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Wind MPPT with Incremental Duty Cycle for a PMSG SWT in a Grid-Connected DC Microgrid

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INTRODUCTION & AIM

This paper presented a Maximum Power Point Tracking (MPPT) algorithm for a small wind turbine (SWT), based on an incremental duty cycle. The SWT in this paper is connected to a grid-connected DC microgrid. The proposed MPPT algorithm varies the duty cycle of a Boost converter according to the changes in the output power to obtain maximum power output at all wind speeds. The MPPT algorithm was tested by simulations, performed on a system modelled in Matlab/Simulink. The simulation model consists of; a SWT driving a Permanent Magnet Synchronous Generator (PMSG), a rectification stage, and a Boost converter which interfaces with a 400V DC-bus DC microgrid. Simulation results of the presented MPPT algorithm operating with varying wind speed are presented demonstrating its performance.

In countries where high wind speeds are a common occurrence, SWTs in remote areas might be an option worthy for consideration for energy generation. Sites in remote areas are generally made up of a number of buildings and dwellings located relatively close to each other, which makes the application of a microgrid system very attractive for electricity supply. A microgrid is made up of a group of electricity generation sources connected together with electrical loads. Microgrids can operate either connected to the supply grid, or independently from it. The main types of microgrids are AC and DC, or a combination of the two types. When operated in grid-connected mode a microgrid is connected to the grid through a coupling point, and when operated in islanded mode the microgrid will function in an autonomous way disconnected from the grid. The SWT system considered in this paper is connected to a DC microgrid which is grid-connected (Fig. 1). A critical issue in the standard AC grid-connected system is the control of the Boost converter, which regulates the terminal voltage of the PMSG to obtain maximum power transfer.

The proposed incremental MPPT algorithm presented in this paper vary the duty cycle of the Boost converter according to the change in the DC link power. A block diagram of the system is shown in Fig. 2. The advantages of this proposed MPPT algorithm is its simplicity, ease of implementation, and its independence of the wind turbine parameters, which can be widely applied to different types of SWTs.

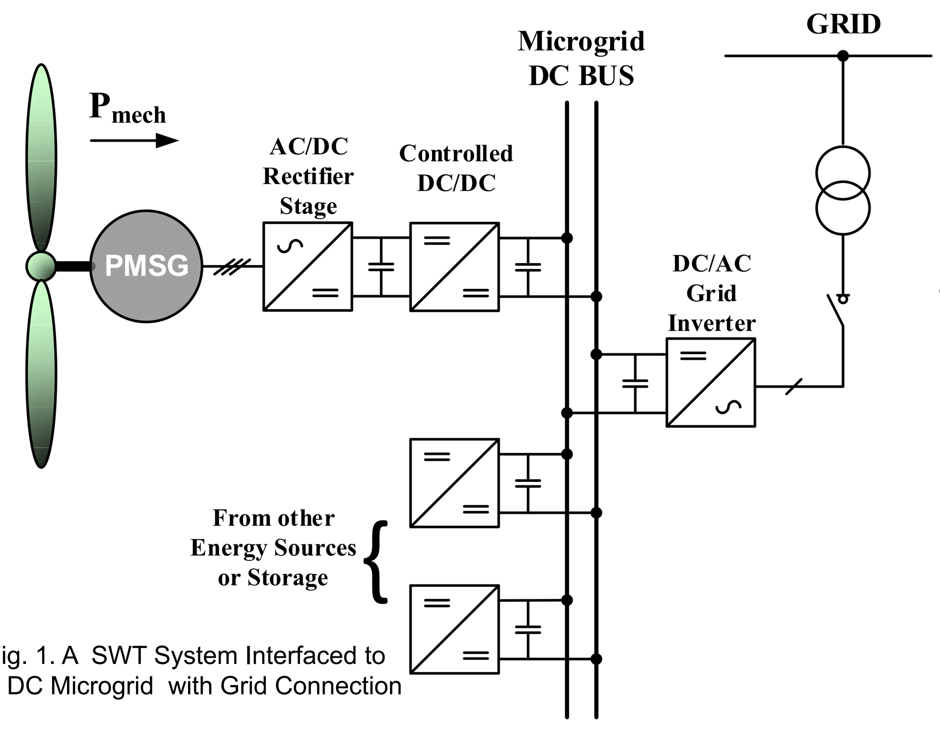


Fig. 1. A SWT System Interfaced to a DC Microgrid with Grid Connection

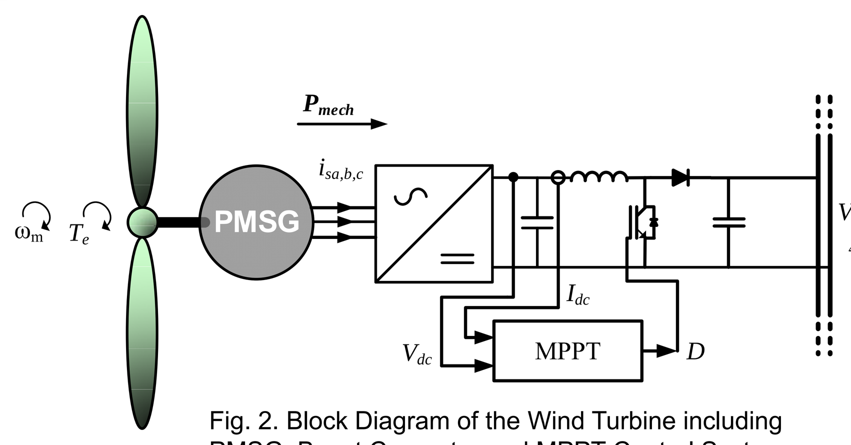
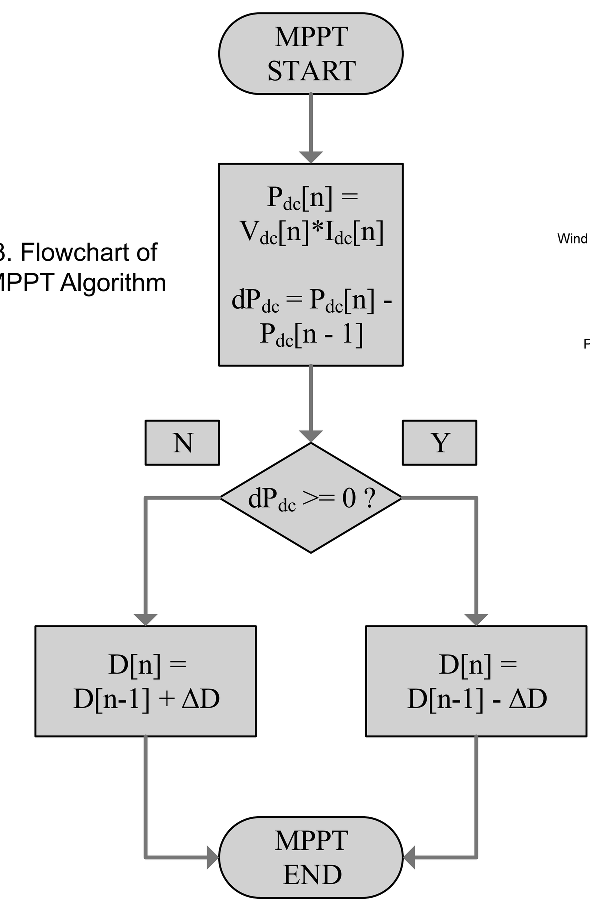


Fig. 2. Block Diagram of the Wind Turbine including PMSG, Boost Converter and MPPT Control System

METHOD

The MPPT algorithm is presented in the form of a flowchart in Fig. 3. This algorithm obtains maximum power by varying the duty cycle D of the Boost converter according to variation in the DC link power P_{dc}. The last DC link power value $P_{dc}[n]$ is obtained from the measured DC link voltage $V_{dc}[n]$ and DC link current $I_{dc}[n]$. The positive or negative variation in P_{dc}, dP_{dc}, is obtained from the difference between the last DC link power value $P_{dc}[n]$ and the previous DC link power value $P_{dc}[n-1]$. If dP_{dc} is positive the previous duty cycle value D[n-1] is decreased by the step size constant ΔD, while if dP_{dc} is negative D[n-1] is increased by ΔD. Where, n is the present sample while n-1 is the previous sample. Thus, the MPPT algorithm would cause the control system to reach a steady state value of maximum power output at any wind speed. The proper selection of the MPPT sampling frequency is very important. High sampling frequencies can cause erroneous power tracking, while a very low sampling frequency will cause the inability to track wind speed changes precisely [1]. Another important selection is the step size constant ΔD. A too small step size causes the MPPT algorithm to take longer to track the maximum power point. On the other hand, a large step size, although it accelerates the tracking, causes larger oscillations around the steady state operating point [1]. Therefore, a compromise for the step size value should be found between fast tracking and minimized oscillations.

Fig. 3. Flowchart of the MPPT Algorithm



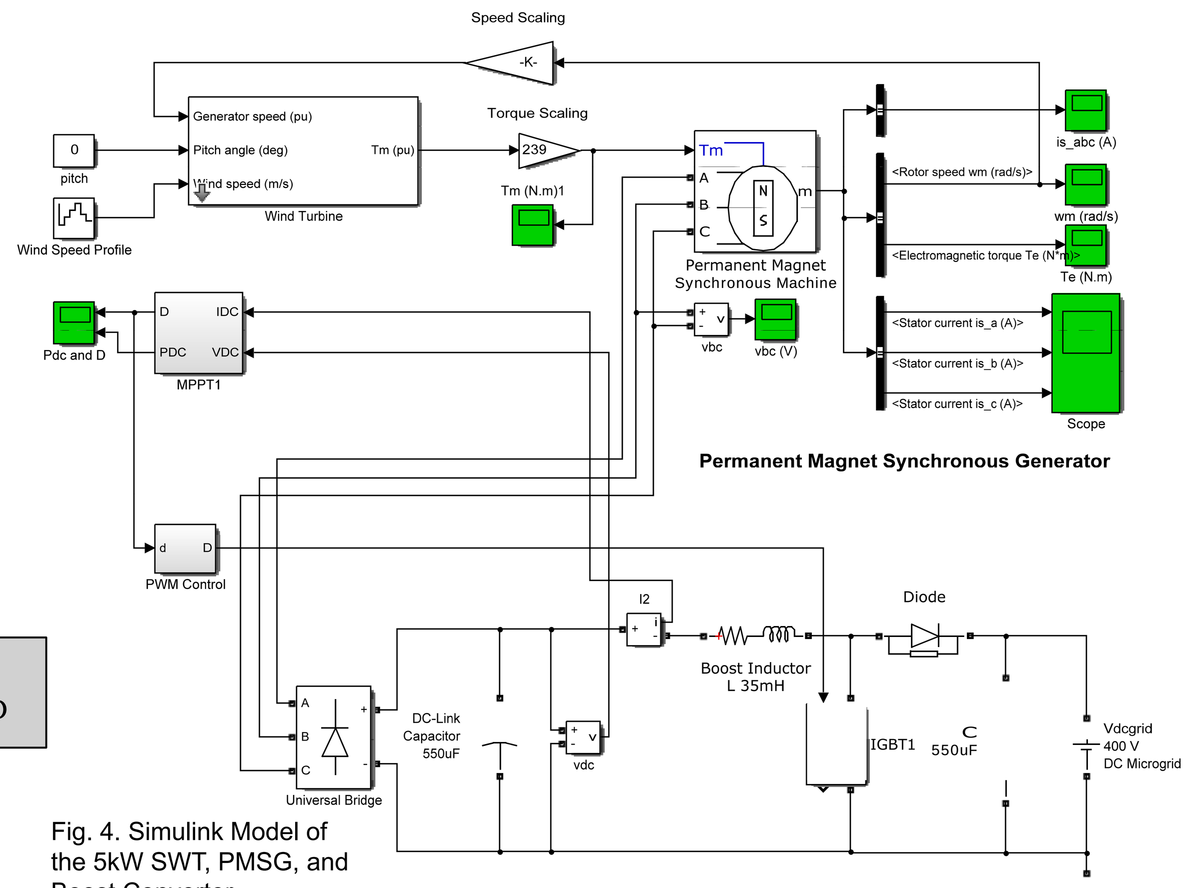


Fig. 4. Simulink Model of the 5kW SWT, PMSG, and Boost Converter

Simulation of the proposed MPPT algorithm was carried out in Matlab / Simulink for a 5kW SWT, with the model shown in Fig. 4. The simulation considered the operation of the SWT with the microgrid operating at a fixed DC voltage V_{dcgrid} of 400V under grid-connected conditions, and with varying wind speed conditions. A wind speed profile was provided to the wind turbine model with varying wind speeds, shown in Fig. 5. Although a step change is not representative of actual wind speed changes, it provides the worst case for the tracking algorithm. The MPPT sampling frequency was set to 100kHz, as the sample frequency of the simulation, while the step size constant ΔD was selected to be 0.05. The PWM frequency for the Boost converter was set to 10kHz.

RESULTS & DISCUSSION

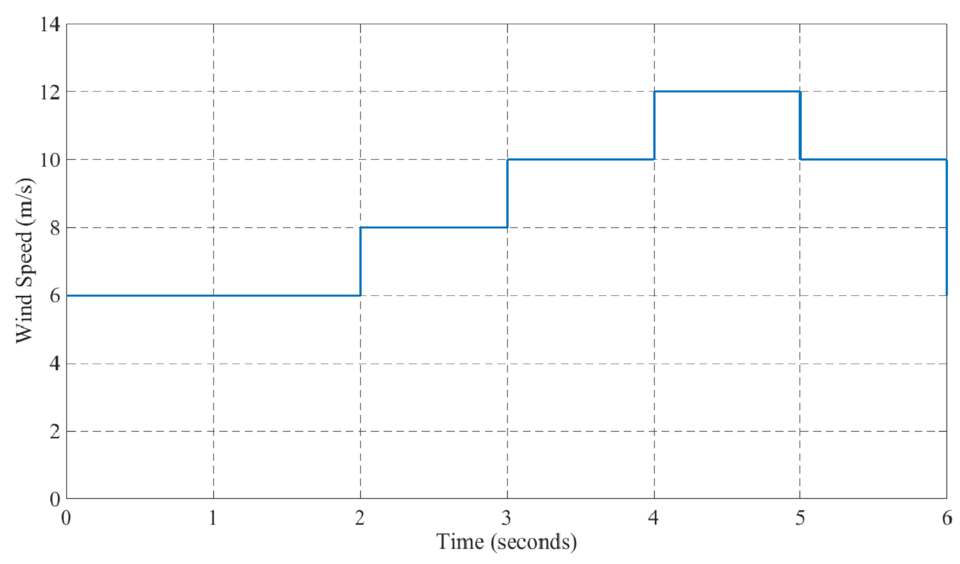


Fig. 5. Wind Speed Profile

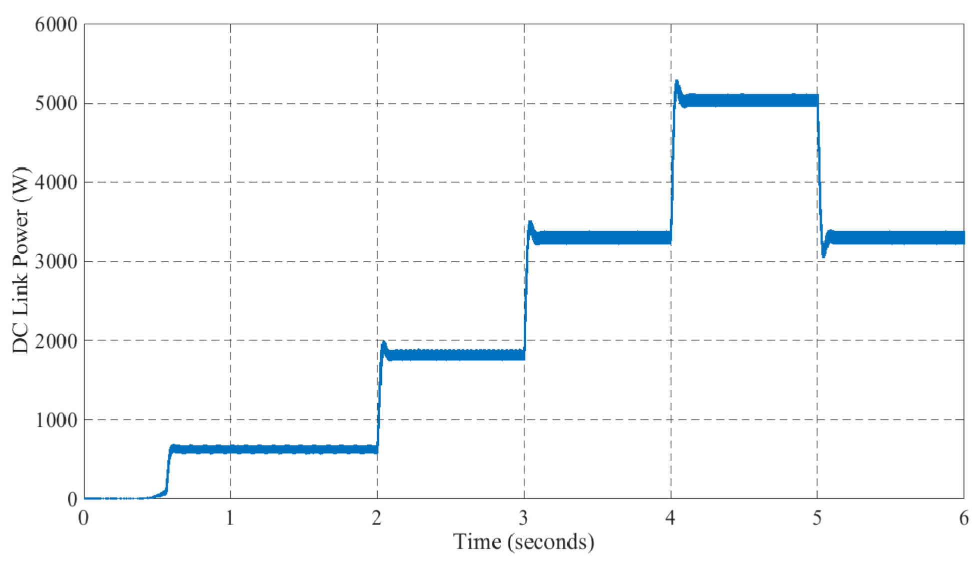


Fig. 6. DC Link Output Power

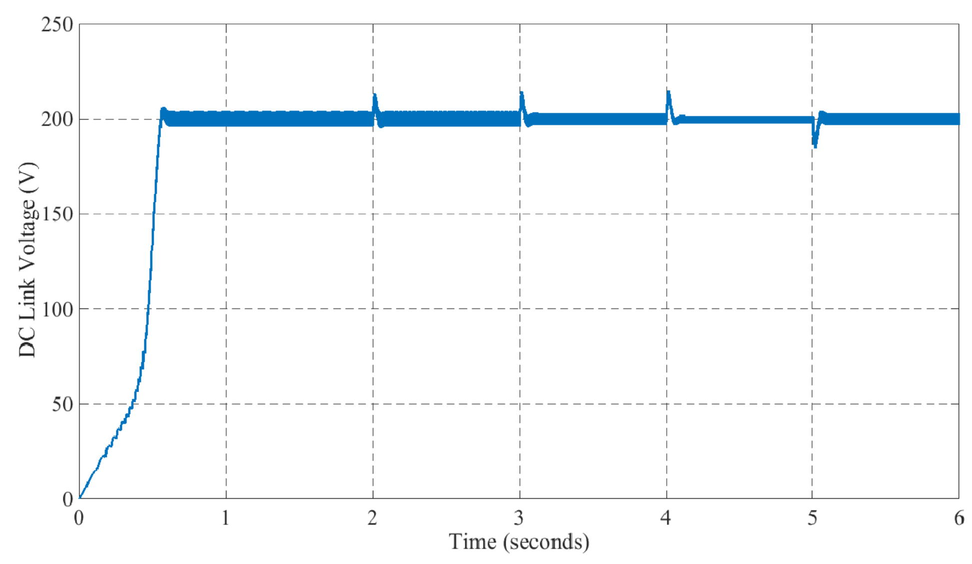


Fig. 7. DC Link Voltage

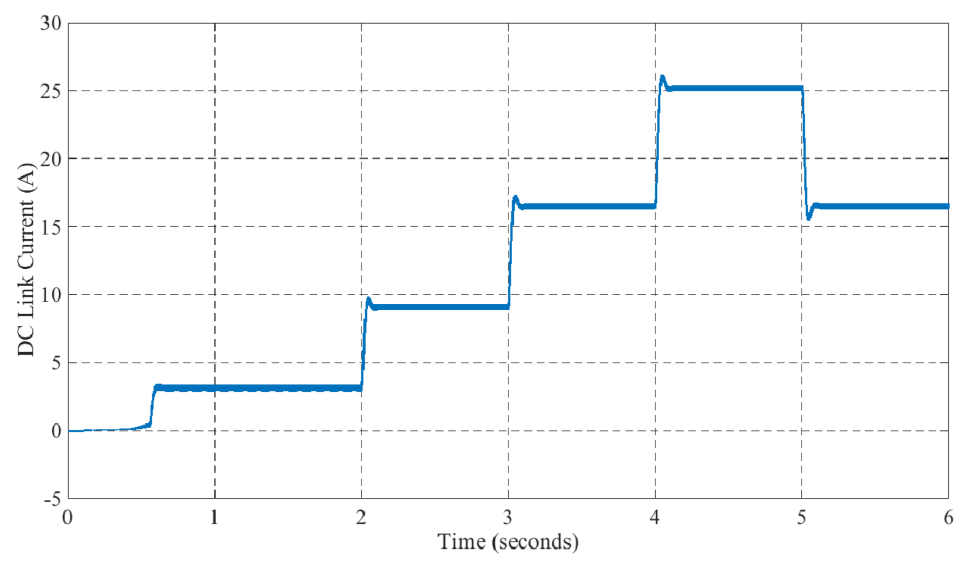


Fig. 8. DC Link Current

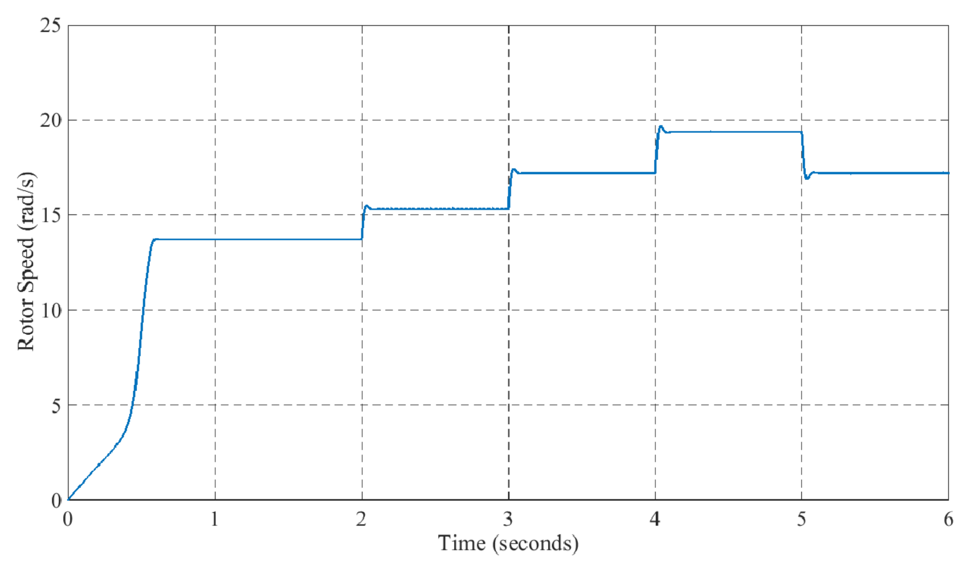


Fig. 9. PMSG Rotor Speed

The simulation results for the DC link output power, the DC link voltage, the DC link current and the PSMG rotor speed are shown in Figs. 6 up to 9. Maximum power transfer was obtained according to the wind speed using the proposed MPPT algorithm. Fig. 6 shows the DC link output power obtained at wind speeds of 6m/s, 8m/s, 10m/s and 12m/s. The output power achieved was about 627W, 1.82kW, 3.3kW and the rated power 5kW, respectively. Figs. 7 and 8 show the changes in the DC link voltage and current, respectively, with changes in the wind speed. Fig. 9 shows the corresponding PMSG rotor speed for the varying wind speeds. In all figures from Fig. 6 to Fig. 9 the start-up of the wind turbine system is also shown, where it reached steady output after about 0.7 seconds.

CONCLUSIONS

In this paper an incremental MPPT algorithm for a small wind turbine was presented. The small wind turbine system was connected to a DC microgrid, which was in turn connected to the grid. The modelled SWT system consisted of a PMSG generator, a 3-phase rectifier, and a Boost converter interfacing the SWT system to the grid-connected DC microgrid. The proposed MPPT algorithm is based on the power-speed characteristic of the WT system and is independent of the system parameters. The MPPT algorithm varies the duty cycle of the Boost converter according to the variations in the output power, to obtain maximum power transfer under different wind speeds. The MPPT algorithm was successfully implemented and tested using a Matlab/Simulink model. A simulation was carried out with varying wind speeds ranging from 6m/s to 12m/s. The simulation results showed that optimal power point operation was achieved for all wind speeds, providing maximum power output into the DC microgrid under all conditions.

REFERENCES

[1] R. Kot, M. Rolak, M. Malinowski, “Comparison of maximum peak power tracking algorithms for a small wind turbine”, Elsevier Journal in Mathematics and Computers in Simulation, Vol. 91 pp. 29–40, 2013.