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SeaBuoySoft – an On-line Automated Windows based Ocean Wave height Data Acquisition and Analysis System for Coastal Field's Data Collection

P.H.Tarudkar, G.V. Ramana Rao
Central Water and Power Research Station, Khadakwasla, Pune-24

ABSTRACT
Measurement of various hydraulic parameters such as wave heights for the research and the practical purpose in the coastal fields is one of the critical and challenging but equally important criteria in the field of ocean engineering for the design and the development of hydraulic structures such as construction of sea walls, break waters, oil jetties, fisheries harbors, all other structures, and the ships maneuvering, embankments, berthing on jetties. This paper elucidates the development of "SeaBuoySoft online software system for coastal field's wave height data collection" for the coastal application work. The system could be installed along with the associated hardware such as a Digital Waverider Receiver unit and a Waverider Buoy at the shore. The ocean wave height data, transmitted by wave rider buoy installed in the shallow/offshore waters of sea is received by the digital waverider receiver unit and it is interfaced to the SeaBuoySoft software. The design and development of the software system has been worked out in-house at Central Water and Power Research Station, Pune, India. The software has been developed as a Windows based standalone version and is unique of its kind for the reception of real time ocean wave height data, it takes care of its local storage of wave height data for its further analysis work as and when required. The system acquires real time ocean wave height data round the clock requiring no operator intervention during data acquisition process on site.

Keywords – on-line, ocean waves, ship maneuvering, waverider buoy, waverider receiver

I. INTRODUCTION

Central Water and Power Station (CWPRS), Pune, INDIA is actively involved in providing Sea-Port solutions to a number of critical and equally challenging problems in the area of costal and offshore engineering. These studies require understanding of wave climate as the sea behaves abruptly. The ocean wave height data are collected at sites to study the wave climate in order to design marine structures, break waters, sea walls etc. In earlier days the available period for the observation of data at a site is less and ranges from 6 months to 9 months (i.e. only pre and post monsoon) due to battery supply issues. The data are normally collected every 3 hours for duration of 20 minutes resulting in 8 records in a day. Thus the ocean wave height data at a site at a time range from approximately 1400 to 2000 records, depending on the period of observation. From this voluminous data, engineers have to obtain meaningful ocean wave characteristics to arrive at a certain design conclusions.

In the past, the receiver recorded the ocean wave heights data on a strip chart ink pen recorder and the DOS based data loggers and thereafter the wave height records were analyzed manually in the laboratory. This has been a tedious and time consuming work and encounters several difficulties while analyzing the data. Also identifying time, date and site specific information has not been possible.

Upon recent advancement in soft computing techniques and availability of inexpensive and reliable devices such as personal computer, testing tools with necessary hardware it is possible to design, develop, test and deploy tailor-made application software to overcome these technical difficulties. A maiden effort towards design and development of In-situ Ocean Wave height Data Acquisition and Analysis System is endeavored and it has been successfully developed in-house at CWPRS, India. The SeaBuoySoft system can be implemented at any site across India all along the coast line for collecting ocean wave height data and its further analysis work.

II. SEABUOYSOFT SYSTEM COMPONENTS

The system consists of Waverider buoy with transmitter in sea waters and a Digital Waverider Receiver unit connected to the receiver antenna at shore courtesy M/s Datawell bv, The Netherlands and an In-house developed SeaBuoySoft software system tem for coastal field data collection and analysis. The system diagram (Fig.1) and brief description of these instruments is as below.

2.1 WAVERIDER BUOY

The Waverider Buoy (Fig 2) is a buoy which senses the movements of the water surface, reads waves by measuring the vertical acceleration of the buoy. The vertical acceleration is measured by means of a stabilized accelerometer suspended in a plastic sphere and placed at the bottom of the buoy. The diameter of the buoy is 70 or 90 cm. The sphere is protected from temperature gradients by foam insulation. In order to obtain vertical displacement, the acceleration signal is integrated twice, which results in a wave height signal. This signal is modulated with RF signal and fed into the signal conditioner circuit, where it is amplified and fed to the antenna. The transmitted power is radiated from a quarter wave length polyester glass fiber whip antenna. The transmission frequency lies between 27.5 & 28MHz. The supply for all electronics is taken from Leclanche cells. The life of the cells is approximately 12 to 18 months. The buoy is moored using chain ballast to provide sufficient stability for use in free floating condition at the area of interest in the ocean.

2.2 DIGITAL WAVERIDER RECEIVER

The Digital Waverider Receiver (Fig 3) is designed for the reception of the wave height data as transmitted by the Wave rider buoy. It contains a radio receiver, phase lock FM demodulator, anti-aliasing filter, analog to digital converter (ADC) and a serial communication port. The digital waverider receiver unit receives and digitizes the wave signal from the waverider buoy. It communicates with the SeaBuoySoft software through RS232 serial port.

2.2.1 RADIO RANGE

Reliable radio reception of a Wave rider over a distance of 50 km is possible if the wave height does not exceed 10 meters. The range is reduced to 30Km for 25 meter wave height.

2.2.2 ANALOG OUTPUT

A continuous analog signal representing the wave height is available. It has a sensitivity of 0.2 V/m and a range of +/- 20.48 meters.

2.2.3 DIGITAL OUTPUT

The digital output is the result of analog to digital conversion. The resolution is 1 cm/bit with a range of 12 bits (+/- 20.48 meters). Data, channel and status bit is transferred via the serial port (RS232) with 2 to 2.56 Hz rate.

2.2.4 SIGNAL QUALITY MONITORING

The phase lock demodulator gets unlocked if there are poor reception conditions. This condition is indicated by the 'UNLOCK' led. A lock/unlock condition before a new ADC sample is indicated in the status bit.

III. SEABUOYSOFT SOFTWARE DESCRIPTION

When the digital waverider receiver is switched ON, Ocean Wave height data transmitted from waverider buoy is received by the digital waverider receiver. Initially the program checks whether the digital waverider receiver system is locked. If there is no signal transmitted by a wave rider buoy, the digital waverider receiver is turned unlocked. This condition indicates that either the problem in the transmitter or the buoy is not in its place or drifted away from its moorings. If the digital waverider receiver is locked, the program starts data acquisition. The signal is sampled at every 0.5 seconds. The sampling frequency is selected using Nyquist criteria (fs >= 2fc) for the wave period ranges from 3 seconds to 30 seconds (very long waves) (i.e. [2]). The wave height signal as acquired is displayed on the monitor after completion of wave data acquisition for a predetermined time interval. The wave analysis is then carried out which includes computation of number of waves in a wave train, significant, maximum and minimum wave heights in a wave train, percentage occurrence of wave heights, and the power spectral density. The analyzed results can then be visualized or printed on a paper if required.

Since the ocean waves normally have periods ranging from 3seconds to 30seconds (i.e. [2]). A sampling rate of 2 samples per second is therefore sufficient to reconstruct the wave. The sampling period of 0.5 seconds is achieved through software. Ocean wave height data acquisition process will continue for a set time which is programmed for 20 minutes.

IV. DESIGN GOALS OF SEABUOYSOFT SOFTWARE

SeaBuoySoft software is designed and developed to achieved the following goals

To make the software systems enable to execute automatically without operator intervention.

To acquire the ocean wave height data at a prescribed frequency and its automatic storage on local hard drive for its easy retrieval as and when required.

To display the wave patterns 'in-situ' as acquired during on-line acquisition process.

To calculate various parameters of interest and visualized graphical patterns on screen required for its in-situ and laboratory analysis. From which a coastal engineer can come to certain design conclusion.

V. OCEAN WAVE HEIGHT DATA ACQUISITION PROCEDURE USING SEABUOYSOFT SOFTWARE

When the digital waverider receiver is switched ON, Ocean Wave height data transmitted from waverider buoy is received by the digital waverider receiver. Initially an on-line automatic window based SeaBuoySoft software (Fig 4) checks whether the proper connection with digital waverider receiver through serial interface (COM port) is made. If so, it then performs on-line wave height data acquisition process, logging and its storage followed by

processing the acquired data; the processed information can be seen on the screen and can also be printed on the hard copies immediately or as and when required. The processed information is stored in the form of data file format for further analysis work. The name of the file is derived using the real time windows system clock automatically. This name is prefixed by an alphabet for the location of the site, followed by serial no. of the file, day, month and the year succeeded by .dwr filename extension. This makes the identification for each data file easier for its retrieval. This facility proves crucial if we stored the substantial data for the seasons say 5 to 10 years or even more and then retrieved it for a specific case study or for comparison of any specific design or development issue of a hydraulic structure before arriving to a certain design conclusion.

In case if windows based software system fails to connect with digital waverider receiver, it can be easily identified as the label turns to red to generate system message "Digital Waverider Receiver is not ready". Software system itself suggests the further remedies for the proper communication need to be made (Fig 5). If the connection succeeds, system message automatically turned to green "Communication with Digital Waverider Receiver is OK".

If there is no signal transmitted by a wave rider buoy, the digital waverider receiver is turned unlocked. The lock/unlock status can be identified by a marker which turned red/green automatically. This condition indicates that either the problem is in the transmitter of the buoy or it is not in its place or drifted down. If everything goes well (i.e. transmission and reception from transmitter to receiver) lock/unlock status marker turns green automatically (Fig.6). This is the indication that the SeaBuoySoft software is now ready for Ocean wave height data acquisition. The automatic feature of detecting the loss of signal received from the wave rider buoy using lock/unlocks status marker is one of the important features of the SeaBuoySoft software. A Start button is provided to start the data acquisition process. On its click the software starts reception and logging of online ocean wave height data. A progress bar processes in blue indicates the ocean wave height data acquisition is in progress (Fig. 6). Every 4 minutes ocean wave height data as acquired is displayed on the screen during the acquisition process.

Once the data acquisition for one record is over, the software system generates the automatic data filename and stored it on the local hard drive path depending on the properties pre-programmed (Fig 7) for site location and serial no. of file. Time and date will be taken from the real time windows system clock. For example a file name which is created automatically can be described as below

File name: A1280714.dwr represents

.dwr is used for automatic filename extension as **d**igital **w**averider **r**eceiver is used for data reception
14 stand for year **2014**
07 stand for the month **July** of year **2014**
28 stand for current date of the month **July 2014**
1stand for **serial no.** of the file (Incremented automatically after every acquisition) and
A stand for name of the **site** (i.e. Agatti)

This feature helps in systematic storage and retrieval of information with self identification as and when required. Data are stored in binary files so that it takes the minimum space for storage. The acquired data are modified and stored in an integer form enabling further saving of disk space. These data files can be utilized for further analysis in laboratory. The same data are also recorded in a back up file. The names of the backup files do not contain real time information but are incremented the pointer for every data record e.g. (00000001.dwr, 00000002.dwr, and so on). It also ensures that even if the windows system's real time clock fails information will still be secured and stored in a separate backup file path. Automatic real-time filename and backup filename creation and storage are the unique feature of this SeaBuoySoft software system.

Ocean wave height data acquisition process will continue round the clock without operator intervention on the site for collecting the numerous wave records (and that much data files will be created and stored on the local hard drive automatically) of the cycle for every 1 to 3 hours which is user selectable (Fig 7).

After completion of ocean wave height data acquisition for a predetermined time interval, the ocean wave height data analysis can be carried out. It includes computation of number of waves in a wave train, significant, maximum and minimum wave heights in the acquired wave record, percentage occurrence of wave heights and the power spectral density graphs can also be plotted by the SeaBuoySoft software system. The analyzed results can then be printed on the hard copies if required.

VI. OCEAN WAVE HEIGHT DATA ANALYSIS USING SEABUOYSOFT SOFTWARE

Following are some of the common definitions (i.e., [2]) normally used during the ocean wave height data analysis process.

Mean line: The line about which the water surface is assumed to fluctuate due to ocean wave action.

Wave height: The vertical distance between the highest and the lowest point of the wave in two successive zero up crossing.

Zero up crossing: Point where the water surface elevation passes through the mean line in upward direction

Total time: Total duration of ocean wave record.

Maximum wave height: Most probable wave height of the highest wave in a wave train
Average Wave height: Average of wave heights in a wave train.
Significant wave height: Average of highest 1/3 waves in a wave train.
Maximum wave period: Period corresponding to maximum wave height.
Average wave period: Average of wave periods in a record.
Significant wave period: The average of periods corresponding to highest 1/3 waves in a given wave train. It is essential parameter during design of Hydraulic structure.
A wave is identified as the two successive zero up crossing in the number of zero crossings. Number of waves is counted between two ups/downs in a given wave train by the program. Program itself locates the crest and through values, addition of which gives the wave height. Simultaneously, the program finds the duration between the two down zero crossings which indicate the wave period. All these values of wave heights and the corresponding wave periods are stored in an array. The program computes the number of waves and sorts it out the percentage of waves in different wave height ranges. It also computes wave period and average wave period corresponding to the maximum wave height in a wave train. As far as frequency domain computation is concerned, initially the numbers of data points in the time series are checked to find whether the number is in the power of two. If not, the time series is linearly interpolated so as to make it the number in the power of two which is mandatory for the application of the FFT techniques. The real and imaginary Fourier coefficients are computed using radix-two Cooley and Tokay algorithm as this method saves computer time and space. The time of the system is saved by converting most of the complex multiplications into summations whereas the space is saved using in place computation technique by overwriting computed Fourier coefficients in an array.
Sea waves are random in nature and therefore the spectral distribution of wave energy provides valuable information about the range of frequencies over which significant amount of wave energy is spread and about the predominant frequencies where maximum energy is concentrated. The knowledge about spectral distribution of wave energy is important for determinant of wave run up and overtopping (i.e., [9]) for evaluation of structural stability. The Fourier amplitudes and Power Spectral Density (PSD) are computed from the sine and cosine Fourier coefficients. The program further computes 0^{th}, 1^{st}, 2^{nd}, 3^{rd} and 4^{th} spectral moments using raw PSD up to a frequency which is four times the frequency at which the amplitude of the spectrum is maximum. The raw PSD is used in order to avoid the change in amplitude of the PSD due to smoothening. Spectral moments are of special interest as they represent the total energy in the wave record, average wave period, significant wave height etc.
Bartlett window function is provided for smoothing of the raw spectrum. To visualize the nature of the spectrum, it is plotted on the screen.
For arriving at the certain design conclusion, it is however, important to determine wave characteristics over different periods and the seasons. The collected ocean wave height data can be rearranged in a tabular form so that the overall picture of the season can be displayed and analyzed graphically.
The statistical analysis of individual records can be made on-site using the software package developed as described earlier.

VII. SOFTWARE DEVELOPMENT ENVIRONMENT

The SeaBuoySoft software for wave height data acquisition and analysis has been developed using Microsoft Visual Basic 6.0 programming language. The purpose of the selection of this programming language is because it provides Graphical User Interface and its user friendly environment for the development, debugging, modification, up gradation, installation and deployment facility with ease. Coding independent modules and interconnecting them help immensely in testing of the software. It also helps in expediting development process.

VIII. FIGURES

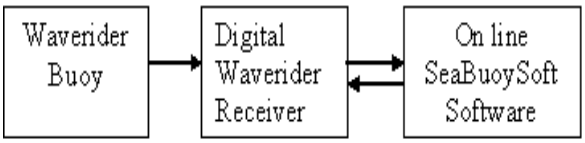

Fig1. SeaBuoySoft system diagram

Fig2. Waverider buoy

Fig3. Digital waverider receiver

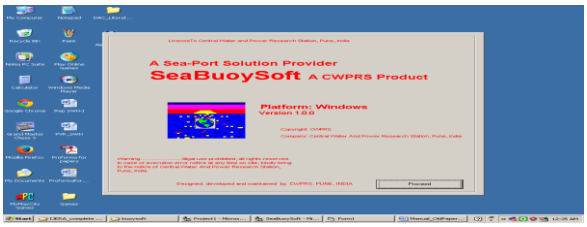

Fig4. SeaBuoySoft front screen

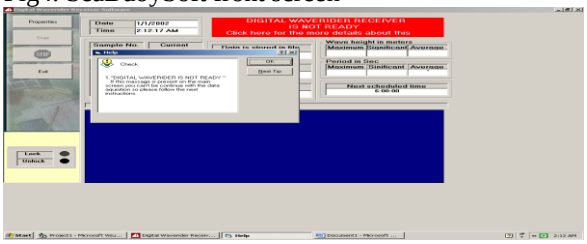
Fig5. Remedies for proper connection

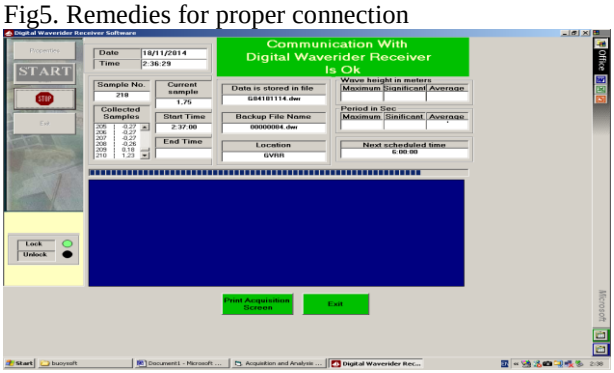

Fig6. Lock status and acquisition is in progress

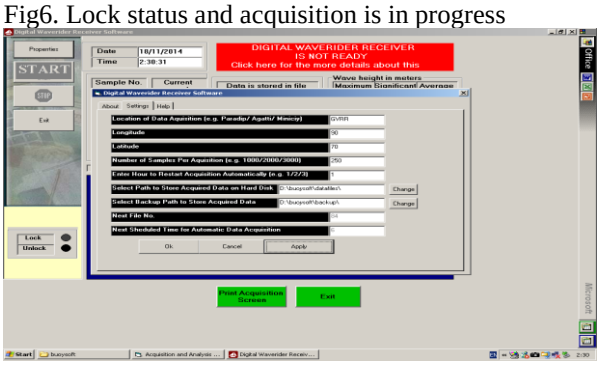

Fig7. Property window to create automatic filename

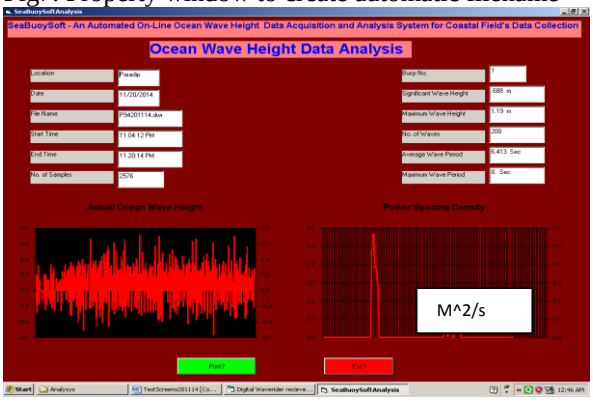

Fig8. Ocean wave height data analysis screen

IX. CONCLUSION

Coastal and offshore engineering studies involve huge resources, finances, accuracy; planning, design and the construction of almost every hydraulic structure. In order to provide safe and economical engineering solutions (i.e., [9]) for the veriety of such applications, information of site specific ocean wave height information plays an important role to ensure safety and success. It can prove vital for practitioners, scientist, engineers, planners, administrators and the decision makers to arrive at certain design conclusions. Site-specific ocean wave height information provided by SeaBuoySoft software system is therefore proved crucial and also it can provide necessary ingredients for the success of any such project in the costal and the offshore waters.

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