Enhancing Energy Efficiency of Induction wind Turbine Machines: An Adaptive Control Approach

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Abstract- The increase in the demand for wind energy on a large scale also gives rise to increased demand for wind energy conversion machines (WECMs). one of these is the induction wind turbine generator otherwise referred to as the Doubly Fed Induction Machine. The doubly-fed induction generator (DFIG) is the preferred choice, however, due to the sensitive nature of this machine, it suffers setbacks as a result of speed variations and grid faults during operation. To overcome these undesirable characteristics, this paper proposes an adaptive control technique to regulate the machine speed when in operation. The sequence of this procedure is to first characterize the performance of the induction machine, design an adaptive control rule base to increase the efficiency of the wind turbine that drives the generator rotor, and train an artificial Neural Network(ANN) in the adaptive rule base to improve the energy generated through the speed control device. The next stage is to develop a conventional proportional Integral Control (PIC) system for Energy Efficiency.The outcomes showed that the conventional generator's efficiency is stable from 4 seconds to 10 seconds at 59.7%. On the other hand, when an adaptive controller is used, generator one gives efficiency of 60.77% over a stable time range of 4 to 10 seconds. When compared to the conventional method, the system's energy efficiency increases by 1.07% when an adaptive controller is used. The final results show that generator two has the highest conventional generator efficiency of 76.5% and the highest adaptive controller generator efficiency of 77.87%. The results show a 1.3% improvement when an adaptive controller is incorporated into the system compared to the traditional Approach

Keyword- Energy efficiency, improvement, fed induction, generator, adaptive control

I. INTRODUCTION

The only difference between the Inductive Wind Turbine Generator and AC electrical generators is that the induction Wind Turbine Generator has extra features that enable them to run at speeds that are either slightly higher or lower than their current rating synchronous speed. Due to the abrupt changes in wind speed, the technology is used in large variable speed wind turbines. A wind turbine's blades attempt to speed up when there is a sudden increase in wind speed, but because synchronous generators are connected to the national grid, which serves as the power grid, they are unable to do so. Therefore, as the power grid pushes back to maintain equilibrium, substantial forces are created in the hub, gearbox, and generator [1]. As a result, the mechanism wears out and breaks down, breaking down the equipment. The stresses are lower while the wind gust's energy is still converted to usable electricity when the turbine generator is allowed to accelerate immediately after being struck by it [2]. The tactical technique for allowing a wind turbine's speed to vary is to allow whatever frequency the generator generates, convert it to DC, and then use an inverter to convert it back to AC at the best output frequency. This method is frequently used in wind turbines for small homes and farms. The inverters needed must be expensive to purchase, install, and maintain if the goal is to generate high power in megawatts [3].In order to solve the issue, doubly fed generators are used; in this instance, the standard field winding fed with DC, where the armature winding produces electricity, would have two three-phase windings, one stationary and one rotating. The term "doubly fed" is used to describe these types of machines when both are independently connected to equipment outside the generator. [4] Okedu. One winding produces three-phase AC power at the synchronous speed frequency when it is connected directl y to the output (grid frequency). In this case, both of the windings—which are connected to 3-phase AC power at variable frequency—could be outputs. The second winding is typically referred to as the field. To account for variations or changes in the turbine's speed, this input power is phase- and frequency-adjusted [5].A converter from AC to DC and from DC to AC is necessary to change the frequency and phase. IGBT semiconductors that are extremely large are used in the construction. The converter allows power to flow in either direction and is therefore bidirectional rather than unidirectional. Both the output winding and this winding are capable of supplying power [6]. In this study, a doubly fed induction generator is used with adaptive control to reduce network subsynchronous oscillations (DFIG)A doubly fed induction generator machine's control strategies, with a focus on adaptive strategies, would be reviewed. In addition to proper design of a doubly fed induction generator control, this will assist in overcoming the limitations of other techniques.

The goal of the study is to use adaptive control to increase the energy efficiency of an Induction Wind Turbine Machine.

1.2 Study Objectives

Adaptive Control Technique is used to perform nonlinear functions appearing in the tracking errors to improve performance in operating conditions. The objectives of this research work are stated in behavioral terms that can be measured before moving on to the next stage, completion, and validation. Consequently, the goals of this work are to Describe the characteristics of the Induction Wind Turbine machine. Create a rule-based adaptive control system to improve the energy efficiency of the induction generator. Develop an adaptive rule base for Artificial Neural Networks (ANN) to improve energy and its control mechanism.

Create an energy-efficient proportional integral PI control system.

Create a Simulink model using the adaptive control technique to increase the energy efficiency of the doubly fed induction generator machine.

Validate and support the energy efficiency of the system both without adaptive control and with it.

II. REVIEWS

2.1 Extent of past works

According to [7], the wound rotor induction machine is typically built as a three-phase winding with the same number of poles as the stator. 2017 (Dickson). The rotor current can be controlled by using three-phase slip rings (and brushes). A variable speed system used in variable speed turbines is the wound rotor induction machine. The mechanical rotor speed and the grid's electrical frequency must be separated to enable variable speed operation. In order to achieve this, the three-phase rotor windings are fed by back-to-back voltage source power converters [8]. In this manner, the electrical stator and rotor frequencies can be matched, regardless of the mechanical rotor speed, and the mechanical and electrical rotor frequencies can be separated. The advantage over greatly oversimplified linear dynamics or the resulting control algorithms is performance in operating conditions using adaptive fuzzy systems, where the errors are significantly minimised to increase efficiency [9]. Additionally, the double fed induction generator (DFIG) appears to have advantages over other types of wind generators [10]. For example, by maintaining a constant rotor current frequency, DFIG can generate nearly constant power from the stator, and by maintaining a desirable tip-speed ratio, DFIG can generate the highest output power at various wind speeds [11]. A wind power generation system equipped with DFIG only requires a converter with one-third of the rated power, producing a system that is reasonably priced and loses little power [12]. Recall that DFIG can maintain a stable power network voltage by producing some controllable reactive power, improving the overall power factor or voltage profile/characteristics [14]. DFIG can regulate reactive power differently from real power with a proper adjustment on the frame. Most power supply companies have suggested a number of methods, procedures, and standards that must be strictly followed when the wind generators are tied to the system in order to prevent instability problems in our power system[15]. As a result, reactive power control in DFIG for wind turbines has gained attention as a research topic in recent years, producing a number of technical findings[16].As the growth of electricity demand is increasing rapidly, optimization technique is one of the better alternatives to fulfill this over growing energy demand [17] [18]. The work done using fuzzy controller to stabilize frequency fluctuation due to system disturbance in Nigerian 330kV Transmission line made use of Fuzzy controller;there are some methods use to determine the transient instability in the power system which are artificial intelligence methods such as artificial neural networks [19];these techniques would not be very effective due to the stochastic nature of the renewable energy source. An adaptive control system automatically corrects for changes in system dynamics by modifying the controller's characteristics, ensuring that the system's overall performance is maintained at its peak. This control scheme accounts for any deterioration in plant efficiency over time.

III Methodology

3.1 Characterizing the doubly Fed Induction Generator machines

The methodology used in this work is the meticulous adherence to the study's goals, which have to do with measuring the data that have been gathered regarding the mechanical output and electrical output of two generators. Equations 3.1 and 3.2 show how the data was used to calculate the generators' efficiency. The mechanical output was divided by the electrical input power to determine the motor's efficiency. The mechanical output power was measured using a torque metre. Based on the motor's speed and load, a torque metre and tachometer were mounted and used to calculate the mechanical power. Induction motors are less effective than large industrial synchronous motors. They are used when constant speed is needed, and because they have a leading power factor, they can compensate for a lagging power factor in the AC line.

A three phase 15hp, 460V, 4pole, 60Hz, 17228 RPM induction generator delivers full output power in a load connected to the shaft. The windage and friction loss of the motor is 750w and full load shaft power or $P_s = 11190W$. The electrical output power = 20000w.

The mechanical power developed becomes

Full load shaft power = 11190W

Pm= Ps+ change in Pm

Pm = 11190+ 750 = 11840W.

Table1: Generators Mechanical and electrical powers.

	Pm(W)	Pe(W)
Generator 1	11940	20000
Generator 2	15300	20000

To calculate the energy efficiency of generator!

Energy efficiency = Mechanical output power x 100%

Electrical output power

Energy efficiency = 11940 xlOO%

20000

Energy efficiency of generatorl = 59.7%

To calculate the energy efficiency of generator 2

Energy efficiency =Mechanical output power x 100%

Electrical output power

Energy efficiency 15300 x l00%

20000

Energy efficiency ofgenerator2 76.5%

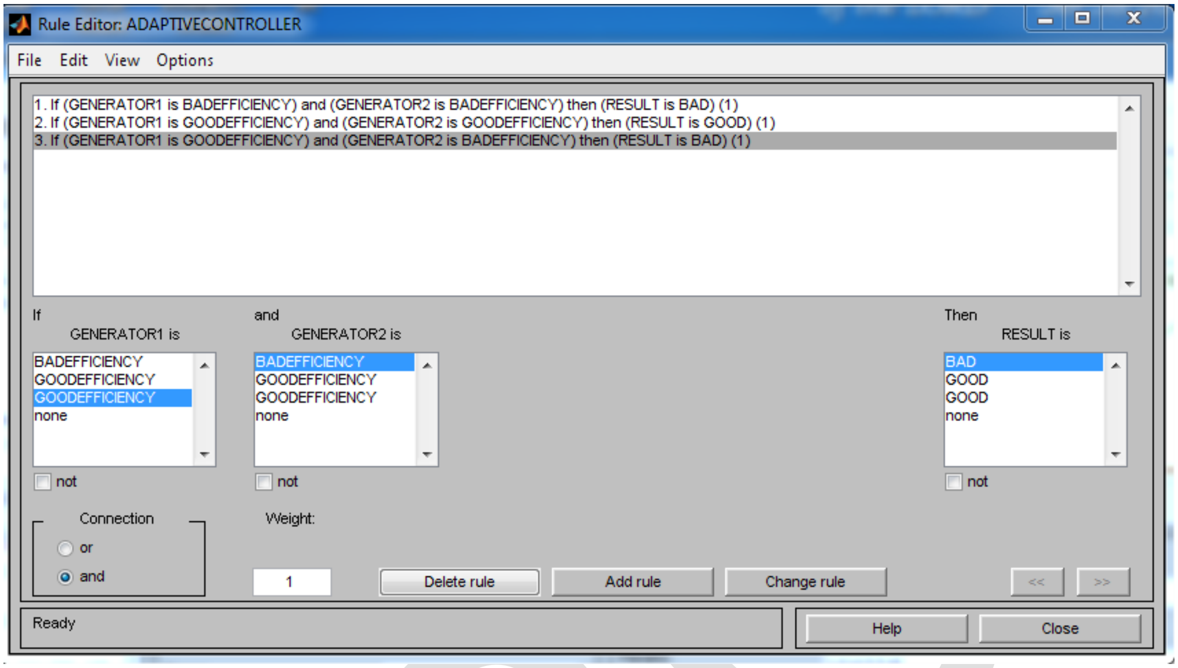

Fig.1 Designed an adaptive control rule base for increase energy efficiency in doubly fed induction generator.

3.2 Designing an adaptive control rule base for increase energy efficiency in doubly fed induction generator.

The adaptive control rule base in Fig. 1 is designed to increase energy efficiency in a doubly fed induction generator. This regulation directs how to assess the generator's effectiveness. To track and improve the induction generator's effectiveness, it is done in the MATLAB environment using the fuzzy toolbox.

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3.3 Training ANN in an adaptive rule base to enhance the energy and its control mechanism

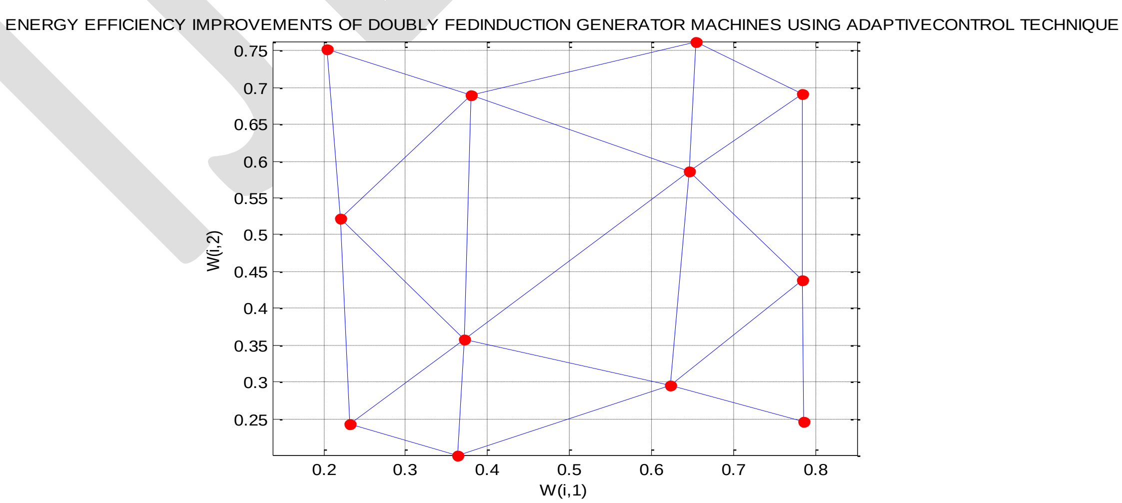

Fig.2 Trained ANN in an adaptive rule base to enhance the energy and its control mechanism

Figure 2 displays a trained artificial neural network in an adaptive rule base to improve energy and its control mechanism. This is accomplished using the three-rule base. These three rules were trained four times, resulting in twelve neurons that mimic human intelligence and follow training instructions to the letter.

3.4 Developing a conventional proportional integral P1 control system for energy efficiency.

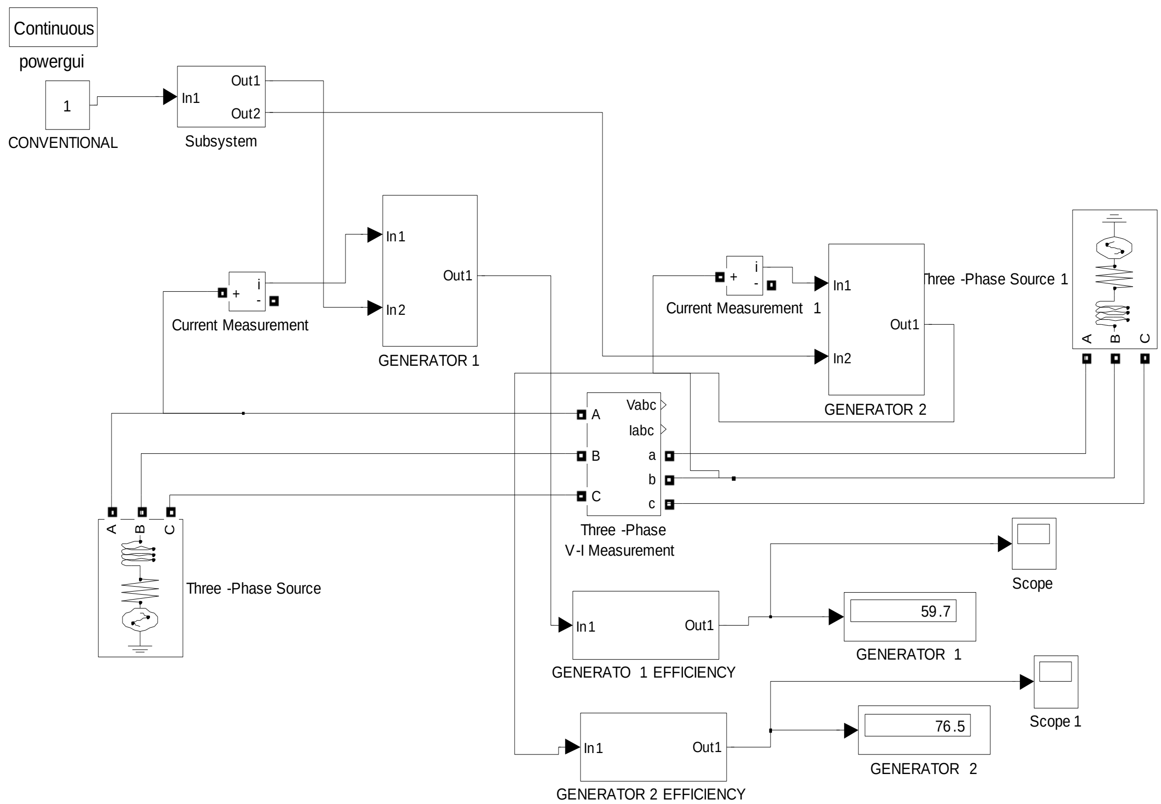

Fig.3 Developed conventional proportional integral P1 control system forenergy efficiency.

Figure3 shows developed conventional proportional integral PT control system for energy efficiency. This is designed in MATLAB environment with the following blocks induction generation, circuit breaker, efficiency subsystem, conventional proportional integral. The computed generator efficiency was imbibed inside the efficiency subsystem. The results obtained were detailed in figures 5 and 6 respectively.

3.5 Designing a Simulink model for energy efficiency improvements of doubly fed induction generator machineusing adaptive control technique.

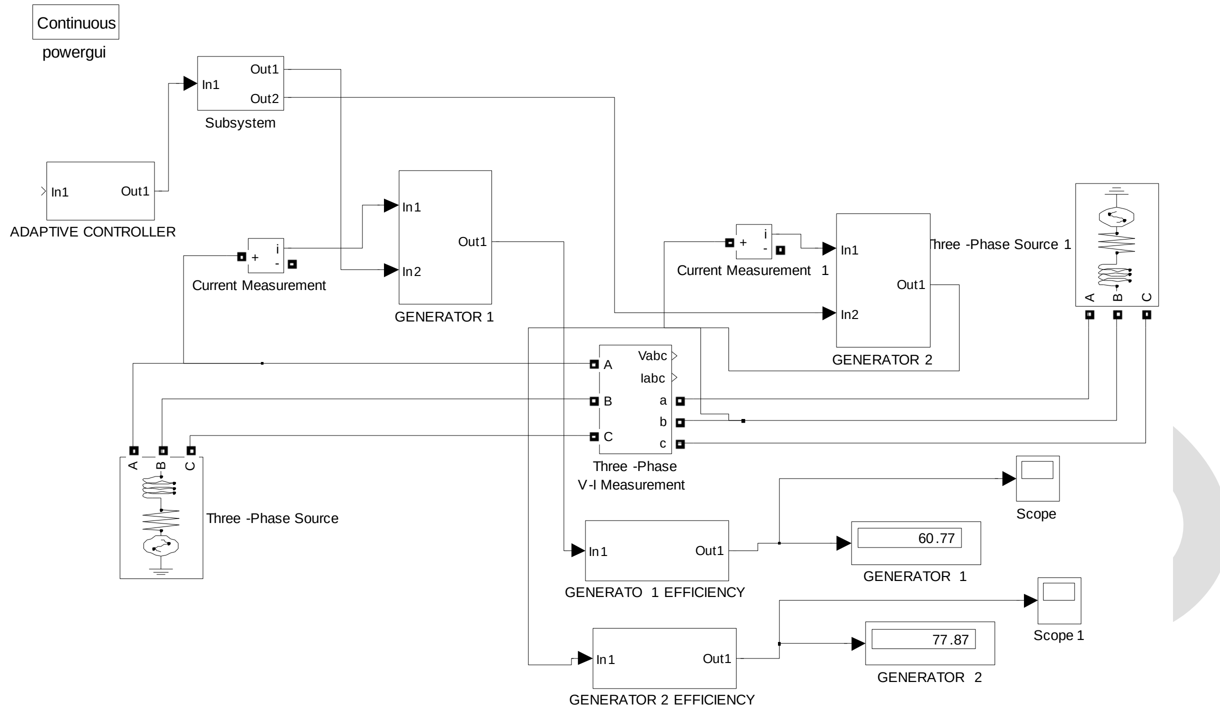

Fig. 4 Designed Simulink model for energy efficiency improvements of doubly fed induction generator machine using adaptive control technique

Figure 4 depicts a Simulink model that was created to improve the energy efficiency of a doubly fed induction generator using adaptive control. The simulated results were displayed in figures 5 and 6 in fig.4 along with a thorough analysis.

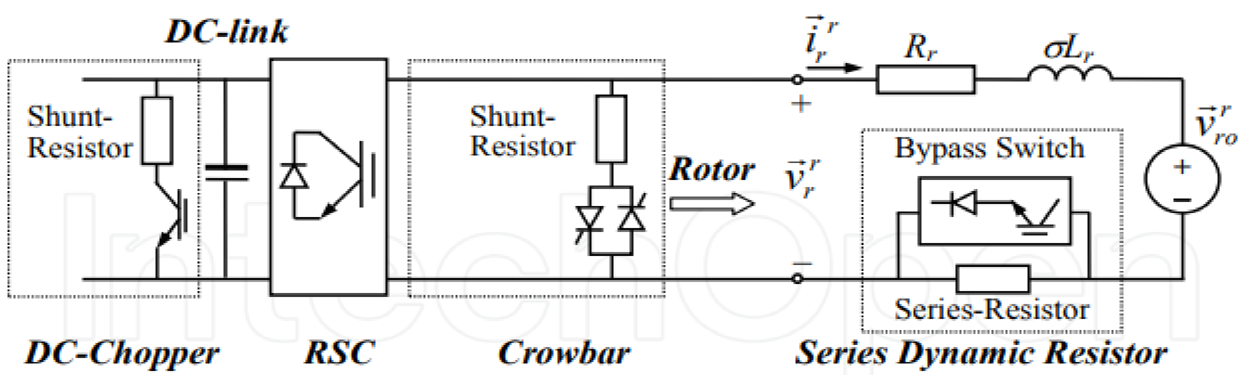

Fig. 5 DFIG rotor equivalent circuit with all protection schemes shown.

IV. RESULTS AND DISCUSSION

The findings from the first objective, which deals with describing the machines under investigation, are calculated and displayed in table 1. The design of an adaptive control rule base for a doubly fed induction generator to increase energy efficiency is shown in Fig. 1. A trained Artificial Neural Network (ANN) with an adaptive rule base to improve energy and its control mechanism is shown in Fig. 2. This is accomplished using the three-rule base. These three rules were taught four times, resulting in twelve neurons that mimic human intelligence and follow instructions when trained. The development of a traditional proportional integral PT control system for energy efficiency is depicted in Fig. 3. The induction generation, circuit breaker, efficiency subsystem, and conventional proportional integral blocks were used in the design of this in the MATLAB environment. The efficiency subsystem ingested the computed generator efficiency. Fig. 4 depicts a Simulink model that was created to better the energy efficiency of a doubly fed induction generator machine using adaptive control. The simulation results were shown in figures 5 and 6 in figure 4 along with a thorough analysis. Figure 5 shows the equivalent circuit for a DFIG rotor that includes all protection methods. Fig. 6 compares the efficiency of the conventional controller generator and the adaptive controller generator 1, respectively. The efficiency of the conventional generator 1 in Fig. 6 remains constant from 4 to 10 seconds at 59.7%. However, when an adaptive controller is used, Generator 1's efficiency is 60.77% over a stable time range of 4 to 10 seconds. When compared to the conventional method, the system's energy efficiency increases by 1.07% when an adaptive controller is used. While Fig. 7 compares the effectiveness of the conventional and adaptive controller generator 2. In Fig. 7, the highest generator 2 efficiency when using a conventional controller is 76.5%, while the highest generator 2 efficiency when using an adaptive controller is 77.87%. The results show a 1.3% improvement when an adaptive controller is incorporated into the system compared to the traditional approach. Table 2 compares the generator 1 efficiency of traditional and adaptive controllers. Table 3 contrasted the respective efficiency of the conventional and adaptive controller generator 2.

Table 2: Comparing conventional and adaptive controller generator 1 efficiency

Time(s)	Conventional generator 1 efficiency (%)	Adaptive controller generator 1 efficiency((%)
0	0	0
2	50	52
4	59.7	60.77
10	59.7	60.77

Table: 3 comparing conventional and adaptive controller generator 2 efficiency

Time(s)	Conventional generator 2 efficiency (%)	Adaptive controller generator 2 efficiency((%)
0	0	0
2	62	64
4	76.5	77.87
10	76.5	77.87

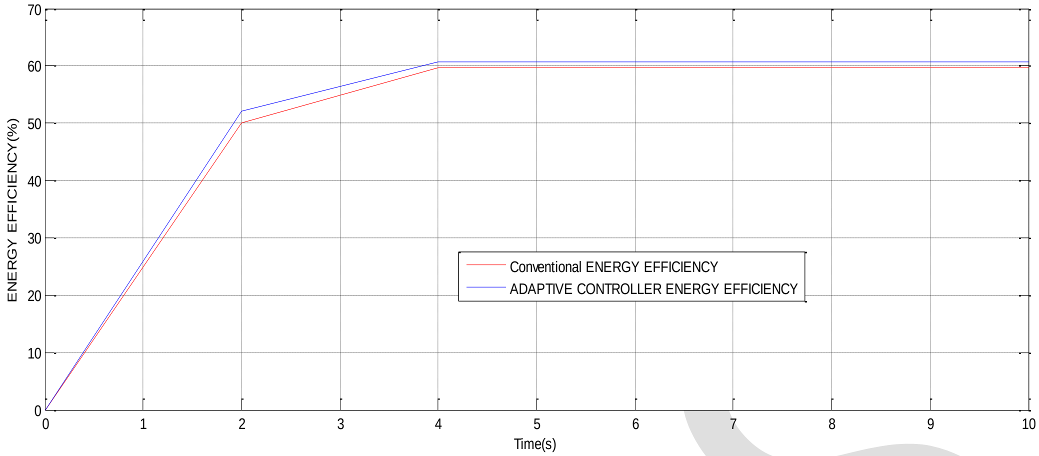

Fig 6 Comparing conventional and adaptive controller generator 1 efficiency

Fig. 6 depicts comparing the effectiveness of generator 1 for conventional and adaptive controllers.

The efficiency of the conventional generator 1 in Fig. 6 remains constant from 4 to 10 seconds at 59.7%. However, when an adaptive controller is used, Generator 1's efficiency is 60.77% over a stable time range of 4 to 10 seconds.

When compared to the conventional method, the system's energy efficiency increases by 1.07% when an adaptive controller is used.

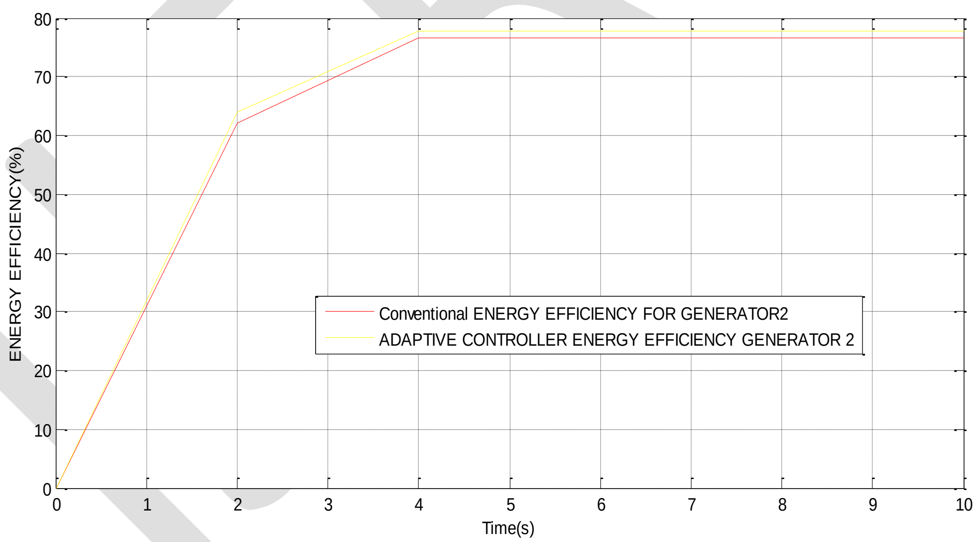

Fig. 7 Comparing conventional and adaptive controller generator 2 efficiency

Figure 7 compares the efficiency of the conventional and adaptive controller generator 2. In Fig. 4.2, the highest generator 2 efficiency for a conventional system is 76.5%, while the highest generator 2 efficiency for a system with an adaptive controller is 77.87%. The results show a 1.3% improvement when an adaptive controller is incorporated into the system compared to the traditional approach.

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V. CONCLUSION

Some manufacturing industries that rely on induction generators for routine production have seen their production capacities reduced as a result of the generators' declining efficiencies. Using adaptive control technique, energy efficiency improvements of doubly fed induction generator machines are used to address this precarious situation of this generator's efficiency decline. The doubly-fed induction generator is characterised by the way it is carried out. Creating a conventional proportional integral PI control system for energy efficiency, training ANN in an adaptive rule base to improve the energy and its control mechanism. Designing an adaptive control rule base to increase energy efficiency in a doubly fed induction generator. creating a Simulink model to improve the energy efficiency of a doubly fed induction generator while validating and defending the energy efficiency both when conventional control is used and when adaptive control is incorporated. According to the results, the conventional generator 1's efficiency remains constant at 59.7% from 4 to 10 seconds. On the other hand, when an adaptive controller is used, generator 1's efficiency is 60.77% over a stable time range of 4 to 10 seconds. The system's energy efficiency has increased by 1.07% when an adaptive controller is used as opposed to the traditional approach. The final results for generator 2 show that it has the highest conventional generator efficiency of 76.5% and the highest adaptive controller efficiency of 77.87%. The results show a 1.3% improvement when an adaptive controller is incorporated into the system co

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