A REVIEW ON SENSOR LESS CONTROL OF DOUBLY FED INDUCTION MACHINE (DFIM)

Arunesh Kumar Singh * and Abhinav Saxena **

* Electrical Engineering Department, Jamia Millia Islamia, New Delhi
aru_dei@yahoo.com
** Electrical Engineering Department, JSSATE NOIDA
abhinaviitroorkee@gmail.com

ABSTRACT: This paper present the review on sensor less control of Doubly fed induction machines using various methods like Model Reference Adaptive Scheme (MRAS), Field oriented control (FOC), Fuzzy logic, Artificial Neural Network(ANN) etc. and the whole analysis reveals the better dynamic performance of Sensor less speed estimation over conventional method of speed and current measurement of DFIM which reduces the error in the measurement of parameters, better noise immune, more efficient and reliable system .

KEYWORDS: Doubly fed induction machine, current sensor.

INTRODUCTION

Doubly fed electric machines are electric motors or electric generators that have windings on both stationary and rotating parts, where both the windings transfer substantial power between shaft and electrical system [21]. Generally the stator winding is directly connected to the three-phase grid and the three-phase rotor winding is fed from the grid through a rotating or static frequency converter. Doubly fed induction machines are typically used in applications that require varying speed of the machine's shaft in a limited range around the synchronous speed(± 30%), because the power rating of the frequency converter is reduced correspondingly. Today doubly fed drives are most common variable speed wind turbine concept [10]. The principle of the DFIM is that rotor windings are connected to the grid by slip rings and back-to-back voltage source converter that controls both the grid and the rotor currents [6]. Thus rotor frequency can be freely differ from the grid frequency (50Hz). With the help of the converter to control the rotor currents, it is also possible to adjust the active and reactive power fed to the grid from the stator independently of the generator's turning speed [16]. A doubly fed induction machine is a wound-rotor doubly fed electric machine (generating mode) has several advantages over a singly fed induction machine in wind power applications. Firstly, the rotor circuit is controlled by a power electronics converter, as a result induction motor is capable to deliver real power and absorb reactive power while the induction generator is able to deliver both reactive power and real power [14]. This has important consequences for power system stability and allows the machine to support the grid during severe voltage disturbances Secondly; the control of the rotor voltages and currents enables the induction machine to remain synchronized with the grid while the wind turbine speed varies. A variable speed wind turbine uses the available wind resource more efficiently than a fixed speed wind turbine, particularly during the light wind conditions [16]. Thirdly, cost of the converter is low when compared with other variable speed solutions because only a fraction of the mechanical power, typically 25-30%, is fed to the grid through the converter, the rest is fed to grid directly from the stator as shown in the Fig 1.

DESIGNING OF SENSOR LESS SCHEME

The increasing concern towards environment and fast depleting conventional resources have moved the interest of the researchers towards rationalizing the use of non renewable energy resources and exploring the renewable energy resources to meet the ever-increasing energy demand. A number of renewable energy sources like small hydro, wind, solar, geothermal, etc. are explored [1]. Since small hydro and wind energy sources are available in adequate amount , their utilisation is felt reasonably promising to accomplish the need of future energy [2]. Harnessing mini-hydro and wind energy for electric power generation is an area of research interest and at present, the focus is being given to the effective utilization of these energy resources for quality and reliable power supply [4]. Doubly fed Induction generators are often used in Wind turbines and some micro hydro installations due to their ability to produce valuable power at varying speeds. Electric motors for variable speed drives have been widely used in many industrial applications. In the early years dc motors were widely used for adjustable speed drives because of their ease of control [2]. However, due to advances in both digital technology and power semiconductor devices, ac drives have become more economical and popular. For accurate torque control and precise operating speeds, more sophisticated techniques are necessary in the control of ac motors [12]. These techniques employ high speed Digital Signal processors and control techniques based on estimation or identification of speed and other machine states. Speed estimation is an important issue of particular interest with respect to Doubly Fed Induction Machine (DFIM) drives as the rotor speed is different from the speed of the revolving magnetic field[19]. The measurement of rotor speed in adjustable speed drives is done using electromagnetic speed transducers. The electromagnetic speed transducers experience errors in speed detection as it is mounted on shaft, some unpleasant vibration produces which shows how they are generally the least reliable drive component [20]. Therefore It is highly desirable to measure the speed without speed sensor connecting to shaft so sensor less speed is preferred in this speed is calculated by using rotor currents as input which is transformed into the rotor position

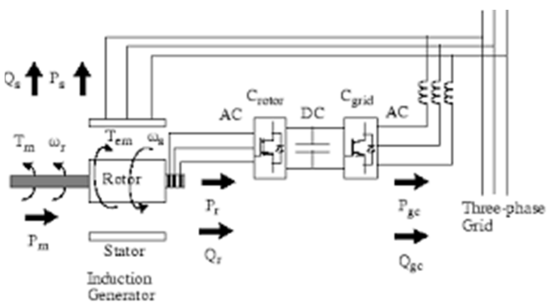

Fig.1 Power Flow Diagram of Doubly fed induction machine

ANALYSIS OF SENSOR LESS SCHEME

Based on Mras

This is one of the best conventional method of estimating the sensor less speed and rotor position of Doubly fed induction machine for variable speed constant frequency, Based on MRAS various method proposed for sensor less control of Doubly fed induction machine (DFIM)

i) A novel scheme was proposed which consist of reference and adjustable models[14]. The reference model is given by stator equations with flux as the outputs while the rotor equations are used to calculate the stator flux by using rotor currents, positions and flux, in order to get accurate rotor flux of adjustable model a modified integrator has been used which reduces the error between reference and adjustable model parameters so there is no requirement of current sensor for rotor position estimation so it reduces the cost and improve the control system reliability.

ii) In other scheme, it was observed that integral term introduced by PI MRAS regulator is cancelled between estimated and real speed, so an additional term depending on rotor flux through a constant gain in adjustable model of the MRAS as a result estimated speed does not exhibit any steady state error[18]

iii) A MRAS scheme based on robust sliding mode power control, the active and reactive power can be computed direc tly without current controller so it gives faster dynamic responses under transient conditions and robust response.

iv) A Novel scheme proposed to improve the performance of DFIG in low speed region in which conventional PI controller was replaced by integrated fuzzy logic controller(IFLC) which is a combination of PI and fuzzy logic controller and whole analysis were simulated on MATLAB

Field oriented control scheme

a) In this scheme, rotor speed is estimated using rotor position which is calculated using rotor flux and stator flux parameters in different references coordinates like stationary, synchronous references frame as shown in Fig 2 , this analysis produce sensor less speed is approximately equal to rotor speed.

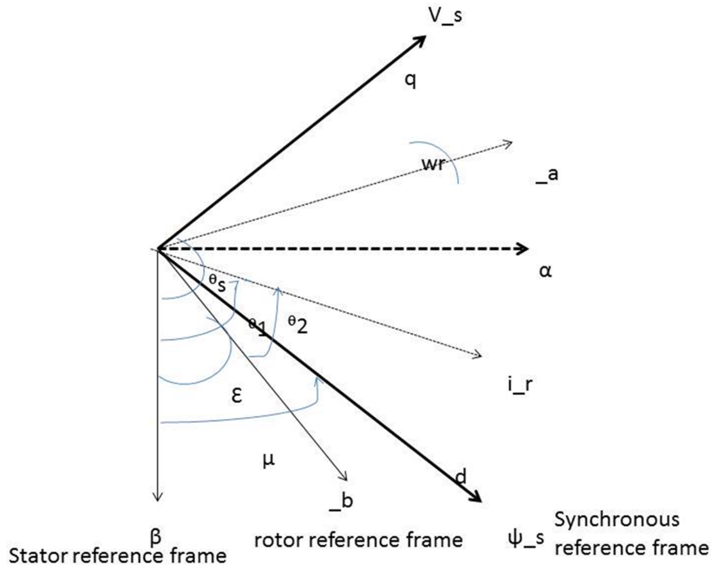

Fig.2 Representation of rotor current in different reference frame

b) In the second scheme, control concept has been derived from first principle of torque production and magnetisation of machines in which the flux estimation parameters is unaffected by uncertainties produced in the resistance which made the entire torque control scheme virtually independent[19]. This technique can be considered as development of a generic controller for variable speed doubly fed induction machine

New Current observer model

A current observer model of a DFIG is presented to improve fault-tolerant capability for wind turbine control systems. The current observer model is constructed by using the stator and rotor voltage output signals as inputs. The dynamic performance and robustness of the proposed observer are investigated by comparing it with the corresponding sensor outputs[20]. The fault tolerant ability of the proposed observer is improved in case of a stator current sensor fault. The comparison shows that the proposed current observer has good dynamic adaptability to active power change of a DFIG and grid voltage dip. Moreover, the proposed current observer has a strong robustness to rotor resistance variation and has an excellent ability to tolerate a fault in the observed current sensor

Multi scalar control scheme

A Multi scalar control scheme of DFIG using current hysteresis PWM technology proposed to improve the performance of dynamic response. By using the rotor current reference components,observer design is simplified which makes the whole control process independent of machine parameters. This proposed speed observer can overcome the some of disadvantages of the traditional open loop speed observer.

PRESENT STATUS SENSORLESS SCHEME

Now days All the analysis of sensor less control of DFIM is performing in various intelligence technique. We will discuss the following intelligence technique with respect to the sensor less control of Doubly fed Induction Machine

Fuzzy logic controller

i) This scheme deals with the sensor less speed control of Doubly fed induction machines at low speed region, initially model of doubly fed machines is fed by inverter with DC link[19]. Then a separate control between flux and motor speed based on fuzzy-MRAS technique was proposed which produce better dynamic performance and eliminate the sensor cable, better noise immunity, more reliability as shown in the fig.3 [20].

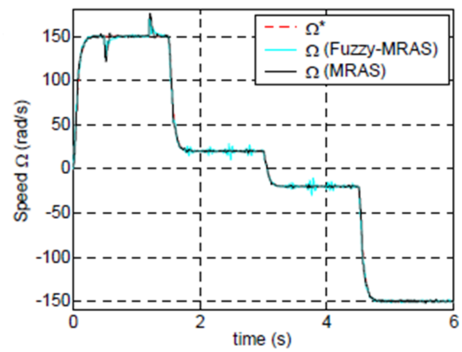

Fig.3 Estimation of speed using MRAS & Fuzzy-MRAS

ii) An adaptive mechanism for sensor less speed estimation of DFIG at a low speed using rotor flux based MRAS speed observer replace the fixed gain PI controller by novel Fuzzy logic adaptive mechanism. It is found that fuzzy logic shows better transient performance as well as load disturbance region in both open loop and closed loop mode of operation when PI controller is removed.

iii) A model reference adaptive control speed control (MRAC) using on-line trained fuzzy neural network (FNN) was applied to the sensor less induction motor drive system[17]. In this method fuzzy logic controller is completely equipped with additional option for online tuning its chosen parameter and PI-type fuzzy logic controller is used as the speed controller, in the FOC, whose connected parameters are trained on-line according to the error between the states of the plant and the reference model[19]. The FNN speed controller is on-line tuned to preserve favourable model-following characteristics under various operating conditions. The rotor flux and speed of vector controlled induction motor was estimated using the full-order state observer and speed estimator. The simulation results were verified in the experimental tests, in the wide range of motor speed and parameters changes. The simulation results shows the performance of FNN adaptive scheme for the control of sensor less DFIG without any knowledge related to plant parameters. This method can deal with large range of parameters variations and external disturbance due to online learning capability

iv) In the high speed range, vector control of rotor flux orientation of an induction machine implements good performance. However, the performance in low speed range deteriorates because of the inaccurate estimation of rotor flux and speed. So A modified voltage model for rotor flux estimation and neuron model-reference adaptive system (MRAS) for speed estimation are used to improve the performance of speed sensorless vector control. To improve the accuracy of rotor flux estimation, the stator resistance is identified on-line. The experimental results show that the proposed scheme yields improved performance in low speed range as shown in figure 4.

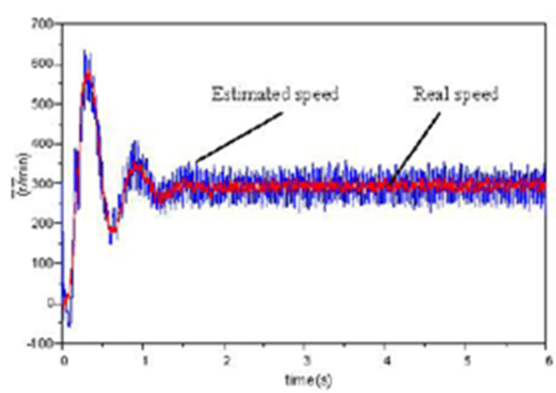

Fig.4 Speed response of sensor less DFIM using neuron MRAS

Artificial Neural Network(ANN)

i) From the aspect of reliability and cost sensor less vector control of wind energy turbine based on ANN was proposed. In this model three radial layer basis function network is used for measure the shaft speed, in addition to this extended luenberger and other neural observer were used to estimate the wind velocity to improve the sensor less control strategy so as to extract the maximum power from cascaded DFIG

ii) Sensorless field-oriented control (SFOC) of the doubly fed induction motor drives requires the information regarding the magnitude and position of the rotor flux and the rotor speed. This paper deals with the application of artificial neural networks (ANN) for estimation of the rotor flux vector and motor speed on the base of phase current measurement only. Various structures of the neural estimators were simulated and their performances were compared. The influence of changing rotor parameters during the drive were tested. The neural network is able to estimate accurately the rotor flux and speed during line-start operation and load torque changes of the motor

iii) A neural network identification scheme for direct torque control (DTC)for doubly fed induction motor speed was proposed. The validity and effectiveness of the proposed identifier as well as its sensitivity to parameter variation were verified by simulation, therefore the performance of speed sensors- less DTC control system can be improved by the novel method as shown in the Fig.5.

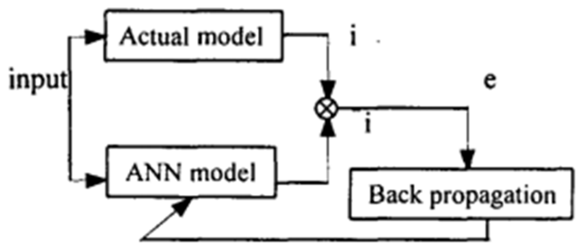

Fig. 5 Structure of neural network

iv) This method presents a online estimation for the stator and rotor resistances of the induction motor for sensor less speed indirect vector controlled drives, using ANN. For the stator resistance estimation, the error between the measured stator current and the estimated stator current using neural network is back propagated to adjust the weights of the neural network. The rotor speed is synthesized from the induction motor state equations. The performance of the stator and rotor resistance estimators is estimated with torque and flux responses of the drive, and investigated with the help of simulations for variations in the stator and rotor resistances from their nominal values. Both resistances are estimated experimentally, using the proposed neural network in a vector controlled induction motor drive. Data on tracking performances of these estimators are presented. With this speed sensor less approach, the rotor resistance estimation was made insensitive to the stator resistance variations both in simulation and experiment.The accuracy of the estimated speed achieved experimentally, without the speed sensor clearly demonstrates the reliable and high-performance operation of the drive as shown in Fig .6

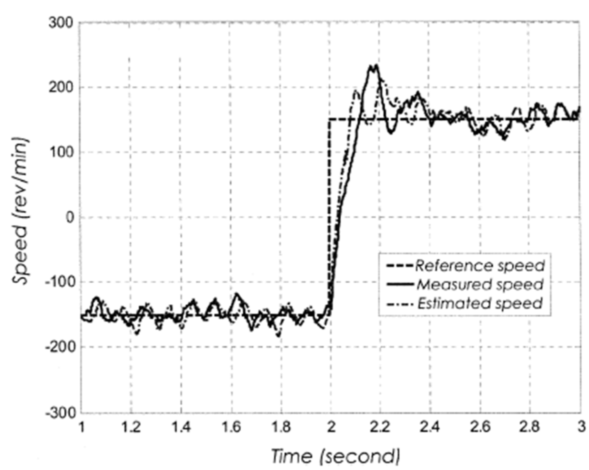

Fig.6 Comparison of Sensor less Reference,measured and estimated Speed of Doubly fed Induction machine

v)) This scheme deals with the sensor less speed control of Doubly fed induction machines at low speed region, A modified voltage model for rotor flux estimation and neural MRAS for speed estimation are used to improve the performance of sensor less scheme. To improve the rotor flux estimation stator resistance is identified online, so this scheme produce better scheme in low speed region.

vi) Another method presents the implementation of a MRAS speed estimation method based on fuzzy logic controller as an adaptive mechanism. An indirect vector controlled induction motor drive has been implemented based on this speed estimation technique[9]. The effectiveness of the proposed speed estimation algorithm has been investigated under dynamic and steady-state operation . A good correlation between simulated, estimated and measured speed signals has been obtained under different operating conditions. The results show the effectiveness and robustness of the proposed speed estimation procedure. The proposed method is based on model reference adaptive control that uses the stator current and rotor fluxes state variables for estimating the speed. In this method, the stator current error is represented as a function of first degree of the estimated speed error. This error is reduced using FL based controller.

vii) This technique proposes a neural network model reference adaptive system for the rotor angle and speed estimation of the doubly fed induction generator used in wind turbines. The model reference adaptive system(MRAS) reference signal is the measured rotor current. The adaptive neural network is adjusted in such a way to minimise the rotor current vector squared error using the steepest descent algorithm. The neural network maximum stable learning rate will be determined for this application. The validity of this neural network model reference adaptive system is verified and analyzed in a real prototype of 7.5-kW doubly fed induction generator[19] . To validate the proposed estimator, the estimated rotor angle and speed in the process of connecting the doubly fed induction generator to the grid and the sensor less regulation according to a random wind speed profile are presented. The rotor angle and speed estimation tested successfully when the wind reaches the desired speed, and the stator grid synchronization and connection to the grid are done as well. A step in the wind speed is also used, producing a step in the stator active power to observe that both stator powers are well decoupled; this shows that the rotor angle is well estimated. Set-point changes in the reactive power show good speed estimation; however, as the module of the rotor current decreases, the ripple in the estimated speed increases slightly. Finally, a random wind speed profile is tested[22]. All tests showed a good rotor angle observer based on the artificial neural network theory for sensor less control of a DFIG used in wind turbines

Neuro-Fuzzy controller

In the paper a model reference adaptive control (MRAC) using on-line trained fuzzy neural network (FNN) was applied to the sensor less induction motor drive system. In this method fuzzy logic controller is equipped with additional option for online tuning its chosen parameters. In this method PI-type fuzzy logic controller is used as the speed controller, in the field oriented control structure, whose connective weights are trained on-line according to the error between the states of the plant and the reference model[21]. The FNN speed controller is tuned to preserve favorable model-following characteristics under various operating conditions. The rotor flux and speed of vector controlled Doubly fed induction motor was estimated using the full-order state observer and speed[21] estimator. The simulation results were verified in the experimental tests, in the wide range of motor speed and parameters changes. An adaptive FN controller can deal with large range of variation in parameter and resist to external disturbance. The selection for the values of the proportional contstant kp and kd has a significant effect on the network performance.

CONCLUSION

This Paper shows the analysis of sensor less control of Doubly fed induction machine on different platform like FOC, MRAS, Fuzzy logic, ANN ,When analysis is done on FOC it is found that that rotor speed can be estimated using rotor position which includes stator and rotor flux quantities which gives value close to the speed measured from speed senor, in other scheme to attain the better performance flux estimation parameters is made unaffected by change in rotor resistance so that the entire torque control scheme become virtually independent , While doing the analysis on MRAS Scheme It is observed that modified integrator used to reduce the error between reference and adjustable model parameters so as to reduces the cost and improve the control system reliability. In other scheme of MRAS the integral term introduced by PI MRAS regulator is replaced by an adjustable gain is introduced to reduce the steady state error and better dynamics. When Sensor less scheme is applied to the intelligence technique like Fuzzy logic It is found that estimation of speed using PI controller replace by rotor flux based MRAS speed observer which shows better transient and steady state performance in both open loop and closed loop mode of operation ,When sensor less scheme is applied on Artificial neural network (ANN) it is found that it gives better performance as compare to other intelligence techniques because rotor flux quantities is independent of parameter variation and a modified voltage model for rotor flux estimation and neural MRAS for speed estimation are used to improve the performance of sensor less scheme

FUTURE SCOPE

The analysis of sensor less control of doubly fed induction machines tells that system can produce better transient and dynamic performance if the sensor less scheme apply on different intelligence technique like Genetic Algorithm(GA) etc. which can results in more reliable and efficient system or it can draw more amount of wind power from Doubly fed induction generator.

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