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Investigation on Modelling and Control of Induction Machine

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Abstract: The usage of renewable resources results in easing the burden on exhaustible fuels. Consequently, there is a marked reduction in pollution and an improvement in the general environmental conditions. Shifting from exhaustible fuel to a clean energy-based system is a sure-shot way of combating the adverse effects of rapid climate change. This study is a comparison of two MPPT control methods applied to a solar energy conversion system. The two algorithms i.e., Perturb and Observe, and Modified Perturb and Observe were implemented in Simulink and their results were compared. The analysis revealed comparative details related to the system.

Keywords: Clean energy; Climate change; Environmental; Incremental conductance; MPPT; Perturb and observe; Pollution; Renewable resources.

Introduction

SEIG

The decrease in the demand for conventional energy sources has increased the power consumption dependency on renewable energy sources such as wind, mini/ micro-hydro, etc. A significant chunk of electricity generation is mainly done by thermal, and nuclear plants. These non-renewable sources have negatively affected the environment so far. Due to the negative and hazardous effects of conventional energy sources on the ecological system, people are moving towards more renewable-based energy sources, especially after the fuel price hike in the 1970s. Usage of an induction machine as a generator is becoming popular with renewable energy sources. The major drawbacks of induction generators are reactive power consumption and poor voltage regulation under varying speeds. However, since the development of static power converters, the control of the output voltage of induction motor is implemented easily (Bojoi et al., 2016).

An externally powered induction machine with an appropriate capacitor bank can be used as a generator. This phenomenon of an isolated generator working with a capacitor bank is known as an isolated Self-excited Induction Generator (SEIG). The SEIG is proven to be convenient for electrical energy generation in remote areas which are not accessible by the public power grid. The many advantages of SEIG over synchronous generators are: easy to build/construct, sheer rugged behaviour, absence of DC power supply for excitation, no synchronisation problems, cheap price and maintenance cost, excellent over-speed capability and self-protection against short circuits and reduced size ruggedness. These are the reasons why induction machine as a generator is becoming more and more popular for renewable energy generation (Banerjee et

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al., 2019; Banerjee et al., 2020). But there are some limitations or disadvantages of SEIG which is worth mentioning: SEIG gives a poor performance in terms of voltage and frequency under frequent variations of operating speeds, which is a common feature in wind energy conversion. SEIG's voltage and frequency depend on the speed of the prime mover, capacitor bank and load. Figure 1 illustrates the per phase equivalent circuit of a SEIG.

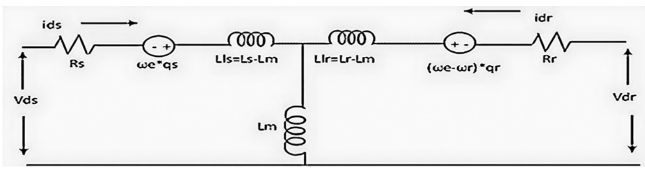

Figure 1: SEIG equivalent circuit.

SEIGs form an air gap flux when the residual magnetism in the rotor interacts with the rotating prime mover. This in turn induces stator voltage, resulting in self-excitation. Since the air gap flux is not self-sustaining, it reduces rapidly unless reinforced by a source of reactive power (Haque, 2009). SEIGs are a rugged and fault tolerant electrical energy source well suited for utilities as a creator of clean energy. SEIGs can be used to supply pump loads in rural areas for irrigation purposes. Such usage is extremely sustainable and will assist in combating the rapidity of climate change. Shridhar et al. (1994) encompass a study of the systems in which SEIGs are used to feed dynamic loads. Mahato et al. (2013) and Singh et al. (2004) can be cited as valuable references for the scientific community working towards the improvement of the rural irrigation scenario.

MPPT

The total electrical power generated from a wind energy conversion system depends upon the precision with which the apex power points are tracked by the maximum power point tracking (MPPT) controller of the conversion system control entity; irrespective of the generator used.

More focus is now on energy generation through wind because of countless environmental benefits. Speed control of the rotor is done within the functioning range of wind turbines for MPPT (Jung et al., 2012). Controllers are utilised depending on the range within which the control of rotor angular velocity is needed.

By adjusting the rotor speed or duty cycle of the converter, MPPT is realised (Sharma et al., 2012; Mirzaei et al., 2014; Garcia-Rodriguez et al., 2016; Martinez-Teran et al., 2013; Byrne et al., 2018; Bagai et al., 2020).

Types of MPPT

Perturb and Observe Method

The P & O MPPT method is used to alter the operating values of the system until the highest power is obtained from it. The tracker is actuated by periodically increasing or decreasing the system voltage. A voltage sensor and current sensor are put to use for continuous tracking. Power is obtained by multiplying the voltage and current. Figure 2 illustrates the flow chart of the scheme while Figure 3 is a representation of the power versus voltage characteristics.

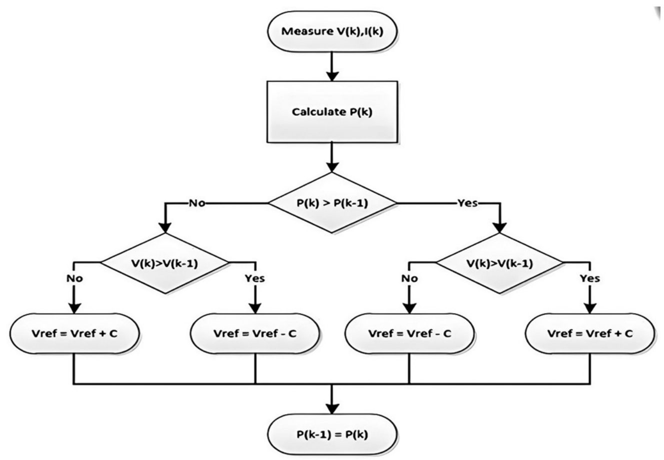

Figure 2: Flowchart of P & O MPPT.

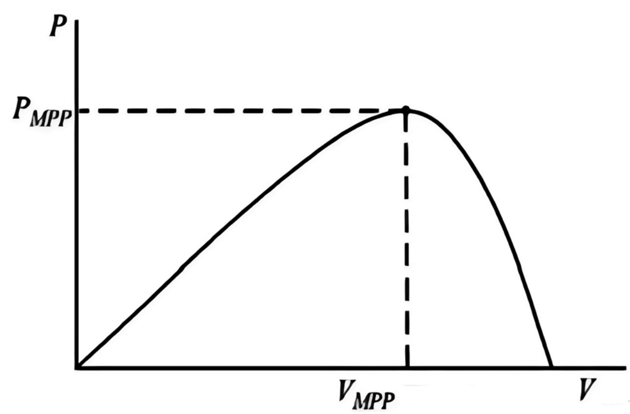

Figure 3: Graph of power vs voltage for P & O algorithm.

Modified Perturb and Observe Method

In the modified P & O algorithm, an additional check is implemented at the maximum power point (illustrated in the flowchart of Figure 4). This results in reduced

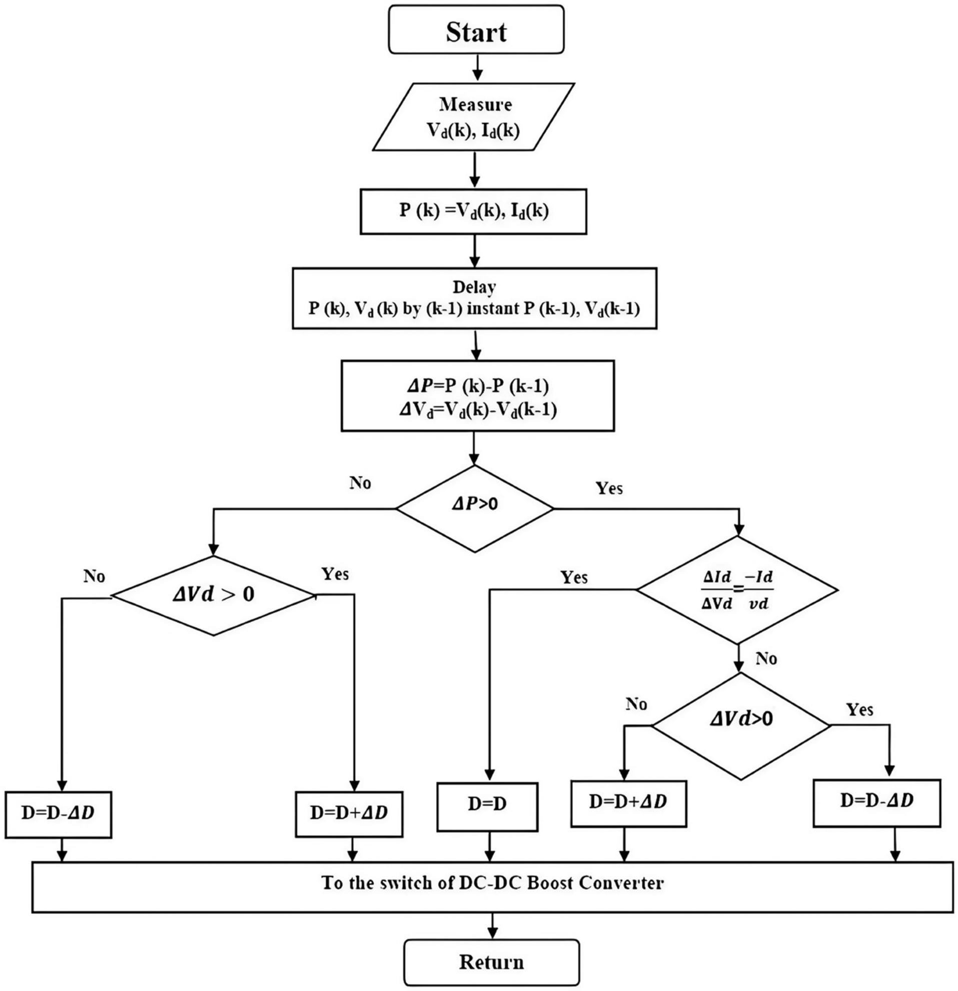

Figure 4: Flowchart of Modified P & O MPPT.

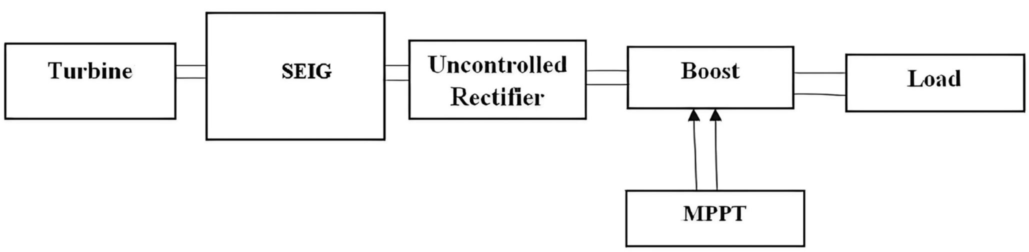

Figure 5: Block diagram of system.

fluctuations about the peak power point thereby yielding better output.

Block diagram of the SEIG based wind energy conversion system has been depicted using Figure 5.

Results

Perturb and Observe Algorithm Output and Modified Perturb and Observe Algorithm Output

Figures 6 and 7 illustrate that as wind power decreases, there is a corresponding decrease in power captured. However, the ripple content in the power obtained by the M P & O algorithm is far less as compared to its P & O counterpart.

The superior performance of the M P & O algorithm as compared to the P & O algorithm was validated in a Permanent Magnet Synchronous Machine (PMSM) based system (Verma et al., 2019). Bagai et al. (2020) proved the same for a doubly fed induction machine (DFIM) based system.

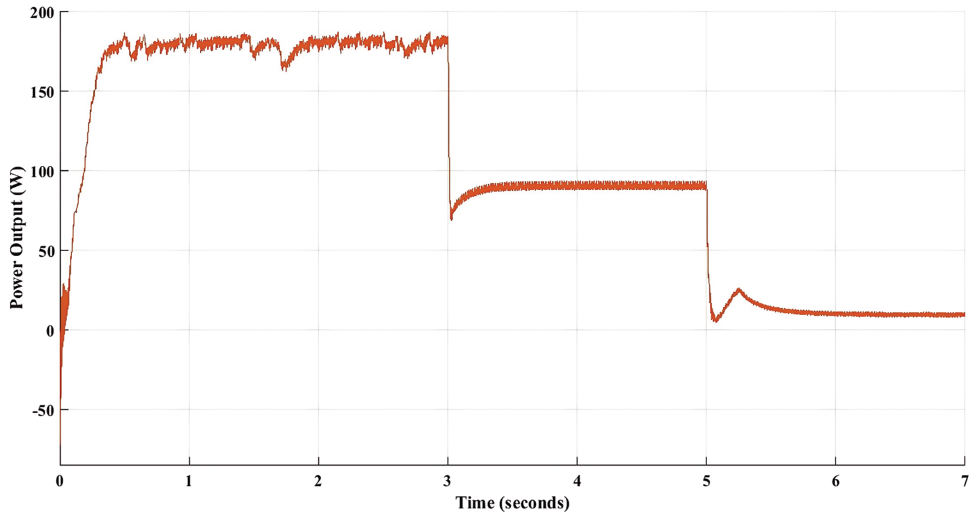

Figure 6: Output power obtained from SEIG when P & O algorithm is applied.

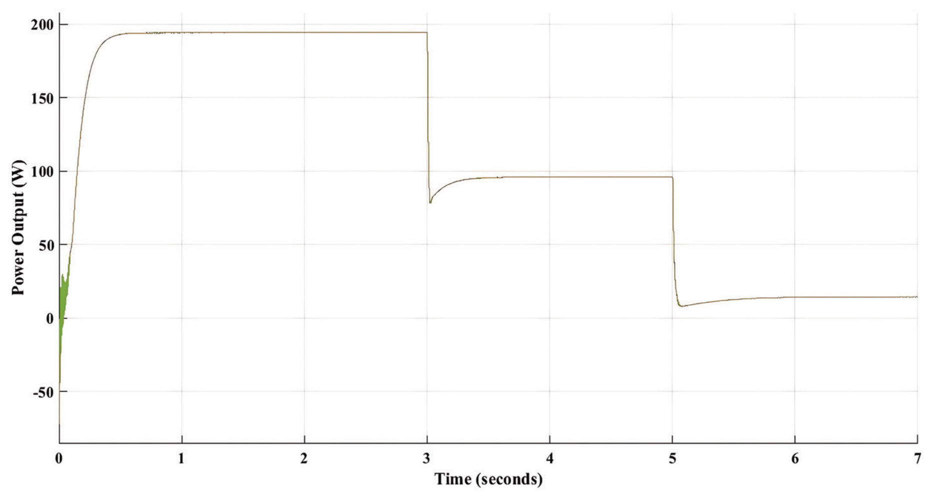

Figure 7: Output power obtained from SEIG when M P & O algorithm is applied.

Conclusions

This study is focussed on the observation made in a variation of power that is directly co-related to wind speed harnessed using a wind turbine. The observed variation is a useful parameter for the estimation of current utility and its control as the wind speed is highly intermittent. The objective of this study was to compare two MPPT algorithms for deciding the suitability of a wind energy conversion system based on a separately excited induction machine.

The graphs and results were plotted using the Simulink model. The salient observations are as follows:

(1) The M P & O algorithm yields a higher output as compared to the P & O model.

(2) The ripple content is drastically reduced when the M P & O algorithm is used in an SEIG-based wind energy conversion system.

(3) As reported in the literature, PMSM as well as DFIG based systems also yield improved output on the application of M P & O algorithm. Hence it has been validated that the M P & O algorithm is superior to the P & O algorithm irrespective of the generator employed for cultivating wind energy.

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