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Configuration of a Renewable Micro Power System for a Remote Village in Mongolia

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KOREATECH

Electric Energy Lab

Contents

1. Problem Statement

❖ **Rapidly growing energy demand**

- Energy demand in 2050 is expected to be doubled

❖ **Safety concerns on nuclear energy**

- Such as Fukushima nuclear plant crisis

❖ **Global warming and depletion of fossil fuels**

⇩

❖ **Renewable Energy Sources are Widely and speedily accepted under the wing of Smart Grid**

2. Research Background

Problem Statement

Research background
- Smart-grid
- Micro-grid

Motivation of Study
- Pilot Project

System design and Simulation
- Approach
- Concept
- Weather Data
- Theoretical Load Demands
- Components
- Optimal System
- Analysis
- Sensitivity Analysis

Conclusion

❖ Renewable Energy Sources

- Energy that comes from resources which are continually replenished such as sunlight, wind, rain, tides, waves and geothermal heat.
- Advantage
  - Can reduce carbon emission
- Weakness
  - Energy output vary under different weather and geographical conditions
  - Grid connection concerns
- Problems observed in Modeling and Configurations
  - Do not consider weather conditions
  - Do not consider load capacity
  - Output change depending on the weather condition – problem of reliability

2. Research Background

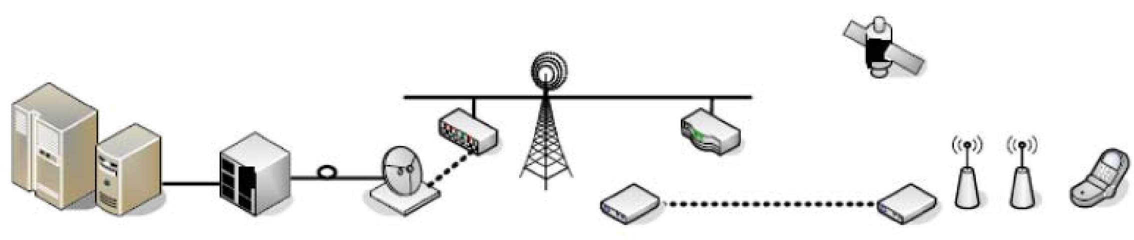
❖ Micro-grid

- A part of Smart grid
- The power supply system localized around distributed generators which becomes independent
- In school, industry complex, military, etc..
- The focus is moved to the Micro-grid from the smart grid
- Developed or ongoing or progressive schedule projects are 405
- Quarter of 2012 : 3[GW] → 2020 : 9[GW]

2. Research Background

❖ Various Definitions of Distributed Generator

- DG a generating plant serving a customer on-site, or providing support to a distribution grid, at lower level voltages – ***IEA***
- DG shall mean generation plants connects to the low voltage distribution system – ***EU directive***
- DG integrated or stand alone use of small, modular electricity generation sited close to the customer load – ***US DoE***



3. Motivation of Study

❖ Pilot Project(2010)

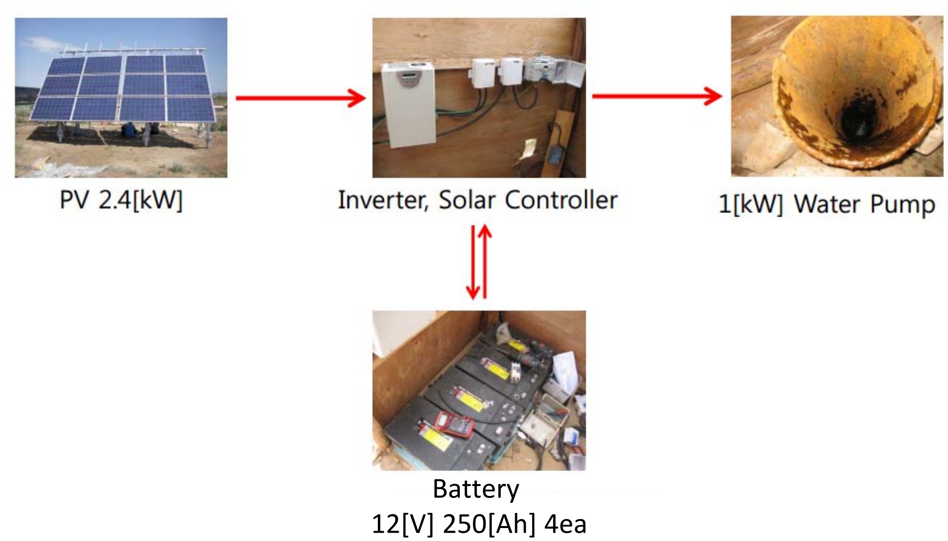
- Bayangnuur in Mongolia lacks water resources and has suffered from rapid desertification
- To prevent desertification an NGO of Korea is planting trees
- Previous work: Supplying power to a submerged pump from solar energy to provide water to the farm

3. Motivation of Study

❖ Post-Project Analysis

- Lack of detailed studies on generation capacity and capability under different weather condition

- Complement of the pilot project through post-analysis
- Bringing up improvement and simulation of the new design



4. System Design and Simulation Result

❖ Approach

- Supplying power to village from Solar and Wind energy sources
- Simulation by HOMER

➢ HOMER?

- Micro-grid design software
- Calculation of various resources for economics of the optimal combination
- The number of case of hundreds or thousands of combinations to find the optimal combination

4. System Design and Simulation Result

❖ Concept

- Considering weather condition and load demand

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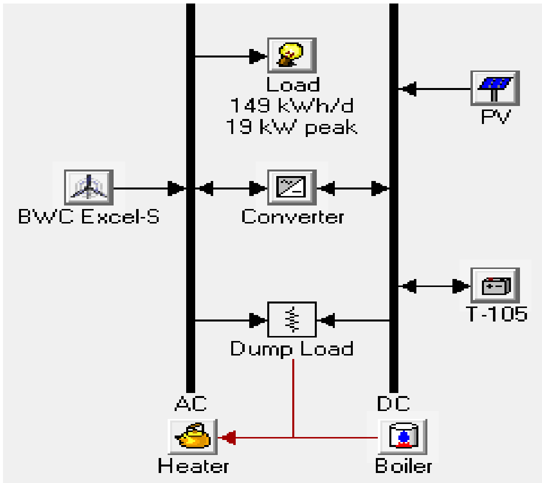
- Off-grid system – because of poor grid condition
- Dump load to supply heat to the heater in winter season

  – protection of battery system



System diagram to be simulated

4. System Design and Simulation Result

❖ Weather Data

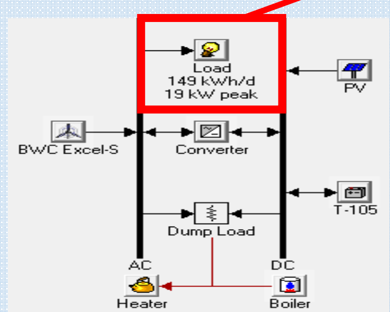
- Yearly temperatures range up to 70[°C]
- Maximum : over 40[°C], Minimum : under -30[°C]
- Available from OPENEI(by the region's latitude and longitude)

➢ Solar insolation and Wind speed for Bayangnuur

Month	Solar radiation	Wind speed	Month	Solar radiation	Wind Speed
Jan	1.77	6.55	Jul	5.91	4.99
Feb	2.84	6.00	Aug	5.26	5.13
Mar	4.25	5.71	Sep	4.40	5.42
Apr	5.53	6.34	Oct	3.07	5.78
May	6.32	5.86	Nov	1.92	6.42
Jun	6.40	5.49	Dec	1.44	6.61

*Radiation : [kWh/m^2/d], Wind Speed : [$^m/_s$]

4. System Design and Simulation Result



❖ Theoretical Demands Load

- 46 persons from 21 households
- 4 water wells each having a 2.2[kW] submersible water pump
- The daily load demand is 141.92 [kWh/day]

➢ Details of Load

Theoretical Demand Load(day)

	Unit power rating [kW]	Usage time [h]	Total consumption [kWh]
TV(22)	0.16	7	14.08
Fridge(22)	0.06	24	19.8
Lamps(66)	0.06	18	17.82
Pumps(4)	2.2	7	52.8
Others(46)	0.01	13	1.84
Total	2.49		141.92

4. System Design and Simulation Result

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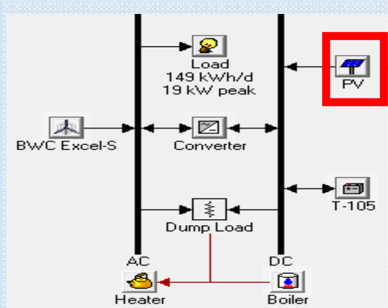
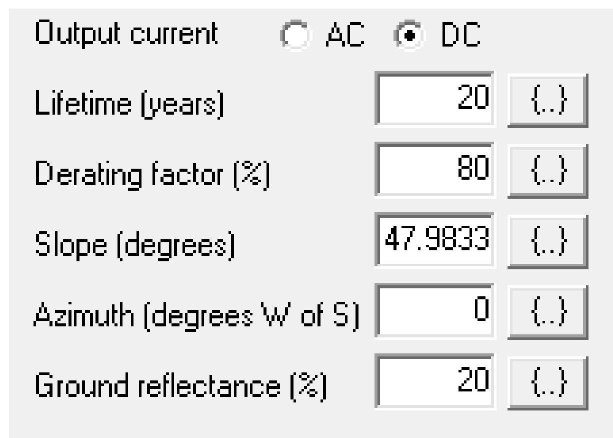


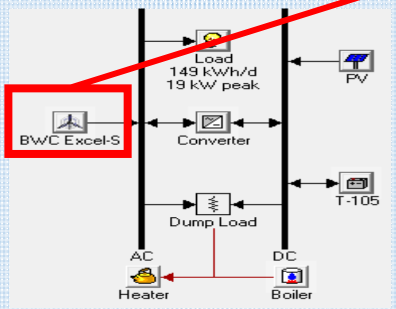
❖ Components

- Photovoltaic Panel(PV)
  - The fixed angle (at 47.98˚) – Region's latitude
  - Without tracker
  - Output variation is considered as -0.5[%] per degree [°C] increase



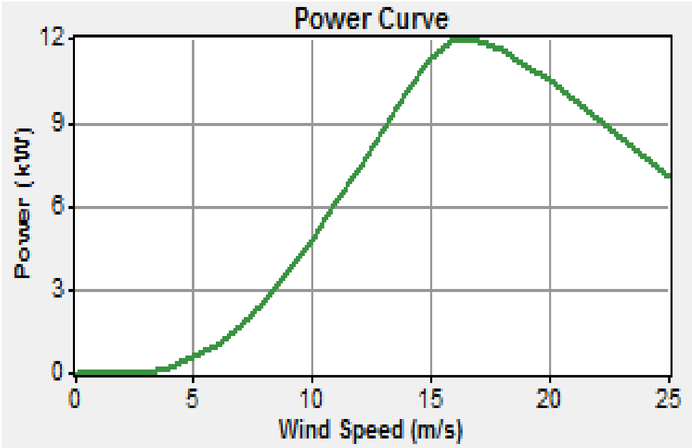
Properties of PV panel

4. System Design and Simulation Result



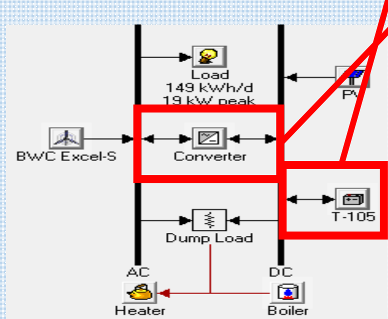
❖ Components

- Wind Turbine(WT)
  - Bergey "Excel-S", capacity is 10[kW]
  - Start-up wind speed 4[m/s], the rated wind speed 12[m/s]
  - Region's wind speed every month up to W.T start-up speed



Power curve of Wind Turbine (EXCEL-S)

4. System Design and Simulation Result



❖ Components

- Battery Bank
  - To stabilize converter output and to prevent abnormal condition
  - Trojan "T-105", 6[V]-225[Ah]
  - DC voltage bus selected 48[V]

- Converter
  - Inversion : converter DC stored in battery bank
  - Rectification : converter AC power generated from a source to DC power
  - Efficiencies : inversion – 90[%], rectification – 85[%]

4. System Design and Simulation Result

❖ Optimal System

- The calculation of HOMER produces the best combination

	PV (kW)	XLS	T-105	Conv. (kW)	Disp. Strgy	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)
	45	1	344	18	CC	$ 276,520	9,865	$ 402,627	0.569	0.85	1,769
	60		424	21	CC	$ 294,320	8,591	$ 404,148	0.572	0.87	1,780

- PV : 45[kW], WT : 10[kW], Battery : 344, Converter : 18[kW]
  - Initial Capital Cost(ICC) is $276,520
  - Operating Cost is $9,865
  - Cost of Energy(COE) is $ 0.569/kWh

- PV : 60[kW], Battery : 424, Converter : 18[kW]
  - Initial Capital Cost(ICC) is $294,320
  - Operating Cost is $8,591
  - Cost of Energy(COE) is $0.572/kWh
  - At night time, PV is not working. So battery capacity should increase
  - Concern of reliability

4. System Design and Simulation Result

❖ Economic Analysis

- Cost of Energy is $0.569/kWh
- About 10 times more expensive than grid price of $0.05/kWh
- Initial capital cost of entire components of configuration is about 69[%] of total cost
- Fuel is diesel, only use the boiler

Net present costs of the system

Component	ICC[$]	Replacement[$]	O&M[$]	Fuel[$]	Salvage[$]
PV	135,000	4,209	0	0	-2,359
WT	48,000	2,003	30,680	0	-373
Battery	79,120	6,885	52,770	0	-922
Converter	14,400	601	9,204	0	-112
Biler	-	-	-	23,520	0
Total	276,520	13,698	92,654	23,520	-3,765

4. System Design and Simulation Result

❖ Emission Analysis

- Include a diesel-fueled boiler system to protect the battery under harsh winter condition
- To minimize the use of diesel fuel, the configuration tries to supply the heater with surplus energy

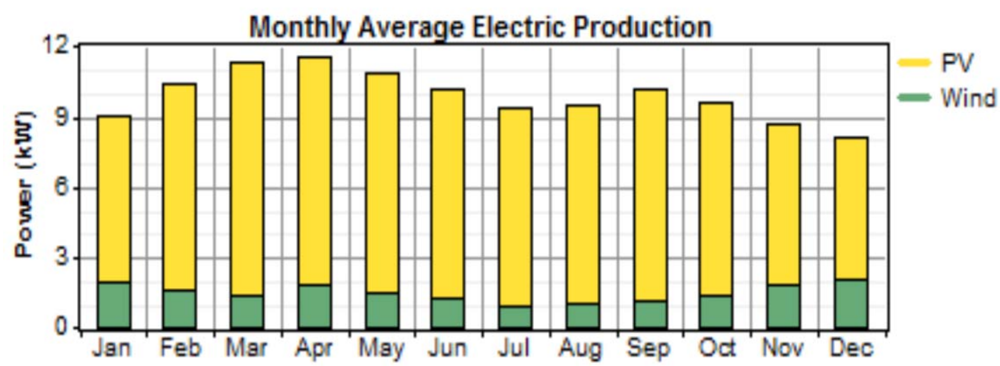
Comparing the emissions of diesel generator and the configuration system

Pollutant [kg/yr]	Emission of the System	Emission from a diesel generator
CO_2	4,681	77,176
CO	0	190
C_5H_{12}	0	21.1
SO_2	9.57	155
NO_2	0	1,700

4. System Design and Simulation Result

❖ Electricity Production from the Renewables

- Yearly electric energy production is expected to be 86,605 [kWh]
- PV : 85[%] - 73,673 [kWh] , WT : 15[%] - 12,932 [kWh]



Monthly Average Electric Production

4. System Design and Simulation Result

❖ Sensitivity Analysis

- Normalized price of 1.0, 0.75 lower by 25[%] of the original price.
- The lowest energy cost is obtained from case6 and case 8 – highest generation capacity
- Case2 and case4 – W.T is determine ICC and COE
- W.T is major variable in the economic analysis of overall system

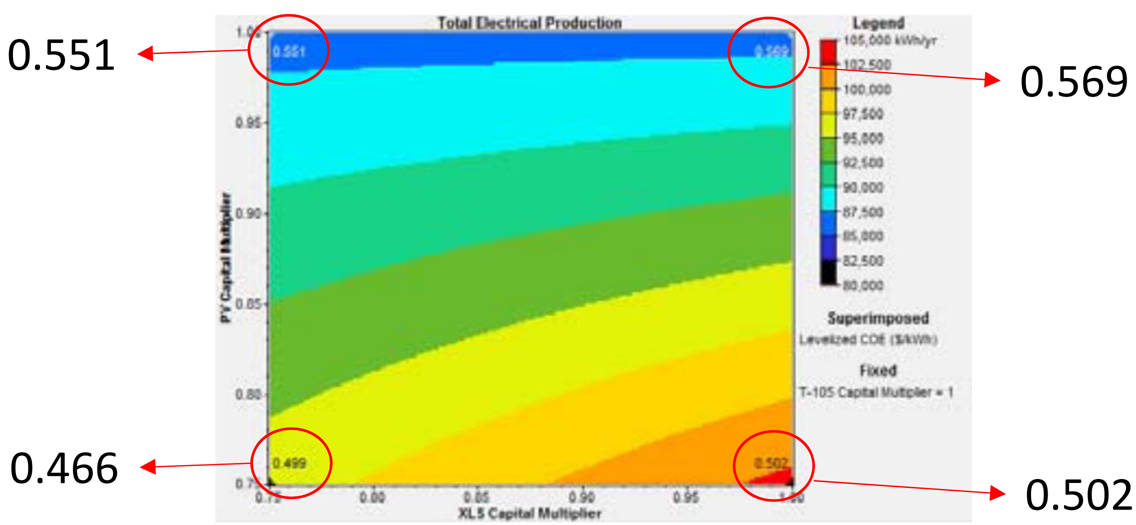
Effect of component costs the system economics

CASE	PV	WT	Battery	PV [kW]	WT [kW]	Battery [EA]	Converter [kW]	ICC [$]	COE [$/kWh]
1	1.00	1.00	1.00	45	10	344	18	276,520	0.569
2	1.00	1.00	0.75	57	0	456	18	264,060	0.532
3	1.00	0.75	1.00	42	10	344	18	264,520	0.551
4	1.00	0.75	0.75	63	10	368	18	239,880	0.521
5	0.75	1.00	1.00	63	0	416	18	251,830	0.502
6	0.75	1.00	0.75	63	0	416	18	227,910	0.466
7	0.75	0.75	1.00	51	10	312	18	236,910	0.499
8	0.75	0.75	0.75	63	0	416	18	227,910	0.466

4. System Design and Simulation Result

❖ Sensitivity Analysis – Electric Energy Production

- The energy cost under the total electric energy production
- Energy cost is lowered as the electric generation increases.
- Main characteristics of renewable energy
  - Do not need fuel for energy production
  - Higher initial capital cost, increased generation capacity, lower energy cost



Cost of energy by total electrical production

4. System Design and Simulation Result

❖ Sensitivity Analysis – Emission CO2

- Focuses on the CO2 emission under different total operating costs
- Not enough surplus energy, the diesel boiler would run more and thus more emission of CO2
- Increase in ICC would increase energy production
- Which turn would lower cooperating and energy cost

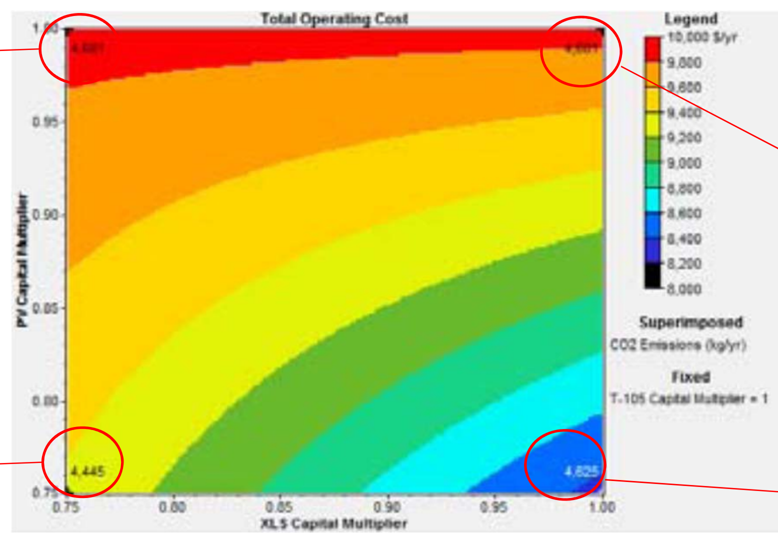
→ reduced CO2

4,836

4,901

4,445

4,625



CO2by Total Operating Cost

4. System Design and Simulation Result

❖ Sensitivity Analysis – Emission CO2

- New suggestion for optimal configuration
- PV - 63[kW], WT – 10[kW]
- Slightly over design configuration has to invest $35,000 more for the initial capital cost
- But, $1,149 reduction in operating cost
- Yearly reduction of the emission in the amount 510[kg]

5. Conclusions

- The configured system was simulated using HOMER and sensitivity analyses were performed
- The optimal configuration acquired was comprised of a 63[kW] PV system, a 10[kW] wind turbine, a bank of 264 batteries, and a converter of 18 kW
- Through sensitivity analysis, characteristics of renewable energy was confirmed
- The operating cost of the configuration was 10 times higher than grid power cost of fossil fuel
- The CO_2 emission amount from the configuration was 16 times lower than that of an equivalent diesel generator system
- More study on Carbon zero system is needed

Thank You

Configuration of a Renewable Micro Power System

For a Remote Village in Mongolia