Improved power quality of a stand engineering essay

Engineering

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Index Terms – induction generator, stand-alone wind energy conversion systems.

I. INTRODUCTIONStand-alone power systems using renewable energy sources like wind, biomass and hydro are attractive to the remote communities. Compared with the grid connected counterparts , they avoid long transmission lines and thereby associate losses and cost. The self-excited induction generators is very suitable for such small or medium power systems compared to other generators structure such as doubly fed induction generators because of its low cost, robustness, less maintenance and inherent overload protection. However , the magnitude and frequency of the generated voltage depends on the rotor speed, excitation current and the load. An induction generator or asynchronous generator is a type of AC electrical generator that uses the principle of induction motor to produce power. Inductiongenerator operate by mechanically turning their rotor faster than the synchronous speed , giving negative slip. A regular AC asynchronous motor can be used as a generator , without ant internal modifications. Induction generators are useful in applications such as minihydro power plants, wind turbine, or in reducing high-pressure gas streams to lower pressure , because they can recover energy with relatively simple controls. An induction generators must be connected to an energized grid to supply power and cannot black start a de-energized distribution system. A capacitor bank must supply reactive power to the motor when used in stand-alone mode. The reactive power supplied should be equal or greater than the machine normally draws when operating as a motor . Terminal voltage will increase with capacitance , but is limited by iron saturation. In induction generators, the magnetizing flux is established by a capacitor bank connected to the machine incase of stand-alone system and incase of grid connection it draws magnetizing current from the grid. For stand-alone systems, frequency and voltage are complex function of machine parameters , capacitance used for excitation and load value type. On the basis of rotor construction , induction generators are two types (i. e., the wound rotor induction generator and squirrel cage induction generator).

Depending upon the prime movers used (constant speed or variable speed) and their locations (near to the power network or at isolated places), generating schemes can be broadly classified. In the fixed speed wind energy conversion system , the prime mover speed is held constant by continuously adjusting the blade pitch and / or generator characteristics. An induction generator can operate on an infinite bus bar at a slip of 1 % to 5 % above the synchronous speed. Induction generators are simpler than synchronous generators. They are easier to operate , control , and maintain , do not have any synchronization problems and are economical. Fig 1. Energy conversion in a stand-alone power generationII . SEIG-VSI SYSTEMFig.. 1 shows the block diagram of the SEIG- VSI system. The wind turbine is connected to the rotor of the induction generator through a step-up gear box. At the stator side of the induction generator , there is an excitation capacitor bank in parallel with the VSI and the consumer load. The VSI has an energy storage device , which can be battery or supercapacitor , connected at its dc bus and offers variable controlled impedance across the SEIG terminals to retain the terminal voltage. Fig 2. Block diagram of the SEIG-VSI systemModelling of the Wind turbineThe mechanical power available in a fix-pitch wind turbine, neglecting the losses in the gear box , is given byPwt = 0. 5Pπr2CP (λ)V3 (1)whereρ air density (kg/m3); R radius of the wind turbine (m); Cp power coefficient of the wind turbine; υ wind speed (m/s); λ tip speed ratio. The power coefficient Cp non linearily with the tip speed ratio λ which is defined as the ratio of the turbine rotational speed and the wind speed. A typical Cp versus λ curve for a three-blade wind turbine. Cp has a unique maximal value in which point the turbine can yield the maximal wind power. Modelling of the SEIGThe model of the induction generator can be developed in the Synchronous reference (d-q) frameυ ds = Rs ids + (dψds /dt) – ωeψqsυ qs = Rs ids + (dψqs /dt) – ωeψdsυ dr = Rr idr + (dψdr /dt) – ωeψqrυ qr = Rr idr + (dψdr /dt) – ωeψqr (2)The stator and rotor flux can be computed as functions of the d-and q axes stator and rotor currents as follows: ψds = Llsids + Lm (ids + idr)ψqs = Llsiqs + Lm (iqs + iqr)ψdr = Llridr + Lm (idr + ids)ψqr = Llridr + Lm (iqr + iqs) (3)wheresubscripts d and q direct and quadrature axes; subscripts s and r stator and rotor variables; subscripts l and m leakage and mutual components; subscript c excitation variables; υ and I instantaneous voltage and current; L inductance; R resistance; Ce excitation capacitance; ω e synchronous rotational speed; ω r electrical rotor speed. It should be noted that the mutual inductance Lm is not a constant and it depends on the nonlinear magnetization characteristics of the SEIG. 3. Modeling of the VSI and Consumer LoadFor the high frequency converters , it is reasonable to describe the converter dynamics with its state- space averaged model. In view of this , the VSI model can be expressed in the d-q frame as follows: υ ds = υ di – L (didi/dt) + ω e Liqiυ qs = υ qi – L (diqi/dt) + ω e Lidi (4)where i represents the VSI variables and L is the filter inductance. The model of a typical RL load can be represented in the d-q frame: υ ds = RLi dL– LL (didL/dt) + ω eL LiqLυ qs = RqLi dL – LL (diqL/dt) + ω e LLidL (5)III. STEADY STATE ANALYSIS1. Output power of the induction generator under different wind speeds. In the steady state, the mechanical power introduced to the induction generator can be expressed with the slip frequency s , rotor current Ir and resistance RrFig 3 Single phase equivalent circuit of the SEIG-

VSI systemPin = -3 (1-s)/s Ir2 Rr. (6)Ignoring the losses of the shaft and gear box , the input mechanical power Pin equals to the wind power extracted by the wind turbinePin = Pwt (7)An incremental search algorithm was implemented to solve the steady state operation points of the SEIG-VSI system. The flowchart of the search algorithm can be illustrated. The calculation starts with the rated wind speed (9 m/s) and the same procedure is repeated at other wind speeds . Based on the solution of X m and s at different wind speeds, the reactive/active power produced/consumed by the generator is obtained and depicted. Fig. 3 Flowchart of the incremental search algorithmIt is indicated that the generator produces more active power and consumes more reactive power with a higher wind speed . Compared with the active power variation , the reactive power varies in a relatively narrow interval (from 1. 07 to 1. 25 pu) within the available wind speed range. The rated active power of the induction generator is selected as the base value. Fig. 4 . Control diagram of the SEIG-VSI systemThe open-loop transfer function matrix of the whole system isG (s) = T (s) [G1 (s). I +G2 (s) . J] (8)Usually the generator speed responses much slower than the electrical variables due to the large turbine and generator inertias. And the operating slip frequency of the wind-driven SEIG around -5 % to -1 % , which has negligible effects on the system characteristics. By considering the generator speed as constant. The block diagram of the proposed when compared with the indirect schemes , the diagram is simple to implement since only voltage loop is required to tune. The dynamic response is faster than that of an indirect scheme which can be affected by a large turbine and generator inertias. Compared with conventional , the improved direct voltage control can further improve the power quality. The load changes hardly affect the controller design and the phase stability margin at the prior cutoff frequency (1kHz) is increased to 58 which is enough for the stable operation of the SEIG –VSI system. Additional damping on the sixth voltage harmonics is also provided with the dominant loops that can help to suppress the harmonics voltage in non-linear load applications. IV. SIMULATION RESULTSThe simulation are carried out in MATLAB/SIMULINK to verify the effectiveness of the improved direct voltage control. The models of the SEIG-VSI are developed in the simulation. The SEIG is modelled as a five-order system in the abc reference frame. The VSI and its controller are modeled as a digital system with a 5kHz switching frequency and 10 kHz sampling frequency. The excitation capacitor is selected to provide the needed reactive power to the SEIG at the rated wind speed. The rotating frequency of the d-q frame for the direct voltage control is set by a constant reference. The system response under different wind speed and load conditions are presented. The harmonic spectra of simulated voltage and current waves can be analysed by FFT to verify the harmful effect and possible design of remedial measures. Operation with Linear R-L LoadUnder the rated wind speed, the R-L load is applied to evaluate the performance of the proposed. It shows that the control strategy has very fast dynamic responses. When the loadincreases, the VSI provides more current to sustain the load voltage and the generator output current preserve the same since the wind speed does not change. Although one-cycle transients appear in the VSI and generator current. The VSI increases the output currents after the wind speed changes but the load voltage and current reserve a constant. Because of the large intertias of the wind turbine and generator, the current response of the VSI is slower than the constant wind speed situation. In both simulations with linear loads, the generated voltages have very low total harmonic distortions (THD). Fig 5. Total harmonic distortion analysisOperation With Nonlinear LoadThe performance of the direct voltage control for nonlinear load application are evaluated with the simulations. The nonlinear load configures with a three-phase diode rectifier powering a resistance . The nonlinear load current are provided by the generator and VSI system. the VSI provides more currents after the load variations while the generator current preserve unchanged due to the constant wind speed. Without feed-forward compensator, the generator voltage is highly distorted with fifth- and seventh-order harmonics and the total harmonics distortion is higher than 5 %. The fifth and seventh harmonics are effectively damped with the compensators and the power quality is highly improved. The VSI increases the nonlinear output currents after the wind speed changes and the currents provided by the SEIG reduce. The loadvoltage reserves a constant magnitude and frequency after the wind speed steps. Fig 6. Load voltage waveformsFig 7. Real power waveformsFig 8 Current output waveformsV . CONCLUSIONThis paper presented the procedures for the capacity and controller design of the stand-alone wind-driven SEIG-VSI system. The VSI capacity can be optimized following the capacity matching calculations for a given load range. For the inductive load, more excitation capacitors can help to reduce the VSI capacity because its ability of reactive power supply. The response is faster than that of an indirect scheme which can be affected by a large turbine and generator inertias and hence there is a further improve in the power quality i. e the value of the total harmonics distortion is found to be of low value. Hence there is improvement in the power quality. APPENDIX IPARAMETERS OF THE SEIG-VSI SYSTEMThe parameters of the wind turbine model as follows: Number of blades 3Rated power (kW) 2Rated wind speed (m/s) 9Gearbox ratio 31Lift to drag ratio 30Cp, max 0. 461λ m 3. 43. Ratings and data of the SEIG are listed as follows: Power (kW) 2Line voltage (V) 208Current (A) 5. 55Frequency(Hz) 60Shaft speed (rpm) 1720Pole pairs 2Stator, rotor resistance (pu) 0. 032Stator, rotor leakage inductances 0. 875Mutual inductance (pu) 0. 061Excitation capacitance (pu) 1. 15Parameters of the VSI and DVC are as follows: DC bus voltage (V) 400Filter inductance (pu) 0. 2Proportional parameter 10Integral parameter 20Feed-forward loop gain 1Time constant of lag corrector 4. 68 X 10-4Time constant of lead corrector 5. 488 X 10-5VI. REFERENCES[1] Bose B. K , Modern Power Electronics and AC Drives (2002) Upper Saddle River , NJ: Prentice Hall.[2] Gupta. S , Singh. B and Murthy. 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