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그린산업 육성을 위한 농업분야 IT융합기술

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IT Convergence Technology in Plant Growing for Low-Carbon Green Industry

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■ Abstract ■

Recently, The Bali Road Map was approved, as it demands that developing countries should also have the responsibility of greenhouse gas reduction from 2013. This suggests that the greenhouse gas and environment should be controlled across industry sectors. Accordingly, this study was conducted to identify the application and effects of the IT convergence technology to the smart farm and realize the low-carbon green industry in Korea.

The smart farm technologies within and outside of Korea were comparatively analyzed for the low-carbon green industry policy. The study subjects were determined to propose the necessity of the study efficiently.

First, the studies on the smart farm for low-carbon green industry policy were examined.

Second, the suitable IT technology for the smart farm as well as the effect and the improvement plan of the IT technology-based smart farm system were examined.

This study now aims to promote the low-carbon green industry policy and IT convergence technology and job creation. These will be achieved by providing the plan for linking the system simulator organization with the low-carbon green industry policy.

Keyword : Smart Farm, Programmable Logic Controller, Low Carbon, Green Industry, IT Convergence

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1. Introduction

1.1 Purpose of the Study

The Bali Road Map was approved, as it demands developing countries to take on the responsibility of greenhouse gas reduction during the second period of the Climate Change Convention since 2013. The discussion on the detailed reduction goal, contents, and methods will be completed in 2012. This includes the presentation of goals and policies on greenhouse gas reduction for each country, the climate change adaptation, as well as the research and development. In addition, studies are actively conducted on the eco-friendly and intelligent farming. The problem of the relevant studies within and outside of Korea is that the comprehensive controller for the farm, especially the one controlling the environmental elements (e.g., temperature, humidity, CO2, and culture medium and light source), has not been sufficiently studied. Besides, there is no efficient system for the energy source [1]. This means that most studies have analyzed the farming methods focusing on the culture medium and light source [2]. This is anartificial method which is the same as the existing method for growing plants in the greenhouse. Mass production and unmanned farm are also not possible. Therefore, studies are required for the mass production and unmanned farm, according to a new concept other than the concept of greenhouse.

To ensure the efficient mass plant production and unmanned farming, this study has proposed the organization and the establishment of a plan for a comprehensive farm control system. The supply system for energy source in the farm is operated with culture medium and light source in the concept of greenhouse. Similarly, the supply system is supported with IT convergence technologies for the control of soil temperature, humidity, water supply, solar power, and wind power generation.

1.2 Subject of the Study

The following subjects were determined to achieve the necessity of the aforementioned study efficiently.

Study Subject 1 : The difference between the Korean and overseas smart farm system studies
Study Subject 2 : Applicable IT and application plan for the smart farm
Study Subject 3 : The effects of the IT-based smart farm system and its improvement plan

1.3 Study Method

This study provides a comparative analysis of existing studies on the smart farm system in Korea and two other advanced countries, conducted between 2006 and 2010. The recent IT design technologies and application plans were also studied. With the conclusion of the aforementioned study, the system organization for linking the smart farm system with the low-carbon green industry policy, its improvement plan, and expected effects were likewise included in the study.

2. Relevant Technologies Within and Outside of Korea

2.1 Studies on the Farming System in Korea

In Korea, there is urgent need Strengthening the competitiveness of agriculture in terms of production, processing and consumption. And development of high-quality services is particularly essential for provide safe food to consumers [3]. and Different sectors that include the Ministry for Food, Agriculture, Forestry and Fisheries; the Rural Development Administration; the Gyeong sang buk-do Agricultural Research Service; Gang neung-Wonju National University, and Insung Tec Co., Ltd., among others study farming. Their studies cover the core elementary technologies for plant cultivation, including the cooling-heating system for temperature/humidity control, carbon measurement system, nutrient supply system, LED source, and unmanned automated system. The research and development, however, are not sufficient in terms of high value added and core industry convergence.

A concrete study system is required to introduce the technology and energy source systematically. In addition, the plant farm is still at the stage of the vinyl greenhouse concept. Its internal devices merely include pumps, thermometers, culture medium hose, and fluorescent lamps that are not controlled by any specific device. Only the individual environmental element controllers involving carbon measurement and pan operation are found in some cases. Therefore, the unmanned automated system for mass plant production and reduced economic burden requires the comprehensive smart farm automated-control system based on the IT technology for each element.

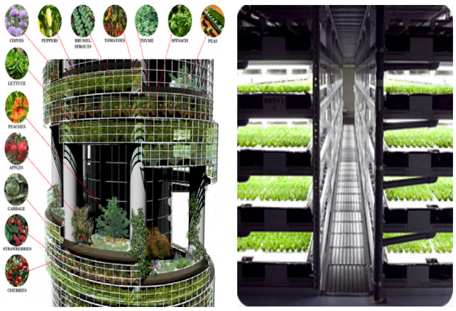
2.2 Studies outside of Korea

In the U.S., a feasibility study was conducted on a thirty-story building farm in July 2008, as one of the smart farm studies. The investigation results show that 200 to 500 million-dollar building farm can produce food for 50 thousand people. The analysis results by Professor Des-

〈Table 1〉 Research activities in Korea

Institution	Main Activity
Ministry for Food, Agriculture, Forestry and Fisheries	◦ 2009 technical demand survey and 2010 three-year plant production factory core elementary technology development project, underway ◦ As of June 2010, contractor selection and three-year core elementary technology development, underway
Rural Development Administration	◦ Core elementary technology development ◦ Horizontal automated plant cultivation system in the greenhouse and LED light processing device for farms ◦ Plant production factory system developed for stable year-round leafy vegetable production (2005)
Gyeongsangbuk-do Agricultural Research Service	◦ Study of stable heading-type lettuce production technology using LED, underway ◦ Fruit gardening, vegetable gardening, and agrochemistry studied
Academia	◦ Core technology for the plant factory is studied in Seoul National University, Kyungpook National University, Gangneung-Wonju National University, Daegu Technical College, and Hankyong National University ◦ Light source, nutrient, and crop
Private sector	◦ InsungTec Co., Ltd. developed the vinyl-greenhouse-concept horizontal automated plant factory system (2008 S&M enterprise technical innovation project) ◦ 165-m2 vinyl greenhouse plant factory was constructed in Yongin, Gyeonggi-do

pommier of Columbia University also showed that the vertical farm produces 10 times higher crop than that of the open-air farmland [4].



[Figure 1] Vertical Farm Concept of the U.S. and Settlement Support Center of Japan

In Japan, the settlement support center Pasona O2 grows rice, vegetables, and flowers such as roses underground, using artificial light sources and hydroponics. This is being promoted to create jobs for the retirees, the aged, and the young people who cannot find jobs [5].

In Canada and the UK, the construction of plant factories is being planned.

2.3 The Pros and Cons Analysis on the Domestic and Abroad Research Situation

In the U.S., the research to commercialize the plant factory has been very active. The research of the overall control systems for the environmental elements such as temperature, humidity, carbon dioxide, culture fluid, supplementary light sources has been sluggish. The systems for the energy sources are not established. The funds for investing to build the plant factories are not prepared. Theoretical research has been done so far.

In Japan, the Government-oriented research has been active. But, currently, the investment is sluggish and Pasona Plant Company has stopped the production due to the power supply problems. The commercialization has failed repeatedly [6].

<Table 2> Research Activities in Different Countries

Country	Main Activity
US	◦ Vertical farm project and nutrient/temperature settings for the vertical farm by crop (Columbia University and others) ◦ Commercialization such as the production of 6,000 semiheading lettuces in the plastic greenhouse (Whittacker) ◦ 16 lettuce crops, 7 eggplant crops, and 4 pumpkin crops with the sealed NFT hydroponics (General Electric) ◦ Commercialization failed because of high-power consumption (Genera Mills) ◦ Feasibility study on a 30-story building farm in Manhattan and Las Vegas ◦ Planning of a 200 to 500 million-dollar building farm that produces food for 50 thousand people
Japan	◦ Control of the plant factory using the solar light is being studied. ◦ Growth diagnosis via SPA and plant factory control using the lighting are being studied. ◦ Settlement support center Pasona O2 is growing rice, vegetables, and flowers, including roses ◦ Completely controlled plant factory with lighting is being studied. ◦ TS farm allows a high-cost effectiveness and expanded distribution of plant factories (Q.P Corp) ◦ Frilly lettuce and romaine lettuce are produced and sold to malls or hotels (SPREAD) ◦ Department store directly grows and sells vegetables (Daiei)
UK	◦ Europe's first plant factory established in the Paington Zoo in Devon (October 2009) ◦ Commercialization underway
Canada	◦ World's first vertical farm, named sky farm, is being constructed in Toronto.

In Korea, Gyeonggi-do Institute of agriculture has developed a plant factory with reduced the energy consumption utilizing the solar energy. The factories are offered to the farmers at reasonable price. The paradox is that the plant factory consumes much more energy compared to the conventional farming.

In time, this problem will be eventually resolved due to the Government's efforts to secure the CCS (Carbon Dioxide Capture and Sequestration) technology. The new opportunities will be given to the existing agriculture and industry due to the nature of the Smart Farm fusion technology. The active researches for the commercialization and the key element technologies for Smart Farm are prospected [7].

3. Farm and IT Convergence Technology

3.1 Study Subject

As mentioned, the results of studies within and outside of Korea and institutions' opinions were collected, and relevant implementation cases of relevant systems were examined. The U.S. and Japan are leading the advanced smart farm studies actively conducted on the solar light, lighting, cost competitiveness, and plant factory control. Meanwhile, in Korea, the studies on the light source, nutrient, and control system are in their early stages. The light source and nutrient are actively being studied, but the control system has not been studied yet. To catch up with the advanced countries, the studies on the control system need to be combined with the domestic IT technology which is excellent in terms of the computer (e.g., PLC and software).

IT convergence technology is technology to create a new IT service technology by combining information and communication technology (hardware and software) with other industries, In other words, IT convergence technology is convergence of hardware, software, network and content and service. Accurate recognition of this convergence concept will be able to realize openness and sharing, and participation, Motto of Web 2.0. It also will accelerate the launch of Web 3.0 era to provide Optimized information to individuals [8].

Accordingly, an application plan of the IT convergence technology was developed for the smart farm with the energy source for the low-carbon green industry policy.

In addition, the study results were presented via the detailed design and prototype organization of the system.

Based on the study results, a program was made, and a prototype system was developed to establish a farm. This study presents the expected effects from the comparative analysis results, combination plan, and implementation plan and design. This study covered the plant cultivation studies in Korea, the US, Japan, the UK, and Canada, including the automated plant factory system of private enterprises.

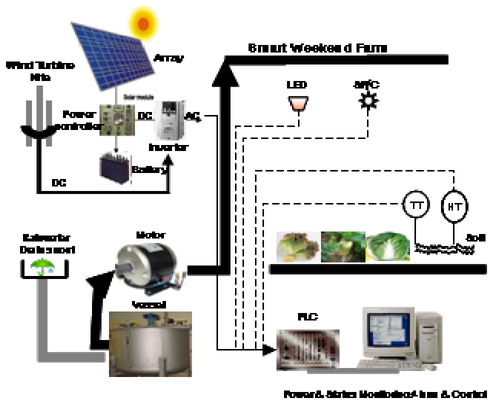
3.2 Development Goal

The goal of the development is to make a smart farm simulator to prepare the plan for automated low-carbon plant production. It requires the elementary technologies, including energy sources such as wind power and solar power, farming and device monitoring, motor control, microprocessor, PLC programming, and wireless interface [9].

The system-monitoring program is developed using the graphic user interface (GUI) for the users' easy handling [10]. Based on the established elementary technologies, the PID control technology is applied to complete the program for monitoring and device control [11, 12].

3.3 Development Contents and Range

The smart farm system in [Figure 2] is developed in three sectors : power source, control panel, and local device. First, the power source consists of a wind power turbine and a solar energy collector. The electricity is stored in the battery via the solar energy collector [13]. The wind power turbine compensates the decrease in the solar energy during rainy season and provides additional energy during ordinary days. Many small turbines must be installed in the building considering the building area and wind speed. The turbines supply the power to the smart controller, smart system, and local devices (light, spring cooler, motor, transmitter, indicator, etc.). The devices require 110/220V power, which is converted from DC to AC through the inverter [14]. Second, the control panel consists of the smart system and smart controller. The smart controller is installed on each floor of the green farm. It consists of the CPU that has the control intelligence, analog input (A/I), analog output (A/O), discrete input (D/I), and discrete output (D/O) modules [15] that monitor and control local devices. While exchanging signals with the smart controller, the smart system monitors and controls the facility and device conditions and hydroponics environment of the green farm [16]. Third, the local devices include the transmitter and control valve for measuring and controlling a number of factors : the level of water in the vessel flowing from the drain spout; the LED lighting that provides light to plants; sprinklers that provide water; the transmitter and temperature/humidity control facility that measure and control the temperature and humidity in the farm; and the motor in the motor control center (MCC). These are monitored and controlled via the smart controller by the smart system.

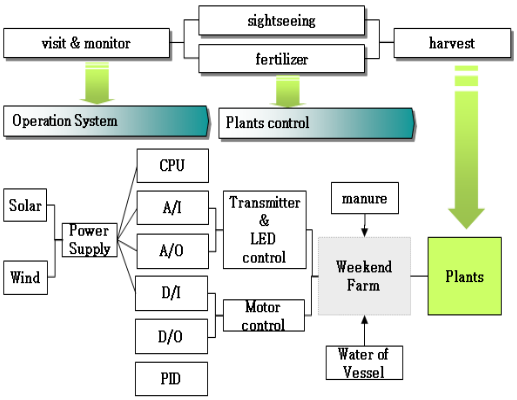


[Figure 2] Smart Farm System Diagram

3.4 System Operation

The data for controlling the temperature, humidity, illuminance, and water suitable for the plant growth are inputted in the PC connected to the PLC. The AI module in the PLC receives the data from the transmitter that measures the temperature and humidity in the farm, and starts the operation of the motor via the D/O module to control the temperature and humidity of soil. The light source (illuminance) for plant growth is controlled via the A/O module. The water is supplied by the sprinkler operation from the vessel so that the humidity measurement coincides with the set value. The PC provides the power/status monitoring screen and the alarm/control-monitoring screen that sounds the alarm when there is malfunction in the data and device.

Because the nutrient is supplied one or two times every crop season, it is not controlled but supplied by manual injection. The wind and solar power supplies the power to the system, lighting facilities, and PLC power supply (P/S) module. The DC power is supplied from the PLC module to the DC devices. The rainwater is collected in the vessel, and is used to supply humidity to the farm.



[Figure 3] Operation Block Diagram

3.5 Difference between Developed and Existing Technologies and Advantage of the Developed Technology

The proposed technology has three different characteristics compared with the existing technology.

First, as for the power source, the existing technology receives power from the power company to supply nutrient and lighting. This system, however, supplies the electric power to all facilities and devices in the farm, and ensures self-sufficiency of electric power. The remaining power can be sold to the power company to create income.

Second, as for the control panel, the existing technology runs the laboratory for nutrient culture and uses beakers and culture medium, and the lighting apparatuses are being changed from fluorescent lamps to LEDs for plant growth. This system automatically controls all the devices that include LED devices, rainwater storage (vessel) for water supply, and water transfer (pump) devices. Therefore, the standby time and effort and labor cost can be minimized as manual operations decrease and farming is remotely monitored.

Third, as for the local devices, the existing technology measures the temperature and humidity of soil using the thermometer, hygrometer, or the gauge on the panel in which they are built. This system automatically controls the temperature and humidity, and displays the temperature, humidity and operation status of devices, including motors on the display. Therefore, it can reduce the economic burden for purchasing unnecessary instruments, and ensure smooth maintenance and farm control.

With a solar power of 1kW, energy production (except for wind power) amounts to 1kW times 3.72 hour per day, which equals to 3.72 kWh per day (3.72 hour per day is a yearly average of sunny period, assuming energy of 1kW/m^2). The power conversion efficiency of the system power module is approximately 70%, and 30% of the power is consumed in the form of heat. Therefore, 3/7 of the output power corresponds to the power consumption. Accordingly, the power consumption of the power module is calculated as follows :

Wpw = 3/7×(I5V×5) (W)

(I5V : current consumption in the 5V DC circuit in each module)

The calculation of the total average power consumption, including all I/O modules, becomes approximately 15.88 W. The power production is approximately 250 times higher than the power consumption. Therefore, the remaining power can be used to control local devices, including motors and instruments. In addition, if the energy production standard is increased from 1 kW to 10 kW, the remaining power can be used for other applications, e.g., domestic use.

4. Effects of the DevelopeD Technology

4.1 Application of the Developed Technology

The proposed technology can be easily applied to plant production without previous farming experience by controlling the plant growth environments (temperature, humidity and culture fluid). In this research, a slim line Smart Farm (Smart Farm S named by Insung tech) is proposed. The Smart Farm S has the following specifications.

Smart Farm S is a closed plant factory with the width less than 80cm requiring the minimal installation space in the store. The internal environmental factors can be fully controlled due to the sealed structure. The vegetables can be grown and used in the Smart Farm S installed within the restaurants [17].

[Figure 4] Drawing of Smart Farm S

〈Table 3〉 Specification

Classification		Spec	Remarks
Specification	size	2,030(L)×745(W)×2,000(H)	
	cultivation Quantity	60(Plate)×180(Pot)	90/month
	Power Consumption	1,100(W)	
Environment Control	Temp/Humidity	Cooling 2,300(W)	
		Power Consumption 0.65KW	
	Culture fluid supply	Automatic Culture fluid supply	Culture fluid Circulation device
	Light source	LED	Bar style
Automatic open and closing device	Cultivation Bed	ABS Injection method	
	Slide method	Automatic Control	
	Opening and Closing	Air Curtain	
	Culture ffluid supply	Automatic Culture fluid Control device	Automatic/Manual

4.2 Expected effects of the Developed Technology

The expected effects of the developed technology is that it can improve the growth potential of convergence service and green product market as a next generation growth drive via the convergence of green energy, green production environment, and IT. The green industry can be promoted by producing the carbon measurement instrument, oxygen supply, air filtration device, and solar and wind power systems as alternatives of fossil fuel. Thus, it can contribute to the enhancement of the food, agriculture, forestry, and fisheries industry and the spread of IT. The use of IT can enhance the food, agriculture, forestry and fisheries industry, and address the aging of farming population, clean food development, environmental problems, and quality of life. In addition, it can create new jobs and have an economic ripple effect.

It is expected that the economic effect of the IT convergence technology in the food, agriculture, forestry, and fisheries industry will amount to 50.9 billion dollars in 2010, and 96.7 billion dollars in 2015. The number of jobs created in the building construction, facility fabrication, weekend farm, free-sample stands, restaurants and sightseeing will amount to 190,000 in 2010 and 260,000 in 2015.

With lettuce as an example of vegetable cultivation, 500 heads/m2 can be produced with fast crop cycles reaching up to 18 times a year. This is about five times larger than that of bare ground cultivation, which produces approximately 108 heads/m2 with 3 crop cycles a year. As the recent climatic disasters and weather changes pose problems in securing food crops, it is expected that the demand for plant farm will increase, and that the world's plant farm market

〈Table 4〉 Expected Effects

Item	Description
Technical aspect	◦ IT supports automation and farming technique so that the aged and novices can easily start farming. ◦ Hybrid new and renewable energy technology cuts the construction cost, and provides hybrid system to the farm. ◦ Application technology is spread for the implementation of u-City. ◦ Advanced automated control technology is realized by the use of the automated farming system.
Economic and industrial aspect	◦ Problems, which include the use of food resources as weapons, global warming, and challenges in clean vegetable production, are solved. ◦ High value-added agricultural products are produced and farm income increases. ◦ The convergence of the agricultural technology and next-generation industrial technology creates a new agricultural business model and jobs.
Application	◦ Clean plant cultivation in residential complex for residential environment improvement and high value added ◦ Increase in the profitability via high value-added cultivation of special-purpose crops and medicinal plants ◦ Establishment of the basis for sale overseas (developing countries) ◦ Construction in Mongolian and Chinese deserts for the prevention of yellow dust

will continue to grow and reach 2,7 billion USD.

5. Conclusion

The green industry is considered a new future growth drive. With the increasing demand for the IT convergence in all industries, IT is combined with diverse challenges, including job creation, green industry, and the diversification of future industries. The green IT convergence industry has a vision to become a future growth drive and a potential of creating a new business model through its application to the technical resource information. Therefore, diverse green industry functions and methods need to be introduced to ensure IT convergence, expert training, and job creation for future industries from the view of discrimination via green industry and IT technology, as the direct preparation of development system.

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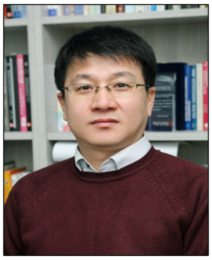

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