

Neural-net model of heat-transfer system on buried thermal well of ground-source-heat-pump*

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Abstract: This paper introduced the NN model of heat-transfer system on buried thermal well from systematic, holistic and non-linear characteristic, and establish the Forecast model of NN to calculate and forecast the heat-transfer model on different input and output variable. From the result, the simulate value was consistent with the experiment value, its calculated precision was higher.

Keywords: ground-source-heat-pump; heat-transfer system on buried well; neural-net model

1. Introduction

For input and output relation of one and two dimension system, we could establish the math's model to figure out, but to several dimension and non-linear system, it's very complex. Although we can though analyzing the datum and it's immanence mechanism to erect the math's model to describe the complexity system based on ignoring the systematic non-linear. But this result was very approximate, moreover is very difficult to find at many circs.

From geometric means of NN model, it corresponded with renewing the given discontinuous datum to a continuous hypersurface; the given point's value is meet with the sample's value at the hypersurface, then extended the unknown point's value that was in estimating series. The input and output node lied on the in-out vector's dimension, the hypersurface that reacted the connection of the in-out was difficult to show by using trad analyses means or sending heat model.

The heat passing which between the buried thermal well exchanger and the rocks was unstable and in infinity field, it was very complex. Actually many non-linear factor have an impact on the heat passing, that included the heat characteristic, density, temperature and humidity of the rock, the material and diameter of the pipe, the characteristic, velocity of flow of the liquid in pipe, the runtime and the run rule etc, but the perfect math's model was not only difficult to describe the relation of so mach factor and it's complex linear connection, but also difficult to answer. So many research only used the model that though predigesting and assumptive. But because neglecting many available factors and it's non-linear at predigesting and

assumptive, the result must not agree with the fact in some degree, some time the unconformity was very great. In this paper, author attempted to use NN model to analyse the heat-transfer system on buried thermal well of GSHP.

This paper adopted three-network structure, the back promulgates calculative means (viz. BP calculative means), the aim's function of study was square error of average (ξ_{AV}), and the aim of study was minimized the ξ_{AV} . Testing the network's capability by using testing datum when modeling; to avoid appearing overflow because of the greater scale, only third of the datum was used to training the network. Moreover, to reduce the amount of input variable, it ought to choose variable carefully. Author has written the study flow chart of the NN and the program of computer model.

2. The application of the NN model of heat-transfer system on buried well

The literature [2] introduced the all year's running record and the testing result of heating and cooling in winter and summer on the heat-transfer system with buried thermal well from July in 2000 to June in 2001. It summed to 54 days from July 6 to Aug 30, 2000 in summer, the testing datum have taken the average by the day, altogether haven 54 groups datum; it summed to 58 days from Nov 22, 2000 to Jan 20, 2001 in winter, the testing datum have taken the average by the day, altogether haven 58 groups datum. The testing datum included the wall's temperature [L9-3, L9-6, L9-9(°C)] of -3m, -6m, -9m on No. 9 well; the outdoor air temperature [Tw(°C)]; the water temperature [J3, C3(°C)] of the entrance and exit in the system; the flux [G(l/h)]; The runtime [H(h)] of the GSHP system daily;

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the quantity of the exchanged heat [Qh(kWh)] of the buried well; the quantity of electricity daily on heat pump system etc.. The detailed datum was referred to the literature [2]. In this paper, only discussing the experiment in summer.

The testing datum was 54 groups in summer experiment, in this paper, 39 groups datum was used to the to train, in those datum, 15 groups was used to test the forecast of the NN model. Need to explain, the data using to train and test was not any especial request, it could be selected random.

2.1 Forecast the wall temperature model of buried well

We selected six parameters what influenced hardly to wall temperature as inputting layer for seeking the wall temperature model of buried well when have known the input, its were T_w , J_3 , C_3 , H , G and Q_h . the hidden layer haven five nerve fiber, the inspiring function was tansing function, the outputting layer haven three nerve fiber which adopted Purelin linear threshold cell, its corresponded to wall temperature at -3, -6, -9m, respectively. The forecast model used three layer NN model, it's frame as Fig. 1.

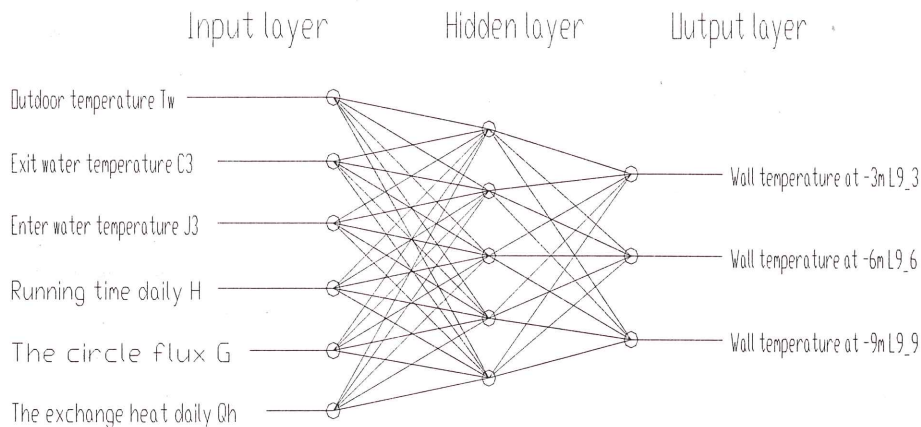


Fig.1.The NN model of forecasting the wall temperature on buried well

Table 1.The forecast value and the measured value of the wall temperature

date	Series No.	Mea-sured value /°C	L9-3			Mea-sured value /°C	L9-6			Mea-sured value /°C	L9-9		
			Forecast value /°C	Absolute error /°C	Rela-tivity error /%		Forecast value /°C	Absolute error /°C	Rela-tivity error /%		Forecast value /°C	Absolute error /°C	Rela-tivity error /%
716	11	30.02	28.61	-1.41	4.70	25.82	25.07	-0.75	2.90	24.92	24.21	-0.71	2.85
717	12	30.70	29.35	-1.35	4.40	25.9	26.13	0.23	0.89	25.60	25.42	-0.18	0.70
718	13	30.80	31.09	0.29	0.94	27.02	27.40	0.38	1.41	25.74	26.90	1.16	4.51
719	14	32.13	33.09	0.96	2.99	28.55	28.99	0.44	1.54	27.61	28.67	1.06	3.84
720	15	31.43	31.71	0.28	0.89	27.77	27.71	-0.06	0.22	27.32	27.27	-0.05	0.18
731	26	33.88	35.03	1.15	3.39	30.00	30.85	0.85	2.83	29.85	30.29	0.44	1.47
801	27	35.48	34.67	-0.81	2.28	31.18	30.27	-0.91	2.92	31.06	29.69	-1.37	4.41
802	28	35.29	36.34	1.05	2.98	31.56	32.06	0.50	1.58	31.35	31.66	0.31	0.99
803	29	34.89	34.78	-0.11	0.32	30.78	31.34	0.56	1.82	30.77	30.83	0.06	0.19
804	30	36.34	36.24	-0.10	0.28	32.44	32.49	0.05	0.15	32.24	32.05	-0.19	0.59
822	48	37.07	36.97	-0.10	0.27	32.78	32.67	-0.11	0.34	32.65	32.37	-0.28	0.86
823	49	35.51	36.36	0.85	2.39	31.27	32.51	1.24	3.97	31.14	31.93	0.79	2.54
824	50	35.30	36.54	1.24	3.51	30.7	32.72	2.02	6.58	30.60	32.17	1.57	5.13
825	51	36.35	36.83	0.48	1.32	31.78	32.96	1.18	3.71	31.7	32.38	0.68	2.15
826	52	36.93	37.09	0.16	0.43	32.41	33.22	0.81	2.50	31.73	32.74	1.01	3.18
Average					2.07				2.22				2.24

The model used the 39 groups that aforesaid datum to train, it's the square root of average of the training error, the average ratio and the error of the availability parameter, when most training time was 100, was very small, the result was fine, at this time stopped training, and inputted the 15 groups of the forecasting datum, to forecast and test the wall temperature. The forecast

value, the measured value and the absolute error, the relativity error as Table 1.

From the table, the forecasting precision was very high, it's relativity error was under the 7%. The average of the relativity error on L9-3, L9-6, L9-9 were 2.07% (the max: -4.7%~+3.51%), 2.22% (the max: -2.92~+6.58%), 2.24% (the max: -4.41 %~+5.13 %).

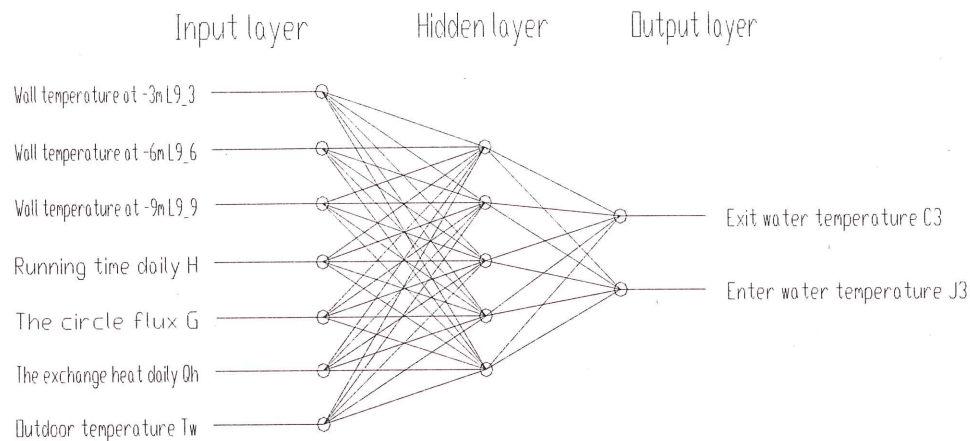


Fig.2 The NN model for forecasting enter and exit water temperature

Table 2. The forecast value and the measured value of the enter and exit water temperature

Date	Series number	C3				J3			
		Forecast value /°C	Measured value /°C	Absolute error /°C	Relativity error /%	Forecast value /°C	Measured value /°C	Absolute error /°C	Relativity error /%
716	11	23.39	24.44	1.05	4.49	26.57	28.39	1.82	6.85
717	12	25.3	24.74	-0.56	2.21	30	29.08	-0.92	3.07
718	13	26.6	25.86	-0.74	2.78	30.99	30.15	-0.84	2.71
719	14	27.97	27.71	-0.26	0.93	31.74	31.49	-0.25	0.79
720	15	27.38	28.68	1.3	4.75	30.5	31.7	1.2	3.93
731	26	29.51	30.03	0.52	1.76	32.83	33.37	0.54	1.64
801	27	29.33	29.07	-0.26	0.89	32.55	32.34	-0.21	0.65
802	28	31.53	29.77	-1.76	5.58	34.44	32.67	-1.77	5.14
803	29	30.41	29.55	-0.86	2.83	34.33	33.78	-0.55	1.60
804	30	32.06	32.57	0.51	1.59	35.04	35.59	0.55	1.57
822	48	32.59	31.55	-1.04	3.19	35.01	34.2	-0.81	2.31
823	49	31.25	31.36	0.11	0.35	33.83	34.2	0.37	1.09
824	50	31.8	30.1	-1.7	5.35	33.83	32.63	-1.2	3.55
825	51	32.32	32.13	-0.19	0.59	35.18	35.17	-0.01	0.03
826	52	32.45	31.76	-0.69	2.13	35.48	34.88	-0.6	1.69
Average					2.63				2.44
The most error		-5.58%~4.75%				-5.14%~6.85%			

2.2 Forecast the NN model of enter and exit water temperature

We also established the three layer BP NN model for

seeking the model of enter, exit water temperature in summer, it's inputting layer haven seven parameter, its were Tw, H, G, Qh, L9-3, L9-6, L9-9; the hidden layer haven five nerve fiber, the inspiring function was

tansing function, the outputting layer haven two nerve fiber which adopted Purelin linear threshold cell, it's frame as Fig.2. The model used the 39 groups that aforesaid datum to train, it's the square root of average of the training error when most training time was 100, was very small, the result was fine. At this time stopped training, and inputted the 15 groups of the forecasting datum, to forecast and test the enter and exit water temperature. The forecast value, the measured value and the absolute error, the relativity error as Table 2.

From the table, the forecasting precision was very high, it's relativity error was under the 7%. The average of the relativity error on the enter and exit water temperature were 2.63% (the max: -5.58%~+4.75%), 2.44% (the max: -5.14~+6.85%).

3. Tag

So it has important practicing meaning to establish

the NN model of the buried well heat transfer system on GSHP, owing to the NN model have been proved that it could closed in upon any non-linear mapping, moreover, it also have been proved the simulate result inosculated with the practice in this paper. But it has many thing to do to establish the NN model that could popularize, appliance, direct the work. In rigid, the textual NN model was only the same with the heat transfer system in the current experiment condition. If wanted to popularize and application, must increase the experimental extent. It could make the model be use in more condition.

References

- 1 Liu Xiangying etc. The summarize of heat-transfer model of buried well exchanger in GSHP, Chongqing Jianzhu University transaction, 1999 №4, 106~111.
- 2 Cheng Jianping, The experiment research on thermal well of GSHP all years and heat transfer model, MS thesis. Chongqing: Chongqing University, 2001(in Chinese).