International Journal of Scientific Research & Engineering Trends
Volume 9, Issue 4, Jul-Aug-2023, ISSN (Online): 2395-566X

Life Cycle Optimization Of Residential Air Conditioner Replacement Using Artificial Neural Network

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Abstract- A two-in two-out steady-state artificial neural network (ANN)-based model for an experimental variable speed direct expansion air conditioning (A/C) system has been developed for simulating its total output cooling capacity and equipment sensible heat ratio under different combinations of compressor and supply fan speeds. Experiments were carried out, and totally sets of experimental data were obtained for ANN training and testing. An ANN-based model having the configuration of 2 neurons in the input layer, neurons in the output layer and neurons in each of the hidden layers, i.e. configuration, was thus developed. The ANN-based model developed can be used to predict the operating performance of the A/C system with a higher accuracy. It is expected that the model developed can help design a multivariable-input multivariable-output strategy to simultaneously control indoor air temperature and humidity.

INDEX TERMS- Artificial neural network, indoor temperature, relative humidity, thermal comfort, thermoelectric air duct.

I. INTRODUCTION

HVAC is an acronym that stands for Heating, Ventilation, and Air Conditioning. The term HVAC is used to describe a complete home comfort system that can be used to heat and cool your home, as well as provide improved indoor air quality. HVAC can be easily confused with the term AC, but AC simply refers to air conditioning on its own, while HVAC refers to the broader system, which may or may not include an air conditioning unit [1].

Components Hvac System

A complete HVAC system has more than one component. In fact, it has multiple units and parts, both inside and outside your home, that all work together doing different jobs to bring you the complete home comfort you need. While there are many different components that can be part of an HVAC system, below are a few of the ones you're most likely to see in your system, plus what they do [2]:

- **Air Conditioner -** An air conditioner cools your home by removing heat and humidity from inside and transferring it outside.
- **Heat Pump -** Contrary to their name, a heat pump can both heat and cool your home. They use refrigerant to absorb, transport, and release heat, and they can reverse the flow of that refrigerant depending on if you need heating or cooling. Heat pumps are powered by electricity, not fossil fuels.
- **Furnace -** Furnaces create heat by burning a fuel source like natural gas or propane. The heat they create is then distributed throughout your home, in order to increase the indoor temperature [3].
- **Air Handler -** Air handlers circulate both warm and cool air formed by other HVAC units throughout your entire home, in order to reach your desired temperature in every room [4].

II. HVAC SYSTEM WORKING

The goal of your HVAC system is to make your ideal home comfort circumstances become a reality. To do this, a complete system must be built from a combination of an air conditioner, furnace, air handler, ductwork, thermostat and even some other units like a humidifier or air purifier.
Once the proper HVAC system for your home is selected and installed, you'll begin controlling the temperature inside with your thermostat. When the thermostat tells the other HVAC units in your home the temperature needs to change, they will begin the process of producing warm or cool air. That newly warmed or cooled air will be distributed throughout your home with the help of ductwork or an air handler. If your home features a ductless system, refrigerant lines will help move the air through the system [5]. HVAC systems can be powered by either gas or electricity, though most systems are now electric. The main exception are furnaces, which tend to be either gas or oil powered [6].

III. HEATING, VENTILATION, AND AIR CONDITIONING (HVAC)

Heating, ventilation, and air conditioning (**HVAC**)[1] is the use of various technologies to control the temperature, humidity, and purity of the air in an enclosed space. Its goal is to provide thermal comfort and acceptable indoor air quality. HVAC system design is a subdiscipline of mechanical engineering, based on the principles of thermodynamics, fluid mechanics, and heat transfer. "Refrigeration" is sometimes added to the field's abbreviation as **HVAC&R** or **HVACR**, or "ventilation" is

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dropped, as in **HACR** (as in the designation of HACR-rated circuit breakers) [7].
HVAC is an important part of residential structures such as single family homes, apartment buildings, hotels, and senior living facilities; medium to large industrial and office buildings such as skyscrapers and hospitals; vehicles such as cars, trains, airplanes, ships and submarines; and in marine environments, where safe and healthy building conditions are regulated with respect to temperature and humidity, using fresh air from outdoors [8].

Ventilating or ventilation (the "V" in HVAC) is the process of exchanging or replacing air in any space to provide high indoor air quality which involves temperature control, oxygen replenishment, and removal of moisture, odors, smoke, heat, dust, airborne bacteria, carbon dioxide, and other gases. Ventilation removes unpleasant smells and excessive moisture, introduces outside air, keeps interior building air circulating, and prevents stagnation of the interior air. Methods for ventilating a building are divided into mechanical/forced and natural types.[2]

IV. PROPOSED METHODOLOGY

Introduction Of Artificial Neural Networks
Artificial neural networks (**ANNs**), usually simply called **neural networks** (**NNs**), are computing systems inspired by the biological neural networks that constitute animal brains.
Neural computing is an information processing paradigm, inspired by biological system, composed of a large number of highly interconnected processing elements(neurons) working in unison to solve specific problems. Artificial neural networks (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 neurons. This is true of ANNs as well [9-15].

An ANN is based on a collection of connected units or nodes called artificial neurons, which loosely model the neurons in a biological brain. Each connection, like the synapses in a biological brain, can transmit a signal to other neurons. An artificial neuron receives a signal then processes it and can signal neurons connected to it. The "signal" at a connection is a real number, and the output of each neuron is computed by some non-linear function of the sum of its inputs. The connections are called edges. Neurons and edges typically have a weight that adjusts as learning proceeds. The weight increases or decreases the strength of the signal at a connection. Neurons may have a threshold such that a signal is sent only if the aggregate signal crosses that threshold. Typically, neurons are aggregated into layers. Different layers may perform different transformations on their inputs. Signals travel from the first layer (the input layer), to the last layer (the output layer), possibly after traversing the layers multiple times. The scope of this teaching package is to make a brief induction to Artificial Neural Networks (ANNs) for people who have no previous knowledge of them. We first make a brief introduction to models of networks, for then describing in general terms ANNs. As an application, we explain the backpropagation algorithm, since it is widely used and many other algorithms are derived from it. The user should know algebra and the handling of functions and vectors. Differential calculus is recommendable, but not necessary. The contents of this package should be understood by people with high school education. It would be useful for people who are just curious about what are ANNs, or for people who want to become familiar with them, so when they study them more fully, they will already have clear notions of ANNs.

Also, people who only want to apply the backpropagation algorithm without a detailed and formal explanation of it will find this material useful. This work should not be seen as “Nets for dummies”, but of course it is not a treatise. Much of the formality is skipped for the sake of simplicity. Detailed explanations and demonstrations can be found in the referred readings. The included exercises complement the understanding of the theory. The on-line resources are highly recommended for extending this brief induction.

Artificial Neuron Model
An artificial neuron is a mathematical function conceived as a simple model of a real (biological) neuron.

- The McCulloch-Pitts Neuron This is a simplified model of real neurons, known as a Threshold Logic Unit.
- A set of input connections brings in activations from other neuron.
- A processing unit sums the inputs, and then applies a non-linear activation function (i.e. squashing/transfer/threshold function).
- An output line transmits the result to other neurons.

Basic Elements Of Ann
Neuron consists of three basic components –weights, thresholds and a single activation function. An Artificial neural network (ANN) model based on the biological neural sytems is shown in Figure 4.1.

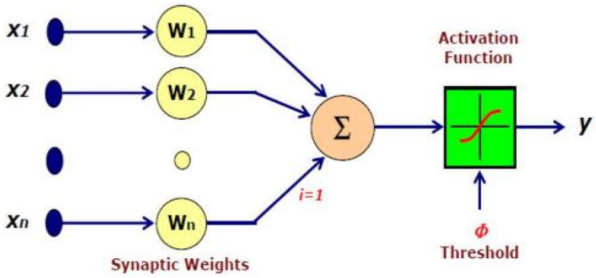

Fig.1 Basic Elements of Artificial Neural Network.

Different Learning Rules
A brief classification of Different Learning algorithms is depicted in figure 4.1.

- Training: It is the process in which the network is taught to change its weight and bias.
- Learning: It is the internal process of training where the artificial neural system learns to update/adapt the weights and biases.

Different Training /Learning procedure available in ANN are

- Supervised learning
- Unsupervised learning
- Reinforced learning
- Hebbian learning
- Gradient descent learning
- Competitive learning
- Stochastic learning

Requirements Of Learning Laws

- Learning Law should lead to convergence of weights
- Learning or training time should be less for capturing the information from the training pairs
- Learning should use the local information
- Learning process should able to capture the complex non linear mapping available between the input & output pairs
- Learning should able to capture as many as patterns as possible
- Storage of pattern information's gathered at the time of learning should be high for the given network.

Networks

One efficient way of solving complex problems is following the lemma "divide and conquer". A complex system may be decomposed into simpler elements, in order to be able to understand it. Also simple elements may be gathered to produce a complex system (Bar Yam, 1997). Networks are one approach for achieving this. There are a large number of different types of networks, but they all are characterized by the following components: a set of nodes, and connections between nodes. The nodes can be seen as computational units. They receive inputs, and process them to obtain an output. This processing might be very simple (such as summing the inputs), or quite complex (a node might contain another network...) The connections determine the information flow between nodes. They can be unidirectional, when the information flows only in one sense, and bidirectional, when the information flows in either sense. The interactions of nodes though the connections lead to a global behaviour of the network, which cannot be observed in the elements of the network. This global behaviour is said to be emergent. This means that the abilities of the network supercede the ones of its elements, making networks a very powerful tool.

Training

Neural networks learn (or are trained) by processing examples, each of which contains a known "input" and "result," forming probability-weighted associations between the two, which are stored within the data structure of the net itself. The training of a neural network from a given example is usually conducted by determining the difference between the processed output of the network (often a prediction) and a target output. This difference is the error. The network then adjusts its weighted associations according to a learning rule and using this error value. Successive adjustments will cause the neural network to produce output which is increasingly similar to the target output. After a sufficient number of these adjustments the training can be terminated based upon certain criteria. This is known as supervised learning.

Such systems "learn" to perform tasks by considering examples, generally without being programmed with task-specific rules. For example, in image recognition, they might learn to identify images that contain cats by analyzing example images that have been manually labeled as "cat" or "no cat" and using the results to identify cats in other images. They do this without any prior knowledge of cats, for example, that they have fur, tails, whiskers, and cat-like faces. Instead, they automatically generate identifying characteristics from the examples that they process.

ANNs began as an attempt to exploit the architecture of the human brain to perform tasks that conventional algorithms had little success with. They soon reoriented towards improving empirical results, mostly abandoning attempts to remain true to their biological precursors. Neurons are connected to each other in various patterns, to allow the output of some neurons to become the input of others. The network forms a directed, weighted graph.

An artificial neural network consists of a collection of simulated neurons. Each neuron is a node which is connected to other nodes via links that correspond to biological axon-synapse-dendrite connections. Each link has a weight, which determines the strength of one node's influence on another.

V. RESULT AND SIMULATION

Overview

The lack of an associative environment between 2D schematics and 3D HVAC design leads to unnecessary errors and design delays. Companies need an integrated solution to design logical lines of HVAC systems in order to validate the design early in the design process. CATIA – HVAC Schematic to Design product (1) enables the user to design and manage logical lines of HVAC systems using standards and specifications according to industry usage. It enables the creation of component catalogs with multi representation, attributes and design rules. The system engineer creates intelligent schematics and HVAC Diagrams. Fully integrated, the designer builds the 3D design directly from 2D diagrams (2D/3D driven). These intelligent diagrams and 3D design capability enable users to create and validate.

This product covers project engineering from basic design up to detailed design.

(1) HVAC: Heat, Ventilation and Air-Conditioning

Benefits

- Improves product performance and quality thanks to standards and material specifications taking into account the design rules, automatic parts placement and multi-representation
- Full associativity between 2D schematics and 3D HVAC design
- Improve design time with an intuitive user interface to annotate, validate the model, query data and generate appropriate report information
- Single geometric modeler for all the equipment and system products (piping, tubing, etc.)
- Full integration between mechanical and equipment and system products
- Capitalize on company know-how to design right the first time
- Organizes catalogs customization with full parametric components alongside technological attributes such as pressure, temperature, etc.

CAPABILITIES

- Creates catalogs of 2D and 3D parametric components according to standards and material specifications
- Defines and manages HVAC lines for different engineering systems
- Creates intelligent schematics with respect to standards and specifications such as text annotation templates, off-sheets connector and automatic gaps
- Designs the 3D preliminary HVAC layout routes with design rules checking (minimun length and turn)
- Adds spec-driven 3D HVAC components to detail the design
- Allows associative 3D creation directly driven by the 2D schematic diagrams
- Provides BOM reports, query and analysis

Workbenches

This option contains:
CATIA – HVAC Design 2

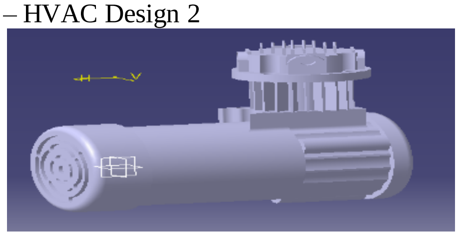

Fig .2 Coil.

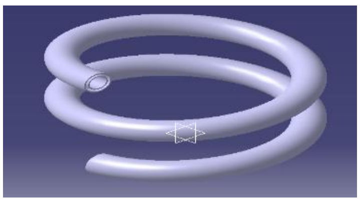

Fig.3 HVAC

Compressor.

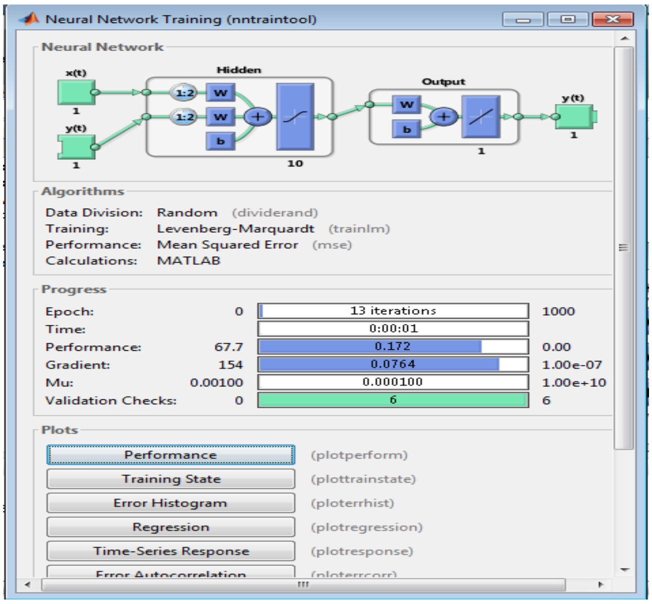

Fig.4 NN Data validation.

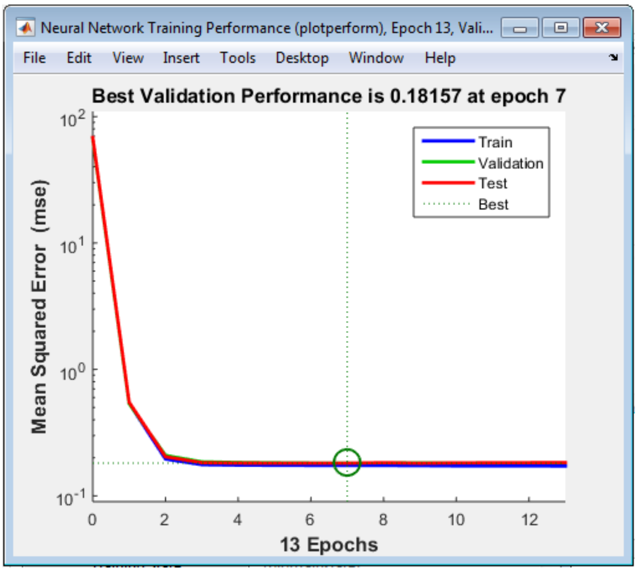

Fig.5. Performance Curve.

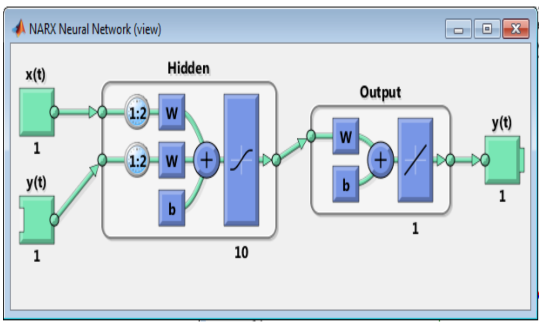

Fig.6 Layers.

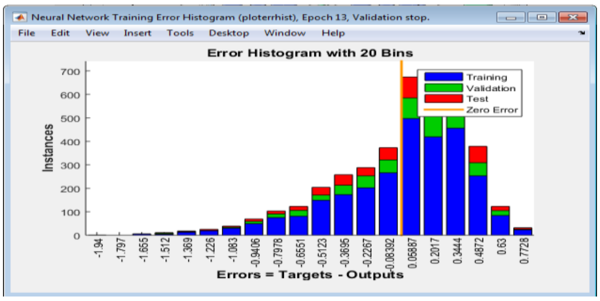

Fig.7 MSE and Stages of ANN.

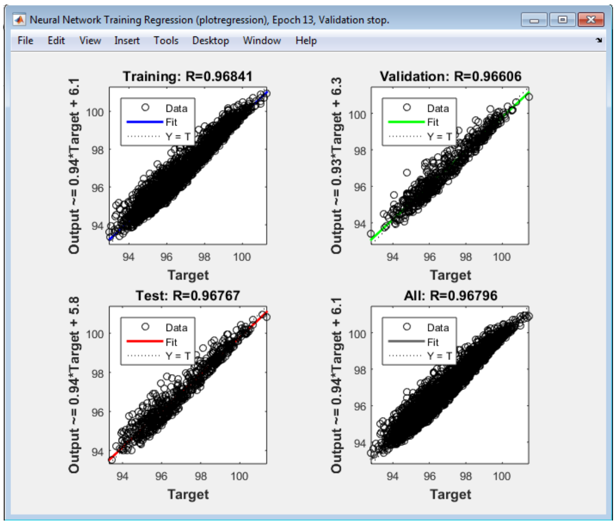

Fig.8 Predicted Outcomes.

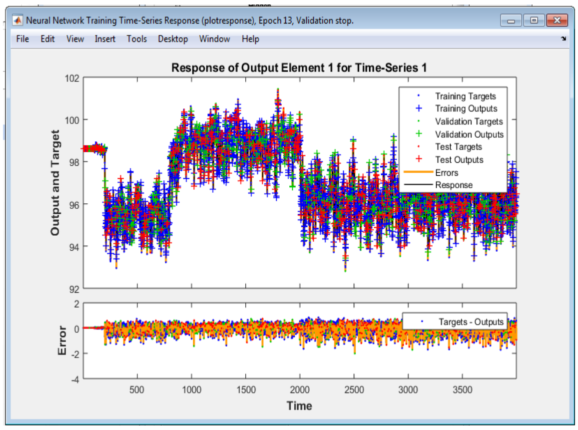

Fig.9 Prediction result across Compressor and HE.

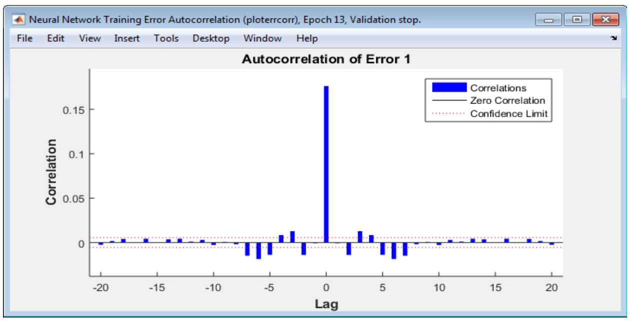

Fig.10 Autocorrelation curve.

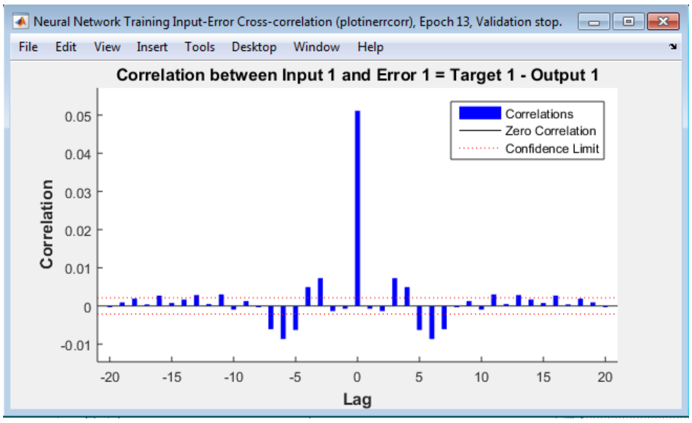

Fig.11 Error Correlation curve.

VI. CONCLUSION

According to the present results, concerning the stopping criteria of the suggested meta-model generation method, we can deduce that appropriate stopping criteria should estimate the efficiency of the artificial neural network through the sample of validation and for all outputs of the ANN, make the correlation coefficient r proper then. This has been approved by Fig. 9, where the ANN give an appropriate efficiency for small sizes of the sample with r > 0.8, but not for the samples of validation. Notably, it is required for the sample of validation to be the design space representative, as it has been assumed in this study, creating another sample, which is independent, by the Latin hypercube sampling approach.

For developing ANN-MM with a few simulations based on physics and for obtaining precise results in multiple-criteria optimization problems of the building this method is suggested that solves the shortcomings of classic Trial and Error methods. Nevertheless, it is globally considered that the efficiency of the meta-model is enhanced in the overall design space following each increase in the sample size of the training. While this is accepted in the present utilization, for other applications such as energy labeling of the building it is flawless. It is needed for an optimum meta-model to have average global precision but a proper efficiency on the Pareto set for multiple-criteria optimization. Therefore, the number of needed simulations based on physics can be decreased by iterative methods with a smart sampling technique.

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