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Evaluation of Stress Resultant of offshore jacket platform using Neural Network

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Abstract : The safety of an offshore platform depends on the predicting environmental phenomena such as wind, current, wave, seismic loadings and accurate calculation of responses of the structure to these loads and determining the strength of the structure. This paper deals with the prediction of stress resultant deflections of fixed offshore platform to the varying environmental loading conditions using neural networks. The manual estimation of stress resultant to the varying loading conditions involves tedious calculation methods and time consuming. The most difficult task is to represent the problem mathematically, involving all possible forcing functions. With the time dependent nature of the environmental loads, estimation of platform response may not be the actual one. Neural networks have the ability to recognize the hidden pattern and accordingly make prediction. Built in dynamism, data error tolerance, lack of any exogenous data and model free solutions makes them even more attractive. Hence an attempt is made to use neural networks in the estimation of deck responses to varying water depth, wave and wind conditions, which will be very useful for the design of offshore structures

With the availability of advanced computer software, the 3D analysis reveals the response behavior of offshore platforms. With the complexity and random nature of environmental loads, the calculated responses may not be accurate to the extent required at all loading state for practical considerations. The back-propagation neural network (BPN) employed here for prediction of response is to refinement of design procedure to make it more economical. This can be a useful tool in periodic inspection of structure to detect structural damages as a requirement for certification. This experimental work depicts prediction of deck displacement resultant of 4 legged offshore jacket platform in 200 m water depth using neural network. With the data of deck displacements at various loading state, the BPN was first trained and later prediction of the deck displacements is obtained for any loading state.

General

A neural network is an information processing system modeled on the structure of the human brain. Its merit is the ability to deal with fuzzy information whose interrelation is ambiguous or

whose functional relation is not clear. The use of neural network for various applications is increasing day by day.

The use of neural network in the field of civil engineering is increasing. The some examples of the use of neural network in the civil engineering field are forecasting of rainfall [3] (French et al 1992), forecasting of runoff [4] (Crespo and Mora 1993), concrete strength [5] (Kasperkiewicz et al. 1995). The uses of neural network in the coastal engineering are sea level prediction [6] (Vaziri M 1991), estuarine instabilities [7] (Gulbert, 1995), wave forecasting [8] (Deo and Naidu 1999), Tide prediction [9] (Deo and Chaudhari 1998), [10] Mandal 2001).

The application of Neural Network is being made in offshore structural engineering field also. Some of those are, stability analysis of rubble mound breakwaters [11] (Mase H 1995), on-line monitoring system for offshore platforms [2] (Mangal, Idichandy & Ganapathy, 1996), neural networks in detection of structural damage [12] (Wu, X, Ghaboussi, 1992), neural network based monitoring of offshore platforms by using impulse and relaxation response [13] (Mangal, Idichandy, & Ganapathy, C, 1995),

Dynamic Response of Jacket Platform

The dynamic responses of an offshore platform are determined using a lumped mass mathematical model with viscous damping, linearized soil spring, and hydrodynamic force function based on Morison's equation. The equation of motion in matrix form is expressed as

$$[M] \{\ddot{X}\} + [C] \{\dot{X}\} + [K] \{X\} = \{F\} \quad (1)$$

$$F_i = \sum C_d \frac{\rho D l}{2} (u - \dot{X}) \left| u - \dot{X} \right| + \left[C_m a - (C_m - 1) \ddot{X} \right] \frac{\pi D^2}{4} \rho l \quad (2)$$

WHERE

[M] = Total mass matrix of the system

[C] = Damping matrix

[K] = Structural stiffness matrix

{F} = Hydrodynamic force

{X} = Nodal displacement

$\{\dot{X}\}$ = Nodal velocities

$\{\ddot{X}\}$ = Nodal accelerations

C_d = Drag coefficient

C_m = Inertia coefficient

u = water - particle velocity

a = water - particle acceleration

The equation (1) can be solved by frequency domain approach using the power spectral density technique. In the present study the wave response dynamic analysis is conducted by frequency domain approach. The dynamic analysis is conducted with the wave and wind forces selected from the P-M spectrum as in Table No. 1 for different water depths starting from 150m to 220m at interval of 5 meter each. At each water depth the structure is subjected to total 33 wave and wind combinations. The stress resultant i.e. deck deflection in global Y-direction is considered for neural network training. As there is a difference of about 35.0 m between deck and still water level, the response of the structure at the water level also estimated.

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The physical description of the selected jacket offshore platform is as follows. The total height of the tower is 235 m. The main legs and deck level braces are of 2.0 m outer diameter and 0.1m wall thickness. All the braces up to height of 155.0 m from the sea bed are of 0.75 metre outer diameter and 0.05 metre wall thickness. The rest of the braces above this height are of 0.5 metre outer diameter and 0.02 metre wall thickness. The deck weight is assumed to be 500 tonnes and is equally distributed to the four deck level nodes.

BPN Prediction of Deck Displacement Response

The predictions of deck displacements i.e. evaluation of stress resultant deflection at deck level by the BPN (Back Propagation Neural Network) with quick-prop updated algorithms are considered for each load case. Fig-1 shows one such BPN structure used in the present work. The input layer consists of 4 nodes corresponding to the parameters wave height, wave period, wind speed and water depth respectively. The hidden layer has only five nodes. The output layer is having one node, which is the predicted deck response parameter. The accuracy of predicted response is compared with the actual ones. The correlation coefficient (r) is calculated to show the agreement of BPN predicted response with the actual. The Fig-2 is shown to depict accuracy of BPN predicted responses.

The predictions of deck displacement considered in three different headings, viz.

1. Fixed water depth with varying wave and wind forces
2. Varying water depth with fixed wave and wind forces
3. Varying water depth with varying wave & wind forces.

Computing Correlation Coefficient (r)

$$r = \frac{\sum x y}{\left(\sum x^2 \sum y^2 \right)^{1/2}}$$

Where, $x = X - X_1$ X = Deck displacement from analysis. X_1 = mean of X .

$y = Y - Y_1$ Y = Deck displacement from neural network. Y_1 = mean of Y

Result and Discussion

The combined effect of wind and waves are taken for training and prediction of responses. There are total 15 different water depths starting from 150 m to 220 m at the interval of 5 m each considered. At each water depth total 33 wave cases and 33 respective wind cases are applied. Considering the combination of wave and wind forces, total 99 load cases at each water depth are applied. To sum up combining all water depth, total 1485 (99 X 15) load cases are considered.

The NN training part was little difficult, as to different combinations of hidden nodes and seeds have to be tried to get the accuracy in deck response prediction. The input parameters considered are water depth, wave height, wave period and wind speed. The output obtained is deck displacement. For testing the accuracy of predicted results with the actual ones, random water depth and load cases are considered. The Fig-2 shows the comparison between NN predicted and actual displacements by using Quickprop algorithm. The Graph for specific water depth from network trained combined for all water depths and all wave and wind load cases are shown in Fig-4 & Fig-5. The Correlation Coefficient (cc) calculated is 0.9952 and 0.9959 with varying water depth and varying wind and wave force combinations. The error between actual and NN-predicted deck displacements are in the range of 0.01 cm to 0.081cm, which is within the appreciable limit. The total data points in this graph are 486 out of which 53 data points are obtained from the neural network prediction. The straight line drawn in the graph is of function $X = Y$, which passes through almost all the NN-tested (predicted) displacement points. Hence the result shows accuracy of prediction in the range of 99%. With this we can conclude the neural network (Quickprop) is accurately predicting the displacement response at deck level to

Sr. No	Wave Height M	Wave period Sec	Wind speed M/sec
1	0.545	4.360	9.0
2	0.691	4.856	10.0
3	0.854	5.356	11.0
4	1.034	5.859	12.0
5	1.231	6.365	13.0
6	1.445	6.873	14.0
7	1.676	7.382	15.0
8	1.925	7.893	16.0
9	2.190	8.405	17.0
10	2.473	8.917	18.0
11	2.772	9.430	19.0
12	3.089	9.944	20.0
13	3.423	10.458	21.0
14	3.773	10.973	22.0
15	4.141	11.488	23.0
16	4.527	12.004	24.0
17	4.929	12.519	25.0
18	5.348	13.035	26.0
19	5.784	13.551	27.0
20	6.238	14.068	28.0
21	6.709	14.584	29.0
22	7.196	15.101	30.0
23	7.701	15.617	31.0
24	8.223	16.134	32.0
25	8.763	16.651	33.0
26	9.319	17.169	34.0
27	9.892	17.686	35.0
28	10.483	18.203	36.0
29	11.090	18.720	37.0
30	11.714	19.237	38.0
31	12.356	19.754	39.0
32	13.015	20.272	40.0
33	13.692	20.791	41.0

various wave and wind loadings, within the allowable limit of error.

Conclusion

Based on the present study, following conclusions are drawn

1. The stress resultant (displacements) predicted by the neural network are closely matching with that obtained from the detailed dynamic analysis.
2. The correlation coefficient of about 0.99 obtained in all cases confirms that neural networks can be effectively used for dynamic response prediction of offshore platforms
3. The response data required for design of offshore platforms can be predicted using neural networks provided some initial observed field measurements are available.

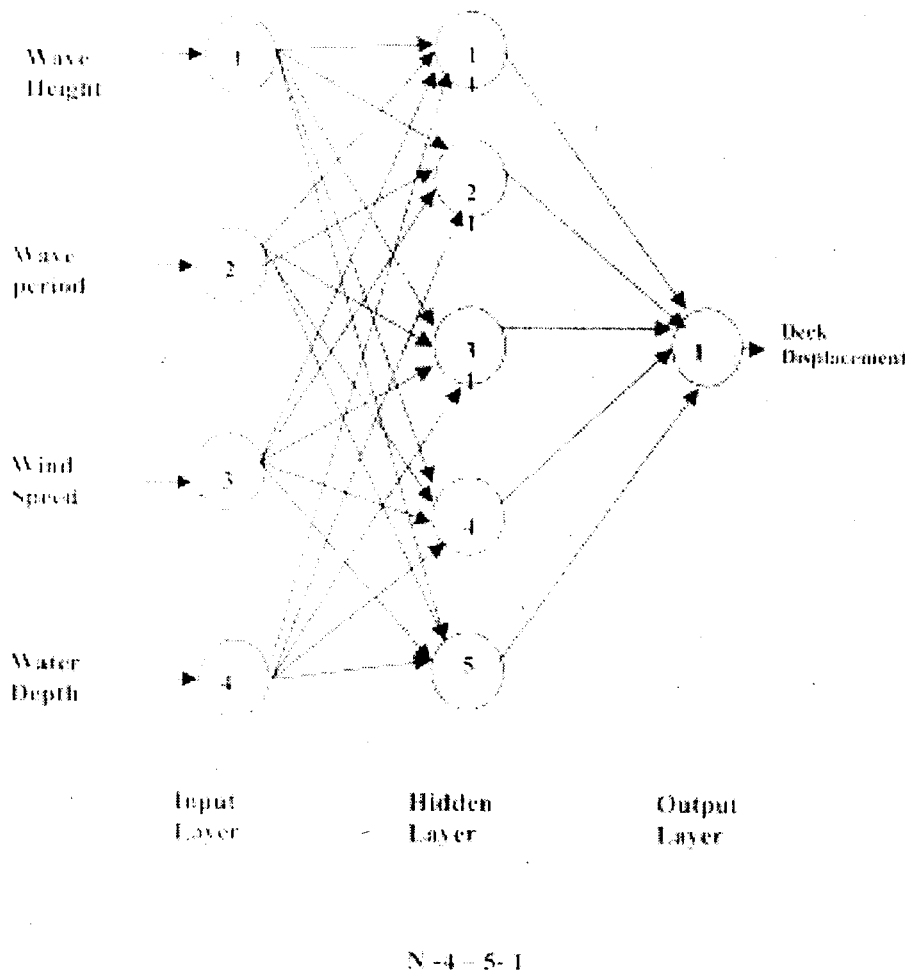


Fig 1 Neural Network structure used

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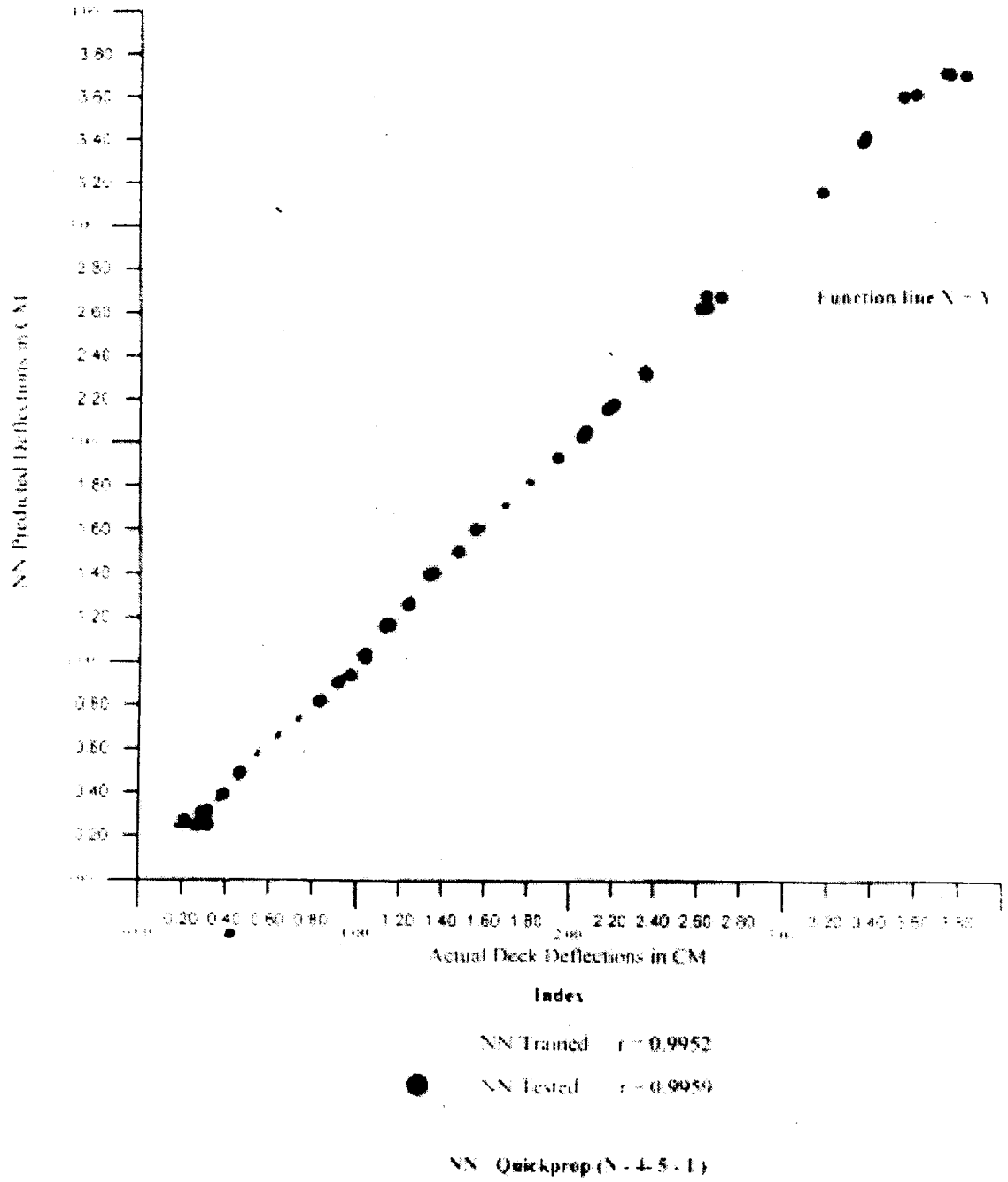


Fig 2: Correlation between the NN Predicted and Actual Deflections at deck Level for varying depth and varying wind & wave Loadings

VARYING WATER DEPTH AND VARYING WIND & WAVE
 Water Depth - varying from 150 m to 220 m at 5m interval
 wave & wind - Total 33 wave and 33 wind combinations at each water-level

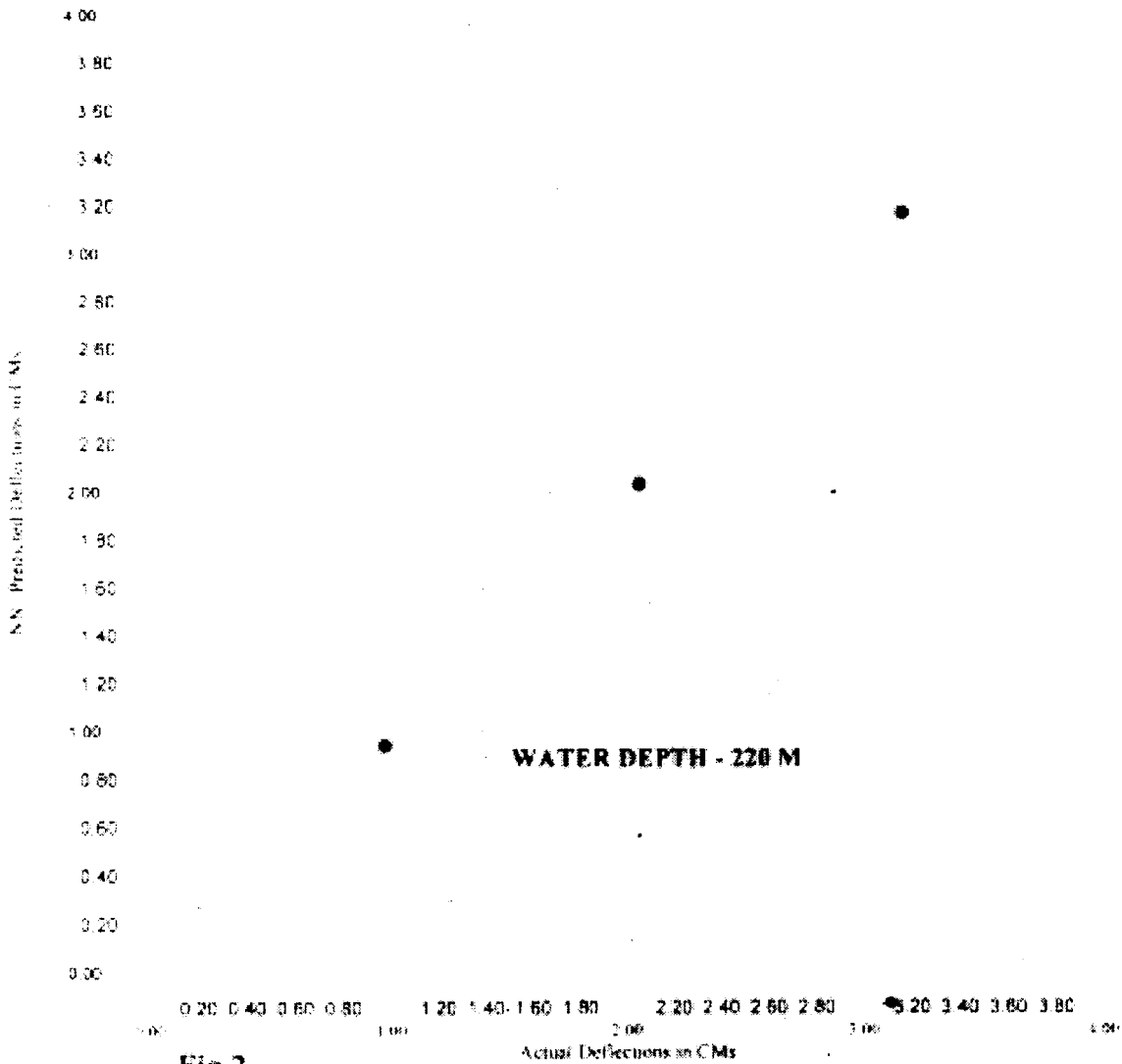


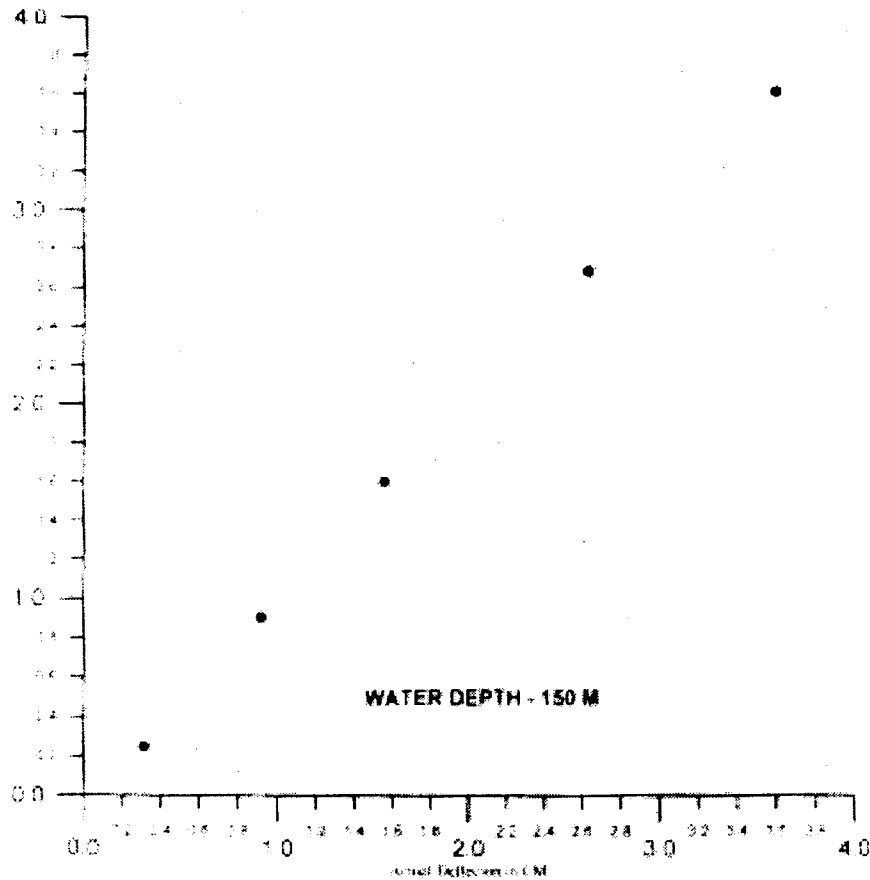
Fig 2

* Graph for Specific water depth from Network trained combinedly for all water depths.

Index
 ○ NN- Trained
 ● NN- Tested
 NN - Quickprop (N - 4 - 5 - 1)

Fig 5 Correlation between the Actual and NN Predicted Deck Deflection

Water Depth - Varying from 150 m to 220 m with the interval of 5 m each
 wave & wind - Total 33 wave and 33 wind combinations at each water level



Graph for Specific water depth from Network trained combinedly for all water depths and at wave and wind load cases.

Index
 ○ NN - Trained
 ● NN - tested
 NN - Backprop (N = 4, 3, 1)

Fig 3 Correlation between the Actual and NN Predicted Deck Deflection

VARYING WATER DEPTH WITH VARYING WIND & WAVE
 Water Depth - varying from 150 m to 220 m with the interval of 5 m each
 wave & wind - Total 33 wave and wind combinations at each water level



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