Introduction to solar PV energy

- Dimensioning -

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The power of the sun - G

- Global Irradiation 0.29-0.4 um
- Instantaneous value (Power) W/m^2
- Units
  - Energy: Wh/m^2
  - Energy: J/m^2
  - Solar Peak Hours
- Conversions
  - 1 wh =3600 J
- Irradiance (W) vs Irradiation (Wh)

G

- Irradiance and irradiation values stand for area densities, i.e.no subscripts are used to indicate the surface area. All symbols refer to horizontal planes; for a tilted plane, the slope ß and the plane azimuth (Alpha) are added in brackets.
- Subscript 0 stands for extraterrestrial or astronomical.
- Subscript h stands for hourly and subcript d for daily.

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The figures

- A nearly constant 1.36 kilowatts per square meter (the solar constant) of solar radiant power impinges on the earth's outer atmosphere.
- Approximately 70% of this extraterrestrial radiation makes it through our atmosphere on a clear day.
- Irradiance at ground level regularly exceeds 1,000 w/m2. In some mountain areas, readings over 1,200 w/m2 are often recorded.

Type of systems

- Grid-Intertied solar-electric system: on grid
- Grid-Intertied solar-electric system with battery backup
- Off-Grid solar-electric system with battery backup (Telcenter A)
- Grid-Intertied solar-electric system with battery and generator backup (Telecenter B)

Type of load

- AC load
- DC load
- Direct pump (no batteries)

Components (I)

- PV
- PV Mounts
- Array PV - DC Disconnect
- Charge Controller (Regulator)
- Battery

Components (II)

- System Meter
- Main DC Disconnect
- Inverter
- AC Breaker Panel (AC Disconnect)
- Kwh meter (Utility Meter)

PV Panel

- Isc
- Voc
- Ipmax, Vpmax (Maximum Power)
- Voltage is enforced by the battery
- Form Factor (Pmax/Isc.Vsc) 0.7-0.8

PV Panel

- Performance: Pmax/Psun ~ 10%-13%
- Normalized conditions 1kW/m^2 sea level 25 C
- Wp (Peak Power)

Testing the panels

- Testing the panels (annex)

PV Panel

- Operation:
  - Ipmax, Vmax
  - Efficency Lost: Pmax – 5%
- Array
  - Same panels
  - Serial = We add V
  - Parallel = We get more I

Battery

- Serial elements: 2 V
- Models: 12 V, 24 V and 48 V
- Car batteries vs Deep Cycle Batteries
  - 1.2 to 1.28 (add water)

Deep Cycle Batteries

- Nickel-Cadmium (vs) Lead-Acid
- Maintenance vs Cost

Sun and Battery Cycles

- Daily
- Seasons
- Weather

Battery Status

- Over charged
  - Gas, oxidation of positive eletrod
  - Reduces acid stratification
  - Controlled 2.35 – 2.4 V
  - Role of regulator
- Over discharged
  - Lower limit 1.85
  - Sulfato Plumboso PbSo4 Lead Sulfate

Battery Parameters

- Vn Nominal Voltage
- Cn Nominal Capacity Ah, Wh
- C100
- SOC vs DOD
- DOD 70% and life of the battery
- Cusable = Cn * MDR (maximum discharge rate)

Temp and Batteries

- Capacity 1%/C
- Low temperatures – Battery charge to avoid freeze (reduce the max. discharge rate)

Loads

- Role of low power devices
- Energy Demands
  - Estimation
  - Forecasting
- User Habits

Regulator

- Cuts at 2.45 V (battery state)
- Maximum current (at least 20% more than the PV)
- Operating tension

Regulator

- Serial (can disconnect) vs Shunt (NO!)
- Charge Controller
  - Senses Temp of Batteries Battery Temperature Compensation (BTC)
  - Can lower the V of the panels to increase the I
  - PWM (Pulse Width Modulation)
  - Measures and cuts (LVD) Low voltage disconnect
  - Maximum Power Point Tracking

Inverter

- Converter DC/AC
- DC/DC (pumps, to start them)
- Sin wave vs modified sin wave
- Be Careful not all equipment can handle a modified sin wave inverter!
- Protection (sc)
- Efficiency

Inverter Parameters

- Protection (against sc)
- Efficiency > 70%

Calculation

- Method: Worse month
- Reliable: how many days without sun?
  - Autonomy days (N)
  - Nominal Voltage?
    - More than 3 KW = 48 V

Worse Month

- What is the worse month?
- We need to know the energy demands (DC + AC) and the energy available
- What PV array angle is optimal?

Orientation

- Towards the equator
- Tolerance of 20 degrees (alpha)
- Angle (ß):
  - $|L| + 10$ = winter
  - $|L| = 0$
  - $|L| - 10$ = summer
- Angle > 20 degrees (dust)

G(ß,r,Lat)

- Daily or monthly average energy at angle B
- $G(B) = f(G(0))$
- $f\ (B) = AG(0) + B(G(0))^2$
- A depends on $r=0.2$ and ß
- B depends on Latitude and ß
- We can always use a simulation tool to get the values!

Imax (Loads)

- Et = E(AC) + E (DC) (Ah) (electric charge)
- Ah/day - Ah/period
- G(B) = Kwh/m2 day
- Imax = Et/G**(ß)**
- Example
  - Nigeria = 3.5 – 4 Kwh.m2 day
  - Et = 100 Ah
  - Imax = 25 A/Kw * m2

Number of par. panels?

- Npp = Immax/Ipmax
- Example
  - 25 A/kw.m2 / 5 A/kw.m2 = 5 Units

Capacity of Battery?

- Normally measure in Ah (electric charge)
- Serie vs Parallel
- Example:
  - C100 = 200 Ah
  - Usable = 200 Ah x discharge depth (70%) = 140 Ah
- Dimensioning
  - Capacity = N. Et (Ah) * 1.2

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Regulator and Inverter Power

- Regulator
  - 20% Imax x Npp
- Inverter
  - Performance at 70% of the load

Conclusion

- Multi-variable system
- Simulation: Worst month
- Set pre-conditions first
- Measure your load
  - Are they any possible energy savings?
- Be careful with the units!