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Power Quality Improvement of Constant Frequency Aircraft Electric Power System Using Genetic Algorithm and Neural Network Control Based Control Scheme

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Abstract

Synchronous Reference Frame Strategy for extracting reference currents for shunt active power filters have been modified using Artificial Neural Network, Genetic Algorithm based controller and their performances have been compared. The acute analysis of Comparison of the compensation capability based on THD and speedwell be done, and recommendations will be given for the choice of technique to be used. The simulated results using MATLAB model are shown, and they will undoubtedly prove the importance of the proposed control technique of aircraft shunt APF.

Keywords: Aircraft electrical system; Shunt Active Filter (APF); Synchronous reference frame strategy; ANN; Genetic algorithm; THD

Introduction

More advanced aircraft power systems [1-3] have been needed due to increased use of electrical power on behalf of other alternate sources of energy. The subsystems like flight control, flight surface actuators, passenger entertainment, are driven by electric power, which flowingly increased the demand for creating aircraft power system more intelligent and advanced. These subsystems have extensive increased electrical loads i.e. power electronic devices, increased feeding of electric power, additional demand for power, and above to all of that great stability problems.

In peculiarity to standard supply system, the source frequency is of 50 Hz, whereas, aircraft AC power system works on the source frequency of 400 Hz [1-3]. Aircraft power utility works on source voltage of 115/200 V. The loads applicable to the plane a system differs from the loads used in 50 Hz system [1]. When we deliberate the generation portion; aircraft power utility will remain AC driven from the engine for the plane primary power. Novel fuel cell technology can be used to produce a DC output for ground power, and its silence process would match up to suitably with the Auxiliary Power Unit (APU). Though when considering the dissemination of primary power, whether AC or DC; each approach has its merits. In DC distribution, HVDC power distribution systems permit the most resourceful employ of generated power by antithetical loss from skin effect. This allows paralleling and loads sharing amongst the generators. In AC distribution, AC Flogging is very clear-cut at high levels too. Due to its high dependence on HVDC system, a wide range of Contactors, Relays can be exploited.

While talking about Aircraft Power Systems we also need to consider increased power electronics application in aircraft which creates harmonics, large neutral currents, waveform distortion of both supply voltage and current, poor power factor, and excessive current demand. Besides if some non-linear loads is impressed upon a supply, their effects are additive. Due to these troubles, there may be nuisance tripping of circuit breakers or increased loss and thermal heating effects that may provoke early component failure. This is a prodigious problem to every motor loads on the system. Hence, decent power quality of the generation system is of scrupulous attention to the Aircraft manufacturer. We discern that aircraft systems work on high frequency so even on the higher frequencies in the range of 360 to 900 Hz; these components would remain very significant. Today, advanced soft computing techniques are used widely in the involuntary control system, and optimization of the system applied. Several of them are such as Fuzzy logic [4-8], optimization of active power filter using GA [9-12], power loss reduction using particle swarm optimization [13], Artificial neural network control [14-18] applied in together machinery and filter devices.

In this paper, ANN based and Genetic Algorithm optimized have been used together to mend the complete performance of active filter for the lessening of harmonics and other delinquents created into the aircraft electrical system because of the non-linear loads [1]. The simulation results clearly show their effectiveness. The simulation results acquired with the new model are much improved than those of traditional method.

The paper has been modified in a sequential manner. The APF outline and the load under contemplation are discussed in Section II. The control algorithm for APF converses in Section III. MATLAB/ Simulink based simulation results are presented in Section IV, and finally Section V concludes the paper [19-23].

System Depiction

The aircraft power system is a three-phase power system with the frequency of 400 Hz. As exposed in Figure 1, Shunt Active Power Filter improves the power quality and compensates the harmonic currents in the system [22,24-28]. The shunt APF is comprehended by using one voltage source inverters (VSIs) connected at the point of common coupling (PCC) to a common DC link voltage [20-23].

The set of loads for aircraft system consist of three loads. The first load is a three-phase rectifier in parallel with an inductive load and an

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unbalanced load connected in a phase with the midpoint (Load 1). The second one is a three phase rectifier connects a pure resistance directly (Load 2). The third one is a three-phase inductive load linked with the ground point (Load 3). Finally, a combination of all three loads connected with system together at a different time interval to study the effectiveness of the control schemes has been used to verify the functionality of the active filter in its ability to compensate for current harmonics. For the case of all three load connected, Load 1 is always connected, Load 2 is initially connected and is disconnected after every 2.5 cycles, Load 3 is connected and disconnected after every half cycle. All the simulations have been done for 15 cycles. The circuit parameters are given in last section - Parameters.

Control Theory

The proposed control of APF depends on Synchronous Reference Frame Strategy, and it has been optimized using artificial intelligent technique like artificial Neural Network and Genetic Algorithm together. Synchronous Reference Frame strategy has been discussed in brief in this section. The following section also deals with the primary application of ANN and GA in the control schemes [19,20].

Synchronous reference frame strategy (SRF)

The reference frame d-q is decided by the angle θ on the d-q frame applied in the p-q theory. Slight modifications are required in the conventional SRF method so that they can be used in aircraft power utility and compensate well the neutral current. For this reasons, the zero-sequence component of current has not been well thought-out. So, the zero sequence subtract block cart from the zero sequence current. The positive sequence and negative sequence component are obtained in output current. After its park transformation, only instantaneous active and reactive current are available in the output current in the



d-q frame. A low-pass filter accomplishes the disunion of the dc and ac factor of the active current for compensation of the reactive and harmonic current. This active current goes through a low-pass filter, and the signal came from dc voltage regulator together though a Park counter-transformation subtracting from the load currents generates the reference current. Reference current is generated (Figure 2).

Application of ANN based control

In this paper, Synchronous reference frame Strategy has been modeled by an artificial neural network (ANN) made up of two hidden layers with 10 neurons each, and one output layer with 3 neurons. The logarithmic activation function is the base of the two hidden layers neurons, and linear activation function for the output layer neurons.

As shown in Figure 3, the ANN has seven inputs (v_a , v_b , v_c , dc voltage error, i_a , i_b , i_c) and three outputs (i_{ra} , i_{rb} , i_{rc}) as observed in the different strategies. The adaptation of the weights (W) and bias (b) in the ANN, is based, first, on the computation of the mean square error (MSE) between the outputs of the PQ technique and those of the ANN, and secondly, on the execution of 'Levenberg-Marquardt backpropagation' algorithm.

The reference current generation unit and dc voltage controller unit has been modeled and their individual and simultaneous effect has been observed.

Application of genetic algorithm

Genetic algorithm (GA) is a search technique used in computing to find an optimal solution for a search problem. It is implemented [9] as a computer simulation in which a population of abstract representations (called chromosomes of the genome) of candidate solutions (individuals) to an optimization problem evolves [11] towards improved solutions. In general, the fittest individuals of any population tend to reproduce and survive to the next generation, thus improving the successive generations [12]. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population [12]. The fitness function is defined over the genetic representation and measures the quality of the represented solution. The fitness function is always problem dependent [11]. By starting at several independent points and searching in parallel, the algorithm avoids local minima and also avoids converging to sub optimal solutions. In this way, GAs have been shown to be capable of locating high performance areas in complex domains without experiencing the difficulties associated with high dimensionality, as may occur with gradient decent techniques or methods that rely on derivative information [15].



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Most of the published papers use this generalized program to fit their objective function but after the popularity of MATLAB as software for simulation and modeling researchers have started using genetic algorithm optimization tool (GAOT) available. MATLAB provides many built in auxiliary functions useful for function optimization [15]. GAOT is not only easy to implement but is faster in simulating.

In this paper, the GA is applied to determine value of inductor filter (L_i) . GA will try to search the best value of the filter inductor. Supply side has been taken as input side for inductor filter. Inductor filter value used in this thesis is 0.25 mH. Offline, computer simulation using MATLAB Simulink has been applied to find out the optimum value for inductor filter.

For the program, the limits, inequality and bounds need to be defined. This paper has attempted to develop a single GA code program for optimizing objective function.

 $\begin{aligned} &x0{=}[V_{dc}; V_{s}; I_{c}; t; L_{f}]; \\ &lb{=}[V_{dcmin}; V_{smin}; I_{cmin}; t_{min}; L_{fmin}]; \\ &ub{=}[V_{dcmax}; V_{smax}; I_{cmax}; t_{max}; L_{fmax}]; \\ &Aeq{=}[]; \\ &beq{=}[]; \\ &A{=}[1{-}11{-}11; 11{-}11{-}1; 00111; 11{-}00{-}1; 11010]; \\ &b{=}[Values of V_{dc}; V_{s}; I_{c}; t; L_{f} depending upon the equations]; \\ &[x, fval, exitflag]{=}fmincon(@myobj,x0,A,b,Aeq,beq,lb,ub). \end{aligned}$

The boundary and limits of parameters in the filter has been defined using the data of ANN model. The data has been collected using MATLAB/Simulink. Finally, a program using genetic algorithm has been written to generate the best value of the filter inductor. After the calculation, GA generates the value of 0.187 mH. After using this inductor value, total harmonic distortion of source current and voltage have been reduced so we can say that inductor value calculated is optimum.

Simulation Results and Discussions

The proposed scheme of APF is simulated in MATLAB environment to estimate its performance. Three loads have been applied together at a different time interval to check the affectivity of

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the control schemes for the reduction of harmonics. A small amount of inductance is also connected to the terminals of the load to get the most effective compensation. The simulation results clearly reveal that the scheme can successfully reduce the significant amount of THD in source current and voltage within limits.

Uncompensated system

Figure 4 shows the waveforms obtained after the simulation of an uncompensated system. It has been observed that the THD of source current calculated when loads connected with the system is 9.5% and THD of source Voltage were 1.55%. By observing these data, we can easily recognize supply has been polluted when loads have been connected and is obviously not within the limit of the international standard.

Compensated system

The performance of APF under different loads connected, when utilizing ANN Control has been discussed below for the control strategy given below.

For synchronous reference frame strategy: From Figure 5 it has been empiric that that the THDs of source current and source voltage were 2.82% and 1.65% respectively. The compensation time was 0.01 sec. At t=0.01 sec, it is apparent that the waveforms for source voltage and source current have become sinusoidal. Figure 5 shows the waveforms of compensation current, DC capacitor voltage, and load current.

The aberration in dc voltage can be acutely apparent in the waveforms. As per claim for accretion the compensation current for accomplishing the load current demand, it releases the energy, and after that it accuses and tries to achieve its set value. If we carefully observe, we can acquisition out that the compensation current is, in fact, accomplishing the appeal of load current, and afterward the active filtering the source current and voltage is affected to be sinusoidal.

For synchronous reference frame strategy using ANN and genetic algorithm: THDs of source current and source voltage have been found 2.62% and 1.03% respectively after making observations from the simulation results shown in Figure 6. The waveforms for source voltage and source current have become sinusoidal at t=0.0068 sec. Compensation time is 0.0068 sec. The waveforms of compensation current, dc capacitor Voltage, and load current have been shown in



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Figure 6. Waveforms show the variations in dc capacitor voltage. Whenever the demand for high load current comes, it releases the energy that in turn increases the compensation current. Later on, it charges and tries to regain its previous set value. By making a simple observation, we can say that compensation current is fulfilling the



demand of load current. After the active filtering, the source current and voltage is forced to be sinusoidal.

Comparative analysis of the simulation results

From Table 1, we can easily say that Synchronous Reference Frame using ANN and Genetic Algorithm (SRF-ANN-GA) has been found best for current and voltage harmonic reduction. When these results have been compared based on compensation time, it has been also found that SRF-ANN-GA strategy is the fastest one.

Conclusion

This paper has done an acute analysis of traditional and Artificial Intelligent Technique (ANN and Genetic Algorithm applied together) based controller for shunt APF in aircraft power utility of 400 HZ. Optimum selection of control strategy based on compensation time and THD has been suggested. Overall Synchronous Reference Frame using ANN&GA (SRF-ANN-GA) has been observed as an optimum choice. Synchronous Reference Frame Strategy's performance has been

Strategy	THD-I (%)	THD-V (%)	Compensation Time (sec)
SRF	2.82	1.65	0.0100
SRF-ANN-GA	2.62	1.03	0.0068

Table 1: Summary of simulation results.



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improved, which itself an achievement for the case of optimization in traditional strategies.

Parameters

The aircraft system parameters are [1]:

Three-phase source voltage: 115 V/400 Hz,

Filter capacitor: 5 µF,

Filter inductor=0.25 mH,

DC capacitor: 4700 µF,

DC voltage reference: 400 V.

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