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Energy Management System for Multi-region Digital Power Supply targeting to Carbon Neutrality

1. Introduction -Needs for Carbon Neutrality

In recent years, countries and companies are keen to express their ambitious goals on climate action. For example, in 2020, a record-breaking number of companies declared their own emissions reduction targets through the Science Based Targets initiative (SBTi) that guides companies' target setting. SBTi approved an average monthly target of 16 in 2020, compared with an average of only six per month in the previous four years. Other global initiatives such as RE100 (Renewable Energy 100%) and CDP (Carbon Disclosure Project) are also common for companies to disclose their goals and progress.

For companies, reducing carbon emissions is becoming a prerequisite not only to gain investment, but also to sell products within the global supply chain. Some big technology companies are aiming to shift electricity used across their manufacturing supply chains to 100% renewable sources by 2030. It's putting pressure on manufacturers around the world to switch to non-carbon energy.

There are a variety of ways in which companies can claim renewable energy usage. One of the simplest methods is to install renewable energy on site and use its output directly at nearby facilities. However, there isn't always enough space to install a large amount of renewable near electricity consumption. Especially in urban areas with limited land, the lack of space around corporate facilities is a serious problem. They can only cover a very small percentage of office or factory consumption after installing renewables in their sites. Volatile power output from solar and wind can also be a serious problem, resulting in an unstable power supply for the necessary demand at each time.

2. Energy Management System (EMS) for Multi-region Digital Power Supply

To address these problems of lack of space near consumption sites and unstable power supply due to renewable energy resources, this paper proposes a new concept called "Multi-region energy management". This will allow companies to achieve each site's decarbonization target while optimizing energy supply and demand at multiple sites by exchanging renewable energy outputs using existing power grids.

One of the key features of this "Multi-region energy management" is to simultaneously optimize the physical energy and environmental benefits of electricity. In each time zone, plans to exchange renewable energy power among multiple sites are determined based on variables at each site, such as generator and battery capacity, energy demand, a decarbonization target, the presence of contracted non-carbon electricity, and the price of environmental certificates in the trading market.

Mitsubishi Electric Corporation is now applying the concept of" Multi-region Energy Management" to actual operations by developing a software called "Energy Management System (EMS) for Multi-region Digital Power Supply". The system is provided as a series of software products developed in-house and packaged by Mitsubishi Electric Corporation.

The "EMS for Multi-region Digital Power Supply" develops the plan of exchanging renewable energy power, an output plan for each generation and storage battery, and a demand forecast plan in order to minimize the total cost, considering the decarbonization target of each site. Each site operates supply and demand based on the plan developed by the EMS. The environmental value of electricity is calculated in 30 minute increments instead of the usual monthly or annual increments.The amount of electricity generated from renewable energy sources (RES) are managed separately from the one from non-renewable energy sources(non-RES) in each storage battery. The "EMS for Multi-region Digital Power Supply" can be applied to the management of electricity energy and decarbonization targets for the company with multiple sites. The concept is shown in Figure 1.

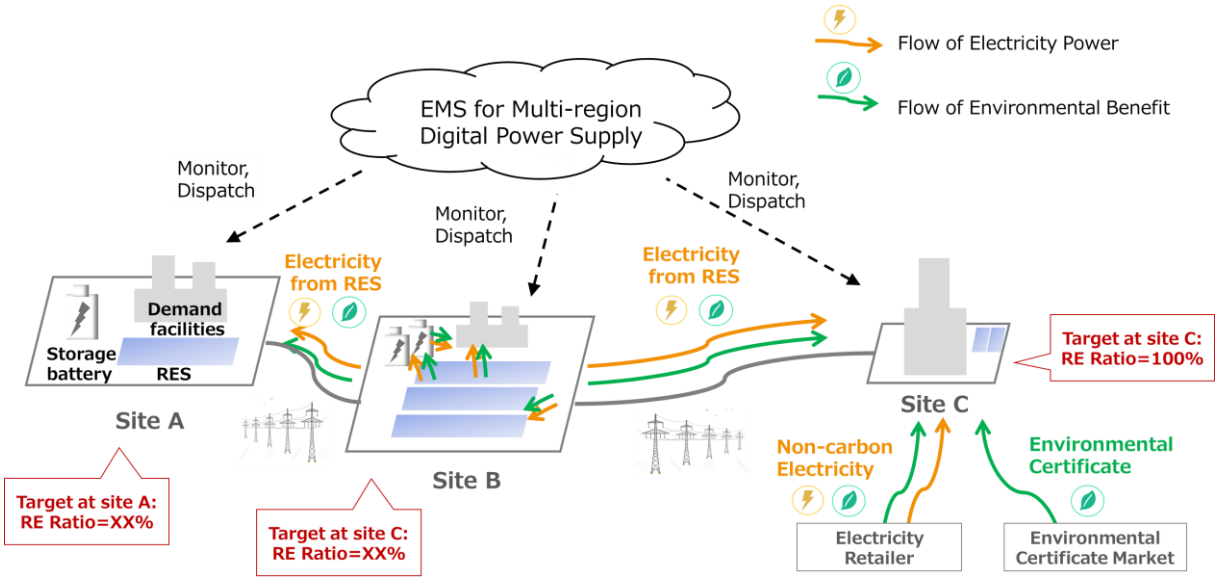

Figure 1. Concept of "EMSfor Multi-region Digital Power Supply"

3. Formulations in optimization

Multi-region EMS develops the plan to minimize the total cost in all sites. The objective function for minimizing total cost is represented by formulas (1).

$$\min F = \sum_{s=1}^{N_{site}} \left\{ \sum_{t=1}^{t_{end}} \left\{ \sum_{i=1}^{N_{gen,s}} \left(Cost_{gen,i,t,s} \cdot P_{gen,i,t,s} \right) + Cost_{grid,t} \cdot \left(P_{in(RE),t,s} + P_{in(NonRE),t,s} \right) + Cost_{buy,t,s} \cdot P_{buy,t,s} \right\} + Cost_{CER} \cdot \left(Vol_{CER\_buy,s} - Vol_{CER\_sell,s} \right) \right\} \quad (1)$$

The constraint on environmental benefits in *s*-th site is represented by formulas (2). Other constraints include constraints on supply and demand balance at each site, operational constraints of generators, capacity constraints of batteries, constraints on charge and discharge power of batteries, and the capacity constraints of the transmission and distribution systems. Transmission losses are not considered for simplicity.

$$\sum_{t=1}^{t_{end}} \left\{ \sum_{i=1}^{N_{gen,s}} \left(RE\_Ratio_{gen,i,t,s} \cdot P_{gen,i,t,s} \right) + P_{in(RE),t,s} - P_{out(RE),t,s} + RE\_Ratio_{buy,t,s} \cdot P_{buy\ t,s} + \sum_{j=1}^{N_{bat,s}} \left(P_{dis(RE),j,t,s} - P_{chr(RE),j,t,s} \right) \right\} + Vol_{CER\_buy,s} - Vol_{CER\_sell,s} \geq RE\_Ratio_{target,s} \cdot \sum_{t=1}^{t_{end}} \left(P_{load,t,s} \right) \quad (2)$$

Here, we describe variables as follow:

- N_{site} is the number of sites participating in the Multi-region EMS scheme.
- t_{end} is the number of time ranges considered in the calculation.
- N_{gen}/N_{bat} are the number of generators/batteries in each site.
- P_{gen} indicates the amount of generating power from a generator.
- P_{buy} indicates the amount of power bought from the electricity retailer.
- P_{in}/P_{out} indicate the amount of power sent from/to other sites. $P_{in(RE)}$ and $P_{out(RE)}$ are the ones generated from RES, and $P_{in(NonRE)}$ and $P_{out(NonRE)}$ are the ones generated from Non-RES.
- $P_{chr\ (RE)}/P_{dis\ (RE)}$ indicates the amount of charging/discharging power generated by RES.
- P_{load} indicates the amount of power demand.

- $Cost_{gen}$ indicates a unit price of a generator.
- $Cost_{grid}$ indicates the transmission cost by using the existing power grids.
- $Cost_{buy}$ indicates the price of electricity bought from the electricity retailer.
- $Cost_{CER}$ indicates a unit price of environmental certificate.
- Vol_{CER} indicates the volume of certificate. Vol_{CER_buy} indicates the one bought from environmental certificate market, and Vol_{CER_sell} indicates the one sold to environmental certificate market.
- RE_Ratio_{gen} indicates the ratio of non-carbon energy to generating power from a generator.
- RE_Ratio_{buy} indicates the ratio of non-carbon energy to power bought from an electricity retailer.
- RE_Ratio_{target} indicates the target ratio of non-carbon energy to demand at a site during the calculated time range.