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MAXIMUM POWER POINT TRACKING BASED OPTIMAL CONTROL WIND ENERGY CONVERSION SYSTEM

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Abstract—Problem of control associated wind energy conversion systems using horizontal-axis fixed-pitch variable-speed low-power, working in the partial load region, consisting in the energy conversion maximization, is approached here under the assumption that the wind turbine model and its parameters are poorly known. Maximum Power Point Tracking (MPPT) by using an approach derived from the optimum seeking methods category, is the proposed control solution aims at driving the average position of the operating point near to optimality. The reference of the rotational speed control loop is adjusted such that the turbine operates around maximum power for the current wind speed value. In order to establish whether this reference must be either increased or decreased, it is necessary to estimate the current position of the operating point in relation to the maximum of Pwt(Ω l) curve. Numerical simulations are used for preliminary checking the control law based on this estimation.

Keywords—*Wind energy conversion systems, Energy optimization, Maximum Power Point Tracking, Optimal Control*

I. INTRODUCTION

Over the past few years, wind energy has shown the fastest rate of growth of any form electricity generation with its development stimulated by concerns of national policy makers over climate change, energy diversity and security of supply. Today, wind power is by far the fastest-growing renewable energy source. Wind power is free, clean and endless. Furthermore, the cost of the electricity produced by wind turbines is fixed once the plant has been built and it has already reached the point where the cost of the electricity produced by wind is comparable with that of electricity produced by some of the conventional, fossil based power plants. Full variable-speed wind energy conversion systems (WECS) are very flexible in terms of which type of generator is used. The electromagnetic conversion is usually achieved by induction machines or synchronous and permanent magnet generators. Squirrel-cage induction generator (SCIG) is one of types of typical wind generator system because of their lower cost, reliability, construction and simplicity of maintenance [1]. Control of variable-speed fixed-pitch WECS in the partial load regime generally aims at regulating the power harvested from wind by modifying the electrical generator speed; in particular, the control goal can be to capture the maximum power available from the wind. For each wind speed, there is a certain rotational speed at which the power curve of a given wind turbine has a maximum (Cp reaches its maximum value)[2]. The control approaches encountered in the WECS control field vary in accordance with some assumptions concerning the known models/parameters, the measurable variables, the control method employed and the version of WECS model used. Depending on how rich the information is about the WECS model, especially about its torque characteristic, this research paper will discuss about optimal control of variable-speed fixed-pitch WECS is based upon maximum power point tracking (MPPT), when parameters λopt and Cpmax = Cp(λopt) are not known

II. WIND ENERGY CONVERSION SYSTEMS MODELLING

Figure 1 presents wind power conversion systems, which uses either SCIG, or permanent-magnet synchronous generator (PMSG). The AC–AC converter is stator grid-connected and rated at the generator's power level. From a system viewpoint, the conversion chain can be divided into four interacting main components which will be separately modelled: the aerodynamic subsystem S1 and the electromagnetic subsystem S2 interact by means of the drive train mechanical transmission S3, whereas S4 denotes the grid interface.

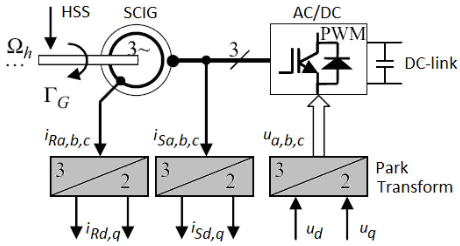

fig:-1 Inputs, outputs, and states of SCIG

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The electrical generators are systems whose power regime is generally controlled by means of power electronics converters. From this viewpoint, irrespective of their particular topologies, controlled electrical generators are systems whose inputs are stator and rotor voltages, having as state variables the stator and rotor currents or fluxes [3]. They are composed of an electromagnetic subsystem, which outputs the electromagnetic torque, further referred to as ΓG, and the electromechanical subsystem, through which the generator experiences a mechanical interaction. Figure 1 illustrates the modelling principle for the SCIG. The necessity of using (d,q) models comes from vector control implementation, which has the advantage of ensuring torque variation minimization and thus better motion control.

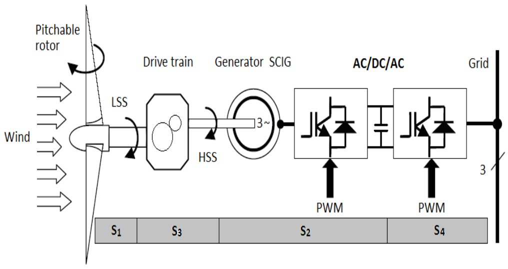

fig:-2 Wind energy conversion system

Many set equations involving the generator's electrical variables-voltages, fluxes and currents-results. In wind energy conversion systems, the generator interacts with the drive train; hence, to this set of equations is usually added the high-speed shaft (HSS) motion equation in the form

A complete control generator can be illustrated in figure 2 that contains a widely employed vector control structure for torque controlling a SCIG. There are two decoupled loops: the first is a rotor flux loop ensuring the field orientation of the induction machine in order to control ΦRd and the second is a torque loop which impose the electromagnetic order to control iSq.

A. Optimal Control Based on Turbine Power Characteristic

Control of variable-speed fixed-pitch WECS in the partial load regime generally aims at regulating the power harvested from wind by modifying the electrical generator speed; in particular, the control goal can be to capture the maximum power available from the wind. For each wind speed, there is a certain rotational speed at which the power curve of a given wind turbine has a maximum (Cp reaches its maximum value). All these maxima compose is known as the optimal regimes characteristic (ORC) (see Figure 3) [5].

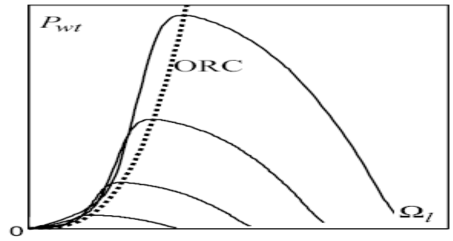

fig:-3 Optimal regional characteristics

By keeping the static operating point of the turbine around the ORC one ensures an optimal steady-state regime, that is, the captured power is the maximal one available from the wind.

B. Maximum Power Point Tracking (MPPT)

A MPPT approach is good choice when parameters λopt and Cp_max=Cp(λopt) are not known. The reference of the rotational speed control loop is adjusted such that the turbine operates around maximum power for the current wind speed value. In order to decides whether this reference must be either increased or decreased, the current position of the operating point in relation to the maximum of Pwt(Ωl) curve must be estimated. The target of MPPT is make the WECS will be operated around the maximum power, using information from the static power characteristic and a minimum of information from the system. The power characteristic of the turbine rotor is completely unknown, but general features of WECS (such as rated power, rated rotational speed, total shaft inertia, etc.) are considered known. The high-speed shaft rotational speed Ωh, and the active power of the generator P are the only available measurements from the system. Figure 4 illustrates about the variable speed control system is used in MPPT optimal control. The approach is based on the computation of the power and rotational speed gradients, employed in a hill-climbing-like method. To determines hP Ω∂∂ value, the result of computation of the power and rotational speed gradients is used, its sign corresponding to the position of the static operating point on the power curve in relation to the maximum of this curve (zero corresponds to the power maximum). An ON-OFF control logic, aiming at keeping Ω∂∂P at small values, updates the speed reference of the generator vector control block with constant variations ±ΔΩh. Given that the WECS parameters (i.e., the optimal tip speed and maximum of the aerodynamic efficiency) are unknown, the MPPT algorithms generally aim at maintaining the optimal operating point by zeroing the value lwtP Ω∂∂ , where Pwt is the total wind power and Ωl is the low-speed shaft (LSS) rotational speed. Therefore, the control input, representing the wind turbine speed reference, depends on the operating point position and on its moving trend, expressed by the sign of lwtP Ω∂∂ (see figure 5) Since the turbine power is not available for measurement, an estimation of its value, obtained based on the measured active power, is used for operating point localisation, leading to a somehow static approach. Also, for obtaining the LSS rotational speed, a measurement of the generator speed is used.

III. OPTIMAL CONTROL OF WECS

Vector Control of Induction Generator A very common structure to control the induction machines motion is the one containing an AC–AC voltage source back-to-back inverter. Insulation between the machine and the grid voltages by means of a DC circuit also provides by this converter. The control input applied to the AC–AC converter results from a vector control structure which employs the induction machine modelling in the (d,q) transformation. A very good performances regarding the torque settling time and oscillations can be obtained by using this technique, making this kind of control suitable for wind conversion applications.

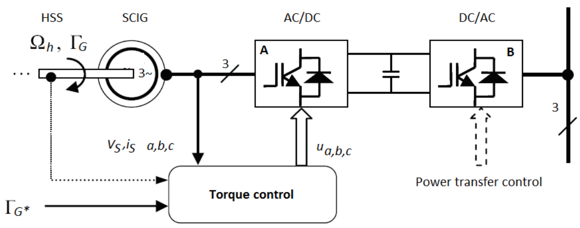

fig:-4 Structure of electromagnetic subsystem

Figure 4 shows about basic of the SCIG-based WECS connection to the electrical grid is given in. By controlling the generator torque, the machine side power converter. A allows the high-speed shaft torque to be varied, thus enabling the variable-speed regime of the turbine. The grid-side converter B is used for transferring the produced electrical power (by DC-link voltage regulation) to the mains, while controlling the voltage and the frequency of the output voltages. In accordance to the control objective, the SCIG motion control – the two power converters are considered ideal (i.e., the imposed tri phased voltages are physically obtained without dynamic and power loss) and are separately controlled.

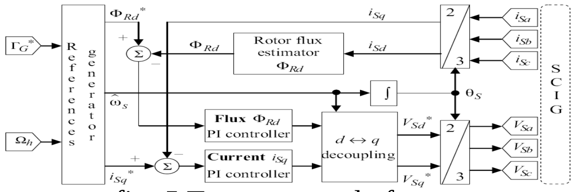

fig:-5 Torque control of generator

The torque control of the generator is realized by suitably controlling inverter A. Depending on the desired electromagnetic torque, the controller must deliver the Vd, Vq voltages and stator flux position θS , which can be used in Park transform for computing the stator voltages amplitude and frequency (VS a,b,c and ωS) [4].

A complete control generator can be illustrated in figure 4 that contains a widely employed vector control structure for torque controlling a SCIG. There are two decoupled loops: the first is a rotor flux loop ensuring the field orientation of the induction machine in order to control ΦRd and the second is a torque loop which imposes the electromagnetic torque in order to control iSq.

IV. DISCUSSION OF SIMULATION RESULTS MATLAB/SIMULINK

Simulations have been performed on low-power variable-speed fixed-pitch WECS as case study. The turbine has variable-speed capability, being equipped with a speed controller based on a vector control structure. The tests concern only the partial-lad region for medium wind turbulence and no wind gusts and have been done for 500 second for a wind sequence having the average speed of about 7.5 m/s and a medium turbulence intensity of I=0.15 (Figure 8), obtained by using the von Karman spectrum in the IEC standard.

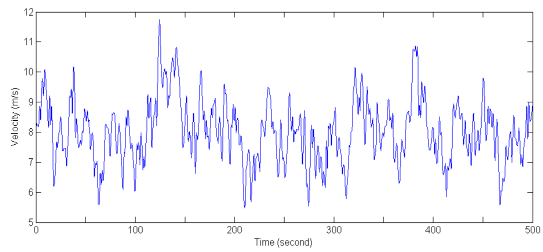

fig:-6 Wind speed sequence used for assesing the MPPT control law

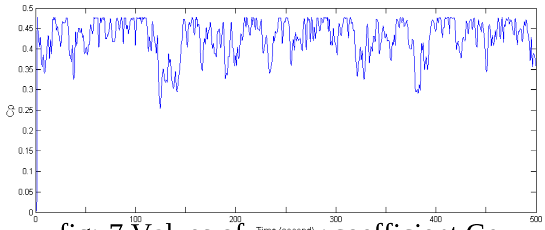

fig:-7 Values of power coefficient Cp

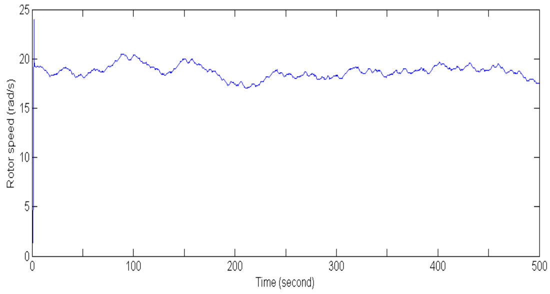

fig:-8 Rotor speed of wind turbine

Figures 6-8 presents the change in value of aerodynamic subsystem and drive train as the time during simulation. The average value of power coefficient CP during simulation is 0.4262 and the maximum value is 0.4763. The variable speed operation of rotor turbine describes by Figure 10 that the value is stable between 18-20 rad/s after controlled by MPPT approach. Figure 11 shows the value of tip speed ratio λ evolution that will find out optimal rotor speed to drive generator/machine during the variable wind speed drives the blade.Finally, the value of generator electromagnetic torque that will produce electrical power is presented by The MPPT based optimal control will calculate an optimal speed reference by variation of speed rotor and active power to estimate the value of rate of wtP∂ / hΩ∂ that indicate the position of the operation point in relation maximum of characteristic Pwt(Ωl)

V.CONCLUSION,FUTURE DEVELOPMENT

This research has presented capability of optimal control of variable-speed WECS based on MPPT method. As MPPT methods show their efficiency when the plant is not sufficiently and/or precisely known, an improvement of measure information processing has been proposed. The Fuzzy logic control law can be applying for the future development. Maximizing the harvested power from the wind is aimed at in this case too, and the control law is an extension of the MPPT method in the sense that the rules base is an extension of the MPPT-control logic. The rules base is therefore built for keeping the operating point around the optimal one (at a small value of hP Ω∂∂). Value Ωh is variable for a certain wind speed and depends on the distance between the optimal and the current operating point and on the speed variation of the latter.

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