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A study on development of ICT convergence technology for tracking-type floating photovoltaic systems

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Abstract

This thesis seeks to establish the foundation for tracking-type floating PV system using ICT fusion technology through acquisition of data regarding solar power generated, amount of insolation and solar tracking sensor and real time monitoring of the system. Prior to implementation in the field, Zigbee based sensor node and coordinator of 2.45GHz bandwidth has been produced and tested by transmitting data received from sensor to coordinator and allowing monitoring not only in operation management PC, but also through mobile devices. In the process, wireless communication coordinator and middleware for information collection have been designed and tracking controller was developed. This thesis also pursues formation of low-cost, high-efficiency USN framework through analysis of signal conditions and speed of transmission.

Keywords: Tracking-type floating PV system, wireless sensor node, USN, gateway

1. Introduction

As communication develops, communication media is becoming more diverse and high speed. Therefore, an essential component in establishing information oriented society is communication method. In this regard, system that allows for inexpensive and convenient data collection and dissemination is required [1]-[3]. Such environment can come to realization through USN (ubiquitous sensor network), a network that collects and manages data through sensors.

USN monitors, stores, processes and integrates object and environment information from sensor attached to objects/living space. Through generation of condition recognition information and knowledge contents, USN is a ubiquitous IT technology [4],[5] of new paradigm, which serves as infrastructure for modern intelligent society, capable of expanding the span of informationization from current human centered around objects. Grafting sensor to wireless device, enhancement of productivity, safety and human living standards will be achieved through acquisition of vast information of constantly changing physical environment by communication and computing between object and human.

Data such as amount of solar power generation, temperature, humidity, insolation amount, wind speed, wind direction, solar tracking sensor are very important components for solar radiation on water, and such data is transmitted to wire network to be monitored. Although safety of transmitted data is ensured, initial investment and maintenance is difficult, while additional monitoring has a downside of costing a lot [5], [6]. Therefore, this thesis developed Zigbee sensor node and coordinator in 2.45 GHz range in ubiquitous groundwork, confirmed data transfer route through wireless mesh network, and formed monitoring and control screen in order to collect data transmitted from sensor node and achieve mobile application.

2. USN Based Tracking Photovoltaic Surveillance Technology

2.1. Tracking photovoltaic system

Solar power generation is categorized into fixed, which fixes the angle of solar module angle at a

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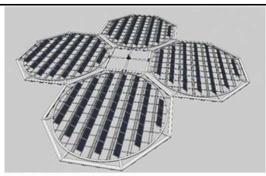
particular angle, and tracking, which tracks the direction and altitude of the sun in order to receive solar radiation in perpendicular angle. Tracking solar power generation is a high efficiency power generation system that generates more energy due to its tracking function, which tracks the sun real time. When installed on the ground, tracking generally generates 30% more power than fixed method.

Tracking photovoltaic system assesses the availability of effective sunlight and tracks the location of the sun, and is designed to perform precise automatic tracking even in circumstances of cloud or rain. For this purpose, solar radiation module is rotated with a separate mechanical device, however, the number of modules that can be rotated simultaneously is limited and frequent malfunction requires considerable amount of effort for maintenance.

In floating PV, the external forces including self-weight of the structure is transferred to the water through the buoyancy in the gravitational direction, so the length of the structure that can resist the gravitational direction can be designed with relatively more freedom. Also, as it floats on the water, it can rotate with a small amount of energy even if the unit rotation capacity is large (over 20 kW), the structure can be made simpler than ground tracking-type if tracking-type is applied to floating PV system, thus reducing malfunction risk and increasing efficiency. The features for each form were shown in the following Table 1.

Table 1. Characteristics of tracking-type floating PV

Classification	Form	Characteristics
Tracking-type floating PV		▫Rotates structures considering the floating characteristics ▫Unit rotation capacity can be greater ▫Increased generation amount than fixed-type ▫Relatively harder construction than fixed-type ▫Horizontal rotation-type and dual-axis type with tilt-variable added

2.2. Selection of wireless communication method and coordinator design

Digital communication method using cables, including analog transmission method, cannot fundamentally resolve problems of existing signal transmission system's method, which has problems with noise, cost of additional installation and inconvenience in maintaining the system [7]. To remedy the inconvenience in the wire communication method, wireless communication method was selected for data acquisition method, and compared various communication methods in Table 2 prior to constructing the system.

Table 2. Communication method comparison

Division	RF	Zigbee	Wi-Fi	W-CDMA
Communication distance	Max 1.5km	Max 300 m	Max 20 km	Radius 3~4km
Frequency	424 MHz	2.4 GHz	2.4/5.0 GHz	2.1 GHz
Channel bandwidth	6 kHz	5 MHz	20 MHz	5 MHz
Transfer rate	1.2~115kbps	250 kbps	2~20 Mbps	2.4~14.4Mbps
Power	+12Vdc ±10%	Battery Power, PoE	90~240 AC	USB Power (5V)
Output voltage	Within 10 mW	0dBm (1mW)	Max 50 mW	Max 200mW
Interface	RS232C	HART/Ethernet	Ethernet	USB
Standards	EIA	IEEE 802.15.4	IEEE 802.11b/g/n	W-CDMA (3GPP)
Construction case	Remote monitoring, PLC wireless connect	Power station, Gas flux, Pressure data transmission	Wnstream dam alarm, Cheonggyecheon	T-Login(SKT) iPlug(KT)
Application parts	Flux, Pressure monitoring	Purification plant (Data)	Wnstream dam alarm (Data + Image)	Outdoor administrators mobile management via W-CDMA
Purpose of use	Low, Middle distance	Low, Short distance	Bulk, Long distance	Bulk, Long distance, Mobile
Security	-	128bit AES	Authentic and Encryption	USIM card-based authentication

Prior to realizing the sensor node, optimal algorithm was derived using NS-2 (Network Simulator Version 2) a network simulation tool.

NS-2 is a discrete event simulator written in 0tcl and C++ language[8], used to assess various protocols such as TCP, routing, multicast protocol in wireless networks. 0tcl is a language that adds object oriented concept to TCL (Tool Command Language) script language, while TCL is a program language that allows control and expansion of application programs. TCL can be used by linking 0Tcl and C++ source and the simulation results can be displayed as GUI through NAM (Network Animator). Fig. 1 shows the simulation process.

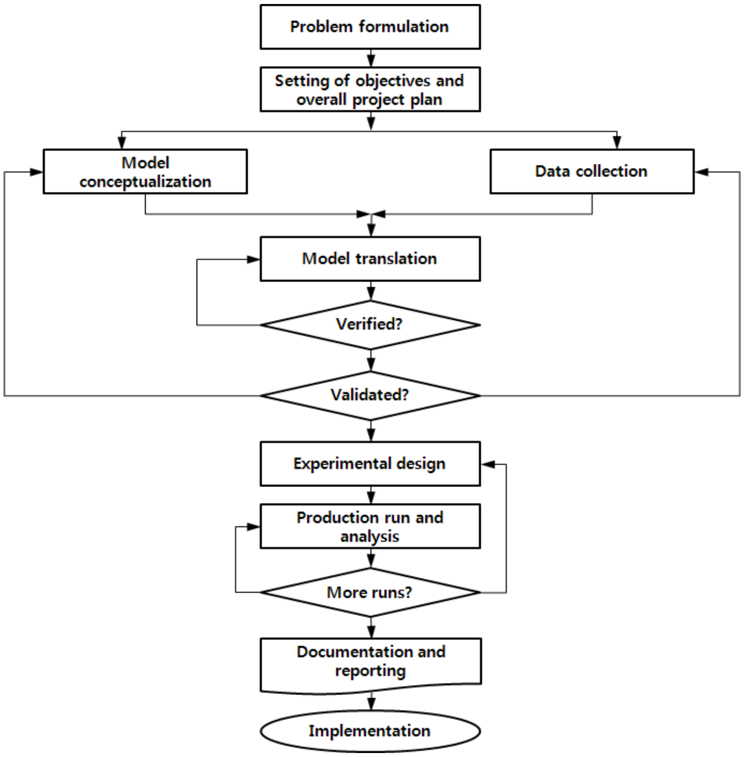
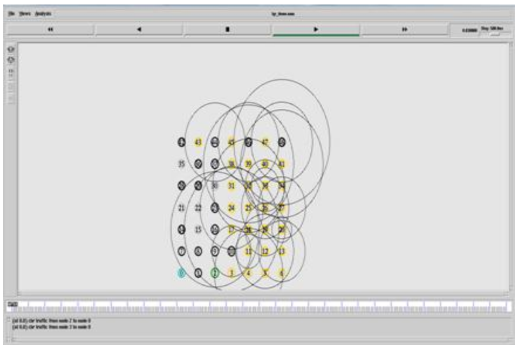
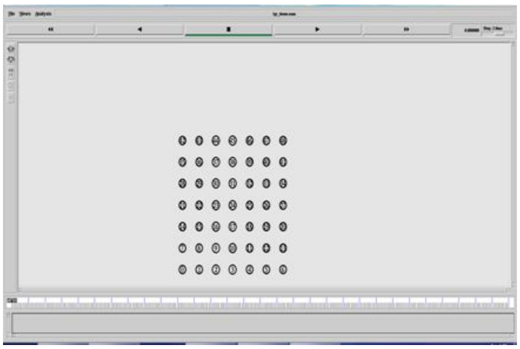


Fig. 1. Simulation process.

Similar to Fig. 2, this thesis observes the results of sensor network routing protocol simulation using NS-2. Average reception and delay time of packet transmitted from sensor node to sink node was compared and as a result, LGR (logical grid routing) proved to provide the most optimal performance.



(a) Simulation process



(b) Initial simulations

Fig. 2. Derivation of optimal algorithm.

In this study, Zigbee communication method was selected for USN wireless communication method in order to enable information sharing among sensors and each sensor performs a more intelligent function. To address the problem that Zigbee communication is short distance, wireless module was used for the coordinator to allow long distance communication.

Table 3. Zigbee coordinator

Division	Specification
Frequency	ISM 2.4 GHz
Transmit power output	60 mW (18 dBm), 100 mW EIRP
Supply voltage	2.8 ~ 3.4 V
Current	Transmit Current 270 mA (@ 3.3 V) Receive Current 55 mA (@ 3.3 V)
RF Data rate	250 Kbps
Receiver Sensitivity	-100 dBm (1% PER)
Network Topologies	Point-to-Point, Point-to-Multipoint, Peer-to-Peer and Mesh
Power-down current	< 10 uA
Number of channels	13 Direct Sequence Channels (software selectable)
Antenna	U.FL Connector, Chip Antenna or Whip Antenna

Coordinator is a device that connects one network to the other; therefore, a coordinator is required in order for the data measured by sensor node to be transmitted to the operation management monitoring PC.

Zigbee coordinator (Table 3) used in this study transmits the information received from sensor node to the operation management monitoring PC through serial port. Configuration of network is shown in Figure 4, which performs RS-485 Ethernet interface communication.

Embedded software loaded in USN (ubiquitous sensor network) module, instead of intelligent control mechanism, uses primitive approach to control such as, solar module surveillance, environment sensor, tracking sensor, user alarm service, serial communication, Analog, and GP10 interface. Development of software to precisely process the limitations of I/O is required. In the case of MCU directly controlling, the surrounding circuits must be precisely driven so that the characteristics of each sensor are accommodated. In order to construct extreme power saving system, an efficient system operation programming, especially in terms of time and codes consumed, is essential. This software must have the modularity in order to be flexibly interconnected with solar power generation information collection middleware.

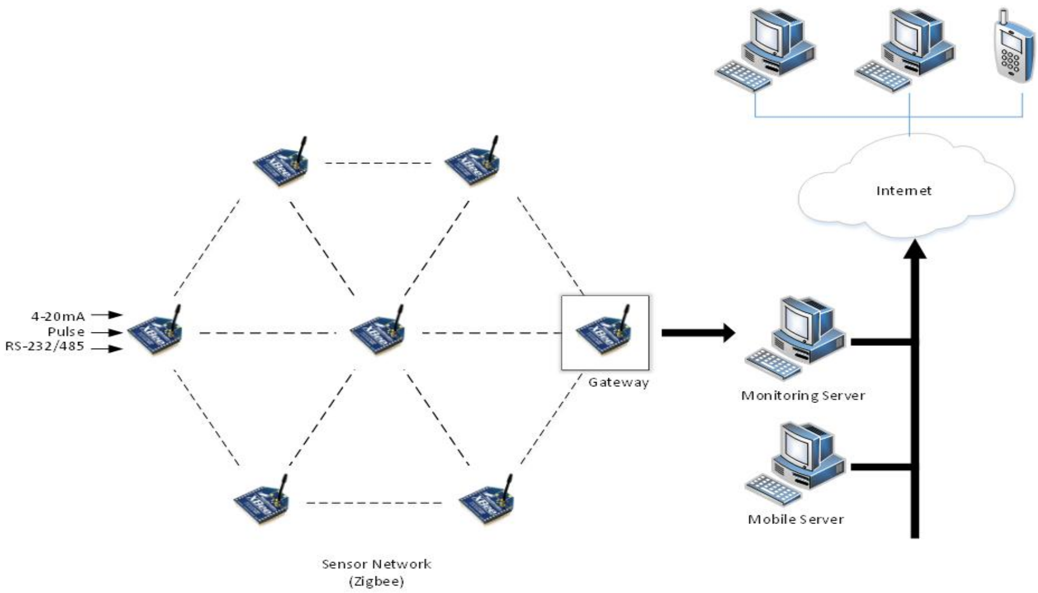


Fig. 3. Configuration of coordinator network.

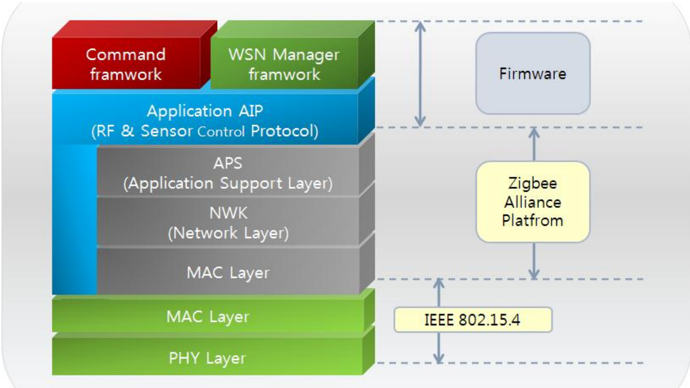
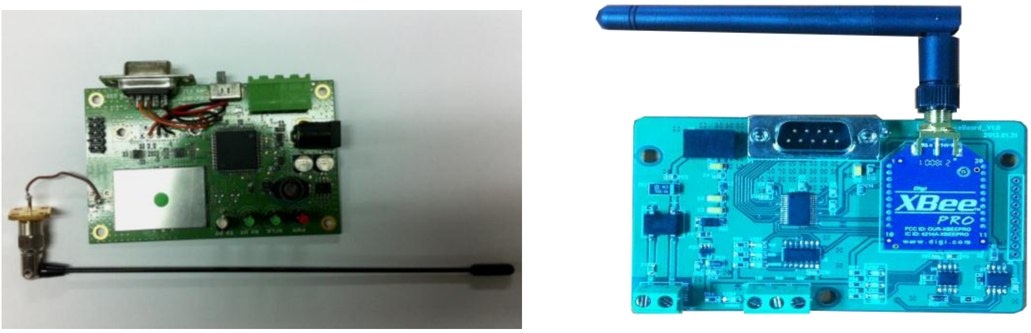


Fig. 4. Configuration of Zigbee stack.

Coordinator and each sensor nodes have been designed; CPU and peripheral parts resilient to temperature and humidity have been selected in consideration of its use on water. Optimized ZIGBEE stack has been used for smooth data communication between wireless sensor nodes, and communication protocol and protocol conversion Interface driver have been designed in order to enable interface with sensor.



(a) Wireless coordinator (b) Wireless sensor node

Fig. 5. Wireless coordinator and wireless sensor node (DV-Interface board).

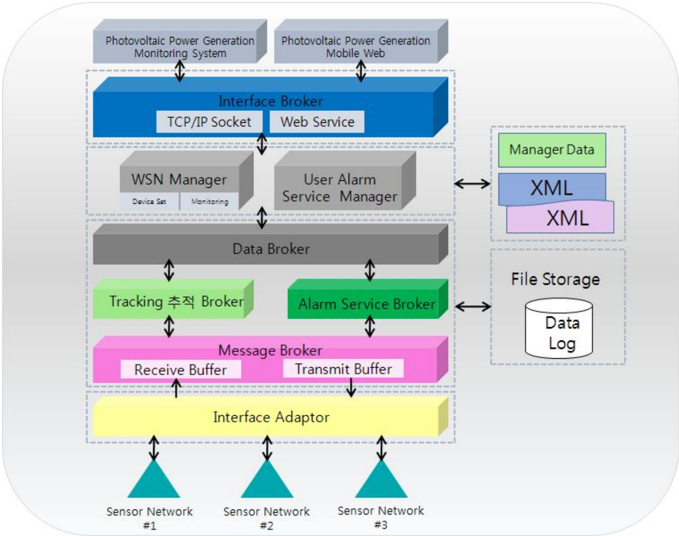
2.3. Middleware design for information collection

The most fundamental role of middleware is to collect data through coordinators in efficient aggregation of sensed data and in support of in-network processing of the data generated from solar module, tracking sensor, environment sensor through photovoltaic system's wireless sensor network. Solar power generator information collection middleware is being developed to process massive amount of data from many equipments and sensors without loss and deliver such data to higher systems. Also, power motor control, malfunction alarm and reporting business logic is loaded, allowing integrated operation.

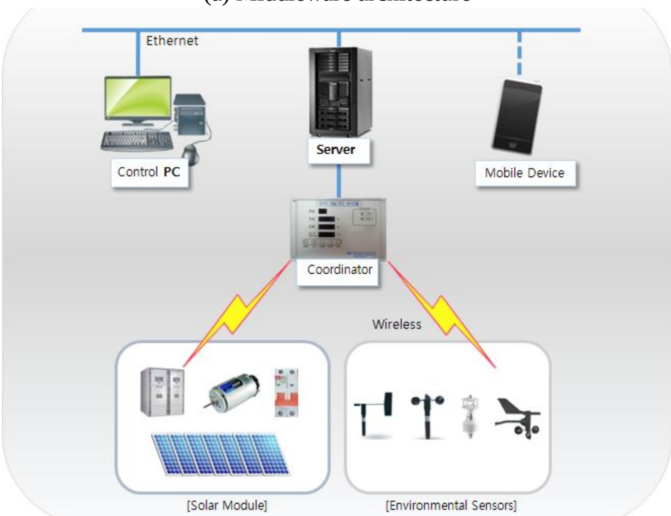
The middleware designed in this task enables smooth data communication interface between each wireless sensor nodes and has been designed and developed in Serial Device Server format composed of intermediately process' S/W and H/W in order to accomplish flexible data collection.

Also, various environment information and power generation status from each wireless sensor node on water is easily interfaced with PC. Middleware has been designed to allow load of communication protocol conversion S/W driver in order for the on-water solar power system to be optimized.

- Capable of independently processing 4 serial channels simultaneously
- Capable of directly connecting to serial device for use
- 10/100 Mbps Ethernet interface and serial interface support of up to 115200 bps
- Auto negotiation (full-duplex and half-duplex)



(a) Middleware architecture



(b) layout

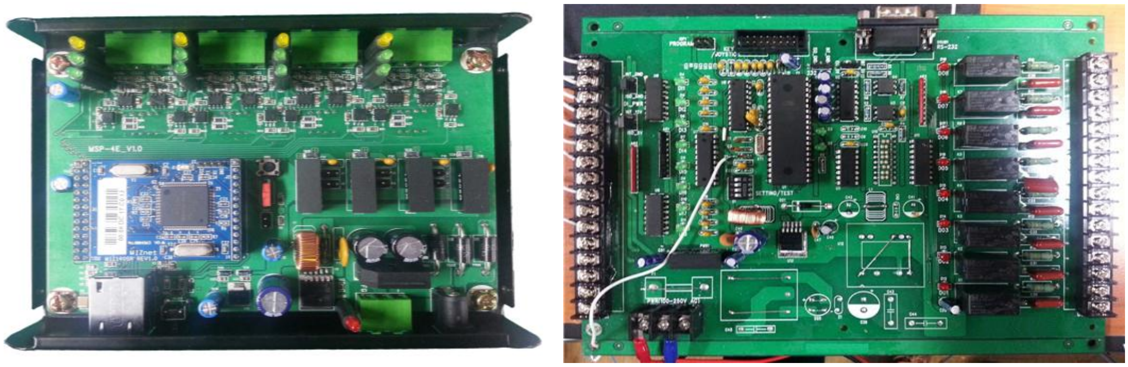
Fig. 6. Middleware architecture and layout for solar power information collection.

2.4. Development of tracking controller

For tracking control of prototype, the controller has been developed and applied, being composed of output section for motor control, serial port for external communication interface, D/I input section for interface with light sensor, etc. Capable of loading drive algorithm S/W, the controller has been designed to have enough input ports so that tracking information necessary for motor control can be received through sensor.

Table 4. Tracking controller specifications

Power	220V AC
D/I	Dry. C/12V 8Point (control BOX switch Interface)
D/O	Dry. C/Motor control 220V
Communication	Serial Port RS-232C
A/I	4~20mA /1Point
CPU	AVR Atmega16(8bit)



(a) Middleware (b) Control board

Fig. 7. Middleware and control B/D (TRACKER_CONT_V1.0).

2.5. Solar power monitoring system construction

Solar power monitoring system used in this study allows monitoring of solar module operation status and power generated through graphs that show the status and progress and aim towards developing monitoring system capable of confirming and lifting solar power system malfunction information. Also, construct efficient system utilizing smart devices to overcome limitations in time and space, developing differentiated application, and enabling remote monitoring of individual sensor node's status information, the lowest level entity in solar power monitoring system.

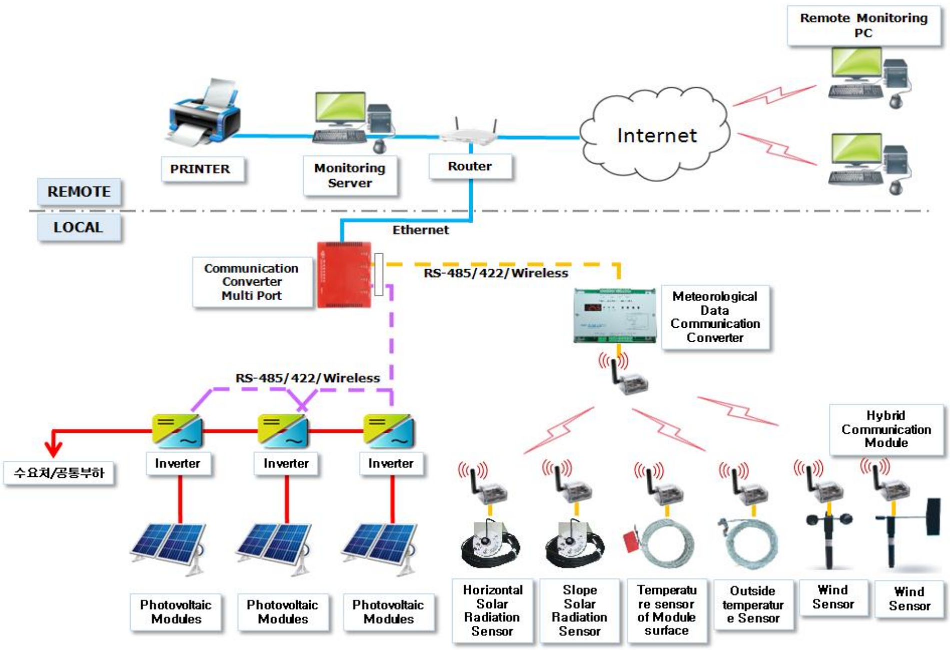


Fig. 8. Solar power monitoring system configuration.

3. Conclusion

In the thesis, a system which uses 2.45 GHz Zigbee network to construct wireless mess network and monitor data from amount of solar power generation, amount of insolation, solar tracking sensor has been implemented for real time monitoring of 100kW tracking on-water photovoltaic system. As a result of such implementation it has been confirmed that data path confirmation and communication setting through monitoring and control screen by wireless mesh network sensor node. Also, the system was constructed so that data surveillance and control is done not only by operation management monitoring PC but also by mobile devices, allowing remote broadcast monitoring. Also, perfect system is to be realized through testing and results analysis considering transmission algorithm for network optimization.

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