Smart Device Based Power Generation Facility Management System in Smart Grid

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***Abstract*— As energy consumption is gradually increased due to rapid development of industrialization, the whole world including our country is faced with an issue of lack of back-up power, exhaustion of fossil energy and global warming. Under this background, as a method of maximizing energy efficiency by preventing global warming and reduction of greenhouse gas emission, smart grid that converged existing power network with IT technology receives concentrative attention as a growth engine of next generation [1-3]. Currently, maintenance of domestic solar power plant management is provided at the center through remote monitoring by using measuring sensor being installed at power plant and as regular check-up or repair being performed at site is progressed by site management personnel by directly moving power generation facility, there is a difference in time and accuracy depending on ability of site management personnel. In this paper, a system of managing smart grid power generation facility by internet of things (IOT) technology is suggested. Maintenance of suggested system for its regular check-up and failure is allowed by site manager conveniently and by using facility recognition based technology instead of existing QR code, its direct application is allowed without additional equipment to smart grid power generation facility being operated at present and by developing power generation facility recognition service using markerless based facility recognition technology, it may be expanded to a technology of recognizing other smart grid power generation facility in the future.**

***Keyword*—Smart Grid, Power plant facility management, Smart Phone, Location Based Service**

I. INTRODUCTION

As energy consumption is gradually increased due to rapid development of industrialization, the whole world including our country is faced with an issue of lack of back-up power, exhaustion of fossil energy and global warming. Under this background, as a method of maximizing energy efficiency by prevention of global warming and reduction of greenhouse gas emission, smart grid that converged existing power network with IT technology receives concentrative attention as a growth engine of next generation [1-3].

Smart grid power generation facilities are under operation by it being spread in various places from small-scaled power generation being installed in general housing, building, parking lot and public facilities to large-scale power generation system being composed in a grid form and these facilities require sustained management and check-up and in case of occurrence of problem such as facility malfunction, power failure or damage, rapid and exact check-up and repair are required to be performed at the site.

However, at present, management of solar energy power generation facilities is performed at the center through remote monitoring by using measuring sensor being installed at the power generation facility and as regular check-up or repair at site is progressed by site management personnel by directly moving power generation facility, there is a difference of time and accuracy depending on ability of site management personnel.

In addition, in case of solar energy power generation facility or wind power generation facility, as it has diversified products, standards and forms, there are a lot of difficulties for exact check-up and in case of small-scaled power generation facility, in view of its features, as maintenance cost is high and a lot of cost is required once a failure is taken place, prevention of failure in advance is required through regular check-up and operational check-up.

Recently, due to popularization of smart phone, a study on industrial application by using smart phone is under way and as smart phone is mounted with wireless internet communication module (3G, 4G, Wifi, etc.), GPS sensor, electromagnetic sensor, image sensor, diversified information provision by using facility recognition technology is enabled [4].

In this paper, a system of managing smart grid power generation facilities by using power generation facility recognition based technology is suggested. Suggested system recognizes smart grid power generation facility image in real time by using image sensor and GPS sensor and it provides site manager with detailed information, hardware drawing, sensor data, facility history of power generation facility.

In addition, it provides location information of facilities so that site manager could identify other surrounding facilities conveniently. When utilizing suggested system, site manage

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could perform regular check-up and maintenance of repair conveniently and by using facility recognition based technology instead of existing QR code, its direct application is allowed without addition equipment to smart grid power generation facility being operated at present and by development of power generation facility recognition based technology using markerless based facility recognition technology, it may be expanded to a technology of recognizing other smart grid power generation facility in the future.

II. Related Works

A. Cimphony (Open Grid System)

Cimphony is data management and analysis application of multiple platform smart grid power generation system having OSGI modular system and Eclipse based user interface. Cimphony module provides an independent service such as geographic information visualization by using data editing, OCL based verification, model based conversion, distributed data and KML.

This system is able to support new standard and data model without change of framework by using model-driven architecture, open standard such as CIM (Common Information Model) and smart grid facility monitoring and management function through data visualization from IPad and IPhone [5].

B. Field Force Data Visualization App with Augmented Reality

This is augmented reality based smart grid site monitoring application that was promoted in renewable energy and smart grid research institute EPRI being composed of consortium including a lot of universities and enterprises.

This system is a conception model of light-weighted, mobile access platform that integrated diversified back office systems and this is a project in which user visualized smart grid facility information in actual world by augmenting it using GIS sensor and electromagnetic sensor built in tablet PC.

As a mobile application program for data control and visualization aiming at supporting site workers, it provides information of site details, location and manual, sensor provided to site staffs and cheaper platform built in power source by utilizing mobile system.

In addition, application user may reserve request for work in real time.

This project is a kind of demonstration project that proves strong power of CIM(Common Information Model) in a conceptual way under actual application environment and it has characteristics of having efficiency of visualizing CIM data, stability of site workers, low cost mobile data platform and CIM base utilizing actual data and system, light-weight and mobile data platform [6].

C. Integrating geographical information and augmented reality techniques for mobile escape guidelines on nuclear accident sites

As a study on integrating augmented reality that provides counterfactual information service for escape and location guidance at the time of nuclear accident, it not only provides guidance of escape route by using augmented reality but also visualizes current nuclear power plant condition in geographical map.

This system supports site workers escape from nuclear accident site in real time by identifying current location after capturing surrounding image by using camera built in user's own working system and visualizing escape route in a map [7].

However, it has a disadvantage that high quality map is required, time of loading escape route is long and people at nuclear accident site may consume a lot of time while waiting for this map.

III. Facility Recognition Based Mobile Power Plant Management System

A. System Configuration

In this paper, power generation facility management system that enables convenient and exact management is suggested in a way that site workers recognize smart grid power generation facilities by using power generation facility recognition technology, transmit it to server through wireless communication such as 3G, WiFi and then provide information of current condition, past history, design drawing by matching it with data stored in server.

Power generation management system may be mainly divided into two parts including smart grid power generation facility management server system for providing site workers with formation relevant to current condition, check-up and management history and design of power generation facility and smart application that recognizes and manages power generation facility by using power generation recognition as shown on Fig. 1.

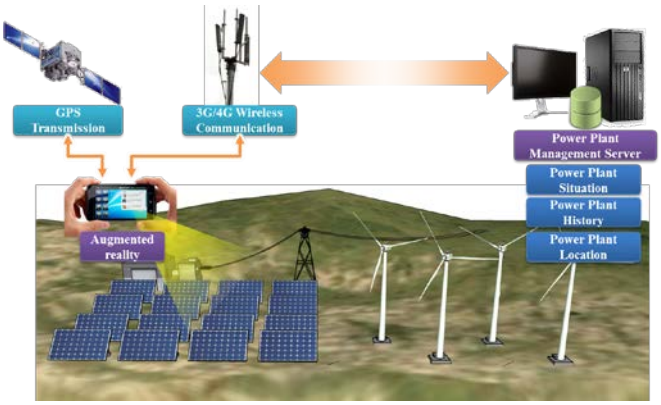


Fig. 1. System layout

B. Power generation facility recognition and registration using power generation facility recognition

Location and image information of power generation facility in power generation facility management server are registered by recognizing power generation facility after using image being shot in screen view of site worker's smart phone and information for power generation facility requested by site worker is provided.

Recognition and registration process of smart grid power

generation facility is as shown on Fig.2.

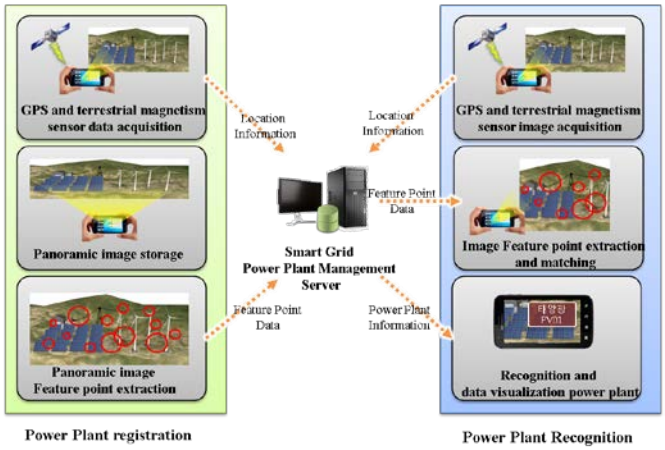
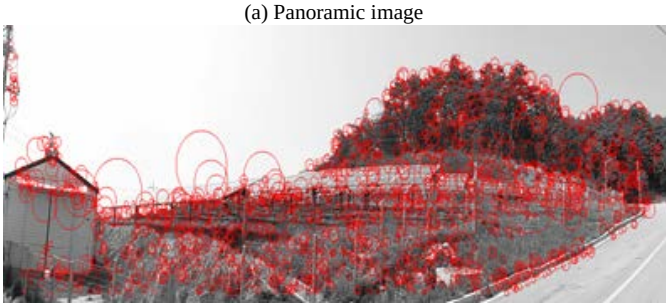


Fig. 2. Recognition and registration process of power generation facility

Registration and recognition process of smart grid power generation facility is that site worker approaches power generation facility within distance of 10cm and makes camera direct at power generation facility and at this time GPS sensor and electromagnetic data are read and at angle of app. 5^{o} to the right/left, power generation facility is shot as panoramic image.

By transmitting GPS sensor, electromagnetic sensor and feature point data to server after extracting feature point of photographed panoramic image as shown on Fig. 3, power generation facility is registered in server data base.

(a) Panoramic image

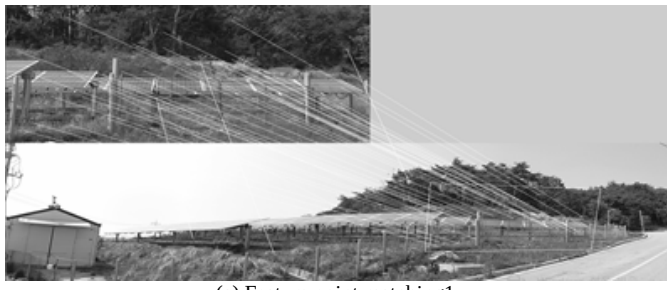


(b) Feature point extraction by using SURF algorithm

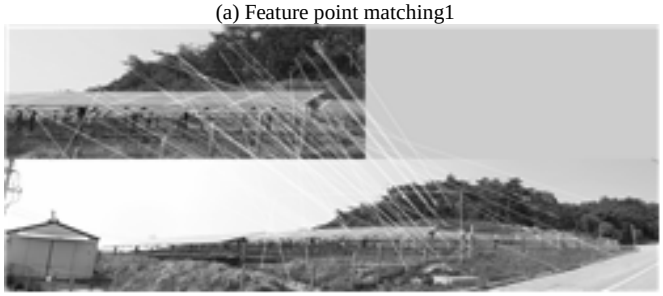
Fig. 3. Recognition and registration process of power generation facility

In a process of recognizing power generation facility by site manager, power generation recognition of worker is requested through the same method as power generation facility registration process.

And then server searches data most similar to facility requested by worker among GPS stored in real time and electromagnetic sensor data and when a result is obtained by matching feature point of panoramic image of searched facility with feature point data transmitted by worker as shown on Fig. 4, information of relevant power generation facility is transmitted to worker but if its matching failed, unrecognizable message is transmitted.



(a) Feature point matching1



(b) Feature point matching2

Fig. 4. Feature point matching test and facility recognition

In this paper, feature point was extracted by using SURF (Speeded Up Robust Features) algorithm so that fast performance ability and feature points that are not changed to rotational change and scale conversion could be found in feature points of panoramic image being transmitted from server and images being obtained from smart phone camera and camera and object would be recognized as identical object even though its angle and distance are different at the time of shooting smart grid power generation facility[8].

C. Power generation facility management server

Smart grid power generation facility management system provides information of current condition, check-up, management history and design drawing of power generation facility based on mobile web application server (WAS: Web application server) in order to ensure convenient interface with smart phone.

Smart grid power generation facility management server system is as shown on Fig. 5.

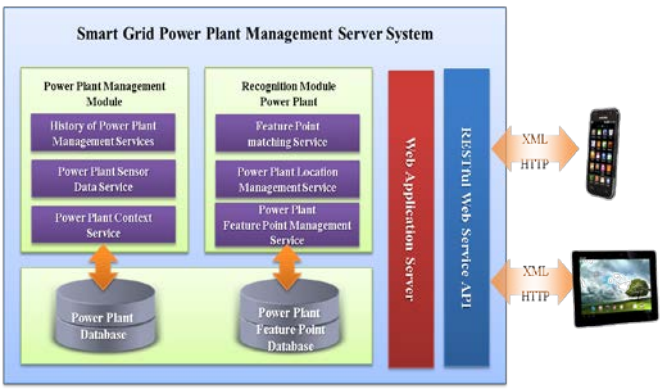


Fig. 5. Power generation facility management server system

Diversified smart phone and tablet PC are supported by

providing an independent interface to platform by utilizing Rest API and a complete interface of smart application is possible by providing power generation facility management service through Rest API.

Management server system of power generation facility is composed of power generation history, sensor data, matching power generation facility data base of its management module that provides situation information service with feature points, location management of power generation facility and feature point data base of power generation facility recognition module that provides its feature point management service.

As shown on Table 1, smart grid power generation management server mainly provides functions of log-in, history, recognition management of power generation facility, environment setting and log-in.

TABLE I
SMART GRID POWER GENERATION MANAGEMENT SERVER MAINLY PROVIDES FUNCTIONS

No	Div	Function	Description
1	Log-in	User log-in	Function of user authentication
2		Password change	Function of changing user ID and password
3	Power generation facility history management	Inquiry of power generation facility information	Detailed information inquiry of power generation facility
4		Addition of power generation facility history	Addition of power generation facility history
5	Power generation facility recognition management module	Power generation facility recognition information storage	Feature point data storage of GPS, electromagnetic sensor data and panoramic image of power generation facility
6		Power generation facility recognition information inquiry	Feature point data inquiry of GPS, electromagnetic sensor data and panoramic image of power generation facility
7		Deletion of power generation information	Function of deleting registered power generation facility information
8	Environment setting	Server setting	Setting of server network and access
9		User setting	Setting of power generation facility manager account and authority
10	Log function	Power generation facility recognition module management log	Storage/inquiry of log record for a function of registration/inquiry/deletion being performed in power generation facility recognition management module
11		Power generation facility history management log	Storage/inquiry of log record for inquiry/addition of facility history being performed in power generation facility history management module

D. Guidance service of location-based smart grid power generation facility

Guidance service of location-based smart grid power generation facility is a service of guiding location of power generation facility so that worker may perform inspection for surrounding power generation facility based on location information obtained through mobile communication network or GPS as shown on Fig. 6 and by guiding location of smart grid power generation facility that is distributed widely, site worker could perform next inspection rapidly.

Location guidance service of power generation facility first reads latitude/altitude coordinates from GPS sensor of smart phone, transmits it to power generation facility management server and power generation management server obtains lineal distance (Euclid distance) with power generation facility location stored in server based on transmitted coordinates and guides location by transmitting location of power generation facilities to site manager through a stage of transmitting ID, GPS coordinates of power generation facility within radius of 5km.

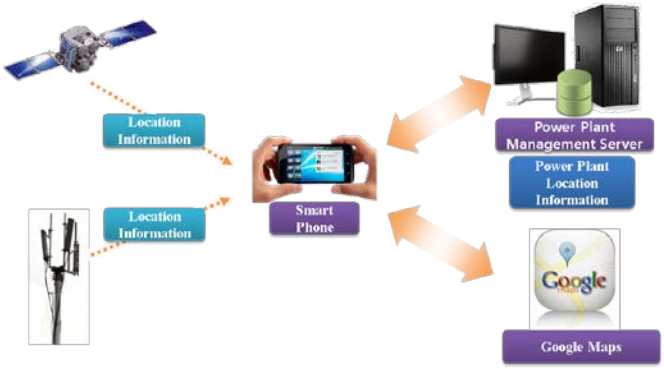


Fig. 6. Guidance service of location-based smart grid power generation facility

E. Smart phone application for smart grid power generation facility management

Major function of smart phone application using power generation facility recognition technology is to recognize power generation facility through smart phone image at site using power generation facility recognition technique and identify location information including its latitude/altitude being interfaced with Google map.

In addition, it may monitor current measurement information of facility such as voltage, current, active, reactive power, provide its detailed information for model name, manufacturer, hard ware layout and manage history of power generation facility.

Intuitive and convenient use is allowed by providing history management, current condition and HW related detailed information in a way of recognizing power generation facility through camera view of smart phone.

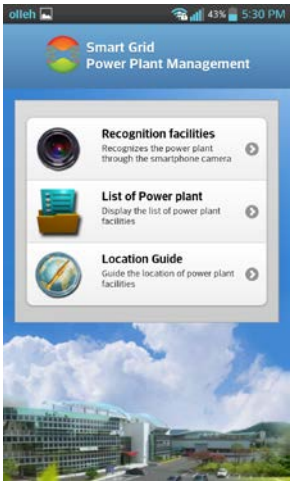
Smart phone application supports both android smart phone being utilized most widely and IPhone and its application was implemented in a hybrid mode using PhoneGap in order to ensure application to smart phone of diversified platforms based on development of just one time.

In addition, user interface of mobile application was composed by using HTML5 and JQuery Mobile and control module of GPS sensor and camera were developed by utilizing PhoneGap library and JavaScript.

Screen of the result of implementing smart phone for smart grid power generation facility management being suggested in this paper is as follows.

Fig. 7 is a screen of log-in implementation that certifies user by transmitting manager ID and password to server after receiving it at site and main menu implementation.

(a) Log-in



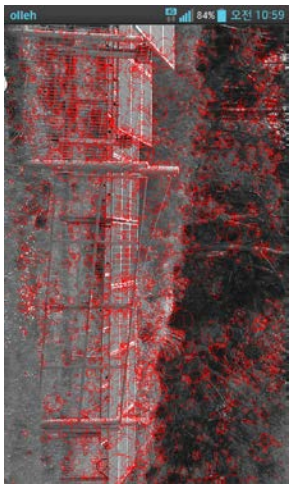
(b) Main menu

Fig. 7. User log-in and main menu

Main menu is composed of three menus including facility recognition that recognizes power generation facility through camera, power generation list that may inquire overall power generation facility and its location guidance and when touching relevant menu, each function is performed.

Power plant recognition transmits data to server after extracting feature points through SURF algorithm followed by photographing panoramic image by using GPS and image sensor of smart phone as shown on Fig. 8.

(a) Facility image 1

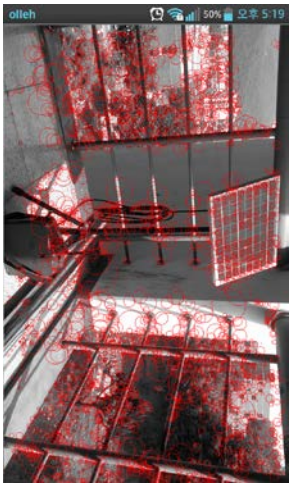


(b) Feature point extraction1

(c) Facility image 2

(d) Feature point extraction2

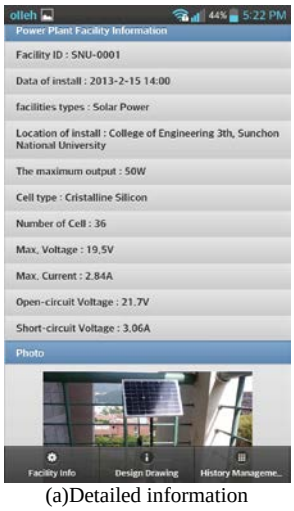
(e) Facility image 3



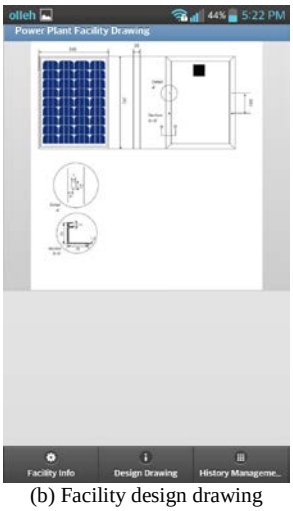
(f) Feature point extraction 3

Fig. 8. Facility recognition

In server, by matching transmitted data with stored data, coincided power plant is found out and as shown on Fig. 9, detailed information, design drawing and management history information of power plant are provided to workers through wireless communication.



(a)Detailed information

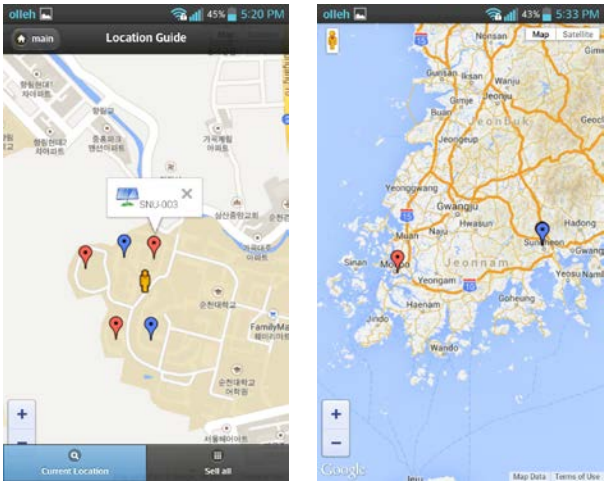


(b) Facility design drawing

(c) Facility management history

Fig. 9. Facility information

Site manager could receive information of current location and overall location of power generation facility as shown on Fig. 10.



(a)Current location guidance of site manager (b)Total location information

Fig. 10. Location guidance service of facility

When implementing location guidance service of power generation facility, it is guided through visualized Google map and when selecting marker of visualized power generation facility, type and information of relevant power generation facility are outputted.

marker being visualized in Google map indicates current location of site manager, marker indicates location of wind power generation facility and marker indicates location of power generation facility, respectively.

IV. EXPERIMENTS

Experiments were composed to test whether the proposed system recognizes power generation facilities and provides its status and detailed information.

The test-bed consists of a small solar panel, an inverter, a battery, a gateway, a power generation facility management server like Figure 11.

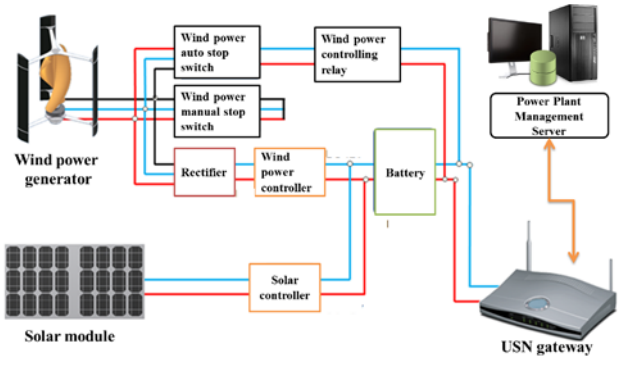


Fig. 11. Diagram of Test-bed

A test was conducted whether it would be possible to check the current status, measurement information, details and temporal data of the power generation facility module using a smart phone.

In addition, the results of a test on recognition rate and recognition time of the power generation facility by angle are like the following Table 2.

TABLE II
FACILITY RECOGNITION TEST

Evaluation item	Front	30°Side	45°Side
Recognition rate (%)	100	92	78
Recognition time (ms)	452	456	470

The power generation facility recognition rate of the proposed system was 100%, 92% and 78%, respectively in front, side angles 30° and 45° like Table 2. The recognition time was 452ms, 456ms and 470ms, respectively in front, side angles 30° and 45°.

It turned out that in spite of a little difference by angle, it recognized the power generation facility accurately, overall.

V. CONCLUSION

In this paper, facility recognition based mobile smart grid facility system by which site manager recognizes smart facilities by using GPS sensor and image sensor of smart phone or tablet PC and diversified information including detailed information, HW drawing, sensor data, management history of facility and location guidance are provided to site manager was suggested.

By having developed smart application based on hybrid architecture, it is expected that simultaneous support to almost all the smart phone platforms would be allowed based on its development of just one time and intuitive and convenience use would be possible by recognizing power generation facility through camera view of smart phone and providing its information to site manager.

In addition, as site manager is able to receive detailed information of facility at site, efficient maintenance for regular check-up and failure could be performed conveniently, overall operation cost could be reduced and furthermore, by using facility recognition technology instead of existing QR code, its direct application is possible without any need of adding equipment to smart grid facility currently under operation.

Owing to development of facility recognition service through markerless based facility recognition technology, it is expected that it may be expanded to technology recognizing T/R facility of smart grid and other facilities in the future and its cheaper construction would be possible as well.

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