Green Base Station | Power Diversification | Power Control

Technology Reports

Environmentally-Friendly, Disaster-Resistant Green Base Station Test Systems

NTT DOCOMO is advancing the study of green base stations, which are radio base stations with environmentally friendly, disaster resistant energy systems. Toward this end, the R&D center has developed a test system aimed at increasing base-station backup time during power outages and contributing to power conservation and protection of the environment through effective use of ecological power generation devices. In this article, we give an overview of the green base station concept and describe our test equipment and basic operational results.

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1. Introduction

Recently, demand to reduce carbon-dioxide emissions and combat global warming has increased as part of corporate social responsibility [1]. The risks associated with the commercial power supply have also increased due to the nuclear power incident after the Great East Japan Earthquake in 2011. As a result, effective use of solar power and other ecological means of power generation to contribute to environmental protection, and increasing the stability of base-station power[2][3] are becoming issues.

On the other hand, base stations receive power from the power company during ordinary times and from lead storage battery backups during power outages. Since the earthquake, power companies have increased their use of fossil fuels[4], so decreasing dependence on commercial power also contributes to protecting the environment and alleviating power shortages. Thus, there is a need to consider how self-sufficient power sources such as ecological power generation and storage batteries can be used to diversify the base-station power supply.

The currently installed lead storage batteries are also large and heavy, which presents significant restrictions on facilities, making it difficult to increase battery running time. Thus, there is a need to use new types of batteries instead of lead storage batteries.

These conditions have lead NTT DOCOMO to study base-station energy systems that can supply power from diverse sources, adding ecological power generation and new storage batteries to commercial power. These sorts of configurations will also provide resistance to disaster, and value can be produced in terms of reducing the amount of commercial power used in ordinary times and contributing to protecting the environment by controlling power supply according to conditions. At NTT DOCOMO, we call base-stations with such energy systems green base stations. We have developed test

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equipment at our R&D center to evaluate the performance and stability of systems implementing this concept. In this article, we describe the green base station concept, our test equipment and results from basic operational testing, and discuss future prospects for these technologies.

2. Green Base Station Overview

An overview of a green base station is shown in **Figure 1**. Firstly, to better guarantee power during power outages, we diversify to use power sources other than commercial power, making base stations disaster-resistant. Candidates for power generation and storage include solar power, wind power, fuel cells and Lithium Ion Batteries (LIB)[*1]. Solar and wind power are ecological power sources that take environmental issues into consideration. Fuel cells can provide long-term backup by supplying them with fuel (methanol-water solution)[5]. LIBs also have longer lifetimes than conventional lead storage batteries and require only one fifth of the size for the same discharge time.

We assume green base stations will also operate during ordinary times, and not only during power outages. For example, by combining solar panels (photo-voltaics, PVs) with storage batteries, power generated by solar panels during clear weather can power the bases station, and when more power than is consumed by the base station is generated the excess can be used to charge the batteries. This reduces the amount of commercial power needed to charge them. Batteries could also be used to contribute to leveling the demand for power by charging them during the night time, when demand is low, and using the stored power when demand is high.

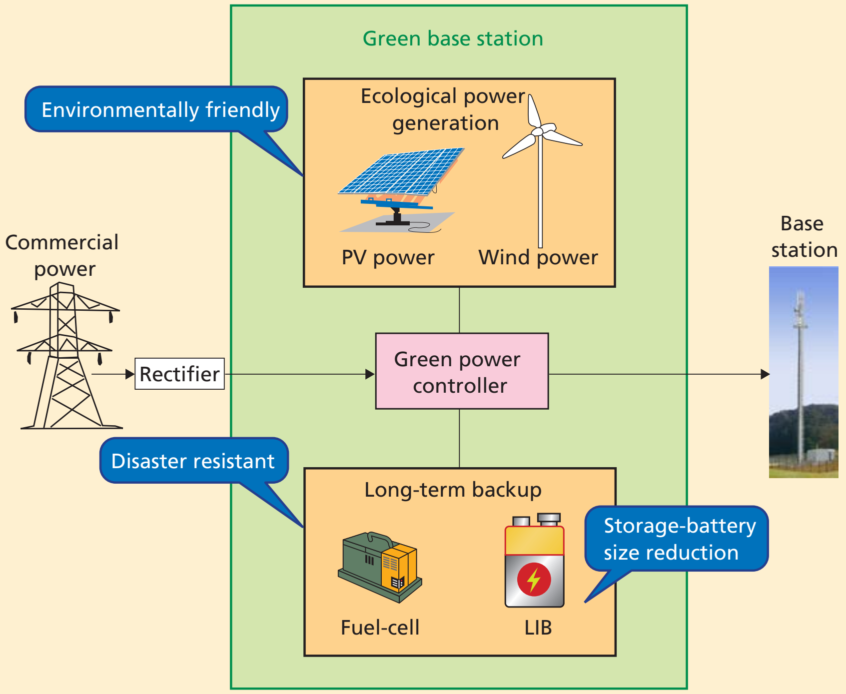


Figure 1 Green base station overview

Another feature of the green base station concept is its ability to create value during ordinary times as well, by controlling the supply of power from appropriate power sources according to conditions and reducing use of commercial power, thus contributing to environmental protection. By converting to green base stations, we can also increase the value of having storage batteries, which till now, were only used during power outages.

3. Configuration of Green Base Station Test Equipment

The differences in configuration between conventional base stations and green base stations are different storage batteries (from lead batteries to LIB), the use of ecological power generation, and the addition of equipment to control them. LIB are widely used in devices such as mobile terminals, but additional preparation necessary for installation must be clarified, including testing and evaluation of performance and safety when used on a large scale and in a fixed environment, as when

*1 **LIB**: A type of storage battery in which lithium ions in the electrolyte move during charging and discharging.

applied to base stations. Also, to combine multiple power sources, the characteristics of each power source must be understood (e.g. eco-power device fluctuation characteristics and battery charging and discharging characteristics), and controls must be implemented that will prevent interruption to communication.

Thus, we developed a test system at the R&D center (Yokosuka City, Kanagawa Prefecture. North Lat.: 35.13 deg., East Long.: 139.40 deg., Alt.: 87 m) to evaluate the performance and stability of systems for implementing green base stations. An external view of this configuration is shown in **Figure 2**. Four solar panels, each with a capacity to generate 200 W, were attached to the roof as an eco-power source. The housing on the left in the photograph holds a 4.5 kWh LIB and the green power controller, and the housing on the right holds a mock base station (without radio transmitter and receiver) that consumes approximately 300 W.

This test system implements the following functions.

- DC integrated control

  Commercial power (output from a rectifier), eco-power devices, and batteries are all connected directly to the green power controller, which provides integrated control as a DC power source.

- Power monitoring and control (visualization)

  The green power controller state can be monitored and controlled remotely. The capacity of each power source can be seen, and power supply switching can be controlled without interruption. The operating temperature range of the batteries is also maintained and charging and discharging can be controlled freely.

- Measurement and monitoring functions

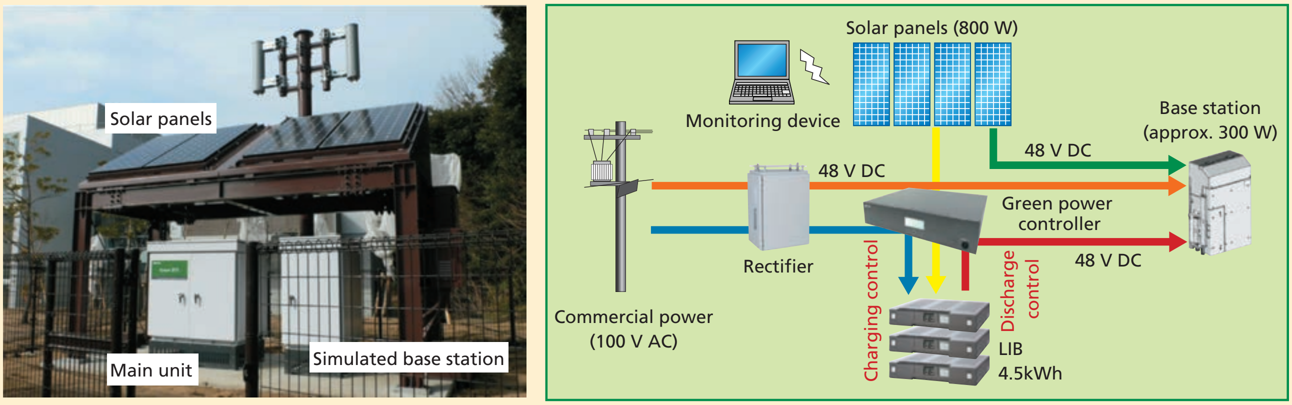
  This system is test equipment, so it includes measuring instruments for each power source, the state of these can be monitored and displayed, and the history analyzed to evaluate performance.

4. Green Base Station Test Equipment Basic Operation and Operational Results

4.1 Operating Modes

The operating modes of this system are shown in **Table 1**. Modes range from using only commercial power, to using commercial power, solar power and batteries together to supply power to the base station.

Figure 3 shows an example of real-time monitoring while operating in mode 4. In this mode, power is supplied using solar power and commercial power, and used to operate the base station and to charge the batteries. Note that if the solar power output exceeds that consumed by the base station (produced power ratio > 100%), the base



(a) Test system external view (b) Test system configuration

Figure 2 Green base station test system

station can operate on solar power alone.

Figure 4 shows an example of measurements when operating in mode 8. In this mode, power is supplied to the base station giving priority to solar and battery power, but also adding commercial power. The figure shows operation using almost no commercial power by increasing battery discharge when the solar power output decreases due to clouds or other factors.

4.2 Examples of Operating Mode Operation and Transitions between Modes

Table 2 gives examples of how these operating modes operate. The green power controller selects the optimal mode based on current and forecast weather conditions. In example 2, it is currently sunny, but the solar power generated is insufficient to operate the base station, so mode 3 is selected during the day. Further, the forecast for the next day is rain, so night-time commercial power is used operate the base station and charge the batteries, so that the base station can run on batteries and commercial power the next day.

The weather (amount of solar radiation) actually fluctuates through the day, so operating modes must switch automatically in response to this fluctuation. An example of a transition from mode 4 to mode 3 is shown in **Figure 5**. After the first 1:35 on the graph, battery charging completes so the current

Table 1 Test system operating modes

	Power supply			Power consumption	
Mode	Commercial power (rectifier)	PV generation	Batteries (discharging)	Base station	Batteries (charging)
1	●			●	
2	●			●	●
3	●	●		●	
4	●	●		●	●
5	●		●	●	
6		●	●	●	
7			●	●	
8	●	●	●	●	

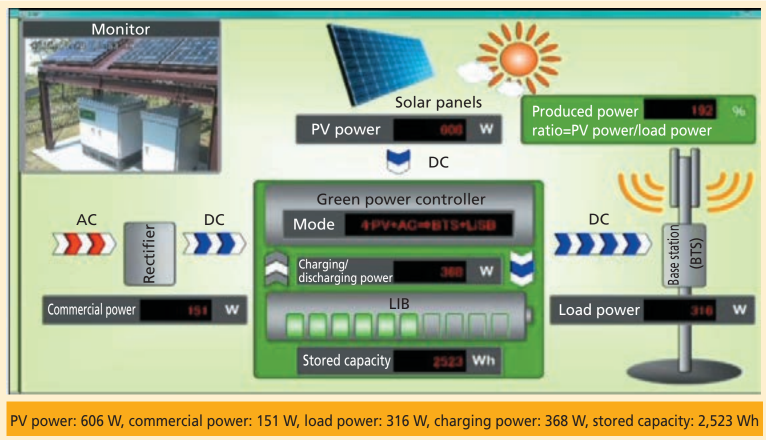


Figure 3 Example of real-time monitoring of Mode 4

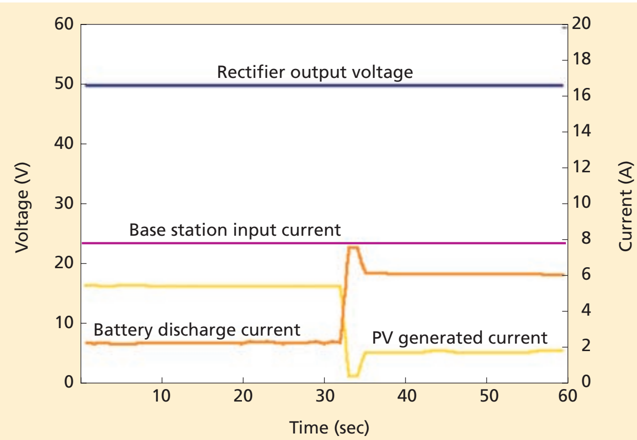


Figure 4 Example of Mode 8 measurements

Table 2 Power operation examples

Example	Conditions			Power operation examples		
	Power conditions	Daytime weather	Next-day forecast	Day time	Night time	Next day, day time
1	Base station power consumption > PV-generated power	Clear	Clear	Mode 3 ●PV → base station Insufficient part from commercial power	Mode 2 ●Night-time power → base station ●Night-time power → LIB charging	Mode 6 (Mode 8) ●PV+LIB discharge → base station Insufficient part from commercial power
2	Base station power consumption > PV-generated power	Clear	Rain	Mode 3 ●PV → base station Insufficient part from commercial power	Mode 2 ●Night-time power → base station ●Night-time power → LIB charging	Mode 5 ●LIB discharge → base station Commercial power after discharge complete
3	Base station power consumption < PV-generated power	Clear	Clear	Mode 4 ●PV → base station ●PV excess → LIB charging	Mode 7 ●LIB discharge → base station	Mode 4 ●PV → base station ●PV excess → LIB charging
4	Base station power consumption < PV-generated power	Clear	Rain	Mode 4 ●PV → base station ●PV excess → LIB charging	Mode 2 ●Night-time power → base station ●Night-time power → LIB charging	Mode 5 ●LIB discharge → base station Commercial power after discharge complete

●:Supply ●:Charging

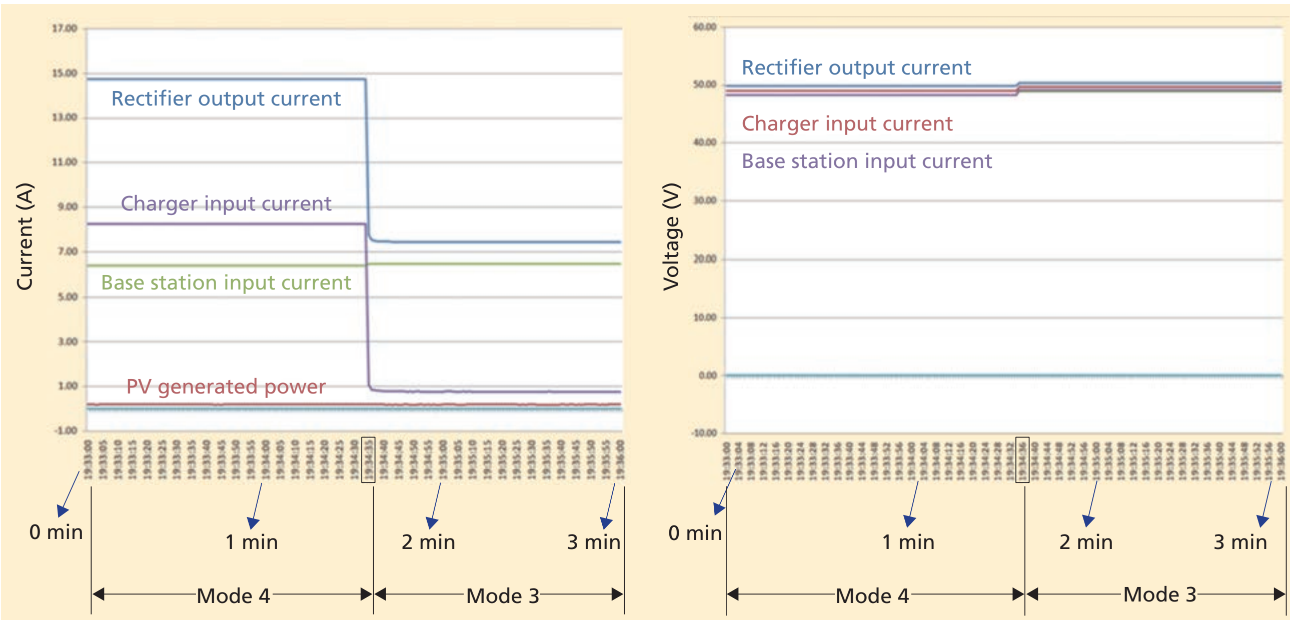


Figure 5 Example of transition from Mode 4 to Mode 3

out of the rectifier and into the charger drops, but the current into the base station remains stable, not changing before and after this transition. This shows how the system controls power to avoid base-station interruption, even through mode transitions.

4.3 Characteristics of Independent Power

We now describe the results of evaluating how the characteristics of independent power fluctuate with various weather conditions when operating the green base station using solar power and LIB, and not using commercial power (AC). Measurements were done operating in mode 6, on independent power, from 8:00 (with LIB fully charged) to 16:00, and in mode 4, to charge in preparation for the next day from 16:00 to 8:00 the following day.

Figure 6 shows data obtained from the test equipment on power generation, charging and discharging characteristics. Positive on the vertical axis indicates PV generation and LIB discharge, while negative indicates LIB charging. Example (a) shows that the base station was able to operate on PV power for most of the day time. Because of this, the LIB returned to a full charge using AC in a short time. In example (b), the LIB compensated for times when the sunshine was weak, so charging the LIB using AC required approximately eight hours. In example (c), power is supplied by discharging the LIB throughout the day, and its depth of discharge[*2] reaches 90%.

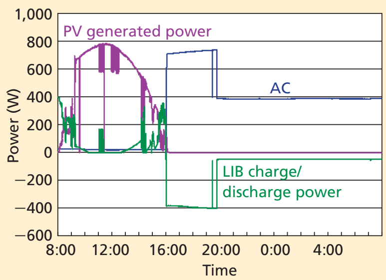


Figure 6(a) Generation/charge/discharge characteristics (Nov. 15-16, 2012, clear skies)

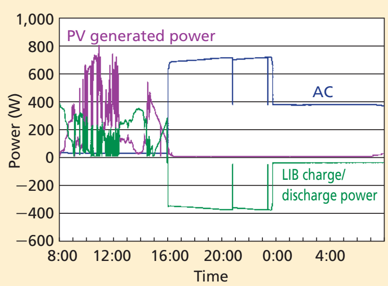


Figure 6(b) Generation/charge/discharge characteristics (Nov. 13-14, 2012, cloudy)

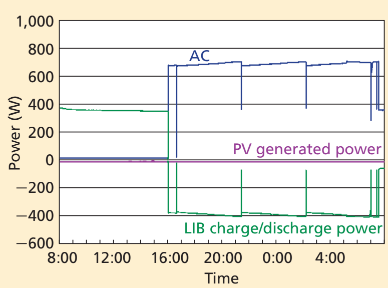


Figure 6(c) Generation/charge/discharge characteristics (Nov. 6-7, 2012, raining)

Figure 7 shows changes in the amount of charge in the LIB. The proportion of the time using AC (16 hours) spent charging the LIB was 24%, 49% and 94% in (a), (b) and (c) respectively. Note that although it is not implemented in the test system, we have also shown the results (AC + PV) if operation is controlled to use excess PV power to charge the LIB when operating on AC and PV (calculated numerically, applying the power generated by the PV over 400 W to charging the LIB).

In the examples with sunny and cloudy weather, battery capacity decreased much less throughout the day when using the excess PV power to charge the LIB and as a result, charging with AC power completed in a very short time. Evaluating these results as above gives charging ratios of 3% and 15% for (a) and (b) respectively.

The above confirms that the characteristics of independent power and the amount of night time AC power used varies greatly according to the weather.

5. Conclusion

In this article, we have described the green base station concept, the test

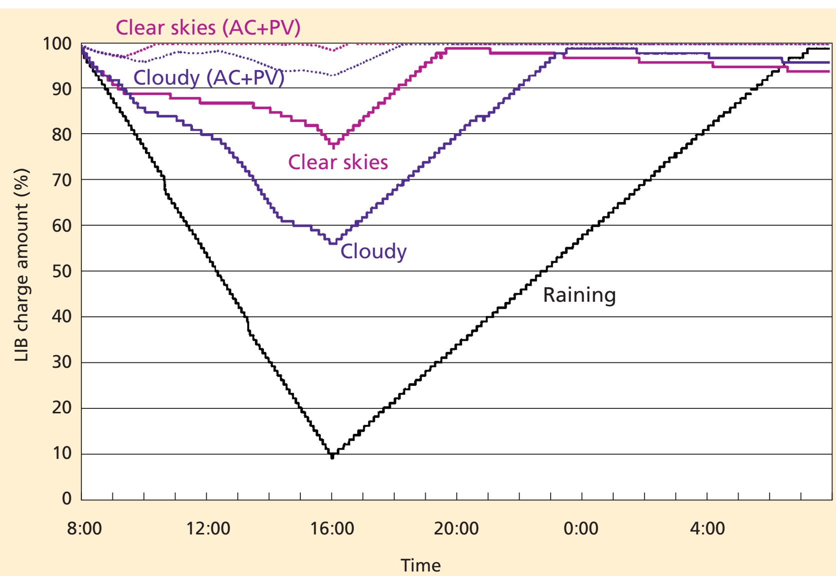


Figure 7 Change in LIB charge amount

*2 **Depth of discharge**: An index indicating what percent of a full charge has been discharged.

equipment built at the R&D center and results from basic operation of this equipment. The data obtained from the test system will be used as indices to design studies to optimize power control, and to perform other evaluations not discussed in this article that we have planned, such as lifetime characteristics of the LIB and safety testing. In the future, we also plan to study an "NTT DOCOMO Smart Grid" concept that will control multiple green base stations through the communications network, coordinating control of power use between the base stations.

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