C6 - Active Distribution Systems and Distributed Energy Resources

PS 3 - Aggregated DER for Enhancing Resilience, Reliability and Energy Security of Distribution Systems

Paper ID_10859

ECONOMIC ANALYSIS OF STAND-ALONE AND GRID-CONNECTED MICROGRID BY USING HOMER

Mikail PURLU, Sezen BEYARSLAN, Belgin Emre TURKAY

ISTANBUL TECHNICAL UNIVERSITY

Motivation

- Meet the increasing energy demand feasibly
- Reduce the electricity cost
- Reduce carbon emissions
- İncrease the reliability of the power system
- Provide on-grid and off-grid solutions for rural areas
- Examine the contribution of energy storage systems
- Sensitivity analyzes

HOMER

- Hybrid Optimization Models for Energy Resources
- A microgrid optimization tool
- Developed by National Renewable Energy Laboratory (NREL)
- Basic functions in HOMER: Imitation, optimization and sensitivity analyzes
- Power balance, load profile, location-spesific tools and system components are all considered

Performance Indicators

- $CoE\ (\$/kWh) = \frac{TAC\ (\$/yr)}{TAEC\ (kWh/yr)}$
- $NPC\ (\$/yr) = \frac{TAC\ (\$/yr)}{CRF}$
- $CRF(i,n) = \frac{i(1+i)^n}{(1+i)^n - 1}$
- $OC\ (\$/yr) = TAC\ (\$/yr) - ACC\ (\$/yr)$

Renewable Energy Generation

- $P_{hyd}(t) = \frac{\eta_{hyd} \cdot h_{net} \cdot \rho_{water} \cdot Q_T(t) \cdot g}{1000\ (W/kW)}$
- $P_{pv}(t) = N_{pv} \cdot P_{pv_r} \cdot f_{pv} \cdot \frac{G(t)}{G_n}\left[1 + \alpha_p\left(T_C(t) - T_{C_n}\right)\right]$
- $P_{e,wt}(t) = \eta_{wt} \cdot A_{wt} \cdot P_{wt}(t)$
- $P_{wt}(t) = N_{wt} \times \begin{cases} 0, & v(t) \le v_{ci}\ or\ v > v_{co} \\ P_r\left(\frac{(v(t))^3 - v_{ci}^3}{v_r^3 - v_{ci}^3}\right), & v_{ci} < v(t) \le v_r \\ P_r, & v_r < v(t) \le v_{co} \end{cases}$

Data Collection

- A grid-connected village in Bursa, Turkey
- Located at 40° 08’ 55.27” North latitude 29° 16’ 06.73”’ East longitude
- The population of this village, located near the Delicay river, is 390 in 2021

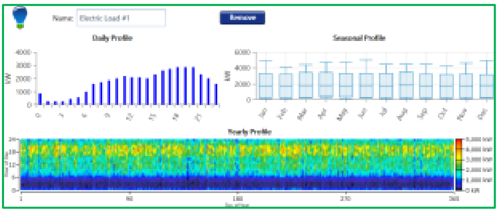

Fig. 1: Load profile

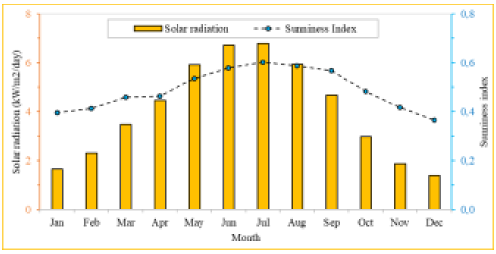

Fig. 2: Irradiance data

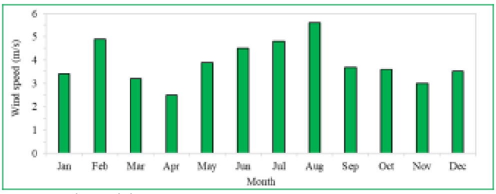

Fig. 3: Wind speed data

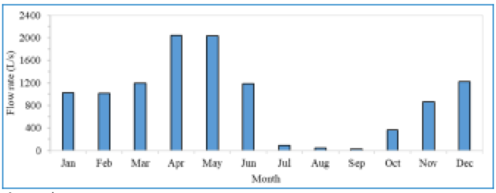

Fig. 4: Flow rate

C6 - Active Distribution Systems and Distributed Energy Resources

PS 3 - Aggregated DER for Enhancing Resilience, Reliability and Energy Security of Distribution Systems

Paper ID_10859

ECONOMIC ANALYSIS OF STAND-ALONE AND GRID-CONNECTED MICROGRID BY USING HOMER

Mikail PURLU, Sezen BEYARSLAN, Belgin Emre TURKAY

ISTANBUL TECHNICAL UNIVERSITY

Results of the stand-alone (off-grid) and grid-connected (on-grid) analyses

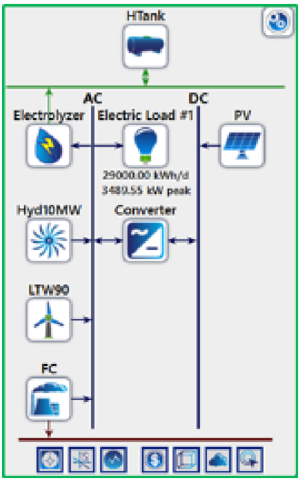

Fig. 5: Off-grid design

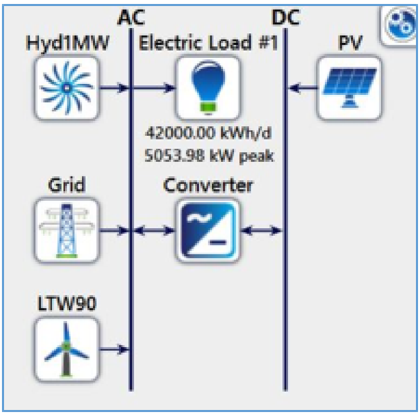

Fig. 6: On-grid design

Table I: Cost of stand-alone systems

Shortage capacities (%)	Type of WTs	NPC (M$)		CoE ($)		OC (M$/year)		IC (M$)	
		HSS	BESS	HSS	BESS	HSS	BESS	HSS	BESS
1	E33	126	73.0	0.638	0.371	2.84	1.87	88.9	48.8
	LT90	97.6	62.3	0.496	0.317	2.27	1.65	68.3	41.0
	E82	126	73.6	0.638	0.374	2.79	1.82	89.6	50.1
5	E33	108	57.6	0.560	0.300	2.51	1.50	75.2	38.2
	LT90	82.1	47.9	0.427	0.249	1.98	1.30	56.6	31.1
	E82	112.6	58.8	0.578	0.306	2.49	1.49	79.7	39.6
10	E33	95.3	49.9	0.507	0.267	2.22	1.32	66.6	32.8
	LT90	73.4	41.7	0.393	0.224	1.81	1.13	50	27.0
	E82	100	50.4	0.528	0.270	2.21	1.32	71.7	33.3

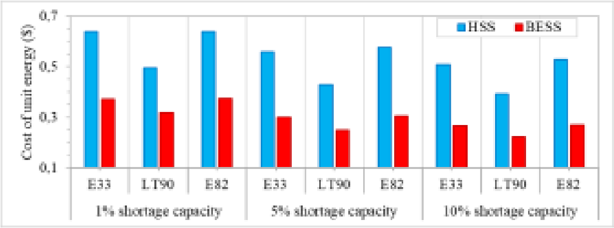

Fig. 7: Comparison of HSS and BESS for stand-alone systems

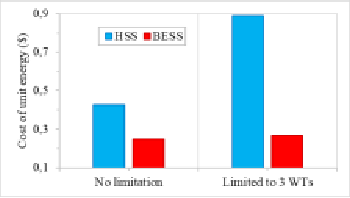

Fig. 8: Comparison of the 3 WTs limited systems with HSS and BESS

ECONOMIC ANALYSIS OF STAND-ALONE AND GRID-CONNECTED MICROGRID BY USING HOMER

Mikail PURLU, Sezen BEYARSLAN, Belgin Emre TURKAY

ISTANBUL TECHNICAL UNIVERSITY

Table II: Cost of grid usage limited systems with different sell-back capacities in on-grid systems

Grid limitation (kW)	Sell-back capacity (kW)	NPC (M$)	CoE ($)	OC (M$/year)	IC (M$)	Renewable energy usage rate (%)
4000	500	43.2	0.195	1.29	26.5	74.7
	750	42.7	0.184	1.25	26.5	75.7
	1000	41.4	0.167	1.12	26.9	80.9
5000	500	22.2	0.106	1.29	5.60	50.3
	750	22.0	0.103	1.27	5.60	51.2
	1000	21.9	0.095	1.12	7.40	61.9

Sensitivty Analyses

- Sensitivity analyses were made for off-grid system by increasing renewable energy sources potential such as wind speed, solar radiation rate and stream flow speed. Renewable energy potential was increased by 25%.

Table III: Cost of sensitivity analyses

Cases	NPC (M$)	CoE ($)	OC (M$/year)	IC (M$)
Initial case (100%)	51.7	0.269	1.40	33.6
125% wind speed rate	42.3	0.220	1.18	27.0
125% solar radiation rate	45.2	0.235	1.27	28.8
125% stream flow rate	50.5	0.263	1.38	32.7

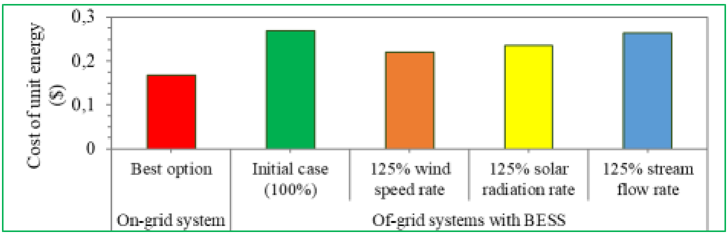

Fig. 9: Cost of unit energy comparison of sensitivity analyses

Discussion

Table IV: Comparison of the best results

HES	NPC (M$)	CoE ($)	OC (M$/year)	IC (M$)
Grid-connected	41.4	0.167	1.12	26.9
Stand-alone with BESS	51.7	0.269	1.40	33.6
Stand-alone with HSS	173	0.889	4.00	121

Conclusion

- Wind turbines have the highest renewable potential
- On-grid systems are more economical than off-grid systems
- Off-grid systems are more environmentally friendly than on-grid systems
- Off-grid systems with BESS are more economical than with HSS