Double Excited Synchronous Electrical Generator Experimental Investigations

Dr. Pramod Khampariya[1], Lagudu Maheswara Rao[2]
[1]Research Guide, Dept. of Electrical Engineering, Sri Satya Sai University of Technology and Medical Sciences, Sehore Bhopal-Indore Road, Madhya Pradesh, India.
[2]Research Scholar, Dept. of Electrical Engineering, Sri Satya Sai University of Technology and Medical Sciences, Sehore Bhopal-Indore Road, Madhya Pradesh, India

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Abstract
The doubly excited unit can be used as a motor or generator with variable speed. The review's significant spotlight is on the genuine and responsive parts of electrical power age from sporadic energy sources, such water or wind. A numerical model of the machine gives a solitary stage comparable graph, dynamic and responsive energy and conveyance, and consistent state properties. Top to bottom experimental work is led to look at a graphical framework and uncover the expected machine consistent state qualities to distinguish the required generator working modes. The excitation parameters of the twice-excited unit and zero-speed grid synchronizing are next investigated for the turbine's best performance. The speed of the turbines will operate at its best efficiency in these circumstances since the power input to the main mover fluctuates One essential thought that can be shown in this study is the utilization of a double-excited generator in a variable speed creating framework to give an electrically managed and inconsistent turbine speed to guarantee the best activity of the whole framework.
Keywords: Double Excited, Synchronous, Electrical, Generator, Experimental

1. Introduction

Any magnetic fluxes that pass from the poles to the armature can return via the mainframe. The needed magnetic material must be cross-sectional, which is specified by the flow condition and is often carbon steel. (J. F. Eastham, . 1992.) In order to meet the requirements for structural strength, substantially more metal is often required due to the required flow capacity. Rolling ring structures with automated machine end-closing ass, which leave a transparent solder, are the most popular. To create genuine cylinders within the surface and square ends for the board, this circular form must be rotated around. To ensure that the final machine can be constructed without superfluous modification and that the pole-shoes are focused along the frame, the necessary geometric proportions must be maintained. There are always some sort of mounting feet soldered into this frame structure.

The end clocks can also be used to fasten surfaces. The stick sod is the most common structure in vehicle starting motors. At the middle of the frame, these bolts may be visible as hexagonally spaced heads. If there is limited room, these fittings can be counter-sunk. The exterior bolt heads will actually prevent installation of the gadget as tightly as is required since, as stated before, this sinking counter is utilized on a starting automobile. There are different structures on DC mainframes, depending on the make, scale, and application. (C. Liu, 2008.)Some units have inbuilt chamber poles and fitting feet and are composed of cast iron or cast steel. Although it creates a very svelte machine, the necessary cutting basically negates any advantages. The flux density, which is mostly outdated, is decreased throughout the casting process. The enormously broad components that make up the mainframe's top and bottom halves have bound flange joints on the horizontal centre axis.

This is due to the frame's inability to be installed without a hoist due to its width and mass. Both the chamber pole and chamber belt require handling cranes at greater sizes, therefore the modular construction serves two primary purposes. The small to medium units' mainframe architecture allows for the stacking of punched laminations. The frame and the field poles become one cohesive unit thanks to this arrangement. (W. Hua, 2009.)Although it may offer a highly strong and reliable construction, punching dies are expensive. Although it's not always the case, field poles are often formed of highly magnetic stainless laminations. The laminated structure is employed on the inner or polar shoe end of the field poles. This is brought about by the field force throbs that occur as the armature rotor's folded attractive design ignores the polar shoe. Inside flows of vortex in the attractive construction are brought about by varieties in field strength. These eddy currents are unsuccessful. It is possible to avoid laminated magnetic systems largely. Structures with laminations that allows magnetic flux to move over the length of the lamination but prevent electric currents from flowing through the surface from one lamination to another.

The completed stack of laminations is housed as a device by a suitable placement of rivets. The outside of the laminated pole is curved to match the inside surface of the mainframe. a typical laminated pole and pole area. Each fracture in a magnet structure causes a considerable hesitation that is roughly comparable to the resistance, making the structure's overall magnetic flow need more ampere turns. (J. A. Tapia, . 2003.)The poles on the mainframe joints are always tightly fastened by the ground bolts since more ampere turns result in greater heat, which is a bad thing.

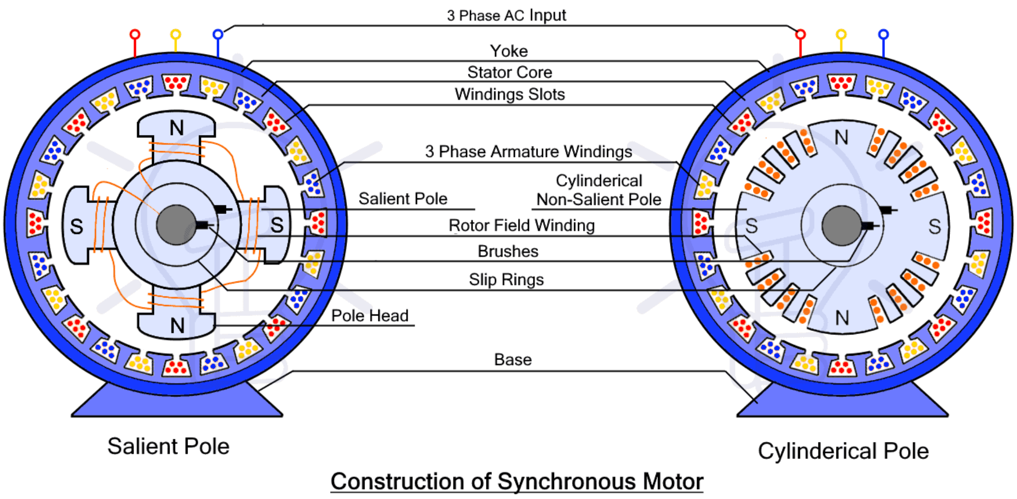

Figure 1: Rotor and Synchronous Motor Winding

When it comes to chemicals, just like with batteries, these actions may be undone and retained electricity. The methods are still ineffective or powerful in relation to one or both of their strengths. There are ongoing developments. The principal use of temperature computation is the direct conversion of thermal energy via thermocouples into electricity, but the voltage is constrained. (R. L. Owen, 2010.)It is crucial to understand the entire process of energy release from coal, liquid or solid hydrocarbon fuels through chemical combustion. As we often cannot send resources into them and withdraw the original fuel, they are not reversible. Currently, it takes around 15 times as much energy to generate a fuel as this fuel's energy when it is burned. The goal of the thermodynamics theory is to understand how chemical energies are released as heat and how to transform that heat energy into mechanical energy by using intermediary fuels.
The release of thermal energy from the fission of heavy materials like uranium or plutonium has given rise to a new and important branch of atomic energy study over the past ten years. Nuclear fusion promises to govern and optimize more energy release times.

2. Review of Litreature

Huda (2019) By expanding or decreasing the current, the voltage at the voltage terminal or power terminal could make the gadget less steady. The change of mechanical energy into electrical energy likewise happens in siphons, plants, turbines, sun based engines, and intensity motors. The mover(s) procured from the main mover is (mechanical energy), and the generator might be described as that (engine, propeller, and diesel). Triple synchronizations are likewise fitting for use with greater power plants, particularly those that incorporate three-stage revolving generators and a synchronous machine. Particular A descriptive word showing that an expression go on into the synchronous is 1.030 KVA. The generator status must be kept inside the ideal working reach. While the round number generator could conceivably have strength, charges and energy affect how dependably it works. (G. Henneberger, 1994)Likewise, the circuits ongoing will change when the heap generator's result voltage shifts. It looks to dissect synchronous generator disturbance changes from three fundamental points: to accumulate data for every one of the three methodology The estimations depended on examinations that uncovered that the typical EMF strength really depended on 48.68, the pinnacle excitement current was at 470.55, the voltage of the EMF acceptance (v), and the EMF consumption was down to 124.9, and the typical EMF current power depended on 124.9. EMF uses and costs are the most noteworthy with an EM force of 46.1.
Kumar (2018) Toby Kumar The synchronous generator is recreated under different situations to decide how much force is created during the stacking supply deficiency, which is to be expected in this article. On account of a synchronous generator on an endless transport, the DP condition is dq0. The force created by the synchronous MATLAB load-associated generator is mathematically re-enacted utilizing the Adams fourth-request Runge-Kutta strategy. (H. Bali, 2010.) The electromagnetic force is bigger if a break between a line-to-blame disappointment and a ground disappointment, as well as a line-to-ground deformity, isn't synchronized or sufficient, as indicated by mathematical information. By expanding burden and changing the power of the ground, the motor is evaluated in legitimate stages.

Every one of meters' information is logged at each move toward request to work out volt and power. This guides in the computation of the engine's power factor for each heap field present status. The bends can be acquired across additional firmly separated augmentations to all the more precisely characterize the bend shapes, contingent upon the effortlessness of charge the executives and how much time accessible. The no-heap bend declines, while perhaps not totally.

Van der Geest et al. (2015) have suggested a technique based on multi-objective optimization and employing finite element models to determine design trends of electrical equipment. Analyzing the power density, power level, and cooling strategy of surface-mounted permanent magnet devices serves as a demonstration of the procedure. The argument is made that power density is more dependent on cooling strategy and rotor surface speed than power level.

Uzhegov et al. (2016): have put the emphasis on mechanical elements and provided a design flow that is broken down into phases in the form of a flowchart. The steps represent mechanical, electrical, and thermal analysis activities. Each step's characteristics and requirements are described. (Y. Amara, 2001.)Two high speed permanent magnet synchronous machines were designed using the given methods. The design flow's output performances are contrasted with the outcomes of the prototypes. A simple technique for the multidisciplinary design of high speed permanent magnet electrical devices is provided by the design methodology outlined.

Fang et al. (2017) provided a rotor design process that merged electromagnetic and mechanical design for a high-speed PMSM with a 200 kW rating. Analyses are done on the mechanical properties of various sleeve materials. (L. Vido, 2005,)For the suggested machine, the electromagnetic design limitations and mechanical strength limits are computed. Combining the rotors' mechanical strength and electromagnetic restrictions yields the dimensions for the rotors with various sleeve configurations. In light of the electromagnetic, warm, and rotor dynamic properties, the ideal rotor type is picked. It is recommended to utilize original rotor geography with lower rotor swirl current misfortunes. The multi-facet sleeve on the new rotor geography is more slender than the single-layer sleeve.

3. Proposed Methodology

The synchronous dynamo's essential polyphaser stage and a progression of groups are utilized to wound the armature. The stator armature drivers' three-stage momentum creates an attractive field that turns consistently at a S-speed of 120 f/p. the association between the rotor posts and the stator turning field. The stator's resultant armature synchronous turning locale spins at a synchronous speed because of the north and south poles of the rotor being secured in arrangement. (Z. Zhang, . 2008.)Every rotor and stator turns at synchronous speed in a clockwise bearing and is secured in synchrony with the other. The rotor drops down when a heap is applied to a synchronous stacking motor shaft because of the stacking counter force, yet it continues to turn at a similar speed comparative with the field turning stator.

Albeit the rotor's speed is as yet synchronized with the turning field, the proportional air hole transition has radically decreased in light of the fact that to the higher air hole hesitance. Assuming the counter force is huge to the point that it moves toward the delivered ideal force and the rotor digresses from sync, the synchronous driver is ended. In this way a synchronous motor either works at certain sync level or not.

The spinning stator field is not locked synchronously or meshing as the rotor slows down because the rotor slides through the rotor field poles so quickly. When a rotor's unit N polar is dragged toward an approaching S polar, torque is produced that moves counter clockwise. The following instant, a rotating rotor's S pole is dragged toward a N pole, producing either zero net torque in the anticlockwise direction or a clockwise torque.

The synchronous motor's distinctive property is that it does not automatically start. It must be immediately connected to the line via a variety of auxiliary methods, much as the A.C. alternator.

Another unique quality of synchronous engines is their hunting sensitivity, which is especially noticeable in applications where the loads change abruptly or are not uniform over the course of a single rotation, such punching press shears, compressors, and pumps. This issue has been resolved while also allowing the synchronous engine to start on its own thanks to the usage of the rotor construction with damper windings. It has never been more usual to employ a synchronous engine. In some horsepower levels and speed ranges, it outsells polyphase induction motors. (Y. Amara L. V., . 2009.)Synchronous polyphaser motors provide the following advantages over polyphaser induction motors. Synchronous engines can be utilized for power factor correction in addition to supplying torque for driving loads. The stronger motors are those with the same horsepower and voltage rating (where run at unity power factor). Rather than the squirrel cage plans utilized in acceptance engines, the field post rotors of synchronous motors might have more extensive air holes, which have lower bearing resistance prerequisites and license more noteworthy wearing. They could be more affordable for similar measure of torque and voltage evaluations. Bit by bit or in synchrony with the a.c. line voltage recurrence, the synchronous engine works. The shaft number influences the engine's genuine speed. An alternator is used as a motor in the synchronous motor. Because of their high working productivity, dependable power factor and moderately low aversion to voltage plunges, synchronous engines are principally utilized in significant power applications.

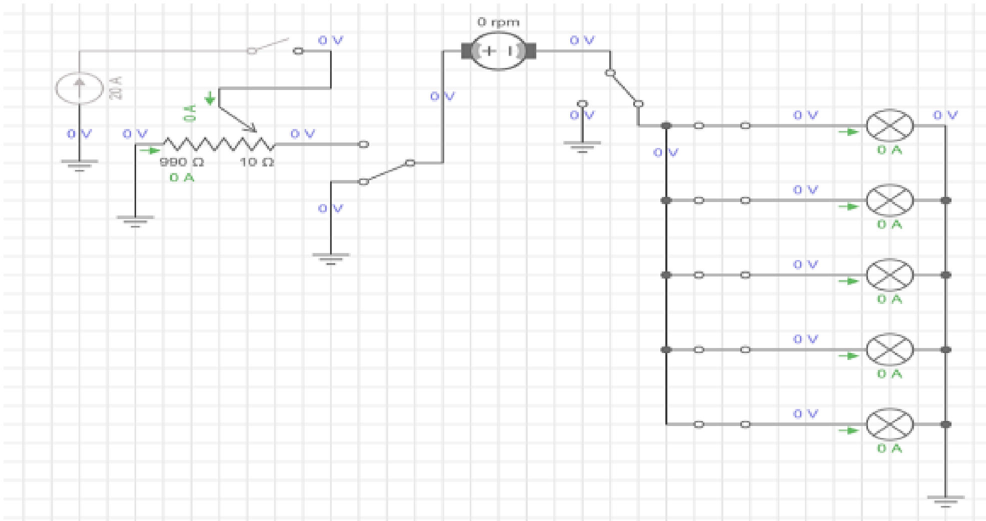

Figure 2: Circuit for double-excitation motor control

These are ceaselessly working pace machines for factories, treatment facilities, power plants, etc, which work and backing the power factor change of siphons, blowers, ventilators, pounds or other huge burdens. Synchronous condensers are synchronous gadgets with no outside screws that are explicitly evolved to check the power factor. They hold tight the transport, giving the gadget responsive control. The unit's field excitation might be changed to adjust the heading of reaction and, subsequently, the gadget's power factor. (D. Akémakou and S. K. Phounsombat, 2000.) To deal with the action of each engine, it is accepted that the framework is associated with a perpetual transport. No power from or conveyed to the boundless transport is affected, and the terminal strain and recurrence are both consistent. In profoundly evolved countries, enormous power frameworks can be found, with generally perpetual transport frameworks. The system is indistinguishable
From the former one with the special case that the shunt generator is mechanized and synchronized with the A.C dynamo by the sync engine. Assistant acceptance engines with less posts stick to the equivalent A.C synchronic engine synchronization approach as alternators in their third cycle. To address the engine slip enlistment disappointment, the acceptance engine needs somewhere around one sets of lower posts. (E. Spooner, . 1989) Every one of the three arrangements require: (1) the synchronous engine has practically zero burdens, and (2) the starting engine power is somewhere in the range of 5 and 10 percent of the synchronous engine rating joined with it. In any case, the fourth way — engine acceptance with damper windings — is by a long shot the most frequently involved technique for turning over synchronous engines.

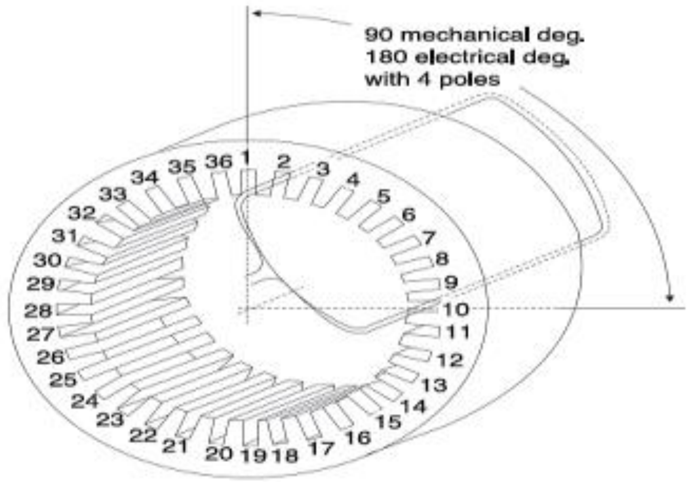

Figure 3: Electric Generator Poles

There are no specialized auxiliary machines required, making this the simplest way. The synchronous motor must be accelerated to a speed equal to its synchronous speed in order to lock the spinning field in synchronicity. With a synchronous engine shaft and a D.C. engine, speed may be increased. As an engine, use the exciter field generator, a little motor that has at least one pole positioned beneath the synchronous motor, Use the winders to power the squirrel cage's induction motor. In labs using synchronous motors without damper windings, the first method is frequently applied. The synchronous drive is often intended to serve as the constant speed prime mover for the D.C. generator. But to synchronize the engine, the D.C generator functions as an engine and acts as an alternator to synchronize the A.C synchronous dynamo to the A.C. supply.

4. Experiment Result

When used in conjunction with delivery, the synchronous dynamo operates similarly to an engine. The DC engine can now function as a generator if the field current is increased so that it is greater than the current of the d.c. bus. If the synchronous engine is intentionally altered in this manner, a leading Ia current is extracted from the line by including an internal Ia sin/reactive current component. Using the same considerations for lead and lagging power, the Ia stator current remains constant. The benefit is that every component Ia sin that exists with the rest of the system employed by the synchronous engine is opposite in step with the component Ia sin. Broad synchronous motors that have been commercially over-excited accomplish significant device power factor gains while working. A synchronous engine is referred to as a synchronous condenser if it is utilized solely to produce a large leading Ia Sin component.

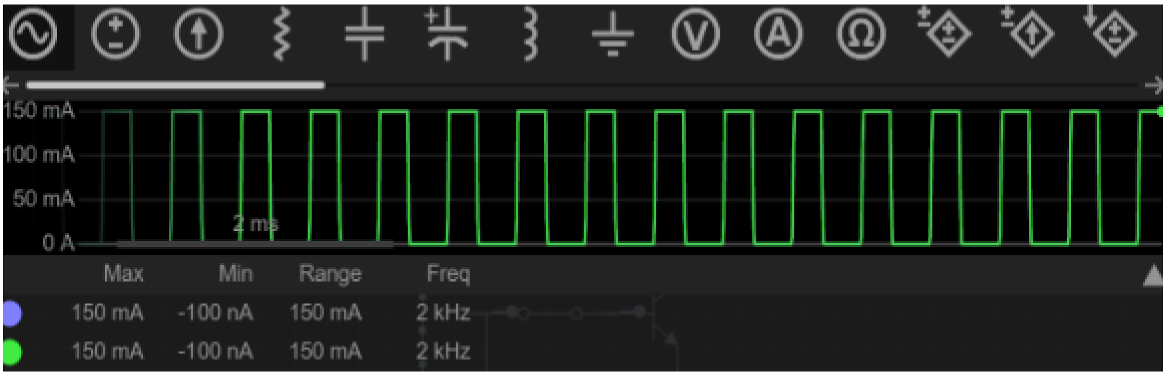

Figure 4: Synchronous signal for double excitation

The fact that a massive condenser is situated on the axis has an influence, thus the name. When a typical mechanical demand is present, the motor is mostly employed as a synchronous power factor fixer by purposefully increasing its exaggeration. The other circumstance still applies if the D.C. field excitement level increases.

This creates the phasor connection by causing a greater EGP voltage than VP. In order for IA cos to perfectly match the original IA once more, the stator power from the line must be the same as in the same load condition (a). The larger EGP then alters how the phases relate to one another. ER the resultant phasor voltage is then turned counter clockwise (c). As the angle between them is still determined by the winding impedance triangle, ER must still be the IA phasor even if it is spinning. The result of the extensive ground alteration is a strong leading load factor. The situation occurs with significantly less D.C field excitation, assuming the same engine load, which is the same input power or VPLA cos as necessary. The phasor sum of ER would take the following course since the quantity of phasor sum in normal VP and lower EGP indicates fewer EGP (b). The efficient stator power must meet the same value condition. To accommodate the original value of IA must be larger. IA needs to be bigger (a). This suggests that the ER phasor will rise proportionately. The angle 2 must be higher than the angle 1 for ER to grow with shorter EGP Only in this angular relationship of shift would a small EGP result in a bigger ER. Since the impedance is the same, ER and IA will likewise have the same phase angle. In these circumstances, the engine places a burden on the power supply due to its lagging energy factor.

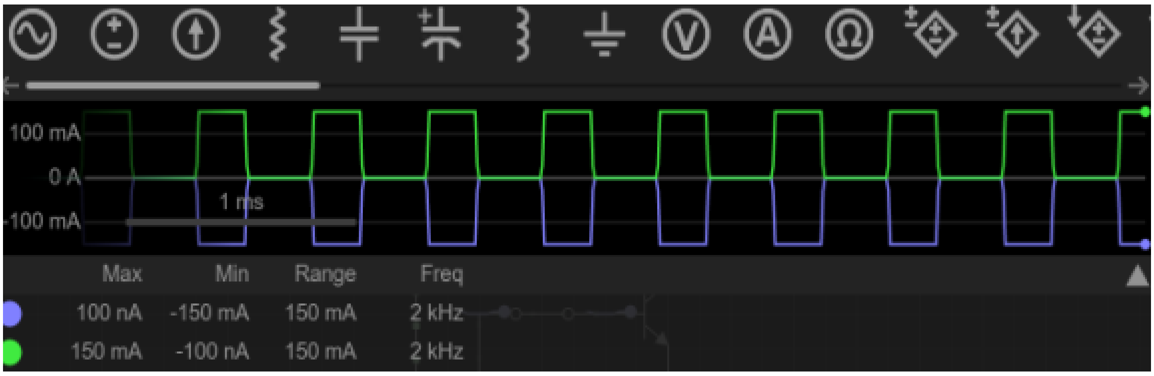

Figure 5: Double Excitation Signal

As the field's excitation is diminished, the length of the slack or cosine % of the point depends on this. Inside, the field's upgraded polarization brought about by a deferred current stator of the power factor made the phasor association. The different stage connections nearby with different excitation levels. At the point when EGP is major areas of strength for that, condition is known as regular field excitement. In such cases, the EGP is barely sufficient to raise it to a level where the phasor aggregate EGP and VP, which delivers the voltage EV, might be created. Present the stator or attenuator. To diminish I2R misfortunes, the opposition Ra is kept as low as possible all through the commonplace stator winding. The essential component of the winding impedance is the inductive reaction. The point between the trauma centre and IA stages is nevertheless not precisely 90 degrees. The entire winding impedance triangle and the sharp line are contained in this edge of the phasor. By setting the D.C. fervour at the legitimate level, the armature current Ia and the stockpile voltage Vp might be impeccably coordinated. This is the standard of the fortitude component: a synchronous engine can work and support its heap all through a wide locale of turning. The voltage provided by EGP will change over a wide reach since the connection between the turning field and the stator curls is equivalent to the communication between sync generators. At the point when EGP set to VP and there are no requirements for supply force, the EGP voltage precisely goes against the VP voltage each step.

Regardless of whether running light, some force is as yet important. The greatest standard force need happens under ordinary burden conditions, permitting the stator current to completely make the imperative strength of the turning stator magnet field. The power reaction element of a synchronous engine for different D.C field excitation flows with consistent power is shown by the V-bend measure.

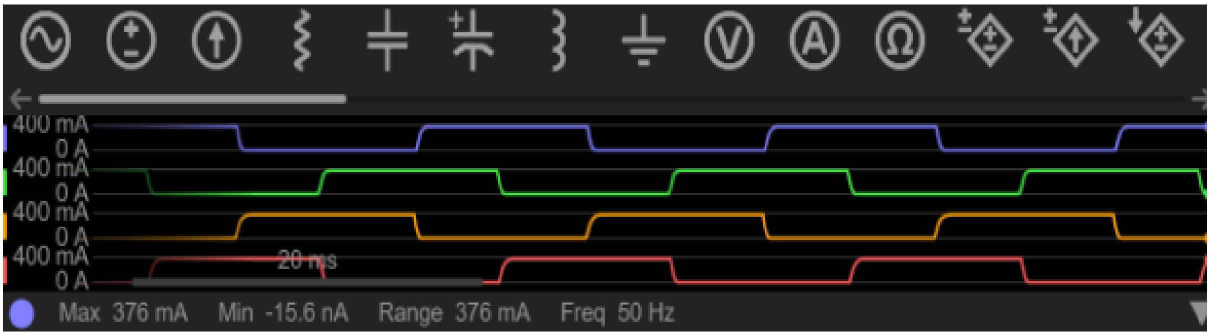

Figure 6: Synchronous and generator excitation signal

5. Comparison with Another Nother Protype

The stator of a 3 kW machine prototype, to which the research machine has been compared, is shown in Fig. 7 The analyzed machine and the prototype both feature the same stator (as well as the same overall size), but the rotor constructions are different. The prototype's rotor's features are shown in Fig. 7. Both machines' rotors have the same overall size, but they have distinct construction. Figs. 7(a) and (b) depict the assembled rotor and the lamination sheet that was utilized to construct the prototype's rotor. The prototype is a mechanism under study with 12 poles. The permanent magnets used in this prototype are ferrite. The air gap flux density may be increased by using the flux concentration concept. Table1 provides further information about this prototype.

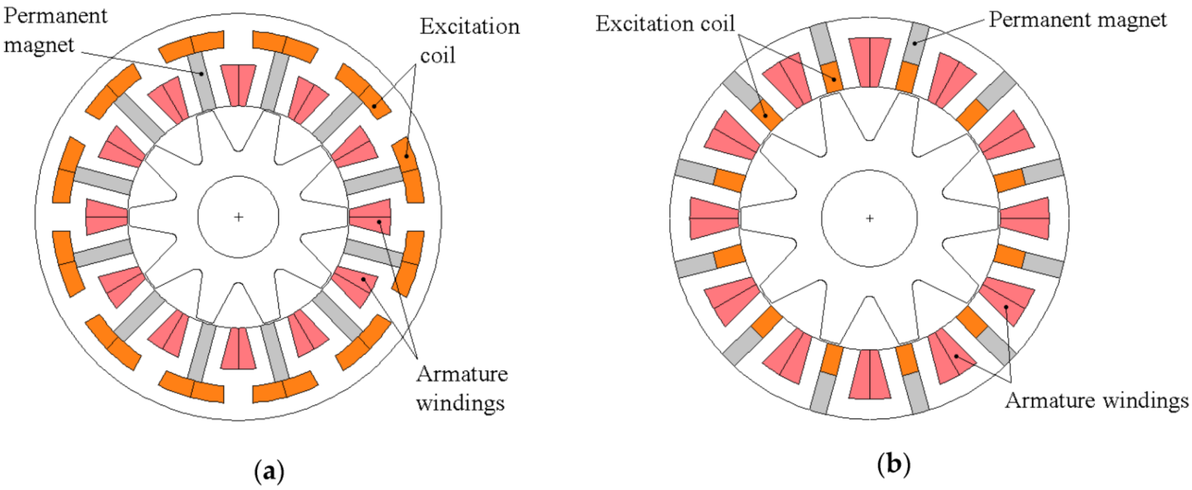

Figure 7: Rotor of double excitation prototype. (a) Lamination sheet. (b) Final assembly

Nominal torque (N.m)	12
Base Speed (rpm)	**2500**
Armature Nominal Current (A)	**12**
Magnet Dimensions (thickness, height, length) (mm)	**(7,41,42)**
Phase resistance	**0.81**

Total Excitation coils resistance	**3.1**
Number of turns of 3 phase armature windings	**4.2**
Number of turns of each excitations coil	**160**

Table 1: Double Excited Synchronous Prototype Data

A finite-element study of the prototype machine (Figs. 7 and 8) has been performed prior to evaluating the capabilities of both machines to regulate flow. This research aids in determining how accurate and successful the FEA is.

For the prototype machine, Fig. 8 plots flux fluctuations against field ampere turns. Moreover, data from 3-D FEA and experimental results are compared in this image. Results from the FEA and experiments show good agreement. With relation to the no-field excitation flux, the air-gap flux varies by % when it is strengthened and by 70% when it is weakened.

EMF waveforms for various excitation currents (AT [Fig. 9(a)], 0 AT [Fig. 9(b)], and AT [Fig.9(c)]) have also been calculated using 3-D FEA. Figs. 9(a), (b), and (c) compare EMF waveforms for various field MMF produced by 3-D FEA and experimental observations.

Field MF	**Maximum flux per phase per turn (mWb)**
110	1.2
210	1.9
324	2.2
410	2.5
490	3.5
502	3.9
509	4.2

Table 2: 3D FE analysis and experimental findings on the characteristic of the prototype machine's excitation flux control.

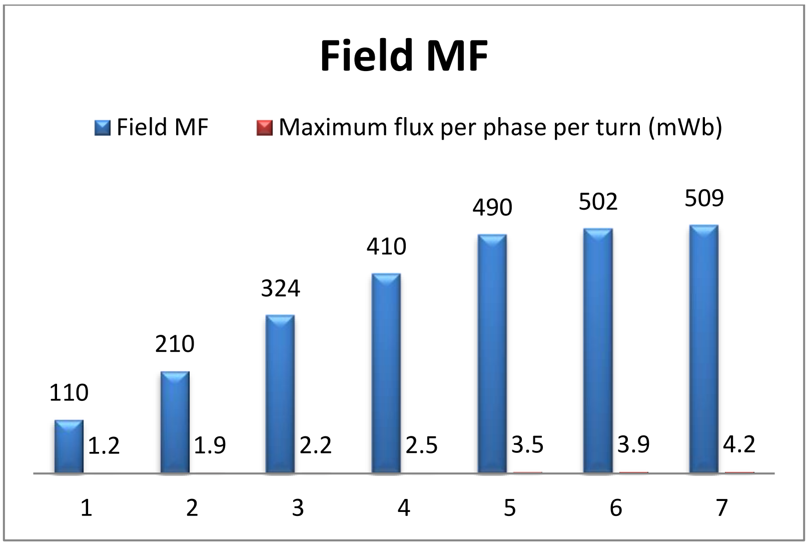

Figure 8: 3D FE analysis and experimental findings on the characteristic of the prototype machine's excitation flux control.

EMF per turn (V)	t/T(pu)
1.2	2.2
1.6	2.6
2.2	3.8
2.9	3.7
3.2	4.5
3.6	5.9
4.2	6.3

Table 3: 3D FE analysis and testing findings for EMF waveforms for various field MMF for prototype machine.

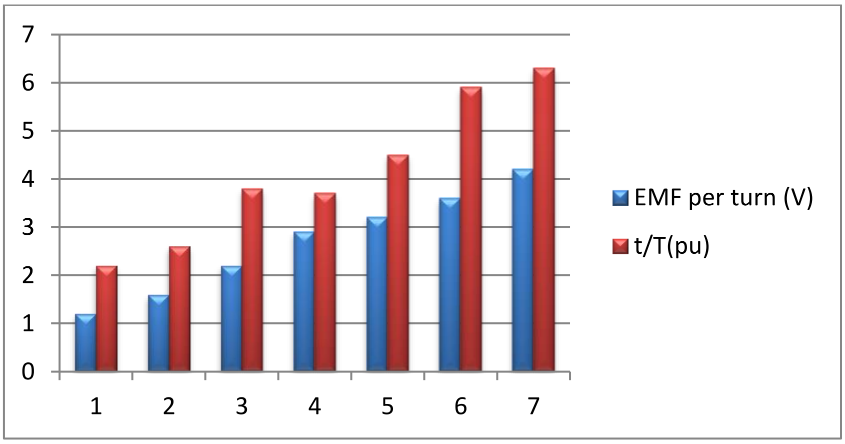

Figure 9: 3D FE analysis and testing findings for EMF waveforms for various field MMF for prototype machine.

6. Conclusion

By changing the rotor recurrence at any mechanical speed, a synchronous engine may be quickly and smoothly synchronized with a power network. When contrasted with a synchronous generator, this gives the upside of far off synchronization, which diminishes gadget personal time when closures happen. (E. Hoang, 2007.)With the utilization of a solitary stage comparable circuit and the supposition that the extent and recurrence of the stator voltage is both steady, the circuit chart was created as a schematic method for outlining the working methods of the generator as per the law.

The circle chart uncovers the relationship of all connected framework factors. The ongoing point, the dynamic and responsive power yields, the power factor point, the twisting flows of stators and rotors, and the power force of a functional point are totally associated with this. A creative twin excitation gadget with solid field debilitating capacities is introduced in this examination. (D. Fodorean, 2007.) The equal double excitation machines incorporate this development. The stator's excitation curls give productive air hole transition the executives while limiting the chance of extremely durable magnet demagnetization.

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