Power System Load Modeling Based On Gene Expression Programming

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Abstract—*A new method of power system load modeling based on gene expression programming, and apply the algorithm to authenticate the actual load analysis, and comparative analysis with load modeling used to the least squares method, explained the advantages and disadvantages of GEP algorithm ,to facilitate the study of the application of power system load modeling later.*

Keywords-Gene Expression Programming;Genetic Operators;Least Squares;Load Modeling;response curve;error.

I. INTRODUCTION

Inspired by the biological characteristics of the expression of genes, scientist Ferreira of Portugal in 1999 firstly proposed a new automatic programming method-Gene Expression Programming(GEP)[1,2] , it belongs to one of evolutionary algorithms , it has a fundamental advantage stems from its unique genetic coding - with a fixed-length strings to represent computer programs, will become a long tree-structured information encoded in the fixed-length string, making based on this representation operator methods are easy to achieve and stability, while knowledge of the structure of individual expression with Genetic Programming(GP) knowledge of comprehensibility and consistency. References [3] pointed out that the GEP algorithm has been applied in many fields, but the application in power system load modeling is still rare.

II. THE NECESSITY FOR LOAD MODELING ALGORITHM RESEARCH

In the process of load modeling currently , model structure is often modeled by the composition of the scene based on the measured data,the load,some typical load characteristics of electrical equipment and mathematical models, then determine it through artificial methods[4]. Faced with thousands of possible combinations of the model structure plan,this method demand the modelers own empirical and high theoretical level, select the optimal model structure by artificial means is very difficult. Therefore, studying the method that does not require human intervention, or less dependent on prior knowledge, take advantage of computers to automatically organize, find and identify the model structure optimization model parameters is of great significance and practical value. References [5] pointed out the direction of research and development of smart grid in modeling.

III. GEP ALGORITHM-BASED

A. *The basic idea*

GEP algorithm integrate and develop the existing genetic algorithm (GA) and genetic programming algorithm(GP). Similar to the GA and GP ,its evolution can be simply summarized as the implementation of several on the population genetic manipulation, so that the population generation generations to evolve, seeking out the best individual to obtain a final solution of the problem. Ferreira pointed out the efficiency of GEP was 2-4 times higher than the efficiency of GA and GP.

Comparison with traditional GP and GA algorithm , The biggest feature of GEP algorithm is the individual's linear string of genes encoding , which is composed of the head and the tail.the head contains the variables of the terminator set T and the functions of the function set F, the tail contains only variables of the terminator set T . h and t must satisfy the relationship:

$$t = h \times (n - 1) + 1 \tag{1}$$

In equation(1) , n is the number of parameters which required the most variable in the function set T , in the individual phenotypes, n perform the nodes of a tree structure's maximum branches number , this design allows the genetic operations of genotype have a very good legitimacy.

GEP's gene has two forms: genotype and phenotype .Therefore, every gene correspond to a K-expression(the effective portion of gene encoding) and a expression tree ,Where K-expression is genotype and expression tree is phenotype ,they can be changed into each other .

For example: existing a function of an actual problem, considering the function set {+, -, *, /} and terminator set {x, y}. If the selected header length h = 6, then according to equation(1),we can obtain t = 7; so the length of the gene is L = 13. Assumed the gene g encode the following genotype: - + / ** xyxxxxxy, the performance encoder shown in Fig.1 .

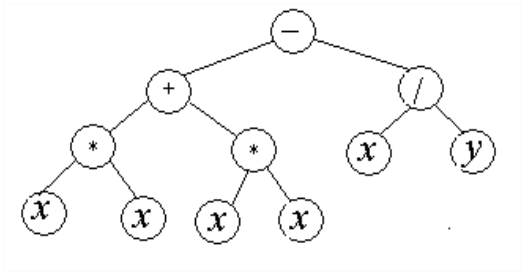

Figure 1. GEP algorithm performance code

From the above example we can find the tree length in gene expression is 11,while the gene's actual length is 13 , which is the GEP encoding characteristics. in the coding region the useless of this genotype coding rear called non-coding region , and this concept is described in detail in references [6].The presence of these non-coding regions of the evolution of the program provides a lot of space. This area makes evolutionary process may produce neutral variation.

B. Genetic operators of GEP

The standard GEP algorithm is very similar to the basic processes of GA, in an iterative process of evolution, each chromosome in the population go through the role of genetic operators to continue to promote the evolution of the entire population. The genetic operators of GEP can be very simple, flexible, including selection, mutation, inverted string, insert string, genetic transformation, a single point of restructuring, two points reorganization ,genetic recombination and so on. The operator makes the vitality of the population increases.Compare with GA and GP ,it can avoid premature.

IV. THE APPLICATION OF GEP IN LOAD MODELING

A. Data processing and model parameters

Port static voltage characteristics test data of an induction motor shown in Tab.1(data in the table are per unit). Known: P , Q, U are the active power of the load, reactive power of the load and voltage respectively under

TABLE I. LOAD CHARACTERISTICS TEST RESULTS

U	P	Q
1.121053	0.484515	0.922466
1.052632	0.428333	0.736968
1.000000	0.412780	0.630898
0.947368	0.403545	0.531095
0.905263	0.400569	0.465205
0.852632	0.386055	0.404971
0.800000	0.386709	0.335861
0.747368	0.380415	0.285312
0.705263	0.375948	0.252639
0.652632	0.373822	0.216848
0.600000	0.374814	0.181531
0.547368	0.367592	0.167480
0.526316	0.366922	0.161788
0.505263	0.371988	0.157905

TABLE II. PARAMETERS OF GEP

Genetic operators	Probability
mutation	0.044
inverted string	0.1
insert string	0.1
genetic transformation	0.1
single point of restructuring	0.4
two points reorganization	0.2
Function set F	{ + , - , *,/}
terminator set T	{u, 1}
Population	30
The maximum iterations	1000
Head length h	25
Fitness	$f = \frac{1}{n}\sum_{i=1}^{n}\left\|p' - p\right\|^2$

the normal operation mode. According to the measurement data, use GEP algorithm that have described above, we can program and analysis under VC++6.0 compiled environment,the termination condition is

$$f < 0.001 \tag{2}$$

Other related parameters have shown in Tab.2.

B. Analysis of results of the example

According to the data of Tab.1, we take use of GEP algorithm and the least squares method respectively to obtain two polynomial function model. After several iterations, we obtain the optimal polynomial model of GEP algorithm:

$$\begin{cases} p = 0.4u^2 - 0.5u + 0.53 \\ q = 2u^2 - 2u + 0.67 \end{cases} \tag{3}$$

We get the optimal polynomial model of the least squares method(here we set the number of polynomial as 2) is:

$$\begin{cases} p = 0.4108u^2 - 0.5151u + 0.5289 \\ q = 2.02u^2 - 2.0827u + 0.6965 \end{cases} \tag{4}$$

According to the data in Tab.1 and Equ.3,Equ.4,under the simulation environment matlab7.0 ,then we can obtain active and reactive power model response curves in GEP algorithm and least squares method to the power function

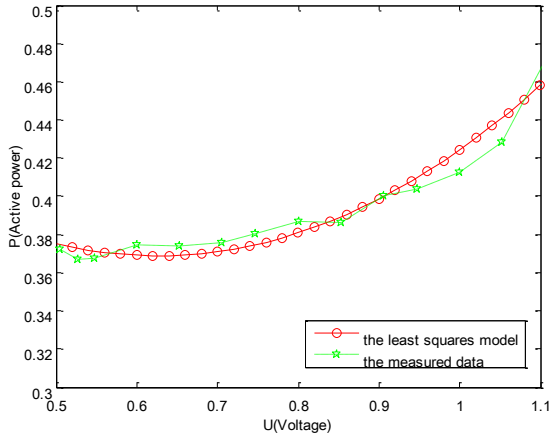

Figure 2. the active power response curve of least squares method

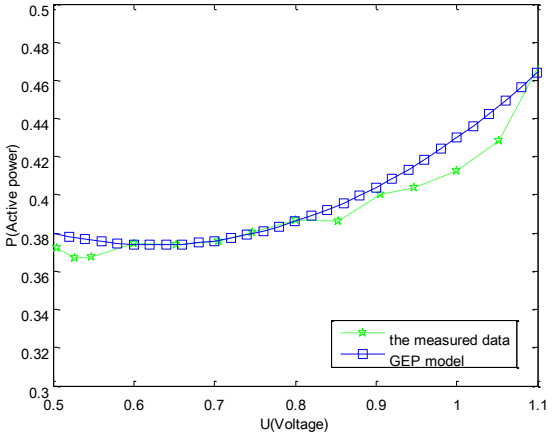

Figure 4. the active power response curve of GEP

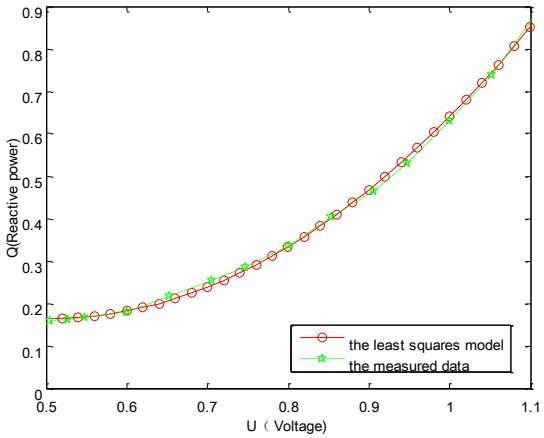

Figure 3. the Reactive power response curve of least squares method

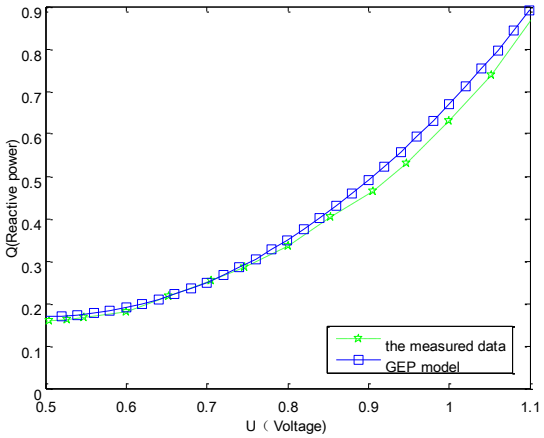

Figure 5. the Reactive power response curve of GEP

load model ,shown in Fig.2, and Fig.3. In addition, we make power deviation analysis between generate models with the measured data, the results showed in Tab.3.

As can be seen from Fig.2 and Fig.3, the response curve of the response curve of the model by the method of least squares is very close.Clearly it can be seen from the data shown in Tab.3, As can be seen from Fig.4 and Fig.5, the response curve of GEP algorithm model and the difference obtained by the arithmetic model GEP and power deviation obtained by the method of least squares model of the power deviation is less than 0.01. By fitting these two algorithms mathematical model is similar essentially.Note: in the Tab.3 , δ p and δ q represent root mean square of the errors .

V. CONCLUSION

After the text edit has been completed, the paper is In this paper, we construct a mathematical model of the static load with GEP algorithm.Through the application of load modeling examples we can prove the feasibility of the algorithm . Its advantage is to make the process automatic, we do not need to understand the data before, its disadvantage is too large amount of calculation, the strong randomness ,at the same time,it need to repeat the experiment many times, then may be possible to produce the optimal model structure.

TABLE III. POWER DEVIATIONS OF TWO ALGORITHMS

Error of active power			Error of reactive power		
No.	The least squares	GEP	No.	The least squares	GEP
1	-0.0185	-0.0123	1	-0.0203	0.0189
2	0.0127	0.0186	2	0.0102	0.0438
3	0.0116	0.0172	3	0.0096	0.0391
4	0.0063	0.0118	4	0.0134	0.0392
5	-0.0007	0.0046	5	0.0103	0.0333
6	0.0032	0.0084	6	-0.0060	0.0137
7	-0.0058	-0.0007	7	-0.0026	0.0141
8	-0.0057	-0.0007	8	-0.0069	0.0071
9	-0.0046	0.0004	9	-0.0104	0.0016
10	-0.0047	0.0002	10	-0.0100	-0.0003
11	0.0058	-0.0008	11	0.0006	0.0085
12	0.0036	0.0086	12	0.0008	0.0070
13	0.0057	0.0107	13	0.0040	0.0096
14	0.0025	0.0075	14	0.0071	0.0122
δp	0.0079	0.0095	δq	0.0095	0.0228

Of course, the automated procedure does not produce the desired model necessarily, we can put GEP algorithm and previously load modeling methods together[7] ,then study further.only in this way ,we can provide new ideas for the study field of power system load modeling .

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