Solar Calculations – from http://www.pveducation.org/pvcdrom/properties-of-sunlight/solar-time

Details of solar calculations used in spreadsheet

Total amount of radiation received by the PV module, G = B_m (direct beam) + D (diffuse)

B_m = DNI[sinδ.sinφ.cosβ - sinδ.cosφ.sinβ.cosψ + cosδ.cosφ.cosβ.cosHRA + cosδ.sinφ.sinβ.cosψ.cosHRA + cosδ.sinψ.sinHRA.sinβ]

Where
DNI = Direct Normal Irradiance (The actual Direct Irradiance given in the downloaded ESP-r data)
δ = declination angle
φ =latitude of location
β = PV module tilt
ψ = module azimuth (orientation as measured from South to West)
HRA = hour angle

D = DHI (180-β)/180

Where
DHI = Diffuse Horizontal Irradiation (The actual Diffuse Irradiance given in the downloaded ESP-r data)

$\delta = \sin^{-1}[\sin(23.45^0).\sin((360/365).(d-81))]$

Where
d is day of the year, with 1st January = 1

$LSTM = 15^0.\Delta T_{GMT}$

Where
Local Standard Time Meridian (LSTM) = reference meridian used for particular time zone = 0 for UK, although the correction is available in the spreadsheet

EoT = 9.87.sin(2B) – 7.53.cos(B) – 1.5.sin(B)

Where
B = (360/365).(d-81)

TC = 4.(Longitude – LSTM) + EoT

TC is time correction factor to correct for longitude position within the actual time zone. The 4 in the equation is because the earth revolves through 1^0 every 4 minutes

Local Solar Time (LST)

LST = LT +(TC/60)

Where
LT = Local time

$HRA = 15^0(LST-12)$

HRA is 0^0 at solar noon, -ve in the morning, +ve in the afternoon

Elevation angle, $\alpha = \sin^{-1}[\sin\delta.\sin\varphi + \cos\delta.\cos\varphi.\cos(HRA)]$

This was used to determine the angle above the horizon of the sun. The industry use of α is to determine PV park capacity factor (www.variablepitch.co.uk), which is defined on a daily basis.

Capacity factor (PV) = daily PV energy production / (PV nominal capacity.number of hours that day when $\alpha > 12.5$)

PV output calculations from www.photovoltaic-software.com/PV-solar-energy-calculation.php

P = A.r.H.PR

Where
P = power (W)
A = Total solar panel area (m^2)
r = solar panel efficiency (%)
H = irradiance
PR = performance ratio for losses (range between 0.5 and 0.9 – 0.9 used for this spreadsheet)

Examples of losses details giving PR value (dependant on site, technology and sizing of system). E.g. Inverter losses, temperature losses, DC and AC cable losses, shading, losses due to weak radiation, losses due to dust, snow etc…