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Adaptive Maximum Power Point Tracking Control Algorithm for Wind Energy Conversion Systems

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ABSTRACT- For small-scale wind energy conversion systems (WECSs), an adaptive maximum power point tracking (MPPT) algorithm is presented in this paper to increase wind energy harvesting. For its adaptability across a wide range of WECSs and quick tracking of maximum power point, the proposed algorithm combines the computational behavior of hill climb search, tip speed ratio, and power signal feedback control algorithms. Using buck–boost-featured single-ended primary inductor converters, the proposed MPPT algorithm is implemented in this paper to extract maximum power from the entire wind velocity profile. A laboratory-scaled dc motor drive-based WECS emulator is used to test the proposed algorithm. The in-lab experimental setup's control schemes are carried out with the help of a 32-bit floating point digital signal controller called TMS320F28335. The experimental results demonstrate that the proposed algorithm's tracking capability is effective and efficient in both sudden and gradual wind conditions.

I. INTRODUCTION

Wind energy has been bridled by numerous ages for millennia to process grain, siphon water and cruising. The development of a 12 kW windmill generator was not utilized to generate electricity until the latter part of the nineteenth century. However, it wasn't until the 1980s that the technology matured enough to produce electricity reliably and effectively. Numerous wind energy systems have been developed since then, and incredible technological advancements have occurred. Simply in last 10 years, the breeze energy industry has encountered a development of very nearly 30% every year. Over 70 nations have wind turbine installations, and the value of new wind energy plants worldwide reached $24 billion in 2006. According to Figure 1.1, the global total cumulative capacity of wind power increased from 6.8 GW in 1996 to 93.8 GW in 2007.

In particular, the wind industry has had record-breaking years in both 2006 and 2007. Before 2007, the most wind energy systems had ever been installed in a single year, reaching 15 GW in 2006 (see Figure 1.2). The global cumulative capacity of wind power increased by 19.8 GW (or 27 percent) to 93.8 GW in 2007, making 2007 yet another historic year (see Figure 1.2). The top ten nations with the highest percentage of installed wind energy conversion systems (WECS) and the top ten nations with the highest percentage of newly installed WECS in 2006 are depicted in Figures 1.3a and 1.3b, respectively. Not exclusively is wind energy harmless to the ecosystem, its advancement additionally fortifies neighborhood economies and protects the nations from full scale conservative shocks of the worldwide products market (unpredictable gas, oil and coal costs). Wind energy is now one of the most promising and fastest-growing energy resources in the world thanks to public demand for cleaner power sources, ongoing cost reductions in wind turbines, and government programs that encourage wind energy. North America, primarily the United States and Canada, was responsible for approximately 17.6% of all wind power installations worldwide in 2006. 2006 was the most important year for the Canadian wind industry, with 113% more new installations than in 2005. With a total of 1.46 GW of installed wind power and 0.78 GW of new installations in 2006, Canada ranked 12th in the world.

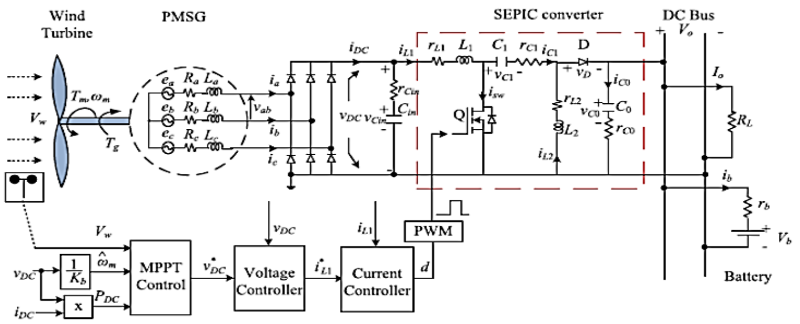

Figure 1: WECS configuration

II. SIMULATION RESULTS

A. Simulation Diagram of Adaptive Maximum Power Point Tracking Control Algorithm for Wind Energy Conversion Systems

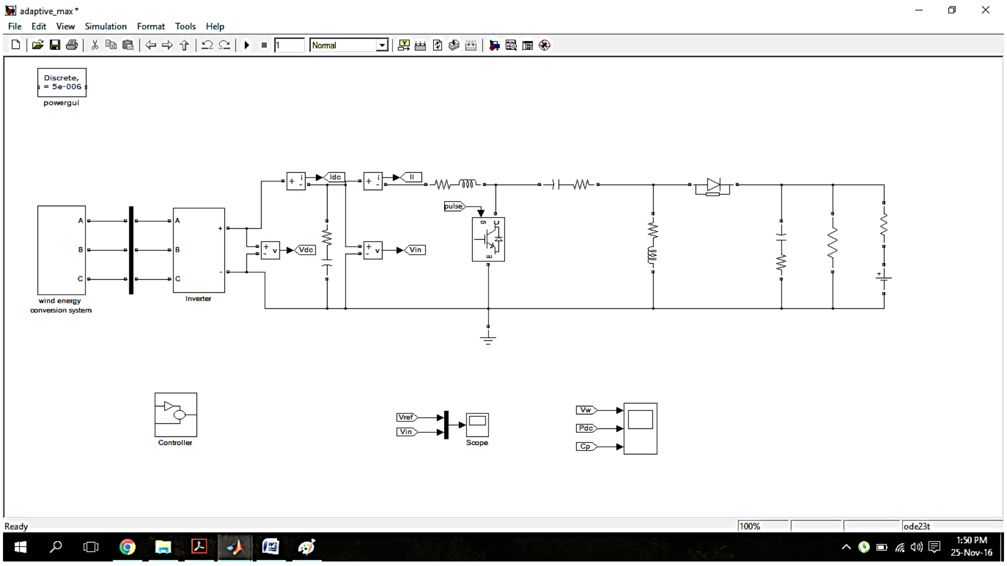

Figure 2: Simulation diagram of adaptive maximum power point tracking control algorithm for wind energy conversion systems

The illustration in Figure is a simulation diagram of the adaptive maximum power point tracking control algorithm for wind energy conversion systems. 4.1 was created to assess how well the proposed MPPT control algorithm extracts maximum power from a given WECS.

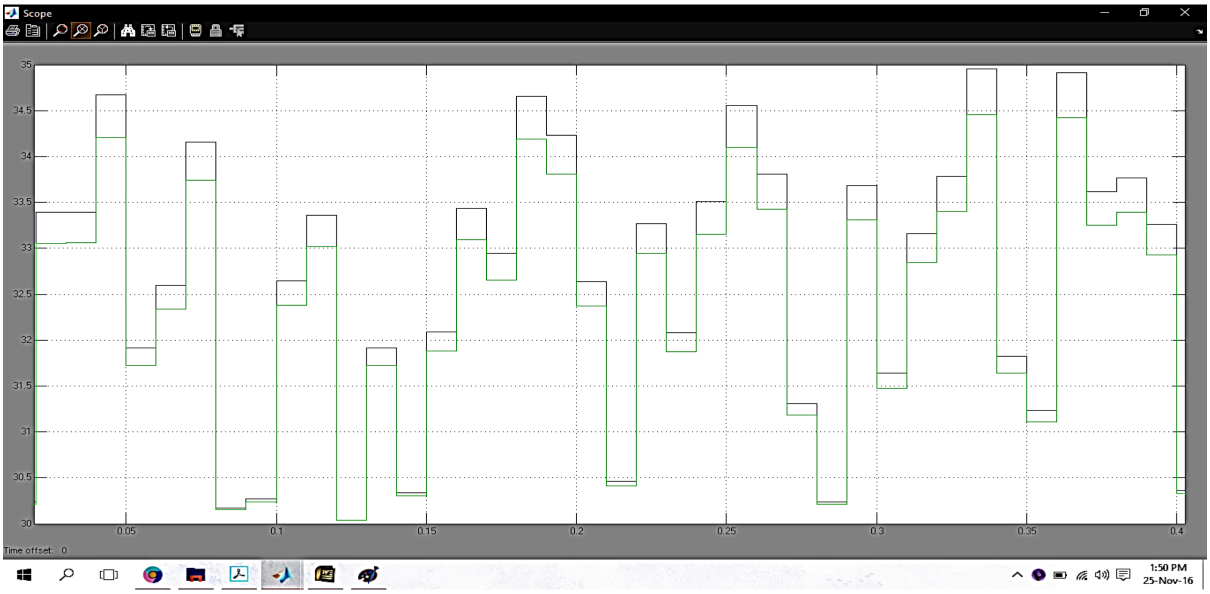

Figure 3: SEPIC's reference signal tracking response

Figure depicts the verified response of the SEPIC dc–dc converter when used in reference signal tracking with a double loop current mode controller. 3. The converter's tracking behavior is guaranteed to be satisfactory regardless of large reference signal variations due to the observed performance.

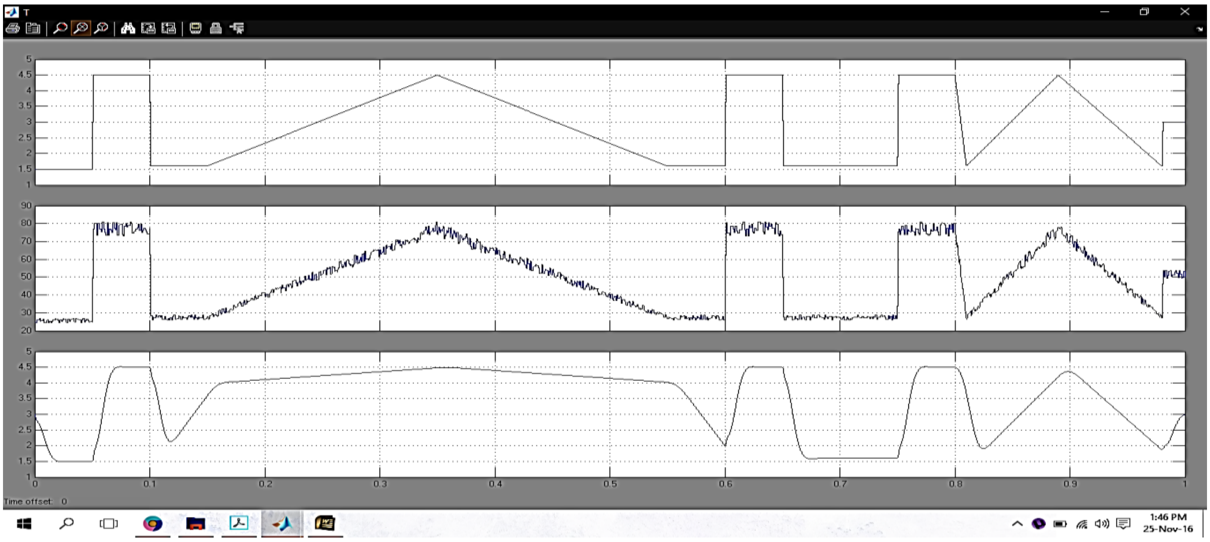

Figure 4: Dynamic response under varying wind conditions

Figure 4 depicts the performance of the proposed MPPT algorithm under both abrupt and gradual wind changes. In Fig. The algorithm searches the lookup table for vDCopt at the index wind velocity of 6.5 m/s and performs turbulent wind condition-related computations at time t1 in section 4.3. This occurs when the system experiences a sudden change in wind speed from 4.5 to 6.5 m/s. The algorithm uses the PSF feature and immediately sends the controller a reference signal without employing a random search procedure because the data at vDCopt is 86.81. The algorithm implements the HCS feature and updates the programmable memory's PDCmax and vDCopt if it notices that (t1 + 25 ms)>PDC(t1). This is due to the fact that the wind velocity remains at 6.5 m/s throughout the subsequent sampling time (t1 + 25 ms). Calculation recovers ideal qualities from the query table and generates reference signal vDCopt as 82.11 V by executing the PSF element of the calculation under fierce breeze condition-related calculations at t2, when wind speed decreases to 5 m/s. When the wind speed gradually shifts from 4.75 to 7 m/s and then from 7.75 to 4.75 m/s, the WECS performs well from t2 to t3. The system's optimal performance is ensured by the nearly 4.7 power coefficient variations between t1 and t3 in turbulent and gradual wind varying conditions.

B. Comparative Study of System Performance with HCS Algorithm:

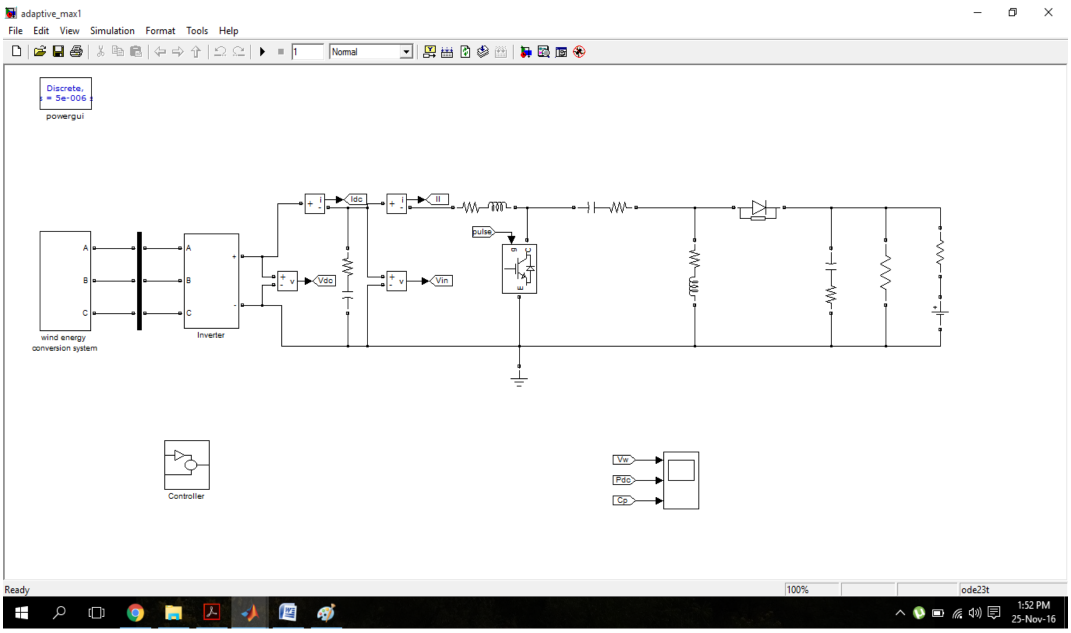

Figure 5: System Performance with HCS Algorithm

This section compares the performance of the system under varying wind conditions using the proposed MPPT algorithm and the HCS algorithm. Framework reaction with HCS calculation is displayed in Fig. 4.4.

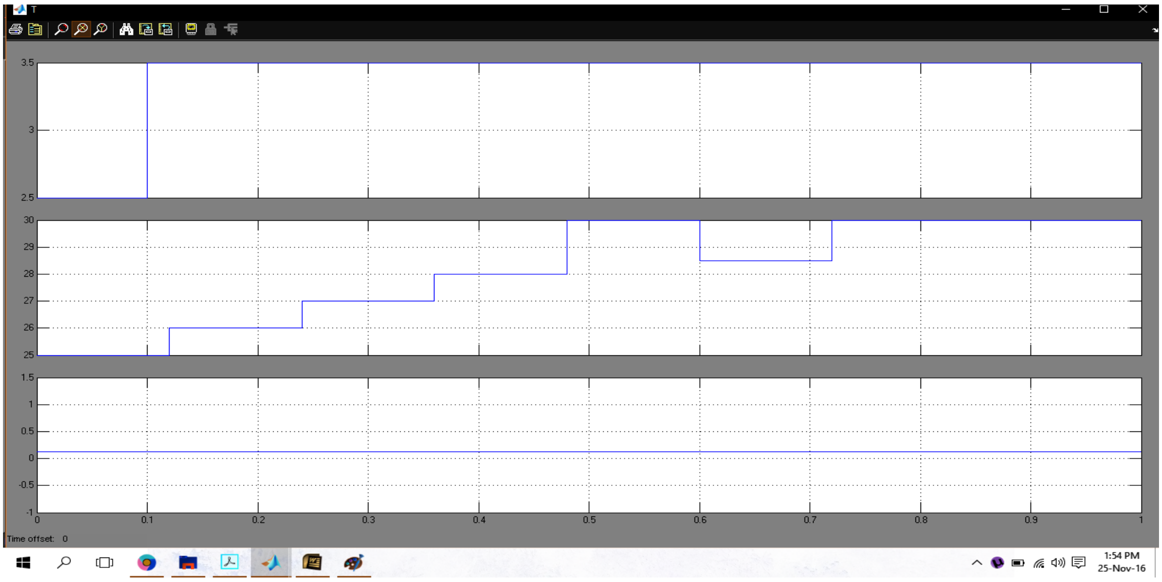

Figure 6: Performance with HCS algorithm

In Fig. 6, when the wind velocity abruptly shifts from 5 to 6.5 m/s at instant t1, the HCS algorithm needs four adjustment cycles to reach the optimal operating point. Time pass among tn and tn+1 is 1.5 s and is given to permit the breeze turbine emulator to answer for the progressions in wind speed and burden. As indicated by proposed calculation extricates 2.0625 Wh, though HCS calculation separates 1.3875 Wh against comparable breeze profile from t1 to t7. System response to gradual changes in wind velocity using the HCS algorithm. The system tries to follow the MPP as wind velocity changes continuously from instant t1. The tracking performance, on the other hand, suffers from inefficiency due to the fact that variations in wind velocity cause the searching process to always begin at an arbitrary point. The deviations in Cp from its optimal point demonstrate this.

C. Comparative Study of System Performance with Proposed MPPT Algorithm

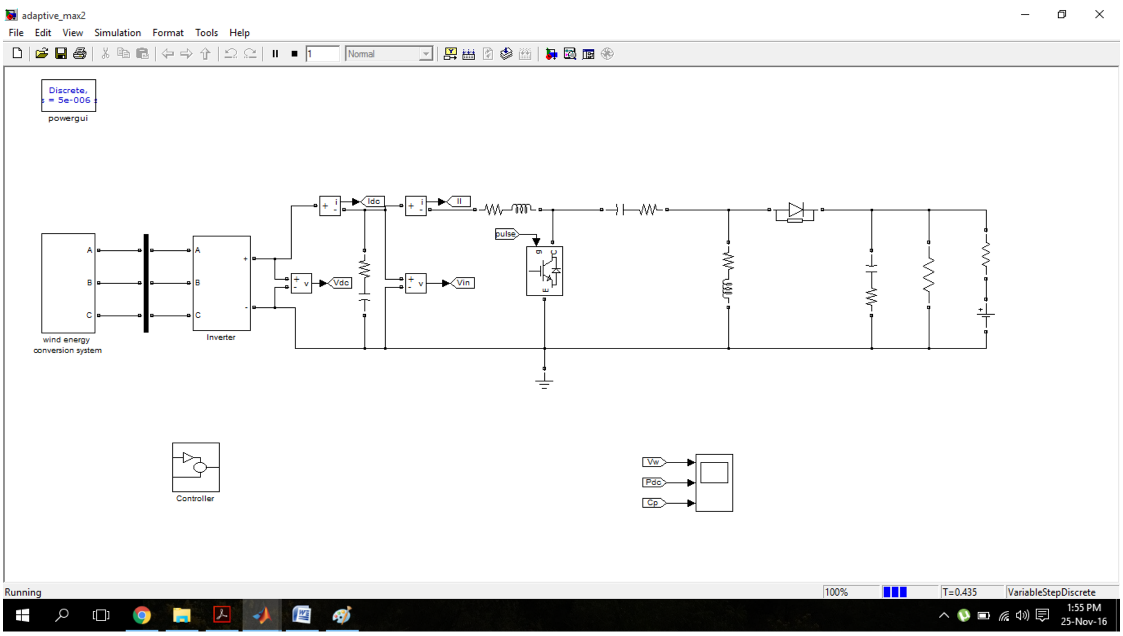

Figure 7: System Performance with Proposed MPPT Algorithm

This section compares the performance of the system under varying wind conditions using the proposed MPPT algorithm and the HCS algorithm. Framework reaction with proposed MPPT calculation is displayed in Fig. 6.

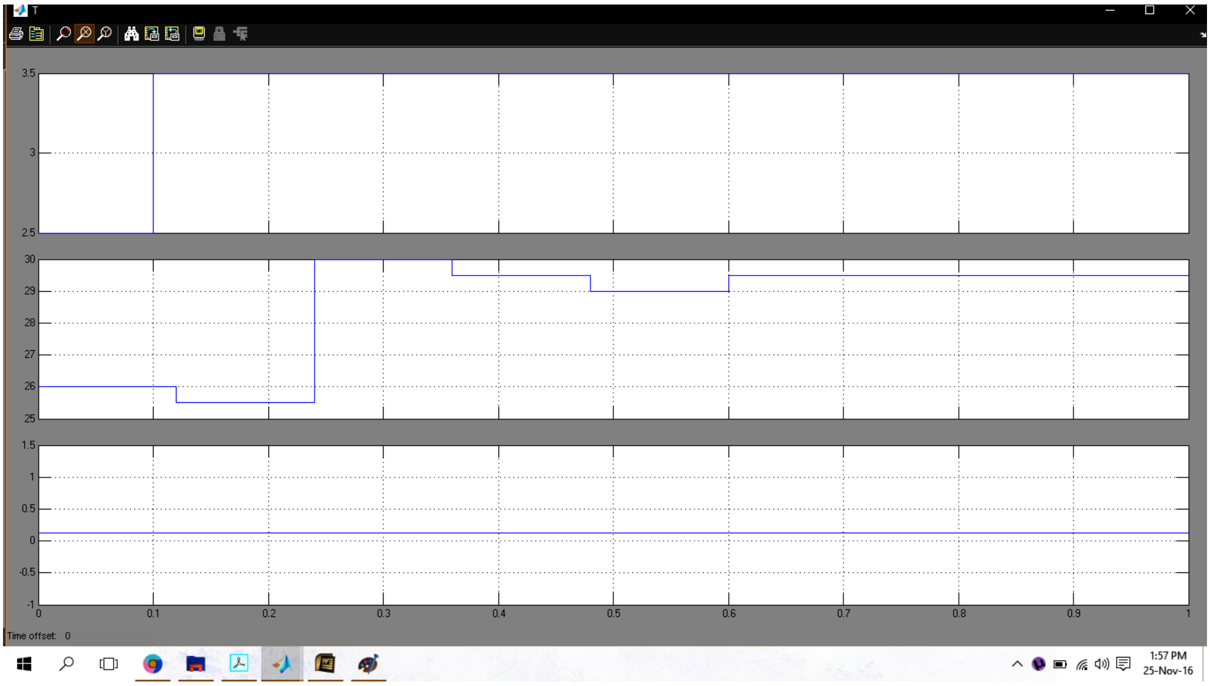

Figure 8: Performance with proposed algorithm

In contrast, the proposed algorithm uses lookup table data to generate the reference signal vDCopt (k + 1) = 86.81 V and promptly places the system at MPP without introducing any arbitrary variations, as depicted in Figure. 8. In contrast, as depicted in Figure, the proposed algorithm causes the system to immediately track MPP without requiring any additional random search operations. 4.7. It can be deduced from the variations in Cp that WECS with the proposed algorithm extracts more energy than HCS does.

III. CONCLUSION

A WECS's power is extremely unreliable by nature. Therefore, aWECS is unable to guarantee continuous power supply to the load. To meet the heap prerequisite at all occurrences, appropriate capacity gadget is required. In order to achieve the desired load power, a hybrid wind-battery system is chosen in this paper. The appropriate controllers connect the WECS to the load in order to mitigate the random characteristics of wind flow. The control rationale executed in the mixture set up incorporates the charge control of battery bank utilizing MPPT and pitch control of the WT for guaranteeing electrical and mechanical security. The maximum power that can be used to charge the battery bank in a controlled manner is tracked by the charge controller. In addition, it ensures that the discharge current of the batteries is within the C/10 limit. The buck converter is safeguarded against overcurrent by the current programmed control method. However, source power may sometimes be greater than battery and load demand due to MPPT control. Pitch action can control the pitch angle in power mismatch conditions to reduce WT output power in proportion to total demand. The pitch control logic ensures that the rectifier voltage does not result in an overvoltage situation in addition to controlling the WT characteristics. MATLAB/SIMULINK is used to develop the hybrid wind-battery system and its control logic. Various wind profiles are used to test it. The improved system's performance is confirmed by the simulation experiment results.

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