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Feature Article: Superconductivity Application in Renewable Energy -Effective Utilization of Renewable Energy by Employing SMES at the ALCA Project

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Global-scale carbon-dioxide reduction is an important and crucial issue for establishing a sustainable society. Whilst the utilization of eco-friendly renewable energy is desirable, their transmission capacities in power grids are limited due to frequency fluctuations, which occurs when the directly transferred output power to a commercial utility grid increases. This is because renewable energies stochastically fluctuate at random. It therefore becomes necessary to utilize power storage facilities effectively to eliminate power fluctuations and convert the renewable power into a controlled electrical power. Amongst the power storage options available include superconducting magnetic energy storage (SMES), which exhibit rapid responses to large input and output power and endure a number of repeated charge and discharge cycles. Also a hydrogen system comprising of a fuel cell power system (FC) and water electrolysis system (EL) offers the potential of greater storage capacities. Both storage systems compensate each other and thus forming a hybrid storage system can be applicable in converting the rapid fluctuating renewable energy source into controllable electrical power. Additionally, SMES can be wound using economical MgB_2 wires and cooled using liquid hydrogen (20 K) since the critical temperature of MgB_2 is 39 K. In the near future, a potential hydrogen gas station for fuel cell vehicles will be able to utilize liquid hydrogen coolant since it is more economical and environmentally beneficial. An advanced superconducting power conditioning system (ASPCS) composed of above-mentioned systems is shown in Figure 1 [1)].

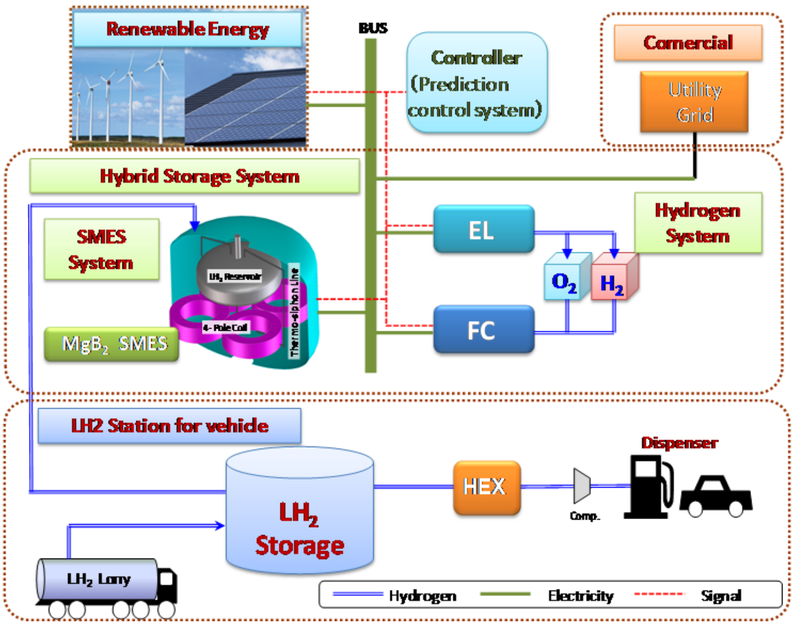

Fig.1 Concept of ASPCS

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In order to use effectively both SMES and hydrogen systems it is necessary to resolve the renewable energy into suitable components. The wind turbine power generated by randomly changing renewable energy can be resolved into an average trend and a rapidly changing component. The trend component is relatively slow and is suitable for hydrogen systems having large storage capacities. The rapidly changing component is suitable for SMES, which exhibits frequent input and output characteristics. The slower trend component can be predicted by applying the Kalman filter algorithm. Figure 2 was measured waveforms during 20,000-22,000 second. The upper graph in Figure 2 shows a 5 MW-class wind power waveform P_{wind}, a predicted trend waveform of P_{pred} associated with the wind and a constant output power P_{out}. The lower graph in Figure 2 shows the waveform from each component, resolved into the supplied power by the fuel cell (FC) $P_{FC} = P_{pred} – P_{out}$, the absorbed power by the EL $P_{EL} = P_{out} – P_{pred}$, and SMES input and output power $P_{SM} = P_{wind} – P_{pred}$ [1]. The figure reveals that the trend well predicts the wind power with slight time lag. It is clear that the SMES input or output energy is frequently charged and discharged whilst a hydrogen storage system exhibits slow but large input/output capacity characteristics. Figure 3 shows a histogram of SMES input and output energies and its frequency performed over 20 hours, almost a day. Table 1 shows the data processed statistically. The figure reveals that the majority of the SMES input/output energy is the repeated charges and discharges of small energy. The number of charges and discharges per day is 2,000, which equates to 720,000 per year. The SMES's repeated tolerance characteristics can be fully utilized here. Since the energies are not so large the SMES's stored energy can also be small. Figure 4 shows the results from a calculation performed to estimate the electric efficiency as a function of the constant output power to the utility grid. Electric efficiency of SMES, EL and FC were 95, 80, 40 %, respectively. In the figure, there are some cases where the efficiency exceeds 80% by appropriately selecting the

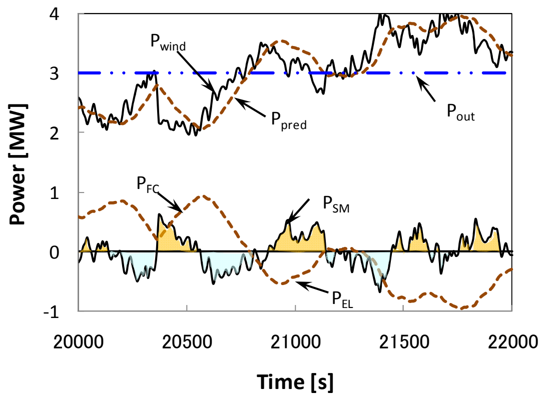

Fig.2 Waveforms of Wind power P_{wind}, Trend prediction P_{pred}, Constant output power P_{out}, SMES P_{SM}, FC P_{FC}, and EL P_{EL}

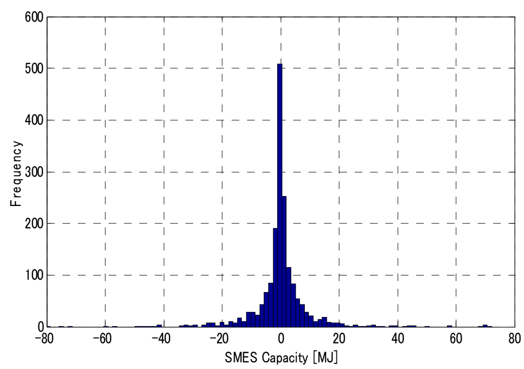

Fig.3 Histogram of SMES input and output energies

Table 1 Statistics of SMES's charge-discharge energy

Charge-discharge frequency	1,780
Average charge-discharge power	0.13 MW
Average charge-discharge energy	5.1 MJ
Dispersion of charge-discharge energy	10 MJ
±3σ	60 MJ

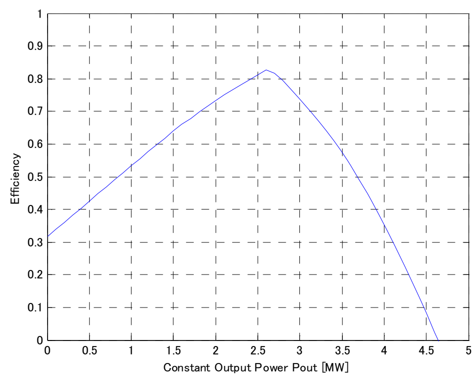

Fig.4 Electric efficiency of ASPCS as a function of the constant output power P_{out}

constant output power [1]. It is therefore anticipated that by exploiting SMES characteristics, the effective utilization of renewable energy will lead to new potential superconducting applications. A 1kW-class compact ASPCS is currently being constructed to verify the concept of this system and will be tested at the Iwatani R&D Center (Amagasaki city).

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Reference:

1) T. Hamajima, *et al*., “Application of SMES and Fuel Cell System Combined With Liquid Hydrogen Vehicle Station to Renewable Energy Control”, IEEE Transactions on Applied Superconductivity, Vol. 22(2012), 5701704(1-4)

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