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Optimization of Power system with Automatic Voltage Regulator using Soft Computing Techniques

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Abstract: ***In an interconnected power system, if a load demand changes randomly, both frequency and tie line power varies. The main aim of automatic voltage controller is to minimize the transient variations in these variables and also to make sure that their steady state errors is zero. Many modern control techniques are used to implement a reliable controller. The objective of these control techniques is to produce and deliver power reliably by maintaining voltage within permissible range. When real power changes, system frequency gets affected while reactive power is dependent on variation in voltage value. That's why real and reactive power is controlled separately. Our objective is here for to study and analyze the Genetic algorithms and their application to the problems of Function Optimization and System Identification. Since there are other methods traditionally adopted to obtain the optimum value of a function (which are usually derivative based), the project aims at establishing the superiority of Genetic Algorithms in optimizing complex, multivariable and multimodal function. The Genetic Algorithm is a popular optimization technique which is bio-inspired and is based on the concepts of natural genetics and natural selection theories proposed by Charles Darwin.***

Keywords: Genetic Algorithm, AVR, PID, ACO, ITAE, IAE

I. INTRODUCTION

In power system, both active and reactive power demands are never steady as they changes continuously with the rising or falling trend. The voltage and frequency controller has gained importance with the growth of interconnected system and has made the operation of power system more reliable. Many investigations in the area of AVR of an isolated power system have been reported and a number of control schemes like Proportional and Integral (PI), Proportional, Integral and Derivative (PID) and optimal control have been proposed to achieve improved performance. The conventional method exhibits relatively poor dynamic performance as evidenced by large overshoot and transient frequency oscillations

Optimization is the selection of a best element from some set of available alternatives.

In the simplest case, an optimization problem consists of maximizing or minimizing a real function by systematically choosing input values from within an allowed set and computing the value of the function. Several new optimization techniques like Genetic Algorithm (GA), PSO, Ant Colony Optimization (ACO), Simulated Annealing (SA) and Bacterial Foraging have emerged in the past two decades that mimic biological evolution, or the way biological entities communicate in nature. Due its high potential for global optimization, GA has received great attention in control system such as the search of optimal PID controller parameters.

The natural genetic operations would still result in enormous computational efforts. The premature convergence of GA degrades its performance and reduces its search capability. GA is a local search technique used to find approximate solutions to optimization and search problems. Genetic Algorithm has been developed by John Holland and his co-workers in the University of Michigan in the early. Genetic algorithms are theoretically and empirically proved to provide robust search in complex spaces. Genetic algorithms are a particular class of evolutionary algorithms that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover.

Schematic diagram showing an overview of the wind energy conversion system

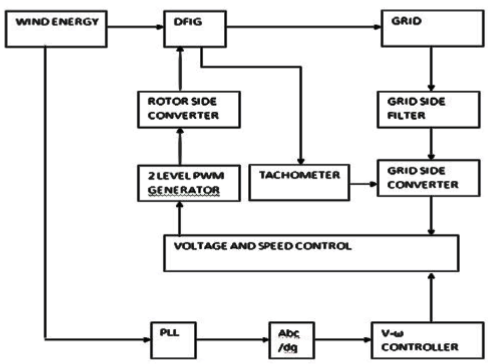

Figure 1 Block diagram of projected system.

The Genetic Algorithms need to be implemented to simple function optimization like Automatic Voltage Regulator. Then the process is to be extended to complex multimodal functions like one of the model of power system i.e. LFC. This paper deals with reduction of error in AVR of the proposed system through simulation in the MATLAB-Simulink environment.

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The computer simulations illustrate the results. It also makes a comparison between the GA technique and different error criteria.

The objective of this work is to design and implement GA-PID controller to search the optimal parameter for efficient control of voltage. The model of the AVR of single area power system is designed using simulink in MATLAB.

II. BASIC AVR CONTROL LOOP

In an interconnected power system, AVR equipments are installed for each generator. The schematic diagram of the voltage control loop is represented in fig.1. The controllers are set for a particular operating condition and take care of small changes in load demand to maintain the voltage magnitude within the specified limits.

Small changes in real power are mainly dependent on changes in rotor angle δ and, thus, the frequency f. The reactive power is mainly dependent on the voltage magnitude (i.e. on the generator excitation). Genetic Algorithms (GA) provide a general approach for searching for global minima or maxima within a bounded, quantized search space. Since GA only requires a way to evaluate the performance of its solution guesses without any prior information, they can be applied generally to nearly any optimization problem.

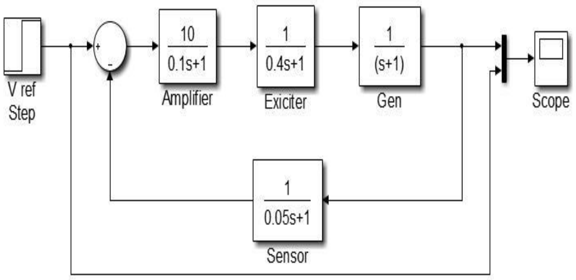

Fig-1.a AVR Control Loop

The aim of this control is to maintain the system voltage between limits by adjusting the excitation of the machines. The automatic voltage regulator senses the difference between a rectified voltage derived from the stator voltage and a reference voltage. This error signal is amplified and fed to the excitation circuit.

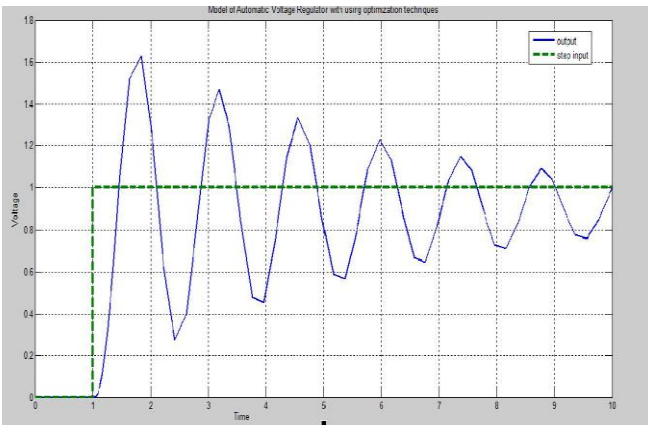

Fig-2 Model of AVR using Optimization Technique

The whole process consists of three steps i.e. firstly is the model preparation, secondly preparation of objective function, then the last comes the application of optimization technique.

CASE 1: AVR Integral Absolute Error (IAE)

Figure shows simulation model of AVR with having Integral Absolute Error criteria. From simulation graph is generated. This is as shown below

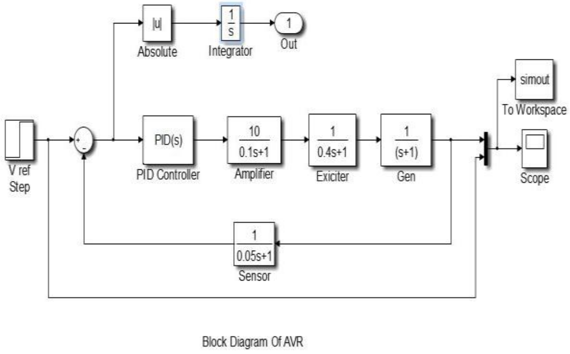

Figure 3.AVR with IAE

This figure shows the output simulation graph

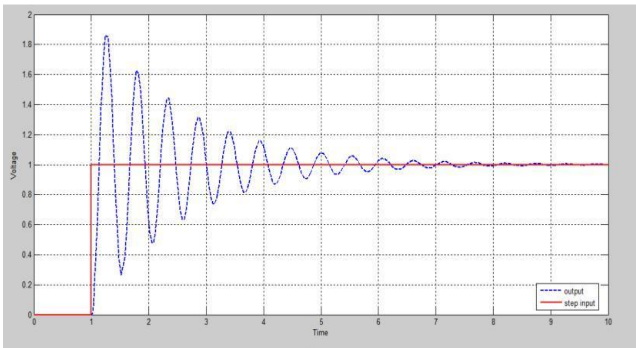

Figure 4. Graph of AVR with IAE

After the model preparation next comes the objective function by which the three variables value is to be calculated. This is basically a MATLAB Programming . In which all the variables in the model i.e. Kp, Ki and Kd values are assign to x(1) , x(2) and x(3) respectively. This values of x(1) x(2) and x(3) are show on MATLAB workspace

```
Simulation function y = iae_b(x)
        assignin ('base','Kp', x(1));
        assignin ('base','Ki', x(2));
        assignin ('base','Kd', x(3)); % assign variable
into MATLAB workspace
        [t,xx,y_out]=sim ('iae_a.mdl',[0  30] );
        y = y_out(end);% evaluate objective function.
```

Now on running the simulation, the graph is obtained which is shown above..

Case 2: AVR Integral Time Absolute Error (ITAE)

Figure show the simulation model of AVR using Integral Time Absolute Error criteria. From the simulation the graph is generated.

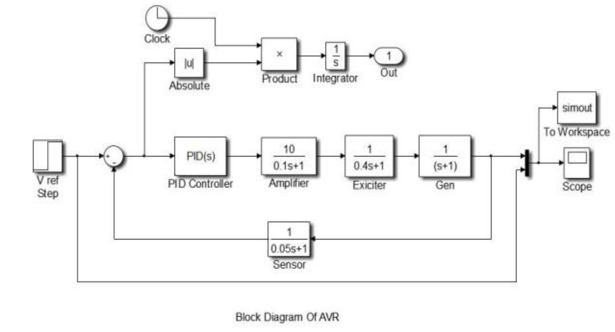

Fig 5.AVR with ITAE

This figure shows the output simulation graph

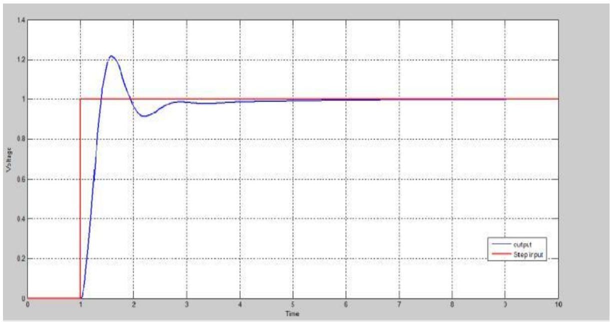

Figure 6. Graph of AVR with ITAE

After the model preparation, the next comes the evaluation of objective function by which the three variables' value is to be calculated. This is basically a MATLAB Programming , in which all the variables in the model i.e. K_p, K_i and K_d values are assign to x(1) ,x(2) and x(3) respectively. This values of x(1) , x(2) and x(3) are show on MATLAB workspace. Simulation

function y = itae_b(x)
assignin ('base','K_p', x(1));
assignin ('base','K_i', x(2));
assignin ('base','K_d', x(3)); % assign variable into MATLAB workspace [t,xx,y_out]=sim ('itae_a.mdl',[0 30]);
y = y_out(end);% evaluate objective function

III. APPLYING OPTIMIZATION TECHNIQUE

Third step is the application of GA technique in the run model. As using MATLAB 12.0, it provides direct accesses to genetic algorithm technique. This provides the best fitness function and best value for the model. It randomly through value and check for the best, and after different iteration it provides the best fitness function and original value of variables that shows the best value for the model the with minimizing the error.

Values of variables on simulation

Criteria	Kp	Ki	Kd
IAE	2.63	1.93	0.81
ITAE	0.0897	0.0397	0.0308

Table shows the value of P ,I ,D using both criteria Where K_p = proportional controller, K_i = Integral controller, K_d = Derivative controller

AVR	Rise Time	Settling time	Settling min	Settling max	Overshoot	Under-shoot	Peak	Peak time
With PID	2.95	60.95	0.289	1.6534	65.767	0	1.6534	21
With PID IAE	4.23	228.46	0.253	1.942	86.08	0	1.942	20
With PID ITAE	5.373	110.49	0.91	1.157	12.48	0	1.157	29

After the completion of all above steps, for knowing the values of output step response of both the cases. I have used a command S = step info (Scope Data(: , 1))
The table shows the step information of the graph .This show that how both the criteria provide different response and reduce overshoot. It reduces the error in the system
Rise time: time taken by signal to change from low value to specified high value
Settling time: time elapsed from instantaneous step input to time of output
Settling min: Minimum value of y once the response has risen
Settling max: Maximum value of y once the response has risen
Overshoot: Percentage overshoot (relative to y final)
Undershoot: Percentage undershoot
Peak: Peak absolute value of y
Peak time : Time at which this peak is reached
S = step info(y ,t) uses the last sample value of y as steady-state value y final.
S = step info(y) assumes t = 1:ns.

IV. VOLTAGE STABILITY IMPROVEMENT BY USING ANN

The method proposed is based on using linear programming technique to generate different training patterns and obtain the input data to ANN. In this study, feed-forward ANN which contains three layers (Two hidden layers and one output layer) is trained by using Back propagation algorithm to determine the proper adjustment of the reactive power control variables required to improve voltage stability. The block diagram of the ANN-based algorithm for improving voltage stability in power systems is shown in Fig. 1. Furthermore, to design a neural network, it is very important to train and test the network. The well-trained neural network should give the right decision for both normal and abnormal operating conditions

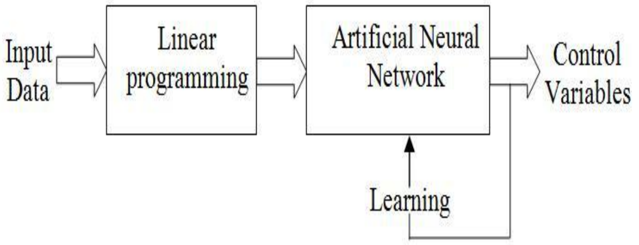

Fig. 7 The block diagram of the ANN-based algorithmfor improving voltage stability in Power System

Training is a stage at which all the weighting factors and thresholds are regulated according to a specific rule, in such a way that the objective function may be minimized. The usual method for training a multi-layer feed-forward neural network is the method of error back-propagation (or back-propagation). In order to use this method, both the desired output and the real output of the network must be available. The difference between desired output and real output is called the error. The algorithm of error back-propagation is based on the learning rule of error correction. This algorithm is an iterative method designed for minimizing the average of the squared error.

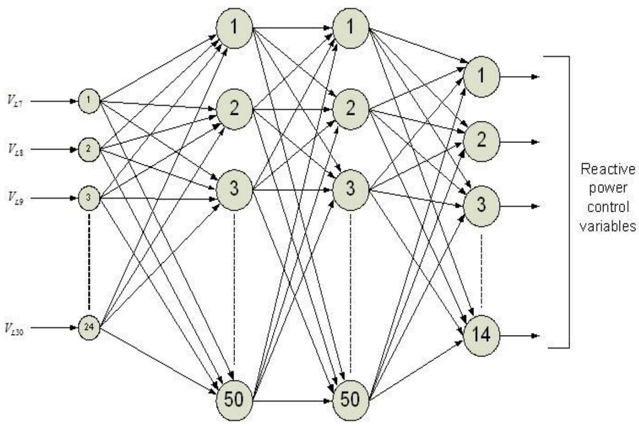

Fig. 8 Structure of neural network concerning 30-bus test system

In this study, in order to improve the voltage stability against load variations in the modified 30-bus test system, initial load flow analysis is carried out for the considered power system for different load conditions. Voltage instability analysis is performed from the data that obtained from load flow. Sensitivities of minimum Eigen value with respect to reactive power control variables are computed. By performing the LP, the recommendations of transformer taps, shunt capacitors, generator voltages are computed. Voltage profile at load buses are considered as inputs to the neural network. The LP recommendation values form the target vectors (desired output). The considered structure of the neural network is shown in Fig.8.

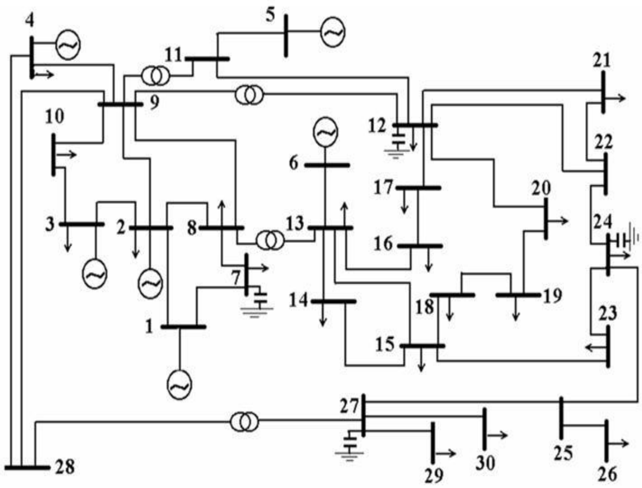

Fig. 9 The modified 30-bus test system

V. RESULTS

Both methods of linear programming and artificial neural networks have been simulated in MATLAB software and have been applied to the modified 30-bus test system. The ANN was trained with the three sets of data as shown in Tables IV and V, obtained by performing load flow and voltage instability analysis for different load factors such as 0.8, 1.0, and 1.2. The decision of each method (LP and ANN) are almost coincident, however the ANN gives these decisions in almost on time. A comparison between the computational time of the proposed ANN technique and LP is shown in Table VIII. It is clearly shown that the ANN technique requires very small computational time to improve voltage stability. These results have been achieved by using a computer with Pentium CPU of 2.6 GHz, 512MB RAM specifications.

THE PRE AND POST OPTIMIZATION CONDITIONS WITH FULL LOAD STATE

Load factor (unity)	Pre Optimization	Post Optimization
V_{min}	0.83 P.U.	0.957 P.U.
λ_{min}	0.186	0.226
power losses	22.72 MW	20.71 MW

VI. CONCLUSION

The results obtained by simulation of AVR reveals the superiority of the Genetic Algorithm over the other criteria. The different criteria of error reduction have their own advantages and disadvantages in the different optimization problems. In this section I have searched and concluded from the table that ITAE criteria better than IAE in case of overshoot .On the other hand, IAE is better in minimum settling time. Thus, this paper summarizes a number of current developments in genetic algorithms.

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It includes both theoretical aspects of genetic algorithms and its variants and some potential applications which incorporate the use of genetic algorithms.

A quick technique to monitor and improve power system voltage stability is proposed, the strategy is based on ANN. Three layers feed-forward ANN with back-propagation is trained to offer the proper rescheduling of reactive power control variables required to reach voltage stability in the day-to-day operation. The considered reactive power control variables are switchable VAR compensators, OLTC transformers and excitation of generators. The training data is obtained by solving several conditions utilizing the LP technique. The outcomes obtained show clearly that the ANN approach is capable of improving voltage stability in power systems.

The trained network is capable of improving the power system voltage stability from minimum to maximum range of load variations at very high speed. A comparison with the LP technique shows the clear superiority of the proposed ANN in achieving the control decision in a short computational time. Furthermore, the ANN is easy in structure and easy to operate compared with linear programming technique. Thus, the method can be used as a guide by the operator in Energy Control Center (ECC) for power system control. The proposed method indicates an important improvement in voltage stability which eventually results in considerable decrease in system losses.

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