Application of Soft Computing in Electrical Engineering

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***Abstract* — This paper presents a comprehensive review of the application of soft computing techniques to solve problems in electrical engineering. Artificial neural networks, fuzzy systems, and genetic algorithms, are the three most important elector of soft computing. Soft computing approach in electrical engineering is for fault diagnosis, conditioning, monitoring, parameter optimization, modeling and control of linear and non linear system. Soft computing techniques are particularly appropriate to support these types of decisions because these techniques are very efficient at handling inaccurate, uncertain, hazy, curtailed and subjective data.**

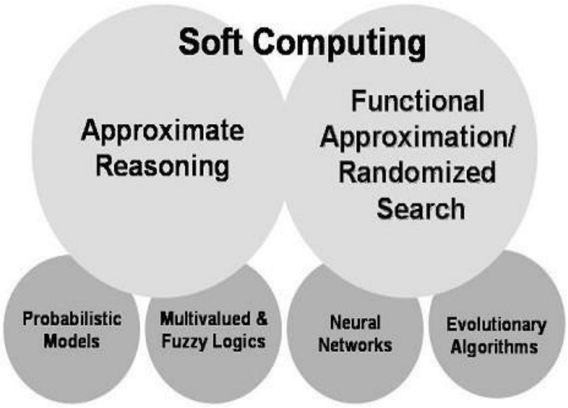
Keywords— Fuzzy logic, Artifical neural network, Evolutionary algorithm, Hybrid network

I. INTRODUCTION

The term soft computing was proposed by the inventor of fuzzy logic, Lotfi A. Zadeh in 1994. Soft computing refers to a collection of computational techniques in computer science, artificial intelligence, machine learning and some engineering discipline which attempt to study, model and analyze very complex phenomenon. Soft computing differs from conventional (hard) computing that aim to make the most of the lenience for imprecision and uncertainty to achieve tractability, robustness, and low solution cost.

Soft computing is the name of a family of problem-solving methods that have analogy with biological reasoning and problem solving (sometimes referred to as cognitive computing). [1]

Soft computing can be then expanded into other components which contribute to a definition by extension, such as the one first given. From the beginning (Bonissone 2002), the components considered to be the most important in this second level are probabilistic reasoning, fuzzy logic and fuzzy sets, neural networks, and genetic algorithms, which because of their interdisciplinary, applications and results immediately stood out over other methodologies such as the previously mentioned chaos theory, evidence theory, etc. The popularity of genetic algorithms, together with their proven efficiency in a wide variety of areas and applications, their attempt to imitate natural creatures (e.g. plants, animals, humans) which are clearly soft (i.e. flexible, adaptable, creative, intelligent, etc.), and especially the extensions and different versions, transform this fourth second-level ingredient into the



well- known evolutionary algorithms which consequently comprise the fourth fundamental

Fig.1 soft computing

II. FUZZY LOGIC

FL is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi- channel PC or work station based data acquisition and control systems. It can be implemented in hardware, software, or a combination of both. FL provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information. FL's approach to control problems mimics how a person would make decisions, only much faster.[2] Fuzzy logic, upon which fuzzy models are based, is a generalization of the binary logic. Unlike the binary logic, however, truth-values in the range (0; 1) are assigned to variables.

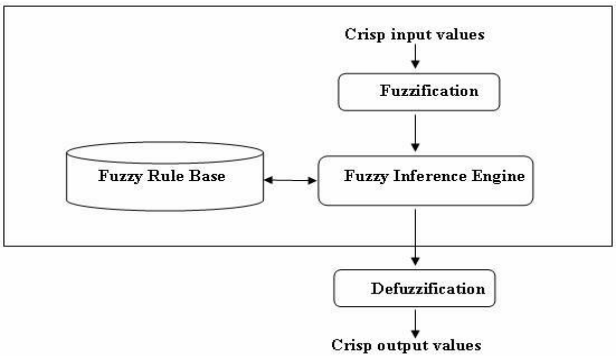


Fig . 2 Diagram For Fuzzy Logic

The membership of element in classical set theory is binary, that is an element x must belong to a set S or not. In fuzzy set, on the other hand, a class admits the possibility of partial membership in itself. For example, if X = {x} denotes a space of objects, the fuzzy set A over X is a set of ordered pairs A = {x; A(x)}, where A(x) is the degree to which x belongs to A. If the function A(x) returns the value 0:0 then x does not belong to A at all. If the value returned is 1:0 then x is totally a member of A. Partial membership of an element x to a set A is modelled by numbers between 0:0 and 1:0. The closer A(x) is to 1:0, the more x belongs to A. For example, a A(x) of 0:5 indicate that x's membership in A is 50% Fuzzy set, therefore, provides a powerful computational model for extending the capability of binary logic in ways that enables a much better representation of knowledge in engineering. Fig 2 (a) &(b) represents a membership function of fuzzy

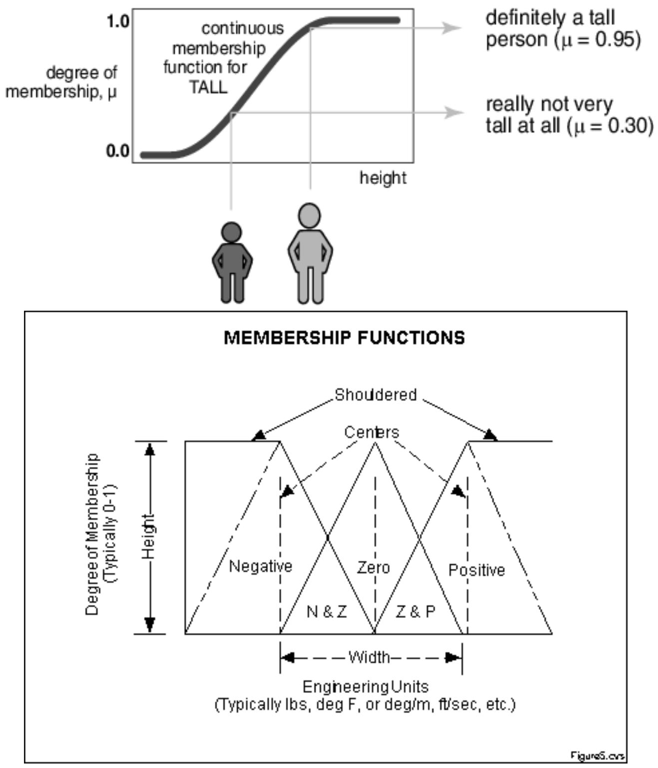


Fig. 3(a) & (b) Membership function

rule can be modified easily modified (2) Robustness is increased. The simulation shows that speed control of BLDC, using FLC, proves that the desired speed can be attained in shorter response time and by analyzing results it reveals that FLC is a good controller and it is capable of controlling of controlling BLDC over a wide range of speed. And also it proves that FLC is much efficient compared to other conventional controller

In This paper propose a fuzzy logic speed controller of induction motor where flux and torque decoupling strategy is decoupled in terms of magnetizing current instead of stator current to alleviate the effects of core loss. Rotor flux and torque of an induction motor (IM) are decoupled to obtain performance of DC motor. The decoupling strategy has been developed in terms of stator current components where the core loss is neglected. Many different controllers including fuzzy logic controller (FLC) with neglecting core loss have been designed to control the speed of induction motor. The outcome of investigation about the effect of core loss on indirect field oriented control (IFOC) has been concluded that the actual flux and torque are not reached to the reference flux and torque if core loss is neglected.. The performances of proposed fuzzy-logic-based controller have been verified by computer simulation. The simulation of speed control of IM using PI and FLC are performed. The simulation study for high-performance control of IM drive shows the superiority of the proposed fuzzy logic controller over the conventional PI controller. The simulation results based on conventional PI controller and the proposed FLC are demonstrated to compare both of those controllers. At last it can be concluded that the performances of the proposed FLC in both transient and steady states are better than those of conventional PI controller.[4]

In this paper author has used fuzzy logic controller for speed control of BLDC motor. Due to high power density and ease of control, brushless dc motor finds its usefulness in various fields such as in battery operated vehicle, wheel chairs and in much industrial application. Three phase semiconductor bridge is used to control this motor. Speed control is achieved in permanent magnet motors usually through conventional controllers. But these conventional controllers pose difficulties when the BLDC control systems is non linear or if there is some load disturbance and parametric variations. To overcome with these problems, an artificial intelligent technique such as fuzzy logic is used.[3] The proposed system is modeled using MATLAB/Simulink. The advantages of FLC are: (1) the fuzzy.

III. ARTIFICAL NEURAL NETWORK

An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurones) working in unison to solve specific problems. ANNs, like people, learn by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurones. This is true of ANNs as well [5]

The working of neural networks revolves around the myriad of ways these individual neurons can be clustered together. This clustering occurs in the human mind in such a way that information can be processed in a dynamic, interactive, and self-organizing way. Biologically, neural networks are constructed in a three-dimensional world from microscopic components. These neurons seem capable of nearly unrestricted interconnections. That is not true of in the case of any proposed, or existing, man-made network. Integrated circuits, using current technology, are two-dimensional devices with a limited number of layers for interconnection. This physical reality restrains the types, and scope, of artificial neural networks that can be implemented in silicon. Currently, neural networks are the simple clustering of the primitive artificial neurons. This clustering occurs by creating layers which are then connected to one another. How these layers connect is the other part of the "art" of engineering networks to resolve real world problems.[6]

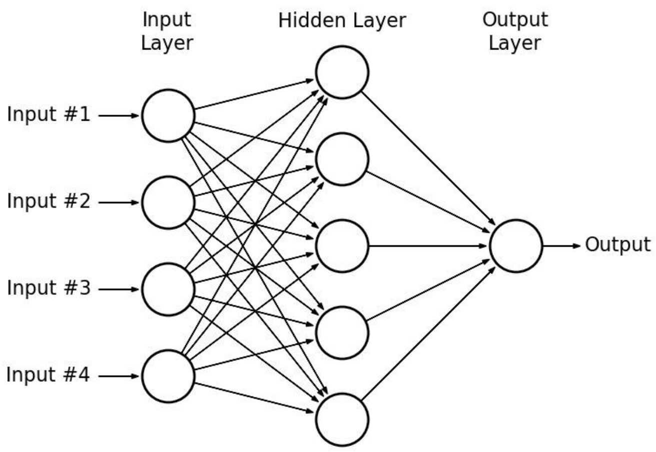


Fig. 4 Simple Neural Network

This paper proposes a technique to analysis electrical losses in distribution transformers 1-phase 30 kVA using of back- propagation neural networks (BPNN). Experimental data at various temperature of transformers obtained from manufacturer, are employed as an input pattern for BPNN while output pattern which corresponding to total losses in transformers. The total number of test set are 150 sets in order to verify the validity of the proposes technique. The results show that average accuracy obtained from the proposes technique gives satisfactory accuracy. Using back propagation neural networks from an analysis used test data in manufacturer to training data 100 sets and test data 50 sets and test data using 150 sets at temperature 35 ,45 and 55°C respectively as in that accuracy be satisfiable by a maximum error is 1.2% received. [7]

IV. EVOLUTIONARY ALGORITHMS

This section gives brief description of the evolutionary algorithms

A. Genetic Algorithm (GA)

In last few decades, GA has been treated as benchmark for various optimization problems. GA consists of four steps i.e. representation, initialization, selection and reproduction with crossover and mutation. Depending on the type of representation genetic algorithms can be broadly classified into two groups (i) Binary coded genetic algorithm (BCGA) and (ii) Real coded genetic algorithm (RCGA).

B. Particle Swarm Optimization (PSO)

In 1995, Kennedy and Eberhart first introduced the PSO Method motivated by social behavior of organisms such as fish schooling and bird flocking. PSO is a population based search technique. Each individual potential solution in PSO is called particle. Each particle in a swarm fly around in a multidimensional search space based on its own experience and experience of neighboring particles.

Let, define the search space S in *n*-dimension and the swarm consists of *N* particles. Let, at instant *t*, particle *i* has its position defined by *Xit* = {*xi*1, *xi* 2. . . *xin*} and velocity defined by *V i*
t = {*vi*1, *vi*2. . . *vin*} in variable space S. Velocity and position of each particle in the next generation (time step) can be calculated as:

$V it+1 = w \times V I t + c1 \times rand() \times (Pit - Xit) + c2 \times Rand() \times (Pg\ t - Xit)$ ……………..(6)

$Xi\ t+1 = Xit + V it+1\ \forall i = 1. . . N$ (7)

Where
N number of particles in the swarm;
w inertia weight;
*c*1, *c*2 acceleration constant;
rand(), uniform random value in the range [0,1];
Rand()
Pg t global best at generation t;
Pi t best position that particle i could find so far.

Performance of PSO depends on selection of inertia weight (*w*), maximum velocity *vmax* and acceleration constants (*c*1,*c*2). The effect of these parameters is illustrated as follows: Inertia weight (*w*): Suitable selection of weight factor *w* helps in quick convergence. A large weight factor facilitates global exploration (i.e. searching of new area) while small weight factor facilitate local exploration. Therefore, it is wiser to choose large weight factor for initial iterations and gradually smaller weight factor for successive iterations. In standard PSO linearly decreasing inertia weight *w* is set as 0.9 at beginning and 0.4 at the end Maximum velocity (*vmax*): With no restriction on the maximum velocity of the particles, velocity may become infinitely large. If vmax is very low particle may not explore sufficiently and if *vmax* is very high it may oscillate about optimal solution. Therefore, velocity clamping effect has been introduced to avoid the phenomenon of ―swarm explosion‖. In general maximum velocity is set as 10-20% of dynamic range of each variable. Velocity can be controlled within a band as:

Vmax = Vini − Vini − Vfin Itermax × Iter………. (8)

Where,
Vini is initial velocity; *Vfan* is final velocity, *iter* is iteration number and *Itermax* is number of maximum iterations. Acceleration constants (*c*1, *c*2): Acceleration constant *c*1called cognitive parameter pulls each particle towards local best position whereas constant *c*2 called social parameter pulls the particle towards global best position. Usually the values of *c*1 and *c*2 are chosen between 0 to 4.

This paper presents a new direct torque control (DTC) strategy for induction motor based on particle swarm optimization (PSO). In conventional direct torque controlled (DTC) induction motor drive, there is usually undesired torque and flux ripple. So Tuning PI parameters (Kp, Ki) are essential to DTC system to improve the performance of the system. In this work, particle swarm optimization (PSO) is proposed to adjust the parameters (Kp, Ki) of the speed controller in order to improve the performance of the system, and run the machine at reference speed. The proposed PSO based DTC control scheme has been implemented. The simulation results of this method have improved the speed performance of the induction motor irrespective of the load torque fluctuations. The proposed PSO method has optimized the parameters of PI controller by minimizing the speed error. It can be concluded that the PSO algorithm employed in DTC of induction motor has resulted in the optimal generation of Kp, KI values. This proposed method has finally improved the dynamic speed behavior of the induction motor when compared with that of a Conventional PI controller based DTC of Induction motor. [8]

In this paper Economic load dispatch problem is an optimization problem where objective function is highly nonlinear, non-convex, non-differentiable and may have multiple local minima. Therefore, classical optimization methods may not converge or get trapped to any local minima. This paper presents a comparative study of four different evolutionary algorithms i.e. genetic algorithm, bacteria foraging optimization, ant colony optimization and particle swarm optimization for solving the economic dispatch problem. All the methods are tested on IEEE 30 bus test system. Simulation results are presented to show the comparative performance of these methods, From the simulation results presented in this paper it is clear that solution quality and robustness of RCGA is better than BCGA. Convergence characteristics of ACO and BFO are attractive and they converge quickly but solution quality is not as good as PSO or GA. From all these findings, it can be concluded that PSO outperforms the others for the chosen set of parameters for solving the Economic Dispatch problem. [9]

V. HYBRID MODELS

The soft-computing techniques, particularly those discussed here, are complementary rather than competitive (Zadeh, 2001, 1994). This implies that a hybrid model employing a combination of artificial neural networks, fuzzy systems, and/or genetic algorithms should produce better results. The various combinations of these approaches have proven useful in the development of robust intelligent systems (Zadeh, 2001). For example, the fuzzy logic based technique can be combined with neural networks to form neuro-fuzzy model [10-11]. There are at least four hybrid models that can be created from the above SC techniques:

I) Neuro-Fuzzy
II) Fuzzy-Genetic III) NeuroGenetic,
IV) Neuro-Fuzzy-Genetic

TABLE1
SOFT COMPUTING CONSTITUENTS

S.No.	Methodology	Strength
1	Artificial neural networks	Learning and approximation
2	Fuzzy systems	Approximate reasoning
3	Evolutionary algorithms Systematic	Random Search/ Optimization

TABLE 2
COMPARISON OF SOFT COMPUTING TECHNIQUES FEATURES.

Methods	Lear ning capac ity	Knowl edge repres entatio n capaci ty	Real-Time Oper ation functi onalit y	Opti misat ion capa city	Data requi reme nts	Exper t input level
ANN	VH	H	H	M	VH	VL
F	M	VH	M	VH	M	VH
G A	M	M	H	VH	M	M
FL-ANN	M	H	M	L	M	VL
FL-GA	M	M	M	L	M	M
ANN-GA	M	M	H	M	M	VL
FL-ANN-G	M	M	M	L	M	VL

V L = Very Low; L = low; M = medium; High= V; H = Very High

A. Neuro-fuzzy

The neuro-fuzzy model, which involves the integration of ANN and FL techniques are perhaps the most popular hybrid technique used in materials engineering. Neuro fuzzy models are able to take advantage of the fuzzy inference mechanism capabilities in fuzzy logic and the learning ability of neural networks. The ANN technique is usually used as the learning algorithm for the defuzzification process in FL based models. Neuro-fuzzy models are regarded as black-box models which provide little insight to help understand the underlying process [10].

B. Fuzzy-genetic

When the FL and GA techniques are combined to develop a solution, the fuzzy-genetic model results. The aim here is to exploit the ability of the fuzzy logic at knowledge description and the optimization capability of the genetic algorithm. Usually, the defuzzification process in fuzzy logic based model are developed using optimal selection of elements from a fuzzy set. Aside from GA, techniques that employ the concepts of interaction, variability, and voting techniques are also used to optimize the defuzzification and membership generation process.

C. Neuro-genetic

When the ANN and GA techniques are combined to develop a solution, the neuro-genetic model results. The aim here is to take advantage of the learning ability of the ANN and optimization ability of the genetic algorithm

D. Neuro-fuzzy-genetic

When the three SC techniques discussed here are combine to develop a solution, the neuro-fuzzy-genetic model results. Usually, the GA approach is used to optimize the performance of a neuro-fuzzy system. The development of this approach is usually guided by heuristics, based on the experiences of an expert engineer. In (Huang, Gedeon, and Wong, 2001)

In This paper presents a review of the most recent developments in the field of diagnosis of electrical machines and drives based on artificial intelligence (AI). It covers the application of expert systems, artificial neural networks (ANNs), and fuzzy logic systems that can be integrated into each other and also with more traditional techniques. The application of genetic algorithms is considered as well. In general, a diagnostic procedure starts from a fault tree developed on the basis of the physical behavior of the electrical system under consideration. In this phase, the knowledge of well-tested models able to simulate the electrical machine in different fault conditions is fundamental to obtain the patterns characterizing the faults. This paper has given a general review of the recent developments in the field of AI-based diagnostic systems in electrical machines and drives. It has covered the application of expert systems, fuzzy logic, ANNs, and combined systems, e.g. fuzzy-NNs The advantages of using AI were shown and some aspects related to the application of minimum a priori knowledge were also discussed[11]

The following heuristics was proposed for its realization:

- Select appropriate well data set.

- Generate fuzzy rules by neural networks.

-Generate hyper-surface membership function by neural network.

- Optimise defuzzification operator parameters by generic algorithms;

- Interpolate fuzzy rules to provide estimates.

VI. CONCLUSION

In this paper, we have presented a review of the applications of soft computing techniques focusing on electrical engineering., we hope that we have given an adequate overview of what is currently happening in this evolving and dynamic area of research. Three soft computing techniques are prominently used in electrical engineering: artificial neural networks, fuzzy logic and evolutionary algorithms. The neuro- fuzzy systems seem to be the most popularly used hybrid of these techniques in electrical engineering. However, neuro- genetic, fuzzy-genetic, and neuro-fuzzy-genetic applications are also emerging. All researchers that have used SC based approach in electrical engineering have reported excellent, good, positive or at least encouraging results. These tools do not provide exact answers to the problems, but are quite handy for problems governed by imprecise and vague data. These tools provide the user with sufficient decision making capabilities when dealing with uncertainty and vagueness. The use of soft computing in the field of Electrical Engineering has made the complicated problems of modeling and prediction of behavior much easier.

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