Design and optimisation of the architecture and the orientation of utility-scale photovoltaic power plants

ANNEXES

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Escola Tècnica Superior
d'Enginyeria Industrial de Barcelona
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1. Tracking model

```matlab
function [Tilt_module] = JIA_Tracking(Azimuth_module,Azimuth_axis,Zenith,Azimuth,Tracker_limit)

Tracker_limit=(Tracking.Tracker_limitd/180)*pi;
    Azimuth_module=(-90/180)*pi; %1-axis tracking the PV modules follow the sun east-west (northern hemisphere)
    Azimuth_axis=0; %Set to 0, this means tracking rotation axis is oriented N-S to allow modules follow the sun E-W

Tilt_module=JIA_Tracking(Azimuth_module,Azimuth_axis,Zenith,Azimuth,Tracker_limit);
    Tilt_module(GHIrradiance==0)=0;

Tilt_module= -sign(Azimuth).*abs(atan(tan(Zenith).*sin(Azimuth-(Azimuth_axis.*pi()/180)))));
Tilt_module(Tilt_module>Tracker_limit)=Tracker_limit;
Tilt_module(Tilt_module<-Tracker_limit)=-Tracker_limit;
End```

2. Self-shading model

function [Nrows, Module_Width, Module_Length, Length_Side_Row, Length_Row] = JIA_Physical_Layout(Nmodules, Nmodules_Side, Nmodules_Bottom, Area_module, Aspect_Ratio, Module_Orientation)

Nrows=floor(Nmodules/(Nmodules_Side*Nmodules_Bottom));

Module_Width=sqrt(Area_module/Aspect_Ratio);
Module_Length=Module_Width*Aspect_Ratio;

if Module_Orientation=="portrait"
    Length_Side_Row=Nmodules_Side*Module_Length;  %Length of the side/lateral of the row ("vertical/inclined" length)
    Length_Row=Nmodules_Bottom*Module_Width;    %length of the bottom of the row (horizontal length)
elseif Module_Orientation=="landscape"
    Length_Side_Row=Nmodules_Side*Module_Width;
    Length_Row=Nmodules_Bottom*Module_Length;
end

function [Mask_Angle] = JIA_Mask_Angle(Length_Side_Row, Tilt_Module, GCR)
%% Minimum array tilt angle at which the view of the sky at a given point along the side of the row is obstructed by a neighboring row
B=Length_Side_Row;
R=B/GCR;  %Distance between bottom edges of neighboring rows, CGR-Ground Coverage Ratio

Mask_Angle=atan(B.*sin(Tilt_Module)./(R-B.*cos(Tilt_Module)));
%%Theoretically the mask angle should be calculated with an integral all over the module height(z).
%%However, SAM developers took the worst case scenario, considering the mask angle from the bottom of the previous row.
%%This is based on Passias work (1984), that states that considering an average mask angle or a worst case scenario
%%does not involve errors greater than 1%.

end

function [F_sky_diffuse, F_ground_diffuse, Reduced_sky_diffuse, Reduced_ground_diffuse] = JIA_Self_Shading_Diffuse_Reduction(Zenith, Tilt_Module, DNI, POA_Incident_Diffuse, GCR, Length_Side_Row, Mask_Angle, albedo, Nrows)
%%This function follows the self-shading algorithm available in the SAM Model document. This is only the self-shading diffuse irradiance reduction
Total_Diffuse_Horizontal=POA_Incident_Diffuse.*2./(1+cos(Tilt_Module));
Beam_Horizontal=DNI.*cos(Zenith);

Reduced_sky_diffuse=POA_Incident_Diffuse-Total_Diffuse_Horizontal.*(1-(cos(Mask_Angle./2).^2)).*(Nrows-1)/Nrows;
Design and optimisation of the architecture and the orientation of utility-scale photovoltaic power plants

F_sky_diffuse=Reduced_sky_diffuse./POA_Incident_Diffuse; %Sky diffuse reduction factor
F_sky_diffuse(POA_Incident_Diffuse<0.1)=1; %Limited (following SAM developers' criteria)

B=Length_Side_Row;
R=B/GCR; %Distance between bottom edges of neighboring rows, GCR-Ground Coverage Ratio

Altitude=(pi/2)-Zenith; %Sun altitude

Y=R.*(sin(pi-Altitude-Tilt_Module)./sin(Altitude)); %Length of ground in front of each shaded row that reflects beam radiation onto the row
Y(Y<0.00001)=0.00001; %Minimum value of Y suggested by SAM developers
F1=albedo.*(sin(Tilt_Module./2).^2); %View factor on the 1st row
F2=0.5*albedo.*(1+(Y./B)-sqrt(((Y.^2)./(B^2))-((2*Y./B).*cos(pi-Tilt_Module))).+1)); %Beam reflected component factor
F3=0.5*albedo.*(1+(R./B)-sqrt(((R.^2)./(B^2))-((2*R./B).*cos(pi-Tilt_Module))).+1)); %Diffuse reflected component factor

Reduced_ground_diffuse=((F1+(Nrows-1).*F2)./Nrows).*Beam_Horizontal+((F1+(Nrows-1).*F3)./Nrows).*Total_Diffuse_Horizontal;
Gr1=F1.*(Beam_Horizontal+Total_Diffuse_Horizontal);
F_ground_diffuse=Reduced_ground_diffuse./Gr1; %Ground diffuse reduction factor
F_ground_diffuse(Gr1<=0)=1;
F_ground_diffuse(POA_Incident_Diffuse<0.1)=1;

end

function [F_DC_Self_Shading] = JIA_Self_Shading_DC_Loss_Factor(Azimuth,Azimuth_module,Length_Side_Row,Length_Row,Tilt_module,Zenith,GCR,Nmodules_Side,Nmodules_Bottom,Nmodules_Stack,Module_Orientation,Module_Width,Module_Length,Reduced_ground_diffuse,Reduced_sky_diffuse,BeamInPlaneIrr,panelDS_struct,DCVoltages_module_hourly_PV2)

Azimuth_SAM=Azimuth+pi; %Sun azimuth, variable change to SAM azimuth notation so as to avoid problems with following equations
Azimuth_module_SAM=Azimuth_module+pi; %Variable change to SAM azimuth notation so as to avoid problems with following equations

Azimuth_effective=Azimuth_SAM-Azimuth_module_SAM; %Azimuth effective is to find an equivalent notation to Appelbaum's work (1979)

B=Length_Side_Row;
R=B/GCR; %Distance between bottom edges of neighboring rows, GCR-Ground Coverage Ratio

Py=B.*((cos(Tilt_module)+cos(Azimuth_effective).*sin(Tilt_module).)/tan((pi/2)-Zenith))); %Shaded portion of the array
Px=B.*sin(Tilt_module).*sin(Azimuth_effective).)/tan((pi/2)-Zenith);

Py(Tilt_module==0)=0; %If no tilt, no shading
Px(Tilt_module==0)=0; %If no tilt, no shading
Py(Azimuth_effective>pi/2)=0; %If azimuth effective >90º, no shading
Px(Azimuth_effective>pi/2)=0; %If azimuth effective >90º, no shading
\[ g = R \cdot \frac{P_x}{P_y}; \quad \text{%Shadow displacement} \]
\[ g(g < 0) = 0; \quad \text{%g always positive (Note: there's an error in the SAM doc for this restriction)} \]
\[ g(P_y = 0) = 0; \quad \text{%To avoid infinity values in the g calculation} \]
\[ g(N_{\text{modules Bottom}} > N_{\text{modules String}}) = 0; \quad \text{%Since we consider wiring modules within string horizontally, assumption of very long rows} \]
\[ g(g > \text{Length Row}) = \text{Length Row}; \quad \text{%g can't be greater than the length of the row} \]

\[ \text{Shade height} = B \cdot (1 - R \cdot \frac{P_x}{P_y}); \]
\[ \text{Shade height} (\text{Shade height} < 0) = 0; \quad \text{%always positive (Note: there's an error in the SAM doc for this restriction)} \]
\[ \text{Shade height} (P_y = 0) = 0; \quad \text{%To avoid infinity values in the shade height calculation} \]
\[ \text{Shade height} (\text{Shade height} > B) = B; \quad \text{%shade height can't be greater than the height of the row} \]

%In the following equations the number 3 corresponds to the (normally) number of bypass diodes present in a PV module
\[
\text{if Module Orientation} = \text{"landscape"} \\
\quad X = (\text{ceil}(\text{Shade height} / \text{Module Width})) \cdot (R - 1) / (R \cdot N_{\text{modules Side}}); \\
\quad \text{%Fraction of each row that shaded} \\
\quad S = ((\text{ceil}(\text{Shade height} / 3) / \text{Module Width})) / 3 \cdot (1 - (\text{floor}(g / \text{Module Length})) / N_{\text{modules Bottom}}); \\
\quad \text{%Fraction of submodules shaded in a string} \\
\quad S(\text{Shade height} > \text{Module Width}) = 1; \quad \text{%Assumption of complete shading, not 100\% correct but valid estimation that compensates total vs partial shaded modules} \\
\text{elseif Module Orientation} = \text{"portrait"} \\
\quad X = (\text{ceil}(\text{Shade height} / \text{Module Length})) \cdot (R - 1) / (R \cdot N_{\text{modules Side}}); \\
\quad S = 1 - ((\text{floor}(g / 3) / \text{Module Width})) / (3 \cdot N_{\text{modules Bottom}}); \\
\text{end} \]

\[
\text{Ratio dt} = (\text{Reduced sky diffuse} + \text{Reduced ground diffuse}) / (\text{BeamInPlaneIrr} + \text{Reduced sky diffuse} + \text{Reduced ground diffuse}); \quad \text{%Ratio of diffuse POA irradiance to total POA irradiance (considering diffuse shading)} \\
\text{Fill factor} = (\text{panelDS_struct.v_mp_ref} \cdot \text{panelDS_struct.i_mp_ref}) / (\text{panelDS_struct.v_sc_ref} \cdot \text{panelDS_struct.i_sc_ref}); \\
\]

%The following coefficients (C1, C2, C3) come from experimental analysis by Deline (2013)
\[ C1 = (109 \cdot \text{Fill factor} - 54.3) \cdot \exp(-4.5 \cdot X); \]
\[ C2 = -6 \cdot (X \cdot 2) + 5 \cdot X + 0.28; \]
\[ C2(X > 0.65) = -6 \cdot (0.65^2) + 5 \cdot 0.65 + 0.28; \quad \text{%If X > 0.65, X = 0.65 in C2 calculations} \]
\[ C3 = \max((-0.05 \cdot \text{Ratio dt} - 0.01) \cdot X + (0.85 \cdot \text{Fill factor} - 0.7) \cdot \text{Ratio dt} - 0.085 \cdot \text{Fill factor} + 0.05, \text{Ratio dt} - 1); \]

%Shade factors
\[ F_{\text{DC1}} = 1 - C1 \cdot (S \cdot 2) - C2 \cdot S; \quad \text{%When small X and small S} \]
\[ F_{\text{DC2}} = (X - S \cdot (1 + 0.5 \cdot 3 / \text{DCVoltages_module_hourly_PV2})) / X; \quad \text{%When large X} \]
\[ F_{\text{DC2}}(X = 0) = 0; \]
\[ F_{\text{DC3}} = C3 \cdot (S - 1) + \text{Ratio dt}; \quad \text{%When large S} \]
max1=max(F_DC1,F_DC2);
max_final=max(max1,F_DC3);
F_DC_Self_Shading=X.*max_final+(1-X);
F_DC_Self_Shading(F_DC_Self_Shading<0)=0;
F_DC_Self_Shading(F_DC_Self_Shading>1)=1;

End
3. Battery model

function [Energy2grid, PV2grid, Battery2grid, PV2battery, EnergyInBattery, EnergyLossOverCharging, Battery_SOC, EnergyInBattery_lasthour, Battery_SOC_lasthour] = JIA_BatteryModel(Battery_Capacity,DODmax,Initial_SOC,Converter_efficiency,Bat_charge_efficiency,Bat_discharge_efficiency,Desired_flatoutput,ACpower_sandia_final)

%Initialisation vectors
Energy2grid=zeros(length(ACpower_sandia_final),1);
PV2grid=zeros(length(ACpower_sandia_final),1);
Battery2grid=zeros(length(ACpower_sandia_final),1);
PV2battery=zeros(length(ACpower_sandia_final),1);
EnergyInBattery=zeros(length(ACpower_sandia_final),1); %Energy present inside the battery
EnergyLossOverCharging=zeros(length(ACpower_sandia_final),1); %Energy that is lost as heat in a resistance to avoid overcharging the battery
Battery_SOC=zeros(length(ACpower_sandia_final),1); %Initialisation battery SOC January 1st
Battery_SOC(1)=1-DODmax;
Battery_SOC(1)=Initial_SOC;
EnergyInBattery(1)=Battery_SOC(1)*Battery_Capacity;

%Minimum SOC and minimum energy in battery, depending on the maximum DOD of the battery
Min_SOC=1-DODmax;
Min_EnergyInBattery=Min_SOC*Battery_Capacity;

%Initialisation iterations
iter=1;

while iter<length(ACpower_sandia_final)

    if ACpower_sandia_final(iter)>=Desired_flatoutput %PV can charge the battery while reaching the desired flat-output
        Energy2grid(iter)=Desired_flatoutput;
        PV2grid(iter)=Desired_flatoutput;
        Battery2grid(iter)=0;
        PV2battery(iter)=ACpower_sandia_final(iter)-Desired_flatoutput;
        EnergyInBattery(iter+1)=EnergyInBattery(iter)+PV2battery(iter)*Converter_efficiency*Bat_charge_efficiency; %Energy in battery for the next iteration (hour)
        if EnergyInBattery(iter+1)>Battery_Capacity %Restriction to avoid overcharging battery capacity
            EnergyLossOverCharging(iter)=EnergyInBattery(iter+1)-Battery_Capacity;
            EnergyInBattery(iter+1)=Battery_Capacity;
            disp('Consider increasing your battery capacity, you are losing energy due to undersized battery')
        end
    end

    iter=iter+1;
end
elseif ACpower_sandia_final(iter)<Desired_flatouput
  %Battery helps to try reaching the desired flat-output

  Energy2grid(iter)=min(Desired_flatouput,ACpower_sandia_final(iter)+(EnergyInBattery(iter)-Min_EnergyInBattery)*Bat_discharge_efficiency*Converter_efficiency);
  % (EnergyInBattery(iter)-Min_EnergyInBattery) is the actual usable battery energy (current SOC-SOCmin)
  PV2grid(iter)=ACpower_sandia_final(iter);
  Battery2grid(iter)=min(Desired_flatouput-PV2grid(iter),(EnergyInBattery(iter)-Min_EnergyInBattery)*Bat_discharge_efficiency*Converter_efficiency);
  PV2battery(iter)=0;
  EnergyInBattery(iter+1)= EnergyInBattery(iter+1)/Battery_Capacity;
  %Energy in battery for the next iteration (hour)
end

Battery_SOC(iter+1)=EnergyInBattery(iter+1)/Battery_Capacity;
iter=iter+1;
end

%Case for the last hour in the year
if ACpower_sandia_final(iter)>=Desired_flatouput
  %PV can charge the battery while reaching the desired flat-output
  Energy2grid(iter)=Desired_flatouput;
  PV2grid(iter)=Desired_flatouput;
  Battery2grid(iter)=0;
  PV2battery(iter)=ACpower_sandia_final(iter)-Desired_flatouput;
end

EnergyInBattery_lasthour=EnergyInBattery(iter)+PV2battery(iter)*Converter_efficiency*Bat_charge_efficiency;
 %Energy in battery for the next iteration (hour)
if EnergyInBattery_lasthour>Battery_Capacity
  %Restriction to avoid overcharging battery capacity
  EnergyLossOverCharging(iter)=EnergyInBattery_lasthour-Battery_Capacity;
  disp('Consider increasing your battery capacity, you are losing energy due to undersized battery')
end

elseif ACpower_sandia_final(iter)<Desired_flatouput
  %Battery helps to try reaching desired flat-output

  Energy2grid(iter)=min(Desired_flatouput,ACpower_sandia_final(iter)+(EnergyInBattery(iter)-Min_EnergyInBattery)*Bat_discharge_efficiency*Converter_efficiency);
  % (EnergyInBattery(iter)-Min_EnergyInBattery) is the actual usable battery energy (current SOC-SOCmin)
  PV2grid(iter)=ACpower_sandia_final(iter);
Battery2grid(iter) = \min\{\text{Desired_{flatoutput}-PV2grid(iter)},(\text{EnergyInBattery(iter)-Min\_EnergyInBattery})\times\text{Bat\_discharge\_efficiency}\times\text{Converter\_efficiency}\};
PV2battery(iter)=0;
EnergyInBattery\_lasthour=\text{EnergyInBattery(iter)}-
Battery2grid(iter)/(\text{Bat\_discharge\_efficiency}\times\text{Converter\_efficiency});
%Energy in battery for the next iteration (hour)
end

Battery\_SOC\_lasthour=\text{EnergyInBattery\_lasthour}/\text{Battery\_Capacity};
End
4. Incidence Angle Modifier (IAM) model

```matlab
function [Transmittance] = JIA_Transmittance(Incidence_angle, Refractive_index_cover, Refractive_index_air, Proportionality_constant, Cover_thickness)

    Angle_refraction = asin(Refractive_index_air/Refractive_index_cover.*sin(Incidence_angle));
    Transmittance = Transmittance_previous.*exp(-Proportionality_constant*Cover_thickness./cos(Angle_refraction));

    %% Parameters used in IAM calculation
    Refractive_index_glass = 1.526;
    Refractive_index_air = 1;
    Proportionality_constant = 4; ddie degree to avoid 0/0 indeterminations and infinites
    Glass_thickness = 0.002;  %Thickness of glass cover in meters
    IncidenceAngle_normal = 1*pi/180;  %It should be 0 degrees, but I use 1
degree to avoid 0/0 indeterminations and infinites

    [Transmittance_normal] = JIA_Transmittance(IncidenceAngle_normal, Refractive_index_glass, Refractive_index_air, Proportionality_constant, Glass_thickness);

    [Transmittance_beam] = JIA_Transmittance(IncidenceAngle, Refractive_index_glass, Refractive_index_air, Proportionality_constant, Glass_thickness);
    IAM_beam = Transmittance_beam./Transmittance_normal;

    IncidenceAngle_ground_diffuse = deg2rad(90-0.5788.*rad2deg(abs(Tilt_module))+0.002693.*(rad2deg(abs(Tilt_module))).^2);  %For IAM calculation
    [Transmittance_ground_diffuse] = JIA_Transmittance(IncidenceAngle_ground_diffuse, Refractive_index_glass, Refractive_index_air, Proportionality_constant, Glass_thickness);
    IAM_ground_diffuse = Transmittance_ground_diffuse./Transmittance_normal;

    IncidenceAngle_sky_diffuse = deg2rad(59.7-0.1388.*rad2deg(abs(Tilt_module))+0.001497.*(rad2deg(abs(Tilt_module))).^2);  %For IAM calculation
    [Transmittance_sky_diffuse] = JIA_Transmittance(IncidenceAngle_sky_diffuse, Refractive_index_glass, Refractive_index_air, Proportionality_constant, Glass_thickness);
    IAM_sky_diffuse = Transmittance_sky_diffuse./Transmittance_normal;
```

5. PV module datasheet: JAM72S01 385-PR

![PV module datasheet](image-url)

**Introduction**

Powered by high-efficiency PERC IUM cells, this series of high-performance modules provides the most cost-effective solution for lowering the LCOE of any PV system large or small.

- **5 busbar solar cell design**
- **Higher output power**
- **Excellent low-light performance**
- **Lower temperature coefficient**

**Superior Warranty**

- 12-year product warranty
- 25-year linear power output warranty

**Comprehensive Certificates**

- IEC 61215, IEC 61701, UL 1703, IEC TS 62804, IEC 61701, IEC 62716, IEC 60098-2-68
- ISO 9001: 2015 Quality management systems
- ISO 14001: 2015 Environmental management systems
- OHSAS 18001: 2007 Occupational health and safety management systems
- IEC TS 62941: 2016 Terrestrial photovoltaic (PV) modules – Guidelines for increased confidence in PV module design qualification and type approval
6. String inverter datasheet: SUN2000-100KTL-USH0

Smart String Inverter
SUN2000-100KTL-USH0

Smart
- 12 strings intelligent monitoring and fast trouble shooting
- Power Link Communication (PLC) supported
- Smart IV Curve Diagnosis supported

Efficient
- Max. efficiency 98.6%
- OEC efficiency 99.1%
- 6 MPPT per unit, efficient reducing string mismatch

Safe
- IEC 61707 compliant to IEC 61707: Type 1
- Residual Current Monitoring Unit (RCMU) integrated inside
- Fuse-free design

Reliable
- Natural cooling technology
- Protection degree of Type 4X
- Type II safety measures for both DC and AC

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Design and optimisation of the architecture and the orientation of utility-scale photovoltaic power plants

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### Smart String Inverter (SUN2000-100KTL-USH0)

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<th>SUN2000-100KTL-USH0</th>
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<tr>
<td>Max. Efficiency</td>
<td>99.7%</td>
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<tr>
<td>DC Output Efficiency</td>
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<tr>
<td><strong>Input</strong></td>
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<tr>
<td>Max. Input Voltage</td>
<td>1,980 V</td>
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<tr>
<td>Max. Current per MPPT</td>
<td>22 A</td>
</tr>
<tr>
<td>Max. Short Circuit Current per MPPT</td>
<td>20 A</td>
</tr>
<tr>
<td>Start Voltage</td>
<td>603 V</td>
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<tr>
<td>MPPT Operating Voltage Range</td>
<td>600 V – 1,000 V</td>
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<tr>
<td>Full Power MPPT Voltage Range</td>
<td>800 V – 1,300 V</td>
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<tr>
<td>Number of Inputs</td>
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<tr>
<td>Number of MPPT Boosters</td>
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<tr>
<td><strong>Output</strong></td>
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<td>Max. Power</td>
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<td>Min. Volt (at 1000 W)</td>
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<td>Max. Total Harmonic Distortion</td>
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<td><strong>Protection</strong></td>
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<td>DC Air Breaker/Circuit breaker</td>
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<tr>
<td>Inverter-side Disconnect Device</td>
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<td>Anti-islanding Protection</td>
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<td>DC Overvoltage Protection</td>
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<td>AC Overvoltage Protection</td>
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<td>Primary String Self Monitoring</td>
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<tr>
<td>DC Surge arrester</td>
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<td>AC Surge arrester</td>
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<td>DC Insulation Fault Protection</td>
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<td>Residual Current Monitoring Unit</td>
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<tr>
<td><strong>Communication</strong></td>
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<td>Display</td>
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<tr>
<td>USB</td>
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<tr>
<td>Power Line Communication (PLC)</td>
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</tbody>
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### Efficiency Curve

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### Circuit Diagram

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Always Available for Highest Yields

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7. Central inverter datasheet: SUNNY CENTRAL

SUNNY CENTRAL
2200 / 2475 / 2500-EV / 2750-EV / 3000-EV

Efficient
- Up to 4 inverters can be transported in one standard shipping container
- Overdimensioning up to 22% is possible
- Full power at ambient temperatures up to 35°C

Robust
- Intelligent air cooling system OptiCool for efficient cooling
- Suitable for outdoor use in all climate conditions worldwide

Flexible
- Custom to all known grid requirements worldwide
- Grid-demand
- Available as a single device or lobby solution, including medium voltage block

Easy to Use
- Improved DC connection area
- Connection area for customer equipment
- Integrated voltage support for internal and external loads

SUNNY CENTRAL 2200 / 2475 / 2500-EV / 2750-EV / 3000-EV
The new Sunny Central: more power per cubic meter

With an output of up to 3000kVA and system voltages of 11kV DC or 1.5kV DC, the SMA central inverters allow for more efficient system design and a reduction in specific costs for PV power plants. A separate voltage supply and additional space are available for the installation of customer equipment. True 1.5kV technology and the intelligent cooling system OptiCool ensure a smooth operation even in extreme ambient temperature as well as a long service life of 25 years.
**SUNNY CENTRAL 1500 V**

<table>
<thead>
<tr>
<th>Technical Data</th>
<th>Sunny Central 1500 EV</th>
<th>Sunny Central 2750 EV</th>
<th>Sunny Central 3000 EV</th>
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<tbody>
<tr>
<td><strong>Input (DC)</strong></td>
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<td></td>
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</tr>
<tr>
<td>MP voltage range Vmp (at 25°C / ±0.5°C / ±0.5°C)</td>
<td>150 V to 1625 V / 1200 V / 778 V / 928 V</td>
<td>1625 V / 1200 V / 849 V / 995 V</td>
<td>1625 V / 1200 V / 956 V / 1252 V / 1200 V / 927 V / 1077 V</td>
</tr>
<tr>
<td>Min. input voltage Voc (at 35°C) / Min. input voltage Voc (at 50°C)</td>
<td>1500 V / 1500 V</td>
<td>1500 V / 1500 V</td>
<td>1500 V / 1500 V</td>
</tr>
<tr>
<td>Max. input current Ims (at 35°C) / Max. input current Ims (at 50°C)</td>
<td>3200 A / 2956 A</td>
<td>3200 A / 2956 A</td>
<td>3200 A / 2956 A</td>
</tr>
<tr>
<td>Max. output current Iac (at 35°C) / Max. output current Iac (at 50°C)</td>
<td>6400 A / 6400 A</td>
<td>6400 A / 6400 A</td>
<td>6400 A / 6400 A</td>
</tr>
<tr>
<td><strong>Number of DC inputs</strong></td>
<td>24 (double pole fused) / 32 (single pole fused) for PV</td>
<td>18 (double pole fused) / 36 (single pole fused) for PV and 6 double pole fused for batteries</td>
<td>2 x 8400 A / 3 x 6400 A</td>
</tr>
<tr>
<td><strong>Available AC fuse size (per input)</strong></td>
<td>200 A, 250 A, 315 A, 350 A, 400 A, 450 A, 500 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Output (AC)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal AC power at 0 °C (at 35°C / ±5°C)</td>
<td>2500 W / 2250 W / 2000 W / 1800 W</td>
<td>2750 W / 2520 W / 2200 W / 2000 W</td>
<td>3000 W / 2790 W / 2400 W / 2100 W</td>
</tr>
<tr>
<td>Nominal AC power at 0 °C (at 35°C / ±5°C)</td>
<td>2024 W / 1800 W</td>
<td>2464 A / 2250 A</td>
<td>2664 A / 2400 A</td>
</tr>
<tr>
<td>Nominal AC current</td>
<td>&lt;3% of nominal power</td>
<td>&lt;3% of nominal power</td>
<td>&lt;3% of nominal power</td>
</tr>
<tr>
<td>Nominal AC voltage / nominal AC voltage range</td>
<td>530 V / 440 V to 660 V</td>
<td>600 V / 480 V to 900 V</td>
<td>655 V / 524 V to 721 V</td>
</tr>
<tr>
<td>AC power frequency</td>
<td>50 Hz / ±3 Hz / 50 Hz</td>
<td>50 Hz / ±3 Hz / 50 Hz</td>
<td>50 Hz / ±3 Hz / 50 Hz</td>
</tr>
<tr>
<td>Min. short-circuit ratio at the AC terminals</td>
<td>&gt;2</td>
<td>&gt;2</td>
<td>&gt;2</td>
</tr>
<tr>
<td>Power factor at rated power / displacement power factor adjustable</td>
<td>0.98 / 0.98</td>
<td>0.98 / 0.98</td>
<td>0.98 / 0.98</td>
</tr>
</tbody>
</table>

**Efficiency**

Max. efficiency [%] / European efficiency [%] / CEC efficiency [%] | 98.6% / 98.5% / 98.4% | 98.7% / 98.6% / 98.5% | 98.8% / 98.6% / 98.5%

**Protective Devices**

| AC system protection | DC break-out switch | DC circuit breaker | Surge arrester, class I |

**General Data**

| Dimensions (W/H/D) | 2783 / 2318 / 1588 mm (109.4 / 91.3 / 62.5 inch) | 2783 / 2318 / 1588 mm (109.4 / 91.3 / 62.5 inch) | 2783 / 2318 / 1588 mm (109.4 / 91.3 / 62.5 inch) |
| Weight | <8.6 kg / <9.5 kg / <10.2 kg | <8.6 kg / <9.5 kg / <10.2 kg | <8.6 kg / <9.5 kg / <10.2 kg |
| Self-consumption (max.) / partial load / average | <0.01 W / 0.00 W / <0.00 W | <0.01 W / 0.00 W / <0.00 W | <0.01 W / 0.00 W / <0.00 W |
| Self-consumption (standby) | <0.00 W | <0.00 W | <0.00 W |
| Noise emission | 67.8 dB(A) | 67.8 dB(A) | 67.8 dB(A) |
| Temperature range (operating) | -40°C to 60°C / -40°C to 60°C / -40°C to 60°C | -40°C to 60°C / -40°C to 60°C / -40°C to 60°C | -40°C to 60°C / -40°C to 60°C / -40°C to 60°C |
| Temperature range (storage) | -40°C to 70°C / -40°C to 70°C / -40°C to 70°C | -40°C to 70°C / -40°C to 70°C / -40°C to 70°C | -40°C to 70°C / -40°C to 70°C / -40°C to 70°C |
| Maximum power (average) / active / reactive power (condensing / non-condensing) | 95% / 100% / 0% / 0% | 95% / 100% / 0% / 0% | 95% / 100% / 0% / 0% |
| Fresh air consumption | 6500 m³/h | 6500 m³/h | 6500 m³/h |

**Features**

<table>
<thead>
<tr>
<th>Function</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>DC connection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC connection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communication with SMA sting monitor (transmitting modem)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enclosure / noise level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply transformer</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Standards and directives complied with**

<table>
<thead>
<tr>
<th>Standard</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>

**Quality standards and directives complied with**

1. Standard features
2. Optional features

**Type designation**

<table>
<thead>
<tr>
<th>Type designation</th>
<th>SC2500 EV</th>
<th>SC2750 EV</th>
<th>SC3000 EV</th>
</tr>
</thead>
</table>

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7. Standard pressure level at a distance of 10 m
8. Values apply only to inverters. Nominal values for SMA inverters from SMA can be found in the corresponding data sheets.
9. AC voltage range can be extended to 753 V or 50 Hz only.
10. A short-circuit ratio of ≥ 2 requires special approval from SMA.
11. Depending on the DC configuration.
SUNNY CENTRAL 1000 V

**Technical Data**

<table>
<thead>
<tr>
<th>Sunny Central 12200</th>
<th>Sunny Central 2475^*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input (DC)</strong></td>
<td></td>
</tr>
<tr>
<td>Nominal AC power at cos φ=1 (at 35°C C/ at 50°C)</td>
<td>570 kW / 890 V / 800 V / 800 V</td>
</tr>
<tr>
<td>Min. AC voltage</td>
<td>542 V / 645 V</td>
</tr>
<tr>
<td>Max. AC voltage V_max</td>
<td>1100 V</td>
</tr>
<tr>
<td>Max. AC current I_min</td>
<td>3964 A / 3000 A</td>
</tr>
<tr>
<td>Max. AC current</td>
<td>5400 A</td>
</tr>
<tr>
<td>Number of DC inputs</td>
<td>24 double pole fuses [32 single pole fuses]</td>
</tr>
<tr>
<td>Max. number of DC outputs per DC input (for each pole)</td>
<td>5 x 800 A / 3 x 500 A / 3 x 600 A</td>
</tr>
<tr>
<td>Integrated zero monitoring</td>
<td></td>
</tr>
<tr>
<td>Available DC fuse rating (per input)</td>
<td>200 A, 250 A, 315 A, 320 A, 400 A, 450 A, 500 A</td>
</tr>
<tr>
<td><strong>Output (AC)</strong></td>
<td></td>
</tr>
<tr>
<td>Nominal AC power at cos φ=0.8 (at 35°C C/ at 50°C)</td>
<td>860 kW / 1600 A</td>
</tr>
<tr>
<td>Nominal AC current I_max</td>
<td>3300 A</td>
</tr>
<tr>
<td>Nominal AC voltage V_min</td>
<td>385 V / 500 V / 420 V</td>
</tr>
<tr>
<td>AC power frequency range</td>
<td>50 Hz / 47 Hz to 53 Hz</td>
</tr>
<tr>
<td>Min. short circuit ratio at AC terminals^1</td>
<td>&gt; 2</td>
</tr>
<tr>
<td>Power factor corrected power / displacement power / load adjustable^1,2</td>
<td>1 / 0.8 overexcited to 0.8 unexcited</td>
</tr>
<tr>
<td>Efficiency</td>
<td>93.5% / 97.5%</td>
</tr>
</tbody>
</table>

**Protective Devices**

- Overvoltage protection
- AC overcurrent protection (optional)
- Lightning protection (according to IEC 61363-1)
- Ground-fault monitoring / remote earth fault monitoring
- Insulation monitoring

**General Data**

- Dimensions (W x H x D) | 1365 x 1598 mm (190.4 x 51.5 / 62.5 inches)
- Weight | 360 kg / 794 lbs
- Refrigeration (max. *) | 270 W / 1000 W / 800 W / 700 W
- Refrigeration (average) | 460 W / 260 W / 240 W / 180 W
- Nominal temperature | 95°C / 208°F
- Temperature range (steady) | 95°C / 208°F
- Temperature range (storage) | 95°C / 208°F
- Maximum operating altitude above MSL: 1000 m / 2000 m / 3000 m / 4000 m
- Freon consumption | 0.01 kg / 0.04 kg
- Mechanical consumption | 0.006 kg / 0.024 kg
- Sound pressure level at 1 meter | 10 m
- Sound pressure level at 1 meter
- Power factor | 1.0 / 0.8 overexcited to 0.8 unexcited
- Efficiency | 93.5% / 97.5%
- Overvoltage protection
- AC overcurrent protection (optional)
- Lightning protection (according to IEC 61363-1)
- Ground-fault monitoring / remote earth fault monitoring
- Insulation monitoring

**Features**

- DC connection
- AC connection
- Communication
- Safety measures
- Supply transformers for external loads
- Domestic and industrial applications
- EMC standards
- Quality standards and directives complied with
- Standard deviations
- Optional
- Preliminary

**Type designation**

- SG220610
- SG247510

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1) Nominal AC voltage variable AC power decreases in the same proportion.
2) Efficiency measured with fixed AC power supply.
3) Efficiency measured with fixed AC current supply.
4) DC load at rated output.
5) DC load at 0.75% of the rated output.
6) DC load at 0.75% of the rated output.
Design and optimisation of the architecture and the orientation of utility-scale photovoltaic power plants