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# Performance Evaluation ofa Frequency Controlled System for a Three-Phase Self Excited Induction Generatorusing Artificial Neural Network

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## ABSTRACT

This paper presents an intelligent technique of controlling the load frequency of a three-phase Self Excited Induction Generator via Artificial Neural Network Algorithm.Thesystem consists of a six-pulse diode bridge rectifier, excitation capacitor,Electronic Load Controller, chopper switch and a variable load unit. The load was radially varied, monitored and controlled by feedforward backpropagationartificial neural network with a view to ensuring a frequency stability at different load level. The Insulated Gate Bipolar Transistor is employed as a chopper switch to engage and disengage the dummy load until threshold frequency stability is attained. The ANN supervises and controlsthe percentage ballast power dissipated to the dummy load by comparing the reference frequency saw tooth wave to generate the switching duty cycle. A suitable capacitor bank is connected in parallel toprovide optimal reactive power for the winding excitation and voltage regulation. The set up was implemented on 2018a MATLAB/SIMULINK environment and tested with a non-linear loadsunder transient and steady-state conditions. The simulation results revealed that the system possesses a stable frequency of 50Hz at different load level conditions and has a relative faster switching time.

**KEYWORDS:**Induction Generator; Artificial Neural Network; Electronic Load Controller; Ballast Load and Reactive Power

**List of Symbols and Abbreviations:**
SEIG: Self Excited Induction Generator
ELC: Electronic Load Controller
ANN: Artificial Neural Network
IGBT: Insulated Gate Bipolar Transistor
PD: Proportional-Derivative
PID: Proportional-Integral-Derivative
$P_{Gen}$: Generated Power
$P_{Load}$: Consumer Load Power
$P_{dump}$: Dumped Power

## I. INTRODUCTION

Electrical energy isone of the basic necessities that drivesthe economy of any nation. The potential of the energy available from the small hydro and the wind sources seem to be quite promising to meet the energy demands, especially in the remote and isolated areas. Exploiting these renewable energy sources to generate electrical power in micro range could come with high initial cost. Induction generator has found applications in remote areas because it offers some advantages viz. reduced cost, robustness,etc..However, there is need to control the output of an induction to generate a steady qualitative power.
De Resendeet al.,2003 proposed fuzzy voltage controlling technique of a three phase induction generator. The result obtained was similar to PD but has faster control action through the shot of the thyristor at the appropriate angle which gives a constant voltage with variation of the applied load, butthe response time is slow.

Tomonobuet al., 2004 studied the terminal voltage and power factor of an induction generator for wind power by adjusting the reactive power using compensating capacitor. It was reported that the power factor and the terminal voltage were kept to a set value. However, this study did not evaluate the performance of the system under transient condition.

T. Nalubegaet al., 2014, analysed control techniques used on induction generators for stand-alone pico hydropower scheme and reported that IGBTs performed a better voltage variation controlling to PID. Meanwhile, both controlled methods maintained a near constant voltage at load variation for systems and had acceptable load response at different variations. The shortcoming of this method was inability to control winding excitation at varying load without voltage fluctuation.

SaptarshiBasaqet al., 2015 proposed a new control technique dual stator induction generator for remote microgrid application. The major merit of this system is the reduced range of capacitive filter to better copper utilization of the stator windings. The system was found to be effective during initial build up for voltage regulation under load and prime mover speed variation. However, the system is insensitive two consecutive transient load variations.

SangHum Lee and Minsuk Sim, 2017 presented a control strategy for a squirrel cage induction generator based on the commercial vehicle using engine-generator system. The slip and vector control method using PSIM to illustrate the characteristics of the system. The results from the study showed that the deviation of the dc link from its reference value during the mentioned transient conditions is below 3% in slip control and 1% in vector control method.

N. Karakasiset al., 2017 presented the performance studies of a wind energy conversion system with an induction generator under various start-up control techniques. It was observed that the charging of the dc-link capacitor from the grid could provide satisfactory WECS start-up performance, however, it absorbs electric energy from the grid for the winding excitation and thus, it cannot be used in stand-alone wind application.

This paper presents an intelligent way of controlling the load frequency of an induction generator in a stand-alone application using Artificial Neural Network technique by providing solution to the shortcomings from the previous Authors.

## II. MATERIALS AND METHODS

The design of the ANN algorithm for the load frequency control of a stand-alone three phase induction generator will be examined. The steady-state and transient analysis at different load conditions will be assessed to evaluate the performance of the controller.

### 2.1 System Configuration and Control Scheme

The block diagram of the SEIG connected to ELC system with three phase non-linear loadis shown in Fig. 1.

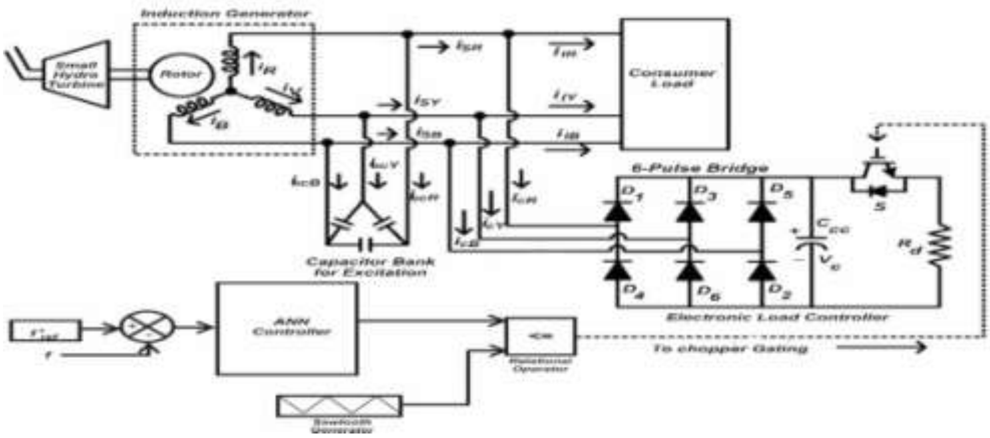


Fig. 1: Block Diagram of anANN-Based Control Technique of a Stand Alone SEIG

The IGBT is used as a chopper switch to provide a variable DC voltage such that when the chopper switch is ON, comparatorcompares the reference signal with the sensed voltage signal from the diode rectifier. The differential signal from the comparator is used to generate the varying duty cycle switching signal whichcontrols the gate of the IGBT. SEIG feeds both consumer load and dummy load in parallel such that the total power is

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appeared constant at varying consumer load as depicted in Equation 1.

$$P_{Gen} = P_{Load} + P_{Dump} \quad 1$$

where, $P_{Gen}$ is the generated power of the generator, $P_{Load}$ is the consumer power and $P_{dump}$ is thedump load power. This dump power ($P_{Dump}$) may be used forspace heating, water heating, battery charging, cooking,baking etc.

### 2.2 ANN Controlling Algorithm

The referenece frequency, $f^*_{ref}$ and load frequency, f are fed to the comparator to generate error signal. The ANN controller generate a carrier signal in the form of a sawtooth waveform and fed to the gate of the IGBT switch as shown in Fig. 2.

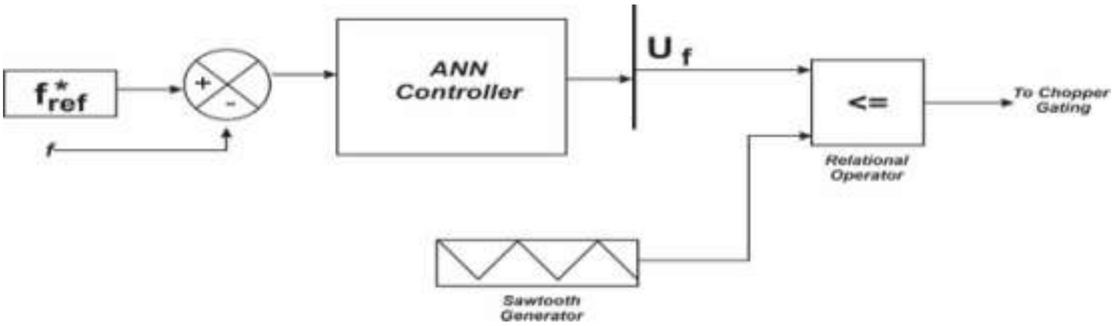


Fig. 2: Block Diagram of ANN Control System Model

#### 2.2.1 Testing the network

The appropriate outputs from the trained data are given by the network to control inputs of the ELC DC chopper circuit.A test point of different samples was used to evaluate the performance of the ANN after training of the neural network. The network is trained using the MATLAB NNET tool box shown in Fig. 3.

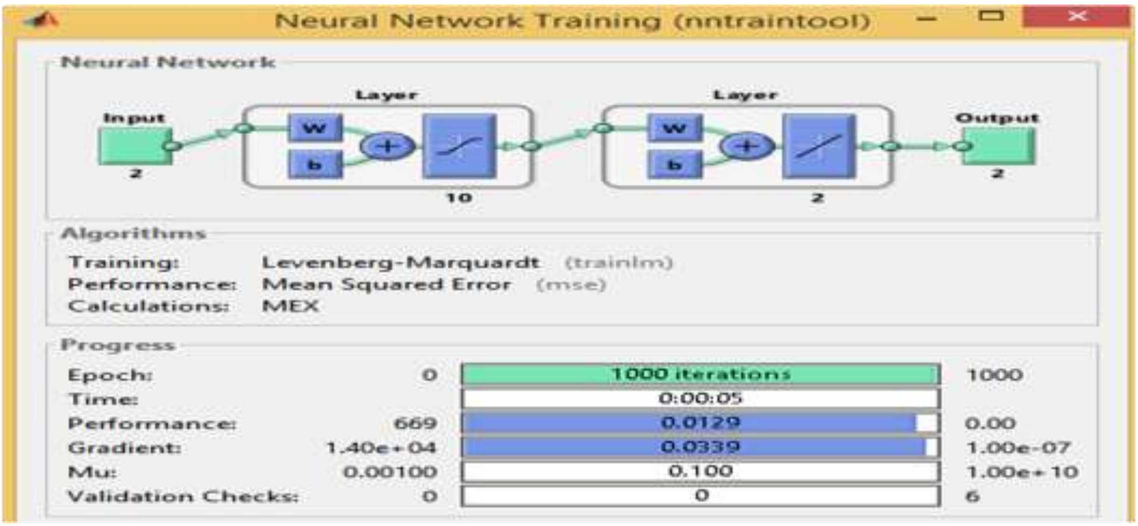


Fig. 3: ANN Training with MATLAB NNET Toolbox

## III. RESULTS AND DISCUSSION

The performance of the controller under transient and steady-state conditions were evaluated and their results were discussed accordingly. Fig. 4 shows the developed controller in MATLAB/SIMULINK environment.

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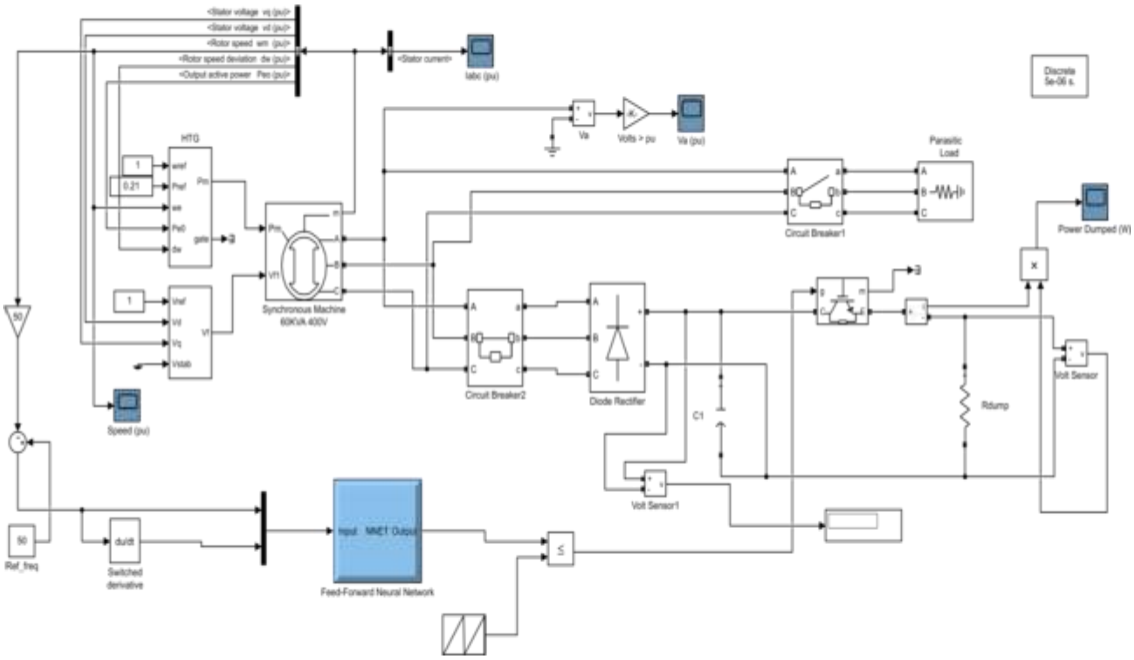


Fig. 4: MATLAB/Simulink of SEIG-ELC with ANN Controller

### 3.1 Performance of the designed ANN controller

The performance evaluation of trained system is shown in Fig. 5 and data points are shown in Table 1.

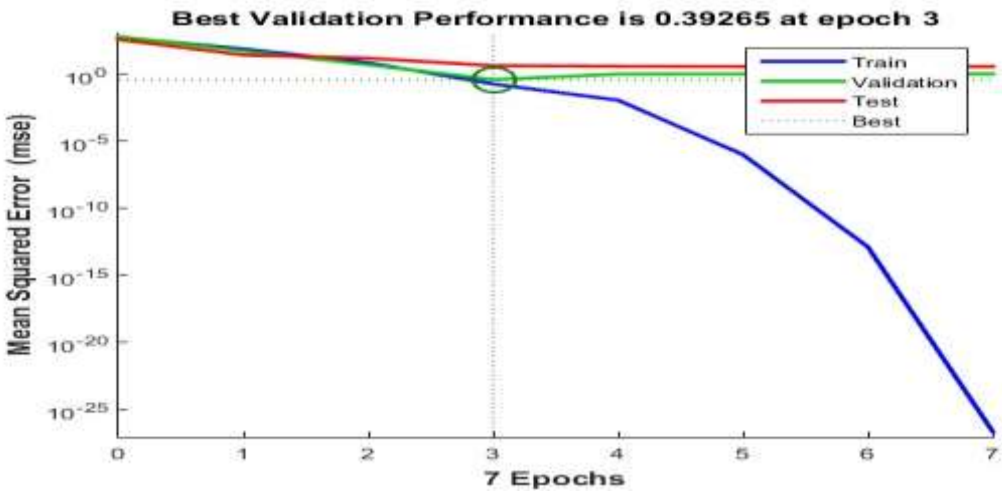


Fig. 5: Performance of Neural network

Table 1: Frequency and Voltage Data Input, and ANN Output data

| Test point | Frequency(Hz) | Voltage **(V)** | Target **(T1)** | Target **(T2)** |
|---|---|---|---|---|
| **1** | 49.6 | 391 | 17.724 | 17.8007 |
| **2** | 49.7 | 400 | 16.88 | 16.8174 |
| **2** | 49.8 | 400 | 15.614 | 15.6228 |
| **4** | 49.9 | 410 | 11.816 | 11.8301 |
| **5** | 50.0 | 393 | 16.88 | 16.8582 |

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|---|---|---|---|---|
| **6** | 50.1 | 402 | 14.77 | 14.7676 |
| **7** | 50.2 | 412 | 14.77 | 14.6336 |
| **8** | 50.3 | 413 | 13.926 | 13.8895 |
| **9** | 50.4 | 399 | 6.752 | 6.9196 |
| **10** | 50.5 | 396 | 16.036 | 15.8739 |

#### 3.1.1 Performance of SEIG-ELC with ANN controller under transient condition

A sudden load of 50 kW was switched ON at 0.4 secondunder opened circuit breaker to evaluate the performance of the SEIG-ELC based on ANN under transient condition.There was a sudden drop in the voltage, however, there is also a sudden rise in the stator currents as shown in Fig. 6. The rotor speedinstability settles to normal at about 0.45 second as shown in Fig. 7 .

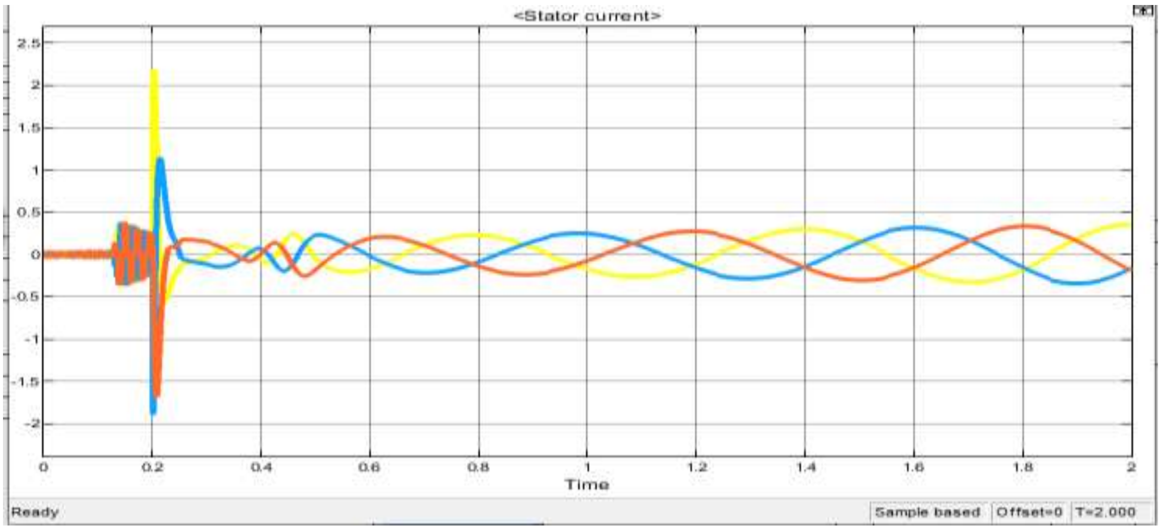


**Fig. 6: Output of stator current under transient condition**

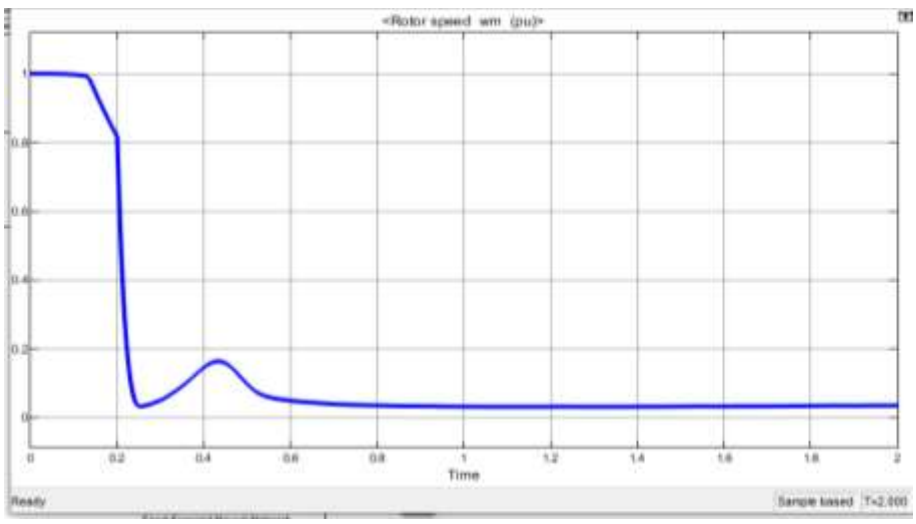


Fig. 7: Speed Variation During Transient Analysis

### 3.1.2 Performance of SEIG-ELC with ANN Controller under Steady-state Condition

The load was linearly increased with a step of 2 kW until it reaches 60 kW to evaluate the performance of the system under steady-state condition. The terminal voltage rises initially beyond 1pu and in about 0.2 seconds it settles to 1pu. The variation in speed during steady-stateis shown in Fig. 8.

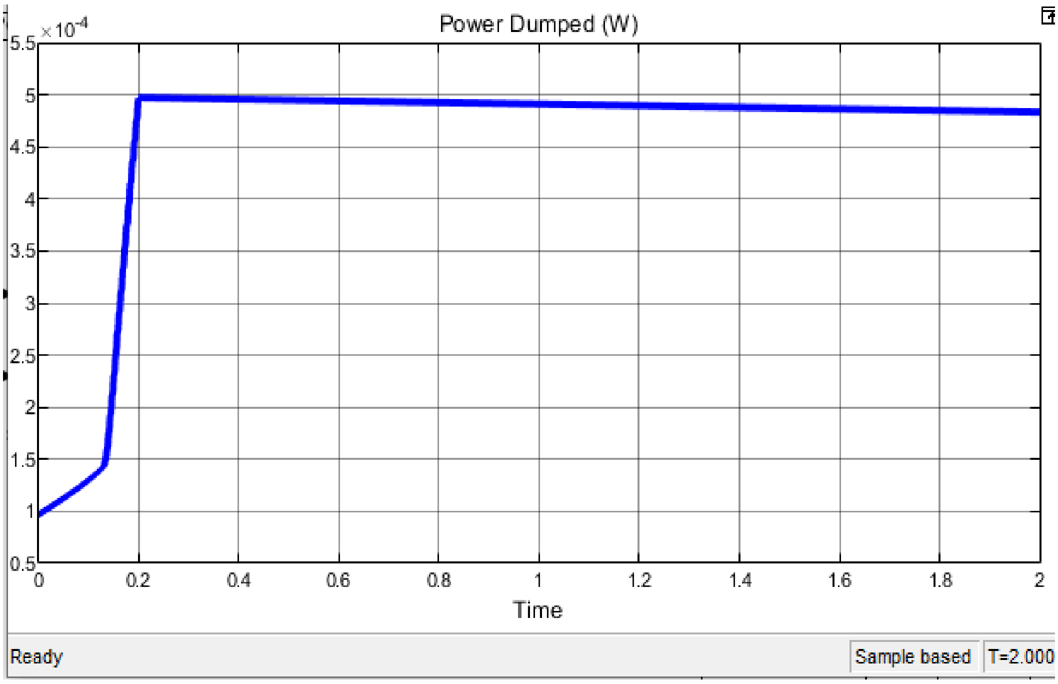


Fig. 8:Variation in Power Dumped During Transient Analysis

## IV. CONCLUSION

This paper has presented an intelligent way of controlling the load frequency of a Self-Excited Induction Generator using Artificial Neural Network. The performance of the controller was evaluated with non-linear loads under steady-state and transient conditions. The system was able to maintain a threshold load frequency of 50Hz at different load variations.

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**CONFLICT OF INTEREST STATEMENT**

The authors declared no conflict of interest

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