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# Reliability and Availability Evaluation of an Autonomous Remote Video Monitoring System for Offshore Sea Farms

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*Abstract –* **In this paper, the availability and reliability of a remote video monitoring system for offshore sea farming plants are studied. The scope of the system is to ensure a video surveillance infrastructure so to supervise breeding cages along with the fish inside them in order to contrast undesired phenomena like fish poaching as well as cages damages. The system is installed on a cage floating structure. It is mainly composed of an IP camera which is controlled by a Raspberry Pi Zero which is the core of the system. Images are streamed thanks to a 3G/4G dongle while the overall system is powered via two photovoltaic panels charging a backup battery. Simulations are carried out considering two seasonal functioning periods (i.e., winter and summer): each of them is characterized by temperature trends defined according to the average temperatures of the system deployment site, 8 km offshore the city of Piombino, Italy. In order to optimize power consumption without hindering application scenario requirements, the system operates according to a duty cycle of 2 minutes out of 15 (i.e., 8 minutes of operation per hour).**

## I. INTRODUCTION

Fish farming has undergone a massive growth for years now, mainly owing to various causes. Primarily, bred seafood could take part within the fight against world hunger without entailing an increase in costs thus proving to be a cheap and valuable alternative for global food supply. Furthermore, bred seafood quality may be easily certified since the complete fish lifetime can be promptly traced throughout the breeding cycle. The upcoming affluence of this sector is also validated by some studies: a prediction on worldwide fishing market in 2030 [1] foresees that 62% of fish for human consumption will be produced via aquaculture by that year. In addition, the Food and Agriculture Organization (FAO) foretold a hopeful situation presuming an aquaculture production expansion up to 58% by 2022 [2]. Concerning Europe, a future discord among fish demand and supply was guessed [3], therefore fostering fish farming may turn to be an advisable initiative. Finally, in Italy aquaculture includes more than 800 companies and the majority of them are situated in the Mediterranean Sea where more than 5000 plants are located.

Offshore sea farms definitely need to rely on surveillance systems so to contrast undesired phenomena like fish poaching as well as breeding cages damages. Therefore, in this paper an autonomous remote video monitoring system for offshore sea farms is presented along with simulations whose outcomes are exploited to study its availability and reliability so to assess its overall effectiveness. The system is designed so to include off-the-shelf components and in order to be energy efficient since it is powered via an energy harvesting system (i.e., two photovoltaic panels and a backup battery). Eventually, the system is installed on a cage floating structure.

The rest of this paper is drawn up as follows. Some related works are reported in Section ii. while Section iii. shows the video monitoring system architecture. The reliability configurations on which simulations are carried out are outlined in Section iv. and simulations results are presented in Section v.. Eventually, Section vi. points out remarks and conclusions.

## II. RELATED WORKS

Autonomous systems for the monitoring of fish behavior within offshore sea farms during feeding phases was reviewed in [4]: amid sundry enabling technologies and processing techniques, the use of video recordings thorough ad-hoc systems and cameras were pointed out thus showing their feasibility.

Video monitoring systems which are deployed in marine contexts are mainly designed for coastal safeguard so to assess erosion [5, 6, 7] rather than for sea farms surveillance. Such systems make use either of standard IP cameras [5, 6], like the one within the system presented in this paper, or of embedded cameras directly controlled by a single-board computer as Raspberry Pi [7], which is the control unit the system that will be presented in the following Section. However, the literature also comprehends works implementing video monitoring systems which are installed on offshore buoys within breeding plants: in [8], cameras are set up within the fish cages while video streaming is ensured by a radio frequency system which is installed on board of the buoy. Similarly, works reported in [9, 10] extend such a surveillance system. On the other hand, marine video monitoring systems are additionally devised in order to operate underwater so to fulfill submarine investigation and exploration purposes [11] as well as for proper aquaculture ponds characterized by turbid water [12].

Concerning video monitoring systems in a broad sense (i.e., which are employed in diverse contexts with respect to the marine one) that rely on photovoltaic energy harvesting systems and a backup battery, works within [13, 14] confirm the suitability of such a technique thus underlining the potential effectiveness of the solution proposed in this paper.

## III. SYSTEM ARCHITECTURE

The block diagram of the video monitoring system is depicted in Fig. 1 and it is composed by 3 main building blocks (i.e., power supply, control and communications and camera).

The power supply block contains 2 photovoltaic panels providing $20\,W$ each, whose task is either to power up the whole system and to recharge a $12\,V$ $25\,Ah$ lead-acid backup battery through a solar charge controller. Photovoltaic panels are fundamental for the long term functioning of the system. Indeed, such a prototype is offshore installed and it is supposed to operate for at least a 6-months timespan, while the mere backup battery only ensures a 48-hours autonomy. Thus additionally highlights the low-power feature of the system components (that will be introduced below) along with the effectiveness of the duty-cycling functioning policy (that will be addressed in the next Section). However, a complete battery discharge is extremely unlikely since it would be the consequence of several hours of darkness.

The control and communications block is the core of the system since it manages the duty cycling of the camera along with images capturing and transmitting towards a remote server, while minimizing power consumption by the activation of the inner elements only for the minimum amount of time needed. Such a working flow is obtained by the following off-the-shelf components:

- DC-DC converter filters out the power supply coming from the appropriate building block so to correctly power each of the system elements;
- Raspberry Pi Zero is the control unit of the system due to Python scripts managing both the camera and the duty cycling of all of the other components;

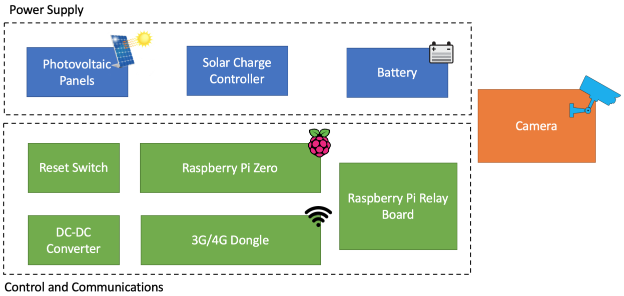


*Fig. 1. Video monitoring system block scheme.*

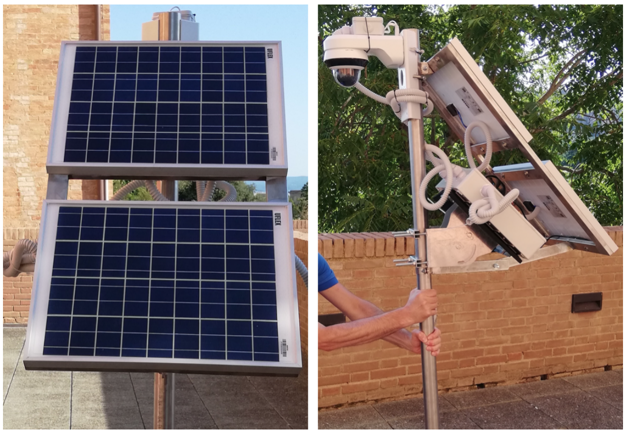


*Fig. 2. Realization of the video monitoring system: photovoltaic panels (left) and pole with camera and IP56 box containing the electronics (right).*

- Raspberry Pi relays board contains relay switches that are directly controlled by the Raspberry Pi so to turn on and off the camera and the other system elements whenever they are needed and only for the strictly necessary time in order to limit the overall power consumption;
- 3G/4G dongle provides Internet connectivity which is exploited to send the captured images, along with debug logs so to perform diagnostic, to a remote server;
- Reset switch performs a daily hardware reset of the whole system acting as a sort of long term watchdog timer so to overcome software issues or unexpected behaviours.

The camera is an off-the-shelf outdoor IP camera produced by Hikvision, which is especially designed so to resist to marine environments.

All of the elements composing the control and communications block are housed within an IP56 box, while the complete system is mounted on a support pole (see Fig. 2) which is offshore installed on a breeding cage floating structure (see Fig. 3).

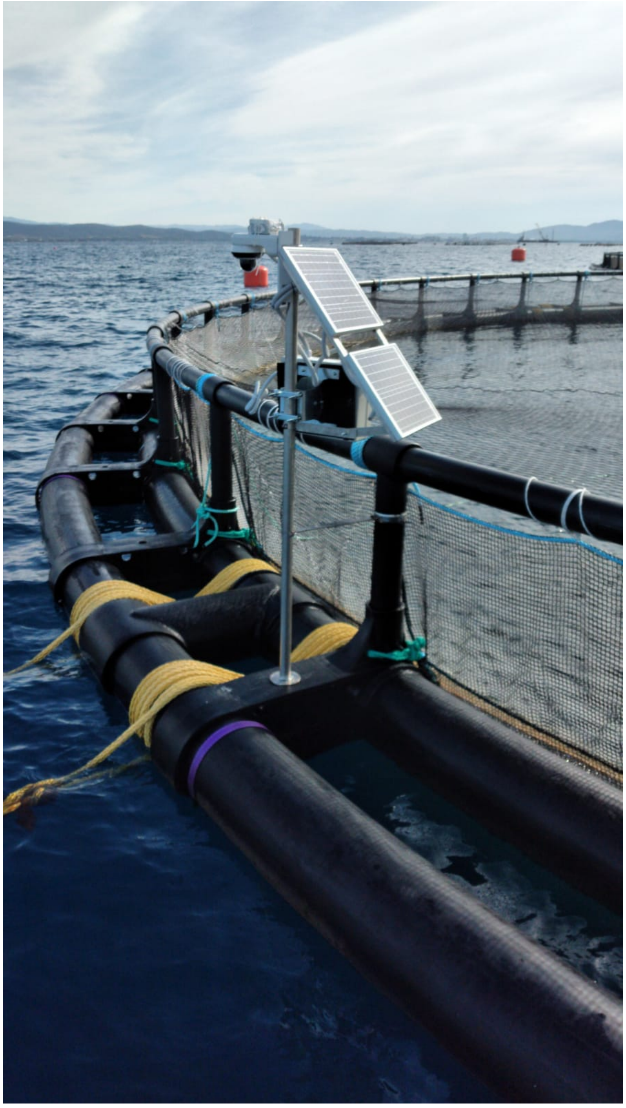


*Fig. 3. Autonomous remote video monitoring system prototype offshore installed on a cage floating structure.*

## IV. RELIABILITY CONFIGURATIONS

The application scenario for this video monitoring system does not necessitate of real-time image streaming. In particular, only snapshots on a regular basis (i.e., one every 15 minutes) are required. Therefore, in order to meet functioning requirements the system operates for a time span of 2 minutes every quarter of an hour within which the picture is taken and remotely sent via the Internet. In so doing, only 8 minutes per hour of system activity is experienced (i.e., 172 minutes per day) thus also optimizing power consumption.

For what concerns weather conditions the system is exposed, two seasonal functioning periods are identified on which availability and reliability simulations are carried out:

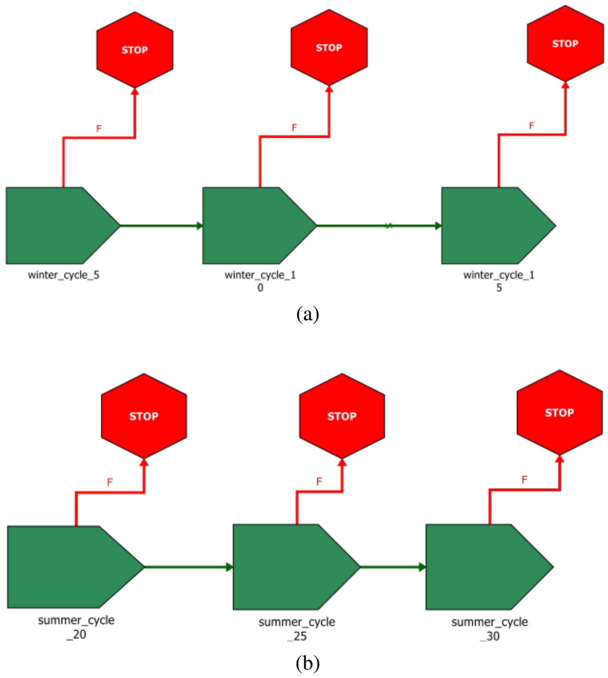


*Fig. 4. Availability and reliability simulation schemes: (a) winter working period and (b) summer working period.*

- **Winter**, that is made up of 3 8-hours time slots, that are daily repeated, which are in turn characterized by a temperature of $5^\circ C$, $10^\circ C$ and $15^\circ C$;
- **Summer**, which accounts for 3 8-hours time slots, which are daily repeated, that are respectively characterized by a temperature of $20^\circ C$, $25^\circ C$ and $30^\circ C$.

Such temperatures are taken into account because of the future system deployment scenario: $8\,km$ offshore the city of Piombino, Italy.

Availability and reliability simulation schemes are shown in Fig. 4, while simulation parameters are summarized in Fig. 5. MIL HDBK 217F database was selected to evaluate individual component failure rates at different temperatures considering an environment of the kind NU (Naval Unsheltered). Unfortunately, such parameters are usually not available from component producers, therefore a conservative approach given by the mentioned database results in worst condition results was followed.

## V. SIMULATIONS RESULTS

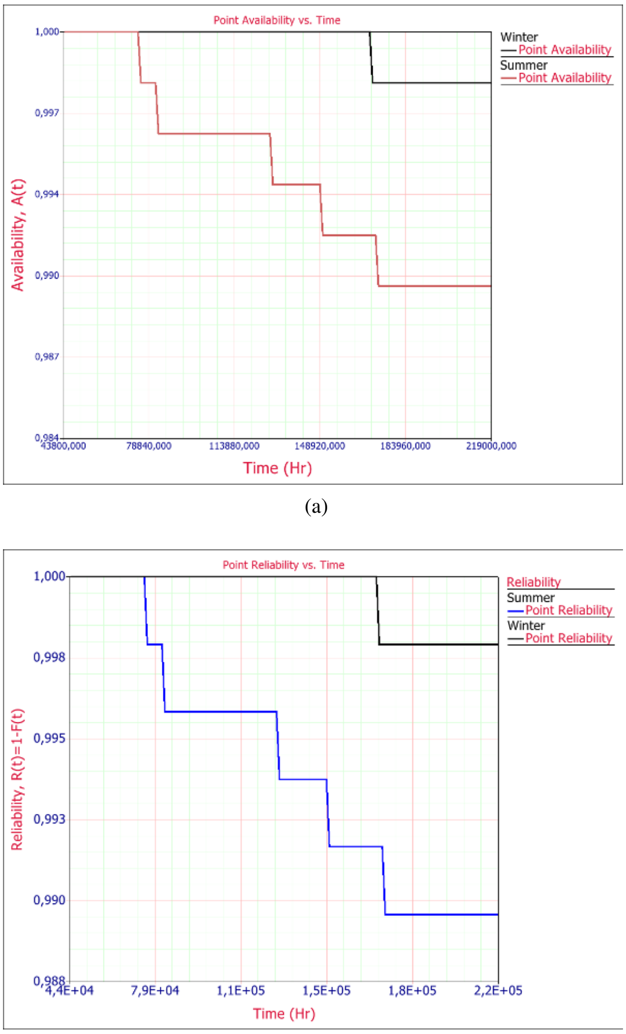
As shown in Fig. 6, simulations were performed by means of the BlockSim software (by Reliasoft) on the two scenarios previously described. Fig. 6a reports results connected to the system point availability while Fig. 6b shows the ones related to point reliability. Both prove that the summer period presents a decrease in the final time values with respect to the winter one. Such results are in

|  |  |  | Temperature [°C] |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|
| Elements | Characteristics | Model | 5 | 10 | 15 | 20 | 25 | 30 |
|  |  |  | MTBF [h] |  |  |  |  |  |
| Solar Charge Controller | $12 \div 24\,V$ $20\,A$ | CMDT-A2420 | 94000 | 93000 | 92000 | 91000 | 85000 | 81000 |
| Reset Switch | $12\,V$ | JK11S V1.1 | 1067577.68 | 1067577.68 | 1067577.7 | 1067577.7 | 1067577.7 | 1067577.68 |
| Battery | $12\,V$ $25\,Ah$ | Victron Energy AGM12-25 | 61674757.2 | 61674757.2 | 61674757 | 15059188 | 11934038 | 9530309.94 |
| DC-DC Converter | $5 \div 12\,V$ | - | 6544336.31 | 5790737.61 | 5145730.2 | 4591034.5 | 4111841.8 | 3696087.57 |
| Raspberry Pi | - | Zero | 9609216.3 | 9607060.01 | 9604400.9 | 9601147.8 | 9597196.8 | 9592432.5 |
| 3G/4G Dongle | - | Huawei E3372 | 79365.08 | 79365.08 | 79365.08 | 79365.08 | 79365.08 | 79365.08 |
| Raspberry Pi Relay Board | - | - | 266894.42 | 266894.42 | 266894.42 | 266894.42 | 266894.42 | 266894.42 |
|  |  | **Total MTBF [h]** | **79336147** | **78579392** | **77930725** | **30756208** | **27141913** | **24313667.2** |

*Fig. 5. Simulation parameters.*

agreement with what expected by the theory connected to the exploitation of the MIL HDBK 217F database where temperature based degradation, under a fixed environment, takes place. To simulate availability model a fixed $48\,h$ repair time was considered. Of course, due to the very small amount of electronic components and to the low system complexity, the system has to be tested especially for winter time on long periods since the overall MTBF is considerably high at those temperatures. Moreover, either the selected duty cycle for system exploitation and the power consumption reduction limit the internal temperature raise and keep it constant for the system to the environmental one without significant degradation rates apparently induced on individual electronics.

Simulations do not include condensation due to temperature excursions. Therefore the rusting due to salty environment condensation is not considered in the results. The overall system is housed within an IP56 box presenting holes to which siphons are connected so to allow heat dissipation via air circulation. However, this also implies that salty air enters within the box coming into contact with system components. This is far from being an optimal solution, albeit it is sufficient for the prototype. Indeed, the latter is supposed to operate just for 6 months during which damages due to saltiness should be limited. As a consequence, salty air from the sea is assumed to be present around the electronics especially if maintenance activities will be performed. Hence, such environment is by far challenging for what concerns junctions and soldering rather than single component performances. In the future, in case of failure, a root cause analysis could be applied on single assets so to verify whether this hypothesis is confirmed or not. The system availability without the charging station is not taken into consideration due to the fact that the system would not work enough time to gather the requested data and it is therefore excluded by the simulations.



(a)

(b)

*Fig. 6. Availability and reliability simulation results: (a) availability and (b) reliability during summer and winter working periods.*

## VI. CONCLUSIONS

The aim of this paper was to describe the architecture of an autonomous video monitoring system to be employed for the remote control of offshore breeding cages in aquaculture plants. The proposed solution is characterized by energy self-sufficiency thanks to an energy harvesting system based on the use of photovolatic panels. In order to demonstrate the usability of the system, simulations were carried out in order to validate its reliability and availability. Results prove that the system can be successfully employed in the proposed application scenario for both winter and summer environmental settings. The current analysis is not including considerations on the possible rusting caused by the operation scenario either on soldering, junctions and connectors which should be included in the future in order perform an utter system reliability and availability analysis.

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