Be the Right ONE

V2G Demonstration: Simultaneous Control of the Peak Shift and the Frequency Adjustment Considering the Daily Vehicles Operation

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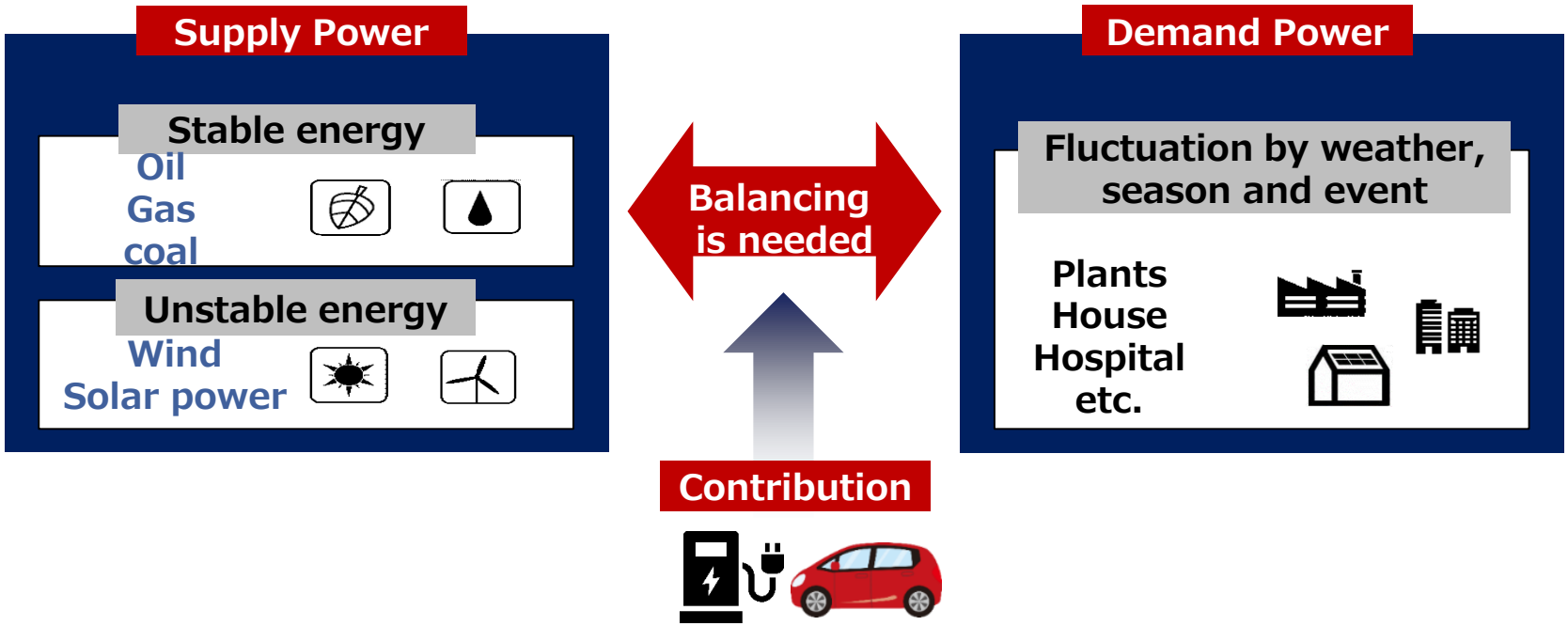
Contents

1. Introduction

■ What is V2G?

Storages are necessary for the spread of renewable energy. Electric vehicles (EVs) have a built-in energy storage system. Vehicle-to-grid (V2G) technology bridges the gap between these two sectors, and also helps regulate energy on the grid.



We encourages the further spread of renewable energy and enhancing the added value of PHEVs/BEVs to contribute toward the realization of a low-carbon society and stable supply of electricity by V2G

2.Purpose of this Demonstration

■ Purpose

This demonstration were completed to answer those two questions.

Question1. What conditions are required for V2G? And, how do we cope with the requirements?

We already know the capability of controlling batteries in EVs for the frequency adjustment if some conditions are prepared. However, it would be difficult to spread V2G in case that conditions are strict.

Question2. Is it possible to control batteries in EVs both for the frequency adjustment and the peak shift simultaneously?

It's the key to adapt V2G not only for the frequency adjustment but also for other functions so that V2G will be spread in the future.

This demonstration were completed to answer those two questions.

Answer for question1:
Users should use EVs somehow as planned so that we can offer the frequency adjustment at high level. And, we can do by improving the way of bidding even if users don't use EVs somehow as planned.

Answer for question2:
Simultaneous control of the frequency adjustment and the peak shift can be achievable as far as the requirements for both are within controllable with SOC which can be used.

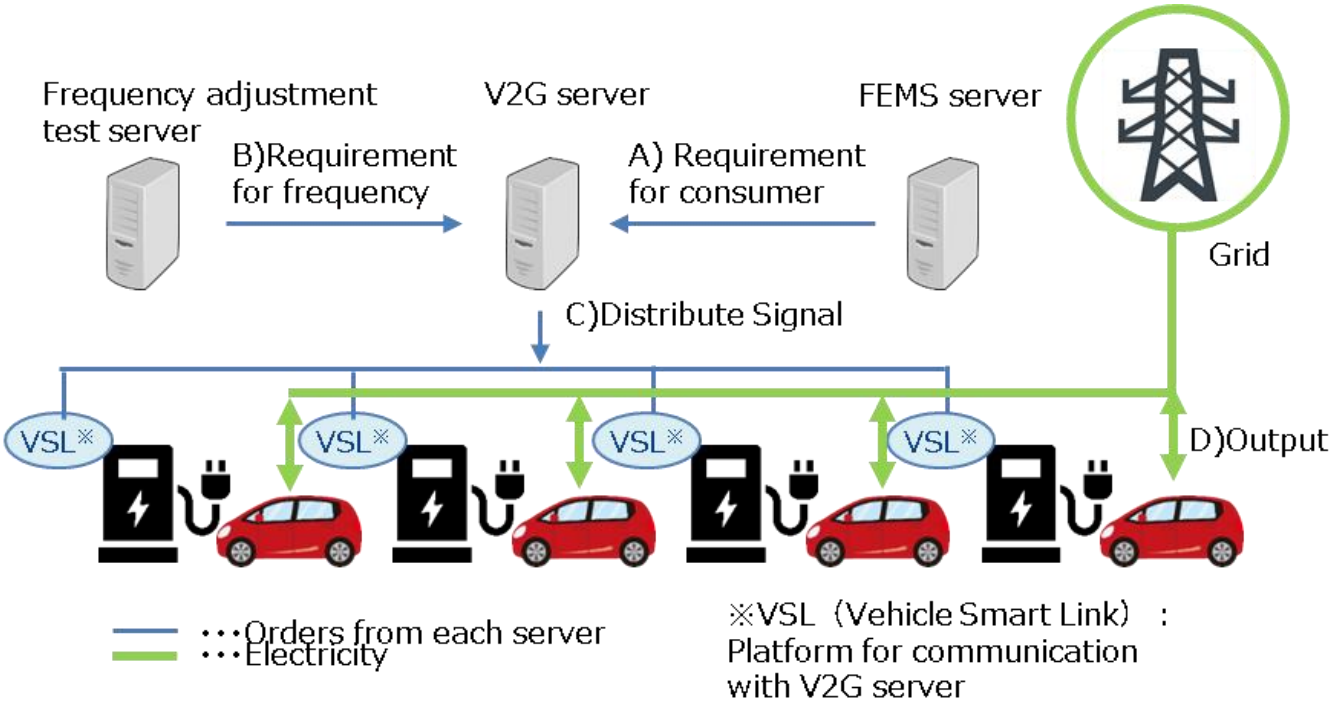
3-1.System Configuration

■ Condition for the frequency adjustment

The frequency adjustment server determines the kW for frequency adjustment and dispatches signals at 5 seconds based on bidding (time period and maximum value) which were to be declared in advance from the V2G server to the frequency adjustment sever by 2:00 p.m. on Tuesday, one week in advance, by using the vehicle operation plan

■ Condition for the peak shift

The FEMS determines the kWh requirement signals in 30-minute units for the next 24 hours based on the vehicle operation plans registered in advance by the users, the current power demand of the factory, etc., and dispatches them to the V2G control server at 30-minute intervals.



3-2.Control Logic of the V2G Server

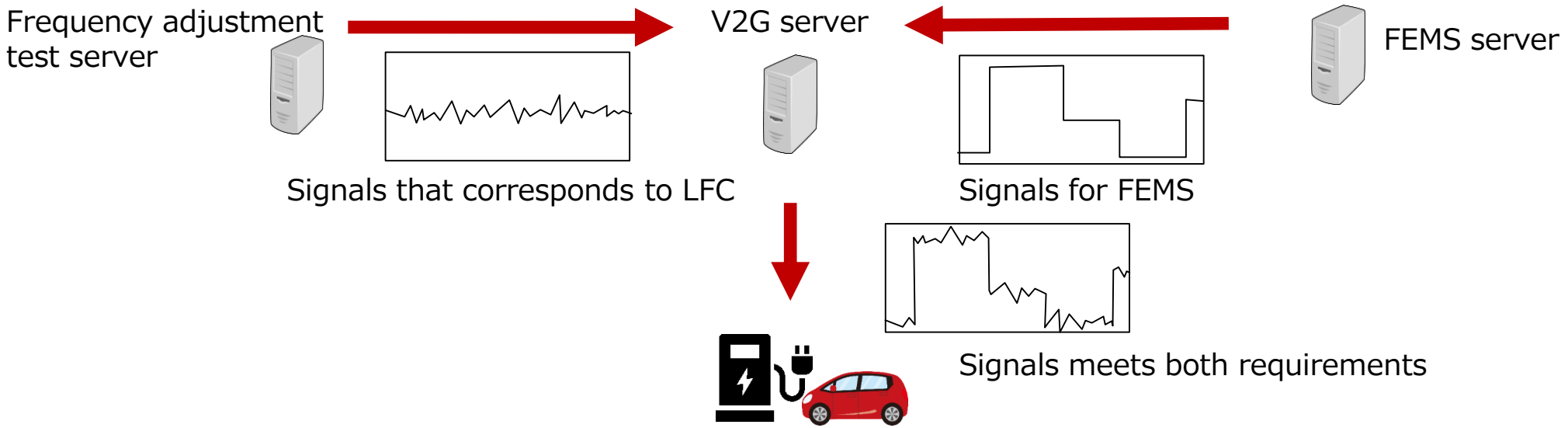
V2G server calculate the distribute signals which meets both requirements as much as possible

■ Point.1

For example, assuming that there is no charging/discharging bias in the requirement signals for frequency adjustment, if a requirement signal of 100 kWh is received from FEMS as a 30-minute block, while a requirement signal of ±x kW is received from the frequency adjustment test server every 5 seconds, the instantaneous distribute signal is 200±x kW.

■ Point.2

However, in actuality, either of the requirement signals may not be satisfied due to unbalanced charging/discharging for frequency adjustment or charging/discharging loss of the requirement signals. At this time, the V2G server should determine the distribute signal comprehensively, taking into account the user's needs, market value, penalty, etc. However, for the sake of simplicity in this demonstration, it was decided to give priority to satisfying the requirement signal for the FEMS.



3-3.Evaluation Methods

■ **For the frequency adjustment, the PJM performance score was used to evaluate whether the required kW for frequency adjustment was satisfied**

The PJM performance score is given by

$$Perfomance\ Score(t) = \max_{i=0\ to\ 5\ min}[A * DelayScore(t+i) + B * CorrelationScore(t+i)] + C * PrecisionScore(t))$$

This is a performance score adopted by PJM, the U.S. grid operation agency, to evaluate frequency control performance. It consists of three types of scores, Correlation Score, Delay Score, and Precision ScoreThe full score is 1.0 and the entry requirement in PJM is 0.75 or higher. In this demonstration, the signals for 30 minutes were taken and calculated.

■ **For the peak shift function, whether or not the kWh requirement signal is satisfied was confirmed by the kWh accuracy**

The kWh accuracy is given by

$$\text{kWh accuracy (\%)} = \frac{\sum \text{EV Output } [kWh]}{\sum \text{FEMS Requirement signals [kWh]}} \times 100$$

■ **The planning accuracy (%) was defined as the percentage of vehicles used according to the pre-registered plan.**

Planning accuracy is given by

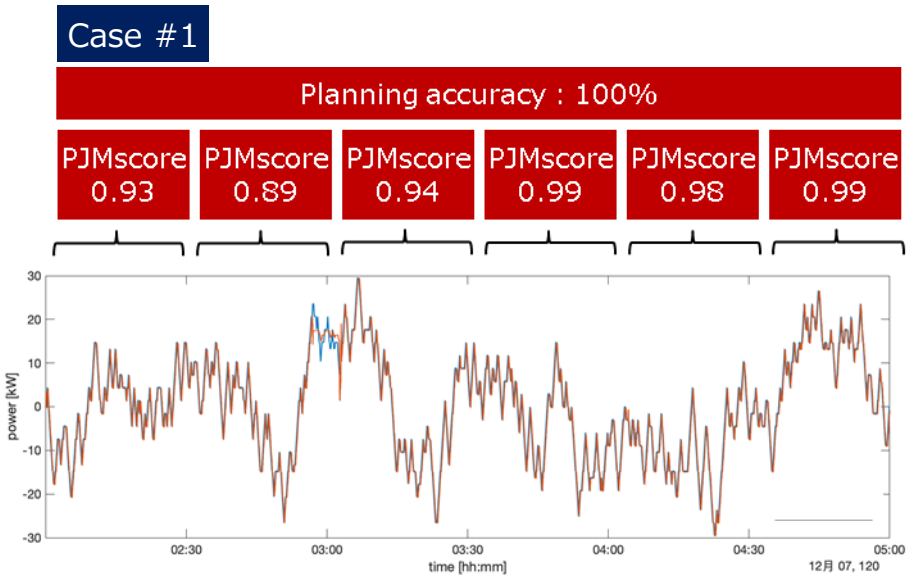
$$\text{Planning accuracy(\%)} = \frac{\text{Actual average number of vehicles connected to EVSE}}{\text{Pre} - \text{registered number of vehicles connected to EVSE}} \times 100$$

4-1.Frequency adjustment

■ Condition

Case #1 : In this 3-hour test, we charged and discharged five EVs which are always connected to EVSEs
Case #2 : In this 3-hour test, we charged and discharged up to 5 vehicles which are used freely

■ Control results and PJM scores



Distribute signal（blue）、Output （red）
＋:discharge, -:charge

■ Consideration

If EVs are connected to EVSEs as planned,
we can offer the frequency adjustment at a high level (almost PJM score > 0.9)

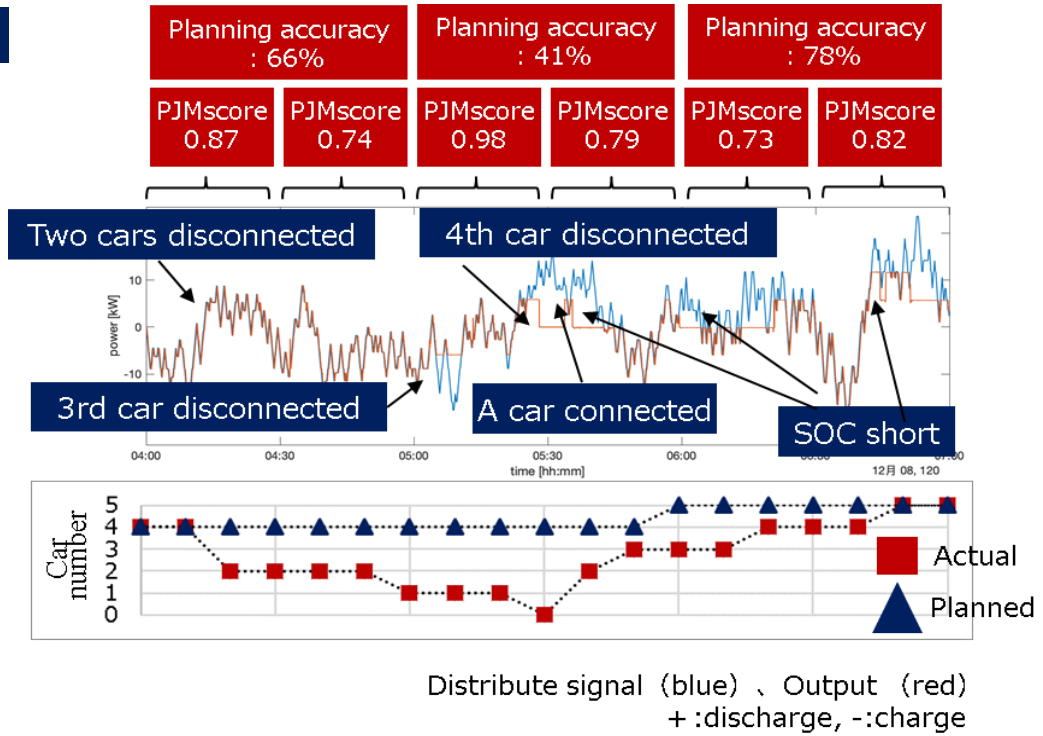
4-1.Frequency adjustment

■ Condition

Case #1 : In this 3-hour test, we charged and discharged five EVs which are always connected to EVSEs
Case #2 : In this 3-hour test, we charged and discharged up to 5 vehicles which are used freely

■ Control results and PJM scores

Case #2



Distribute signal（blue）、Output（red）
+:discharge, -:charge

■ Consideration

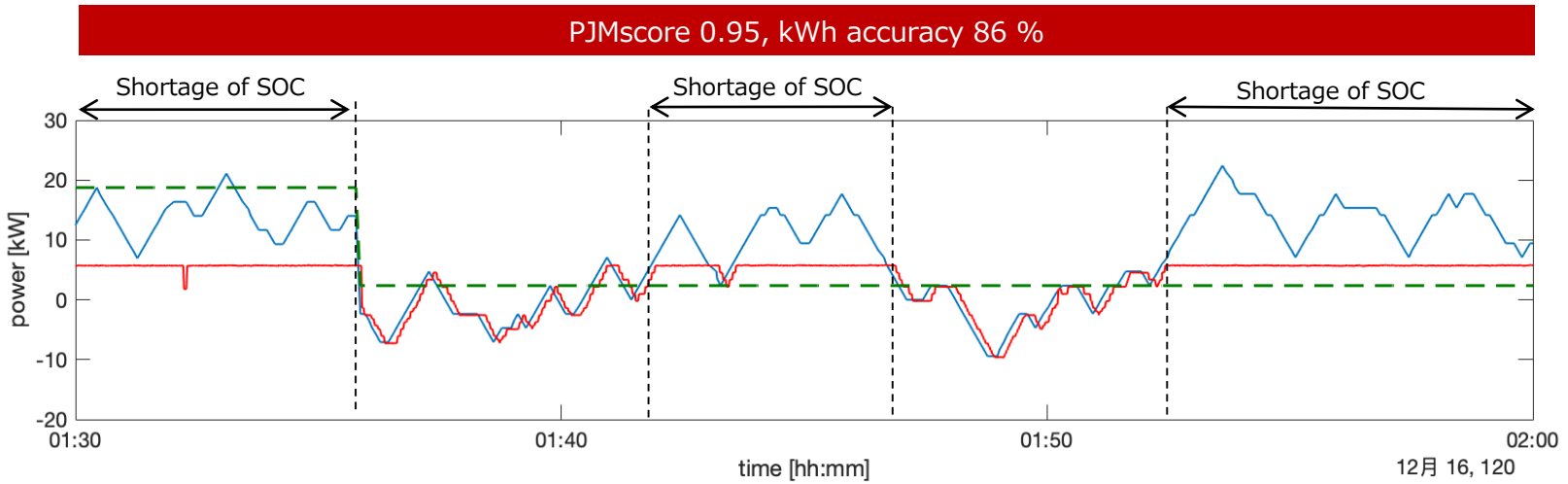
Although the PJM score decreased as the planning accuracy decreased because cars got disconnected and the state of charge got short, it was confirmed that there is a possibility to exceed the PJM entry requirement (PJM score of 0.75 or higher).
⇒**we can offer the frequency adjustment by improving the way of bidding even if users don't use EVs somehow as planned.**

4-2.Frequency adjustment and peak shift

■ Condition

In this thirty-minute test, we charged and discharged four EVs which are always connected to EVSEs

■ Control results and PJM score



Distribute signal(blue), Output (red), Requirement for consumer(green)

+:discharge, -:charge

■ Consideration

<u>Simultaneous control of the peak shift and the frequency adjustment can be achievable as far as the requirements for both are within controllable with SOC which can be used.</u>

5.Conclusion

■Result

Question1. What conditions are required for V2G? And, how do we cope with the requirements?
⇒ **Answer. Users should use EVs somehow as planned so that we can offer the frequency adjustment at high level. And, we can do by improving the way of bidding even if users don't use EVs somehow as planned.**

Question2. Is it possible to control batteries in EVs both for the frequency adjustment and the peak shift simultaneously?
⇒ **Answer. Simultaneous control of the frequency adjustment and the peak shift can be achievable as far as the requirements for both are within controllable with SOC which can be used.**

■Future tasks for introducing the V2G system into vehicles which are actually used in our society are bellows.

-Modification of the control logic of the V2G server in line with the reserve market regulations in Japan because it would be better to keep the balance both values of the frequency adjustment function and the peak shift function considering penalties from reserve market etc.

-Modification of the calculation system of the V2G server for bidding which were to be declared in advance so that PJM scores would not decrease even if the vehicles are used in a way that deviates from the operation plan registered in advance.