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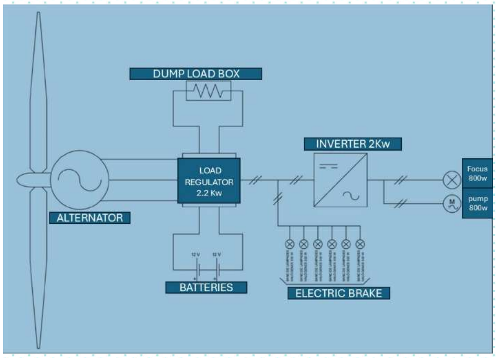
Control Strategy for Isolated Small Wind Generators for Countryside Uses

Ll. Pacheco[1], N. Luo[1], I. Ferrer[1], J. Vilà,[1] J. R. Gonzalez[2]
[1] Department of Electrical Engineering, Electronics and Automation, University of Girona, Campus Montilivi, 17003 Girona (Spain)
[2] Department of Mechanical Engineering and Industrial Construction, University of Girona, Campus Montilivi, 17003 Girona (Spain)
*Corresponding author: +0034 686 750 724, e-mail: lluis.pacheco@udg.edu

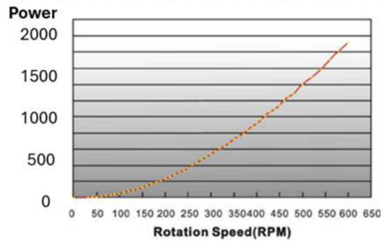
Introduction

Rural areas are considered suitable applications for small, isolated wind generators. In this study, the energy produced is used to fill water storage tanks that can support agricultural and livestock activities. The small horizontal-axis wind turbine has a power rating of approximately 2 kW; the electrical output is primarily used to supply a water pump that fills two water tanks, although the remaining energy can be used to power an electrical system. Wind energy can be regulated through an active pitch control system that is capable of reducing wind-induced forces on the blades. In addition, the control actions aim to match the load to the energy produced. The control strategy consists of a set of states that generate different actions on the electrical system.

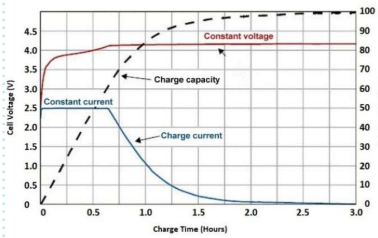


The Small-Wind Generator

Consists of a three-phase synchronous generator of permanent magnets where eight pairs of poles are assumed with 1800W of output power with a nominal output tension of 400V. The output power is a function of the rotation speed, as is given by the manufacturer of wind turbines



Battery units play an important role in stand-alone systems because the power accumulated is related to the time that can provide energy. Key considerations include economic aspects such as cost, as well as technological aspects such as load profile, durability, and the time expended for loading from minimum to maximum. The figure depicts the charging voltage and current for a lithium-ion battery, with an expected life of 7 years. When no production is achieved, the power of the batteries should guarantee the system's operation.



Pitch Control

Can be achieved using a DC linear actuator, which produces a displacement of the pitch angle between different positions that generate different output power levels. The differences can be used as references for different speeds to reach the new position, and they may be commanded using pulse-width modulated, PWM, signals

The Electrical Stall System

The output power is the generated power, and the time instant t_i refers to the current time, while t_{i-1} refers to the previous instant. The demanded power at time t_i includes the electrical braking power at t_{i-1} .If the demanded power exceeds the output power, then the power is reduced. The system loads are driven by an inverter that supplies a pump and an electrical system.

$$PElectricBrake\,(t_i) = PElectricBrake\,(t_{i-1}) + (POutput\,(t_i) - Pdemanded\,(t_i))$$

The Power Control Strategy

Name of Variable	Meaning
P_g	Power generated
P_{gmin}	Minimal Power generated
W_l	Water level of the tanks
V_{bat}	Tension of the battery
V_{batMAX}	Maximum tension of the battery
P_{bat}	Power consumed by the battery
P_{lights}	Power consumed by complementary electrical loads
I_{bat}	Current of the battery
$V_{batlights}$	Voltage battery threshold for connecting the lights
V_{batmin}	Voltage level for battery discharged
$P_{batthres}$	Power generated threshold for connecting the lights
P_{batDel}	Power provided by the battery

Names of variables and meaning

state	Water Pumping	Electricity lights	Pulse width Modulated Electric Stall System	Batteries	Generator
Start	OFF	OFF	OFF	Discharged	OFF
State 1	OFF	OFF	OFF	Discharged	$P_g > P_{gmin}$
State 2	ON	ON	Is possible	Discharged	$P_g > P_{bat} + P_{lights}$
State 3	OFF	ON	ON	Discharged	$P_g > P_{bat} + P_{lights}$
State 4	ON	OFF	Is possible	Discharged	$P_g > P_{bat}$
State 5	OFF	OFF	Is possible	Discharged	$P_g > P_{bat}$
State 6	OFF	ON	Is possible	Discharged $V_{bat} > V_{batlights}$	$P_g > P_{lights}$
State 7	ON	ON	Is possible	Fully charged	$P_g > P_{bat} + P_{lights}$
State 8	ON	OFF	Is possible	Fully charged	$P_g > P_{bat}$
State 9	OFF	ON	ON	Fully charged	$P_g > P_{bat} + P_{lights}$
State 10	OFF	OFF	ON	charged	$P_g > P_{gmin}$
State 11	ON	ON	OFF	Fully charged and deliver energy	$P_g > P_{bat}$
State 12	ON	OFF	OFF	Fully charged and may deliver energy	$P_g + P_{batDel} > P_{bat}$
State 13	OFF	ON	Is possible	Fully charged and may deliver energy	$P_g > P_{gmin}$
State 14	OFF	OFF	OFF	Fully charged	OFF
State 15	ON	OFF	OFF	Fully charged	OFF

States and related actions

Conclusion

The implemented control strategy shows a preference for supplying electricity to the water pump; however, tank levels must be considered. In this work, the stored water is intended for crop irrigation and livestock feeding. Water storage in tanks is considered an efficient form of energy storage; therefore, tank capacity could be increased, and the use of hydraulic turbines and potential energy could be analyzed as a suitable solution in future studies, with the aim of reducing battery size and lowering total cost. Thus, for example, an 18 V, 2 A, 36 W/50 W micro-hydroelectric generator may be a viable option that can reduce battery capacity requirements. It is noted that the proposed batteries have a voltage of 12 V and a capacity of 120 Ah.

References

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