A heuristic computing approach using sequential quadratic programming to solve the fifth kind of induction motor model

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Abstract: The purpose of the current investigation is to solve the fifth kind of induction motor model using an advanced computational scheme by operating the artificial neural networks (ANNs), global scheme as genetic algorithm (GA) along with the rapid local search sequential quadratic programming technique (SQPT), i.e., ANN-GA-SQPT. ANNs is implemented to discretize the fifth kind of induction motor model to express the merit function based on the mean square error. The numerical presentation of the proposed ANN-GA-SQPT is pragmatic for three different problems based on the fifth kind of induction motor model to authenticate the efficacy, consistency and importance of the proposed ANN-GA-SQPT. Moreover, statistical representations are provided in order to check the precision, convergence and accuracy of the present ANN-GA-SQPT.

Keywords: Induction motor nonlinear models; Statistical performances; Artificial neural networks; Sequential quadratic programming technique; Genetic algorithm.

1. Introduction

The induction motor behavior along with the circuits of dual rotors is signified by a fifth kind of boundary value problems (BVPs). This model is consistent of two variants, shaft speed and other is dual rotor. Generally, the addition of two more variables for the belongings of a second rotor circuit demonstrating deep bars, rotor distributed constraints and a starting cage. To evade the additional form of the variables of computational load, the additional rotor routes are obligatory, the system shows the fifth kind and the resistance of rotor is algebraically transformed to the rotor exactness. This happened due to supposition that the rotor current's occurrence is dependent of rotor speed and this method is effective for the steady state response with sinusoidal energy [1].

The study of the fifth kind of differential models occurs in the viscous and elastic fluid models [2-3]. Caglar et al. [4] applied B-spline of sixth degree to solve the fifth kind of linear/non-linear boundary value models. Agarwal discussed the conditions in the individuality and presence of the solutions of these models [5]. Siddiqi et al [6–7] worked to find the outcomes of 6^{th}, 8^{th}, 10^{th} and 12^{th} kind of BVPs using these degree splines. Siddiqi et al proposed the fifth-kind of linear BVPs based on the non-polynomial spline [8-9]. Noor et al [10] applied decomposition technique to get the results of fifth kind of BVPs in the form of convergent series. Viswanadham et al. [11] applied a collocation scheme with B-splines of 6^{th} degree as a basic function in order to solve the fifth kind of special case BVPs. Sabir et al [12-13] solved the singular fifth kind of differential system using the variational iteration approach. Akram et al [14] implemented the kernel space approach to get the solutions to fifth kind of BVPs. Siddiqi et al. [15] solve the fifth kind of singularly perturbed BVPs using the spline based non-polynomial approach. Viswanadham et al [16] established a collocation, finite element and quartic B-spline schemes. The celebrated form of the induction motor nonlinear models of fifth kind is written as [17]:

$$\begin{cases} v^{(5)}(\Omega) + f(\Omega)v(\Omega) = u(\Omega), & \Omega \in [c,d] \\ v(c) = a_0,\ v'(c) = a_1, v''(c) = a_2, \\ v(d) = b_0,\ v'(d) = b_1. \end{cases} \quad \textbf{(1)}$$

Where a_0, a_1, a_2, b_0 and b_1 are the finite and real constant values, $f(\Omega)$ and $u(\Omega)$ are continuous on $[c,d]$. The mentioned approaches for solving the higher kind of BVPs have specific accurateness, performance and competence and limitations. Whereas, the computing stochastic solvers using the heuristic schemes originated by the artificial neural networks (ANNs), global scheme as genetic algorithm (GA) along with the rapid local search scheme as sequential quadratic programming technique (SQPT), i.e., ANN-GA-SQPT. The designed procedures of ANN-GA-SQPT have not been implemented for the induction motor models of fifth kind. Few recent applications of the stochastic based solvers are biological prey-predator system [18], doubly singular systems [19], functional form of the nonlinear singular models [20-21], Thomas-Fermi singular model [22], SITR based COVID-19 system [23], dengue fever SIR nonlinear system [24], three-point second kind of differential system [25], singular periodic boundary value models [26], heat conduction of human head system [27], HIV dynamics [28] and mosquito release system in a heterogeneous state [29]. The purpose of these investigations is to solve the induction motor models of fifth kind numerically using the stochastic computational schemes of ANN-GA-SQPT. Few major backgrounds of the proposed ANN-GA-SQPT are given as:

- A design of ANN is presented to achieve the numeric results of the induction motor models of fifth kind using the hybrid GA-SQPT.
- A consistent and accurate matching of the results obtained through ANN-GA-SQPT and the reference results validate the exactness of the proposed approach.
- Authentication of the proposed ANN-GA-SQPT via the performance measures in terms of mean absolute deviation (MAD), variance account for (VAF) and Theil's inequality coefficient (T.I.C).

- The merits and advantages of the designed scheme is to perform comprehensive and easily by operating the induction motor models of fifth kind using the hybrid computational framework ANN-GA-SQPT to tackle competently the complex systems.

The remaining portions are provided as: Section 2 provides the methodology based on the ANN-GA-SQPT. Section 3 gives the detail of statistical measures. Section 4 shows the simulations and discussions, while the final remarks along with future research reports are drawn in the final section.

2. Methodology: ANN-GA-SQPT

In this section, ANN-GA-SQPT structure is presented for the numerical simulations of the induction motor models of fifth kind. The fitness structure along with the optimization of GA-SQPT is also provided.

2.1 ANN procedures

The ANNs are prominent for the stable and consistent outcomes in various areas. The mathematical illustrations of the model (1) are given as:

$$\hat{v} = \sum_{j=1}^{J} r_j T(w_j \Omega + s_j), \tag{2}$$

$$\hat{v}^{(n)} = \sum_{j=1}^{J} r_j T^{(n)}(w_j \Omega + s_j), \tag{3}$$

where r_j, w_j and s_j designate the j^{th} form of ***r*, *w*** and ***c*** vectors, whereas $\hat{v}$ is the approximate solution form. The log-sigmoid activation function (LSAF) i.e., $T(\Omega) = \left(1+e^{-\Omega}\right)^{-1}$ together with its fifth-order derivative applied as a merit function. The efficient form of the LSAF is written as:

$$\hat{v} = \sum_{j=1}^{J} r_j \left(1+e^{-(w_j\Omega+s_j)}\right)^{-1}, \tag{4}$$

$$\hat{v}^{(n)} = \sum_{j=1}^{J} r_j \frac{d^n}{dt^n}\left(\left(1+e^{-(w_j\Omega+s_j)}\right)^{-1}\right). \tag{5}$$

The fifth kind of derivative is given as:

$$\hat{v}^{(5)}=\sum_{j=1}^{J} r_j w_j^{\,5}\left(\begin{array}{l}\dfrac{120e^{-5(w_j\Omega+s_j)}}{\left(1+e^{-(w_j\Omega+s_j)}\right)^6}-\dfrac{240e^{-4(w_j\Omega+s_j)}}{\left(1+e^{-(w_j\Omega+s_j)}\right)^5}+\dfrac{150e^{-3(w_j\Omega+s_j)}}{\left(1+e^{-(w_j\Omega+s_j)}\right)^4}\\ -\dfrac{30e^{-2(w_j\Omega+s_j)}}{\left(1+e^{-(w_j\Omega+s_j)}\right)^3}-\dfrac{e^{-(w_j\Omega+s_j)}}{\left(1+e^{-(w_j\Omega+s_j)}\right)^2}\end{array}\right), \quad \textbf{(6)}$$

where the weight vectors are $\boldsymbol{r}=[r_1, r_2, \ldots r_J]$, $\boldsymbol{w}=[w_1, w_2, \ldots, w_J]$ and $\boldsymbol{s}=[s_1, s_2, \ldots, s_J]$, respectively. The fitness function is signified as:

$$E_{Fit}=E_{Fit-1}+E_{Fit-2}, \quad \textbf{(7)}$$

where E_{Fit-1} and E_{Fit-2} are the fitness functions based differential systems and boundary conditions, defined as:

$$E_{Fit-1}=\frac{1}{J}\sum_{k=1}^{J}\left(\hat{v}_j^{(5)}+f_j+7\hat{v}_j-u_j\right)^2,$$

$$E_{Fit-2}=\frac{1}{5}\left(\left(\hat{v}_0-a_0\right)^2+\left(\hat{v}_0'-a_1\right)^2+\left(\hat{v}_0''-a_2\right)^2+\left(\hat{v}_J-b_0\right)^2+\left(\hat{v}_J'-b_1\right)^2\right).$$

2.2 Optimization procedure: GA-SQPT

The ANNs is trained through the weight vectors to function the computational strength of GA-SQPT. The graphical depictions of ANN-GA-SQPT for the induction motor models of fifth kind are illustrated in 1st figure.

GA is operated as a weight vector (***W***) to present the ANN modeling. The population with aspirant clarifications of GA is proficient using the bounds of actual values. However, each aspirant value contains few fundamentals that are unidentified weights in ANNs. In recent years, GA is executed in frequent optimization submissions like the humanitarian logistics in emergency scheduling [30], heterogeneous bin storing [31], reduce the cost in multi-energy building source [32], residential buildings deign for building envelope [33], traveling salesman models [34], singular delayed, prediction and pantograph differential models [35], optimum set of matching clusters [36], prediction differential models [37], nonlinear singular models of third kind [38], glass transitions in cooked candies [19] and queens problems [40].

The laziness of GA is fixed by applying the hybridizing procedures with suitable local scheme by using the best GA performances as a prime weight. Consequently, a well-organized local search SQPT is applied for adjustment of the parameter. SQPT is implemented in numerous submissions, e.g., flight vehicle guidance [41], noise covariance estimation [42], minimization of cost using the hybrid photovoltaic, battery storage model and diesel generator [43], prediction differential second order models [44], flight vehicle guidance [45] and optimization of central air-conditioning [46]. The detailed procedure is provided in Table 1.

Table 1: Optimization representations of GA-SQPT

```
[GA] process start
      Inputs:
      The parameters having same elements of the system are:
```

$\boldsymbol{W}=[\boldsymbol{r},\boldsymbol{w},\boldsymbol{s}]$, where $\boldsymbol{S}=[s_1,s_2,...,s_J]$, $\boldsymbol{r}=[r_1,r_2,...r_J]$ and $\boldsymbol{w}=[w_1,w_2,...,w_p]$.

Population: The set of chromosomes is given as: $\boldsymbol{P}=[\boldsymbol{W}_1,\boldsymbol{W}_2,...,\boldsymbol{W}_j]^t$.

Output: The global Best weights is signified as $\boldsymbol{W}_{\text{B-GA}}$

Initialization

Produce $\boldsymbol{W}$, a weight vector of real numbers.

Fitness design

Achieved E_{Fit} for $\boldsymbol{W}$ using Eq the fitness functions

Termination Standards

Processes terminate, when any of the form is achieved

E_{Fit} = 10^{-21}, StallGenLimit=80,Population Size =150

Generations=65, TolCon = TolFun=10^{-21}.

Move to **[storage].**

Storage

$\boldsymbol{W}_{\text{B-GA}}$, E_{Fit}, generation, time and function count

[GA] Ends

[SQPT] Starts

Inputs

Start point: $\boldsymbol{W}_{\text{B-GA}}$

Output

Best GA-SQPT weights are indicated as $\boldsymbol{W}_{\text{GA-SQPT}}$

Initialize

Limited constraints, assignments, iterations and other stated values.

Terminate

The process terminates, when one of the below conditions is achieved as:

E_{Fit} ≤ 10^{-20}, TolFun = TolCon= 10^{-22}, Iterations = 520

MaxFunEvals=273000 and TolX=10^{-21}

While (Terminate)

Fitness (E_{Fit}) assessment

Calculate E_{Fit} using Eq (7).

Adaptations

Use {fmincon} in SQPT. Regulate $\boldsymbol{W}$ for SQPT.

Compute E_{Fit} to simplify $\boldsymbol{W}$ by using Eq 7

Store

Store $\boldsymbol{W}_{\text{GA-SQPT}}$, E_{Fit}, fun counts, iterations and time for SQPT trials.

[SQPT] End

3. Statistical performance

The statistical investigations using TIC, MAD and VAF are obtainable to authenticate the reliability and constancy of the proposed ANN-GA-SQPT. The mathematical representations of these operators are given as:

$$\text{MAD}=\sum_{j=1}^{n}\left|v_j-\hat{v}_j\right|, \tag{8}$$

$$\text{T.I.C}=\frac{\sqrt{\frac{1}{n}\sum_{j=1}^{n}\left(v_j-\hat{v}_j\right)^2}}{\left(\sqrt{\frac{1}{n}\sum_{j=1}^{n}v_j^2}+\sqrt{\frac{1}{n}\sum_{j=1}^{n}\hat{v}_j^2}\right)}, \tag{9}$$

$$\begin{cases}\text{V.A.F}=\left(1-\dfrac{\operatorname{var}\left(v_j-\hat{v}_j\right)}{\operatorname{var}\left(v_j\right)}\right)*100\\ \text{EVAF}=\left|\text{VAF-100}\right|.\end{cases} \tag{10}$$

4. Results and discussions

The comprehensive solutions to solve three different problems of the fifth kind of induction motor system are provided in this section.

Problem 1: Consider the fifth kind of induction motor system involving trigonometric function is shown as:

$$\begin{cases}v^{(5)}(\Omega)+\sin(\Omega)v(\Omega)=\left(-1+\sin(\Omega)\right)\sin(\Omega)+\left(1+\sin(\Omega)\right)\cos(\Omega)\\ v(0)=v'(0)=1, v''(0)=-1,\\ v(1)=\sin(1)+\cos(1),\ v'(1)=-\sin(1)+\cos(1).\end{cases} \tag{11}$$

The true form of the fifth kind of induction motor system (11) is $\sin(\Omega)+\cos(\Omega)$, while the related E_{Fit} is given as:

$$\begin{aligned}E_{Fit}&=\frac{1}{N}\sum_{j=1}^{N}\left(\hat{v}_j^{(5)}+\sin(\Omega_j)\hat{v}_j-\sin(\Omega_j)\left(\sin(\Omega_j)-1\right)-\cos(\Omega_j)\left(\sin(\Omega_j)+1\right)\right)^2\\ &+\frac{1}{5}\left(\begin{aligned}&\left(\hat{v}_0-1\right)^2+\left(\hat{v}_0'-1\right)^2+\left(\hat{v}_0''+1\right)^2\\ &+\left(\hat{v}_N-\sin(1)-\cos(1)\right)^2+\left(\hat{v}_N'+\sin(1)-\cos(1)\right)^2\end{aligned}\right).\end{aligned} \tag{12}$$

Problem 2: Consider a fifth kind of induction motor system involving exponential and trigonometric functions is provided as:

$$\begin{cases} v^{(5)}(\Omega)+v(\Omega)=4\cos(\Omega)e^{\Omega}-2\left(-1+\sin(\Omega)\right)e^{\Omega}+5\sin(\Omega)e^{\Omega} \\ v(0)=1,\ v'(0)=0, v''(0)=-1, \\ v(1)=-e\left(-1+\sin(1)\right),\ v'(1)=-e\left(\cos(1)+\sin(1)\right)+e. \end{cases} \tag{13}$$

The true form of the fifth kind of induction motor system (13) is $-e^{\Omega}\left(\sin(\Omega)-1\right)$ and the related E_{Fit} is given as:

$$\begin{aligned} E_{Fit} &= \frac{1}{N}\sum_{j=1}^{N}\left(\hat{v}_j^{(5)}+\hat{v}_j-4e^{\Omega_j}\cos(\Omega_j)+2e^{\Omega_j}\left(\sin(\Omega_j)-1\right)-5e^{\Omega_j}\sin(\Omega_j)\right)^2 \\ &+\frac{1}{5}\begin{pmatrix} \left(\hat{v}_0-1\right)^2+\left(\hat{v}_0'\right)^2+\left(\hat{v}_0''+1\right)^2 \\ +\left(\hat{v}_N+\left(e\sin(1)-1\right)\right)^2+\left(\hat{v}_N'-e+e\left(\sin(1)+\cos(1)\right)\right)^2 \end{pmatrix}. \end{aligned} \tag{14}$$

Problem 3: Consider a fifth kind of induction motor system is provided as:

$$\begin{cases} v^{(5)}(\Omega)-v(\Omega)=-e^{\Omega}\left(15+10\Omega\right) \\ v(0)=v'(0)=1, v''(0)=0, \\ v(1)=0,\ v'(1)=-e. \end{cases} \tag{15}$$

The true form of the fifth kind of induction motor system (15) is $-\Omega e^{\Omega}\left(\Omega-1\right)$ and the related E_{Fit} is given as:

$$\begin{aligned} E_{Fit} &= \frac{1}{N}\sum_{j=1}^{N}\left(\hat{v}_j^{(5)}-\hat{v}_j+e^{\Omega_j}\left(10(\Omega_j)+15\right)\right)^2 \\ &+\frac{1}{5}\left(\left(\hat{v}_0\right)^2+\left(\hat{v}_0'-1\right)^2+\left(\hat{v}_0''\right)^2+\left(\hat{v}_N\right)^2+\left(\hat{v}_N'+e\right)^2\right). \end{aligned} \tag{16}$$

The proposed form of the ANN using the optimization GA-SQPT procedures is applied to solve three problems of the fifth kind of induction motor system. The best weight vector performance is validated to achieve the numerical measures of the fifth kind of induction motor system. The mathematical representation of weight vectors is provided as:

$$\begin{aligned} \hat{v}_{P-1}(\Omega) &= \frac{-9.5782}{1+e^{-(0.7864\Omega-0.9746)}}-\frac{5.9042}{1+e^{-(-1.156\Omega-3.3120)}}-\frac{2.7995}{1+e^{-(-1.002\Omega-0.2316)}}-\frac{0.2943}{1+e^{-(-0.6883\Omega+15.8628)}} \\ &-\frac{0.2744}{1+e^{-(0.110\Omega-12.246)}}-\frac{0.5485}{1+e^{-(-0.972\Omega+0.0824)}}-\frac{2.6134}{1+e^{-(-0.163\Omega-16.1574)}}-\frac{5.6600}{1+e^{-(-1.0231\Omega+1.7343)}} \\ &-\frac{1.9196}{1+e^{-(-1.3465\Omega+3.3816)}}-\frac{0.1317}{1+e^{-(-0.2873\Omega-1.6535)}}, \end{aligned} \tag{17}$$

$$\hat{v}_{P-2}(\Omega)=\frac{-19.7437}{1+e^{-(-0.4870\Omega-14.166)}}-\frac{4.1891}{1+e^{-(-3.880\Omega+9.2435)}}-\frac{5.6648}{1+e^{-(0.494\Omega+5.9538)}}-\frac{8.7495}{1+e^{-(-1.4155\Omega+2.4846)}}$$
$$-\frac{0.8604}{1+e^{-(1.3608\Omega-0.1785)}}-\frac{0.5965}{1+e^{-(-0.333\Omega-14.535)}}+\frac{3.7478}{1+e^{-(-1.696\Omega-0.6171)}}-\frac{9.1244}{1+e^{-(0.6878\Omega+3.9541)}} \quad \textbf{(18)}$$
$$-\frac{4.8322}{1+e^{-(1.6404\Omega+0.6211)}}-\frac{11.1027}{1+e^{-(-1.9578\Omega+2.1537)}},$$

$$\hat{v}_{P-3}(\Omega)=\frac{0.0276}{1+e^{-(-13.434\Omega+18.648)}}-\frac{2.5881}{1+e^{-(1.4435\Omega-1.0071)}}-\frac{0.0204}{1+e^{-(6.5778\Omega+4.9177)}}-\frac{17.0475}{1+e^{-(1.3494\Omega+1.4544)}}$$
$$-\frac{-1.1362}{1+e^{-(-3.2536\Omega+6.0823)}}-\frac{11.4822}{1+e^{-(-4.244\Omega+7.879)}}+\frac{7.1814}{1+e^{-(1.5836\Omega+14004)}}-\frac{20.000}{1+e^{-(-0.1993\Omega+7.6753)}} \quad \textbf{(19)}$$
$$-\frac{10.9099}{1+e^{-(0.9872\Omega+0.7389)}}-\frac{9.7699}{1+e^{-(-2.5438\Omega+4.2452)}},$$

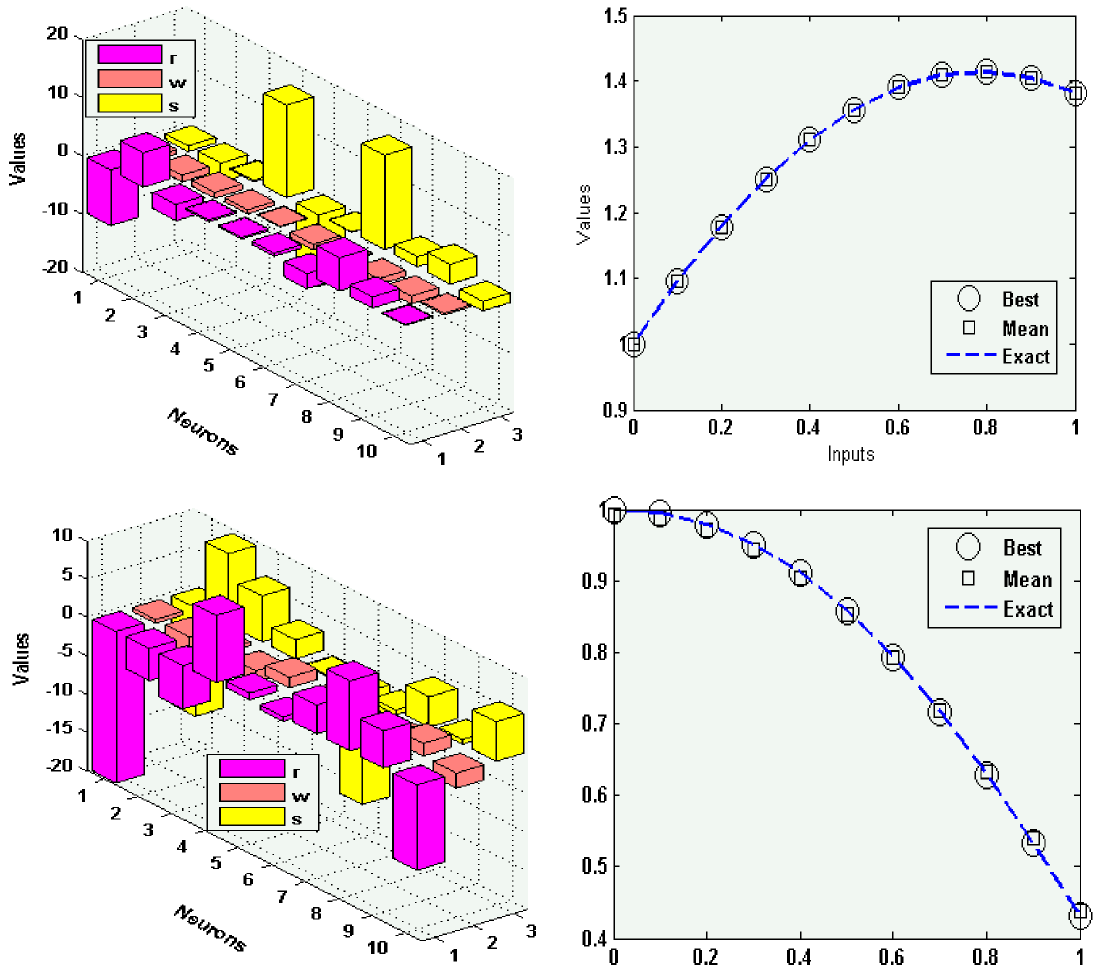
The graphical performances of the ANN-GA-SQPT are provided to solve each problem of the fifth kind of induction motor system are plotted in Figs 1-4. The ANN-GA-SQPT performance using the optimization is executed for sixty trials. Fig. 1 provides the plots of weights set based on the Eqs 17-19 along with the comparisons of the best, exact and mean solutions of the fifth kind of induction motor system through ANN-GA-SQPT. It is witnessed that the results through ANN-GA-SQPT matched with exact and mean results over one another for each problem of the fifth kind of induction motor system. The AE values are provided in Fig. 2(a). The best AE performances lie around 10^{-07} to 10^{-09}, 10^{-05} to 10^{-06} and 10^{-04} to 10^{-06} for each problem of the fifth kind of induction motor system. Fig 3(b) illustrate the performance procedures for each problem of the fifth kind of induction motor system. The best FIT performances lie around 10^{-09} to 10^{-10}, 10^{-08} to 10^{-09} and 10^{-05}-10^{-06} for problems 1, 2 and 3. The best MAD values lie around 10^{-08}-10^{-09}, 10^{-05} to 10^{-06} and 10^{-03}-10^{-04} for problems 1, 2 and 3. The T.I.C operator performances lie around 10^{-11} to 10^{-12}, 10^{-09} to 10^{-10} and 10^{-08}-10^{-09} for problems 1, 2 and 3. The best EVAF performances lie around 10^{-13}-10^{-14}, 10^{-09} to 10^{-10} and 10^{-05} to 10^{-06} for problem 1, 2 and 3. It is witnessed through these investigations that the proposed solver is accurate for each problem of the fifth kind of induction motor system.

The graphical form of the statistical procedures together with histograms are narrated in Figs. 3 and 4 for each problem of the fifth kind of induction motor model. The FIT convergence of MAD, T.I.C and EVAF is observed for sixty trials based on the fifth kind of induction motor system. The obtained results proved the satisfactory performances, which shows about 75% trials accomplish specific FIT, MAD, EVAF and TIC.

For more approval of ANN-GA-SQPT, statistical outcomes are proficient for sixty trials using semi-interquartile range (S.I.R), minimum (Min) and median for the fifth kind of induction motor system. The Min values represent the best trials, whereas S.I.R is defined as $\frac{1}{2}(Q_3-Q_1)$, where Q_3 and Q_1 are the 3rd and 1st quartiles. The Min, S.I.R and Med processes are provided in Table 2, which authenticates the performances for each problem of the fifth kind of induction motor system. Table 3 indicates the computational competence of ANN-GA-SQPT based on completed iterations, functions count and time implementation to observe the decision variables.

Case 1

Case 2



Case 3

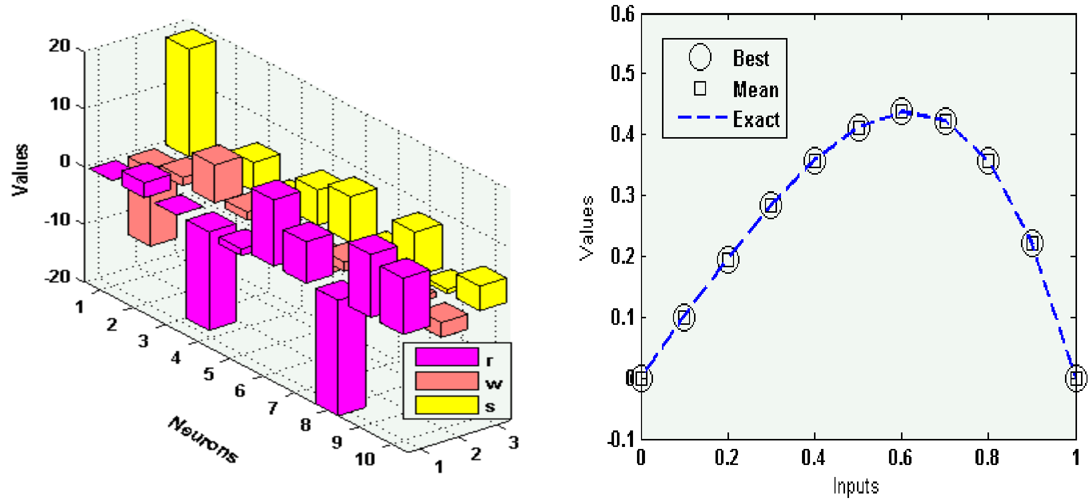
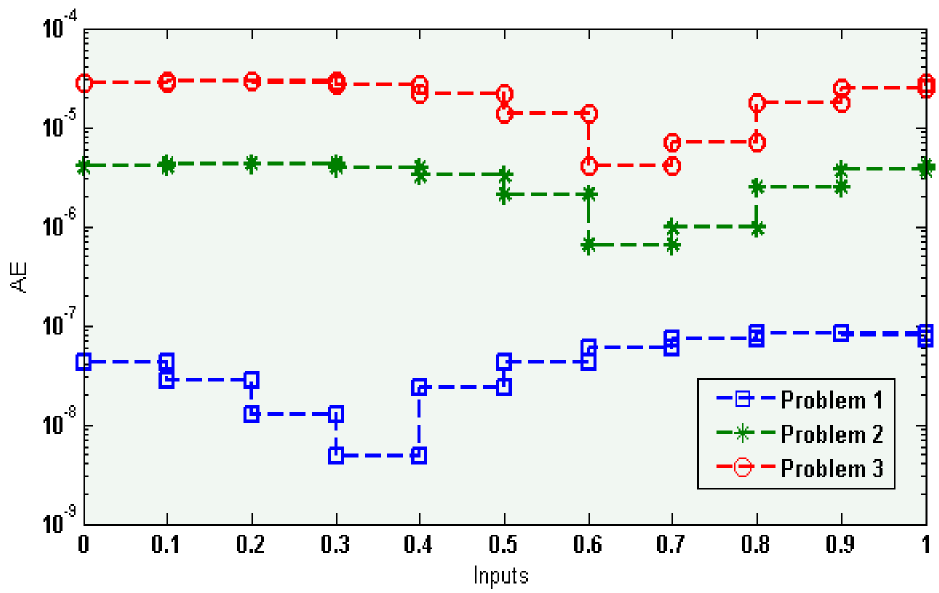
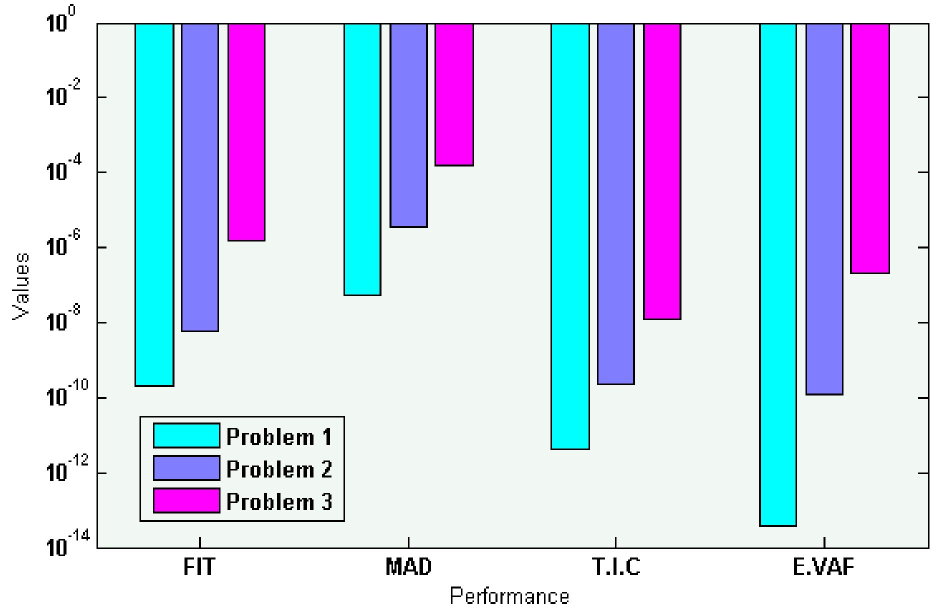


Figure 1: Best weights along with comparison of mean, best and exact solutions for the fifth kind of induction motor system

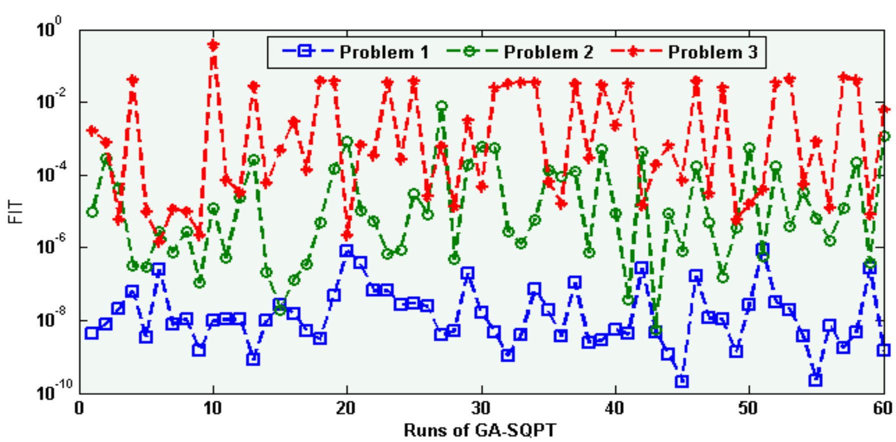


(a) Values of the AE for each problem of the fifth kind of induction motor system

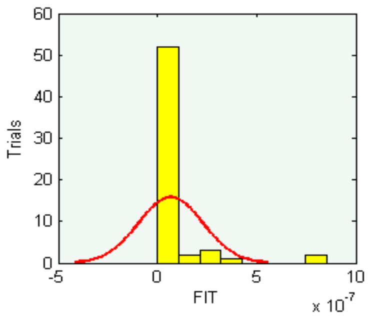


(b) Performance investigations for for each problem of the fifth kind of induction motor system

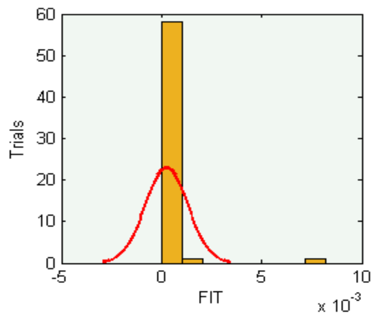
Figure 2: AE and performance investigations for the fifth kind of induction motor system



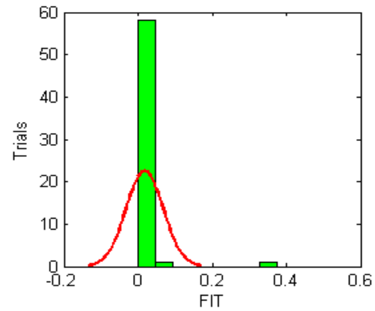
Fit values along with convergence studies to solve each problem of the fifth kind of induction motor system



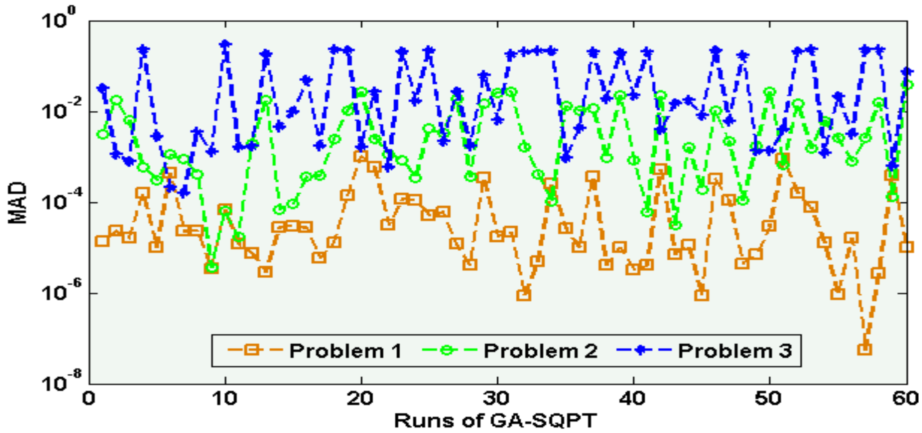
(a) Problem 1: Histogram



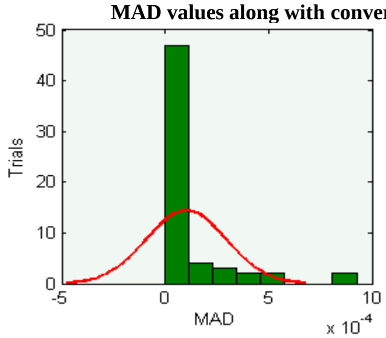
(b) Problem 2: Histogram



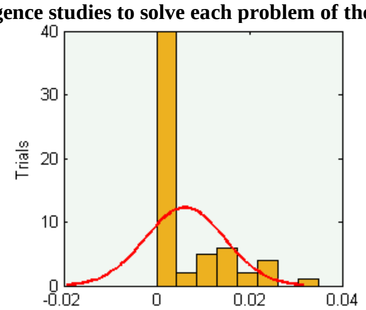
(c) Problem 3: Histogram



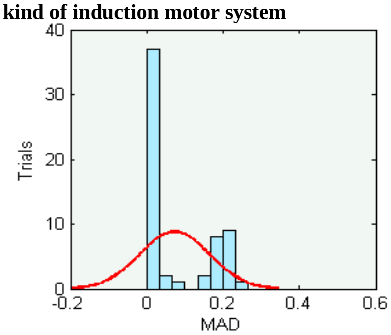
MAD values along with convergence studies to solve each problem of the fifth kind of induction motor system



(d) Problem 1: Histogram

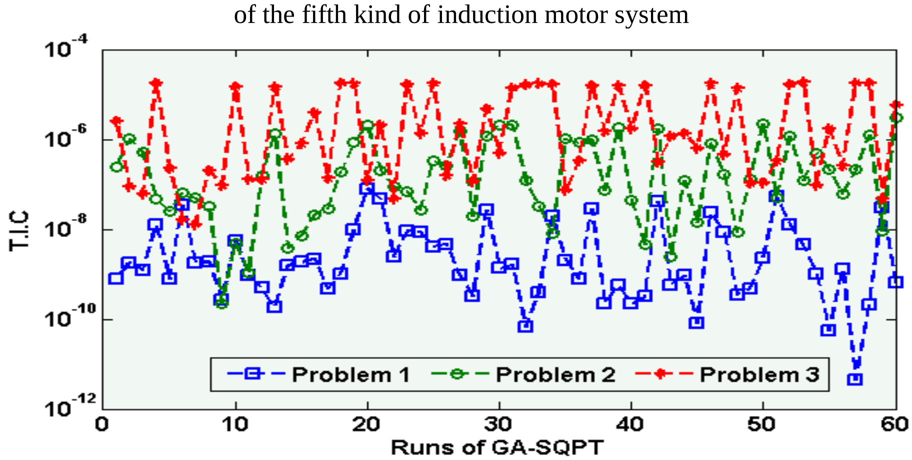


(e) Problem 2: Histogram

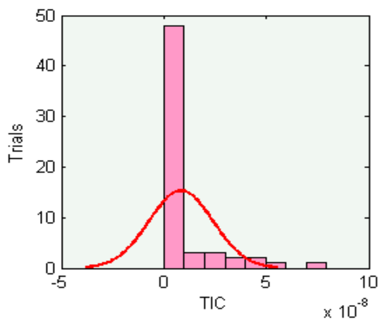


(f) Problem 3: Histogram

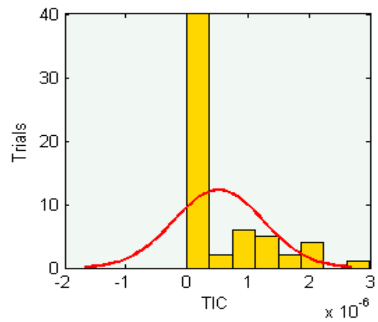
Figure 3: Convergence plots of Fit and MAD together with the Hist values using GA-SQPT to solve each problem of the fifth kind of induction motor system



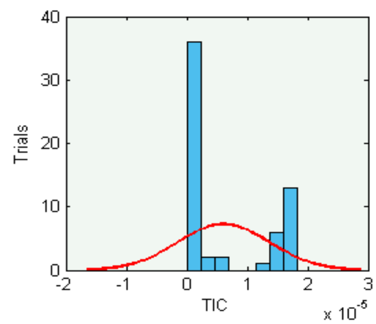
T.I.C and convergence studies for the fifth kind of induction motor system



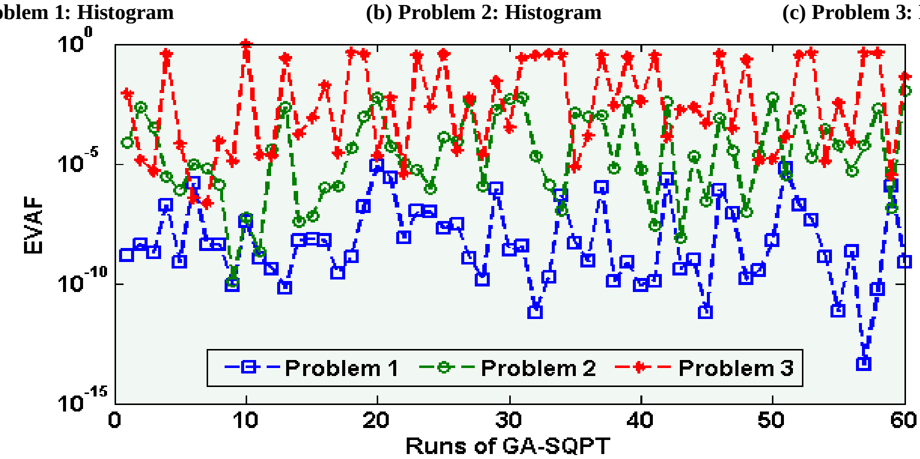
(a) Problem 1: Histogram



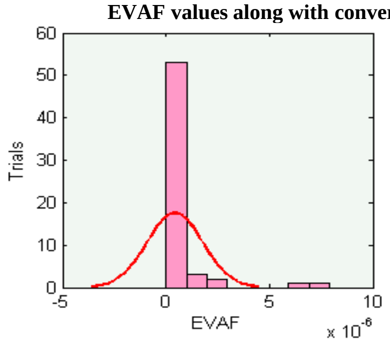
(b) Problem 2: Histogram



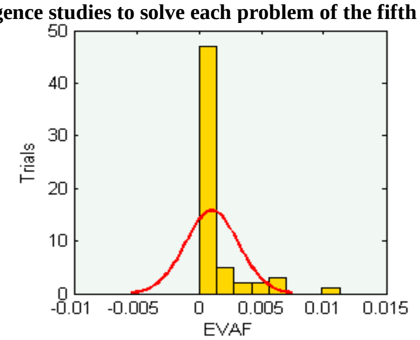
(c) Problem 3: Histogram



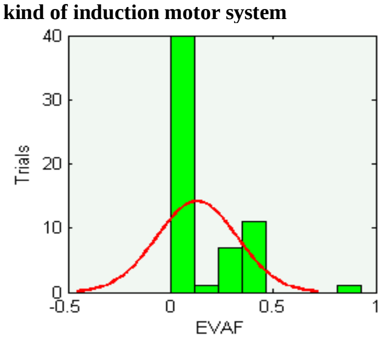
EVAF values along with convergence studies to solve each problem of the fifth kind of induction motor system



(d) Problem 1: Histogram



(e) Problem 2: Histogram



(f) Problem 3: Histogram

Figure 4: Convergence plots of T.I.C and EVAF using GA-SQPT to solve each problem of the fifth kind of induction motor system

Table 2: Statistics investigations for the fifth kind of induction motor system

τ	Example 1			Example 2			Example 3		
	Min	**Med**	**S.I.R**	**Min**	**Med**	**S.I.R**	**Min**	**Med**	**S.I.R**
0	4.184E-08	2.325E-05	6.155E-05	4.732E-06	2.008E-03	6.269E-03	4.659E-05	2.095E-02	1.206E-01
0.1	2.808E-08	2.474E-05	6.499E-05	4.809E-06	2.134E-03	7.034E-03	1.219E-04	2.221E-02	1.273E-01
0.2	1.242E-08	2.505E-05	6.534E-05	4.664E-06	2.160E-03	7.134E-03	2.077E-04	2.245E-02	1.261E-01
0.3	4.876E-09	2.336E-05	6.042E-05	4.157E-06	2.014E-03	6.699E-03	1.889E-04	2.091E-02	1.164E-01
0.4	2.321E-08	1.926E-05	4.925E-05	3.231E-06	1.662E-03	5.628E-03	1.508E-04	1.725E-02	9.466E-02
0.5	4.175E-08	1.280E-05	3.194E-05	1.906E-06	1.109E-03	3.768E-03	9.391E-05	1.148E-02	6.214E-02
0.6	5.909E-08	4.116E-06	9.737E-06	2.846E-07	3.940E-04	1.273E-03	2.258E-05	3.532E-03	1.870E-02
0.7	7.322E-08	5.335E-06	1.494E-05	1.451E-06	4.330E-04	1.462E-03	5.532E-05	4.286E-03	2.895E-02

0.8	8.187E-08	1.407E-05	3.836E-05	3.040E-06	1.159E-03	3.746E-03	1.282E-04	1.226E-02	7.477E-02
0.9	8.256E-08	2.066E-05	5.594E-05	4.139E-06	1.731E-03	5.514E-03	8.684E-05	1.834E-02	1.090E-01
1	7.229E-08	2.299E-05	6.183E-05	4.326E-06	1.937E-03	6.102E-03	1.946E-04	2.054E-02	1.202E-01

Table 3: Complexity performance for the fifth kind of induction motor system

Problem	Iterations		Implementation of time		Functions count	
	Mean	S.D	Mean	S.D	Mean	S.D
1	1016.9629	370.6674	1202.7167	17.6866	79394.9500	9334.2190
2	1086.4833	420.5107	1205.0000	20.8657	79458.6333	10854.7935
3	950.13830	288.8112	1205.0000	23.7865	76623.9667	6605.0374

4. Conclusion

The present studies are associated to solve the fifth kind of induction motor system using the artificial neural networks together with the hybridization of global genetic algorithm and local search sequential quadratic programming technique. An error-based fitness function is designed through the differential model and boundary conditions. The optimization of this function is performed through GA-SQPT. The exactness of ANN-GA-SQPT is observed in order to compare the proposed results with the exact solutions. The AE values are noticed around 10^{-06} to 10^{-08} for each problem of the induction motor system. The performance of the scheme based on the different statistical operators is observed in good measures for solving the fifth kind of induction motor differential-based system. In order to authenticate the stability, reliability and competence of the ANN-GA-SQPT, different statistical presentations using T.I.C, EVAF and MAD operatives have been accessible to get the accurate and precise results of the fifth kind of induction motor system. Additionally, the statistical presentations for sixty independent executions are also considered and most of the exactions accomplished higher accuracy level to solve each problem of the fifth kind of induction motor system.

In the future, the proposed ANN-GA-SQPT solver can be implemented to solve the biological systems, partial differential models and fractional differential model [47-58].

Availability of data and material

The research stated in the present data is not based on any data.

Competing Interest

The authors declare that there is no conflict of interest regarding this work.

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Authors' contributions:

All authors of the present paper has worked in research in an equal way to obtain the results of this paper.

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