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DESIGN AND DEVELOPMENT OF AN UNMANNED/AUTONOMOUS OCEAN SURFACE VEHICLE USING SELF-SUSTAINING DUAL RENEWABLE ENERGY HARVESTING SYSTEM

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Abstract. This study pioneers a breakthrough in sustainable energy solutions by developing a cutting-edge system for powering autonomous Smart Ocean surface vehicles. The research delves into the exploration of renewable energy harvesting techniques, specifically focusing on solar and hydro flow energy systems, with the aim of creating a self-sustaining power infrastructure. Through rigorous experimentation and modeling, we design and implement a versatile test rig setup to analyze the efficacy of these techniques under varying surface water conditions. Additionally, we investigate and assess distributed solar power systems ranging from 100W to 700W, as well as hydro flow power systems within the same power range, to ascertain their viability for real-world applications. Furthermore, we engineer and optimize the necessary electronic hardware utilizing IoT and industry-grade components, enabling efficient harnessing of dual renewable energy sources to power propulsion systems for our autonomous vehicles. This research introduces novel approaches to energy sustainability for autonomous ocean surface vehicles. The study disregards traditional methods and instead aims to unveil unconventional solutions for powering these vehicles. Through a series of experimental investigations, we seek to redefine the boundaries of renewable energy utilization in marine environments. By leveraging cutting-edge technologies and industry-grade components, our work aims to establish a new paradigm in the propulsion systems of autonomous oceanic vehicles.

Key words: Autonomous, vehicle, unmanned, underwater, renewable energy, IoT.

1. Introduction. The exploration and utilization of the world's oceans have long been of paramount importance for scientific research, commercial ventures, and national security interests. In recent years, technological advancements have revolutionized our ability to navigate and understand the vast expanses of the underwater realm [1]. Among the most groundbreaking innovations are Unmanned Underwater Vehicles (UUVs) and Autonomous Underwater Vehicles (AUVs), which have emerged as indispensable tools for a wide range of maritime applications [2].

UUVs and AUVs are equipped with sophisticated sensor payloads, enabling them to conduct observation, surveillance, monitoring, and inspection tasks with unparalleled precision and efficiency. From assessing marine ecosystems and monitoring underwater infrastructure to conducting reconnaissance missions and detecting underwater threats, these vehicles play a pivotal role in expanding our understanding of the oceans and safeguarding maritime interests.

However, despite their undeniable utility, UUVs and AUVs face significant operational challenges that limit their effectiveness and autonomy [3]. Chief among these challenges are the constraints imposed by their reliance on battery power. The limited energy storage capacity of onboard batteries restricts the range and duration of autonomous missions, necessitating frequent recovery for recharging and data offloading. This reliance on support vessels not only introduces logistical complexities but also incurs substantial operational costs, particularly in remote or inaccessible marine environments [4].

Moreover, the data storage capabilities of UUVs and AUVs are often insufficient to accommodate the vast amounts of information collected during extended missions. This limitation hampers the vehicles' ability to

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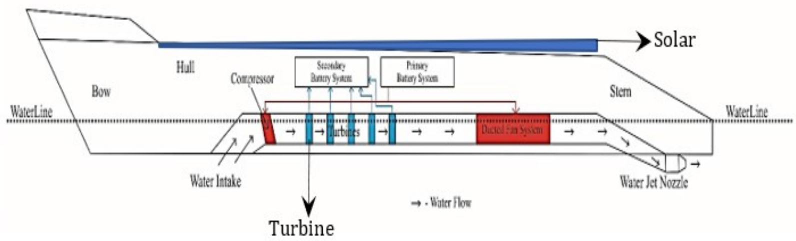

Fig. 3.1: Schematic Conceptual Design

conduct prolonged monitoring or surveillance operations autonomously, necessitating frequent data transfer and processing, further exacerbating the reliance on support infrastructure [5].

In light of these challenges, there is a pressing need to develop innovative solutions that enhance the autonomy, endurance, and operational efficiency of UUVs and AUVs. By addressing the limitations associated with battery capacity, data storage, and operational autonomy, researchers and engineers aim to unlock the full potential of unmanned underwater vehicles, paving the way for transformative advancements in ocean exploration, environmental monitoring, and maritime security.

This paper explores the current state of UUV and AUV technology, identifies key challenges and limitations, and proposes novel approaches to overcome these obstacles [6]. Through interdisciplinary collaboration and technological innovation, the goal is to usher in a new era of autonomous underwater exploration and observation, facilitating advancements in scientific research, commercial applications, and national defense strategies.

2. Related Work. A remolded acoustic energy decay model preserved relative in acoustic energy attenuation inverse of distance square is used to generate training data. Multilayer perceptron (MLP) is the model to train these data and predicts accurate relative 3D space coordinates [7].

In depth discussion about AI chips and AI hardware. An improved controller design method based on echo state network with delay output (DO- ESN) is proposed for designing the controller of a class of nonlinear system [8]. The survey provides a comprehensive literature review on combined MBC-ANN techniques that are suitable for UAV flight control, i.e., low-level control [9].

The objective is to pave the way and establish a foundation for efficient controller designs with performance guarantee. The application of artificial intelligence (AI) in unmanned aerial vehicle (UAV) is discussed [10].

The basic connotation of AI technology is introduced. Review the history and classification of machine learning, and talk about the most recent applications of machine learning to UAVs for autonomous flight [11].

Paper reviews AI-enabled routing protocols designed primarily for aerial networks, including topology predictive and self-adaptive learning-based routing algorithms, with an emphasis on accommodating highly dynamic network topology [12]. An algorithm of a model reference adaptive controller for nonlinear systems based on Radial Basis Function (RBF) Neural Networks (NN) is proposed [13].

A nonlinear adaptive controller for an unmanned aerial vehicle (UAV) has been developed using Echo State Network (ESN), which is a form of three-layered recurrent neural network (RNN) [14]. Application of echo state network (ESN) for the nonlinear control of a fixed-wing unmanned aerial vehicle (UAV) is presented. The data required for the network training is generated using a validated flight dynamics model of the UAV [15].

3. Methodology. The project describes to harvest dual renewable energy from solar and hydro-turbine, the fig.3.1.a shows the schematic figure of the conceptualized design.

The proposed design integrated with solar panel and whereas the hydro flow duct turbine will be mounted at water-line area at the bottom portion [16]. The energy generated from solar power pack will be stored in the solar back-up battery, whereas the platform cruises the water flows in to duct chamber and the water streams cuts the turbine fin blades and rotational flow of the shaft coupled with the generator will produce the hydro energy and stores in the battery [17]. Functional flow of the system describes the solar power pack

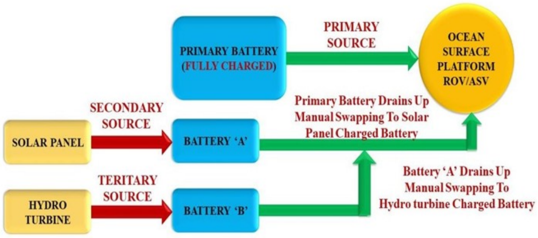

Fig. 3.2: Functional Lay-out

Fig. 3.3: Indigenously developed DC generator

system and hydro-duct flow turbine coupled to the ocean surface platform integrated with Battery Management System (BMS) and Switch Over Circuit (SOC) will enables the system to monitor the battery management and switching of the battery from one source to another [18].

3.1. Battery Charging. The battery needed to be charged in volts of 1.5 times so 24V. The amp needed must be at least 50% of the current rating of the battery, so we choose 18A since this can only be made in our hull. To increase the amp, we need to increase the solar cells [19].

3.2. Selection of DC Generator. The DC generator selected is practically constant speed, regardless of the load, which would produce consistent power generation [20]. The generator load calculations are arrived to the speed significant to produce the power output required, the fig.3.2.a. Shows the indigenously developed DC generator, which produces 300 watt with 15 VDC. The generator is a PMDC (Permanent Magnet Direct Current Generator) [21].

3.3. Selection of Battery Pack. The battery pack unit will be a three-unit system, where the primary battery will be initially full charged and battery-A & Battery-B is charging through solar panel and hydro duct turbine. The lithium-ion battery was selected for efficient charging and customized indigenously developed with 14.8V/18Ah rating. The system architect was conceptualized from above parametrical studies and flow of the working was schematized.

The system architecture consists of 4 major packs as shown in Fig 3.5:

- Battery Management pack
- Energy (solar and hydro) harvesting pack
- Control and communication pack
- Propulsion pack

The functional working of the system is that the microcontroller-processing unit will be charging from solar panel and hydro-turbine through generator to the battery sources initially assigned will be charging. The Battery Management System (BMS) will be monitoring the battery source, as initial primary battery drains out the Switch over Circuit (SOC) will be switching the primary battery source to battery-A and battery-B

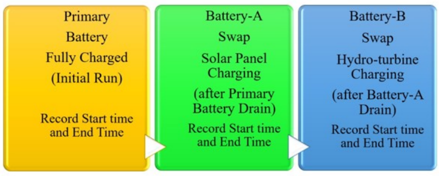

Fig. 3.4: Battery pack unit

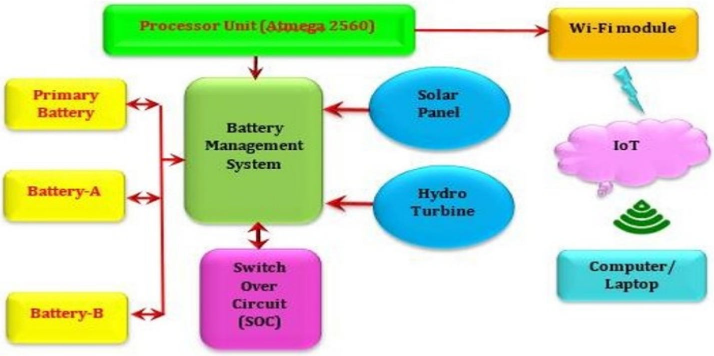

Fig. 3.5: System Architecture

and vice-versa the charging will be relayed from one source battery to other. The wireless Wi- Fi module will be transmitting the data to shore computer/ laptop.

3.4. Solar Energy Harvesting System Design. The connection of solar arrays selected with 156*156 mm monocrystalline cell is follows:

- Connecting 48 cells in series with 4 cells in an array gives 24V/9A. -12 Arrays
- Connecting another 48 cells in parallel with 4 cells in array gives 24V/18A–24 Arrays.

In the existing hull the 24 arrays can be placed in both sides and in middle bars. Each array would be in a square configuration and also the system would be engaged in a straight line of arrays on the bar with angled rotating system as per the sun movement in the sky.

The basic idea developed was to create a set of arrays which would be able to independent and connected in series or parallel which ever fitted the role accordingly. It was devised to make sure that in an active war zone, if any one array also gets damaged the remaining arrays would support the recharging system. This concept is meant to increase the reliability and endurance and not by using a single panel which would be a liability.

The mount for the solar system will have 5 parallel cylinder pipes and 2 perpendiculars main structure. The structure is strategically mounted on to the three bars by means of adjustable clamps and tightly mounted. On top of each pipe, one end of the pipe will have a bearing housing to hold the shaft that is clamped with the solar array. The other end is mounted with a servo motor housing where it can be hinged with the rotating shaft. The length of the occupied solar area in the middle section is1600mm and breadth is 630 mm approximately. The servomotor is connected to the micro controller with input feed data according to the azimuth angle of the sun's rays the solar panels will be aligned according to the highest efficiency angle.

4. Results and Discussion. The circuit designed, were developed shown in fig 4.1 which is significant function for switching between input renewable energy sources and batteries, based on operating conditions. The Battery Management System (BMS) with Switch Over Circuit (SOC) manages to monitor the operation of the Battery with high voltage will be utilized for load and low voltage for charging and the other battery in idle.

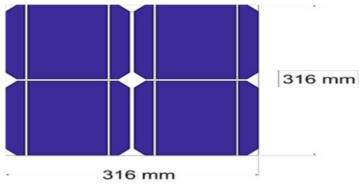

Fig. 3.6: Solar array layout of single panel

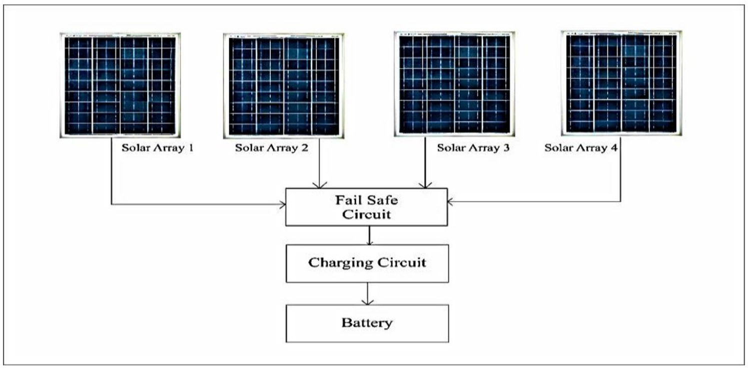

Fig. 3.7: Basic block diagram of the distributed solar array concept

The developed circuit focus on the power produced from solar energy and hydropower which stored in batteries. Since battery is the primary component for energy supply, we should have an alternate source for emergency. Hence, a second battery is used in case of low power or a failure in first battery. Thus, the SOC circuit switch between two batteries, after switching, the disconnected battery will be charged using the power from DC Generator.

The fully charged battery will be automatically cut-off from DC Generator using transistor and voltage regulator. Fig. 4.1 indicates the test evaluation carried out on the electronic hardware unit developed, which the Visual Basics (VB) displays the BMS and SOC working and data stored.

The figure 4.2 displays data from hardware testing of the Battery Management System (BMS) with the Switch Over Circuit (SOC). The plotted data likely includes voltage levels, current measurements, or other relevant parameters monitored during the testing phase. The trends in the data could provide insights into the performance and efficiency of the BMS and SOC in managing the battery system under different operating conditions.

Fig. 4.3 illustrates the voltage levels of the solar power system over time. The curve might show how the voltage fluctuates throughout the day as solar energy is harvested and stored in the battery. The trend could reveal patterns in solar power generation and help assess the effectiveness of the solar panel array in charging the battery under varying sunlight conditions.

The web-page data display (Fig 4.4) presents real-time or logged data from the IoT monitoring system. It includes parameters such as battery voltage, energy consumption, or system status, transmitted wirelessly to a web interface for remote monitoring and analysis. The displayed data provides valuable insights into the performance and operation of the renewable energy harvesting system, facilitating remote monitoring and management.

The trial fetches the solar panel data and performance of BMS with SOC were tested, and stored data were evaluated with IoT monitoring were checked.

- Developed web page performance for getting values from the boat while running were interpreted.
- The Values will be automatically stored in an Excel sheet

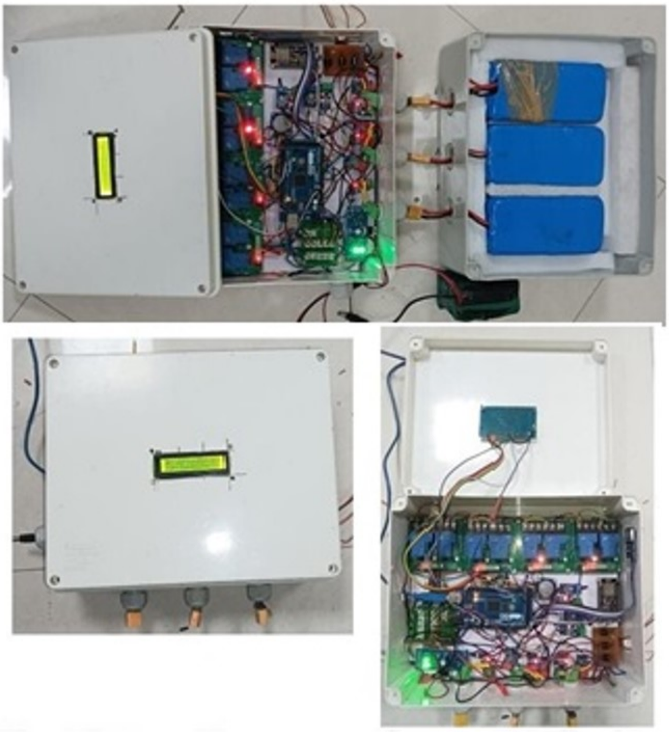

Fig. 4.1: BMS and SOC connected to Primary Battery, Solar battery, and Turbine battery

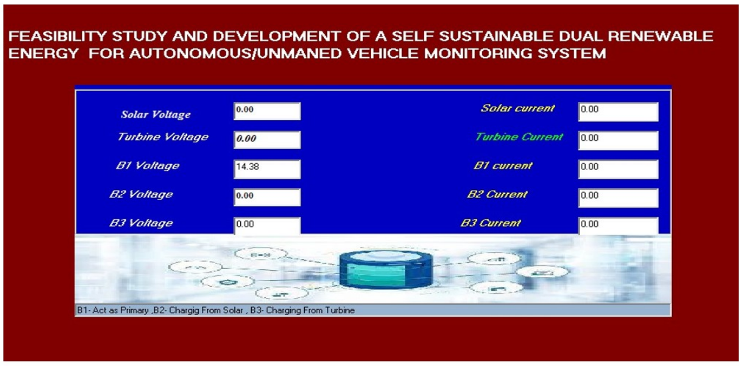

Fig. 4.2: BMS with SOC hardware testing data

- Whenever we need the data, the data sheet can be downloaded.

The performance of hydro-duct turbine was not evaluated in the phase I trial, since the floating platform (existing platform within the University) were not compatible, due to that performance of the hydro-duct turbine study were not carried out. Feasibility study on dual-renewable energy harvesting were carried out successfully. As Dual renewable energy source emphasis, as solar power system drops, the hydro-turbine energy charged system utilization will fetch the Ocean surface platform further.

5. Conclusion. Earlier the existing floating platform available with university has been utilized, where non- compatibility of the platform was studied. Further, a 50W platform was designed. Overall achievement

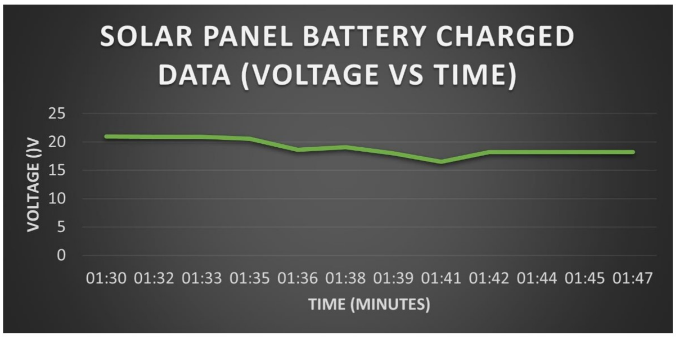

Fig. 4.3: Solar Power Charged Graph Plotted Voltage vs Time

SELF SUSTAINABLE DUAL ENERGY HARVESTING FOR AUTONOMOUS OCEAN VEHICLE MONITORING SYSTEM

SWITCH OVER CIRCUIT

	Volts	Amps	Status
SOLAR DATA	2.56	0.00	ON
GENERATOR DATA	0.00	0.00	CHARGING

BATTERY MANAGEMENT SYSTEM

	Volts	Amps	Status
BATTERY 1 DATA	12.11	0.02	DISCHARGIN G
BATTERY 2 DATA	2.39	0.00	CHARGING
BATTERY 3 DATA	0.00	0.00	CHARGING
RPM			

SWITCHING RELAY

SOLAR RELAY	R1	GENERATOR RELAY	R2

DISCHARGE MANAGEMENT RELAY

BATTERY 1 RELAY	R3
BATTERY 2 RELAY	R4
BATTERY 3 RELAY	R5

CHARGE MANAGEMENT RELAY

BATTERY 1 CHARGING RELAY	R6
BATTERY 2 CHARGING RELAY	R7
BATTERY 3 CHARGING RELAY	R8

Fig. 4.4: IoT Web-Page Data Display (IoT web link: https://in.000webhost.com/cpanel-login)

of the project is in case of absence of solar power, the power generated during running of the boat, the power stored in the battery-B through turbine rotation will provide power after sunset. Solar system was developed and integrated on the boat. Feasibility study on dual-renewable energy harvesting was carried out. Technology demonstrated can be adopted to a bigger ocean surface vehicle will enhance the more efficient result. Higher rate of power harvest feasible with larger platform. Incorporating an ocean surface platform with ducted Hull at the bottom, for hydro turbine integration will increase flow more laminar and better energy produce can be achieved.

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