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Energy Efficiency Improvement of Doubly FedInduction Generator Machines using AdaptiveControl Technique

Bakare Kazeem[1], Ezekiel Nnamere Aneke[2], Ngang Bassey Ngang[3], OnubaChinedu Obinna[4],

[1]*Department of Electrical and Electronic Engineering, Enugu State University of Science and Technology (ESUT), Nigeria*

[2]*Department of Electrical and Electronic Engineering, Enugu State University of Science and Technology (ESUT), Nigeria*

[3]*Department of Electrical and Electronic Engineering, Enugu State University of Science and Technology (ESUT), Nigeria*

[4] *Department of Electrical and Electronic Engineering, Federal University of Technology Owerri, Nigeria.*

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ABSTRACT

The inefficiency of enhancing the percentage efficiency of the generators to boost the production capacity of the industries that solely depend on the generator for their daily production is addressed by energy efficiency improvements of doubly fed induction generator machines using adaptive control technique. It is done in this manner, characterizing the doubly-fed induction generator. Designing an adaptive control rule base for increase energy efficiency in doubly fed induction generator, training ANN in an adaptive rule base to enhance the energy and its control mechanism, developing a conventional proportional integral PI control system for energy efficiency,designing a Simulink model for energy efficiency improvements of doubly fed induction generator machine using adaptive control technique and validating and justifying the energy efficiency conventionally and when adaptive control is incorporated in the system. The results obtained were conventional generator 1,efficiency is stable at 4s through 10s at59.7%. On the other hand, the efficiency of generator 1 when adaptive controller is incorporated in the system is 60.77% at a stable time of 4s through 10s. The percentage energy improvement when adaptive controller is incorporated in the system when compared to the conventional method is 1.07%. The final results obtained in generator 2 are the highest conventional generator 2 efficiency 76.5% while the highest generator 2 efficiency when adaptive controller is incorporated in the system is 77.87%. The percentage improvement when adaptive controller is imbibed in the system over the conventional method is 1.3% from the results obtained.

Keyword: energy efficiency, improvement, fed induction, generator, adaptive control

I.INTRODUCTION

Doubly fed electrical generators are the same as AC electrical generators, the difference is that they include additional features which allow them to operate at speeds slightly above or below their rated synchronous speed. The application is in large variable speed wind turbines, due to the fact that wind speed can increase or decrease abruptly. When there is sudden increase the wind speed, the wind gust hits a wind turbine, the blades try to speed up, but a synchronous generator is tied to system frequency of the national grid that is the power grid and cannot speed up. Hence, large forces are developed in the hub, gearbox, and generator as the power grid pushes back to maintain equilibrium [1]. This causes equipment breakdown due to wear and damage to the mechanism. When the turbine Generator is allowed to speed up immediately when hit by a wind gust, the stresses are lower with the power from the wind gust still being converted to useful electricity [2]. The tactical technique approach to allowing wind machine speed to vary is to allow whatever frequency the generator produces, change it to DC, and then convert it to AC at the optimal output frequency using an inverter. This is the practice commonly applied in small house and farm wind turbines. If the purpose is to generate high power in megawatts, the inverters required must be high and costly to acquire, install and maintain [3].

Doubly Fed generators are used to overcome the problem; in this case, the usual field winding fed with DC, where the armature winding generates electricity comes out, there would be two three-phase windings, one stationary and one rotating. Both separately connected to equipment outside the generator; that is where the term doubly fed is used for this kind of machines [4] Okedu.

One winding is connected directly to the output, and generates 3-phase AC power at the synchronous speed frequency (grid frequency). The second winding usually referred to as field, in this case both windings could be outputs; and are connected to 3-phase AC power at variable frequency. This input power is adjusted in frequency and phase to compensate for variation or changes in speed of the turbine [5].

Changing the frequency and phase requires an AC to DC and DC to AC converter. The construction is done using very large IGBT semiconductors. The converter is not unidirectional, but bidirectional, to allow power pass in either direction. Power can flow from this winding as well as from the output winding [6].In this study, adaptive control is used to damp network sub synchronous oscillations via doubly fed induction generator (DFIG)

The review would establish the control techniques with emphasis on adaptive control technique of a doubly fed induction generator machine. This will help to improve on the limitation of other techniques; as well as proper design of a doubly fed induction generator control**.**

1.1 Aim of the Study

The paper is aimed at using Adaptive Control Technique to improve the energy efficiency of Doubly Fed Induction Machine.

1.2 Objectives of Study

To improve performance in operating conditions, the model uncertainties and the nonlinear functions appearing in the tracking errors are reasonably approximated by adaptive Control Technique. To achieve the aim of this research work, the objectives are stated in behavioral terms that could be measurably determined before getting to the next step, then to completion and validation. Therefore the objectives of this work are to

- Characterize the doubly-fed induction generator/machine.
- Design an adaptive control rule base for increase energy efficiency in doubly fed induction generator
- train Artificial Neural Network (ANN) in an adaptive rule base to enhance the energy and its control mechanism
- Develop a conventional proportional integral PI control system for energy efficiency
- design a Simulink model for energy efficiency improvements of doubly fed induction generator machine using adaptive control technique
- Validate and justify the energy efficiency conventionally and when adaptive control is incorporated in the system.

II. REVIEWS

2.1 Extent of past related works

Wound rotor induction machine is normally constructedas a three-phase winding with the same number of poles as the stator based on [7]. (Dickson, 2017). Three-phase slip rings (and brushes) are used to allow control of the rotor current. Wound rotor induction machine is a variable speed system used in variable speed turbines. To allow variable speed operation, the mechanical rotor speed and the electrical frequency of the grid must be decoupled. To this end, back-to-back voltage source power converters are used to feed the three-phase rotor windings [8]. In this way, the mechanical and electrical rotor frequencies are decoupled and the electrical stator and rotor frequency can be matched, independently of the mechanical rotor speed. Performance in operating conditions using adaptive Fuzzy System where the errors are considerably minimized to enhance efficiency is the advantage over the largely oversimplified linear dynamics or the resultant control algorithms where they appear to be too complex for real-time implementation [9].Doubly fed induction generator (DFIG) seems to have advantages over other types of wind generators [10]. For instance, by maintaining the rotor current frequency at a steady level, DFIG can produce almost constant power from the stator, and by keeping an optimal tip-speed ratio, DFIG is able to produce the maximum output power at different wind speeds [11]. A wind power generation system provided with DFIG needs a converter with only one-third of the rated power, resulting to a cost-effective system with minimal power loss [12]. DFIG can also regulate reactive power differently from real power with a proper adjustment on the frame [13].Recall that DFIG can maintain a stable power network voltage by producing some controllable reactive power, thus improving the overall power factor or voltage profile/characteristics [14]. In order to prevent instability problem in our power system , most power supply companies have proposed several methods, procedures and standards which must be strictly adhered to when the wind generators are tied to the system[15]. Hence, reactive power control in DFIG for wind turbines has become a research topic of interest these days leading to a number of technical results on reactive power control of DFIG in wind turbines[16].

III. METHODOLOGY

3.1 Characterizing the doubly Fed Induction Generator machines

The methodology involves in this work is the step-by-step adherence to the objectives of the study; which has to do with the measurement of the collected data of the mechanical output and electrical output of two generators. The information was used to compute the efficiency of the generators as shown in equations 3.1 and 3.2.This was used to calculate the motor's efficiency by dividing the mechanical output over the electrical input power. Torque meter was applied to measure the mechanical output power. Torque meter and tachometer were mounted and used to determine the mechanical power based on the motor's speed and load.

Large industrial synchronous motors are more efficient than induction motors. They are used when constant speed is required; having a leading power factor, they can correct the AC line for a lagging power factor.

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 generator1
Energy efficiency = <u>Mechanical output power x 100%</u>
Electrical output power
Energy efficiency = <u>11940 xlOO%</u>
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 <u>15300 x l00%</u>
20000
Energy efficiency ofgenerator2 76.5%

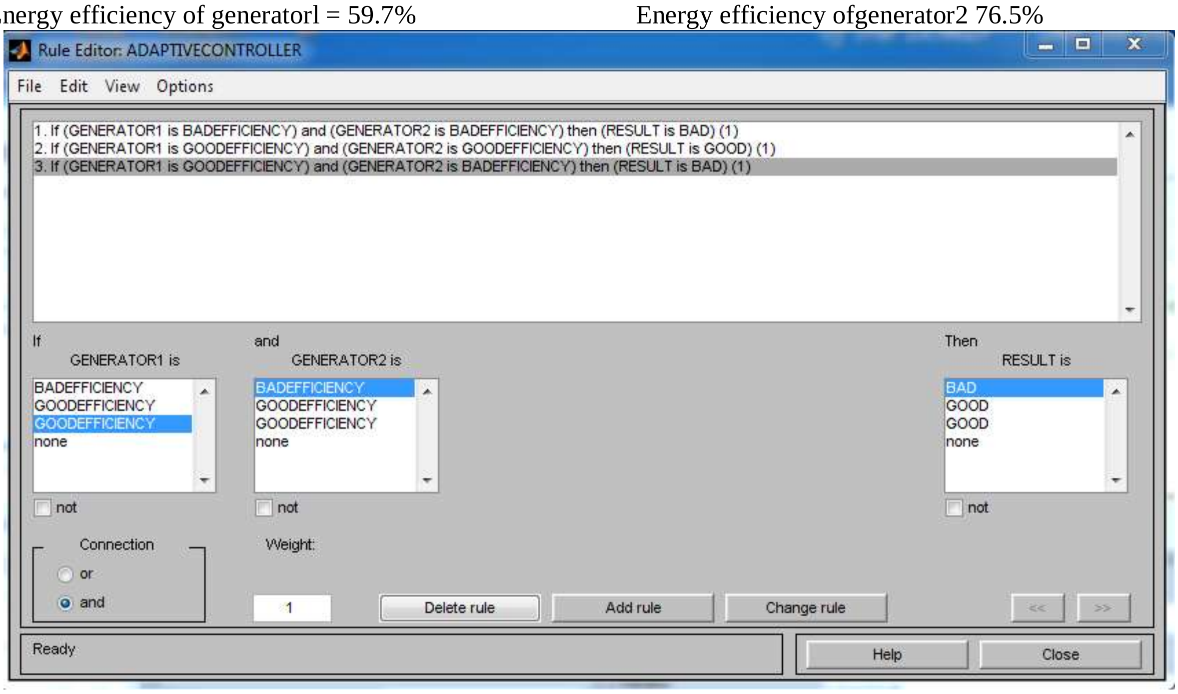

Fig.1Designed an adaptive control rule base for increase energy efficiency in doubly fed induction generator.

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

Fig 1 shows designed adaptive control rule base for increase energy efficiency in doubly fed induction generator. This rule guides in monitoring the efficiency of the generator. It is done in fuzzy tool box in MATLAB environment to monitor and enhance the efficiency of the induction generator.

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

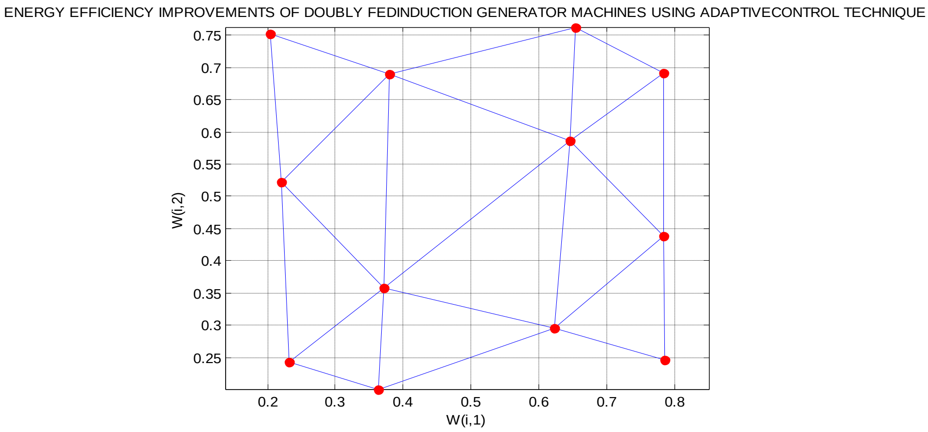

Fig.2 Trained ANN in an adaptive rule base to enhance the energy and its control mechanism

Figure2 shows trained ANN in an adaptive rule base to enhance the energy and its control mechanism. This is done from the rule base that is three in number. This three rules where trained four times to have twelve neurons that mimics human intelligence to do exactly what they are instructed through training to do.

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

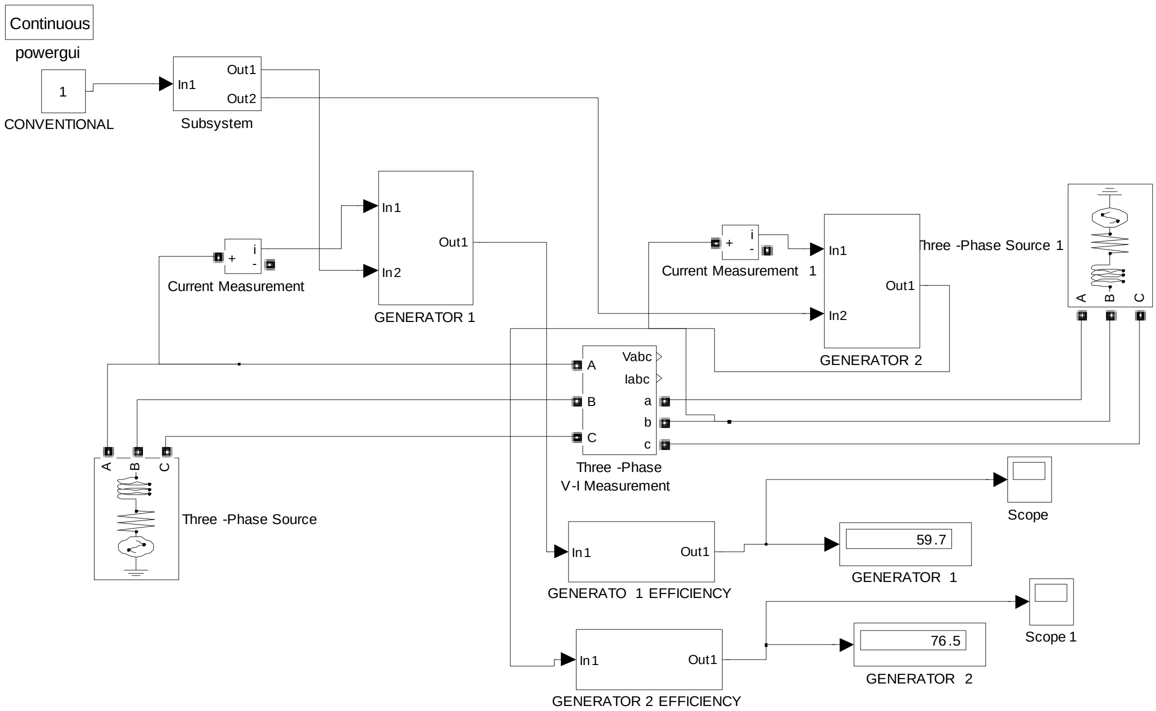

Fig.3 Developed **conventional proportional integral P1 control system forenergy efficiency**.

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.

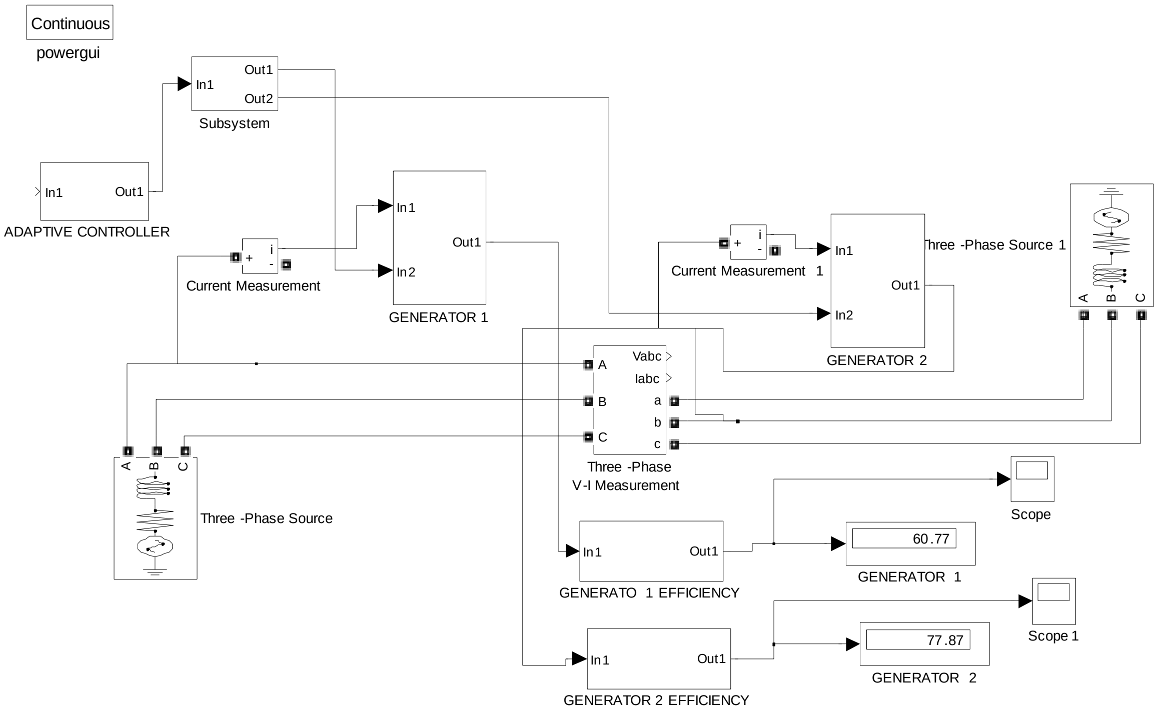

Fig. 4Designed Simulink model for energy efficiency improvements of doubly fed induction generator machine using adaptive control technique

Figure4 shows designed Simulink model for energy efficiency improvements of doubly fed induction generator machine using adaptive control technique. In fig .4 the simulated results obtained were shown in figures 5 and 6 with a comprehensive analysis.

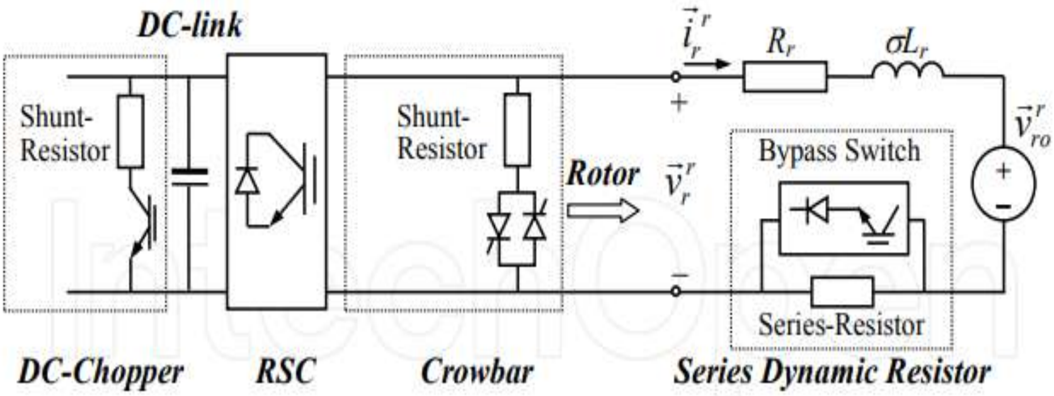

Fig. 5 DFIG rotor equivalent circuit with all protection schemes shown.

IV. RESULTS AND DISCUSSION

The results obtained from the first objectives which has to do withcharacterizing the machines under study are calculated and shown in table 1.Fig.1 shows the Design of an adaptive control rule base for increase energy efficiency in doubly fed induction generator. Fig 2 shows the trainedArtificial Neural Network (ANN) in an adaptive rule base to enhance the energy and its control mechanism. This is done from the rule base that is three in number. These three rules were trained four times to have twelve neurons that mimics human intelligence to do exactly what they are instructed through training to do.Fig 3 shows the developmentof 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. Fig 4 shows designed Simulink model for energy efficiency improvements of doubly fed induction generator machine using adaptive control technique. In fig .4, the simulated results obtained were shown in figures 5 and 6 with a comprehensive analysis. Fig. 5 DFIG rotor equivalent circuit with all protection schemes shown. Fig 6 Comparing conventional and adaptive controller generator 1 efficiency; Fig 6 shows Comparison between conventional and adaptive controller generator 1 efficiency. In fig 6 the conventional generator 1 efficiency is stable at 4s through 10s at59.7%. On the other hand, the efficiency of Generator 1 when adaptive controller is incorporated in the system is 60.77% at a stable time of 4s through 10s. The percentage energy improvement when adaptive controller is incorporated in the system when compared to the conventional method is 1.07%.While Fig 7 shows the comparison of conventional and adaptive controller generator 2 efficiency. In fig 7 the highest conventional generator 2 efficiency is76.5% while the highest generator 2 efficiency when adaptive controller is incorporated in the system is 77.87%. The percentage improvement when adaptive controller is imbibed in the system over the conventional method is 1.3% from the results obtained.Table 2 is a Comparison between conventional and adaptive controller generator 1 efficiencyTable 3 Compared conventional and adaptive controller generator 2 efficiency accordingly.

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

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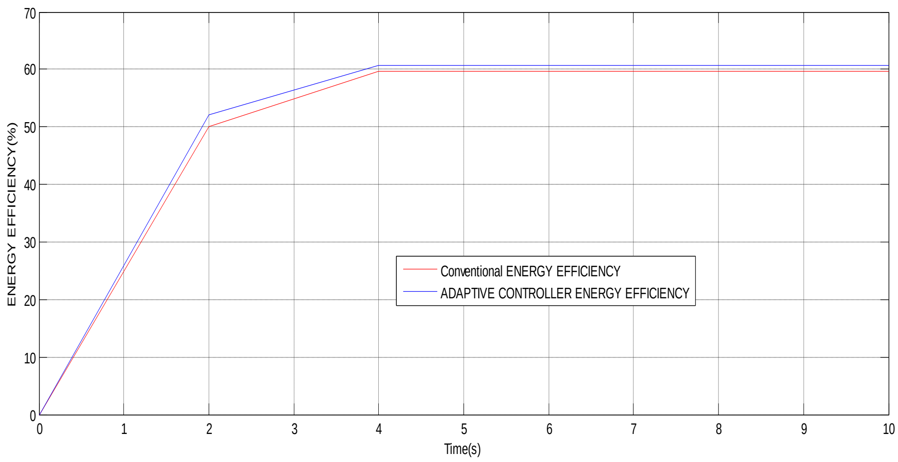

Fig 6 Comparing conventional and adaptive controller generator 1 efficiency

Fig 6 shows Comparing conventional and adaptive controller generator 1 efficiency.

In fig 6 the conventional generator 1 efficiency is stable at 4s through 10s at59.7%. On the other hand, the efficiency of Generator 1 when adaptive controller is incorporated in the system is 60.77% at a stable time of 4s through 10s.

The percentage energy improvement when adaptive controller is incorporated in the system when compared to
the conventional method is 1.07%.

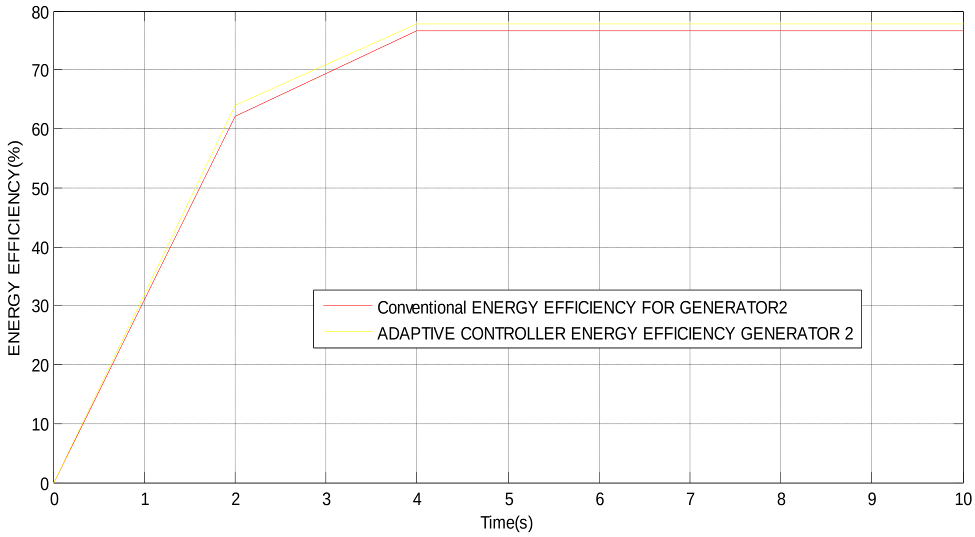

Fig. 7comparing conventional and adaptive controller generator 2 efficiency

Figure7: shows comparing conventional and adaptive controller generator 2 efficiency. In fig 4.2 the highest conventional generator 2 efficiency is76.5% while the highest generator 2 efficiency when adaptive controller is incorporated in the system is 77.87%. The percentage improvement when adaptive controller is imbibed in the system over the conventional method is 1.3% from the results obtained.

V. CONCLUSION

The reduction in efficiencies of induction generators has led to the reduction of production capacities of some manufacturing industries that depend on these generators for their routine production. This precarious situation of reduction in efficiency of this generator is addressed by energy efficiency improvements of doubly fed induction generator machines using adaptive control technique. It is done in this manner, characterizing the doubly-fed induction generator. Designing an adaptive control rule base for increase energy efficiency in doubly fed induction generator, training ANN in an adaptive rule base to enhance the energy and its control mechanism, developing a conventional proportional integral PI control system for energy efficiency. Designing a Simulink model for energy efficiency improvements of doubly fed induction generator machine using adaptive control technique and validating and justifying the energy efficiency conventionally and when adaptive control is incorporated in the system. The results obtained are conventional generator 1 efficiency is stable at 4s through 10s at59.7%. On the other hand, the efficiency of generator 1 when adaptive controller is incorporated in the system is 60.77% at a stable time of 4s through 10s. The percentage energy improvement with adaptive controller incorporated in the system; compared to the conventional method is 1.07%. The final results obtained in generator 2 are the highest conventional generator 2 efficiency,76.5% while the highest generator 2 efficiency with adaptive controller incorporated in the system is 77.87%. The percentage improvement when adaptive controller is imbibed in the system over the conventional method is 1.3% from the results obtained.

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