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Spooling Device Optimization with IP Camera and Active Infrared Sensor

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ABSTRAK

Desain yang sangat padat pada lokasi gulungan kabel streamer pada kapal seismik dapat menimbulkan titik-lemah karena lokasinya di tengah geladak dan area kerja operator di geladak belakang. Hal ini meningkatkan risiko kerusakan peralatan dan risiko terhadap keselamatan operator. Operator harus berjalan bolak-balik atau menugaskan operator lain untuk memantau gulungan kabel streamer yang berarti diperlukan waktu tambahan selama pengoperasian. Kedua opsi tersebut berkontribusi terhadap paparan ekstra risiko keselamatan dan penggunaan operator yang tidak efisien. Pada penelitian ini IP camera digunakan untuk memonitoring gulungan kabel streamer dan active infrared sensor digunakan untuk mendeteksi titik lemah. Desain sistem yang diimplementasikan ini mengurangi titik lemah sehingga mengurangi risiko keselamatan, meningkatkan efisiensi waktu, dan mencegah kerusakan peralatan.

***Kata kunci**: optimisasi, kapal seismik, kabel, perangkat penggulungan*

ABSTRACT

The compact design of streamer cable reel locations on seismic vessels creates blind-spots due to their location in the center of the deck and the operator's work areas aft of the deck. This increases the risk of equipment damage and the risk to operator safety. The operator must walk back and forth or assign another operator to monitor the streamer cable reels which means additional time is required during operation. Both options contribute to the extra safety risk exposure and inefficient use of operators. In this research, IP camera is utilized for monitoring streamer cable reel and active infrared sensor to detect blind spots. The implemented system design reduces blind spots that decreasing safety risks, improves time efficiency, and prevents equipment damage.

***Keywords**: optimization, seismic vessel, streamer cable, spooling device*

1. INTRODUCTION

The first step in exploring offshore oil and gas begins with an offshore seismic survey or marine seismic survey. A seismic vessel tows seismic acoustic sources to generate sound waves and one or several streamer cables during a marine seismic survey. The streamer cable contains hundreds of hydrophones as receivers to record sound waves **(Blintsov et al, 2020)**. Figure 1 shows an illustrative example from the top view of twelve streamer cables spread towed by a seismic vessel. A seismic vessel can tug several streamer cables with lengths of up to 12 kilometers on each streamer cable.

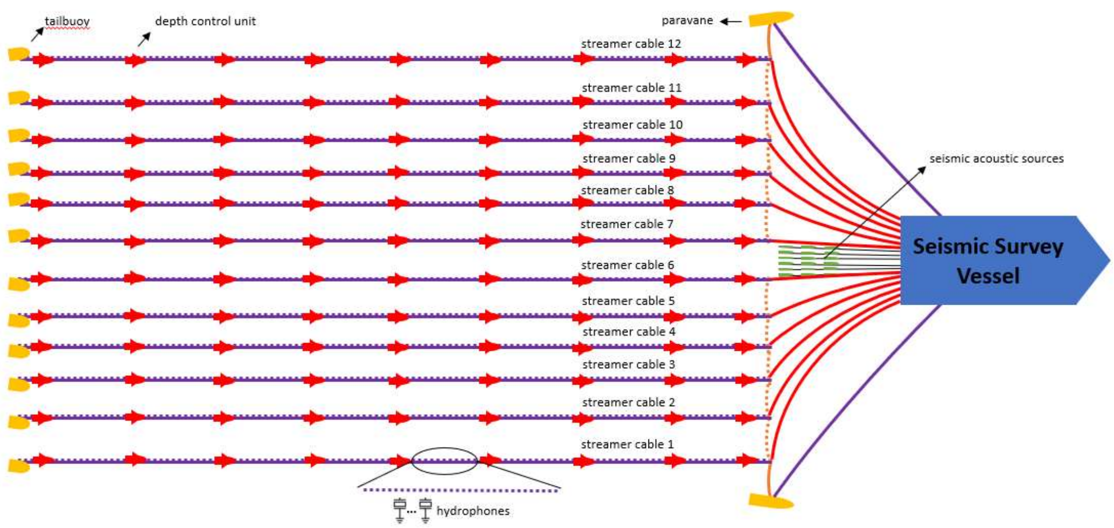

Figure 1. Top View Of Seismic Survey Vessel Towing Seismic Streamer Cables

Figure 2 shows an illustration of a seismic vessel towing streamer cables from the side view. Seismic acoustic source signals penetrate the sea bottom layers and are reflected back to the sea surface and recorded by hydrophones in the streamer cable. The safe speed limit for the seismic vessel is about five knots in average. This speed is required for towing the streamer cables safely and also for survey requirements. Based on this average speed, each streamer cable would have tension up to 30 kN or around 3.059 ton-force **(Blintsov et al, 2020) (Doyle, 2012)**.

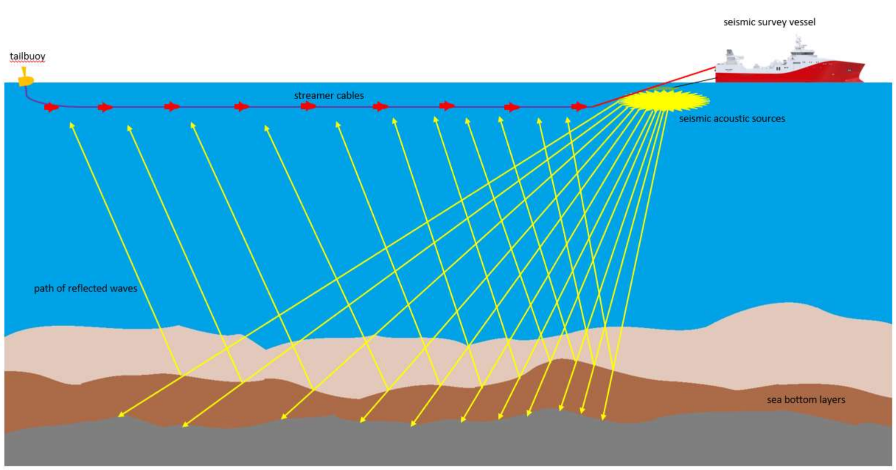

Figure 2. Side View Of Seismic Survey Vessel Towing Seismic Streamer Cables

During streamer cable recovery (de-mobilization) the streamer cables would need to be coiled and stored in the streamer cable reels at the back deck of the seismic vessel. Each seismic vessel has the capacity and capability to store streamer cables that vary from six streamer cables up to 20 streamer cables. The capacity and capability depend on vessel design, vessel size, back deck size, and how many streamer cable reels are installed on the back deck of the seismic vessel. Seismic vessel typically has a compact design of back deck where the streamer cable reel (SCR) locations introduce some blind spots. The operators are unable to monitor a particular SCR in real-time use of these blind spots, their views are blocked by the other SCR. The most important task for the operator in driving the SCR is ensuring the streamer cables are coiled and spooled properly by having a good visual of the SCR itself. In order to achieve this with the current condition of SCR with blind spots, the operator has to walk back and forth to each SCR to monitor and safely use the SCR.

Figure 3 is an illustration of the typical compact design of SCR locations at the back deck of the seismic vessel. The operators normally stand aft of the vessel during streamer cable recovery as shown in Figure 3. The operator normally faces backward to monitor incoming streamer cables and equipment that are coming out of the sea and approaching the SCR. As can be seen in Figure 3, some SCR locations on the seismic vessel are located in line (in front of each other) which protrudes the visibility of the operators (blind spots), therefore operators are unable to monitor SCR with blind spots.

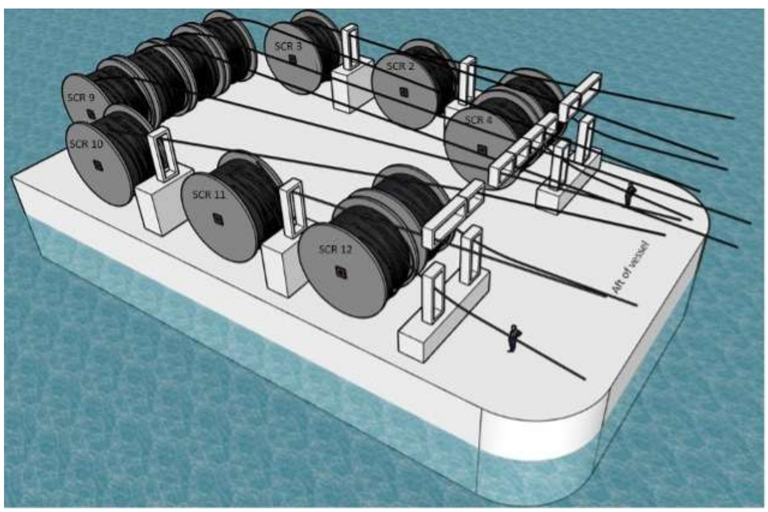

Figure 3. Side View of Typical Streamer Cable Reel (SCR) Locations at the Back Deck of The Seismic Vessel

SCR locations at the back deck of the seismic vessel from the back view can be seen in Figure 4. Based on the Figure 4 illustration, SCR 1 is located behind SCR 2 and 3 (SCR 1 is closer to the operator), therefore SCR 2 and 3 cannot be monitored in real time by the operator that is standing at the aft of the vessel as they are blocked by SCR 1 & 4. In a similar situation on the other side, SCR 12 is located behind SCR 10 and 11 (SCR 12 is closer to the operator), therefore the operator that is standing aft of the vessel would not be able to monitor SCR 10 and 11 in real-time as they are blocked by SCR 9 & 12.

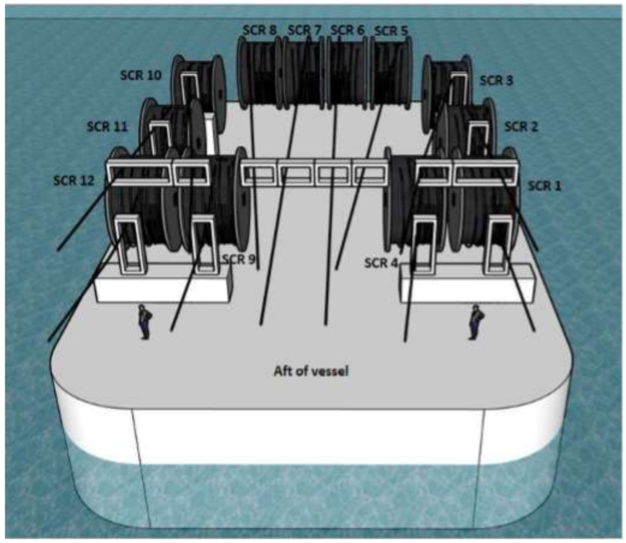

Figure 4. Back View of Typical Streamer Cable Reel (SCR) Location at the Back Deck of The Seismic Vessel

In order to visualize the blind spots on SCR 2, 3, 10 & 11, Figure 5 illustrates a closer view from a different angle which is the operator's working area during streamer cable recovery. As can be seen in Figure 5, the view for SCR 2, 3, 10, and 11 are blocked (SCR with blind spots) from where the operators normally stand at aft of the vessel.

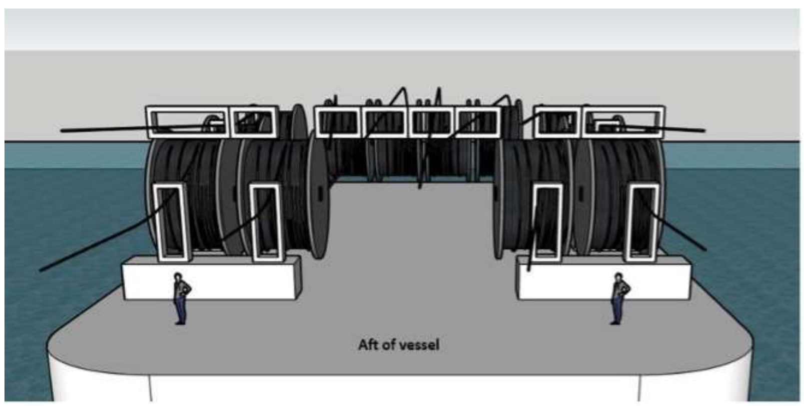

Figure 5. Operator View of Typical Streamer Cable Reel (SCR) Locations at the Back Deck of The Seismic Vessel

The operators have to walk back and forth from the aft of the vessel to each SCR with the blind spots in order to monitor those SCR and check the spooling of streamer cable in the SCR. Every 500 meters of each streamer cable has been recovered, this essential monitoring task (which includes the operator walking back and forth to the SCR with blind spots) during streamer cable recovery; is critical and must be repeated to prevent any mis-spooled which may lead to equipment damage. Figure 6 illustrates the path of the operators to each SCR with blind spots.

Slips, trips or falls on the same level is the most reported injuries offshore based on Offshore Statistics & Regulatory Activity Report 2019 by UK Health & Safety Executive. Slips trips or falls on the same level were the most common injury type and accounted for 27% of all injuries reported based on the statistics on yearly basis since 2012 **(Salmon, 2020)**. As can be seen in Figure 6, there are always additional slips, trips or falls risk exposures whenever the operator who drives the SCR walks back and forth to monitor the SCR. This is also can contribute to the operator's fatigue. Meanwhile, the slippery deck, sea state conditions, and entanglement hazards are additional potential hazards when performing this task. There is an option to have an additional operator to be assigned to stand nearby the SCR with blind spots and monitor these SCRs and then communicate with the SCR driver via radio, but this means an inefficient additional operator exposed to back deck activities.

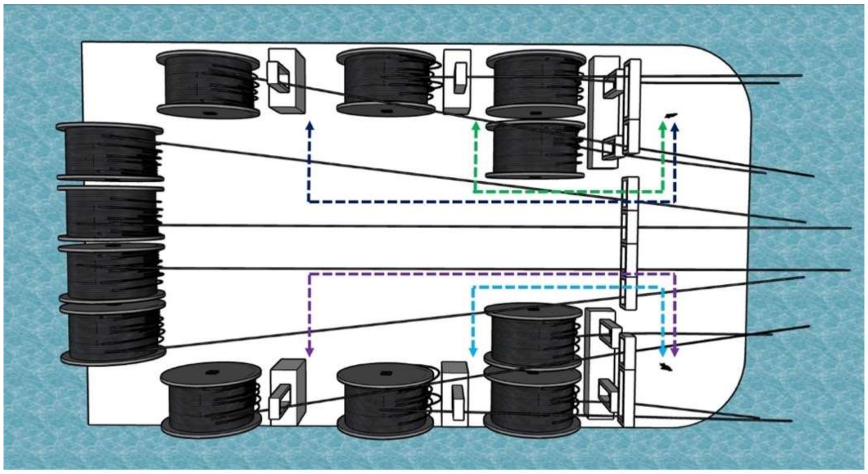

Figure 6. Top View of Typical SCR Locations With Path of the Operators to Each SCR with Blind Spots

Each SCR should automatically spool the streamer cable by using current widely spooling device technology, unfortunately the current spooling device technology do not provide monitoring system, meanwhile without monitoring the progress of streamer cable spooling especially not in real-time, the streamer cables may not be properly spooled. If uneven spool occurred or if streamer cable only spooled on one side, eventually the coiled streamer cable would create slack loop on the bottom part of SCR.

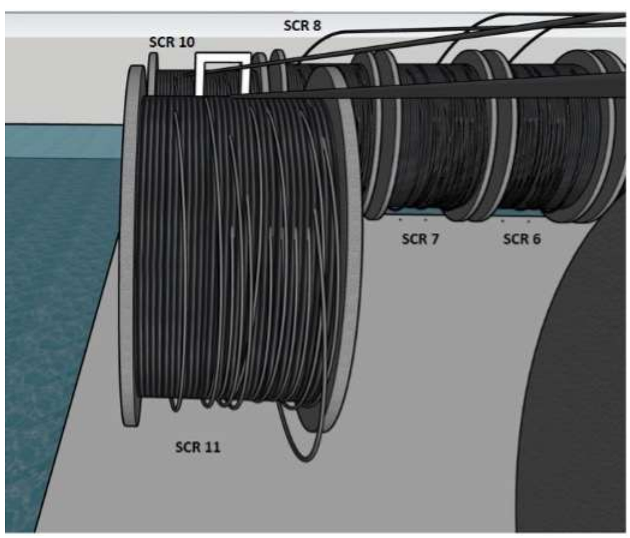

Figure 7. Illustration Example for Streamer Cable Slack Loop on the Bottom Part of SCR 11

Figure 7 illustrates the slack loop of streamer cables in SCR 11 at the early stage. Extra safety risk for operator and extra damage risk for streamer cables and other equipment would occur because of this slack loop of streamer cables. The potential risk of the streamer cable getting snapped will be higher. Furthermore, potential risk of broken electronics while streamer cable under tension during deployment will be higher too. Operational downtime also will be higher because the slack loop has to be undone which contribute extra time needed to re-spool the streamer cables properly. The whole operation would be less efficient because of this issue and operational downtime may escalate if the re-spool operation took longer time.

Even though the operator realizes the streamer cable has been mis-spooled and creating slack loop in the SCR, the operator has to manually stop the SCR – there are no auto-stop or auto-braking system for the SCR. Until this research was written, there was no research for all aforementioned problems in seismic industry. The slack loop of streamer cables may occur on the bottom part of SCR whenever the streamer cables are not properly spooled or only spooled on one side. The slack loop of streamer cables contributes extra safety risk for operator and extra damage risk for the equipment. This paper suggests a system design that may enable a better monitoring system especially for the SCR with blind spots, prevent any unnecessary extra risk for both operator and equipment, and improve overall operations efficiency.

2. METHOD

2.1 Technology Options Material

Poor design and validation of equipment is one of most important causal factors in Health, Safety and Environment (HSE) incidents or accidents **(Johnsen, 2009)**. A system is required to overcome the problem definition as mentioned on the previous section and efficiently utilize the compact design of back deck in order to provide validation of equipment. This paper suggests a system design to optimize the spooling device as complementary of current system, the result will be a safer back deck work environment, increase time efficiency and prevention in equipment damage.

The proposed system design in this paper is called Streamer Cable Reel Intelligent System (SCRIS) which has combination of monitoring system and slack loop detector. This system design would enable the monitoring system for the streamer cable spooling and slack loop detector to enhance the safety factor (both for operator and equipment) which is auto-stop/auto-braking system for the reel if there is any slack loop in the SCR.

Assessment of opportunities, selection of best match, and consideration of terms have to be combined to decide which technology will be used on a system **(Mortara, 2012)**. There are some options of technology in the market that may be used for this system design, the technology may be acquired from third party and can be implemented in a project **(Eskelin, 2001)**. In order to decide the best match technology for this system design, some consideration and comparison of technology options have to be taken. Data collection for technology options has been taken prior deciding final decision. Analog closed-circuit television (CCTV) camera and Internet Protocol (IP) camera are the two options for the streamer cable monitoring. Analog CCTV is one of mature monitoring system that has been in the market for decades, while the IP camera is an attractive and emerging technology. Meanwhile, active infrared system and image recognition from camera are the two options for the slack loop detector. Active infrared system has been in the industrial market for decades and still widely being used in many industries. The image recognition from camera is an attractive with more innovation to come.

2.2 Comparison of Best Match Technology for Monitoring System

There are two options of technology for the streamer cable monitoring system: analog CCTV camera and IP camera. Based on our data collection and study about monitoring system from many sources, Table 1 shows our compilation of rating comparison between IP Camera and analog CCTV **(Ludwig, 2021) (Edwards et al, 2021) (Popovic et al, 2012) (Costin, 2016) (Kleinerman, 2011)**. According to the data collection and study from many sources, there are 13 criteria that we found applicable in order to determine the best match technology to be applied on the system design in this paper. The criteria in the Table 1 were chosen to compare between IP Camera against analog CCTV and to determine the best match technology and then eventually decide which monitoring system technology would be use for this paper.

Table 1. IP Camera and Analog CCTV Comparison

Criteria	IP Camera	Winner		Analog CCTV
Ease of installation	Easy, basic skill of networking, no special technician.	✓	×	Need CCTV technician to come onboard.
Technology maturity	20 years & emerging.	×	✓	Mature, 50 years but getting obsolete.
Intelligence	Video motion detection.	✓	×	No onboard intelligence.
Scalability	Easy to add more cameras to the switch.	✓	×	Closed Circuit. Limited channels on patch panels and expensive patch panels.
Recording	Yes, through FTP to any network HDD and cheaper.	✓	×	Yes, but only to the CCTV computer system (DVR) and expensive. No more than 15,000 hours (1.7 year) lifespan.
Image quality	Clearer, better resolution.	✓	×	Less clear, less resolution.
Low light condition	Weaker; Use CMOS (Complementary Metal Oxide Semiconductor) sensors.	×	✓	Better; Use CCD (Charged Coupled Device) sensors.
Cabling/flexibility	Single Cat 5 or Cat 6 cable to any switch with power over ethernet.	✓	×	Single coaxial cable to the main board; To power the camera, a nearby power outlet needed or a separate power cable. Combined video-power cable can be used, but this increases the cabling cost.
Cable price	Cheaper & easy to purchase.	✓	×	More expensive.
Remote viewing	Can be viewed on any computer/device connected to network.	✓	×	Only can be viewed on CCTV Display system. Additional device required for remote viewing.
Wireless	Yes, available	✓	×	Yes, but require additional device.
Durability	Weatherproof IP66	✓	✓	Weatherproof IP66
Price	Cheaper than CCTV	✓	×	More expensive.
Total winner	IP Camera	11	3	

Based on Table 1 comparison above, IP camera has more advantages than analog CCTV camera therefore IP camera will be chosen for SCRIS. IP Camera technology is not as mature as analog CCTV, but the stability has been proven on many industries **(Popovic et al, 2012) (Costin, 2016) (Kleinerman, 2011)**. The weakness of IP Camera in low light is not an issue in seismic vessel as it always has full 24 hours full illumination. Choosing IP camera technology would also in-line with emerging IoT technology; it is not only enabling full real-time monitoring but also reducing the associated hazards and improving personnel safety **(Reyes et al, 2019)**.

2.3 Comparison of Best Match Technology for Slack Loop Detector

Slack loop detector is the first trigger in SCR auto-stop system whenever there is a streamer cable loop on the bottom of SCR. The capability to detect any object (in this case is the slack loop of streamer cable under the SCR) as quick as possible and send back the trigger is the basic and mandatory requirement of slack loop detector. A trigger signal will be sent into actuator on PLC system for SCR to slowly reduce the reel movement until the SCR stopped in a safe speed and also trigger signal to enable sound alarm for the operator. Therefore, this slack loop detector has to work and react as quick as possible.

There are two options of technology for the slack loop detector: active infrared sensor and image recognition from camera. Based on our data collection and study from many sources, Table 2 shows compilation of rating comparison between active infrared sensor technology and image recognition **(Singh et al, 2021) (Alavi, 2012) (Su et al, 2021) (Omron, 2021)**.

According to a study, the delay in processing the image recognition around 1.5 – 3.5 seconds **(Singh et al, 2021)**. Another study simulated some image processing algorithms to detect motion on a scenario of multiple moving objects with 249 frames in video stream, the average time taken ranges between 4.1 seconds to 25 seconds **(Alavi, 2012)**. Based on these studies, the option of image recognition on the camera would take some process time to recognize an object or slack loop of streamer cable under the SCR, hence there will be some delay.

Table 2. Active Infrared Sensor and Image Recognition Server Comparison

Criteria	Active infrared sensor	Winner		Image recognition server
Ease of installation	Easy and basic wiring installation	✓	×	Require computer and software engineer to come onboard vessel
Price	Cheaper (150-200 USD each)	✓	×	Around 1600 USD
Scalability	Easy to add more infrared sensors	✓	×	Additional point will require more GPU which is expensive
Accuracy & speed	Once the beam is interrupted (loop of able under the SCR) then it can send trigger almost immediately	✓	×	Unknown accuracy, require further study & test. Delay in processing the image recognition: 1.5 – 3.5 seconds
Maintenance	Low maintenance cost	✓	×	Server require air conditioner for cooler temperature
Total winner	Active Infrared Sensor	5	0	

On the other hand, an active infrared sensor has two pieces which emits infrared from one piece reflects onto the other. Once the beam is interrupted (loop of cable under the reel) then it can send trigger almost immediately, extremely fast response time because light travels at high speed **(Omron, 2021)**. The criteria in the Table 2 were chosen to compare between active infrared sensor and image recognition and to determine the best match technology and then eventually decide which technology would be use for slack loop detector in this paper. Based on Table 2 comparison, the active infrared sensor system is the best match and suitable for SCRIS. Active infrared sensor may not be the most sophisticated technology, but it is the best match and appropriate technology for SCRIS.

3. RESULTS AND IMPLEMENTATION

Based on our analysis on previous section, this paper suggests a system design to implement SCRIS using IP Camera and active infrared sensor for slack loop detector. The location of IP Cameras illustrated in Figure 8, two IP Cameras for each SCR with blind spots, one on top (to monitor the spooling) and one on bottom (to monitor any slack loop).

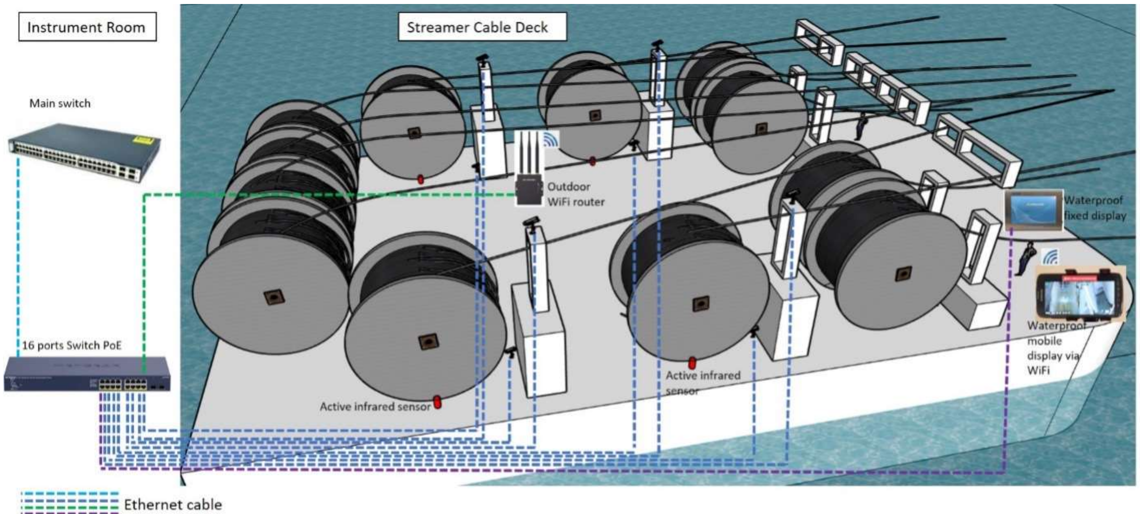

Figure 8. IP Cameras Schematic Connection Diagram and Active Infrared Sensor Locations

IP Camera can also be accessed anywhere especially on the same network, for example through a mobile display (e.g., tablet or mobile phone) that is mounted on top of the SCR remote control or a dedicated waterproof fixed display that normally available on the back deck at the aft of vessel. The infrared sensors illustrated in Figure 8 are installed on the bottom of each SCR with blind spots. The real-time video stream from any IP camera would be able to displayed on a waterproof mobile display connected to the outdoor wireless router. The waterproof mobile display attached on the SCR remote control can be seen on Figure 9. The operator would be able monitor the SCR with blind spots while standing anywhere on the streamer cable deck. This gives a lot of flexibility for the operator and at the same time keep monitoring the spooling of the streamer cable.

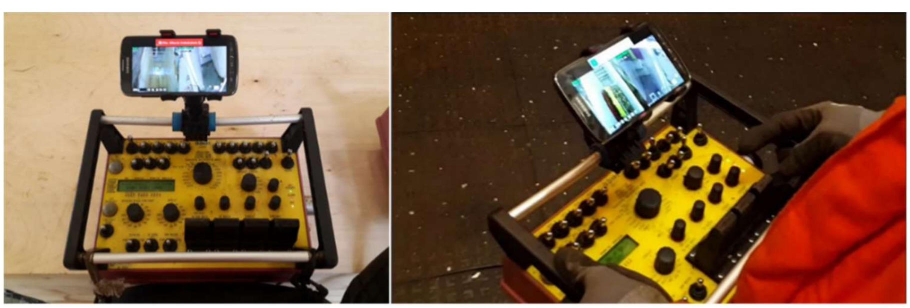

Figure 9. SCR Remote Control with Waterproof Mobile Display

Figure 10 shows a closer look of active infrared sensors for bottom part of SCR 11. Figure 10 illustrates an example of active infrared sensor detects the slack loop of streamer cable on the bottom of SCR 11. Active infrared sensor as a failsafe would detect the slack loop if the operator was distracted and not monitoring the bottom camera display, and then immediately send trigger to PLC to safely stop the SCR (auto-stop the SCR), and at the same time a sound alarm would be triggered to as a warning for the operator.

Implementation of active infrared sensors as slack loop detector for SCR 2, 3, 10 and 11 are using through-beam active infrared sensors. The emitter and receiver element are installed opposite each other on SCR 11 as can be seen on Figure 10. Emitter element beams the infrared light to the receiver element. The emitted infrared light would be interrupted whenever an object (in this case of study is a streamer cable) passing between emitter and receiver element; it completely blocks or reduces the amount of infrared light enters the receiver element **(Omron, 2021)**. The reduction or blockage of infrared intensity is used to detect the slack loop of streamer cable.

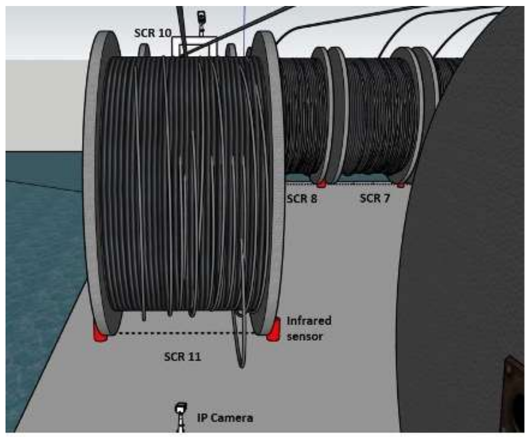

Figure 10. Illustration for Emitted Infrared Light Interrupted by the Slack Loop of Streamer Cable on the Bottom of SCR 11

Auto-stop for SCR is programmed in PLC ladder diagram with input from slack loop detector. Figure 11 shows all the variable defined in PLC ladder for auto-stop system with input from slack loop detector. All inputs, outputs and mode are defined at the beginning of PLC ladder for slack loop detector which are variables in the PLC hydraulic system for SCR, such as DI_IN_1 for machine run status (indicates whether the SCR is running or not), DI_IN_2 for active infrared status. AO_SPEED_TEMP variable also defined here as a temporary value for the rotation speed of SCR.

PLC ladder for slack loop detector can be seen on Figure 12, which is the sequence of slack loop detector that will send a trigger signal to the PLC system to slow down the rotation of SCR until fully stop whenever active infrared sensor detects any slack loop from the streamer cable (interruption of infrared light on the through-beam active infrared sensors). At the same time, it will also send trigger signal to activate the siren or alarm (DO_OUT_3). This sequence applies on any of three modes that mentioned before, which are PVG, Parker Tension Valve or Parker 2 Speed. The steps of slowing down the rotation of SCR is using timer mode, where the rotation speed will be checked every one second and will be subtracted (SUB) or reduced until the variable AO_SPEED_TEMP has zero value, which means the SCR is no longer rotates.

▼ Input	
DI_IN_1	Bool
DI_IN_2	Bool
MODE	Int
▼ Output	
DO_OUT_1	Bool
DO_OUT_2	Bool
DO_OUT_3	Bool
AO_OUT_1	Int
AO_OUT_2	Int
InOut	
Static	
▼ Temp	
AO_SPEED_TEMP	Int
Normalized	Real
ScaledOutput	Int

Figure 11. Variables for PLC Ladder Diagram of Lack Loop Detector

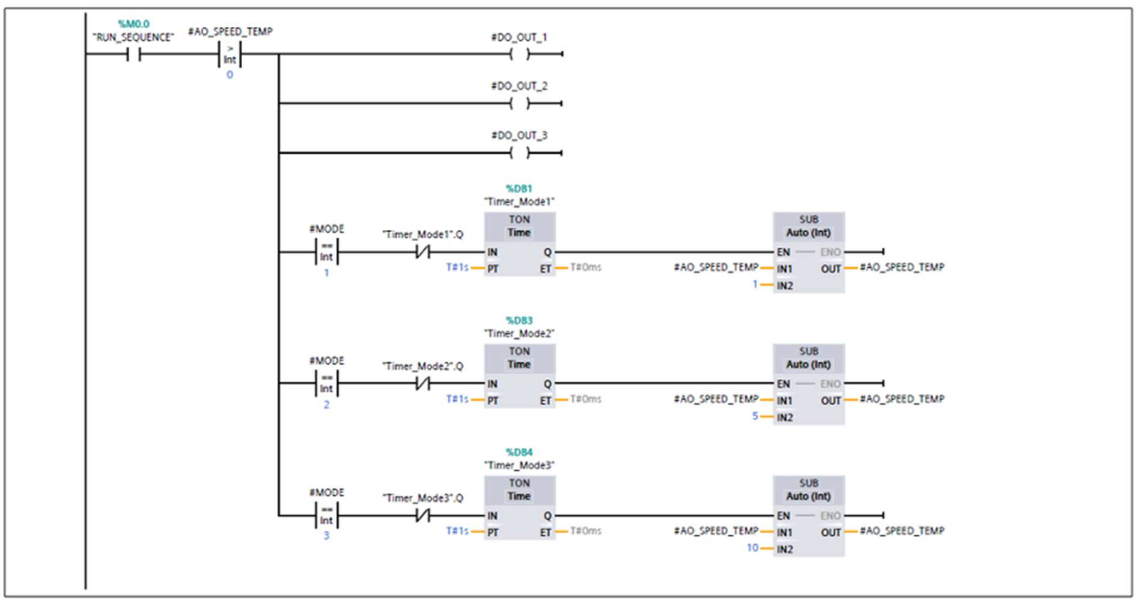

Figure 12. PLC Ladder for Slack Loop Detector

The operator conducted accuracy tests for slack loop detector on each SCR with blind spots (SCR 2, 3, 10 and 11) after the implementation by simulating slack loop of the streamer cable. The alarm sounded and trigger signal activated auto-stop process for the SCR to be fully stop in safe speed as soon as the simulated slack loop of streamer cable passed the infrared beams. As can be seen on Table 3, there were 100 tests conducted on each SCR with blind spots; the accuracy result shows between 97% to 99% accuracy which indicates the slack loop detector performed well. There were only very few failed tests happened which was found to be caused by misalignment of through-beam emitter and receiver during the first installation. As part of the accuracy tests, the operator was always able to spot any slack loop in the waterproof mobile display before the incident could have happened.

Table 3. Accuracy Test Result for Slack Loop Detector

SCR Location	Number of tests	Passed test	Failed test	Accuracy
SCR 2	100	97	3	97%
SCR 3	100	99	1	99%
SCR 10	100	98	2	98%
SCR 11	100	99	1	99%

4. CONCLUSION

Based on the simulation and tests, it shows that on our system design has optimized the streamer cable reel spooling system for monitoring blind spots. The implementation of our system design of SCRIS clearly would benefits the marine seismic industry company and the operators in safety such as less operator required during the task, less fatigue and less stress. This is aligned with the first priority of every company in marine seismic industry which is HSE. The operator would be able to monitor all SCR through IP camera displays thus the operator would be no longer need to walk back and forth to the SCR that had blind spots; therefore, the risk of slips, trips and falls would be significantly reduced.

A failsafe from active infrared sensors that is applied on the slack loop detector would intercept with accuracy between 97 % to 99%, and notify the operator even if the operator was distracted because the SCR would auto-stop and alarm would be sounded. This system design of SCRIS enables higher standard of HSE for the company, thus the client satisfaction would be higher too. The potential risk of damage equipment caused by slack loop of streamer cables are prevented. Furthermore, this system design would optimize the whole operation which is more efficient and operation downtime as mentioned on previous section are eliminated, therefore the client's job completion will be faster; this would benefit both the seismic industry company and the client.

Further implementation on system design of SCRIS can also be implemented by installing on other SCRs if required. Further development can be added by implementing recording system into the system design of SCRIS, the recorded video might be useful for any other improvement or analyzing any incident. Each seismic vessel design might be different but the basic architecture of this system design of SCRIS would be the same, therefore system design of SCRIS can always be implemented on any other seismic vessel.

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REFERENCES

Alavi, S. (2012). Comparison of Some Motion Detection Methods in cases of Single and Multiple Moving Objects. *International Journal of Image Processing 6*(1), 389-396.

Blintsov, V. S., Trunin, K. S., & Tarelko, W. (2020). Determination of Additional Tension in Towed Streamer Cable Triggered by Collision with Underwater Moving Object. *Polish Maritime Research 2*(106), 58-68.

Costin, A. (2016). Security of CCTV and Video Surveillance Systems: Threats, Vulnerabilities, Attacks, and Mitigations. *Proceedings of the 6th International Workshop on Trustworthy Embedded Devices*, (pp. 45–54).

Doyle, E. (2012). Simulation Training for Replenishment at Sea (RAS) Operations: Addressing the Unique Problems of. *TransNav, International Journal on Marine Navigation and Safety od Sea Transportation*, *6*(2).

Edwards, B., & Ziegler, J. (2021, April 15). *Legacy CCTV vs IP cameras: The differences for Security Program Design and Development*. Retrieved from https://www.securitymagazine.com/articles/94565-legacy-cctv-vs-ip-cameras-the-differences-for-security-program-design-and-development

Eskelin, A. (2001). *Technology acquisition: Buying the future of your business*. Addison-Wesley.

Johnsen, S. O. (2009). Suggested proactive indicators to be used in oil and gas industry based on a survey of accidents in the industry. Dalam *Reliability, Risk, and Safety, Three Volume Set*. CRC Press.

Kleinerman, R., & Feldman, D. (2011). *Power over Ethernet (PoE): An Energy-Efficient Alternative*. Santa Clara: Marvell Semiconductor, Inc.

Ludwig, S. (2021). *Pro's and Cons for IP vs. Analog Video Surveillance*. Retrieved from www.securitymagazine.com/articles/88854-pros-and-cons-for-ip-vs-analog-video-surveillance.

Mortara, L., & Ford, S. (2012). *Technology Acquisitions: A guided Approach to Technology Acquisition and Protection Decisions*. Cambridge: University of Cambridge, Institute for Manufacturing.

Omron. (2021). *General Purpose Sensors in Compact Plastic Housing E3Z*. Retrieved from https://cdn.kempstoncontrols.com/files/2b84ae0dd19ae9cd355e4fedd8467388/E3Z-T61%202M.pdf.

Omron. (2021, February 15). *Technical Explanation for Photoelectric Sensors*. Retrieved from www.ia.omron.com/data_pdf/guide/43/photoelectric_tg_e_8_5.pdf

Popovic, G., & Arsić, N. (2012). Overview, Characteristics and Advantages of IP Camera Video Surveillance Systems Compared to Systems with Other Kinds of Camera. *International Journal of Engineering Science and Innovative Technology 2*(5), 356-362.

Rayes, A., & Salam, S. (2019). *Internet of Things from Hype to Reality: The Road to Digitization 2nd edition IoT Oil and Gas Solutions*. Switzerland: Springer.

Salmon, D. (2021, March 15). *Offshore Statistics & Regulatory Activity Report 2019*. Retrieved from www.hse.gov.uk.

Singh, J., Wheeler, J., Fong, N., & Chaudhary, S. (2021, August 2021). *A comparison of Public Cloud Computer Vision Service*. Retrieved from https://osf.io/9t5qf/#!.