Technical Feasibility and Optimization of Utility-Scale Hybrid Solar-Wind Energy Systems on Texas Farms & Ranches

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Introduction

***Hybrid solar-wind renewable energy systems** may improve grid stability due to complementary daily and annual time profiles of wind speed and solar radiation [1]

*Integrating utility-scale hybrid facilities into **farms and ranches in South Texas** leverages the region's abundant agricultural land and natural resource availability while offering farmers a source of supplemental income

*This study conducts a technical analysis of **five solar-wind hybrid ratios** for a **100 MW hybrid facility**, using four selected farms and ranches in the "South" ERCOT (Electric Reliability Council of Texas) load zone as case studies to assess and optimize energy production, variability, and reliability

Materials and Methods

SOLAR POWER OUTPUT

1. Used National Renewable Energy Laboratory (NREL)'s Solar PVWatts Calculator to determine DC array output (W) based on National Solar Radiation Database (NSRDB) Global Horizontal Irradiance (GHI) data

WIND POWER OUTPUT

1. Obtained wind speed (m/s) data from NREL's National Solar Radiation Database (2018-2020) at farm coordinates

2. Converted wind speed at anemometer height to wind speed at turbine height using the following equation (2):

$$U(z)/U(z_r) = \ln\left(\frac{z}{z_0}\right) / \ln\left(\frac{z_r}{z_0}\right)$$

$U(z)$ = wind speed at wind turbine height
$U(z_r)$ = wind speed at anemometer height
z = wind turbine height
z_0 = surface roughness length (see table)

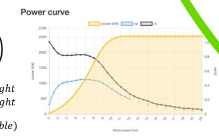


Figure 3. GE 2.5 MW Turbine Power Curve [3]

3. Converted wind speed at wind turbine height using wind turbine power curve (supplied by manufacturer)

Energy Production Metrics

***Capacity Factor** – ratio of energy output to facility nameplate capacity (100 MW)

***Coefficient of Variation** – ratio of standard deviation to mean of energy output

08/12/2019 17:00	08/26/2019 18:00
08/12/2019 18:00	07/13/2020 16:00
08/26/2019 17:00	08/13/2020 16:00
08/12/2019 16:00	08/28/2020 17:00
08/13/2020 17:00	08/14/2020 18:00
08/28/2020 16:00	08/12/2020 17:00
07/13/2020 17:00	08/13/2019 18:00
08/13/2019 16:00	08/13/2020 18:00
08/14/2020 17:00	08/12/2020 16:00
08/13/2019 17:00	08/14/2020 16:00

Figure 1. ERCOT Peak Demand Hours (2018-2020)

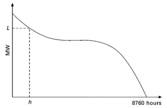


Figure 2. Sample Power Output Duration Curve [2]

***Firm Capacity** – energy output available 25%/50%/75%/87.5%* of the time (*based on conventional coal-fired power plant)

***Peak Average Capacity Percentage (PACP)** - average capacity factor for 20 peak ERCOT load demand hours from 2018-2020

Research Highlights

***Five 100 MW scenarios were analyzed, reflecting different solar panel-wind turbine permutations**

Table 1. 100 MW Facility Scenarios*
**1st quartile of operational utility-scale renewable facilities in Texas*

	# Solar Panels (395 W)	# Wind Turbines (2.5 MW)
Scenario 1 *100% Wind*	0	40
Scenario 2 *75% Wind/25% Solar*	63,300	30
Scenario 3 *50% Wind/50% Solar*	127,000	20
Scenario 1 *25% Wind/75% Solar*	190,000	11
Scenario 5 *100% Solar*	253,000	0

***Daily and annual fluctuation in MW energy output (measured by capacity factor) was analyzed for each scenario**

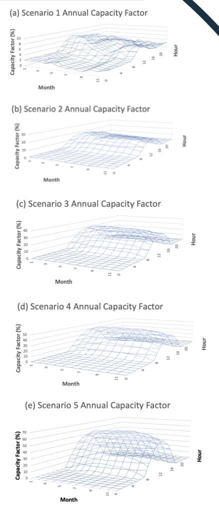


Figure 4. Annual and Daily Capacity Factor Comparison: (a) Scenario 1, (b) Scenario 2, (c) Scenario 3, (d) Scenario 4, (e) Scenario 5

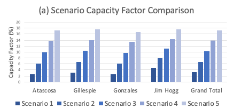
***Solar-wind hybrid ratios were optimized based on increased energy generation, decreased energy variability, and increased energy reliability**

Table 2. Results Summary

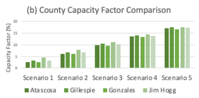
	GENERATION	*VARIABILITY*					*RELIABILITY*
	Capacity Factor	**Coefficient of Variation**	**Firm Capacity (25%)**	**Firm Capacity (50%)**	**Firm Capacity (75%)**	**Firm Capacity (87.5%)**	**Peak Average Capacity Percentage (PACP)**
Atascosa	Scenario 5	Scenario 2	Scenario 5	Scenario 3	-	-	Scenario 5
Gillespie	Scenario 5	Scenario 1	Scenario 5	Scenario 3	Scenario 1	-	Scenario 5
Gonzales	Scenario 5	Scenario 3	Scenario 5	Scenario 3	Scenario 1	-	Scenario 5
Jim Hogg	Scenario 5	Scenario 2	Scenario 5	Scenario 3	Scenario 1	-	Scenario 5

Data Analysis

Capacity Factor



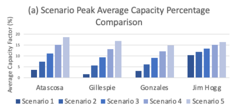
***Solar-favoring scenarios exhibit greater capacity factor compared to wind-favoring scenarios in all counties**



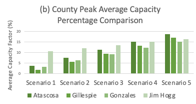
***Scenario capacity factor trends are similar across four counties (with exception of slightly elevated wind-favoring scenario capacity factor in Jim Hogg county)**

Figure 5. Capacity Factor Comparison: (a) Scenario and (b) County

Peak Average Capacity Percentage (PACP)



***Solar-favoring scenarios exhibit greater PACP compared to wind-favoring scenarios in all counties**



***Wind-favoring scenarios demonstrate greater PACP difference between counties**

Figure 6. Peak Average Capacity Percentage (PACP) Comparison: (a) Scenario and (b) County

Coefficient of Variation

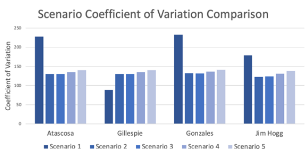


Figure 7. Scenario Coefficient of Variation Comparison

***Elevated Scenario 1 coefficient of variation; similar coefficient of variation between Scenarios 2-5**

Firm Capacity

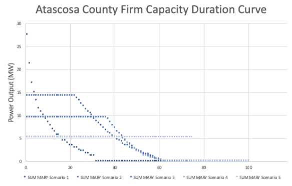


Figure 8. Atascosa County Firm Capacity Duration Curve

Table 3. Atascosa County Firm Capacity Duration Data (MW)

	25%	**50%**	**75%**	**87.5%**
Scenario 1	2.19	0	-	-
Scenario 2	12.66	2.33	0	-
Scenario 3	20.66	2.62	0	-
Scenario 4	28.74	2.32	0	-
Scenario 5	36.66	0.59	0	-

***Solar-favoring scenarios reliably produce more energy 25% of the time, while hybrid (50% wind/50% solar) scenarios produce more energy 50% of the time**

Discussion & Conclusion

*In selected counties, **solar-favoring scenarios** result **in greater total energy generation (capacity factor)** and **energy reliability (PACP)**; **hybrid scenarios** result in a slight decrease in energy variability as measured by the **coefficient of variation** and a discernible decrease in energy variability as measured by **firm capacity (50%)**

*Potential energy variability reductions and energy reliability improvements are highly dependent on relative wind speeds and solar radiation levels → further investigation needed to determine:

(1) if wind turbines properly scaled to regional wind speeds (ex. decreased nameplate capacity) could improve energy generation and reliability outcomes for hybrid renewable facilities

(2) if hybrid scenarios are more favorable in regions with greater average wind speeds (ex. West Texas)

References

1. Cohan et al., "Assessing Solar and Wind Complementarity in Texas".
2. "GE 2.5 - 120". Wind-turbine-models.com.
3. "Load Duration Curve," Renewable Energy System Design, 2014.

Acknowledgements

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