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A Noval Coordinated Control for Virtual Synchronous Generator Using Back To Back Motor Drive System

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ABSTRACT: The virtual synchronous generator (VSG) control which enables inverter-interfaced distributed generators (DGs) to possess inertia like synchronous generators (SGs) provides a promising solution to the lack of inertia of a future power grid. The energy buffer emulating the kinetic energy variation is essential to this technique. In this study we propose a new control scheme for a smart motor i.e., a back-to-back motor drive system which temporarily utilizes the kinetic energy stored in rotating loads. With this system significant frequency regulation support can be achieved through merely a control mechanism update and without any dedicated energy storage system. To achieve it the VSG control is applied to the grid side converter of the back-to-back motor drive system and a coordinated control between the VSG control and the motor speed control is proposed. The proposed coordinated control has a faster frequency support response and a lower sensitivity to grid voltage unbalance and distortion than previous control schemes based on frequency measurement. The parameter tuning of the proposed control is discussed based on stability analyses and verified by simulation studies. The effectiveness of suppression of grid frequency fluctuation by the proposed system is verified through experimental results obtained with a commercial blower.

I. INTRODUCTION

An increase of the installed capacity of renewable energy such as photovoltaic power generation reduces the rotational stand by capacity in the power system and poses a serious challenge to the safe and stable operation of the power grid. Based on VSG photovoltaic grid-connected inverters a relatively stable DC-side voltage can be obtained through maximum power point tracking control (MPPT) and a DC-DC converter circuit in the DC-side photovoltaic array. Thus the VSG on the inverter side can simulate the active/frequency control and reactive/voltage control characteristics ofsynchronous generators from the external characteristics which can provide certain inertia and damping for the grid. This is of great significance for stabilizing the grid voltage and improving the anti-disturbance capability. The VSG control strategy was first proposed by the European VSYNC paper. Based on the VSYNC study the University of Leuven in Belgium the Netherlands Energy Research Center the Delft University of Technology the German Lloyd's Technical Universities and other institutions have proposed current type VSG control strategies with the external characteristics of controlled current sources To compensate for the defects of current VSGs scholars from the University of Liverpool the Hefei Institute of Technology and the University of Toronto have proposed voltage-type VSG control strategies with the external characteristics of controlled voltage sources The voltage type VSG is suitable for the application of grid-connected operation and isolated island mode in weak power grid environments with high permeability. A mathematical model of an inverter based on VSG control was established and the active and reactive power control strategy of a VSG in the droop mode was designed On this basis an adaptive control method of the moment of inertia was proposed. This method changed the moment of inertia according to the acceleration and slips difference of a VSG and reduced the overshoot in the dynamic process by reducing the speed and frequency.

In terms of low voltage ride through capability was studied and the idea of a VSG was applied to the wind power field On the other hand the constant power control of a VSG when the grid frequency and voltage change has been proposed In this control the constant active and reactive power can be output. However when the grid voltage is unbalanced the proposed control strategy becomes invalid.

II.IDENTIFY,RESEARCH ANDCOLLECT IDEA

2.1 Smart induction motor variable frequency drives for primary frequency regulation:

This article proposes an induction motor variable frequency drive to investigate its potential in handling smart grid's frequency. This can thus mitigate the grid reliance on expensive power plants. To this end a primary frequency controller is presented enabling the drive to reduce its power in proportion to grid frequency drop. The dynamic limitation of the drive due to load's inertia is considered through a motor's speed rate limiter. Moreover an appropriate inertia emulator is proposed for the smart drive by inspiring the inertial response of a direct-on-line motor. The impacts of speed rate maximum reserve power and motor driven load's inertia on dynamic behavior of the smart motor load during the frequency support are addressed. Besides the effectiveness of the smart drive's contribution in primary frequency regulation of the IEEE 39-bus test system is explored. In this regard a critical droop coefficient that guarantees the maximum reserve power delivery for the smart drives is analytically derived. Finally the proposed approach is extended to include the critical droop derivation for a set of smart drives with different sizes and priorities to rank their participation in primary frequency regulation process.

2.2 Fast frequency response from smart induction motor variable speed drives:

The induction motor variable speed drives can successfully participate in the power system primary frequency control. A new control strategy for fast frequency support from the diode front-end induction motor variable speed drive is presented in this project. By this practical restrictions are considered. In this context an existing conventional scheme presented in literature is firstly modified by deploying an estimated motor's power losses for a more exactly control design. Next a novel control scheme is proposed. It attains the fastest frequency support from the drive and simultaneously restricts its minimum power consumption to a given positive value to prevent regeneration mode during the frequency support process. The frequency of applied voltage to the motor is adjusted through a proportional-integrator compensator with deviation of the drive's consumption power from its reference power as input. The reference power is synthesized by permanent and temporary components which are determined based on deviation and time derivative of the power system's frequency respectively. The effectiveness of the proposed smart drive for the primary frequency control is investigated using the New England 39 bus and a more realistic Great Britain 36 zone test networks. It improves system frequency response in terms of the rate of change of frequency and the frequency nadir. Furthermore the new control scheme can contribute to quickly damping inter-area oscillations in multi-machine power systems.

2.3 Virtual energy storage: converting an ac drive to a smart load

This paper proposes a new smart-load concept using ac drives. The concept is based on a secondary control layer coordinated with the network and the load to provide active power support. The general smart-load concept is developed and synthesized for its practical implementation in network power-frequency support applications. A multi-power-frequency droop line is proposed. The final idea is applied to a fan load powered by an ac drive based on an induction motor and a two-level voltage source converter. Experimental results show that a full power-frequency response can be achieved by the smart load within 2 s of the network frequency deviation.

III. WRITE DOWN YOUR STUDIES AND FINDINGS

The first step in modeling a dynamic system is to fully define the system. If you are modeling a large system that can be broken into parts you should model each subcomponent on its own. Then after building each component you can integrate them into a complete model of the system. For example the demo house heat example model of the heating system of a house is broken down into three main parts.

- ➢ Heater subsystem
- ➢ Thermostat subsystem
- ➢ Thermodynamic model subsystem

The most effective way to build a model of this system is to consider each of these Subsystems independently.

The second step in the modeling process is to identify the system components. Three types of components define a system:

• **Parameters** — System values that remain constant unless you change them

• **States** — Variables in the system that change over time

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• **Signals** — Input and output values that change dynamically during a simulation

In Simulink parameters and states are represented by blocks while signals are represented by the lines that connect blocks. For each subsystem that you identified ask yourself the following questions

- How many input signals does the subsystem have?
- How many output signals does the subsystem have?
- How many states (variables) does the subsystem have?
- What are the parameters (constants) in the subsystem?
- Are there any intermediate (internal) signals in the subsystem?

Once you have answered these questions you should have a comprehensive list of system components and you are ready to begin modeling the system.
The third step in modeling a system is to formulate the mathematical equations that describe the system. For each sub system use the list of system components that you identified to describe the system mathematically.
Your model may include

- Algebraic equations
- Logical equations
- Differential equations for continuous systems
- Difference equations for discrete systems
- You use these equations to create the block diagram in Simulink.

After you have defined the mathematical equations that describe each subsystem you can begin building a block diagram of your model in Simulink. Build the block diagram for each of your subcomponents separately. After you have modeled each subcomponent you can then integrate them into a complete model of the system. After you build the Simulink block diagram you can simulate the model and analyze the results. Simulink allows you to interactively define system inputs simulate the model and observe changes in behavior. This allows you to quickly evaluate your model.

Finally you must validate that your model accurately represents the physical characteristics of the dynamic system. You can use the linearization and trimming tools available from the MATLAB command line plus the many tools in MATLAB and its application toolboxes to analyze and validate your model.
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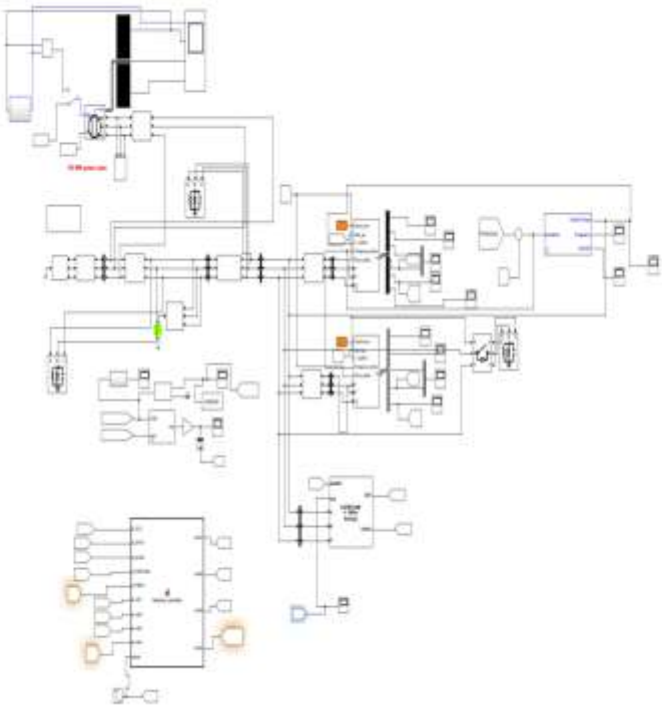
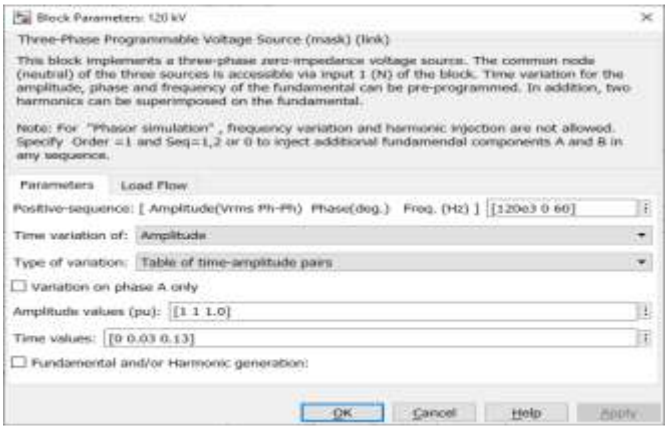
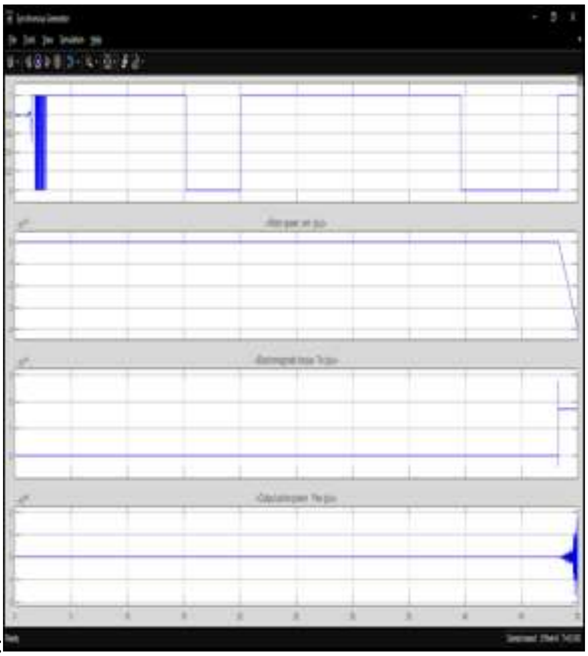
3.1 SIMULATION DIAGRAM:



3.2 INPUT SOURCE:



3.3 OUTOUT OF SYNCHRONOUS GENERATOR



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IV.EXISTING SYSTEM

A novel coordinated hybrid maximum power point tracking (MPPT)-pitch angle based on a radial basis function network (RBFN) is proposed for a variable speed variable pitch wind turbine. The proposed controller is used to maximize output power when the wind speed is low and optimize the power when the wind speed is high. The proposed controller provides robustness to the nonlinear characteristic of wind speed. It uses wind speed, generator speed and generator power as input variables and utilizes the duty cycle and the reference pitch angle as the output control variables The duty cycle is used to control the converter so as to maximize the power output and the reference pitch angle is used to control the generator speed in order to control the generator output power in the above rated wind speed region.

4.1 BLOCK DIAGRAM OF RBFN FOR WECS

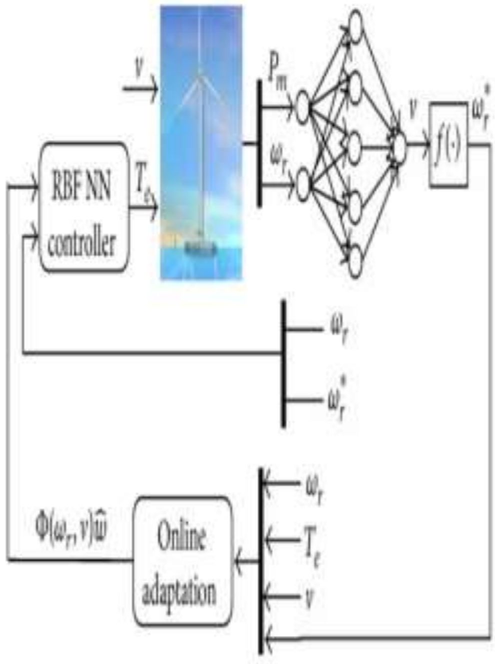

Fig.4.1 Block diagram of RBFN for WECS

A novel coordinated hybrid MPPT-Pitch angle control strategy employing RBFN based ANN technique for PMSG based WECS was proposed to enhance the overall efficiency of wind power generation in all operating regions. The proposed controller tracks the maximum power when the wind speed is below the rated wind speed and limits the output power in the high wind speed region. To develop the controller a highly non-linear wind speed input was considered.

The wind speed, generator speed and generated power were selected as the control input variables. The duty cycle and pitch command to the blade were considered as the controlled output variables. The selection of which output variable to be activated is based on the wind speed. In the low wind speed region the duty cycle is generated to control the power electronics converter thus obtaining maximum available power from the wind speed. When the wind speed exceeds the rated wind velocity the blade tends to change its angle in order to limit the output power.

V.PROPOSED SYSTEM

VSG-based coordinated control scheme for the BTB motor drive system of an IM which can provide grid frequency regulation support by utilizing the kinetic energy stored in the rotating load.

- Unlike conventional BTB motor drives in which dc-link voltage is regulated by the GSC the proposed control regulates the dc-link voltage by the MSC to facilitate the implementation of VSG control in the GSC. A coordinated control between the GSC and the MSC is then proposed to adjust the motor speed at a steady state while providing grid frequency control support during the grid frequency fluctuation.
- The stability of the proposed system is analysed based on a small-signal model and verified by simulation.
- The proposed control can restrain the motor speed variation within a range defined by the user during the grid frequency regulation support process.
- When the motor torque reaches a maximum limit by considering the q-axis current saturation of the IM the proposed control method can reduce the dc-link voltage variation which may trip the motor drive system. The proposed method is verified by experimental tests using a commercial 2 kVA blower installed in a 6 kVA scale-down weak grid.

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5.1 POWER COMPENSATION DIAGRAM

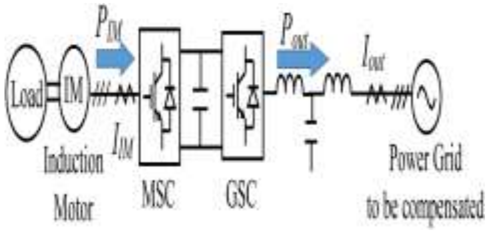

Fig. 5.1 power compensation

A VSG simulates the rotor equation of a synchronous generator introduces virtual inertia and damping in the active frequency control and simulates the excitation regulation of the synchronous generator in the reactive power-voltage control. The control equations are displayed in equations.

5.2 OVERALL BLOCK DIAGRAM OF A VSG

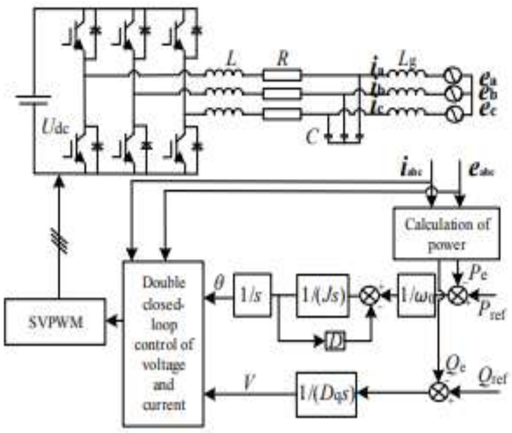

Fig.5.2 Overall block diagram of a VSG.

Control block diagram of a VSG In this figure Udc is the DC side voltage R, L and C are the filter inductor internal resistance, filter inductor and filter capacitor ia, ib and ic are the output currents of the VSG, ea, eb and ec are the three-phase voltage of the grid and Lg is the inductance of the line. The amplitude and phase angle of the reference voltage are obtained by Pref and Qref through the VSG control algorithm and the three-phase modulation wave is obtained after the current instruction calculation and the current closed-loop control.

If the three-phase power grid is unbalanced and only the fundamental wave electromotive force is considered the grid electromotive force can be described as a combination of the positive sequence electromotive force negative sequence electromotive force and zero sequence electromotive force. For a three-phase VSG without a midline connection since there is no zero-sequence current channel the zero-sequence electromotive force has no effect on the power. Therefore the zero-sequence electromotive force is not considered. When the grid voltage is unbalanced the VSG output instantaneous complex power.

Where the positive and negative sequence grid voltage complex vectors and are the positive and negative sequence output current complex vectors. The instantaneous active power and reactive power expressions can be represented as P0 and Q0 are the instantaneous active power and reactive power average components Ps and Qs are peaks of the active and reactive power fluctuations according to the sinusoidal distribution and Pc and Qc are the peaks of the active power and reactive power fluctuations according to the cosine distribution. Since the instantaneous active and reactive mean components are given values only power fluctuation calculations are given here. The values are given by e and i are the instantaneous values of the grid voltage vector E and the current vector I. When the grid voltage is unbalanced the output current contains positive and negative sequence components. The VSG output instantaneous active and reactive power includes 2 times the frequency of the active and reactive power fluctuation components in addition to the average power P0 and Q0 components. Therefore when the grid voltage is unbalanced it is necessary to realize the three control targets of the output current balance and the active power and reactive power fluctuation suppression. The corresponding positive and negative sequence current reference values can be calculated in the following two aspects under dq coordinates.

1) The VSG output current balance i.e. the output current only contains the positive sequence current component while the negative sequence current component is zero. The output instantaneous average active power and reactive power is substituted into the reactive-voltage and active-frequency control loop of the VSG to obtain a constant reference voltage amplitude V and a phase angle θ. This results in obtaining the three-phase reference voltage v* of the VSG. In addition v* is subjected to dq decomposition and positive and negative sequence separation to obtain the positive sequence components and Since v* is the three-phase equilibrium voltage, the negative sequence component is zero and the reference value of the output current positive sequence component is calculated as shown in equation. At this time where and the grid voltage imbalance state is determined. Then and are unchanged. Since the current only has a positive sequence component

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and the voltage contains a negative sequence component it definitely causes fluctuations in the VSG output power.

2) The output active and reactive power of the VSG are constant i.e. twice the grid frequency fluctuations of the active and reactive power are eliminated. At this time equivalent to adding a certain component of the negative sequence currents and the active and reactive constant negative sequence current reference can be obtained. This value is calculated as shown in equation. Since there is a negative sequence current the fluctuations of the active power or reactive power are correspondingly reduced and the imbalance of the output current increases accordingly. Therefore a comprehensive equilibrium point needs to be found between the three control targets to improve the output power quality of the VSG when the grid voltage is unbalanced. The negative sequence current is zero the power is very large and when the active or reactive power fluctuation is zero it leads to an increase in the output current imbalance. Therefore based on the establishment and derivation of integrated wave function expressions of the current imbalance the active power fluctuation value and the reactive power fluctuation value this project analyzes the mutual constraint relationships among the three and designs a VSG integrated control strategy to minimize the fluctuations of a VSG under grid voltage imbalance.

VI.CONCLUTION

In this paper a VSG-based coordinated control for a back-to-back motor drive system in order to provide frequency regulation support for the grid by utilizing the kinetic energy stored in the rotating load connected such as blowers, fans, pumps and compressors for space heating cooling. The proposed control scheme inherits the advantages of the VSG control such as PLL-free and providing synchronizing power. Throughstability analyses simulation studies using MATLAB Simulink. The tests using a commercial blower the following features of the proposed system are confirmed. 1) The proposed motor drive system can suppress the grid frequency deviation and the ROCOF more efficiently than PLL-based methods such a sowing to a faster response and a lower sensitivity to grid voltage unbalance and distortion. 2) The parameters need to be properly tuned to separate the bandwidths of the control loops in a cascaded structure. Nevertheless the parameters are tolerated in wide ranges. 3) The proposed control system does not affect the basic function of a motor drive system i.e., adjustable motor speed operation at a steady state. 4) A proposed function allows the user to restrict the motor speed variation within a predefined range while providing grid frequency regulation support.

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