Road Map for Local Implementation of REN in Isolated Power Systems

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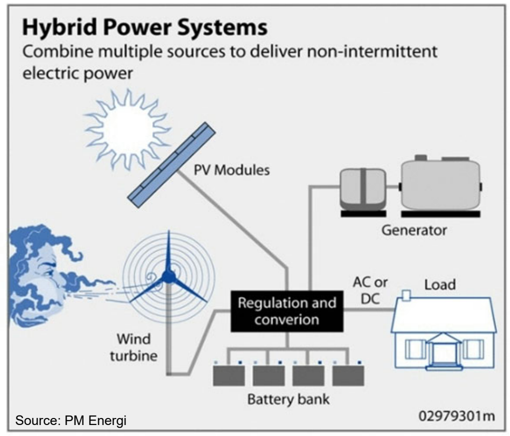

Agenda

Proposal for a roadmap for implementation of REN In smaller isolated power system

Theoretical fundamentals

1. *Energy savings*
2. *Load estimation*
3. *Wind estimation*
4. *PV estimation*
5. *System Design – Simulation*

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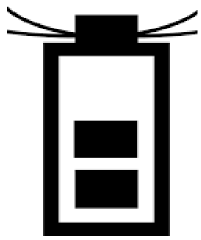
Isolated Power systems

Power production

Power grid

Power consumption



Power storage

Power and Energy Balance

frequency

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Hybrid Systems

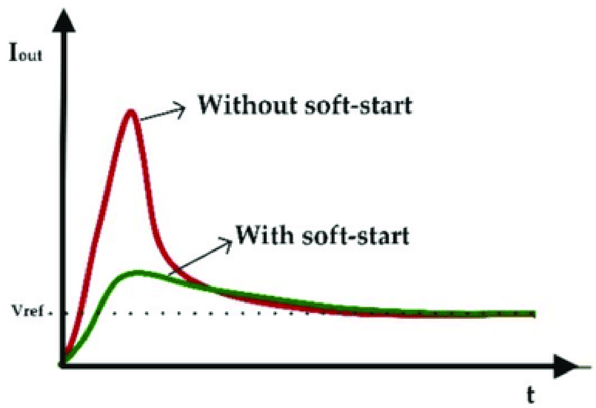
	Diesel	Hybrid	Hybrid	REN
Diesel-gen set	100	75	50	0
REN. WT / PV		25	50	100
Storage Battery			+	+
Risk of excess of energy			+	+
References	**Greenlandic settlements**	**Sarfannguaq Sisimiut**	**Vejrø Igaliku**	**Assaqutaq**

Grid forming Unit
Frequency and voltage
Control

Power balance

Stability

$$P_{prod} = P_{load}$$



Synchronous generator	Inverter
Inertia	max/overcurrent

In-rush current limiter

- NTC
- Softstarter
- Current limiting devices

Short Circuit current

Energy Balance

$$P_{prod} = P_{load}$$

$$P_{prod} + Bat_{discharge} = P_{load} + Bat_{charge}$$

Design of a hybrid system

Hour by hour estimation
Over one year

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1. Energy Savings

The cheapest kWh is the kWh not produced

Control the design of

- Light
  - LED
  - armatures
- Cooking
  - Inductive heating
- Cooling
  - Efficient freezer
  - Efficient refrigerator
- Heat pumps
  - Hot water - heating
- Efficient pumps
- Efficient rotating machines
  - A 75% loaded machine is more efficient than a larger and low loaded machine, even if you feel the smaller machine is warm/hot.

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2. Load estimation

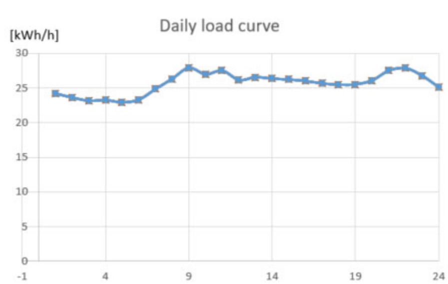
Yearly comsumption

8760 h/year

Daily consumption

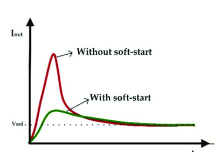
24 h/day

Working days / Week-end days



Source : Vejrø

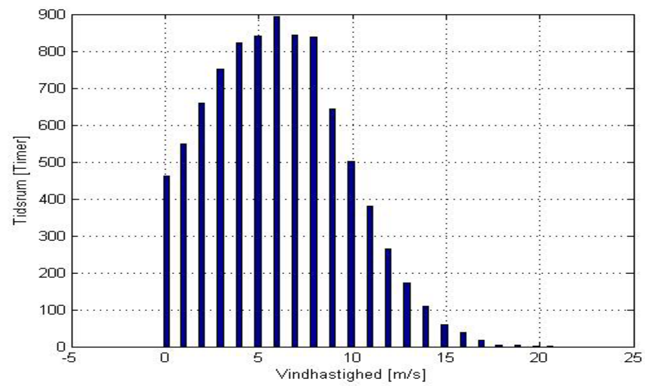
Peak loads / Load steps



3. Wind Estimation

- Wind measurements (over 3 years)
  - Large changes from year to year
- Meteorological service organization
  - Standard wind year
  - NASA surface meteorology and solar energy database
- WASP
  - AEP: Annual Energy Production
  - AEP: Optimal position of turbine
- Installation
  - Transport of turbine
  - Foundation
  - Distance to power system
  - Cable protection

Wind distribution 10 m



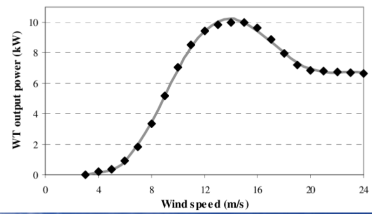
Considerations for selection of wind turbine type

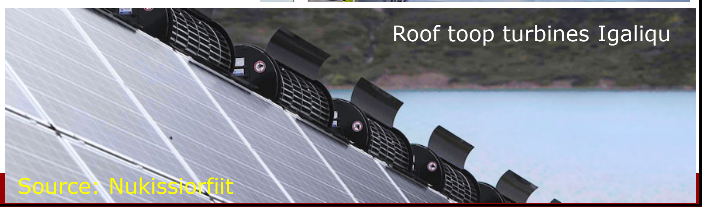
- Production of Wind Power
- Stability – size of WT compared to DG
- Extreme winds – Mechanical / Electrical loads
- Stall /pitch regulation – power curve
- Generator type - converter
- Arctic temperatures – location of electronics – icing – colour of blades
- Installation – foundation – distance to power system – Cable protection
- Maintenance – expertise available

The decision of type is yours

– keep it simple

Small stall regulated wind turbine – power curve





Experience from Sarfannguaq Wind Turbine

- Small 6 kW WT compared to the smallest DG 135 kVA
- Supporting wires to stabilize the tower
- No electronics in wind turbine
- Cables in halves tubes placed above the rocks
- ½ km to power station with control and inverter electronics
- Transport of wind turbine by boat and helicopter- two hoist tower and nacelle, total 1000 kg

- No changed in security of supply – stable isolated power system
- Large temperature changes and specially low temperatures – no problem are seen
- No icing seen
- Some noise but far from habitation
- Production lower than estimated – some stability problems in the inverter system
- Reliable Monitoring and communication system needed
- Installation cost very high


6 kW Proven wind turbine

Proven WT 6000 (Kingspan)

4. PV Estimation

- Solar irradiation measurements

- Meteorological service organization
  – Standard solar irradiation year
  – NASA surface meteorology and solar energy database

- Simulation programs
  – PV-sol, Valentin Software
  – Limited positive experience

PV*SOL premium

- Installation
  – Roof / racks on ground
  – Distance to Inverter
  – Cable protection
  – Direction east / south / west or combinations
  – Tilt angel

Considerations for selection of PV system

- Type of PV Cells
- Negative temperature coefficient 0.4%/ºC
- Production dependent of direction of irradiation
  - Angle
  - Albedo effect - reflections from surroundings
- Fragile to mechanical forces
  - Wind
  - Snow shedding / Ice
  - Vandalism
- Installation - mounting system
- Expected long lifetime
  - No mechanical parts
- Simple integration in a power system by use of inverter technology
- Combined with storage technology (Batteries)
  - Grid forming capabilities available

PV Cell Types

Monocrystalline	Polycrystalline	Thin Film
Thin slices of single crystal	Multicrystalline material	extra thin layer of semiconducting material
most expensive	less expensive	lot less expensive than silicon based cells
Efficiency 15- 22%	Efficiency 13 - 16 %	Efficiency 4-9 %
~ 200 W/m^2	~ 150 W/m^2	~ 75 W/m^2

Experience from PV systems , Sisimiut

- Simple roof mounting
  - Chimney effect: 5 – 10 cm between roof and panels
- Tilt 45 º, south, Albedo effect from sea bay
- Rack mounting
  - Elevate the panels > 20 cm above ground/roof
- Climate condition
  - Temperature
  - Snow and ice
    - tilt angle > 45°
- Easy integration in power system utilizing electric power technology, Indoor inverter
- Expected long life time
- Approximately similar or higher production pr m^2 in Sisimiut compared to DTU
- No maintenance – (cleaning of the surfaces)

Monthly PV production

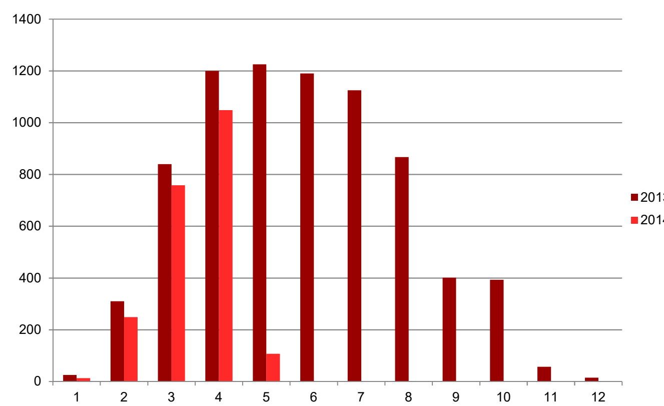
Approximately similar or higher production pr m^2 in Sisimiut compared to DTU

Installed PV: 7,04 kWp

2013: 7648 kWh
2014: 2114 kWh (until 2'nd of May)

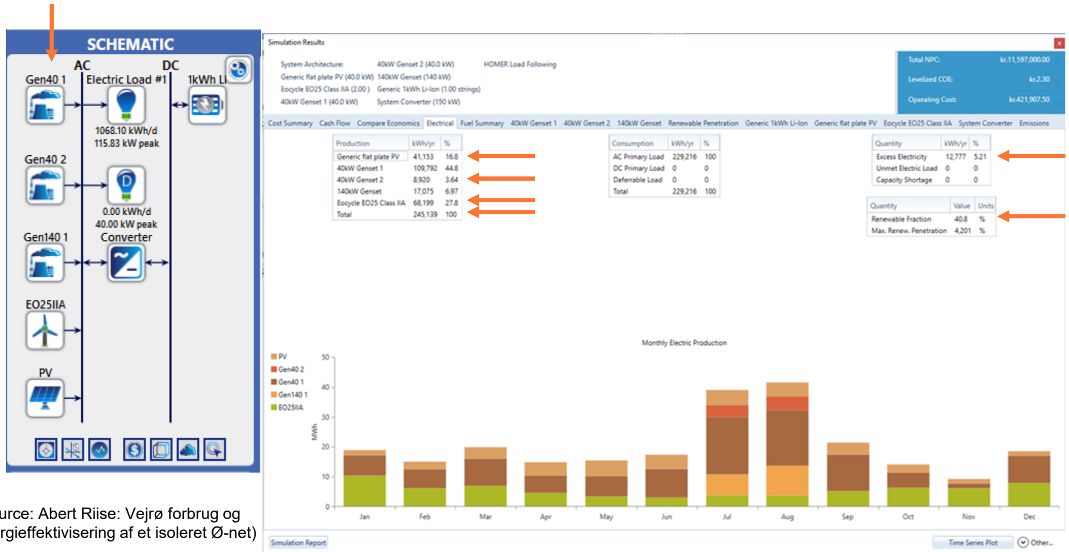
GL: 1,08 KWh/Wp
DK : 0,85-1,0 kWh/Wp

– keep it simple



5. System Design – Simulation

HOMER



(Source: Abert Riise: Vejrø forbrug og energieffektivisering af et isoleret Ø-net)

System Design - Simulation

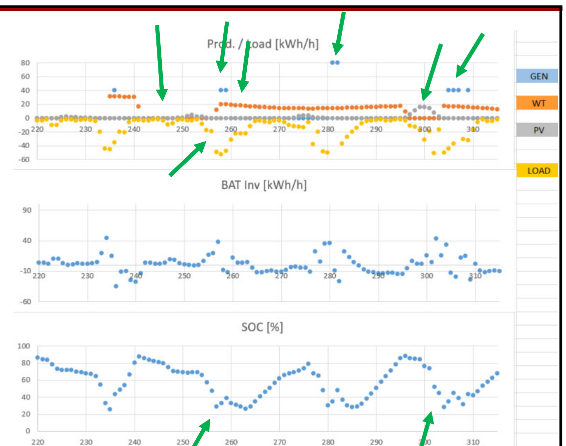
Time series calculations

- Load series
- Irradiation – PV production series
- Wind forecast

Control strategy

- Grid Forming Unit: DG or Battery/Inverter
- Curtailment – disconnect DG's, WT, PV (excess of energy)
- Battery storage

VejrØ Island
4 days of simulation
Bat / Inv Grid forming
DG slave
Prioritized sources



	Power [kW]	Available enable 1	Priority	Storage [kWh]
Battery storage				200
Batteri Inv	180	1	1	
Diesel Generator 1	40	1	6	
Diesel Generator 2	40	1	7	
Diesel Generator 3	140	1	8	
WT 1	25	1	4	
WT 2	25	1	5	
PV 1	20	1	2	
PV 2	20	1	3	

	Operation time	Energy produced		
	[h]	[kWh/year]	[%]	[%]
Batteri Inv	8760	132	0,1	
Diesel Generator 1	534	21360	20,7	22,0
Diesel Generator 2	33	1320	1,3	
Diesel Generator 3	1	40	0,0	
WT 1	5055	37955	36,8	59,1
WT 2	4205	22994	22,3	
PV 1	7125	12286	11,9	18,9
PV 2	6607	7193	7,0	
Load		103179	100,0	

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Conclusion
Hybrid Systems

	Diesel	Hybrid	Hybrid	REN
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Grid forming Unit
Frequency and voltage Control

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