Design and Simulation of Reliable and Efficient Hybrid Solar-Wind Power System Using Improved MPPT P& O Algorithm

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Abstract - ***This paper explains the design and simulation of a solar-wind hybrid energy system with an Improved perturb and observe (P&O) maximum power point tracking algorithm to extract the maximum power from hybrid solar-wind power system. The hybrid system where the solar power output is improved at different weather conditions and excessive power is stored in a battery and the wind power output also improved as per the availability of ever variable wind speed. The improved control algorithms identify the operating limit violation and adjust itself nearer to the best possible maximum power point. Improvements of these methods can be obtained with the fast sampling rate and the perturbation size using MATLAB/Simulink to simulate the system and to verify the outcomes.***

Keywords — *hybrid power system1, maximum power point tracking (MPPT)2, photovoltaic (PV) power system3, improved perturb and observe (P&O)4*

1. INTRODUCTION

Nonconventional energy sources on the way to becoming a well-established energy source in the coming decades and expected to play an important role in meeting the world's power demand, due to their abundant availability and less impact on the environment. Initial high capital cost of solar modules is the main barrier of solar energy going widespread. Another disadvantage of solar energy production is that the power generation is not constant throughout the day, as it changes with weather conditions. The efficiency of solar energy conversion to electrical energy yet to reach its best, now it is around the range of 19–21% [1] in good conditions and even lesser especially in low irradiation regions. Hence technology is required to improve the efficiency of solar system by embedding with other renewable energy recourses. Wind energy is the best available renewable recourse to be used with solar system to improve the reliability and efficiency of the power system. The most popular MPPT methods in PV systems uses perturbation and observation (P&O) algorithm, which ensure that the power converters operate at the maximum power point (MPP) of the solar array. PV and wind turbine can be used as hybrid power systems using the MPPT for improving efficiency of the system rather only using PV modules or wind mills separately. The wind turbine can also operate with maximum aerodynamic efficiency. These systems are called Solar-wind hybrid systems [3] and may be used to supply electricity energy to stand-alone loads, e.g., small villages that are not connected to the main utility. In order to improve the efficiency.

The main objectives of MPPT algorithms are to achieve faster and accurate tracking performance and reduce the oscillations for both solar and wind systems. Separate MPPT algorithms are explained based on the type of the control variable for solar and wind power system. Among different algorithms, much focus has been on perturb and observe (P&O) method [1] [8]. MPPT techniques can be improved through the optimum adjustment of the sampling rate and perturbation size both in accordance with the converter dynamics. This paper explains the optimum parameters of the improved P&O techniques to improve output and efficiency of solar-wind hybrid system.

2. THE PROPOSED MODEL

The dynamic proposed model of solar and wind hybrid system is shown in Fig. 1 is consisting of consisting of PV generation system, Wind energy conversion system (WECS) as main components and also have a Battery energy storage system (BESS). Both systems are connected to a common load after conversion of power to required AC through appropriate converters and inverters.

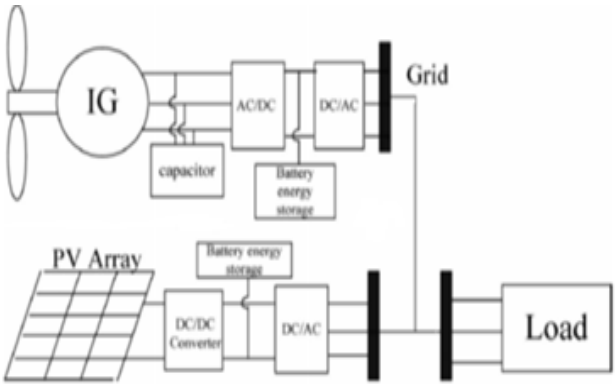

Fig 1- Proposed Hybrid System

3. THE PROPOSED IMPROVED MPPT SYSTEM

3.1 Improved MPPT Control Algorithm Of The Wind Energy System

The wind power generation system explained in this paper with the MPPT controller using P&O algorithm is shown in

Fig.2. the operating condition for P&O algorithms is considered under sudden wind speed change, especially in scenario of wind speed slowdown. A conventional P&O algorithm does not perform properly under this operational condition due to its slow response to sudden change of wind speed. The proposed algorithm is able to detect the sudden wind speed change, which is projected into dc-link voltage slope change. When a sudden dc-link voltage slope exceeds a certain threshold, the wind speed is verbally expressed to be transmuting rapidly. Corresponding adjustment at the machine to perpetuate generation with MPPT control, which gives an advantage over conventional P&O algorithms.

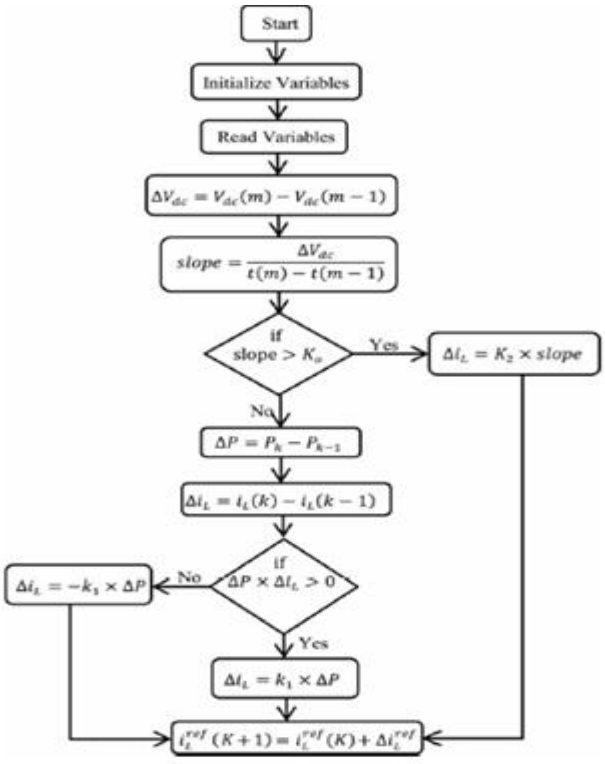

Fig.2- Flow chart of Improved MPPT algorithm for wind energy system

The algorithm works in two distinct modes: Under slow wind fluctuation conditions it will work in the normal P&O mode in which an adaptive step size is employed with the power increment utilized as a scaling variable.

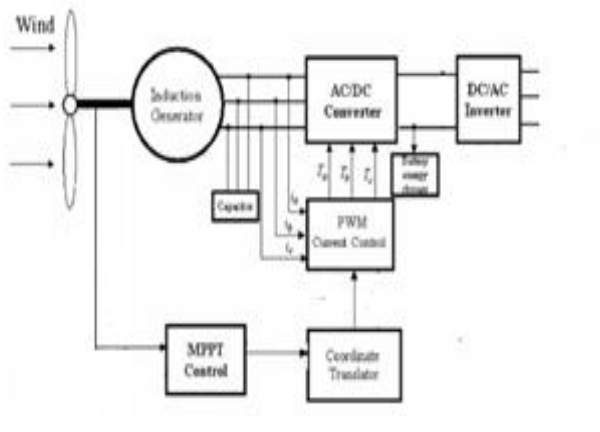

Fig.3: Configuration of wind energy system

Under sudden wind speed change conditions the second mode i.e the predictive mode works for bringing the operating point to the vicinity of the MPP and it will avail obviate the generator from stalling by rapidly adjusting the generator torque in replication to sudden drops in wind speed.

3.2. Conventional P& O Algorithm flow chart of solar energy system

Figure-4 shows the generally followed MPPT P&O algorithm for solar system.

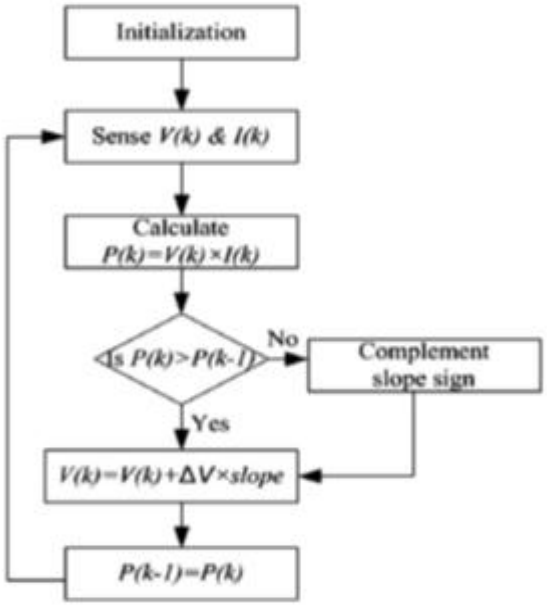

Fig 4: The Flow chart of P&O method

3.2 Improved MPPT Control Algorithm Of The Solar Energy System

It is very difficult to quickly acquire the maximum power point (MPP) by using the conventional perturbation and observation (P&O) MPPT algorithm and the tracking course is not accurate under changing weather conditions.

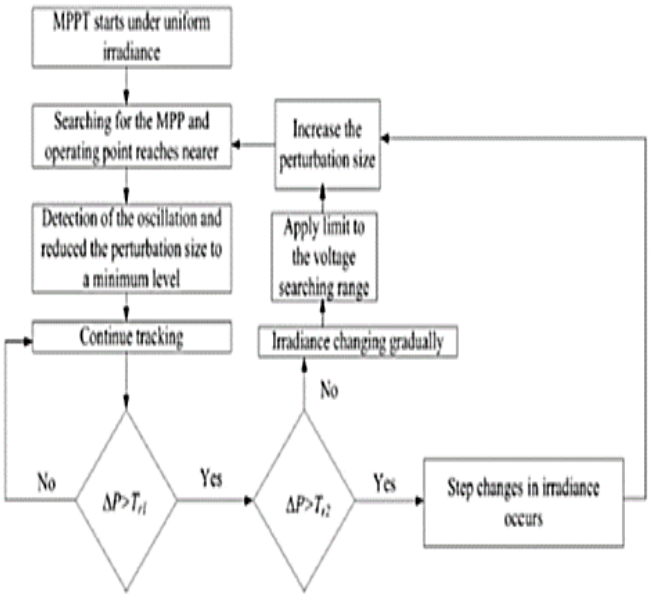

Fig. 5: Flow chart of Improved P&O Algorithm for Solar system

To improve the performance and efficiency of MPPT tracking, Improved Perturbation and Observation (IP&O) method is used based on auto-tuning perturbation step. A satisfactory trade-off between fast transient responses and steady state performance can be obtained with a small perturbation step size.

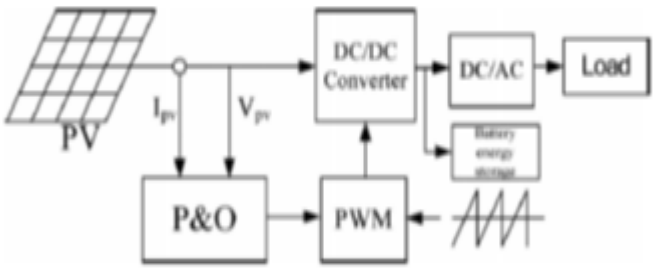

Fig.6: Configuration of P&O in Solar system

For the changing environment, it is required to implement MPPT to get the operating voltage close to the maximum power point under keeping economy point of view of solar cells. The improved P&O method periodically increases or decreases the solar cell's voltage as mentioned before to seek the maximum power point. A variable step method is proposed in this paper to achieve the maximum power point by adjusting the step length according to the distances to the MPP. The step length of duty ratio *D* is the ratio of the variation of power *P* to voltage *V*, which is the slope of each operating point under very short sampling time. Fig. 4 shows the control block of the improved P&O method.

4. SIMULATION RESULTS

The hybrid system shown in Fig. 1 is simulated using MATLAB/ Simpower and the PV system used in the simulation were conducted to show performance of the model under various conditions, with the comparison of various MPPT schemes for the improved P&O method.

4.1. MPPT System Performance

4.1.1 Wind Power MPPT

Time simulation is done for the hybrid power system with constant load under sufficient wind and irradiance. The turbine output power characteristics and the wind power output characteristics is analysed.

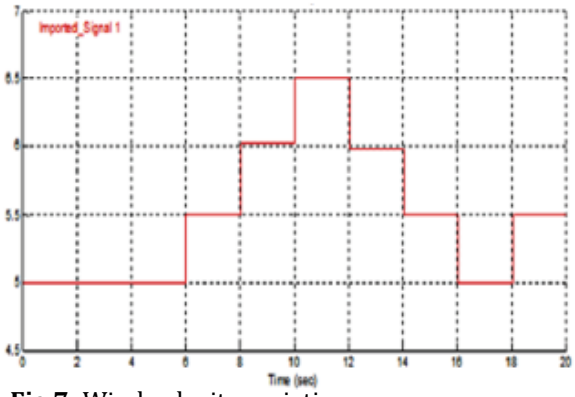

Fig.7: Wind velocity variation

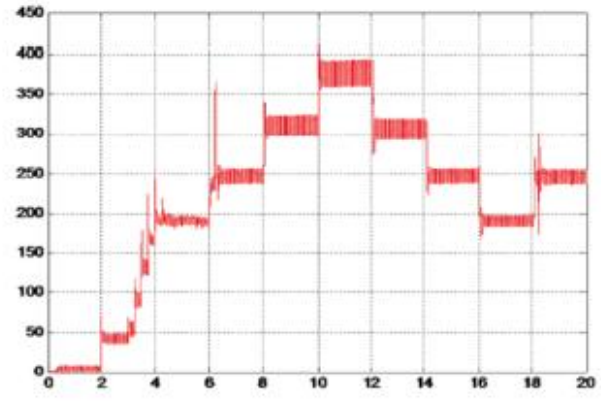

Fig.8: Power Variation with change in wind velocity

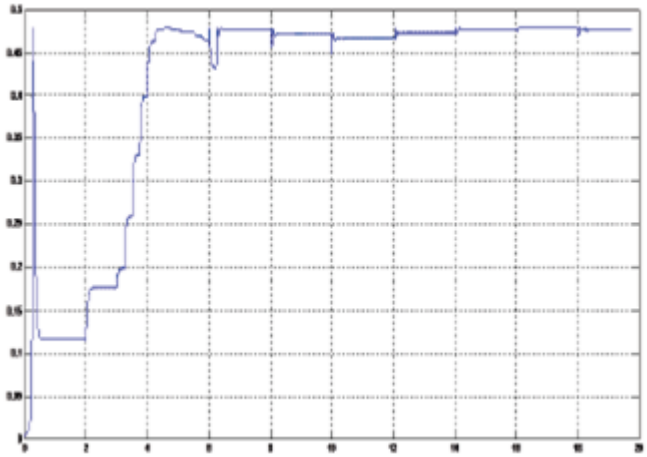

Fig.9: Variation in power co-efficient

The proposed algorithm has been tested under different conditions of rapidly changing wind velocity as shown in Fig. 7, .The wind turbine tracks maximum power point of the wind velocity. Controller developed accordingly to track the reference input inductor current generated by the MPPT algorithm. Effective tracking feature of the proposed MPPT algorithm is verified from power characteristics as shown in Fig. 8. Maximum power point tracking capability of the wind energy conversion system is proved by observing the power coefficient, Cp, of the system as shown in Fig. 9. This result proves the operation of the wind energy conversion system at maximum power point.

4.1.2. Solar PV Simulation result with conventional P& O MPPT

The output power from PV is shown in Fig. 10. From Fig. 12 for conventional PV, we can see that the controller provides a better performance than P&O in fig 13 to 15using Improved P&O algorithm for both in the transient and the stability.

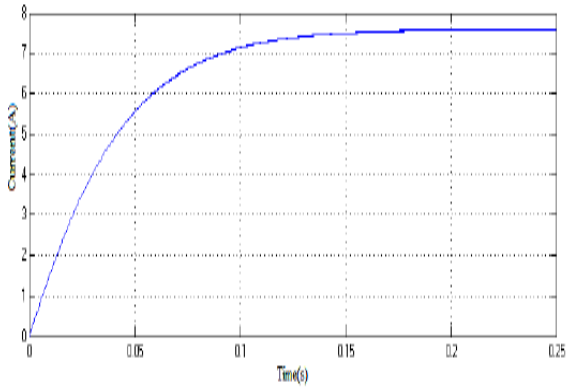

Fig.10: Output current

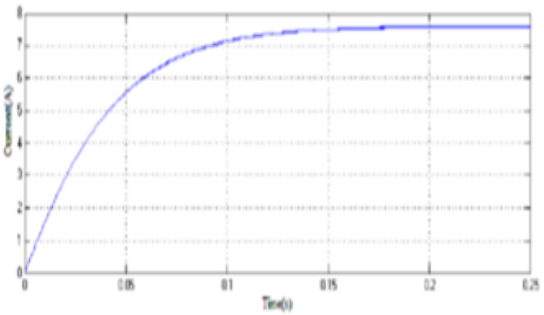

Fig.11: Output Voltage

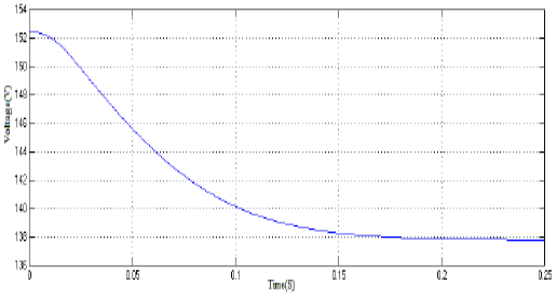

Fig.12: Output power

4.1.3. Solar PV Simulation result with improved P& O MPPT

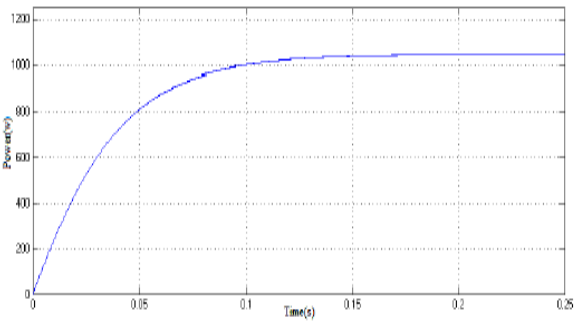

Fig.13: Output current

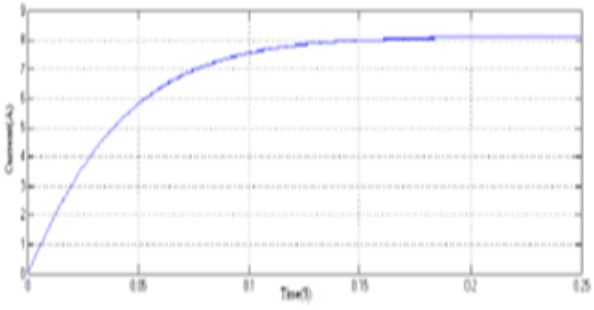

Fig.14: Output Voltage

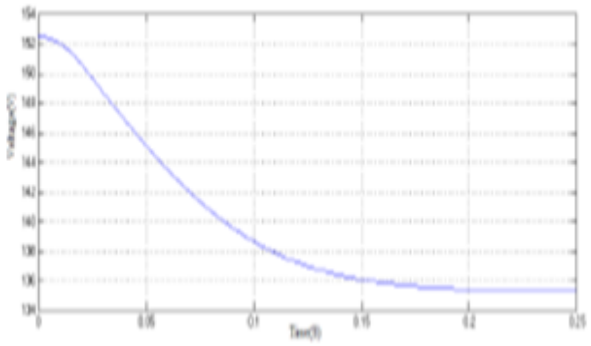

Fig.15: Output power

From figure 13, 14 and 15 it is clear that the power output is increased using the improved P&O method.

4.2. Performance comparison of both P&O methods: 4.3.

Table 1 shows Analytic Evaluation of Output Efficiency with Various Solar Temperatures at Constant Irradiance.

Irradiance (W/Cm²)	Efficiency (%)	
	P&O	IP&O
400	36.98	45.35
600	57.38	59.56
800	77.72	79.52
1000	89.84	94.32

Table 1: Efficiency at different Irradiance

It can be found that power availability with various irradiance at various temperature, the IP&O method gives higher power than P&O method. It shows that the performance of proposed IP&O control strategy is efficient than P&O control.

Figure16 shows a comparison of power and fig 17 compares the efficiency between P&O and IP&O method at different irradiance.

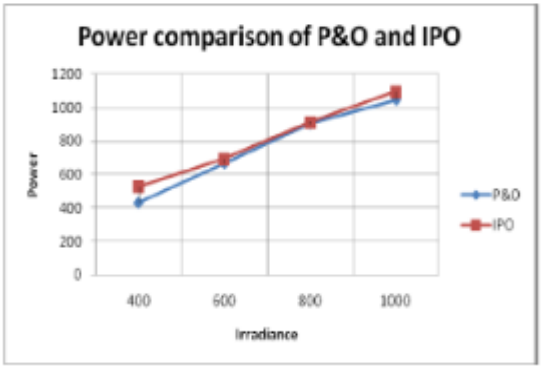

Fig.16: Power comparison of P&O and Improved P&O at various irradiance

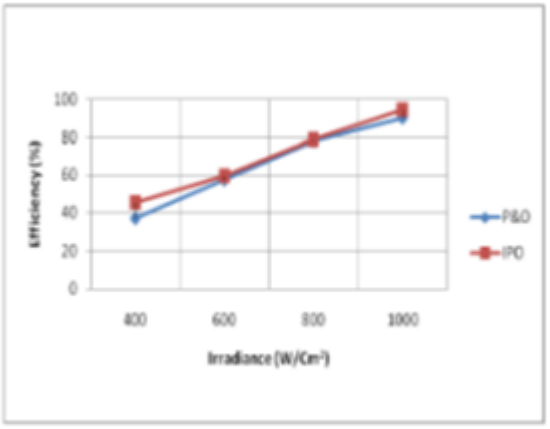

Fig.17: Efficiency comparison P&O and Improved P&O at various irradiance

5. CONCLUSION

It can be concluded that the IP&O method has given higher efficiency than P&O method for both solar and wind system. From the analytic evaluation shows that the proposed IP&O control strategy gives well performance than P&O control. It is found that IP&O method is more capable to tracked than conventional P&O method , also works efficiently at variable temperature with constant irradiance for PV cell and at turbulent wind conditions in case of wind energy system. Also it is observed that for solar system the power is reduced by increasing of temperature and IP&O method has capability to track power efficiently than P&O at different temperature with constant irradiance. The WEC MPPT algorithm utilizes the dc-side current as the perturbing variable, while the dc-link voltage slope information is utilized to detect turbulent wind speed change. Compared to the conventional P&O methods, the proposed MPPT method gives optimum result irrespective of the loading conditions or the wind speed range. Yet, like other methods, the proposed algorithm does not require anemometer or generator speed quantifications. The correctness and validity of improved MPPT method is verified through simulation under varied weather conditions. It was found that, for all the tests, the MPPT of the proposed P&O increases by approximately two to five percentage points. This improvement is important since a hybrid power system installation has a life-time of approximately twenty years. Since these proposed version has little variation to conventional algorithm structure, the improvements can be easily implementable.

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