เอกสารอ้างอิง

[1] ข้อมูลผู้ผลิตไฟฟ้ารายเล็กมาก, Available online; http://www.eppo.go.th

[2] ระเบียบการรับซื้อไฟฟ้าจากผู้ผลิตไฟฟ้ารายเล็กมากเฉพาะการผลิตไฟฟ้าระบบ Cogeneration, Available; http://www.pea.go.th

[3] ระเบียบการรับซื้อไฟฟ้าจากผู้ผลิตไฟฟ้ารายเล็กมากเฉพาะการผลิตไฟฟ้าจากพลังงานหมุนเวียน, Available; http://www.pea.go.th

[4] ระเบียบการรับซื้อไฟฟ้าจากผู้ผลิตไฟฟ้ารายเล็กเฉพาะการผลิตไฟฟ้าระบบ Cogeneration, Available; http://www.pea.go.th

[5] ระเบียบการรับซื้อไฟฟ้าจากผู้ผลิตไฟฟ้ารายเล็กเฉพาะการผลิตไฟฟ้าจากพลังงานหมุนเวียน, Available; http://www.pea.go.th

[6] Federal Energy Manage. Program, U.S. Dept. Energy, "Using distributed energy resources," May 2002. [Online]. Available: http://www.eren.doe.gov/femp/

[7] J. Eto, R. Lasseter, B. Schenkman, J. Stevens, H. Volkommer, D. Klapp, E. Linton, H. Hurtado, J. Roy, and N. J. Lewis, "CERTS Microgrid Laboratory Test Bed Report,"[Online]. Available: http://certs.lbl.gov/CERTS_P_DER.html

[8] NIST Framework and Roadmap for Smart Grid Interoperability Standards, Available: http://www.nist.gov/smartgrid

[9] IEEE P2030 Draft Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation With the Electric Power System (EPS) and End-Use Applications and Loads, http://grouper.ieee.org/groups/scc21/2030/2030_index.html

[10] http://www.thailandindustrialtoday.com

[11] http://www.vanwestholland.com/turbo_blower_parts.html

[12] http://www.ventekenergy.com

[13] http://biomassmagazine.com

[14] http://www.news.cornell.edu/stories/Jan10/CHPopening.html

[15] http://www.energy-green.tk/wp-content/uploads/Biomass-10.jpg

[16] http://www.wedotanks.com/anaerobic-aerobic-wastewater-treatment-plant.asp

[17] http://www.waste2energyworld.com/pyrolysis.htm

[18] H. L. Willis and W. G. Scott, Distributed Power Generation Planning and Evaluation. New York: Marcel Dekker, 2000.

[19] A. M. Borbely, R. Brent, J. Brouwer, S. Cherian, and P. S. Curtiss, "Distributed Generation: The Power Paradigm for the New Millennium," Boca Raton, FL: CRC Press, 2001.

[20] M. Geidl, G. Koeppel, P. Favre-Perrod, B. Klöckl, G. Andersson, and K. Fröhlich, "Energy hubs for the future," IEEE Power and Energy Magazine, No. 1 vol. 5 Jan./Feb. 2007, pp. 24–30.

[21] R. C. Dugan, T. E. McDermott, and G. J. Ball, "Planning for distributed generation," IEEE Industry Application Magazine, vol. 7, No. 2 Mar./Apr. 2001, pp. 80–88.

[22] T. J. Hammons, "Integrating renewable energy sources into European grids," International Journal of Electric Power Energy System, vol. 30 Oct. 2008 No. 8, pp. 462–475.

[23] E. J. Coster, J. M. A. Myrzik, and W. L. Kling, "Integration of distributed generation in medium voltage grids and Protection issues," International Journal of Distributed Energy Resources, vol. 5, No. 3 Jul. 2009, pp. 167–186.

[24] Thu Lan T. Nguyen, J. E. Hermansen and M. Sagisaka, "Fossil energy savings potential of sugar cane bio-energy systems," Applied Energy, Volume 86, Supplement 1, November 2009, pp. S132-S139.

[25] T. Suramaythangkoor and S. H. Gheewala, "A Potential alternatives of heat and power technology application using rice straw in Thailand," Applied Energy, Volume 87, Issue 1, January 2010, pp. 128-133.

[26] W. Amatayakul and C. Azar, "Determinants and land-use patterns of commercial cultivation of a fuel-wood crop in Thailand," Energy for Sustainable Development, Vol.12, Issue 1, Mar. 2008, pp. 22-32.

[27] A. Evans, V. Strezov and T. J. Evans, "Sustainability considerations for electricity generation from biomass," Renewable and Sustainable Energy Reviews, Volume 14, Issue 5, June 2010, pp. 1419-1427.

[28] R. M. Carlos and D. B. Khang, "A lifecycle-based success framework for grid-connected biomass energy projects," Renewable Energy, Volume 34, Issue 5, May 2009, pp. 1195-1203.

[29] V. H. M. Mandez, J. R. Abbad and T. G. S. Roman, "Assessment of Energy Distribution Losses for Increasing Penetration of Distributed Generation," IEEE Transactions on Power Systems, vol. 21, No. 2, May 2006, pp. 533-539.

[30] H. A. Gil and G. Joos, "Models for Quantifying the Economics Benefits of distributed Generation," IEEE Transactions on Power Systems, vol. 23, No. 2, May 2008, pp. 327-335.

[31] M. Thomson, D. Infield, M. Stokes, M. Rylatt, J. Mardaljevic, and K. Lomas, "Secondary distribution network power flow analysis," Power and Energy Systems Conference, Palm Springs, CA, 2003.

[32] M. Thomson and D. G. Infield, "Network power- flow analysis for high penetration distributed micro-generation," presented at theCIRED 18th. International Conference of Electricity Distribution, Turin, Italy, 2005.

[33] J. Teng, Y. Liu, C. Chen, and C.-F. Chen, "Value-based distributed generator placements for service quality improvements," International Journal of Electric Power and Energy System, vol. 29, no. 3, pp. 268–274, Mar. 2007.

[34] J. Hong, "The Development, Implementation, and Application of Demand Side Managment and Control (DSM+c) Algorithm for Integrating Micro-generation System within Built Environment," Doctoral thesis, University of Strathclyde, Glasgow, Scotland, 2009.

[35] Daroj K., "Enhance Benefits Use of Reactive Power from Small Power Producers (SPPs) to Reduce Real Power Loss in Distribution Systems", 31st Electrical Engineering Conference (EECON-31) 29-31 Oct. 2008, Royal Hills Golf Resort and Spa, Nakornayok.

[36] S. Horowitz, A. Phadke, and B. Renz, "The future of power transmission," IEEE Power and Energy Magazine, vol. 8, no. 2, pp. 34–40, Mar./Apr. 2010.

[37] B. Maurhoff and G. Wood, "Dispersed generation reduce power costs and improve service reliability," Proceedings of Rural Electric Power Conference, May 2000, pp. C5/1–C5/7.

[38] J. A. Greatbanks, D. H. Popovic, M. Begovic, A. Pregelj, and T. C. Green, "On optimization for security and reliability of power systems with distributed generation," IEEE Bologna Power Tech Conference, Bologna, Italy, Jun. 23–26, 2003.

[39] K. Kauhaniemi and L. Kumpulainen, "Impact of distributed generation on the protection of distribution networks, Proceedings of 8th. IEE Conference on Development of Power System Protection, 2004, pp. 315–318.

[40] S. M. Brahma and A. A. Girgis, "Development of adaptive protection scheme for distribution systems with highpenetration of distributed generation," IEEE Transaction on Power Delivery, vol. 19, No. 1 Jan. 2004, pp. 56–63.

[41] S. M. Brahma and A. A. Girgis, "Microprocessor-based reclosing to coordinate fuse and recloser in a system with high penetration of distributed generation," Proceedings IEEE Power Engineering Society Winter Meeting, 2002, vol. 1, pp. 453–458.

[42] P. M. Anderson, Power System Protection. New York: IEEE, 1998.

[43] Kunder, P. Power System Stability and Control. McGraw-Hill 1994.

[44] N. Hatziargyriou, H. Asano, R. Iravani, and C. Marnay, "Microgrids," IEEE Power and Energy Magazine, vol. 5, no. 4 Jul./Aug. 2007., pp. 78–94.

[45] B. Kroposki, R. Lasseter, T. Ise, S. Morozumi,S. Papatlianassiou, and N. Hatziargyriou, "Making microgrids work," IEEE Power and Energy Magazine, May/Jun. 2008, pp. 40–53,

[46] N. Hatziargyriou, H. Asano, R. Iravani, and C. Marnay, "Microgrids: An overview of ongoing research, development, and demonstration projects," IEEE Power and Energy Magazine, vol. 5, no. 4 Jul./Aug. 2007, pp. 78–94.

[47] [42] S. M. Amin and B. F. Wollenberg, "Toward a smart grid," IEEE Power and Energy Magazine, vol. 3, no. 5 Sep./Oct. 2005, pp. 34–41.

[48] T. F. Garrity, "Getting smart," IEEE Power and Energy Magazine, vol. 6, no. 2 Apr.-Mar. 2008, pp. 38–45.

[49] Engineering Thermodynamics 3rd edition, SI Units Version, R. K. Rajput.

[50] Steam Its Generation and Use, The Babcock & Wilcox Company, 41st edition

[51] The Jet Engine, Rolls-Royce 1996, 5th edition

[52] Gas Turbine Engineering Handbook, Gulf Professional Publishing 3rd edition

ภาคผนวก ก

ภาคผนวก ก 1

```
% This program obtains Bus Admittance Matrix for power flow calculation
% "Optimal Power Dispatch of Small Power Producers to Reduce Real Power
  Loss in Distribution System"

basemva = 100;  accuracy = 0.0001;  maxiter = 100; lamda=1;
j = sqrt(-1);
nl = linedata(:,1); nr = linedata(:,2); R = linedata(:,3);
X = linedata(:,4); Bc = j*linedata(:,5); a = linedata(:,6);
nbr = length(linedata(:,1)); nbus = max(max(nl), max(nr));

Z = R + j*X;          %branch impeance
y = ones(nbr,1)./Z;   %branch admittance

Vm=0; delta=0; yload=0; deltad=0;
c=0;d=0;Nslackb=0;Nloadb=0;NPV=0;NQV=0;
%   Defined column of Busdata
for k=1:nbus
    n=busdata(k,1);kb(n)=busdata(k,2); Vm(n)=busdata(k,3);
    delta(n)=busdata(k,4);Pd(n)=lamda*busdata(k,5);
Qd(n)=lamda*busdata(k,6);
    Pg(n)=lamda*busdata(k,7); Qg(n) =
busdata(k,8);Qmin(n)=busdata(k,9);
    Qmax(n)=busdata(k,10);Qsh(n)=busdata(k,11);

    if  Vm(n) <= 0  Vm(n) = 1.0;
        else delta(n) = pi/180*delta(n);
             P(n)=(Pg(n)-Pd(n))/basemva;     % Formulated P
             Q(n)=(Qg(n)-Qd(n)+ Qsh(n))/basemva;    % Formulated Q
             S(n) = P(n) + j*Q(n);  % Formulated S
    end
end
for k=1:nbus
    switch kb(k)
        case 0
           angleindex(k) = c + 1;  % bus angle index
           c = angleindex(k);
           voltindex(k) = d + 1;  % bus voltage index
           d = voltindex(k);
           Nloadb = Nloadb + 1;
        case 1
           Nslackb = Nslackb + 1;
        case 2
           angleindex(k) = c + 1;  % bus angle index
           c = angleindex(k);
           NPV = NPV + 1;
    end
end
Nbangle = length(find(angleindex));
Nbvolt = length(find(voltindex));                    % Matrix to convert
Matbangle = find(transpose([angleindex]));          % Jacobian to real
Matbvolt = find(transpose([voltindex]));            %    bus index

Ybus = zeros(nbus,nbus);      % initialize Ybus to zero
```

```
% formation of the off diagonal elements
for k=1:nbr;
       Ybus(nl(k),nr(k))=Ybus(nl(k),nr(k))-y(k)/a(k);
       Ybus(nr(k),nl(k))=Ybus(nl(k),nr(k));
end

% formation of the diagonal elements
% formation with tap a:1 in the reverse sides of tap 1:a
for  n = 1:nbus
     for k = 1:nbr
         if nl(k)==n
         Ybus(n,n) = Ybus(n,n)+y(k)/(a(k)^2) + Bc(k);
         elseif nr(k)==n
         Ybus(n,n) = Ybus(n,n)+y(k) +Bc(k);
         else, end
     end
end
Ym = abs(Ybus); teta = angle(Ybus);
```

ภาคผนวก ก 3

```
%   Power flow calculation by Newton-Raphson method within PQ Limit
% "Optimal Power Dispatch of Small Power Producers to Reduce Real Power
  Loss in Distribution System"

maxerror = 1; converge = 1;
iter = 0;

%%%%%%%%%%%%%%%%%%%%%%%%%%% Start of iterations%%%%%%%%%%%%%%%%%%%%%%

while maxerror >= accuracy & iter <= maxiter % Test for max. power
mismatch

Jacob1 = zeros(Nbangle);
Jacob2 = zeros(Nbangle,Nbvolt);
Jacob3 = zeros(Nbvolt,Nbangle);     %Initializing Jacobian matrix
Jacob4 = zeros(Nbvolt);

iter = iter+1;

%Formulated elements of Jacobian matrix J1
for mm = 1:Nbangle
   for n = 1:nbus
     m = Matbangle(mm);
          if n~=m
             Jacob1(mm,mm)= Jacob1(mm,mm)+
Vm(m)*Vm(n)*Ym(m,n)*sin(teta(m,n)- delta(m) + delta(n));
          else ,end
   end
end
for mm = 1:Nbangle
     for nn = 1:Nbangle
      m = Matbangle(mm);
      n = Matbangle(nn);
          if n~=m
             Jacob1(mm,nn)= -Vm(m)*Vm(n)*Ym(m,n)*sin(teta(m,n)- delta(m)
+ delta(n));
          else ,end
   end
end
%Formulated elements of Jacobian matrix J2
for mm = 1:Nbangle
   for nn = 1:Nbvolt
      m = Matbangle(mm);
      n = Matbvolt(nn);
        if n == m
            Jacob2(mm,nn)= 2*Vm(m)*Ym(m,m)*cos(teta(m,m));
            for  k = 1:nbus
               if k ~= m
                Jacob2(mm,nn)= Jacob2(mm,nn)+
Vm(k)*Ym(m,k)*cos(teta(m,k)- delta(m) + delta(k));
               end
            end
        else , end
     end
```

```
end
for mm = 1:Nbangle
   for nn = 1:Nbvolt
     m = Matbangle(mm);
     n = Matbvolt(nn);
       if n~=m
        Jacob2(mm,nn)= Vm(m)*Ym(m,n)*cos(teta(m,n)- delta(m) +
delta(n));
       else ,end
   end
end

%Formulated elements of Jacobian matrix J3

for mm = 1:Nbvolt
     for nn = 1:Nbangle
       m = Matbvolt(mm);
       n = Matbangle(nn);
       if n == m
         for k = 1:nbus
           if k ~= m
             Jacob3(mm,nn)=
Jacob3(mm,nn)+Vm(m)*Vm(k)*Ym(m,k)*cos(teta(m,k)- delta(m)+delta(k));
           end
         end
       elseif n~=m
         Jacob3(mm,nn)= -Vm(m)*Vm(n)*Ym(m,n)*cos(teta(m,n)- delta(m) +
delta(n));
       else ,end
   end
end
%Formulated elements of Jacobian matrix J4
for mm = 1:Nbvolt
     m = Matbvolt(mm);
     Jacob4(mm,mm)= -2*Vm(m)*Ym(m,m)*sin(teta(m,m));
end
for mm = 1:Nbvolt
   for n = 1:nbus
     m = Matbvolt(mm);
       if n~=m
        Jacob4(mm,mm)= Jacob4(mm,mm)- Vm(n)*Ym(m,n)*sin(teta(m,n)-
delta(m) + delta(n));
       else ,end
   end
end
for mm = 1:Nbvolt
   for nn = 1:Nbvolt
     m = Matbvolt(mm);
     n = Matbvolt(nn);
       if n~=m
        Jacob4(mm,nn)= -Vm(m)*Ym(m,n)*sin(teta(m,n)- delta(m) +
delta(n));
       else ,end
   end
end
Jacob=[Jacob1 Jacob2;Jacob3 Jacob4];
```

```
%----------------------------Finished Jacobian Session-----------------
-----------%

                              % Calculated P & Q at each Jacobian bus
Pcal = zeros(1,Nbangle);
for mm = 1:Nbangle
    m = Matbangle(mm);
    for k = 1:nbus
        Pcal(mm)= Pcal(mm)+ Vm(m)*Vm(k)*Ym(m,k)*cos(teta(m,k)- delta(m)
+ delta(k));
    end
    Psched(mm)=P(m);
    DelP(mm) = Psched(mm) - Pcal(mm);
end
Qcal =  zeros(1,Nbvolt);
for nn = 1:Nbvolt
    n = Matbvolt(nn);
    for k = 1:nbus
        Qcal(nn)= Qcal(nn)- Vm(n)*Vm(k)*Ym(n,k)*sin(teta(n,k)- delta(n)
+ delta(k));
    end
    Qsched(nn)=Q(n);
    DelQ(nn) = Qsched(nn) - Qcal(nn);
end
%----------------------------Finished Calculatd P & Q------------------
----------%

                              % Updated angle and voltage each iteration
Delmat = inv(Jacob)*transpose([DelP DelQ]);
for mm = 1:Nbangle
    m = Matbangle(mm);
        ang(mm) = delta(m);
end
for nn = 1:Nbvolt
    n = Matbvolt(nn);
        volt(nn) = Vm(n);
end
angvolt = Delmat + transpose([ang volt]);
for m = 1:nbus
    for nn = 1:Nbangle
        n = Matbangle(nn);
        if n == m
            delta(m) = angvolt(nn);
        else , end
    end
end
for m = 1:nbus
    for nn = 1:Nbvolt
        n = Matbvolt(nn);
        if n == m
            Vm(m) = angvolt(nn+Nbangle);
        else , end
    end
end

for n = 1:nbus
```

```
    if busdata(n,2)==2
        Qcal(n) = 0;
        for k = 1:nbus
            Qcal(n)= Qcal(n)- Vm(n)*Vm(k)*Ym(n,k)*sin(teta(n,k)-
delta(n)+delta(k));
        end
        Qg(n) = Qd(n)+Qcal(n)*basemva-Qsh(n);
        if Qg(n)< Qmin(n) | Qg(n)> Qmax(n)
            if Qg(n)< Qmin(n)
                Qg(n) =  Qmin(n);
            elseif Qg(n)> Qmax(n)
                Qg(n) =  Qmax(n);
            else end
            kb(n) =  0;
            Q(n)=(Qg(n)-Qd(n)+ Qsh(n))/basemva;
            c = 0;d = 0;
            for k=1:nbus
                switch kb(k)
                 case 0
                    angleindex(k) = c + 1;  % bus angle index
                    c = angleindex(k);
                    voltindex(k) = d + 1;  % bus voltage index
                    d = voltindex(k);
                 case 2
                    angleindex(k) = c + 1;  % bus angle index
                    c = angleindex(k);
                end
            end
            Nbangle = length(find(angleindex));
            Nbvolt = length(find(voltindex));                    % Matrix
to convert
            Matbangle = find(transpose([angleindex]));      % Jacobian
to real
            Matbvolt = find(transpose([voltindex]));         %     bus
index
            maxerror = 1;
         else , end
     else,end
end
maxerror = max(abs(Delmat));
end
     %%%%%%%%%.............End  While Loop................%%%%%%%%%%


if iter == maxiter & maxerror > accuracy
   fprintf('\nWARNING: Iterative solution did not converged after ')
   fprintf('%g', iter), fprintf(' iterations.\n\n')
   fprintf('Press Enter to terminate the iterations and print the
results \n')
   converge = 0; pause, else, end


if converge ~= 1
   tech= ('ITERATIVE SOLUTION DID NOT CONVERGE'); else,
   tech=('Power Flow Solution by Newton-Raphson Method');
end
V = Vm.*cos(delta)+j*Vm.*sin(delta);
deltad=180/pi*delta;
```

ภาคผนวก ก 7


```
i=sqrt(-1);
k=0;
P = zeros(1,nbus);
for m = 1:nbus
    for k = 1:nbus
        P(m)= P(m)+ Vm(m)*Vm(k)*Ym(m,k)*cos(teta(m,k)- delta(m) +
delta(k));
    end
end
Q =  zeros(1,nbus);
for n = 1:nbus
    for k = 1:nbus
        Q(n)= Q(n)- Vm(n)*Vm(k)*Ym(n,k)*sin(teta(n,k)- delta(n) +
delta(k));
    end
end
for n = 1:nbus
     if kb(n) == 1
     k=k+1;
     S(n)= P(n)+j*Q(n);
     Pg(n) = P(n)*basemva + Pd(n);
     Qg(n) = Q(n)*basemva + Qd(n) - Qsh(n);
     Pgg(k)=Pg(n);
     Qgg(k)=Qg(n);     %june 97
     elseif  kb(n) ==2
     k=k+1;
     S(n)=P(n)+j*Q(n);
     Qg(n) = Q(n)*basemva + Qd(n) - Qsh(n);
     Pgg(k)=Pg(n);
     Qgg(k)=Qg(n);  % June 1997
  end
yload(n) = (Pd(n)- j*Qd(n)+j*Qsh(n))/(basemva*Vm(n)^2);
end
busdata(:,3)=Vm'; busdata(:,4)=deltad';loss=sum(P);
Pgt = sum(Pg);  Qgt = sum(Qg); Pdt = sum(Pd); Qdt = sum(Qd); Qsht =
sum(Qsh);
```

```
% Formulated Curl of Power loss by angle and voltage magnitude
% "Optimal Power Dispatch of Small Power Producers to Reduce Real Power
  Loss in Distribution System"

CurlPLa = zeros(Nbangle,1);


for m = 1:Nbangle
    k = Matbangle(m);
    for l = 1:nbus
        if k ~= l
            termkl = Vm(k)*Vm(l)*Ym(k,l)*sin(teta(k,l)-
delta(k)+delta(l));
            termlk = -Vm(k)*Vm(l)*Ym(k,l)*sin(teta(k,l)-
delta(l)+delta(k));
            CurlPLa(m,1)= CurlPLa(m,1) + termkl + termlk;
            PPP(m,l) = termkl + termlk;
        end
    end
end

CurlPLv = zeros(Nbvolt,1);


for m = 1:Nbvolt
    k = Matbvolt(m);
    for l = 1:nbus
        if k ~= l
            termkl = Vm(l)*Ym(k,l)*cos(teta(k,l)-delta(k)+delta(l));
            termlk = Vm(l)*Ym(k,l)*cos(teta(k,l)-delta(l)+delta(k));
            CurlPLv(m,1)= CurlPLv(m,1) + termkl + termlk;
            VVV(m,l) = termkl + termlk;
        end
    end
    CurlPLv(m,1)= CurlPLv(m,1)+2*Vm(k)*Ym(k,k)*cos(teta(k,k));
end

CurlPLav = [CurlPLa;CurlPLv];
CurlPloss = inv(transpose(Jacob))*CurlPLav;
```

ภาคผนวก ก 9

```
% This program prints the power flow solution in a tabulated form
% on the screen.

%clc
disp(tech)
fprintf('Maximum Power Mismatch = %g \n', maxerror)
fprintf('No. of Iterations = %g \n\n', iter)
head =['    Bus  Voltage  Angle    ------Load------    ---Generation---
Injected'
       '    No.  Mag.      Degree     MW       Mvar       MW       Mvar
Mvar '
       '
'];
disp(head)
for n=1:nbus
     fprintf(' %5g', n), fprintf(' %7.3f', Vm(n)),
     fprintf(' %8.3f', deltad(n)), fprintf(' %9.3f', Pd(n)),
     fprintf(' %9.3f', Qd(n)),  fprintf(' %9.3f', Pg(n)),
     fprintf(' %9.3f ', Qg(n)), fprintf(' %8.3f\n', Qsh(n))
end
    fprintf('      \n'), fprintf('    Total              ')
    fprintf(' %9.3f', Pdt), fprintf(' %9.3f', Qdt),
    fprintf(' %9.3f', Pgt), fprintf(' %9.3f', Qgt), fprintf('
%9.3f\n\n', Qsht)
```

```
% This program is used in conjunction with LFNewton
% for the computation of line flow and line losses.

SLT = 0;
fprintf('\n')
fprintf('                          Line Flow and Losses \n\n')
fprintf('     --Line--  Power at bus & line flow    --Line loss--
Transformer\n')
fprintf('     from  to    MW      Mvar     MVA       MW       Mvar
tap\n')

for n = 1:nbus
busprt = 0;
   for L = 1:nbr;
       if busprt == 0
       fprintf('   \n'), fprintf('%6g', n), fprintf('      %9.3f',
P(n)*basemva)
       fprintf('%9.3f', Q(n)*basemva), fprintf('%9.3f\n',
abs(S(n)*basemva))

       busprt = 1;
       else, end
       if nl(L)==n      k = nr(L);
       In = (V(n) - a(L)*V(k))*y(L)/a(L)^2 + Bc(L)/a(L)^2*V(n);
       Ik = (V(k) - V(n)/a(L))*y(L) + Bc(L)*V(k);
       Snk = V(n)*conj(In)*basemva;
       Skn = V(k)*conj(Ik)*basemva;
       SL  = Snk + Skn;
       SLT = SLT + SL;
       elseif nr(L)==n  k = nl(L);
       In = (V(n) - V(k)/a(L))*y(L) + Bc(L)*V(n);
       Ik = (V(k) - a(L)*V(n))*y(L)/a(L)^2 + Bc(L)/a(L)^2*V(k);
       Snk = V(n)*conj(In)*basemva;
       Skn = V(k)*conj(Ik)*basemva;
       SL  = Snk + Skn;
       SLT = SLT + SL;
       else, end
         if nl(L)==n | nr(L)==n
         fprintf('%12g', k),
         fprintf('%9.3f', real(Snk)), fprintf('%9.3f', imag(Snk))
         fprintf('%9.3f', abs(Snk)),
         fprintf('%9.3f', real(SL)),
             if nl(L) ==n & a(L) ~= 1
             fprintf('%9.3f', imag(SL)), fprintf('%9.3f\n', a(L))
             else, fprintf('%9.3f\n', imag(SL))
             end
         else, end
  end
 end
 SLT = SLT/2;
 fprintf('   \n'), fprintf('    Total loss                         ')
 fprintf('%9.3f', real(SLT)), fprintf('%9.3f\n', imag(SLT))
 %clear Ik In SL SLT Skn Snk
```

ภาคผนวก ข

Optimal Scheduling of Biomass-Based Distributed Generator to Reduce Real Power Loss; Considering Limitation of Energy Supply

Komson Daroj
Department of Electrical and Electronics Engineering, Faculty of Engineering,
Ubonratchathani University, Phone 045-353367, Fax 045-353333, E-mail: daroj@hotmail.com

Abstract

The framework of planning for scheduling biomass based Distributed Generator (DG) to reduce real power loss in a distribution system is proposed in this paper. The proposed methodology is formulated as an optimization problem with considering limitation of energy supply. A linear programming in accordance with sensitivity factors; real power loss to apparent power injected from synchronous DG, is adopted to solve for the optimal solution, which is the annual scheduled plan of DG. A 38-bus radial distribution system is examined to verify the potential of the proposed method for implementing in a real system.

Keywords: distributed generator, limit energy supply, real power loss, distribution system, sensitivity.

1. INTRODUCTION

Biomass energy has significant impact to energy policy and management of several agricultural countries including Thailand, which is recognized as one of the world leaders in agricultural production and export [1]–[3]. Biomass resources, especially agricultural residues e.g., bagasse, rice husk, palm oil wastes, and wood residues are abundant in the country. Traditionally, biomass has been burned for using as energy source in rural of Thailand for decades. Rice husk can be used as heat source in the brick-manufacturing industry and as bedding material for animals. Besides, rice straw and bagasse are already used as raw material in pulp and paper manufacturing process. It is also extensively used for various applications e.g., animal feed, compost, and soil conditioner on agricultural land [4].

In 2002, the Very Small Power Producers (VSPPs) program was established under Thailand's energy policies in supplement to the existing Small Power Producers (SPPs) program. The VSPPs program allows a generator of a private entity, state agency, state-owned enterprise or an individual with his own generating unit to sell no more than 10 MW of electrical power to the distribution utility. Connecting to the grid may be accessed through distribution or sub-transmission lines of the Provincial Electricity Authority (PEA) or Metropolitan Electricity Authority (MEA). Objectives of the additional program are to promote efficient use of domestic natural resources which will help decrease expenditure from imported fuel [5]. In addition, others key objectives are to promote optimum use of energy by using efficient electricity generation, and to alleviate the government's investment burden in the electricity generation and distribution systems. However, preliminary regulations trial by various government agencies regarding energy related affairs have not been fully verified. This provides the opportunity for researcher to propose administered strategies and technologies to compatible with the new paradigm.

According to the main objectives of VSPPs program, production of electricity has to use renewable energy resources, e.g. biomass or biogas, photovoltaic, wind and micro-hydro. Although amount of these energy resources depends mainly on government policies and drought, however it can be forecasted after harvest season with high degree of accuracy [6]. Rice husk and bagasse are by products of the rice milling and sugar cane processes, which can be stored for a future use [3]. Since VSPPs program was launched, bio-energy has more valuable as a result it became a competitive energy source for electricity production industry. From [5], biomass-based power plants have the most impact to the system consisting of 53 projects with installed capacity of 720 MW. These are 42.1% of the total number of the existing SPPs's projects, which contributes to 82.6% in term of capacity signed under the Power Purchase Agreement (PPA).

According to the size and connected location, generators under VSPPs program can be classified into a broad definition of DG. This kind of generation has significance impacts to the system both in a normal operation and transient state. In a steady state view point, benefits of using DG to reduce loss and improve voltage profile are basically interested [7]–[9]. In literatures, this can be achieved through both the planning and real time operation procedures. From planning perspective, selecting the optimal type, size and location of the DG are interested in literatures. These schemes always have limitation for a real implementation in practice. For example, in Thailand, gaining benefits from DG under VSPPs program through planning stage cannot be implemented owing to type, size, and location of DG are normally proposed by private sectors without intervention from the government agencies. Thus, enhance benefits use from DG in real time operation is very is very interested scheme.

In this paper, the scheduling plan for dispatching biomass based Distributed Generator (DG) to reduce real power loss in a distribution system is proposed. This is a real power management scheme, which can be applied in real time operation. It is formulated as an optimization problem with considering limitation of energy supply. A linear programming together with sensitivity factors of real power loss to apparent power are adopted to solve for the optimal solution, which is the annual scheduled plan of DG. A 38-bus radial distribution system is examined to verify the potential of the proposed method for implementing in a real system.

2. Problem Formulations

Consider a system comprised N buses. Subscripts G, P and Q are denoted for generation bus, real and reactive power respectively. The superscripts *min* and *max* represent minimum and maximum values. The calculation framework can be described as follow;

2.1 Real Power Loss Sensitivity Factors

Real power loss of a system can be expressed in (1).

$$P_{loss} = \sum_{a=1}^{N}\sum_{b=1}^{N} |V_a||V_b||Y_{ab}| cos(\theta_{ab} - \delta_a + \delta_b) \quad (1)$$

where

$|V_a|$ and $|V_b|$ are the voltage magnitude at *bus-a* and *b*,

$|Y_{ab}|$ is the magnitude of elements of bus-admittance matrix, at row-*a* and column-*b*,

θ_{ab} is the angle of Y_{ab}, and

δ_a and δ_b are the angle of V_a and V_b respectively.

To obtain $\partial P_{loss} / \partial P_k$ and $\partial P_{loss} / \partial Q_k$, we first calculate $\partial P_{loss} / \partial \delta_k$ and $\partial P_{loss} / \partial |V_k|$ defined by (2) and (3).

$$\frac{\partial P_{loss}}{\partial \delta_k} = \sum_{u \in k}\left[\frac{\partial P_{loss}}{\partial P_u}\cdot\frac{\partial P_u}{\partial \delta_k} + \frac{\partial P_{loss}}{\partial Q_u}\cdot\frac{\partial Q_u}{\partial \delta_k}\right] \quad (2)$$

and

$$\frac{\partial P_{loss}}{\partial |V_k|} = \sum_{u \in k}\left[\frac{\partial P_{loss}}{\partial P_u}\cdot\frac{\partial P_u}{\partial |V_k|} + \frac{\partial P_{loss}}{\partial Q_u}\cdot\frac{\partial Q_u}{\partial |V_k|}\right]. \quad (3)$$

These relationships can be presented in (4).

$$\begin{bmatrix} \dfrac{\partial P_{loss}}{\partial \delta_k} \\ \dfrac{\partial P_{loss}}{\partial |V_k|} \end{bmatrix} = [J]^T \begin{bmatrix} \dfrac{\partial P_{loss}}{\partial P_k} \\ \dfrac{\partial P_{loss}}{\partial Q_k} \end{bmatrix}. \quad (4)$$

where the terms $\partial P_{loss} / \partial \delta_k$ and $\partial P_{loss} / \partial |V_k|$ can be obtained from (5) and (6) respectively. The $[J]$ is a Jacobian matrix used in a traditional Newton-Raphson power flow.

$$\frac{\partial P_{loss}}{\partial \delta_k} = \sum_{a=1,\neq k}^{n} |V_k||V_a||Y_{ka}| sin(\theta_{ka} - \delta_k + \delta_a) \quad (5)$$

$$\frac{\partial P_{loss}}{\partial |V_k|} = \sum_{a=1,\neq k}^{n} |V_a||Y_{ka}| sin(\theta_{ka} - \delta_k + \delta_a) + 2|V_k||Y_{kk}| sin\,\theta_{kk} \quad (6)$$

The term $\partial P_{loss} / \partial P_k$ and $\partial P_{loss} / \partial Q_k$ are real power loss sensitivity factors due to an incremental change of real and reactive power at *bus-k*, which can be solved from (4).

2.2 Loss Minimization of a Specified Period

Minimizing real power loss for a specified time period T with considering energy limit can be stated as below.

$$Minimize \quad \sum_{h=1}^{T}\sum_{g \in G}\left(\frac{\partial P_{loss.h}}{\partial P_{g,h}} P_{g,h} + \frac{\partial P_{loss,h}}{\partial Q_{g,h}} Q_{g,h}\right) \quad (7)$$

subject to

$$S_{sch_i} = \sum_{j=1,\neq i}^{N} S_{ij} \quad (7a)$$

$$E_T = \sum_{h=1}^{T}(P_{g,h} \times h) \quad (7b)$$

$$P_g^{min} \le P_g \le P_g^{max} \quad (7c)$$

$$Q_g^{min} \le Q_g \le Q_g^{max} \quad (7d)$$

$$V_k^{min} \le V_k \le V_k^{max} \quad (7e)$$

The objective function of (7) is to minimize real power loss for a specified period T according to real and reactive power dispatching. Equality constrains (7a) are power flow balancing. Equality (7b) is an energy limited supply constraint amount of E_T for a specified duration T. The duration of T may be selected based on a cycle of a load profile e.g., daily, weekly monthly or seasonally. The inequality constraints (7c) and (7d) are to ensure that the injected real and reactive power are within specified limit, whereas constraint (7e) is to confirm that all bus voltage magnitude are within an acceptable range.

2.3 Global Loss Minimization

The objective function (7) presented in section 2.2 has to be applied under a long enough period to obtain a global solution. However, load profile in a real system is periodical by nature thereby the extended condition to solve for a global solution by using a load cycle is described in this section as below.

For the real power loss minimized using (7); denoted as ΔL_T; the total real power loss L of an extended period can be calculated from (8).

$$L = \frac{E}{E_T} \times \Delta L_T \quad (8)$$

For an incremental change of power $\Delta P_{g,h} + j\Delta Q_{g,h}$ added to the solution of objective function (7), the adjusted total real power loss $L + \Delta L$ is change to (9).

$$L + \Delta L = \frac{E \times \left(\Delta L_T + \dfrac{\partial P_{loss,h}}{\partial P_{g,h}} \Delta P_{g,h} + \dfrac{\partial P_{loss,h}}{\partial Q_{g,h}} \Delta Q_{g,h}\right)}{(E_T + \Delta P_{g,h})} \quad (9)$$

Subtract (8) from (9), we obtain the changed real power loss ΔL as stated in (10).

$$\Delta L = \frac{E \times \left(\dfrac{\partial P_{loss,h}}{\partial P_{g,h}} \Delta P_{g,h} + \dfrac{\partial P_{loss,h}}{\partial Q_{g,h}} \Delta Q_{g,h} - \dfrac{\Delta L_T}{E_T}\right)}{(E_T + \Delta P_{g,h})} \quad (10)$$

The optimal solution of (10) must be satisfied the condition state in (11).

$$\frac{\partial P_{loss,h}}{\partial P_{g,h}} \Delta P_{g,h} + \frac{\partial P_{loss,h}}{\partial Q_{g,h}} \Delta Q_{g,h} - \frac{\Delta L_T}{E_T} = 0 \quad (11)$$

A linear programming is used to obtain the optimal solution. However, due to limit of the page, the algorithm and flowchart for solving cannot be presented in this paper.

3. TEST SYSTEM

A 38-bus radial distribution system from [9] as shown in Fig. 1 is adopted as a tested system.

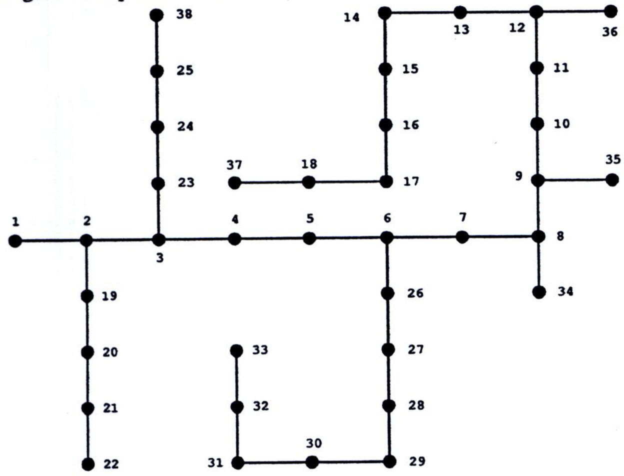

Figure 1 Network topology of a 38-bus radial distribution system

4. NUMERICAL RESULTS

In the simulation, we adopt some assumptions, which can be described as follow;

- cycle of a daily load profile as shown in the appendix is used in the study,
- DG is committed to a system all the time with capability of injecting power within its lower and upper limitations until its energy resource is empty.

Details of simulation with the obtained results can be described below.

4.1 Impact of DG Placement

To evaluate the broad-view impact of DG placement contribute to a system loss, the simulation is performed by connecting DG at each bus with power injection at its full capacity 10 MW. The obtained result of loss reduction in this case is shown in the appendix. For convenience, the daily loss reduction is illustrated in Fig. 2.

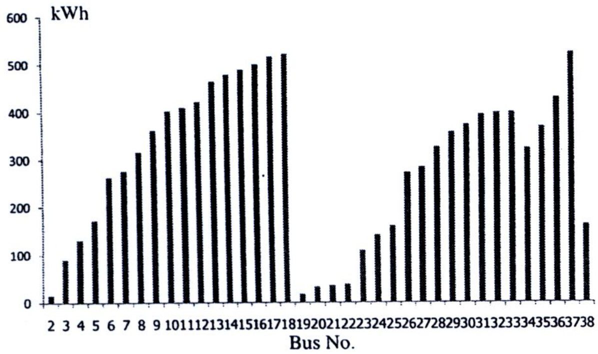

Figure 2 Daily loss reduction of connecting 10 MW DG at each bus

4.2 Optimal Daily Loss for a Specified Energy Reserve

In this case, we first calculate the minimal loss for an allocated energy-supply on a daily basis. The obtained result can be shown in Fig. 3.

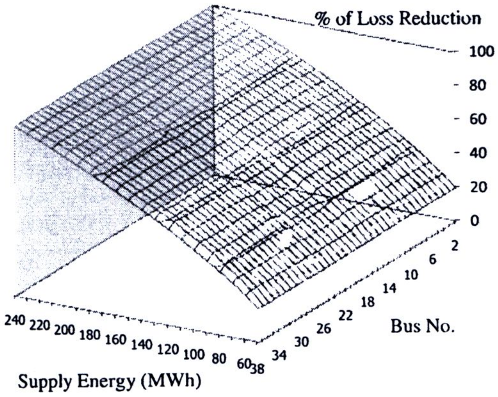

Figure 3 Percentage of Loss Reduction

From Fig. 3, it reveals that the trend of loss reduction in percent compare with its based-case is quite similar regardless from the location of DG. Moreover, the reduction of the system loss is depended on the limitation of energy supply.

4.3 Generation Scheduling

Scheduling plan for DG is varied according to the location of DG and its energy reserve. In the Simulation, DG at bus No. 37 has the most impact to reduce the system loss. Daily scheduling of this unit according to a specified amount of energy reserved can be shown in Fig 4.

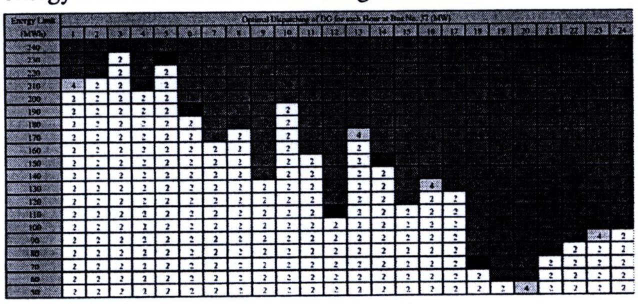

Figure 4 Optimal Dispatching of DG at Bus No. 37

4.4 Optimal Loss Reduction and Generation Scheduling

The optimal scheduling plan for DG can be calculated according to the proposed methodology as presented in section 2.3, which can be shown in Fig. 5.

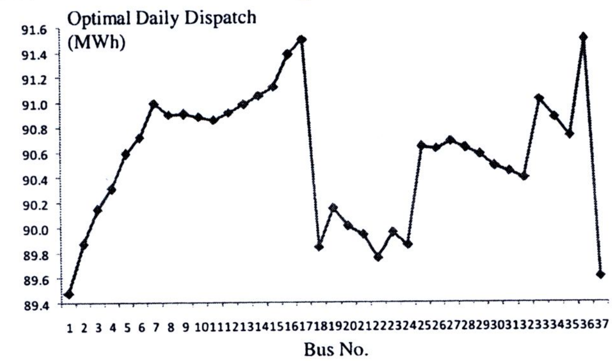

Figure 5 Optimal volume of energy dispatch

It should be noted that the optimal scheduled energy are quite the same regardless of the connected location of DG.

The percentage of additional loss reduction at the optimal scheduling of Fig. 5 can be shown in Fig. 6.

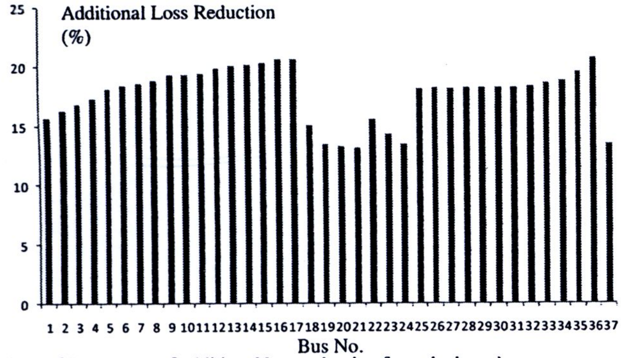

Figure 6 Percentage of additional loss reduction from the based case

5. CONCLUSIONS

In this paper, framework for scheduling biomass based Distributed Generator (DG) to reduce real power loss in a distribution system is proposed. The optimal solution is the annual scheduled plan of DG with considering limitation of energy supply. Applying the proposed method to a 38-bus radial distribution system, the additional loss reduction is about 13-20% compare with the based case without planning. This verified that the proposed method has a potential to implement in a real system.

REFERENCES

[1] Thu Lan T. Nguyen, J. E. Hermansen and M. Sagisaka, "Fossil energy savings potential of sugar cane bio-energy systems," Applied Energy, Volume 86, Supplement 1, November 2009, Pages S132-S139.

[2] A. Evans, V. Strezov and T. J. Evans, "Sustainability considerations for electricity generation from biomass," Renewable and Sustainable Energy Reviews, Volume 14, Issue 5, June 2010, Pages 1419-1427.

[3] R. M. Carlos and D. B. Khang, "A lifecycle-based success framework for grid-connected biomass energy projects," Renewable Energy, Volume 34, Issue 5, May 2009, Pages 1195-1203.

[4] T. Suramaythangkoor and S. H. GheewalaA, "Potential alternatives of heat and power technology application using rice straw in Thailand," *Applied Energy, Volume 87, Issue 1, January 2010, Pages 128-133.*

[5] http://www.eppo.go.th

[6] W. Amatayakul and C. Azar, "Determinants and land-use patterns of commercial cultivation of a fuel-wood crop in Thailand," Energy for Sustainable Development, Vol.12, Issue 1, Mar. 2008, Pages 22-32.

[7] V. H. M. Mandez, J. R. Abbad and T. G. S. Roman, "Assessment of Energy Distribution Losses for Increasing Penetration of Distributed Generation," *IEEE Transactions on Power Systems, vol. 21, No. 2, May 2006*, pp. 533-539.

[8] H. A. Gil and G. Joos, "Models for Quantifying the Economics Benefits of distributed Generation," IEEE Transactions on Power Systems, vol. 23, No. 2, May 2008, pp. 327-335.

[9] Daroj K., "Enhance Benefits Use of Reactive Power from Small Power Producers (SPPs) to Reduce Real Power Loss in Distribution Systems", 31st Electrical Engineering Conference (EECON-31) 29-31 Oct. 2008, Royal Hills Golf Resort and Spa, Nakornayok.

Komson Daroj received the B. E., M. E. and Ph.D. degrees in electrical engineering from Chulalongkorn University, Bangkok, Thailand, in 1993, 1999 and 2006 respectively. His research interests are power system planning, operation & control, distribution system planning and power quality.

DAILY LOSS REDUCTION OF A BASED-CASE 38-BUS TESTED SYSTEM

Bus	Hourly Average Loss Reduction (kW)																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
2	0.46	0.44	0.42	0.42	0.43	0.52	0.55	0.52	0.58	0.62	0.65	0.61	0.65	0.72	0.72	0.68	0.63	0.87	0.88	0.88	0.84	0.82	0.75	0.71
3	2.71	2.57	2.46	2.50	2.59	3.09	3.26	3.06	3.43	3.62	3.76	3.51	3.73	4.19	4.15	3.97	3.73	5.20	5.27	5.28	5.04	4.83	4.39	4.15
4	3.87	3.68	3.52	3.56	3.74	4.51	4.78	4.42	4.96	5.23	5.44	5.11	5.38	6.08	6.00	5.77	5.42	7.61	7.73	7.75	7.39	7.07	6.39	6.00
5	5.03	4.78	4.58	4.63	4.90	5.95	6.31	5.80	6.47	6.85	7.15	6.73	7.03	7.98	7.87	7.58	7.12	10.07	10.24	10.28	9.79	9.34	8.42	7.88
6	7.52	7.14	6.83	6.91	7.41	9.10	9.67	8.76	9.78	10.38	10.87	10.27	10.65	12.13	11.95	11.57	10.84	15.55	15.86	15.92	15.14	14.41	12.89	11.99
7	7.89	7.48	7.17	7.24	7.79	9.59	10.21	9.21	10.29	10.90	11.40	10.77	11.16	12.74	12.55	12.15	11.40	16.43	16.77	16.84	16.00	15.20	13.58	12.61
8	9.00	8.54	8.18	8.25	8.90	10.93	11.65	10.49	11.76	12.43	12.98	12.26	12.69	14.52	14.29	13.85	13.03	18.81	19.20	19.27	18.32	17.39	15.47	14.36
9	10.25	9.73	9.32	9.39	10.12	12.47	13.30	11.97	13.42	14.20	14.84	13.98	14.50	16.62	16.36	15.84	14.88	21.63	22.08	22.17	21.08	19.99	17.78	16.50
10	11.34	10.74	10.30	10.40	11.21	13.87	14.82	13.31	14.89	15.76	16.46	15.49	16.07	18.43	18.16	17.57	16.53	24.22	24.73	24.84	23.60	22.36	19.85	18.42
11	11.51	10.92	10.45	10.57	11.40	14.12	15.08	13.53	15.13	16.02	16.73	15.75	16.34	18.74	18.46	17.87	16.81	24.65	25.18	25.29	24.04	22.77	20.21	18.75
12	11.85	11.21	10.75	10.88	11.74	14.55	15.55	13.94	15.59	16.50	17.22	16.19	16.81	19.30	19.01	18.40	17.31	25.45	25.99	26.10	24.81	23.50	20.85	19.34
13	12.91	12.21	11.70	11.88	12.87	16.03	17.17	15.31	17.09	18.05	18.80	17.64	18.33	21.06	20.76	20.12	18.96	28.15	28.76	28.88	27.46	25.97	22.97	21.28
14	13.28	12.57	12.05	12.22	13.24	16.54	17.73	15.78	17.61	18.58	19.34	18.15	18.84	21.66	21.37	20.71	19.53	29.06	29.70	29.83	28.35	26.79	23.68	21.92
15	13.59	12.87	12.32	12.49	13.57	16.96	18.20	16.16	18.01	18.98	19.75	18.53	19.22	22.12	21.83	21.16	19.97	29.78	30.45	30.58	29.07	27.44	24.23	22.42
16	13.87	13.13	12.58	12.75	13.89	17.43	18.71	16.56	18.40	19.38	20.17	18.93	19.58	22.56	22.26	21.61	20.42	30.54	31.24	31.38	29.84	28.15	24.81	22.94
17	14.26	13.51	12.95	13.11	14.37	18.14	19.49	17.13	18.97	19.94	20.74	19.47	20.08	23.16	22.87	22.26	21.06	31.64	32.42	32.56	30.95	29.15	25.60	23.61
18	14.42	13.66	13.10	13.26	14.56	18.39	19.77	17.34	19.20	20.16	20.96	19.68	20.27	23.41	23.10	22.52	21.32	32.08	32.86	33.00	31.37	29.53	25.90	23.85
19	0.53	0.51	0.48	0.48	0.50	0.59	0.62	0.59	0.67	0.72	0.75	0.71	0.75	0.84	0.83	0.79	0.73	0.99	1.00	1.00	0.95	0.92	0.84	0.80
20	1.01	0.96	0.91	0.91	0.93	1.08	1.12	1.10	1.24	1.36	1.45	1.41	1.46	1.61	1.59	1.52	1.39	1.81	1.83	1.84	1.74	1.69	1.56	1.49
21	1.10	1.05	1.00	0.99	1.00	1.15	1.21	1.19	1.35	1.50	1.57	1.54	1.60	1.77	1.73	1.66	1.51	1.95	1.98	1.99	1.89	1.83	1.69	1.61
22	1.16	1.11	1.06	1.05	1.06	1.22	1.28	1.26	1.45	1.61	1.69	1.64	1.72	1.90	1.87	1.78	1.62	2.08	2.12	2.13	2.01	1.95	1.81	1.72
23	3.34	3.18	3.05	3.07	3.11	3.67	3.87	3.71	4.18	4.37	4.51	4.20	4.52	5.08	5.04	4.77	4.49	6.19	6.26	6.26	5.99	5.75	5.26	5.01
24	4.55	4.37	4.17	4.12	4.07	4.71	4.94	4.91	5.59	5.78	5.93	5.49	6.00	6.74	6.70	6.27	5.89	7.96	8.02	8.01	7.66	7.37	6.79	6.55
25	5.34	5.12	4.90	4.77	4.62	5.26	5.48	5.58	6.33	6.50	6.67	6.15	6.76	7.65	7.62	7.03	6.62	8.85	8.92	8.90	8.52	8.25	7.60	7.37
26	7.76	7.36	7.05	7.14	7.65	9.39	9.98	9.04	10.10	10.74	11.25	10.64	11.04	12.58	12.39	11.97	11.22	16.08	16.41	16.47	15.66	14.90	13.33	12.40
27	8.08	7.67	7.33	7.43	7.96	9.76	10.37	9.40	10.52	11.22	11.77	11.13	11.56	13.16	12.95	12.52	11.71	16.79	17.13	17.19	16.33	15.54	13.91	12.93
28	9.23	8.75	8.36	8.49	9.06	11.06	11.72	10.68	12.04	12.94	13.64	12.94	13.43	15.30	15.03	14.50	13.48	19.30	19.69	19.77	18.72	17.85	15.97	14.83
29	10.05	9.50	9.08	9.23	9.81	11.97	12.66	11.58	13.11	14.18	15.00	14.24	14.80	16.85	16.54	15.94	14.74	21.10	21.54	21.63	20.43	19.50	17.46	16.20
30	10.48	9.91	9.46	9.62	10.22	12.45	13.16	12.06	13.67	14.81	15.70	14.92	15.52	17.64	17.30	16.67	15.39	22.05	22.50	22.60	21.34	20.37	18.25	16.93
31	11.01	10.40	9.92	10.13	10.73	13.02	13.78	12.67	14.44	15.74	16.65	15.84	16.50	18.79	18.41	17.72	16.30	23.33	23.81	23.92	22.57	21.57	19.33	17.95
32	11.12	10.49	10.02	10.24	10.83	13.15	13.90	12.79	14.60	15.94	16.85	16.02	16.70	19.03	18.65	17.94	16.47	23.60	24.09	24.21	22.84	21.83	19.57	18.17
33	11.14	10.50	10.03	10.28	10.86	13.19	13.94	12.82	14.63	15.97	16.89	16.06	16.74	19.07	18.69	17.98	16.52	23.69	24.17	24.30	22.92	21.91	19.64	18.23
34	9.15	8.69	8.33	8.39	9.05	11.12	11.86	10.68	11.99	12.69	13.24	12.49	12.96	14.80	14.58	14.14	13.28	19.16	19.55	19.62	18.65	17.70	15.76	14.64
35	10.51	9.96	9.55	9.60	10.29	12.64	13.47	12.19	13.66	14.43	15.08	14.19	14.76	16.93	16.68	16.08	15.12	21.95	22.41	22.50	21.37	20.30	18.06	16.79
36	12.01	11.37	10.90	11.01	11.90	14.73	15.77	14.12	15.82	16.73	17.49	16.44	17.06	19.59	19.29	18.66	17.57	25.86	26.41	26.55	25.23	23.91	21.22	19.71
37	14.45	13.70	13.14	13.30	14.61	18.48	19.87	17.42	19.25	20.22	21.02	19.74	20.32	23.47	23.17	22.58	21.39	32.20	33.00	33.14	31.49	29.64	26.00	23.93
38	5.38	5.17	4.94	4.81	4.66	5.31	5.53	5.62	6.39	6.55	6.72	6.20	6.80	7.70	7.67	7.10	6.68	8.92	9.00	8.97	8.59	8.32	7.65	7.42