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A REVIEW OF INDUCTION GENERATOR BASED MICROGRID ACTIVE AND REACTIVE POWER CONTROL

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ABSTRACT

As a result of development and population growth, there is an increase in the need for electricity. The majority of electricity produced today comes from non-renewable energy sources, which are expensive to use and have negative environmental effects. Because of this, the world is looking for renewable energy sources, such as wind and small hydro that are both sustainable and environmentally friendly. These forms of energy are affordable and environmentally benign. Induction generators are currently employed extensively in place of synchronous generators in the majority of wind energy or small hydro projects. A cheap, low-maintenance, and effective solution for using renewable energy is provided by induction generators.The induction generator's link to the grid causes it to operate concurrently with the synchronous generators, which presents difficulties for the grid operators. Therefore, the review of many elements of induction and synchronous generator operating under diverse circumstances is the main topic of this study. The dynamics of both generator types are impacted by changes in load. By adjusting their active and reactive power, voltage and frequency changes can be managed. The major goals are to increase the system's stability and dependability against changes in load and faults while maintaining constant voltage and frequency.

1. INTRODUCTION

Significant work has been done in recent years to improve the use of renewable energy sources. Humanity became interested in these energy sources after realizing that traditional sources would run out eventually. If no replacement is found, it is acknowledged that these resources would soon run out. Due to their free availability, quantity, and environmental friendliness, renewable energy sources are replacing traditional energy sources throughout the entire world. With the aid of induction generators, the usage of renewable energy sources based on wind and small hydro is heavily considered [1]. Synchronous generators are utilized to produce electricity in existing power plants, nevertheless.

Different dynamics are displayed by synchronous generators depending on the load. Power generated is transported to the distribution system, then, as needed, to the consumer. Power quality is impacted in this process from generation to distribution. Voltage dip, frequency volatility, and other issues related to power quality are concerns on the system's load side. Controlling the dynamics of the synchronous generator or the excitation and input power to the synchronous generator are two ways to manage these voltage dips and frequency changes. The load is supplied with both active and reactive power by the synchronized generator (SG). According to the behavior of the load, active and reactive power also fluctuate when the load varies.

A grid is created by connecting several SGs in parallel and using that grid to drive the load. Adding an additional SG unit to a grid could be quite expensive, so using a self-excited induction generator

(SEIG) instead of a conventional SG unit is more advantageous. The induction generators have a few benefits, including minimal maintenance requirements, low cost, no synchronization issues, and sturdy construction [2]. A capacitor bank coupled in a delta configuration provides the induction generator's excitation. The induction generator's limitation is that it can only produce constant active power at constant input while also drawing reactive power [3].

Generally, synchronous generators are operated in parallel to provide reliable power at an affordable price, however this method has far lower generation costs than induction generators [4]. In order to provide [5-8] reliable power at an affordable price, parallel operation of synchronous generators and induction generators is used, which is advantageous in small power plants. Micro hydro power plants are utilized to give power to the load in distant places devoid of a main grid. This study examined how well parallel-operated synchronous and induction generators operated. There are several ways to regulate the system's active and reactive power in order to keep the voltage and frequency stable. These methods also reveal systemic issues when the load changes.

2. STRATEGIES

2.1 STATCOM's VOLTAGE-FREQUENCY CONTROL: A managed reactive power source is STATCOM. [9-11] presents a number of schemes outlining the dynamic stability of the system under various load situations, such as R-load, R-L load, and R-L-C load. The voltage received at the load side drops in relation to the voltage at the sending end whenever the load changes. As a result, both the load angle and the quantity of current pulled from the source (in the case of a lagged load) increased.

The usage of VSC-based STATCOM with DSP-based firing modules is employed to address this issue. Fig. 1 displays the method's single line diagram. This results in a three-phase voltage that is introduced into the system to supply the load with the necessary reactive power. By doing this, the voltage is kept constant and the line current is reduced. Based on load, this compensation is given. Additionally, it lessens the mmf (magneto-motive force) load angle between the stator and rotor. By adjusting the firing angle of the VSC, which is based on a DSP module firing angle controller, the injected voltage is adjusted. [9] presents a table with data from various load circumstances representing the value of voltage, current, and load angle.

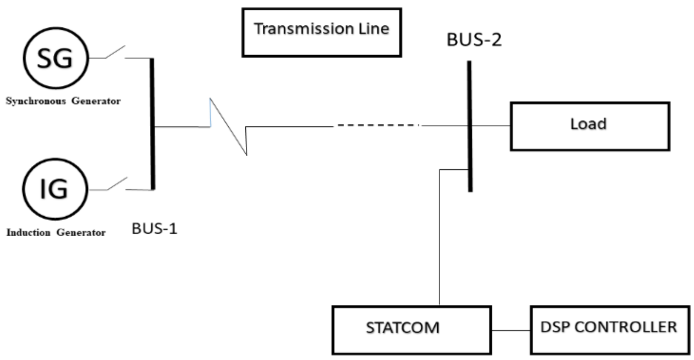


Fig.1: STATCOM Methodology (Single Line Diagram) [9]

2.2 VOLTAGE-FREQUENCY GOVERNANCE USING SVC: To manage the system voltage in this architecture, a hybrid model made up of a Static Var Compensator (SVC) and capacitor bank is used [12]. In terms of contrast, the hybrid system offers superior voltage regulation than the capacitor bank by itself. The capacitor bank is parallel coupled with a three phase, four leg SVC to compensate for reactive power. The star-connected excitation capacitors have a neutral point, and the four-legged SVC has an additional leg. The single-phase load can be connected using this neutral and fourth leg. This hybrid topology in [12] provides the capacitance switching pattern as C, 2C, C+2C, 4C, C+4C. Capacitor switching, which is depicted in Figure 2, is connected to the PWM inverter, which is a component of the SVC. SVC has the ability to regulate current imbalance brought on by imbalanced loading. It offers discrete domain transfer functions for both the internal and external control loops. The reason for this is that all of the variables are changed into dqo reference frames as a result of the control action provided by the DSP controller. It displays the system's behavior at various load switching instants. It demonstrates that operation with just one capacitor outperforms hybrid topology in terms of responses

By lowering SVC's rated power, the capacitor linked in parallel with SVC lowers the system cost. Through this plan, the load at the induction generator will receive a balanced voltage.

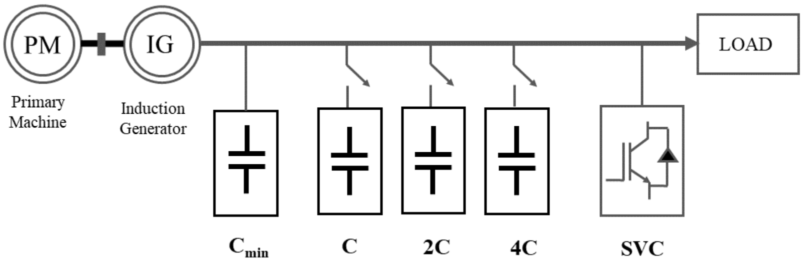
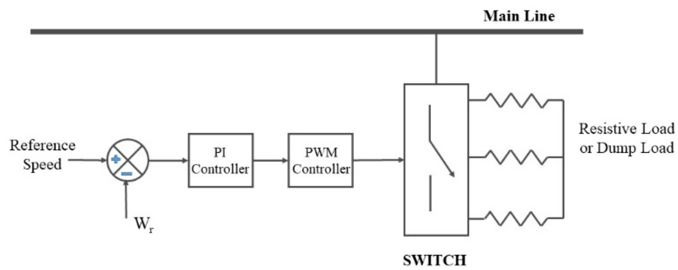
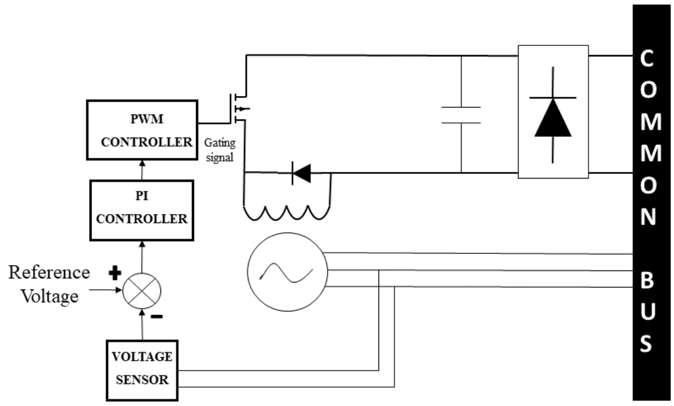


Fig.2 For regulation of Voltage (Hybrid System) [12]

2.3 ELECTRONIC LOAD CONTROLLER ROLL: In order to supply the load with a constant voltage and speed, synchronous generators run in parallel with induction generators in this approach. It is well known that the load changes over time, which may have an impact on the terminal voltage. By offering the excitation control in accordance with the change in load, this terminal voltage is maintained. When we provide a constant excitation current while increasing the load, the terminal voltage decreases. In order to maintain a voltage of 1 pu (per unit), we must modify SG excitation. At lagging load, this excitation power will supply the VARs and maintain a constant voltage. The power input for the SG unit is constant in this system since the governor action is constant. Due of SG's ability to deliver constant active power at constant speed, it is unaffected by changes in load. The induction generator delivers power in accordance with the available head and flow because it lacks excitation and speed control. The constant VAR is provided by the capacitor bank utilized with the induction generator. The SG unit regulates variable or necessary VAR according on the load. Because of the consistent mechanical input, the active power is constant. There would be some extra power that might have an impact on the system's performance if the load demand was lower than the supply active power. Therefore, the system uses an electronic load controller (ELC) to reduce the surplus active power.A dump (resistive) load Electronic Load Controller (ELC) is employed in this manner [13–17]. To maintain a consistent active power throughout the operation, this ELC injects additional active power into the dump load. This technique enables the frequency or speed to be managed. Excitation control and load control are the two main control actions in this scheme, and they are illustrated in Figs. 3 (a) and (b) correspondingly



(a)



(b)

Fig. 3: (a) ELC Control; (b) Dynamically control of excitation system

2.4 CONTROL BASED ON COLLABORATION USING A VIRTUAL SYNCHRONOUS GENERATOR

The aforementioned proposal offers the system connected to a doubly fed induction generator (DFIG) under an unbalanced grid voltage the collaborative control based on a virtual synchronous generator (VSG) [18–22]. In the system, where the main grid is situated at a considerable distance, DFIG is connected. Electromagnetic torque and power fluctuations could happen when DFIG is linked to the grid under an unbalanced voltage state, which could have an impact on the system's frequency and voltage [23].

VSG technique is employed to address this issue. Reduced order generalized integrators (ROGI) are employed in VSG systems. As indicated in Fig. 4, the converters are used on the rotor side converter (RSC) and grid side converter (GSC) of the DFIG. RSC smooths out electromagnetic torque variations, and GSC enhances the output power quality. Both converters compare the dynamic behavior of the PLL-based vector control system to the dynamic behavior of the VSG-based system in order to identify the better qualities. The block diagram for VSG-based V-f control is shown in Fig. 4. The lower order generalized integrator's transfer function and its outcomes are shown in [21].

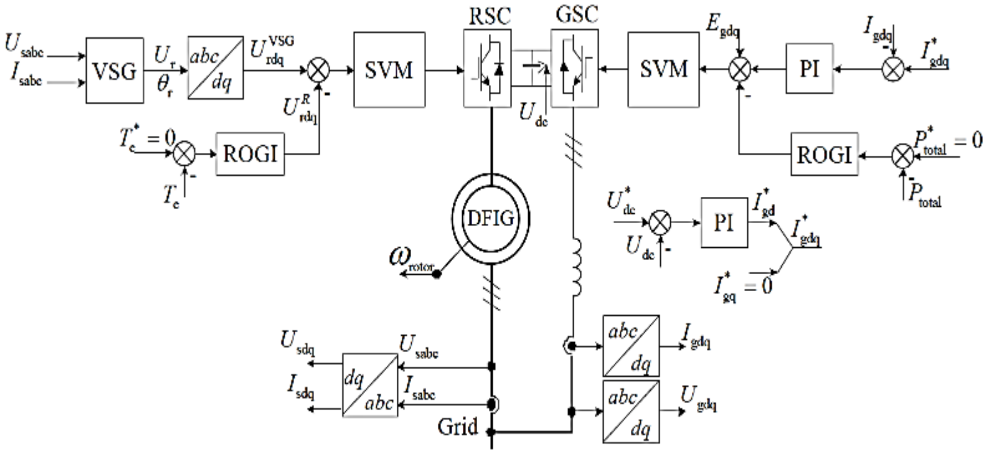


Fig.4: Collaboration of VSG with DFIG

3. DIFFERENT SCENARIO OF OPERATION

3.1 TRANSIENT ACTIONS WHILE UNDER A FAULT CONDITION

The internal emf of the machine, their impedance, and the impedance up until the fault site define the current when a fault occurs in a system. Any machine that has a problem, experiences a transient. The equal area criteria demonstrate the synchronous generator's transient behavior in the presence of a fault, but for the induction generator's asynchronous behavior, this method is not appropriate for induction generator [24–26]. An induction generator's torque speed characteristic determines how stable it is. The mechanical torque and electric torque of an induction generator should be equal for it to operate steadily.The electric torque of the generator is impacted and falls short of the mechanical torque whenever a system fault causes the output voltage and power to reach zero. Slip rises as the generator accelerates.The machine begins to slow down as soon as its electric torque exceeds its mechanical input, which also results in less reactive power being absorbed. Additionally, it slows down the machine's speed. Braking torque is the torque present at this moment. The machine's transient stability can be increased in two different ways [26]:

i. Lowering the rotor reactance, mutual inductance, stator resistance, and stator reactance
ii. Raising the resistance of the rotor

The best strategy is to increase rotor resistance. By increasing the degree of rotor resistance, this broadens the stability region's range. The stable zone for the generator is depicted in Figure in [26].

3.2 ISOLATED INDUCTION GENERATOR EXPANSION

In the case of salient pole SG and SEIG delivering an inductive load, this system is focused on the reliable power supplied at a low cost and minimal maintenance [27, 28]. In order to keep the system stable using this way, either the mechanical input to the system needs to be regulated or power electronic converters need to be employed. The induction generator's (IG) primary machine gives shaft torque to the IG so that it can provide the most active power possible and lessen the load on the SG. The capacitors used to supply IG with reactive power have a value that allows them to supply extra VAR to the load.

As a result, the reactive power provided by SG is reduced. In this procedure, the size of SG can be decreased to increase the size of IG. The sole function of SG in this system is to give controlling action.The biggest drawback of this plan is the possibility of changing the voltage profile if the extra VAR is absorbed by SG. Reactive power needs to be handled in a certain way to address this issue.

3.3 TOPOS FOR EXCITATION CONTROL

Reactive or magnetizing current, which is drawn from the stator supply, keeps the rotating magnetic field of the machine in place. The magnetizing component is managed by a different unit while in generating mode. The following are a few techniques for controlling the magnetizing current or excitation:
a. fixed capacitor;
b. switched capacitor;
c. AC/DC converter;
d. controlled capacitor;
e. capacitor and PWM-controlled inductor;
f. switched capacitor with optimized control based on space vector (SV) theory.
All of these techniques require switching the capacitor using various topologies [29–33], and summary table 2 compares the efficiency of each technique. This technique also generates transient voltage and current, both of which are bad for the system. Additionally, it lowers the equipment's effectiveness and efficiency. Only by switching the capacitor at the point that the voltage crosses the zero line can this transient in voltage and current be mitigated. It is also discussed how the snubber circuit protects the thyristor during L-C switching [29].

The space vector theory-based economic strategy is provided [29] as a means of avoiding the transient problem. By adding or subtracting the condenser group voltage from the reference voltage, a hysteresis controller is utilized to adjust the absolute value of voltage. As a consequence, there are fewer switching devices now. When there is a minimal voltage difference between the capacitor voltages, the condenser group is switched. When the load is at its highest and lowest points, the voltage changes.

4. LIMITATION OF SELECTIVE METHODS AND REPLACEMENTS

Regardless of being used in a contemporary power system, the constraints indicated in the preceding section are explained in this section.Since there is no control over the power input to the system in section-II (c) approach, the frequency is regulated by ELC. Active power is lost when dump loads are used in ELC. This lost active power generates heat, which could have a negative impact on the system's functioning.

The machine experiences a transient state as a result of a significant disturbance or a fault condition in the system. In the event of a sudden short circuit, the machine's capacity to transfer power becomes ideally zero. This causes the system to heat up, which may damage the machine's insulation and cause instruments and gadgets to burn. It also leads in the withdrawal of a lot of current from the system. The machine should have a high transient stability limit to handle this circumstance. The machine's transient stability can be improved by a variety of elements, including high inertia constant, quick fault clearing, raising system voltage, and high-speed circuit breakers.

To give the system the most active power possible, the induction generator runs at maximum capacity. When using an induction generator alongside a synchronous generator, the capacitor bank that feeds VAR to the induction generator and the linked load serves as the reactive power source. This lessens the synchronous generator's need for reactive power. The main drawback of this plan is that the voltage profile will alter if the extra VAR is absorbed by the SG. It is necessary to manage the voltage in order to solve this issue, either by adjusting the synchronous generator's excitation or the capacitor bank's reactive power.

The DC motor serves as the primary mover for both the synchronous and induction generators in the innovative analysis (section-III D). This system's performance [36] can be enhanced by using a power converter in place of the diode rectifier. In a closed loop control action, the power converter is utilized to manage the voltage provided to a DC motor that is coupled with an induction generator. The system becomes more susceptible to changes in load as a result. According to the demands of the load, the amount of active and reactive power is delivered. The system becomes more stable as a result.

To provide the necessary reactive power, each generator unit contains a separate capacitor unit. To maintain the system voltage constant, the bus is additionally connected to another source of reactive power.

The VAR compensator, which is used to regulate the voltage profile, is the source of reactive power besides the capacitor bank. This shows the mathematical analysis of the parallel capacitor unit and VAR compensator design. This design is carried out while taking both ideal and undesirable situations into account. Any IG unit that is malfunctioning will be turned off in order to preserve voltage stability or system stability. The VAR compensator must be able to provide the load with the required additional reactive power (about a 20% increase in rating). This VAR compensator works with a current-controlled VSC and a DC link capacitor, which is utilized to support a DC bus and supply enough reactive power depending on the load.

Depending on the type of load, this compensator behaves like a trailing or leading VAR source. It behaves like an inductor when the voltage surpasses the reference value. Reactive power is used excessively by this inductor.The DC bus capacitor should be able to supply the system with instant energy when the load suddenly changes as well as during transient situations.

5. CONCLUSION

The dynamics of synchronous and induction generators under various loading conditions are examined in this work. This demonstrates various strategies for managing the generators' voltage and frequency as well as for overcoming their technical constraints. Changes are made to the system to control it against loading conditions and during fault conditions in order to increase system stability.These adjustments are accomplished utilizing a variety of devices, including STATCOM, ELC, VSG-based collaborative control, and various excitation control systems. This paper presents and reviews all of these systems in great detail.

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