right)V_R \\ &\quad + \left(\frac{{Z_{se}}^2}{4Z_0}\sinh\gamma l + Z_0\sinh\gamma l + Z_{se}\cosh\gamma l\right)I_R \\ &= \left(\left(1 + \frac{Z_{se}Y_{sh}}{2}\right)\cosh\gamma l + \left(\frac{Z_{se}}{2Z_0} + \frac{{Z_{se}}^2 Y_{sh}}{8Z_0} + \frac{Z_0 Y_{sh}}{2}\right)\sinh\gamma l\right)V_R + \left(Z_{se}\cosh\gamma l + \left(\frac{{Z_{se}}^2}{4Z_0} + Z_0\right)\sinh\gamma l\right)I_R \end{aligned} \tag{7}$$

$$\begin{aligned} I_S &= \left(\frac{Y_{sh}Z_{se}}{4Z_0}\sinh\gamma l + \frac{Y_{sh}}{2}\cosh\gamma l + \frac{1}{Z_0}\sinh\gamma l\right)\left(V_R + \frac{Z_{se}Y_{sh}}{4}V_R + \frac{Z_{se}}{2}I_R\right) \\ &\quad + \left(\frac{Y_{sh}Z_{se}}{4}\cosh\gamma l + \frac{Y_{sh}Z_0}{2}\sinh\gamma l + \cosh\gamma l\right)\left(I_R + \frac{Y_{sh}}{2}V_R\right) \\ &= \frac{Y_{sh}Z_{se}}{4Z_0}\sinh\gamma l\, V_R + \frac{Y_{sh}}{2}\cosh\gamma l\, V_R + \frac{1}{Z_0}\sinh\gamma l\, V_R + \frac{{Y_{sh}}^2 {Z_{se}}^2}{16Z_0}\sinh\gamma l\, V_R + \frac{Z_{se}{Y_{sh}}^2}{8}\cosh\gamma l\, V_R + \frac{Y_{sh}Z_{se}}{4Z_0}\sinh\gamma l\, V_R \\ &\quad + \frac{Y_{sh}{Z_{se}}^2}{8Z_0}\sinh\gamma l\, I_R + \frac{Z_{se}Y_{sh}}{4}\cosh\gamma l\, I_R + \frac{Z_{se}}{2Z_0}\sinh\gamma l\, I_R + \frac{Z_{se}Y_{sh}}{4}\cosh\gamma l\, I_R + \frac{Y_{sh}Z_0}{2}\sinh\gamma l\, I_R + \cosh\gamma l\, I_R \\ &\quad + \frac{Z_{se}{Y_{sh}}^2}{8}\cosh\gamma l\, V_R + \frac{Z_0{Y_{sh}}^2}{4}\sinh\gamma l\, V_R + \frac{Y_{sh}}{2}\cosh\gamma l\, V_R \\ &= \left(\left(Y_{sh} + \frac{Z_{se}{Y_{sh}}^2}{4}\right)\cosh\gamma l + \left(\frac{Y_{sh}Z_{se}}{2Z_0} + \frac{1}{Z_0} + \frac{{Y_{sh}}^2{Z_{se}}^2}{16Z_0} + \frac{Z_0{Y_{sh}}^2}{4}\right)\sinh\gamma l\right)V_R \\ &\quad + \left(\left(\frac{Z_{se}Y_{sh}}{2} + 1\right)\cosh\gamma l + \left(\frac{Z_{se}}{2Z_0} + \frac{Y_{sh}Z_0}{2} + \frac{Y_{sh}{Z_{se}}^2}{8Z_0}\right)\sinh\gamma l\right)I_R \end{aligned} \tag{8}$$

Comparing with the standard equations of the two port network, we get the A B C D constants as

$$A = \left(1 + \frac{Z_{se}Y_{sh}}{2}\right)\cosh\gamma l + \left(\frac{Z_{se}}{2Z_0} + \frac{{Z_{se}}^2 Y_{sh}}{8Z_0} + \frac{Z_0 Y_{sh}}{2}\right)\sinh\gamma l \tag{9}$$

$$B = Z_{se}\cosh\gamma l + \left(\frac{{Z_{se}}^2}{4Z_0} + Z_0\right)\sinh\gamma l \tag{10}$$

$$C = \left(Y_{sh} + \frac{Z_{se}{Y_{sh}}^2}{4}\right)\cosh\gamma l + \left(\frac{Y_{sh}Z_{se}}{2Z_0} + \frac{1}{Z_0} + \frac{{Y_{sh}}^2{Z_{se}}^2}{16Z_0} + \frac{Z_0{Y_{sh}}^2}{4}\right)\sinh\gamma l \tag{11}$$

$$D = A \tag{12}$$

Also the equations of the operating power P_S and the maximum power $P_{S\text{-max}}$ of the compensated transmission line are obtained as

$$P_S = \frac{|A||V_S|^2}{|B|}\cos(\beta - \alpha) - \frac{|V_S|^2}{|B|}\cos(\delta + \beta) \tag{13}$$

When $\delta + \beta = \pi$, $P_S = P_{S-max}$.

$$P_{S-max} = \frac{|A||V_R|^2}{|B|}\cos(\beta - \alpha) + \frac{|V_S||V_R|}{|B|} \tag{14}$$

3. Hybrid Series-Shunt Compensators Package

3.1. HSSC Working Main Screen & User Manual
The Working Main Screen of the HSSC package and the HSSC User Manual are shown in Fig. 3 & 4 respectively.

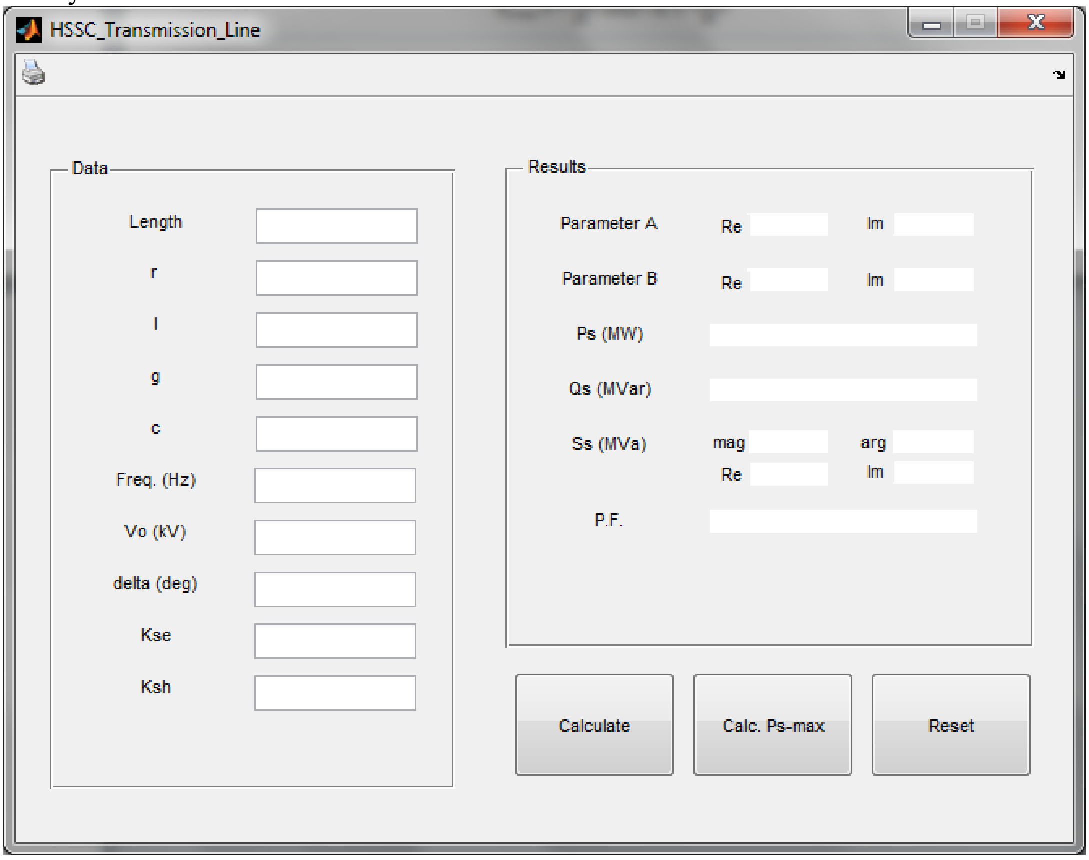


Figure 3. HSSC working main screen.

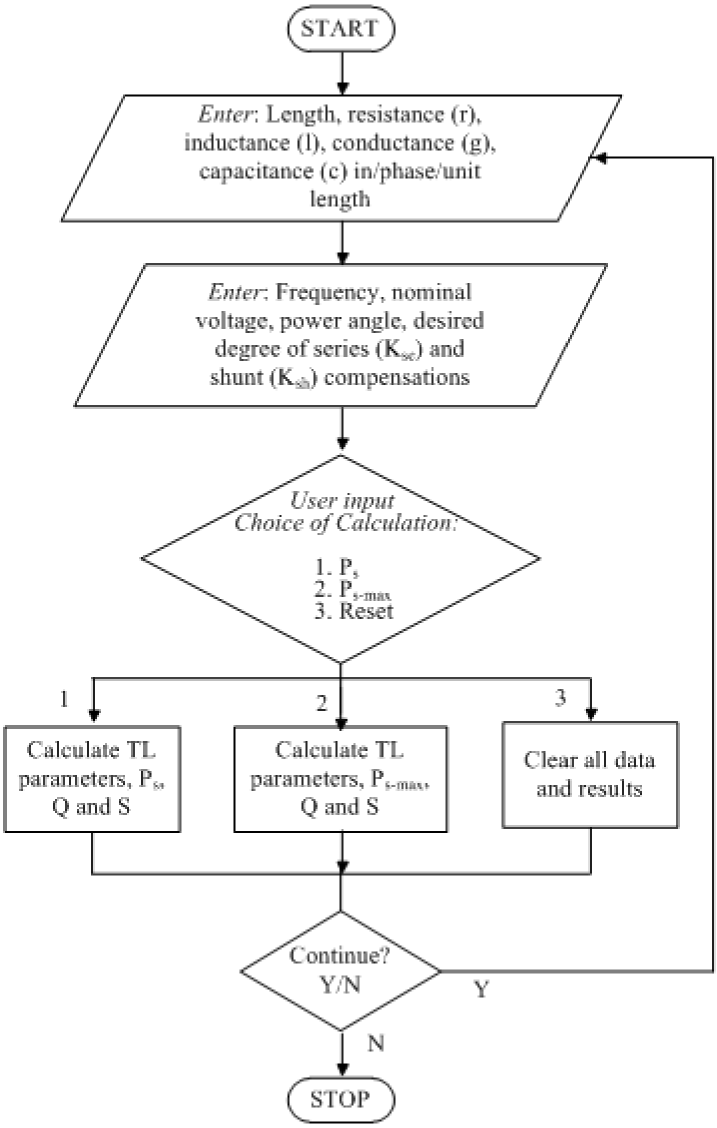


Figure 4. HSSC user manual.

3.2. Program Coding

The program coding of HSSC by using the Matlab R2013b and Matlab GUI is given in two segments as shown below.

```
function calc_Callback(hObject, eventdata, handles)
% hObject    handle to calc (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
length=str2double(get(handles.length,'String'));
r=str2double(get(handles.resistance,'String'));
l=str2double(get(handles.inductance,'String'));
g=str2double(get(handles.conductance,'String'));
c=str2double(get(handles.capacitance,'String'));
f=str2double(get(handles.freq,'String'));
Vo=str2double(get(handles.volt_nom,'String'));
d=str2double(get(handles.delta,'String'));
Kse=str2double(get(handles.Kse,'String'));
Ksh=str2double(get(handles.Ksh,'String'));
R=length*r;
L=length*l;
G=length*g;
C=length*c;
d=d*pi/180;
i=sqrt(-1);
XL=2*pi*f*L;
XC=1/(2*pi*f*C);
BC=1/XC;
Z=R+XL*i;
Y=G+BC*i;
Z0=sqrt(Z/Y);
gammal=sqrt(Z*Y);
Xc=Kse*XL;
Zc=-Xc*i;
Bsh=Ksh*BC;
Ysh=-Bsh*i;
paraA=((Zc/(2*Z0))+((Zc^2)*Ysh/(8*Z0))+(Z0*Ysh/2))*sinh(gammal+1+(Zc*Ysh/2)
)*cosh(gammal);
Ar=real(paraA);
Ai=imag(paraA);
A1=abs(paraA);
alpha=angle(paraA);
paraB=(((Zc^2)/(4*Z0))+Z0)*sinh(gammal)+Zc*cosh(gammal);
Br=real(paraB);
Bi=imag(paraB);
B1=abs(paraB);
beta=angle(paraB);
Ps=(A1*(Vo^2)/B1)*cos(beta-alpha)-((Vo^2)/B1)*cos(d+beta);
Qs=(A1*(Vo^2)/B1)*sin(beta-alpha)-((Vo^2)/B1)*sin(d+beta);
Ss=(A1*(Vo^2)/B1)*exp(i*(beta-alpha))-((Vo^2)/B1)*exp(i*(d+beta));
Ssr=real(Ss);
Ssi=imag(Ss);
Ss1=abs(Ss);
theta=angle(Ss);
pf=cos(theta);
% 'if' condition below define that if error% of d is < 0.5% then 'Ps-max
% (MW)' will show, else 'Ps (MW)' will replace the textbox
if (abs((d+beta)/pi-1)<0.005)
    set(handles.text_ps,'String','Ps-max (MW)');
else
    set(handles.text_ps,'String','Ps (MW)');
end
set(handles.Ar,'String',Ar);
set(handles.Ai,'String',Ai);
set(handles.Br,'String',Br);
set(handles.Bi,'String',Bi);
set(handles.Ps,'String',Ps);
set(handles.Qs,'String',Qs);
set(handles.Ss1,'String',Ss1);
theta=theta*180/pi;
theta=sprintf('%.2f%c',theta,char(176));
set(handles.theta,'String',theta);
set(handles.Ssr,'String',Ssr);
set(handles.Ssi,'String',Ssi);
set(handles.pf,'String',pf);
```

The above section is intended for calculating the sending end real power/operating power, the reactive power, the apparent power and the power factor. The apparent power is represented in rectangular as well as polar forms for through understanding of the concept. The user input choice of calculation 1 displays the said results.

```
function calc_psmax_Callback(hObject, eventdata, handles)
% hObject    handle to calc_psmax (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
length=str2double(get(handles.length,'String'));
r=str2double(get(handles.resistance,'String'));
l=str2double(get(handles.inductance,'String'));
g=str2double(get(handles.conductance,'String'));
c=str2double(get(handles.capacitance,'String'));
f=str2double(get(handles.freq,'String'));
Vo=str2double(get(handles.volt_nom,'String'));
% d=str2double(get(handles.delta,'String'));
Kse=str2double(get(handles.Kse,'String'));
Ksh=str2double(get(handles.Ksh,'String'));
R=length*r;
L=length*l;
G=length*g;
C=length*c;
% d=d*pi/180;
i=sqrt(-1);
XL=2*pi*f*L;
XC=1/(2*pi*f*C);
BC=1/XC;
Z=R+XL*i;
Y=G+BC*i;
Z0=sqrt(Z/Y);
gammal=sqrt(Z*Y);
Xc=Kse*XL;
Zc=-Xc*i;
Bsh=Ksh*BC;
Ysh=-Bsh*i;
paraA=((Zc/(2*Z0))+((Zc^2)*Ysh/(8*Z0))+(Z0*Ysh/2))*sinh(gammal)+
(1+(Zc*Ysh/2))*cosh(gammal);
Ar=real(paraA);
Ai=imag(paraA);
A1=abs(paraA);
alpha=angle(paraA);
paraB=(((Zc^2)/(4*Z0))+Z0)*sinh(gammal)+Zc*cosh(gammal);
Br=real(paraB);
Bi=imag(paraB);
B1=abs(paraB);
beta=angle(paraB);
d=pi-beta;
Psmax=(A1*(Vo^2)/B1)*cos(beta-alpha)-((Vo^2)/B1)*cos(d+beta);
Qs=(A1*(Vo^2)/B1)*sin(beta-alpha)-((Vo^2)/B1)*sin(d+beta);
Ss=(A1*(Vo^2)/B1)*exp(i*(beta-alpha))-((Vo^2)/B1)*exp(i*(d+beta));
Ssr=real(Ss);
Ssi=imag(Ss);
Ss1=abs(Ss);
theta=angle(Ss);
pf=cos(theta);
d=d*180/pi;
set(handles.delta,'String',d);
set(handles.Ar,'String',Ar);
set(handles.Ai,'String',Ai);
set(handles.Br,'String',Br);
set(handles.Bi,'String',Bi);
set(handles.text_ps,'String','Ps-max (MW)');
set(handles.Ps,'String',Psmax);
set(handles.Qs,'String',Qs);
set(handles.Ss1,'String',Ss1);
theta=theta*180/pi;
theta=sprintf('%.2f%c',theta,char(176));
set(handles.theta,'String',theta);
set(handles.Ssr,'String',Ssr);
set(handles.Ssi,'String',Ssi);
set(handles.pf,'String',pf);
```

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The above program section is intended for calculating the maximum sending end real power/operating power in addition to displaying the already calculated reactive power, the apparent power and the power factor as in the previous section. Here also the apparent power is represented in rectangular as well as polar forms for through understanding of the concept. The user input choice of calculation 2 displays the said results. The user input choice of calculation 3 resets all the data to facilitate new computations.

4. An Illustrative Example

The suitability of the developed package has been ascertained by applications to various transmission study systems and it is found to be technically sound. The application to a prototype transmission system is presented here.

4.1. System Data

The sample transmission line considered [24] in this study has the following data:

l = 550 miles
V_0 *= 500 kV (line to line), double circuit*
f =60 Hz
R = 0.02495 ohm/mile/phase/circuit
G = $2x10^{-12}$ *mho/mile/circuit*
L = 1.3925 mH/mile/phase/circuit
C = 0.020885 μF/mile/phase to neutral/circuit

4.2. Program Output

The line parameters are entered in the HSSC Working Main Screen Data column. The package is designed such that both series and shunt compensation is possible at a time. The degree of series as well as shunt compensation can be varied from 0% to 100% (i.e. 0 to 1 p.u.); however due to stability reasons, it is limited to a maximum of 70%. As an illustration, the degree of shunt compensation is kept fixed at 50% and the series compensation is varied from 0% to 70% for a power angle of 30 degrees and the results are shown in Table 1.

Table 1. Fixed Shunt & Variable Series Compensation.

Degree of Compensation (p.u.)		Ps (MW)	Qs (MVar)	Ps_{max} (MW)
k_{se}	k_{sh}			
0.0	0.5	546.10	-210.83	1118.26
0.1	0.5	579.53	-185.93	1191.91
0.2	0.5	621.79	-161.54	1285.46
0.3	0.5	675.98	-137.52	1406.28
0.4	0.5	746.89	-113.84	1566.06
0.5	0.5	842.41	-90.84	1784.54
0.6	0.5	976.45	-69.91	2097.63
0.7	0.5	1175.73	-55.64	2577.88

From the results of Table 1, for the given transmission line configuration, for every degree of compensation, the real power, reactive power and the maximum power transfer are increasing as the degree of series compensation increases. For series and shunt compensation of each 0.5 p.u. (50%),

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Fig. 5 shows the screen shot of "*choosing user input choice of calculation 1*" and Fig. 6 shows the "*screen shot of choosing user input choice of calculation 2*".

As a second illustration, the degree of series compensation is kept fixed at 50% and the shunt compensation is varied from 0% to 70% for a power angle of 30 degrees and the results are shown in Table 2. From the results of Table 2, for the same transmission line configuration, for every degree of shunt compensation, the reactive power gets varied whereas the real power and the maximum power transfer remain constant irrespective of the variations in shunt compensation. That means, reactive shunt compensation affects the reactive power and the series compensation affects the real power transfer.

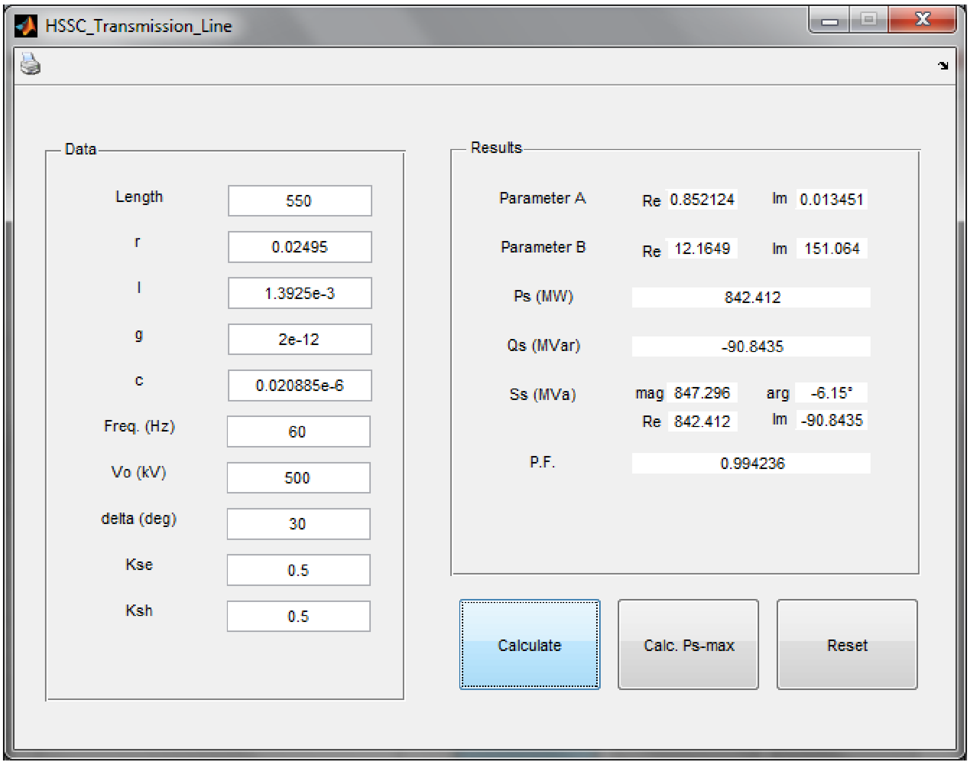

Figure 5. User input choice of calculation 1.

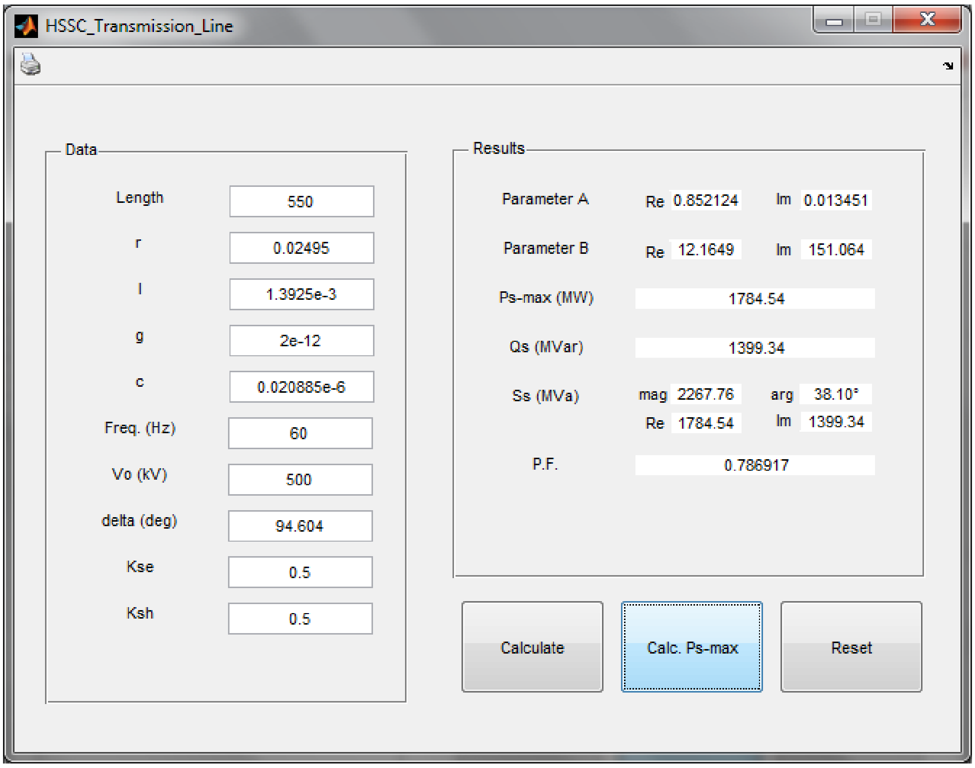

Figure 6. User input choice of calculation 2.

Table 2. Fixed Series & Variable Shunt Compensation.

Degree of Compensation (p.u.)		Ps (MW)	Qs (MVar)	Ps_{max} (MW)
k_{se}	k_{sh}			
0.5	0.0	842.41	-361.49	1784.54
0.5	0.1	842.41	-307.36	1784.54
0.5	0.2	842.41	-253.23	1784.54
0.5	0.3	842.41	-199.10	1784.54
0.5	0.4	842.41	-144.97	1784.54
0.5	0.5	842.41	-90.84	1784.54
0.5	0.6	842.41	-36.71	1784.54
0.5	0.7	842.41	17.42	1784.54

As a third illustration, the degrees of series and shunt compensations are varied from 0% to 70% for a power angle of 30 degrees and the results are shown in Table 3. From the results of Table 3, it is seen that, for every degree of compensation, the real, reactive and maximum power transfer gets varied following the variations in compensation.

Table 3. Variable Series & Shunt Compensation.

Degree of Compensation (p.u.)		Ps (MW)	Qs (MVar)	Ps_{max} (MW)
k_{se}	k_{sh}			
0.0	0.0	546.10	-481.48	1118.26
0.1	0.1	579.53	-402.44	1191.91
0.2	0.2	621.79	-323.93	1285.46
0.3	0.3	675.98	-245.78	1406.28
0.4	0.4	746.89	-167.97	1566.06
0.5	0.5	842.41	-90.84	1784.54
0.6	0.6	976.45	-15.78	2097.63
0.7	0.7	1175.73	52.62	2577.88

From the above three illustrations, it could be seen that compensation techniques especially series and shunt compensation (hybrid) is quite effective for enhancing electric power transfer of transmission lines and simple packages such as the developed one will be very useful for educating students as well as power engineers.

5. Conclusions

This paper has deliberated the application of series and shunt compensation of transmission lines for enhanced real and reactive power transfer. A programmable approach is used to quantify the amount of power transfers for various compensation levels and based on that a user friendly educative software package is developed and presented. Due to the graphical user interface approach, the data manipulation task and output task have been made simple and the program part is also very flexible for modifications when demanded. The series and shunt compensation techniques result in transmission line relaying and protection issues, and adverse effect on the power system stability, etc. and all these issues are not under the concern of this paper.

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