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ELECTRICAL AND INSTRUMENTATION SYSTEM OF BACKWARD BENT DUCTED BUOY

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ABSTRACT

The Backward Bent Ducted Buoy (BBDB) is a low cost-wave energy device to convert wave energy into electricity. Its operation is based on oscillating water column (OWC) principle. The OWC chamber of buoy is integrated with power module that consists of axial inflow turbine and permanent magnet direct current generator (PMDC) to extract the power produced in it. Extensive care was taken to acquire the process data of process measurements to analyze the behavior of the BBDB. In spite of the difficulties involved in erection, integration, operation of power system, and process instruments, The BBDB was successfully demonstrated for 10m sea depth. This paper aims to describe the design considerations and detailed design of the power back-up system for instrumentation, measurement scheme required to analyze the behavior, wireless communication, data analysis, and recommendations for future developments of the BBDB instrumentation.

Keywords: BBDB, Floating wave energy device, Transmitters, MRU, Wireless DAS.

1. INTRODUCTION

The OWC principle is an attractive approach to convert wave energy into electrical energy as exemplified by operational plants in several countries [1][4]. Fixed OWC based wave energy plant in India was established by IIT-Madras at Vizhinjam-Kerala in 1989 and it was handed over to NIOT later. The power produced by the plant was utilized to produce ten thousand liters of desalinated water per day. During the operation, several combinations of power modules were tested by NIOT [5]. The plant was operational till 2010 and it was decommissioned since studies on this plant were completed. Now the focus is towards developing floating wave power devices.

BBDB uses an oscillating column of water in reverse L shaped chamber or duct, such that the open mouth of the duct is away from the incident waves. The horizontal limb has an opening to the sea and is submerged under water. The vertical limb traps a column of air at the upper region of the duct and a regulated vent allows air to pass in and out under cyclic pressure and partial evacuation of air due to an oscillating water surface. The enclosed water column is, not influenced by the wave movements around the buoy, whereby it oscillates relative to the wave motion moving the buoy itself. The air current, which arises, drives an air turbine installed above the water column.

The air current, which arises, this airflow becomes a means to produce Power.

Fig 1.0 BBDB at 10 m sea depths

An instrumentation system was designed along with the self sustained power backup system for BBDB. To evaluate BBDB at mooring state on real time basis at different sea conditions [2], BBDB was deployed 300 m away from the south break water of Ennore 13° 14’ 51” N, 80° 20’ 46” E (Fig1.0).

2. POWER MODULE

The Power module is an axial inflow turbine coupled with an electrical generator [3] and it was selected to match the turbine speed- torque characteristics.

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A PMDC of 360W, 3000RPM was chosen because of its higher efficiency, constant field excitation, power generation at lower speeds. The detailed dimensions are shown in Fig.2.0.

POWER (W)	SPEED (RPS)	VOLTAGE (V)	CURERENT (A)	INSULATION CLASS
360	50	180	2.07	B

Table 1.0 Rating of PMDC

PMDC is connected to two numbers of 100 ohm resistances through automatic loading system. Table 1.0 contains the detailed specifications.

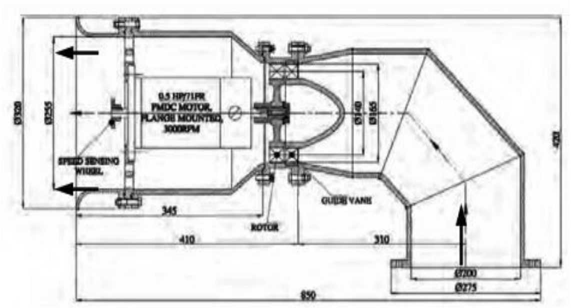

Fig 2.0 Power module of BBDB

3. DESIGN OF PV BASED POWER BACK UP SYSTEM

To power up process instruments and DAS, a self sustained power backup system is required. Nominal energy requirement of the Instrumentation system along with DAS is 1416Wh per day. To meet this requirement, two modules of 180W PV panels with four lead acid batteries were used.

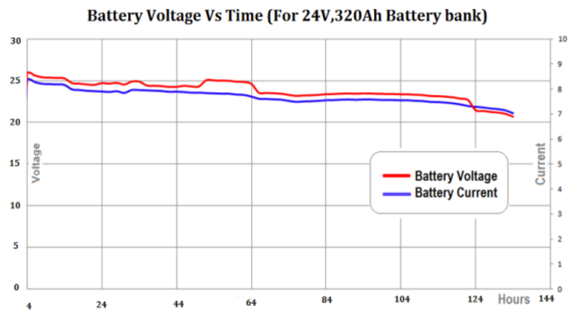

Fig3.1-Battery Discharge characteristics

Battery bank discharge test was conducted with rated load and the results were plotted (Fig3.1). The Fig.3.2 represents the block diagram of powering up instrumentation system.

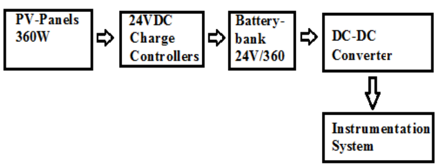

Fig 3.2 Power backup system of BBDB

4. INSTRUMENTATION SYSTEM

Instrumentation system design involves measurement plan (Table 2), preparation of piping and instrumentation diagram (Fig 4.0), selection and mounting of sensors, data acquisition, recording, wireless Transmission and real time study of dynamic characteristics of floating body. The measurement plan describes the typical measurements represented in Table 2.0.

TYPE OF MEASUREMENTS	LOCATION OF SENSORS	TYPE OF SENSOR
Differential pressure	DP Across Turbine DP Across Orifice	Peizo resistive
Pneumatic pressure	OWC chamber	Peizo resistive
Turbine speed	PMDC shaft	Electro magnetic
Load cell	Mooring line of the buoy	Strain gauge
Voltage	PV panel Battery charging current PMDC	Hall effect sensor
Current	PV panel current Battery discharge current Load current	Hall effect sensor
Roll,Pitch,Yaw,Heave of the buoy	CG of the buoy	Motion Reference Unit (MRU)

Table 2.0 Measurement plan

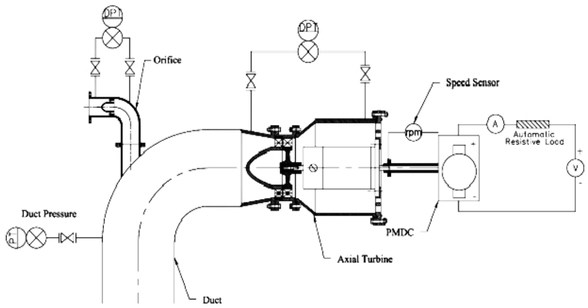

Fig4.0-Piping and instrumentation diagram

5. DATA ACQUISITION SYSTEM

Data acquisition system is designed and programmed to offer real time data acquisition and monitoring of all of the measurements shown in Table 2. The DAS has two subsystem namely Compact Real Input & Output System (cRIO) and wireless RF system.

5.1 Compact RIO based system

CRIO used along with multi channel 4-20mA analog input modules. To process 4-20mA signals from load cell, Differential pressure transmitters, speed sensor, V&I sensors of PMDC,V&I sensors of PV.

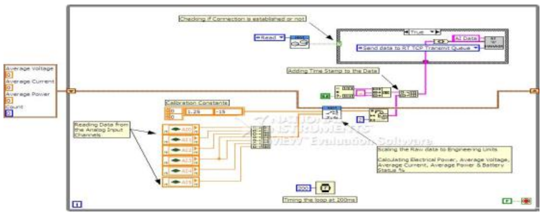

Fig 5.1 Lab view main-VI

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This cRIO and analog input modules were programmed with lab view. The main VI of the DAS is shown in Fig 5.1.CPU of cRIO is programmed to send the data simultaneously to auxiliary data storage unit (industrial CPU) and to the shore station through RF communication. Data recorded in both communication nodes and a data backup file created for each five minutes with 5Hz sampling rate and real time Plots were developed for monitoring the performances of the BBDB.

MRU is programmed and interfaced to cRIO through RS232. The application program developed will wait for the measurements data from MRU and will store the data in separate text files with the same timestamp information.

The data logging is done by creating a tab delimited text file. The name of the file comprises of an array which contains time and date stamp. There upon, the file is appended for next five minutes with the new data sets collected at the end of each 0.2 second interval which corresponds to sampling frequency of 5 Hz. The file is closed after five minutes and a new file is created with updated time and date in its name. The data files can be processed on the computer later on a continual basis. The real time data is displayed on base station by graphical interface designed specifically for this application.

5.2 Wireless RF system

The wireless communication was made through RF modem for data acquisition. Pre-Wi Max MODEMs were used in the range for 2.5 GHz. The unidirectional antenna was used at buoy side and 3m height Omni-directional antenna was used at base station.

5.3 Integration of instruments with DAS

All the process instruments, PV modules, RF switching unit are mounted on the buoy. DAS and power backup system are mounted inside the buoyancy chamber of the buoy (Fig 5.2). The buoyancy chamber is water sealed to protect all instruments from flooding.

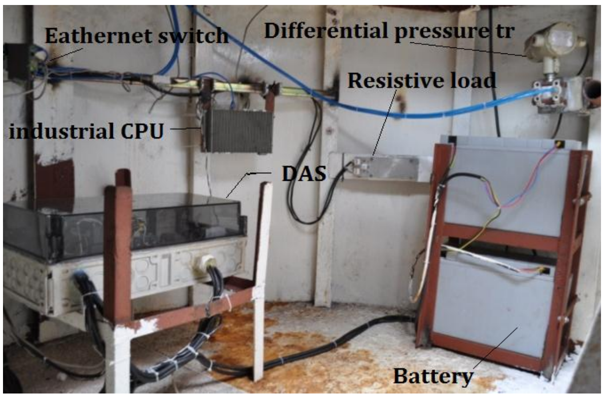

Fig5.2 Electrical & Instrument system inside BBDB

The schematic diagram of integrated instruments was shown in block diagram [Fig 5.3].

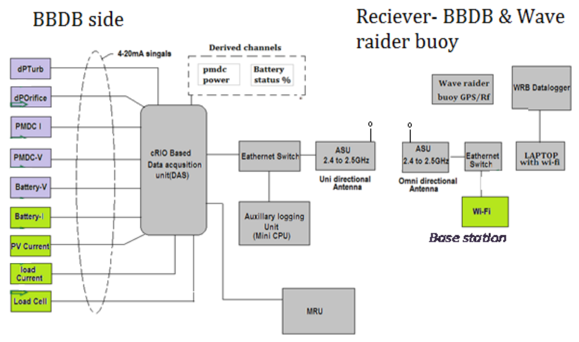

Fig 5.3 Integration of BBDB Instruments with DAS

6. OCEAN OBSERVATION SYSTEM

To understand the behavior of the buoy in terms of roll, yaw, pitch, heave, MRU has used as shown in block diagram [fig6.1].

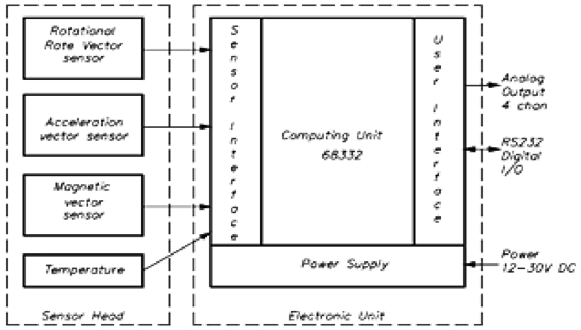

Fig 6.1 Internal block diagram of MRU

The WRB used along with BBDB is to measure the significant wave height and wave period of the waves. MRU was mounted at the CG of the BBDB and WRB was moored 100m apart from BBDB. MRU data's were collected through wireless communication of cRIO and WRB data's collected through separate GPS channel.

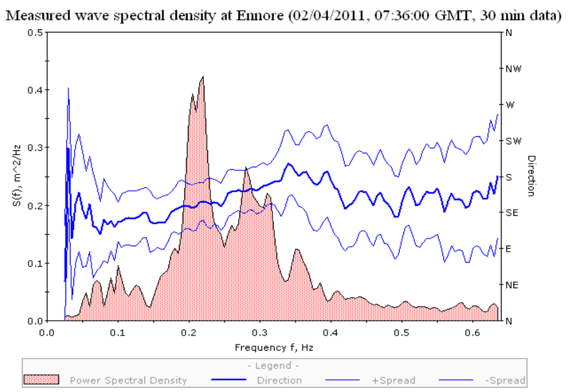

Fig 6.2 Collected WRB data spectrum

Fig 6.2 shows that the wave spectrum of WRB. The datas were analyzed and correlated. Comparative study of the power module also helps for future scaling up of the buoy.

7. DATA ANALYSIS

Experiments conducted during rough and calm sea weathers and data collected continuously for analysis those are discussed herewith.

7.1 Typical cycle data for calm sea condition

The average wave period observed using WRB data during calm sea weather was 3.5 seconds. During this wave period of time, the Differential pressure contours across the turbine and the orifice are observed was shown in Fig7.1. At differential pressure of around 0.2kPa, Average shaft power of 20W was supplied to the generator.

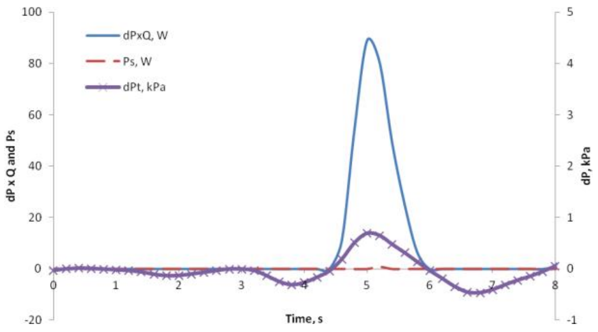

Fig 7.1 Data during calm sea conditions

7.2 Typical cycle data for rough sea condition

The wave period estimated from the pressure curve crossing datum was 3.8s during rough sea conditions (Fig. 7.2). This condition was encountered around new moon in the first week of April 2011. Waves of 1.8 m height were observed occasionally with the help of WRB. Peak speed and shaft power were logged and those were 780 rpm and 63 W respectively.

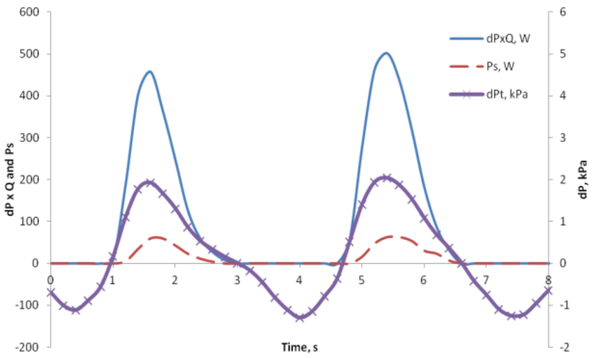

Fig 7.2 Data during rough sea condition

8. CONCLUSIONS

BBDB sea trials were performed at different weather conditions safely and remote monitoring and data logging were performed at base station remotely.

Instrumentation system was done in situ successfully along with auxiliary data storage. PMDC output power crossed 100Watts at around 1500 RPM during trials; real time data were monitored and collected for a range of sea-states. Those were post processed to create a power map of the device. There were no failure events in the power take-off system, and sustained and successful operation was achieved, as a result of the careful and robust design philosophy.

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NOMENCLATURE

Symbol

P	Power	(W)
I	Current	(A)
V	Voltage	(volt)
dP	Differential pressure	(kPa)
Q	Air flow	(m^3/s)

Subscripts

s	Shaft
t	Turbine

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