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# Design and Test Bed Experiment of Graph-Based Maintenance Management System for Yokohama Zone Undersea Cable Protection

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***Abstract***

*The number of incidents involving disconnections and damages of undersea cables caused by ships' anchors, fishing nets, sudden current changes or other heavy objects thrown overboard has increased recently around the waters of the Republic of Korea. To deal with this situation, the Korean government and its affiliated organizations are providing GPS-assisted alarm units which inform the coordinates of the cables, their routes, and other relevant information, in addition to operating the surveillance ships regularly. Despite such efforts, the number has not decreased widely. Thus, in this paper, we are introducing a Graphic-based Maintenance System developed by the SUNCOM Co. (a venture company) and delivered to KT (Korea Telecom). The system assists in maintaining and managing the undersea cables and its application uses C++ and Visual Basic. Through field tests, the systems have been proven to be effective and efficient in preventing many accidents that could have been caused by human errors and reducing the social and monetary costs involving restoration works and business disruptions.*

***Keywords**: Undersea Cable, Undersea Cable Protection System, Yokohama Zone, Test Bed*

## 1. Introduction

Undersea cables are being spread around the world as a human neural network connecting respective countries. Being located at the eastern edge of the Asian continent, Korea acts as an undersea cable hub that connects Asian and North American countries. The record shows that the cable damages often occur due to human errors more than natural disasters. The causes of accidents, to mention a few, are: fishing nets, sands or wastes thrown by the ships operating near the cables; heavy and anchors; and some loose maintenance works. Until now, the government was unable to deal with these accidents efficiently so that the system introduced in this paper may well serve their purpose by removing the underlying causes, while avoiding the unnecessary costs that could have been avoided.

## 2. Related Research

### 2.1. Undersea Cables

Since undersea cables - which connect continents and land and islands across the waters to enable communications – needed to be laid at the bottom of the sea, they are easily damaged or severed by the ships' anchors or fishing gears, not to mention, natural phenomena like currents, sea breezes, waves, and frictions with sea-beds [1 - 7]. In order to avoid damages, they normally use armored cables and these cables, fall into two types

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depending on their usages - for the shallow sea and for the deep sea. While the shallow-sea cables are laid on a continental shelf region (water depth of approx. 500m) where the slope is relatively moderate starting from the coast requiring armored cables, the others are laid on the bottom of the deep sea where there are lesser fishing activities and damages by natural phenomena so that the use of non-armored will be possible. Figure 1shows international undersea cable network (Northeast Asia) diagram.

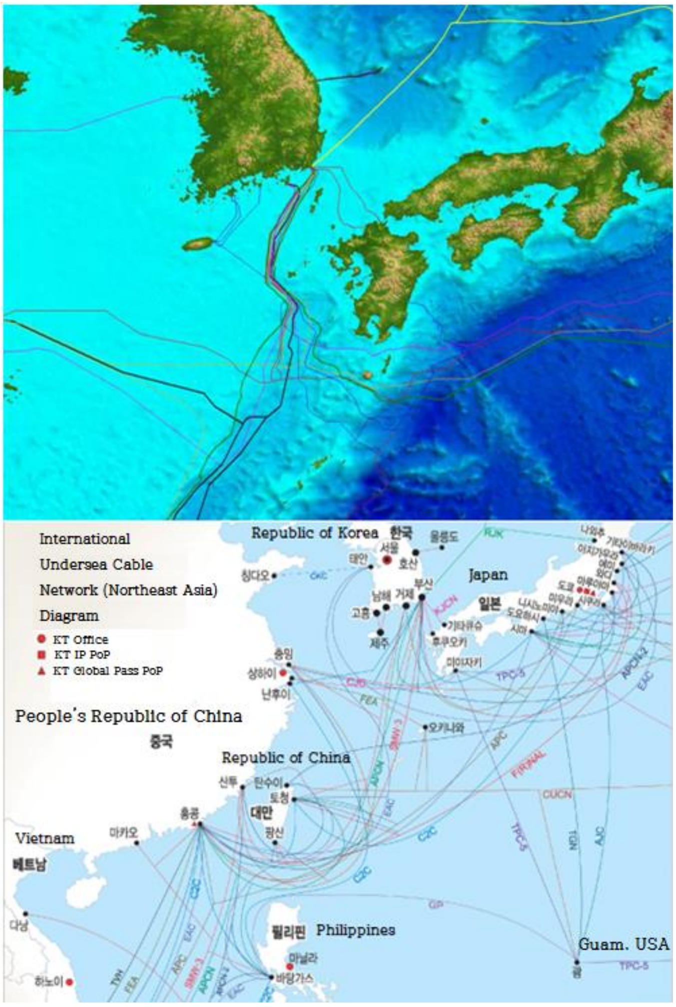


**Figure 1. International Undersea Cable Network (Northeast Asia) Diagram**

### 2.2. Yokohama Zone

One of the crucial cable maintenance zones in the Asia-Pacific region is the Yokohama Zone and the improvement was made to the zone by deploying at least two ships at all times for monitoring and maintenance purposes following the international treaties "The Agreement for the Maintenance of Pacific Ocean Cable Systems in the Yokohama Zone" (1997), which was then reinforced with "Yokohama Zone ROV Agreement" (2001). These agreements define a strict maintenance procedure as well as the security requirements for most of crucial submarine cables in the region [8].

In early days, when the basic coaxial submarine cables were laid to accommodate commercial communication service, cable companies or owners usually made a contract with a independent cable maintenance company who operated ships to maintain the cables. However, such a practice became obsolete when the number of new cable systems had increased and required maintenance skills were not sufficiently provided to handle each system's complexity, in addition to the limited number of cable maintenance ships. The necessity of establishing a collaborative agreement was recognized between the Maintenance Authorities (MAs) and ship operators for the employment of maintenance ships, which resulted in saving the costs by sharing the operating expenses [8].

In accordance with this agreement, a new cable maintenance zone, the Yokohama Zone (YZ) was created for the cables covering North Asia and Northwest waters of the Pacific. Surrounding zones are the North America Zone, the SEAIOCMA Zone, and the Fiji Zone in the Asia-Pacific Region, and including YZ, the maintenance works in these zones are being consistently upgraded and improved by deploying newer ships and ROVs, encouraging a two-ship maintenance operation [8].

Among these worldwide submarine cable maintenance zones, our attention has been given to the Yokohama Zone Figure 2.

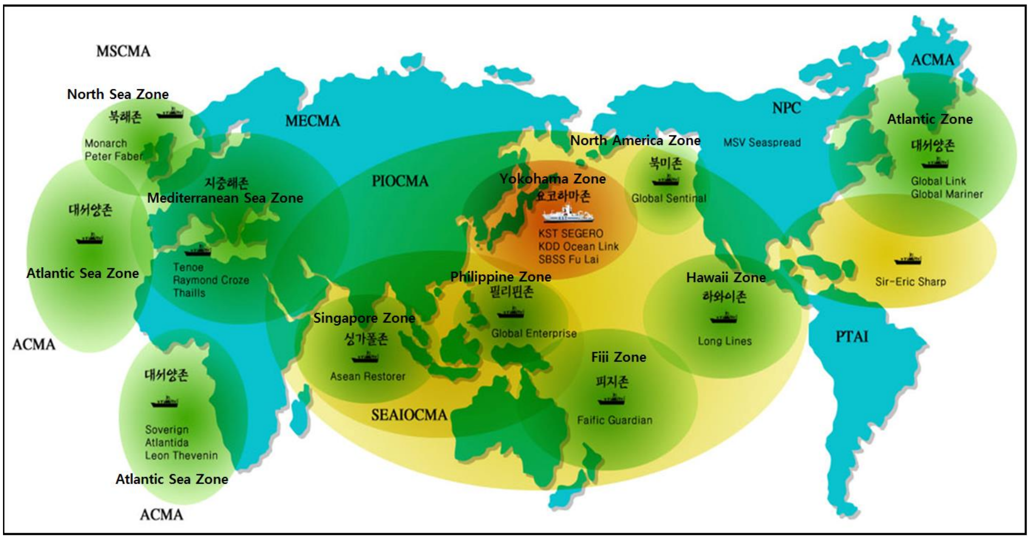


**Figure 2. Present Status of the World Undersea Cable Maintenance Zones [17]**

## 3. Graph-based Maintenance Management System for Yokohama Zone Undersea Cable Protection

### 3.1. Installation Status of Undersea Cables

Figure 3 shows the installation status of undersea cables. Importantly, the undersea cables are divided into the GIS map and cable RPL.

a) GIS MAP
   Land and maritime layout building using the GIS map
b) CABLE RPL
   Building the Database for undersea cables
   Management by cable classes
   Precise positioning and undersea cable management using the GUI

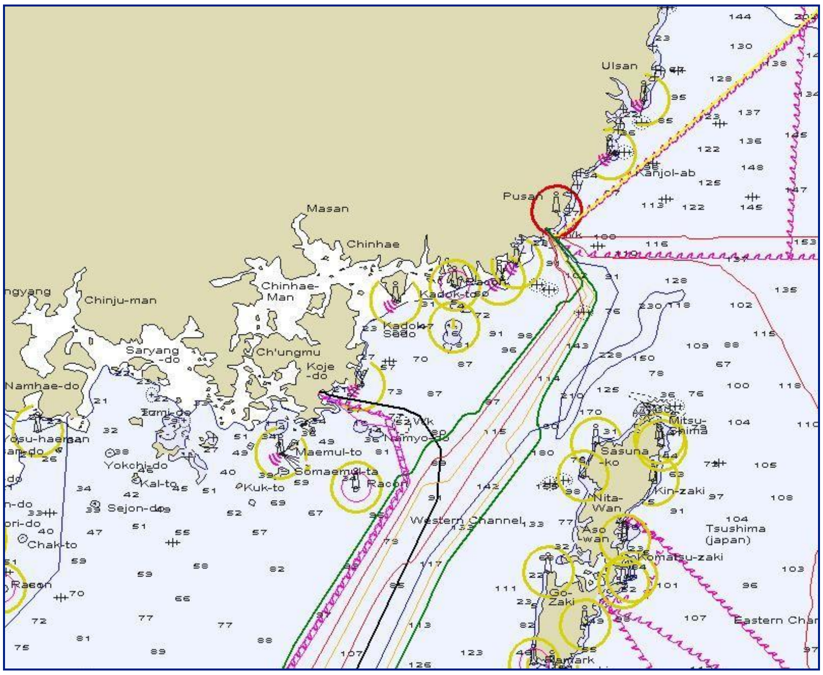


**Figure 3. Installation Status of Undersea Cables**

### 3.2. Location Search

This paper has developed the system that can prevent accidents by determining safety after informing the work location to the situation room, prior to engaging in the tasks like material dumping or anchor dropping. Figure 4 shows Content of development and Range of development.

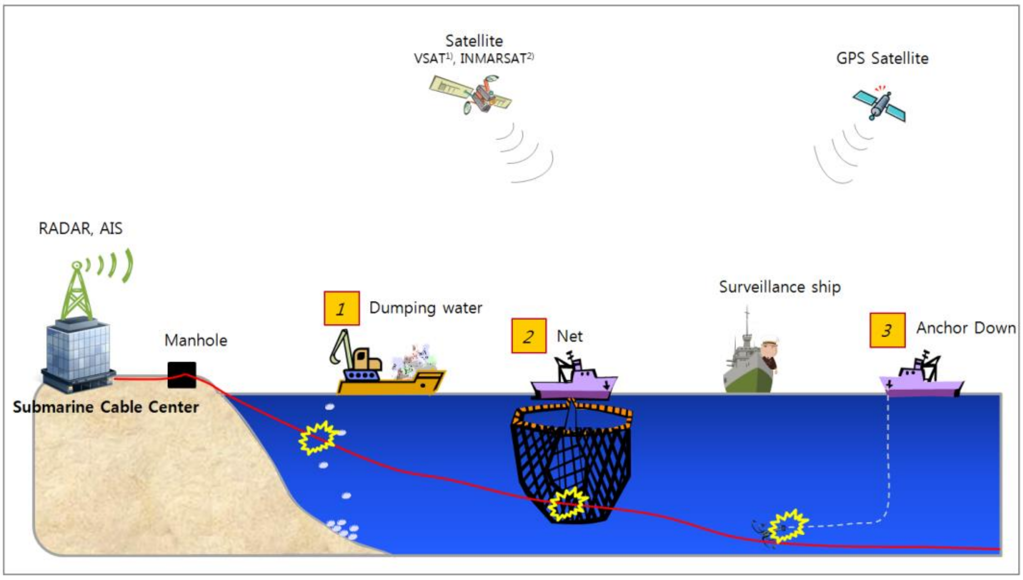


**Figure 4. Content of Development and Range of development**

a) Location search

In case a ship needs to perform tasks such as dropping the dredged matter or anchor in its current position, inform its position and work details to the situation room with a phone or mail using ship's GPS, then initiate the task after receiving safety information to prevent cable severance. 'Figure 4' shows location search.

b) Location search development

The accident area reaches the coastal waters where mainly many small-sized ships operate actively. They can go forward with their tasks after receiving work permission before or during operation using wire/wireless phones. In order to reduce the time for a ship to stay on the sea, install the system which can monitor the status of cable installments on a real-time basis in the situation room and check the resulting value(s) immediately when the status report has been received then inform the ship the result. Search the distance between the point where the search request was issued and the cable laid nearest that point. Make judgment calls immediately depending on the type of work.

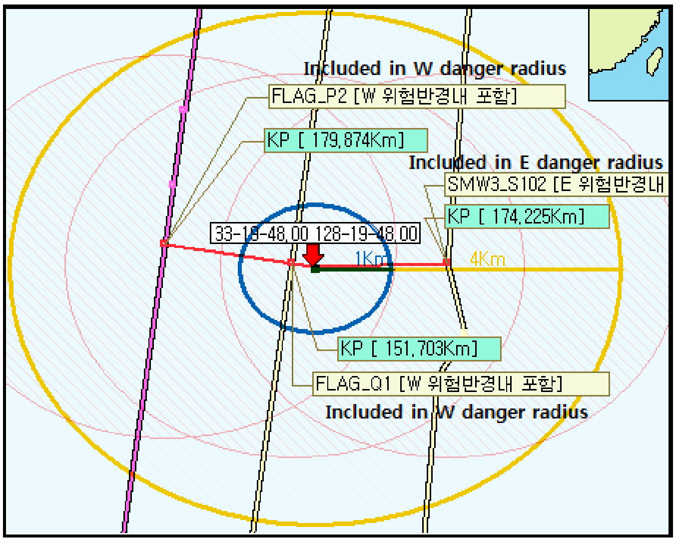


**Figure 5. Location Search**

### 3.3. The Positioning Algorithm within the Operating Radius

The positioning algorithm within the operating radius first asks about the possibility of commencing the work and second, searches the location, and finally informs the possibility by issuing 'Yes' or 'No' after checking the result and orders position shift to the ship. Figure 6 shows Positioning algorithm within the operating radius.

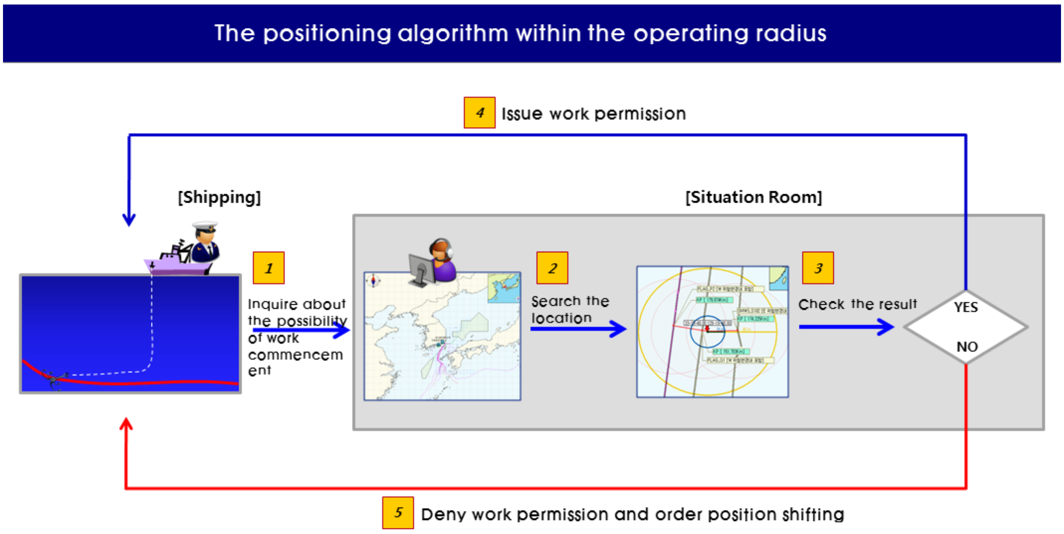


**Figure 6. Positioning Algorithm within the Operating Radius**

### 3.4. Radar Search

This is the system that generates alarm and orders position shifts when a ship who neglected the report duty or of foreign nationality operates without a permission at the location where the cable(s) has been laid. 'Figure 6' shows radar search.

a) RADAR

*Set up the radar at the location where many accidents occur or cable(s) is laid and many ships navigate on. Detect the ship that stays above the location where cable(s) is laid for a long period of time and issue warning announcement by acquiring AIS signal.*

b) Content of development

The system hat can detect ship's identification code with the radar against the ship neglecting the report duty or belonging to a foreign nationality.

Detect the ship that stays above the location where the cable(s) is laid for a long period of time and issue warnings and order position shift using the surveillance ship. When the warning has been issued, inform the situation to an officer in charge with SMS transmission. Figure 7 shows Radar search mechanisms.

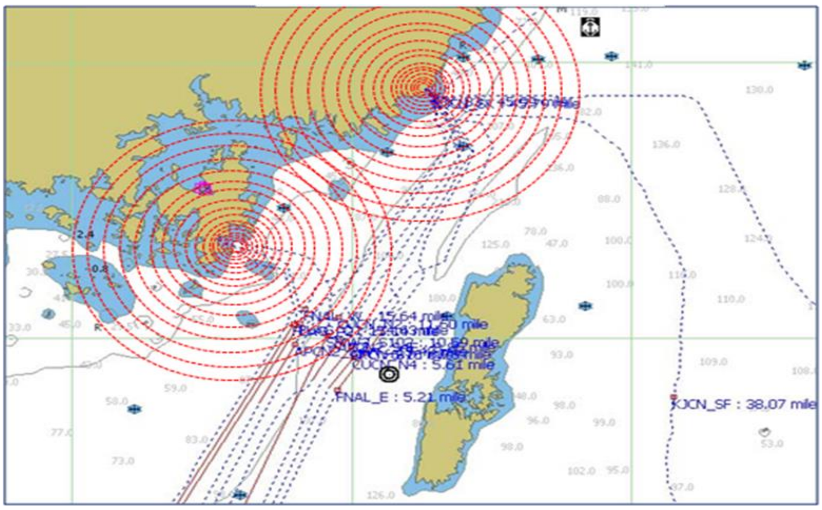


**Figure 7. Radar Search Mechanisms**

 

### 3.5. Radar Search Algorithm

Figure 8 shows Radar search algorithm. First, if a ship stays within the radius of installed cable set by the administrator for a long period of time, maintain surveillance with radar and report the situation. Second, send in an alarm to the situation room. Third, send SMS message. Fourth, announce warnings. Finally, dispatch patrol boat(s) for surveillance.

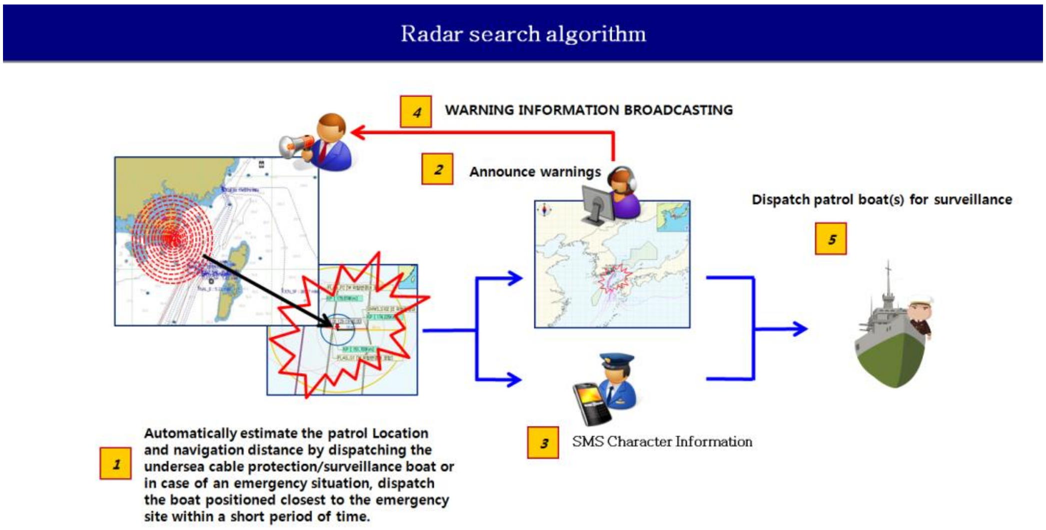


**Figure 8. Radar Search Algorithm**

### 3.6. Surveillance Ship

Automatically estimate the patrol location and navigation distance by dispatching the undersea cable protection/ surveillance boat or in case of an emergency situation, dispatch the boat positioned closest to the emergency site within a short period of time.

**a) Assessment of ship's line of movement by the patrol boats**

Assess the location of the patrol boats using GPS and VSAT and dispatch them to the location where the accident has occurred within a short time

**b) Content of development**

This is a system that can maintain surveillance of ships operating illegally and prevent accidents by placing patrol boats for undersea cables.

It is practically impossible to seize the ship(s) that caused the accident by dispatching the patrol boat(s) from the port after it has occurred and such a slow approach could lead to increased damages.

A database for the base of the expense account balance can be established by automating the operation records of patrol. 'Figure8' shows assessment of ship's line of movement by the patrol boats.

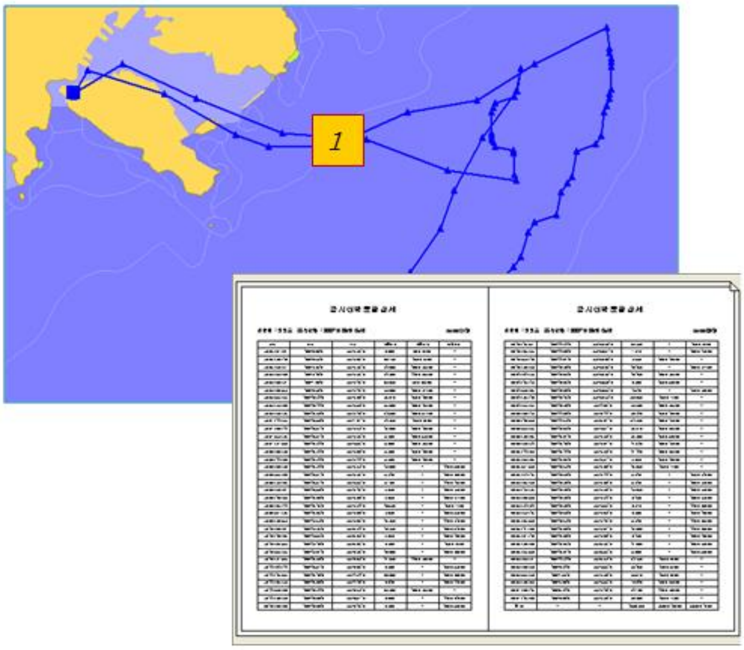


**Figure 9. Assessment of Ship's Line of Movement by the Patrol Boats**

## 4. Graph-based Maintenance Management System for Undersea Cable Protection: Main Screen

Once successfully logged in, it moves to the page below. Left screen shows the Map section and the right shows Map control section.

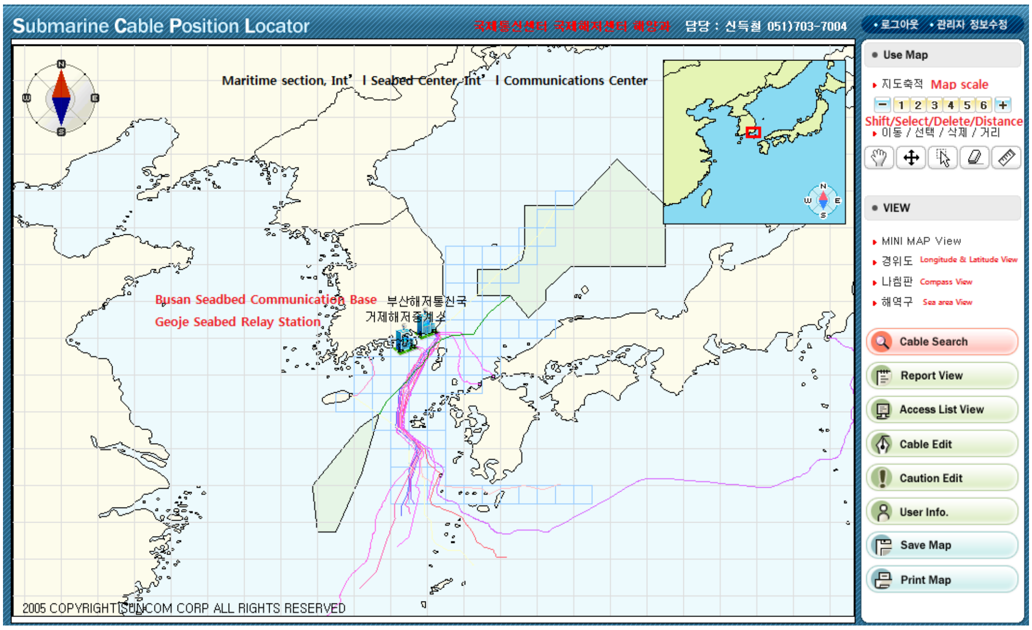


**Figure 10. MAIN SCREEN**

a) Map control section
This is a menu for the Map control.

 

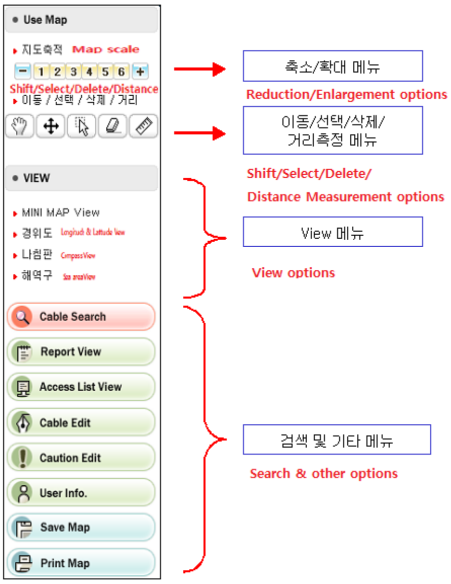


**Figure 11. Map Control Section**

MAP SCALE: enlargement or reduction of the map
MOVE/SELECT/DELETE/DISTANCE: make
movements on the map, select object(s), delete screen, measure distance
MINI MAP View: hide or show the mini-map
Longitude & Latitude View:
hide or show Longitude & Latitude
COMPASS VIEW: hide or show compass
SEA AREA VIEW: hide or show relevant sea area
Cable Search: a button initiating the cable search
Report View: a button to view the cable search report
Access List View:
a button to view the search statistics during the specific period
Cable Edit: a button to revise and register the cable
Caution Edit:
a button to set phrase(s) on a warning window
Save Map: a button to save the map on screen
Print Map: a button to print the map on screen
b) Execution result screen (1)

Below picture shows that the search radius is within the danger radius of 3- types of cables.

Operating radius: blue circle
Danger radius of each cable: red circle
Search location: red arrow / search coordinates
Shortest point: a point with the shortest distance
from the cable
Cable information: cable name, direction from the
search location and the shortest distance
Search radius: yellow circle
*The Cable BoX can be moved by dragging it after pushing the button.*

 

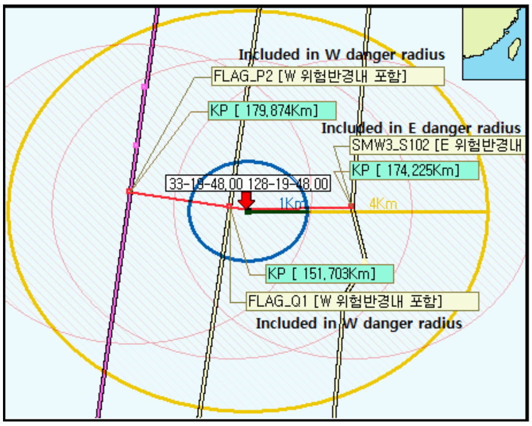


**Figure 12. Execution Result Screen (1)**

**c) The distance search for each cable**
Searches the distance from the entered coordinates to a specified cable.

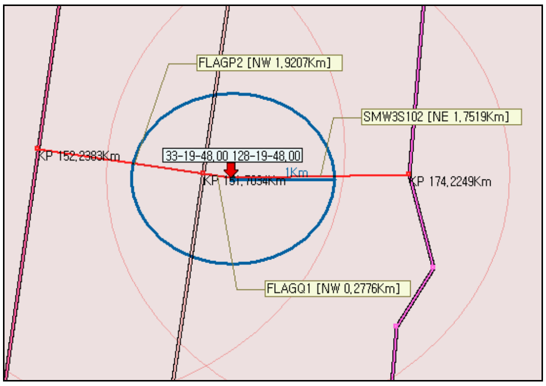


**Figure 13. The Distance Search For Each Cable**

***d) Search method (1)***
Input form: "Degree"
Coordinates: Latitude 33.33/Longitude 128.33
Operating radius: 1km
Search method: cable distance search
Cable name: FLAGQ1
Work type: sea sand collection
*Click the button after the set-up process. Once the searching process is performed, a warning window will be loaded together with a warning sound if the relevant radius is within a danger radius of cable(s).*

 


**Figure 14. Search Method (1)**

*e) Execution result screen (2)*

**Shortest distance search**

Searches as many number of shortest-distanced cables as the user specified from the coordinates entered.

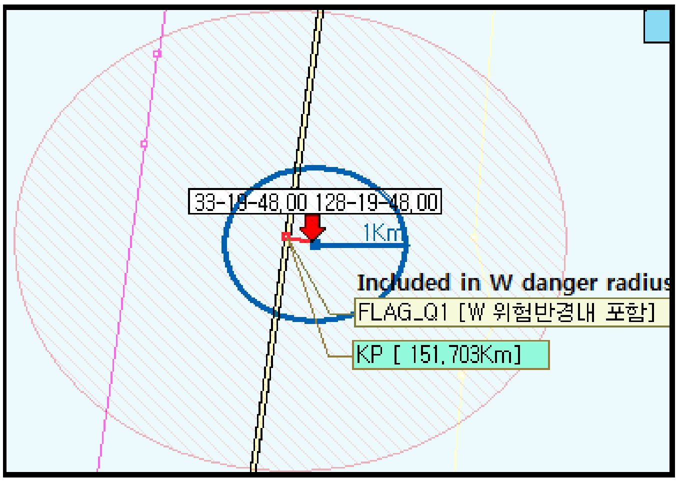


**Figure 15. Execution Result Screen (2)**

f) Search method(2)
Input form: “Degree”
Coordinate: Latitude 33.33/ Longitude 128.33
Operating radius: 1km
Search method: shortest distance search
Number of cables: 2
Work type: sea sand collection

Click the button after the set-up process. Once the searching process is performed, a warning window will be loaded together with a warning sound if the relevant radius is within a danger radius of cable(s).

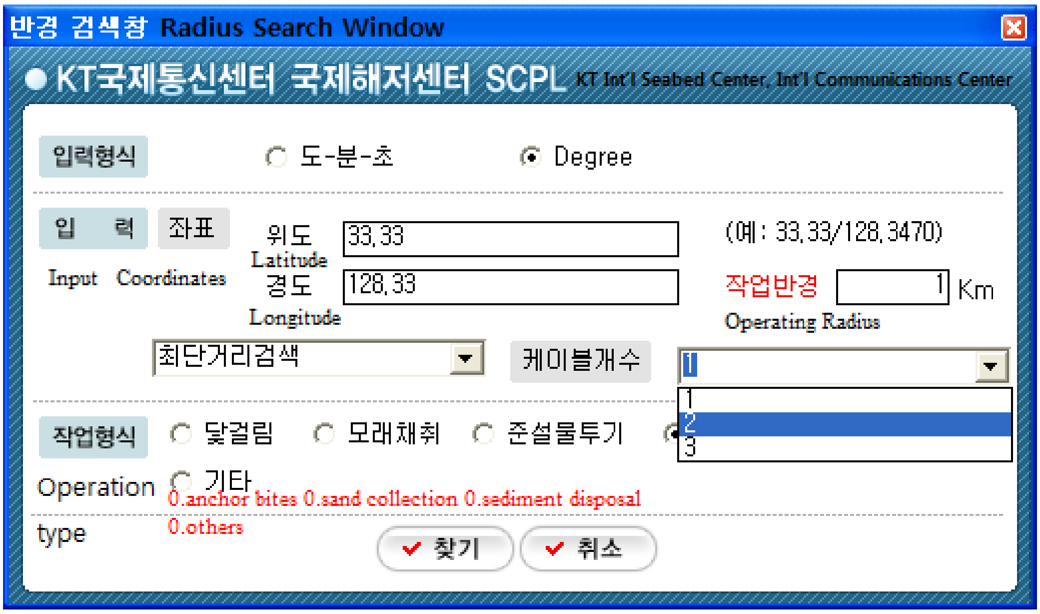


**Figure 16. Search Method (2)**

*g) Execution result screen (3)*
*2 cables with the shortest distances have been searched.*

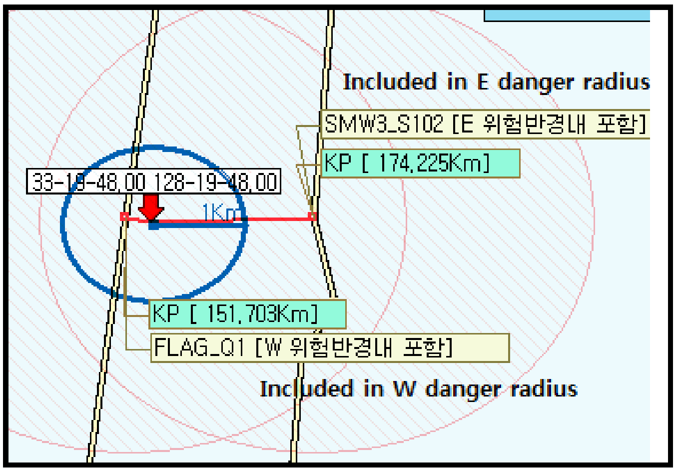


**Figure 17. Execution Result Screen (3)**

## 5. Comparison with Other System

The government of the Republic of Korea is making efforts to protect the undersea power cables [Figure 18-19].

By using the system described in Figure 18, the Korea Electric Power Corp (KEPCO) and ISENTECK Co., LTD. have developed a hazard pre-sensing communication system for the undersea power cables for the period of 15 months (03/05/2005 ~ 02/08/2006).

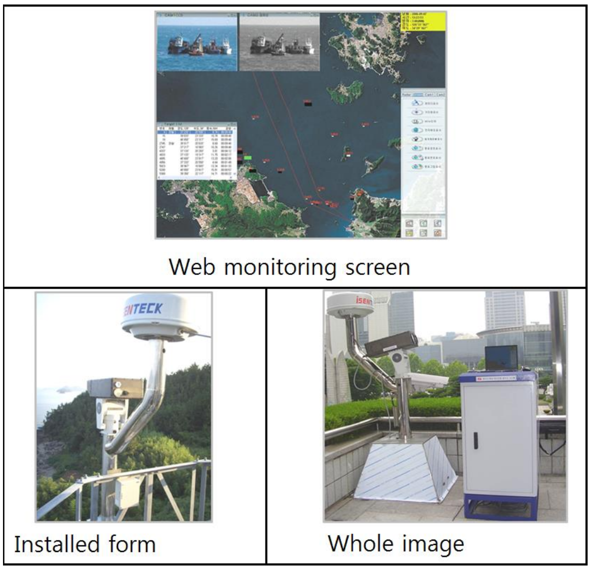


**Figure 18. The Communication System for Sensing the Hazards on Undersea Cable Routes in Advance (Pre-Sensing)**

KEPCO has laid undersea power lines to supply power to the lines on islands that were anticipated could be damaged by the fishing boats interrupting the supply of power and causing serious damages. Thus, they started to develop a system that aimed to monitor the maritime activities for stable power transmissions and finally completed it in September of 2006 after conducting the final evaluation tests at Haenam Power Conversion Station, Jeonrasnam-do.

This system is organized as following:

Acquire and trace targets by converting the radar data received from the radar signals processing unit into 2-dimsion images at the management server and using a fixed-target removal and movement prediction algorithm that utilizes the mask map.

The target information is recorded and maintained at the database and then provided to the multiple users through exclusive network.

The targets acquired in a surveillance area will be traced and monitored remotely by allowing the user to distinguish and identify targets on the display easily by applying high-definition images on the 2-dimension position data received from the radar system.

As described in Figure 19, a total of 8 protective buoys for the Jindo – Jeju undersea power cable have been installed on the 24th of November, 2012 by the Mokpo Regional Maritime Affairs and Port Office (Head of office: Choi, Ik-Hyun) to supply power to Jeju Island stably.

As for the Jindo – Jeju undersea cable burial zone, the traffics by the large ships and fishing boats are quite heavy at the waters of the southern tip of Jindo island so that it would become a great danger for the ships and could cause enormous trouble for the power supply situation to Jeju Island. Since this line assumes about 36% of the power transmission to Jeju Island, if the power line sustains damages from the anchors of the ships who try to take cover at the nearest port when the weather is severe, the outcome will be very serious.

A port office official explained that they will be protecting the cable by installing 2 light buoys near Dongryeong Inlet, 8 on the eastern sea of Dokgeo Island (Jodo-myeon), on both the left and right sides along the cable.


**Figure 19. Positions of the Light Buoys Along the Jindo - Jeju Undersea Power Cable**

The methods used by the domestic and foreign engineers can be classified into following forms: 1) piled up stones; 2) flexible mattress; 3) ferroconcrete; 4) enclosing the cable; 5) hard mattress; 6) bag structure; 7) buried; and others.

The stone piling protection method includes Rock Dumping, Side Stone Dumping, and Precision Rock Building. For the second form, there are CM (Articulated Concrete Mattress), FCM (Flexible Concrete Mattress), Flexweight(a kind of Urethan pipe), S-FCM(Steel Forced FCM), As-FCM(Anchor-resistant Steel Forced FCM),Electro-forming Mattress, and ASF(Artificial Seaweed Fronds). For the ferroconcrete structure, PCU (Pre-cast Concrete Unit), A-duct, and U-duct are available. The cable enclosing is possible with Cast Iron Pipe and Uraduct. The Concrete Mattress, Seamat, and W-mattress are hard mattress types. The Bag structure includes Stone Bag, Concrete Bag, Mortar Bag, and Grouting Bag. For the Burials, there are Burying (Plough), Trenching (Water Jetting), Trenching (Wheel Cutter), Trenching (Chain Cutter), and Trenching (Dredging), depending on the burial machines. Others include Underwater Barriers and electro-forming Artificial fish-reeves (cf. KEPCO 2007). Figure 20 is the typical protection method [9].


**Figure 20. Protection Methods of Submarine Cable [9]**

The related research has been conducted by Jinho woo et. Al [10]. with the title of Numerical Simulation of Arch Type Submarine Cable Protector Under Anchor Collision (2009). The corresponding small-scale test bed experiment was conducted as described in [Figure 21-23].

**Figure 21. Anchor Modeling [10]**

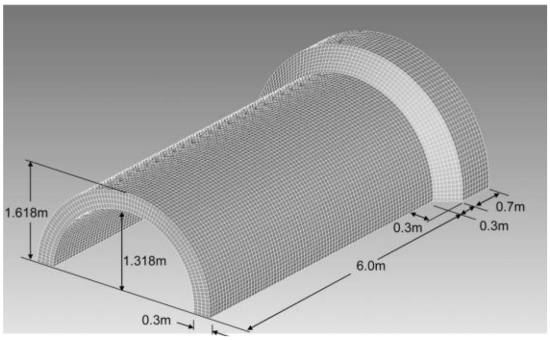


**Figure 22. Concrete Mattress Modeling [10]**

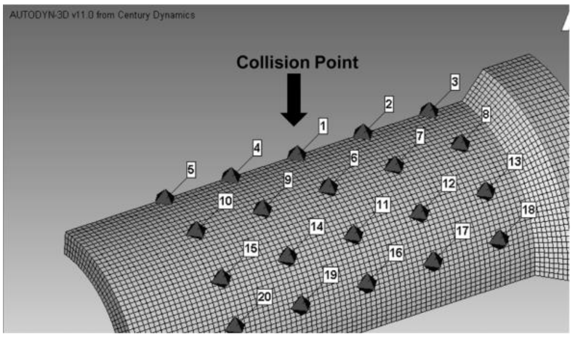


**Figure 23. Arch Type Cable Protector Modeling and Positions of Gauge Points and Collision Point [10]**

## 6. Results and Future Work

The algorithms used for the positioning, radar searching, and ship surveillance purposes are specifically designed to protect undersea cables by providing adequate information to the ships operating within the coastal waters of the southern Korean peninsula. Its graphic nature allows the users of the system to easily comprehend the situation where they are positioned at so that they can avoid any unintended human errors and liabilities.

After being delivered to KT, a major ICT company in Korea, several shipping companies have adopted the system. Researchers expect that the number of users will increase when additional functions are added to the system in the future.

The researchers have also concentrated on the methodology which protects the cables with ICT technologies, expecting that this platform technology will be useful for not just the undersea power cables but also for other cables.

## Acknowledgements

The program copyright for the proposed Graphic-based Maintenance Management System for Undersea Cable Protection system is being held by SUNCOM Company and its delivery price to Republic of Korea's KT_(Korea Telecom) was 80 million Korean won. KT still carries out underwater cable protection works using this program. The first draft of this paper was presented in 2015 at The 11th International Conference on Multimedia Information Technology and Applications (MITA 2015), June 30-July 2, 2015, Tashkent, Uzbekistan, IEEE Region 10, Changwon Section [11]. The researchers grateful to 3 anonymous commentators who have contributed to the enhancement of this paper with their valuable suggestions at the conference.

 

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