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Harmonic Analysis of DFIG Wind Turbine

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Abstract:- This proposal investigates the self-excitation of the asynchronous generator while operating in an isolated mode. With this research, we hope to improve the quality of electrical energy produced under various environmental conditions and to promote the use of renewable energies throughout rural areas in order to better support rural areas in the areas of educational advancement, clean water access, livestock and agriculture development, and information and communication dissemination. The focus of this project is on the description and modeling of the wind turbine's many mechanical components. In addition, the asynchronous generator under self-excitation is modeled in steady-state and transient modes. In both vacuum and charge, test results and simulations have shown the impact of the wind system's self-excitation capability on its output quantities (voltage, current, and torque) (resistive and inductive). The amplitude, waveform, and frequency of the asynchronous wind turbine are imposed on the network when it is connected. The asynchronous machine, on the other hand, has a low power factor, which indicates that it needs reactive energy at isolated spots. We may remedy this irregularity by employing variable capacitors to increase the power factor. The reactive power (excitation current) must be continuously provided in accordance with the connected load. This necessitates the use of an intelligent energy management system.

At 3-10 mph dominating winds and 4-6mph average yearly wind speeds, the widespread use of 7–15meter diameter wind turbines (WT) is explored. Power characteristics of WT may be generated using a technique that considers the distribution of wind flow and electric energy consumption patterns. We've investigated the frequency-controlled asynchronous generator wind turbine control algorithms to enable rotor braking in partial loading, stabilizing nominal power, and complete stop modes. Analyzing the combined mechanical properties of a wind turbine and a generator illustrates this strategy. Gain-frequency control and automated distribution of produced power between self-contained power grid consumers and static energy storage are discussed in this wind turbine control system. Based on the generalized energy flow theory of three-phase electromechanical converters, we present approaches for optimizing generator operating modes.

Synchronous & Asynchronous generator mathematical model system

I. INTRODUCTION

Wind turbines include both mechanical and electrical components, therefore this chapter presents a dynamic model of the system to understand the dynamic performance of the system and to build a controller. To begin, the basic equations describe the machine's interaction between voltage and flux. The dynamic model may be derived from these simple equations. We have aerodynamic and mechanical component models as well. This approach also explains the decoupling control of active and reactive power. With this information, we can determine how to implement vector control in a way that maximizes efficiency and minimizes power losses while still maintaining a stable voltage level in the grid. The grid-side converter has two primary goals: control of the DC-link bus voltage and control of the active and reactive powers transferred bidirectionally between the machine's rotor and the grid. This control technique emphasizes these two goals. A complete assessment of the system's behavior is carried out based on the final machine and control system equation modeling, resulting in performance curves that disclose the current, voltage, or various magnitude needs, depending on the machine's unique operating circumstances. Using the Simulink model built in this chapter, the rotor position estimate and the performance comparison findings of the system under unbalanced dynamic behavior will be applied to Chapters Four and Five, respectively.

II. DOUBLY-FED INDUCTION GENERATOR DYNAMIC MODEL

The equivalent circuit of a DFIG shown in figure 3.1 may be described using a variety of various reference frames, such as the stationary frame, the rotor frame, or the synchronous frame oriented to either stator flux [22] or stator voltage [47]. Figure 3.2 of Chapter 3: Mathematical Model of DFIG System illustrates a simplified DFIG model with three windings in each of the stators and rotors. Instantaneous voltages, currents, and flux for this machine are as follows:

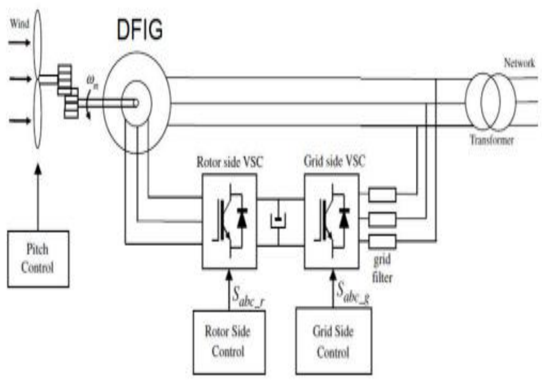

Fig. 1: System configuration of the wind turbine

III. VECTOR CONTROL SYSTEM

Reactive power exchanged with the grid is controlled by the d-axis, which is normally set to zero to operate with a unity power factor. Using an approach similar to the one used to manage the q-component, an error is formed when the measured reactive power is compared to the reference reactive power, which is used to calculate the reference d-axis component of the rotor current. When the error is greater than or equal to zero, the d-axis component's reference voltage may be determined by a second PI controller. Finally, the PWM module is used to compute the modulation indices needed to control the RSC, as illustrated in figure 3.4. There are four PI controllers in the outer control loop depicted in figure 3.4, which judged the rotor currents and voltages in the inner control loop. The stator's active and reactive power transmission functions.

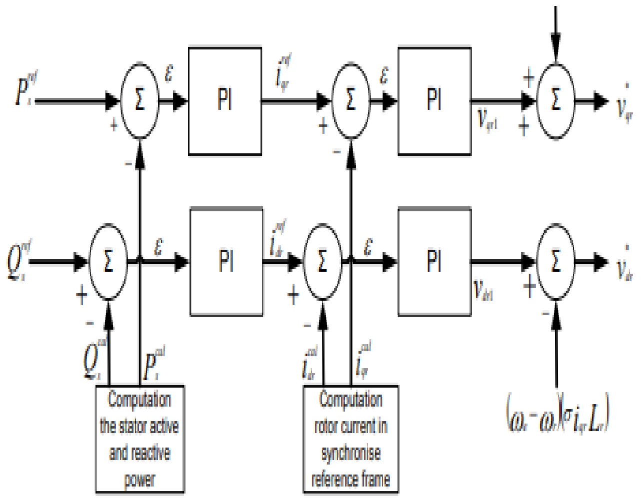

Fig. 2: Block diagram of RSC controller

IV. SYNCHRONOUS GENERATOR

A. Synchronous Generator as a Wind Power Generator

According to the Wikipedia entry on this machine, it is a rotating magnetic field on the rotor that generates electricity, while the stationary stator has many windings to provide the created power. Excitation of the rotor's magnetic field is achieved either by mounting permanent magnets directly onto the rotor or by **energizing** the rotor's field windings with an external DC current.Slip rings and carbon or graphite brushes are used to transfer the DC field current to the synchronous machine's rotor. Sophisticated synchronous generators are easier to build since they don't need complicated commutation. As with an automobile alternator, the synchronous generator has two common components: a motor and an inverter.

Main Components of synchronous Generator

- To produce an AC voltage, the stator physically and electronically displaces three distinct (3-phase) armature windings by 120 degrees.
- Using slip rings and carbon brushes, the rotor connects to an external DC power supply through slip magnets or coiled field coils to carry the magnetic field.

Synchronous generator terminology differs from that of a DC generator in that the machine's components are described using the opposite language. Field windings are the windings that generate the primary magnetic field, while armature windings are the windings that generate the main voltage, which is the stator windings in a synchronous machine. There are two types of windings in the synchronous machine: field windings and armature windings.

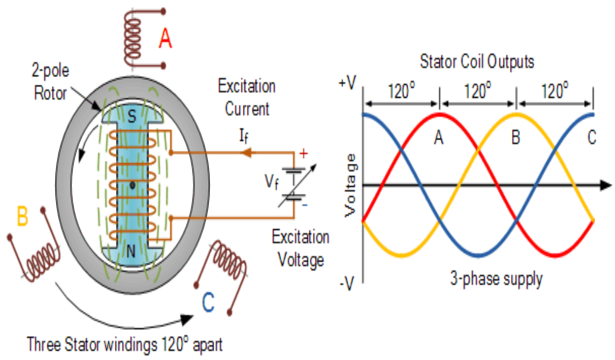

Fig. 3: Synchronous Generator Construction

Using the two-pole wound prominent rotor in the preceding example, we can see the fundamental building blocks of a synchronous generator. In order to generate a field current, this winding is coupled to a DC supply voltage. An electromagnetic field with fixed North and South poles is generated around the coil by an external DC excitation voltage of up to 250 volts DC.

When the turbine blades turn the rotor shaft of the generator, the rotor poles will also spin, creating a rotating magnetic field (assuming direct drive). Every time the rotor spins, an emf and a current are generated in the stator coils as a result of the magnetic flux being cut through them one by one by the rotor. Since the rotor's rotation speed, magnetic field strength, and the number of stator winding turns all depend on the magnetic field's intensity, it's easy to see how stator winding turns **to** affect **the** voltage induced there. Stator windings A, B, and C, which are electrically 120o apart, provide a three-phase voltage supply in the stator windings as illustrated in the diagram above.

Because the coils in this 3-phase stator winding are fixed, they do not need to pass through massive, unreliable slip rings, commentators, or carbon brushes on their way to the load. In addition, the lack of rotational and centrifugal forces in the windings makes it simpler to wound and insulate them, resulting in higher voltages being produced.

B. Permanent Magnet Synchronous Generator

Wound-field synchronous machines need DC stimulation in the rotor winding, as we've seen. On the generator shaft, brushes and slide rings are used to excite it. However, there are a number of drawbacks, such as the need for regular maintenance and the need to clear up carbon dust. Brushless excitation, which **utilizes** permanent magnets rather than electromagnets, is another option.

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C. The Generators Synchronous Speed

Rotor speed and the number of magnetic poles on the rotor affect the output voltage's frequency, which is referred to as "angular velocity." The synchronous machine has two poles, a North pole and a South pole, as shown above. Two poles (North-South) or one pair of poles (North-South) are used in the machine.

One cycle of induced emf is created for every 360o rotation of the rotor, hence the frequency will be one cycle per entire revolution. It is possible to produce two more induced emf cycle cycles for every rotor rotation by increasing the number of magnetic poles to four (two pairs).

The number of induced emf cycles generated by a single pair of poles, P, is consequently equal to the number of pole pair revolutions produced by the rotor. This means that if we use P/2 for the number of cycles per revolution and N/60 for the number of rotations per second, we can get the frequency () of the induced emf as follows:

$$\text{Frequency}, (f) = \frac{P}{2} \times \frac{N}{60} = \frac{PN}{120} \text{ Hz}$$

If you're using 50Hz or 60Hz appliances, you'll need to keep the generator's speed constant at 50Hz or 60Hz in order to maintain the needed frequency of 50Hz or 60Hz for your appliances. The rotor's mechanical rotation is **synchronized** with the frequency of the emf generated.

When employing a two-pole machine, the rotor must revolve at 3600 revolutions per minute, whereas a four-pole machine must rotate at 1500 revolutions per minute. In the case of a wind turbine synchronous generator, this synchronous speed may not be attainable due to the continuously changing wind speed and power. This may be simple to accomplish with an electrical motor or steam generator-driven synchronous generator. Our last wind turbine design lesson taught us that the rotor's ideal tip speed ratio is critical for all wind turbines. It's very uncommon for blades to have an angular velocity between 100 and 500 revolutions per minute, thus to get a TSR of 6 to 8 we would need a synchronous generator with at least 12 magnetic poles. It is also necessary to have some kind of speed limiter like a CVT to maintain the rotor blades revolving at their maximum speed in a direct drive wind turbine system. In contrast, the more poles a synchronous machine has, the bigger, heavier, and more costly it gets, which may or may not be acceptable.

A gearbox-driven synchronous machine with fewer poles and a greater rotational speed of 1500-3600 rpm is one option. Increasing the rotor blades' low rotational speed via a gearbox permits the generator speed to stay more stable when the **turbine** blade speed varies since a 10% **chance** at 1500rpm is less of a concern than a 10% **chance** at 100rpm. As the generator's speed fluctuates, this gearbox allows it to be used at a broad variety of speeds, making it more flexible.

As a result, the usage of a gearbox or pully system needs frequent maintenance, which adds weight to the wind turbine; produces noise; increases power losses**, and** affects system efficiency as more energy is needed to operate the gearbox's gears and internal components.

The absence of a mechanical gearbox in a direct drive system has several benefits, but it necessitates a bigger synchronous machine and a more expensive generator, both of which must run at low speeds. So, how can we run a synchronous generator in a low-speed wind turbine system whose rotor blade speed is solely dictated by the wind's power? This may be done by converting the 3-phase supply into a continuous DC supply.

D. Synchronous Generator Rectifiers

When converting AC to DC, electronic devices called diode rectifiers are used (direct current). The synchronous generator output may be rectified into a DC supply, allowing the wind turbine generator to operate at speeds and frequencies other than the specified synchronous speed.

The variable frequency and changeable voltage output of the generator may be used to create a variable DC voltage. Once it's been converted from AC to DC, the generator may be used to charge batteries or power a variable-speed wind turbine. Alternator-generator is subsequently transformed into the direct current generator.

Generator AC is converted to variable DC supply, which in turn relies on the generator rotational speed, through diode bridge circuits, which are the most fundamental rectifier circuits. In this synchronous generator rectifier circuit, a 3-phase rectifier converts the generator's three-phase output to direct current (DC).

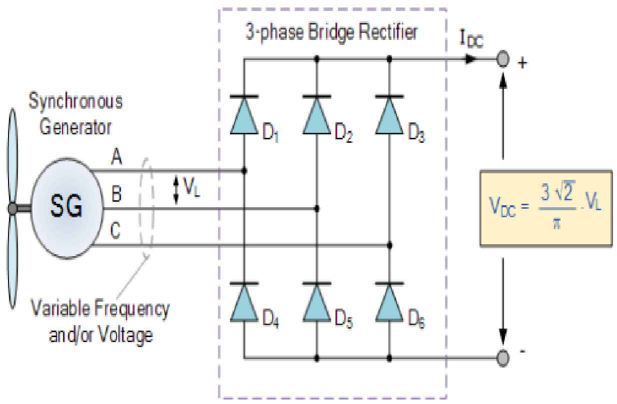

Fig. 4: Generator Rectifier Circuit

Above is a schematic for a three-phase, full-bridge AC to DC rectifier. Changing the generator speed alters the generator frequency, thus the wind turbine may run its generator at a frequency independent of the synchronous frequency. As a result, based on the real wind speed, the generator's speed may be varied throughout a greater range and operate at the best speed to get maximum power.

There is a little amount of non-DC voltage coming out of the 3-phase bridge rectifier. Both a DC level and a significant AC variance may be seen in the output voltage. "Pulsating DC" is a common term for this waveform, which may be used to charge batteries but is not suitable as a DC source. A filter or smoothing circuit is used to eliminate the AC ripple content. Using a mixture of inductors and capacitors, these ripple filters provide a smooth DC voltage and current.

Only when their frequency, phase angle, and output voltage are identical to the grids, as we saw above, can synchronous machines be linked to the mains grid as part of a grid-connected system. As a result, we may use either a single-phase or three-phase inverter to match the utility grid's frequency and amplitude by rectifying their output voltage and frequency into a continuous DC supply.

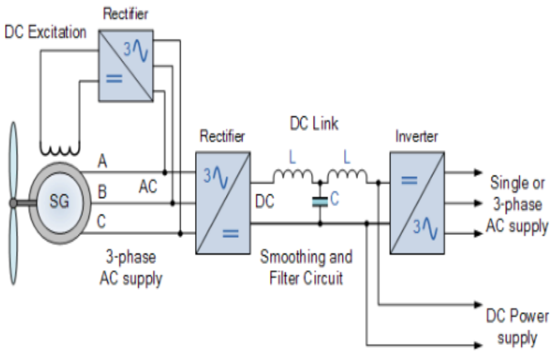

Fig. 5: Synchronous Generator Circuit

E. Synchronous generator

However, one of the biggest drawbacks of wind power turbine generators, the wound rotor synchronizer, is that it may be very difficult and expensive to construct. In order to achieve high synchronous speed, gearless direct drives need a huge number of poles in their rotors. Due to the increased spinning speeds, a gearbox or drive train is required for generators with fewer poles.

The fundamental output frequency of synchronous generators is synchronizedwith the rotor's rotating speed. Slip rings and brushes are used to excite the rotor windings of grid-tied generators, which must maintain a set speed to match the utility grid frequency.

The fixed-speed operation has the significant drawback of not capturing the maximum amount of wind energy possible. In situations when the wind speed exceeds or falls short of the predetermined synchronous speed, wind energy is squandered.

Another sort of electrical equipment, the Induction Generator, often known as an "Asynchronous Generator," will be the subject of our next lesson on Wind Energy and Wind Turbine Generators. Three-phase grid-connected AC energy may also be generated using asynchronous generators.

V. SIMULATION & RESULTS

A. Analysis of Turbine Characteristics: MATLAB

Wind turbines of both horizontal and vertical axes are employed in wind power systems. Because the vertical barriers (egg beater) type is positioned on the ground, it can take the wind from any direction without the need for yaw mechanisms, and hence is recommended for high power output. The downsides include a significant pulsing torque that is dependent on wind speed, turbine speed, and other turbine design parameters, as well as a lack of self-starting capability. A vertical turbine's aerodynamic torque may be measured.

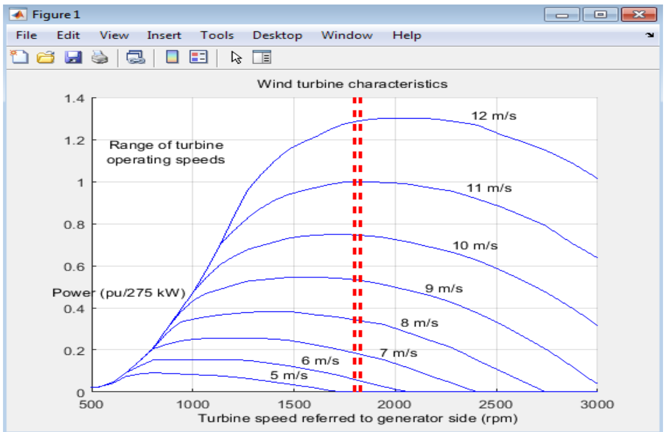

Fig. 6: Wind Turbine Characteristics

Tip-speed ratio (TSR) is defined as the ratio of turbine blade speed to free stream wind speed in a comparable but continuous region, while power coefficient (C) is defined as the ratio of actual power provided to the free stream power flowing through a similar but uninterrupted area. At first, second, and fourth harmonics of the basic angular velocity of a turbine, the oscillatory torque is more dominating and is described by the equation.

B. MATLAB

It is possible to separate the thesis from the remainder of the paper. The primary goal is to get you up and running as fast as possible. It's important to remember that "doing" is the key here. Consequently, the greatest way to learn is to do it for yourself first. You'll get a better understanding of MATLAB by working through the examples. Mathematical formulae and basic numerical expressions will be covered in this tutorial. The acronym MATLAB stands for MatrixLaboratory. Matrix software produced by the LINPACK and EISPACK teams was the initial inspiration for MATLAB's development. One of the most powerful languages for technical computing is MATLAB [1]. Computing, graphics, and the programming environment are all integrated into one. As an example, MATLAB provides an extensive set of data structures and tools for editing and debugging, as well as support for object-oriented programming. For teaching and research, MATLAB is a good choice. Comparing MATLAB to more traditional computer languages (such as C and FORTRAN), there are several benefits of using MATLAB to solve technical challenges. MATLAB is an interactive system that uses an array as its primary data type, which eliminates the need for any kind of dimension operations. Since it became commercially accessible in 1984, the software package has become a standard at many colleges and businesses throughout the globe. It features a robust set of built-in algorithms that can perform a broad range of calculations. In addition, it contains simple graphics instructions that allow for the instant presentation of findings. Toolboxes are collections of specific applications. Many domains of applied science and engineering have their own toolkits, such as signal processing, symbolic computing, control theory, simulation, and optimization, to name a few.

As soon as you've signed into your account, just double-click the shortcut for MATLAB on your Windows desktop (MATLAB 2021). The MATLAB desktop is a specific window that displays when MATLAB is launched. One might think of the desktop as a collection of other windows. The Command Window is one of the most useful features on the desktop.

- A chronology of the commands
- This Is Where It's At
- the most recent version of the encyclopedia
- Web-based Help
- Pressing the Power button

C. Wind-Turbine Asynchronous Generator Synchronous Condenser with Excitation in Isolated Network

MATLAB Simulink Sim Power and extremely realistic models of the system components were used to implement the suggested technique. The system components were simulated at a time step of 5 microseconds in order to reflect their genuine behavior. Wind gusts and load step changes in wind profile and load profile, respectively, are utilized to synthesize the worst system circumstances in a RAPS system to demonstrate the resilience of the proposed technique. Using these worst-case situations, the suggested control method may be shown in terms of voltage and frequency regulation. The suggested RAPS system in Fig. 4.1 is put to the test under a variety of load and wind speed variations to see how it performs. Simulated DC link stability, DC link stability, hybrid energy storage performance, and maximum power extraction from wind were all evaluated in this respect. Appendices A and B include a detailed description of the RAPS system and the PMSG-based wind turbine generator. Variable wind and load conditions were used to evaluate the reactions of the RAPS system components.

Figure 4.2 depicts the RAPS system's voltage and frequency characteristics, while Figure 4.3 depicts the system's power-sharing across its many components. Figure 4.5 depicts the wind condition in which the system was simulated. In this example, the wind speed is set at 12 m/s at the start. It dips to 9 mph after and then increases to 10 mph by the end of the day. It is set to 0.5 pm, which means that the power factor of the load demand is 0.8. (i.e., real power demand is 0.4 pu). Increasing the load by 0.8 power factor to 0.86 pu takes place at the specified time. There is no added burden (i.e., 0.36 pu having a power factor of 0.8)

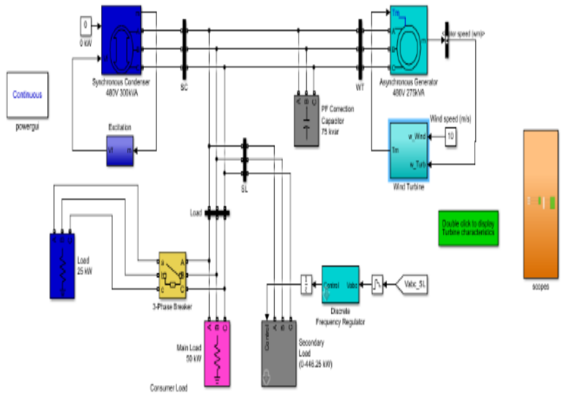

Fig. 7: isolated wind turbine asynchronous generator.

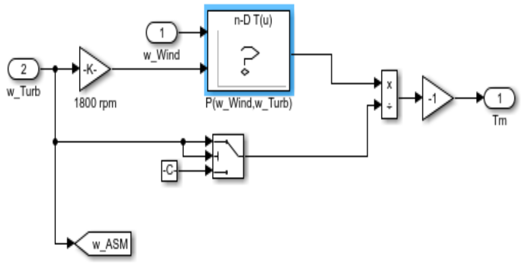

Fig. 8: Sub-System Wind turbine

D. Description

This example [1] illustrates a generic HPNSWD system with high penetration and no storage. [2] Hydro-Quebec developed this technique to lower the cost of providing energy to isolated northern towns. Wind penetration (wind capacity installed/peak electricity demand) is influenced by the cost of fuel transportation and wind availability at the location. Northern Power Systems (Vermont, USA) commissioned the first commercial implementation of HPNSWD technology in 1999 on St. Paul Island, Alaska [3]. An induction generator with a 480 V, 300 kVA output, a wind turbine, a 50-kW customer load, and a variable secondary load make up the HPNSWD system shown in this example (0 to 446.25 kW).

An induction generator and a synchronous diesel generator are needed to meet the load requirements when the wind speed is below a certain threshold. The diesel generator may be turned off when wind power exceeds demand. Synchronous machines may be employed as condensers in this all-wind mode since their excitation systems keep the grid voltage stable. To maintain the system's frequency, a secondary load bank is employed to absorb excess wind power generated by the wind turbines.

Eight sets of three-phase resistors are linked in series with GTO thyristor switches in the Secondary Load block. There is a binary progression in the nominal power of each set, allowing the load to be adjusted from 0 to 446.25 kW in increments of 1.75kW. Ideal switches are used to model GTOs.

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E. Simulation

A model of wind turbine operation is shown below when a 10-meter-per-second wind speed provides sufficient energy for running the load. To imitate a synchronous condenser, the synchronous machine's mechanical power input (Pm) is adjusted to zero and the diesel generator is turned off. The example shows how the frequency control system works dynamically when a 25 kW extra customer load is turned on.

As soon as the simulation has begun, look at the voltages, currents, and powers on the two scopes, as well as the asynchronous speed of the machine and the overall system frequency. Your workspace has been pre-loaded with the initial circumstances (initial vector) so that simulation may begin in a steady state.

In generator mode, the asynchronous machine's speed is somewhat higher than the synchronous speed (1.011 pu). The turbine's output power is 0.75 pm at 10 m/s wind speed, according to turbine parameters (206 kW). Because of the losses in the asynchronous machine, the wind turbine generates 200 kW. The secondary load absorbs 150 kW to maintain a steady 60 Hz frequency while the primary load is 50 kW. It is activated at the time of t=0.2 seconds. During a brief dip in frequency, the frequency regulator reduces the amount of power the secondary load consumes for the frequency to return to 60 Hz. The voltage remains at 1 pU, and there is no flickering.

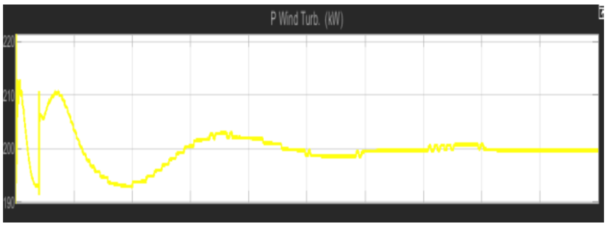


Fig. 9: Power of Wind Turbine

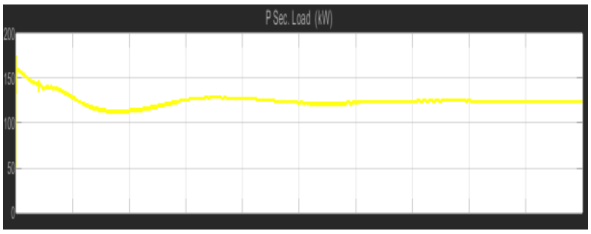


Fig. 10: Power of Wind Turbine of Load

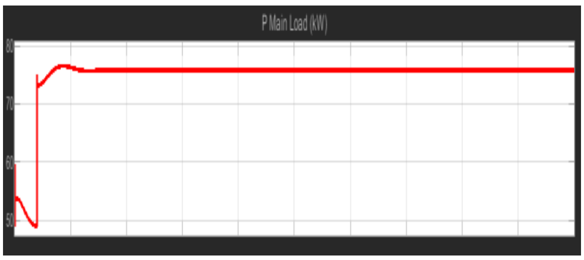
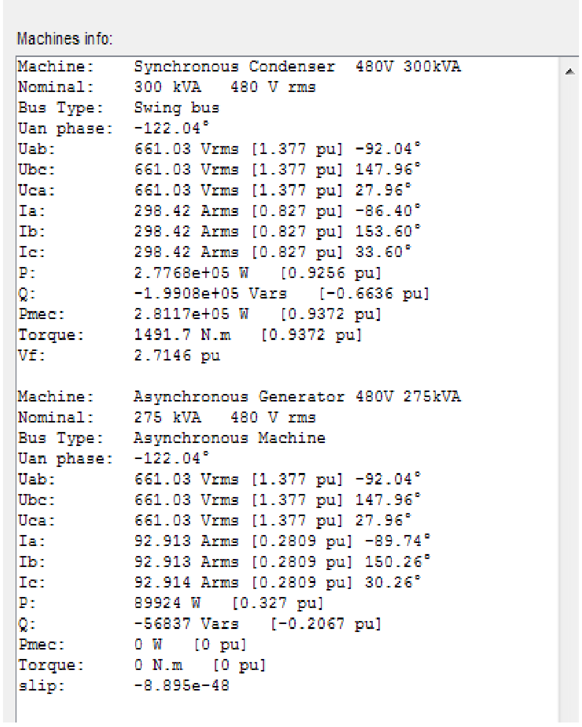


Fig. 11: Power of Wind Turbine Main Load


Machines info:

Machine: Synchronous Condenser 480V 300kVA
Nominal: 300 kVA 480 V rms
Bus Type: Swing bus
Uan phase: -122.04°
Uab: 661.03 Vrms [1.377 pu] -92.04°
Ubc: 661.03 Vrms [1.377 pu] 147.96°
Uca: 661.03 Vrms [1.377 pu] 27.96°
Ia: 298.42 Arms [0.827 pu] -86.40°
Ib: 298.42 Arms [0.827 pu] 153.60°
Ic: 298.42 Arms [0.827 pu] 33.60°
P: 2.7768e+05 W [0.9256 pu]
Q: -1.9908e+05 Vars [-0.6636 pu]
Pmec: 2.8117e+05 W [0.9372 pu]
Torque: 1491.7 N.m [0.9372 pu]
Vf: 2.7146 pu

Machine: Asynchronous Generator 480V 275kVA
Nominal: 275 kVA 480 V rms
Bus Type: Asynchronous Machine
Uan phase: -122.04°
Uab: 661.03 Vrms [1.377 pu] -92.04°
Ubc: 661.03 Vrms [1.377 pu] 147.96°
Uca: 661.03 Vrms [1.377 pu] 27.96°
Ia: 92.913 Arms [0.2809 pu] -89.74°
Ib: 92.913 Arms [0.2809 pu] 150.26°
Ic: 92.914 Arms [0.2809 pu] 30.26°
P: 89924 W [0.327 pu]
Q: -56837 Vars [-0.2067 pu]
Pmec: 0 W [0 pu]
Torque: 0 N.m [0 pu]
slip: -8.895e-48

Fig. 12: Wind Turbine Parameter

F. Deconstructing Signals Using the FFT

Using the Fourier transform, a signal may be deconstructed into its frequency-domain representation from a time-domain representation. Violating frequencies are shown in the frequency domain. It's a new perspective on the same signal.

It is the digitizer's job to digitize waveform data into discrete values. This data cannot be subjected to the Fourier transform as a result of the transformation. An alternative is the discrete Fourier transform (DFT), which yields discrete values, or bins, for the frequency domain components. FFT is a more efficient way to dissect a signal than a standard discrete-time Fourier transform (DFT). The signal in Figure 1 shows you what I'm talking about. This particular signal contains two frequency domain spikes, one for each of the two sines that made up the signal in the first place: a high and a low-frequency signal.

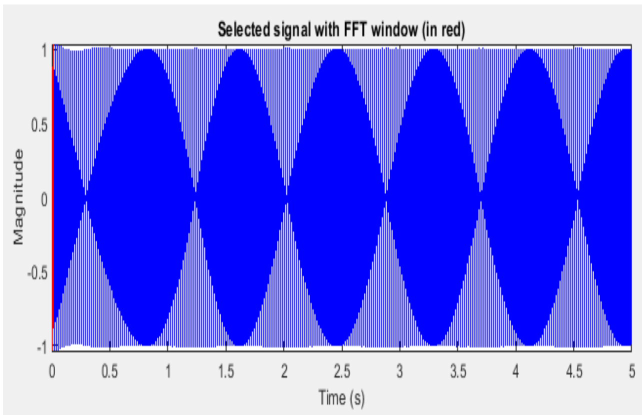


Fig. 13: Voltage of Wind Turbine Vabc(PU) FFT window

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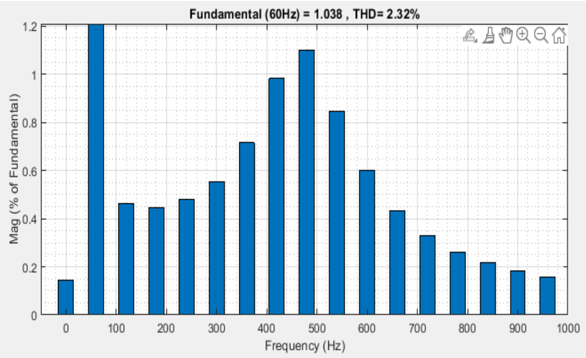

Fig. 14: THD analysis Voltage of Wind Turbine Vabc(PU)

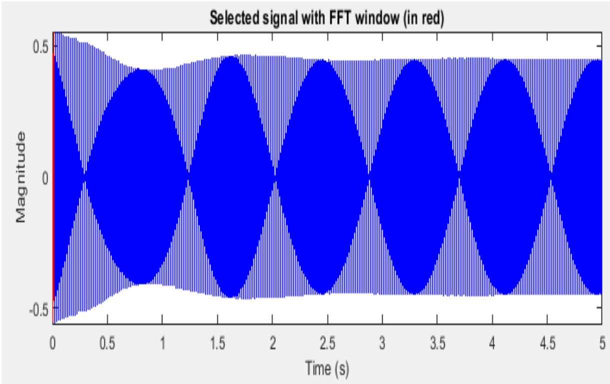

Fig. 15: Current of Wind Turbine FFT windowIabc load (PU/275Kva)

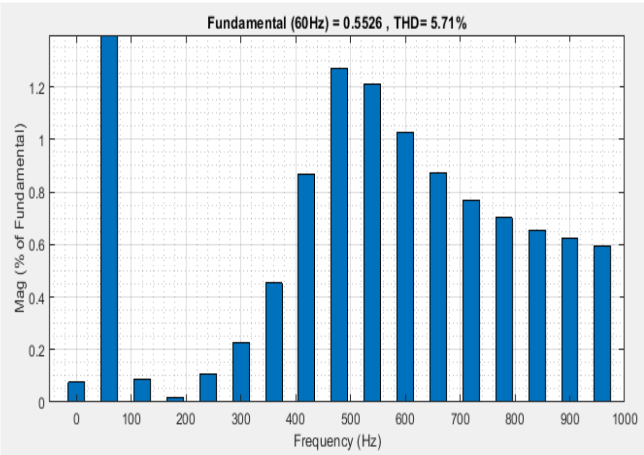

Fig. 16: THD analysis Current of Wind Turbine FFT window Iabc load (PU/275Kva)

G. Maintain the state of things as they were when you started

The simulation begins in a steady-state condition with all states initialized. A file named "power wind gen. SLX" contains a record of the beginning circumstances. The contents of this.mat file is automatically loaded into your workspace when you open this model using the InitFcn callback (found in Model Properties/Callbacks) ("initial" variable).

The starting conditions recorded in the "initial" variable will no longer be valid if you edit this model or change parameter values for power components. Simulink will generate an error notice. For your updated model's beginning circumstances, complete these steps:

- Uncheck the "Initial state" option in the Configuration Parameters window.
- The 3-Phase Breaker block may be disabled by double-clicking the 3-Phase Breaker block " (deselect "Switching of phase X" parameters for phases A, B, and C").
- In step 3, set the Simulation Stop Time to 20 seconds. The Stop Time must be an integer number of 60 Hz cycles to produce beginning circumstances that are consistent with the 60 Hz frequency.
- The simulation may now begin. When the simulation is complete, check the waveforms on the scopes to see whether the steady state has been achieved.
- Check "Initial state" in the Configuration Parameters window in step no.
- Simulate to ensure that your model is stable at startup.
- Repeat steps 7 and 8 to re-enable breaker switching " (check "Switching of phase X" parameters for phases A, B, and C").
- Revert the Simulation Stop Time to 5 seconds
- Please save your model before proceeding to the next step.

VI. SYNCHRONOUS GENERATOR ISOLATED NETWORK WIND TURBINE

Operating a wind turbine generator on its own in the face of changing wind and load circumstances is tough in this scenario. In addition, the limited reactive capabilities of the wind generation system make it more difficult because of the high demand for reactive power. Distinct Frequency Regulator blocks govern the frequency. The eight three-phase secondary loads are switched using an 8-bit digital signal generated from this analog signal. Switching is done at the zero crossing of the voltage to reduce voltage disruptions.

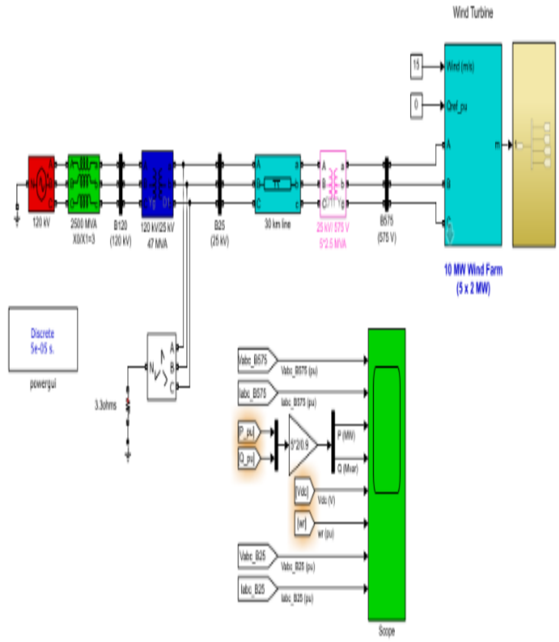

Fig. 17: isolated wind turbine synchronous generator

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A. Wind Turbine Modeling and Simulation

VSC-based energy conversion systems linked to power grids may be modeled using three different modeling approaches in Specialized Power Systems. Such a fine-grained representation (discrete) is that shown in the model named power wind type 4 diet. Power electronic IGBT converters are shown in great detail in the model. The model must be discretized at a reasonably short time step to obtain acceptable accuracy with the switching frequencies of 2000 Hz and 3000 Hz in this case (2 microseconds). Over very short periods, this model is ideal for monitoring harmonics and control system dynamics (typically hundreds of milliseconds to one second).

The typical discrete model is like the one seen here. There are analogous voltage sources that generate the average AC voltage over one cycle of the switching frequency in this sort of model for the IGBT Voltage-sourced converters (VSC). A DC-DC converter also employs a similar approach. Harmonics are not included in the average model, but the dynamics arising from the interplay of the control system and the power system are. In this paradigm, the time increments are substantially greater (usually 50 microseconds), enabling simulations lasting several seconds.

The "power wind dfig" model in the Renewable Energy examples library uses a phasor model (continuous). There is a better fit with this model for the long-term simulation of low-frequency electromechanical oscillations (tens of seconds to minutes). A complex number is used instead of sine waves to simulate the sinusoidal voltages and currents of a system using the phasor simulation approach (50 Hz or 60 Hz). Transient stability software employs a similar method.

B. Description

A 30 km, 25 kV feeder transports electricity from a 10 MW wind farm, which consists of five 2 MW wind turbines, to a 120 kV grid. A synchronous generator, a DC-DC IGBT boost converter, and a DC/AC IGBT PWM converter based on voltage sources make up the wind turbine in this example. The method optimizes the turbine speed to capture maximum energy from the wind at low wind speeds while reducing mechanical stress on the turbine during gusts of wind. The wind speed is maintained at 15 m/s in this case. The DC-DC converter's control mechanism is utilized to keep the speed at 1 p.c. At 0 Mvar, the wind turbine's reactive power is controlled.

For an overview of the model's construction, you may "Look Under Mask" by selecting "Wind Turbine Type 4" from the context menu. The initialization function of the Model Properties specifies a sampling time of 50 microseconds for discretizing the model.

If you're interested in learning more about the components of a wind turbine, you may do so by accessing the "Wind Turbine " block menu. Select "Turbine data for a single wind turbine," check "Display wind turbine power characteristics," and then click Apply in the Display menu Figure 4.12 shows the Cp curves of the turbines. Figure 2 shows the relationship between wind speed and the power output of the turbine, the lambda tip speed ratio, and the Cp value. The Pitch angle is 8.9 degrees, and the generator speed is 1 pu when the wind speed is 15 meters per second. The turbine's rated power output is 1 pu at this wind speed.

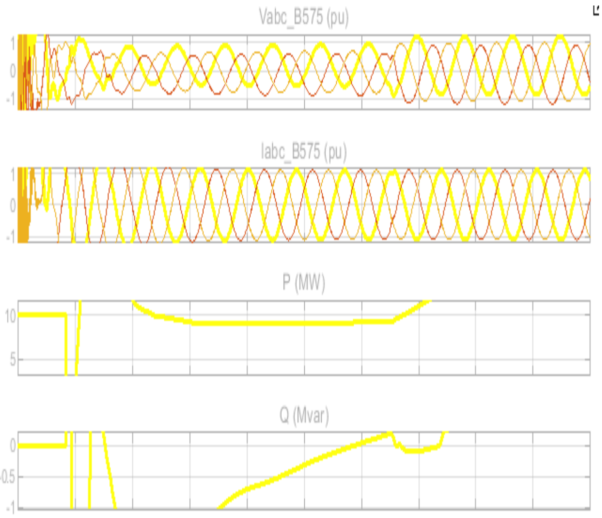

Fig. 18: Isolated wind turbine synchronous generator Vabc_B575(pu),Iabc_B575(pu),power.

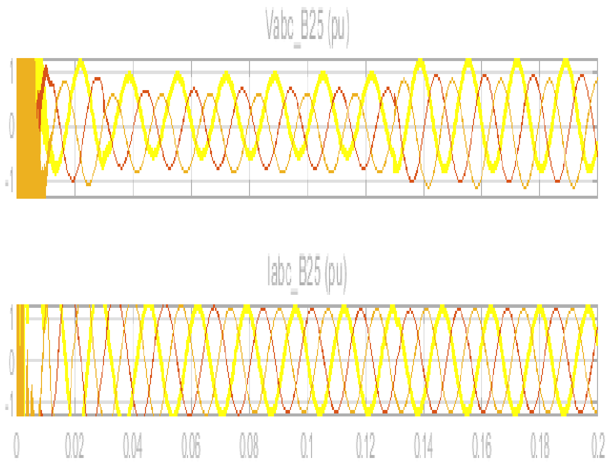

Fig. 19: Isolated wind turbine synchronous generators Vabc_B25(pu), Iabc_B25(pu)

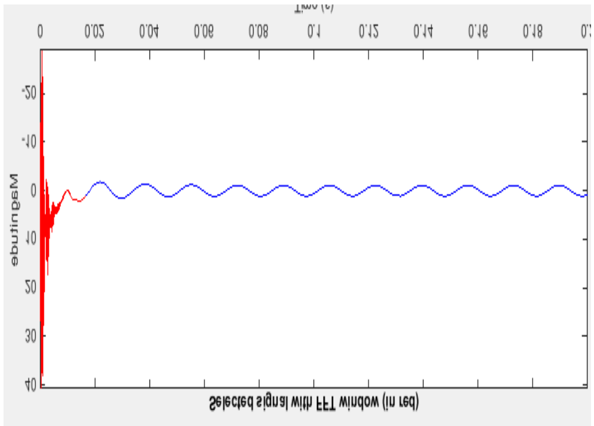

Fig. 20: Current of Wind Turbine FFT window Iabc load

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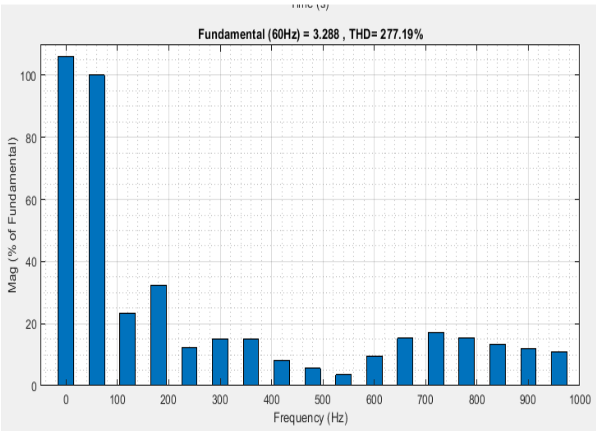

Fig. 21: THD analysis Current of Wind Turbine FFT window Iabc load (pu/275Kva)

VII. CONCLUSION

As part of this research, a PMSG with an integrated battery and supercapacitor, as well as a synchronized condenser and a dump load, was operated independently for the first time. The complete RAPS system is modeled under over- and under-generation situations, including wind gusts and load step changes, to emulate the most severe operational conditions. For the reach system component, the effectiveness of the chosen control technique is evaluated by looking at how much it helps to regulate the load side voltage and frequency. The voltage and frequency control at the load side, the DC bus stability, the maximum power extraction capacity of wind turbine generators and the performance of the hybrid energy storage system have all been examined.

The simulated behavior shows that the suggested technique is capable of controlling voltage and frequency within strict bounds under all situations, including the worst-case scenarios, such as wind gusts and load changes. Supercapacitor-based energy management further improves battery storage performance because it absorbs demand generation mismatch ripple while allowing the stable component of the power to be stored in batteries. In addition, the supercapacitor prevents battery operation in places with a high rate of the depth of drain. For the duration of its operation, the proposed control algorithm is capable of maintaining a power balance in the RAPS system while maximizing wind power production. For all scenarios, even when the reactive power demand is very high, the RAPS system can keep the load voltage within acceptable limits with the addition of the synchronous condenser.

The back-to-back converter's vector control method and aerodynamic, mechanical, and electrical components and controllers are all part of this investigation's model and design ideas. We looked at how well the system performed under typical conditions. This research examines the DFIG-based wind turbine in two operating modes: sensor and sensorless vector control. Using a PI controller and QRMRAS algorithm, the rotor position was detected and its performance was compared to that of RCMRAS. QRMRAS and RCMRAS dynamic rotor detection parameter modifications have been studied.

The integrated error index was used to assess the quality of the system response; the integral of time multiplied by absolute error and the integral absolute error were used as criteria. It has been determined that the QRMRAS delivers lower values of ITAE and IAE than the RCMRAS in a systematic study of rotor angle detection.

VIII. FURTHER WORK

Future development, enhancement, verification, and analysis of the current project are several avenues for overcoming its current constraints. The following suggestions are possible.

The simulation findings presented in this work should be verified if feasible by conducting experimental sets of tests A better fault ride through (FRT) capability and sensorless control techniques might be developed with the verification effort. In addition, the proposed system should be field validated before it can go into production. To simulate a genuine voltage drop, you may use a small-scale kit DFIG system that behaves like a full-scale machine. You need also to utilise a suitable grid simulator.

- After grid disruptions, an inquiry into voltage recovery should be conducted using interaction among wind turbines in wind farms.
- Additionally, the usage of QRMRAS in DFIG-based stand-alone systems with diverse operating circumstances should be examined for its accuracy and sensitivity.
- Converter protection solutions for asymmetrical faults are still needed for the DFIG system since these failures create persistent negative sequence components whose effect continues for the length of the voltage drop.
- The power converter controller of the DFIG should be improved to contribute to the FRT capabilities for longer-lasting problems.
- There should be a greater focus on developing a strong DFIG system when developing complete speed and frequency deviation prevention mechanisms.

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