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Fusion Plant and Local Grid System with Innovative Electricity Storage by Inverse Dam

インバースダムによる革新的電力貯蔵を持つ地域エネルギーシステムと核融合プラント

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Impacts of a fusion veneration plant on the electricity grids due to the large start-up power and possible sudden change of output due to disruption are analyzed by a numerical model. These effects could be strong constraints for fusion electricity to be introduced into the grids because of the resulted fluctuations on frequency, and thus considered to be a major limits for the share in the future energy market. Effects of an electricity storage using inverse dam that is reversibly used for conversion of electricity to and from potential energy of sea water in the storage volume built in the sea was also evaluated. Its effect to stabilize the electricity on the grid could be significant in the local grids of limited capacity, particularly when consisted of considerable renewables under the policy of electricity liberalization and separation between generation, transmission and distribution. Combination of fusion plant with electricity storage is expected to play a major role for the deployment of fusion in the future grid systems both in highly de-carbonized grids and immature grids.

1. Introduction

Almost all the fusion reactor designs assume large and stable electricity grids to be connected, and expect unlimited and steady electricity sales and large and pulsed power supply for starting plants. Although such grids are available for the countries where fusion research is current pursued, majority of the future energy market where fusion would be deployed are anticipated to be significantly different. Even in the large grids in advanced countries, future system will be rather different from the present ones deeply depending on fire powered plants with capabilities to respond demands. Because of the introduction of renewables such as wind and solar electricity is already jeopardizing the stability of the grids, and at the same time, liberalization of power business and separation of power generation, transmission and distribution is breaking the grids into smaller local units.

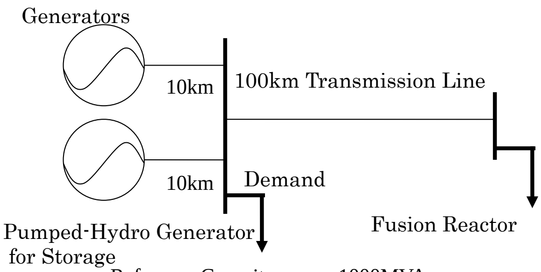
This paper reports some strategic scenarios for fusion to be deployed into smaller grids with renewable and sources with less flexibility. An innovative concept, “Marine Inverse Dam” that is an enclosing fence or vessel to pump out sea water for charging electricity, is one of the main components of the system for electricity storage. Fusion can be installed in the grids up to ~10GW capacity as base load, and the Inverse Dam works as a capacity to store excess electricity from fusion, and unstable and unpredicted renewables. Fusion plants are started only when the consumption is small, and the grids are expected to supply electricity for fusion plant, without observing voltage or frequency fluctuation or possible power outage due to the temporal imbalance of grid capacity and load. Starting up fusion to minimize the impact to the grid mainly depends on this combination of the storage capacity, time constant and configuration with the grid containing other generation sources, storage and consumers.

This study describes some case studies for the size of the grids, size and operation modes of the inverse dam, composition of other power sources on the grid, and possible consumption patterns. Emerging markets where fusion is expected to be deployed in the developing countries, and mature and changing localized grids with renewables and nuclear to minimize the carbon dioxide emission are considered.

2. Analysis

It is estimated that a few hundreds of MWs of electric energy is needed to start a fusion power plant, meaning effects of a power withdrawal to start it on a regional power system will undeniably be significant and possibly unacceptable depending on the size and characteristics of the system. Also, sudden loss of power within the matter of seconds can happen by disruption depending on the thermal and mechanical characteristics of the generator power train.

In order to assess the magnitude of the effect and propose feasible ways to minimize it, a simplified numerical dynamic model based on practical time constants was made. The model local system is composed of fusion, and other generation systems with a storages representing an inverse dam, that typically has a characteristics of the pumped hydro station.



Reference Capacity	:1000MVA
Transmission Voltage	: 115kV
System capacity	: 7-15GWe
Impedance per 100km	:0.0023+j0.0534[p.u.]
Capacitance	:jY/2 = j0.1076[p.u.]

Fig.1. Simplified model of the electric grid with fusion and storage

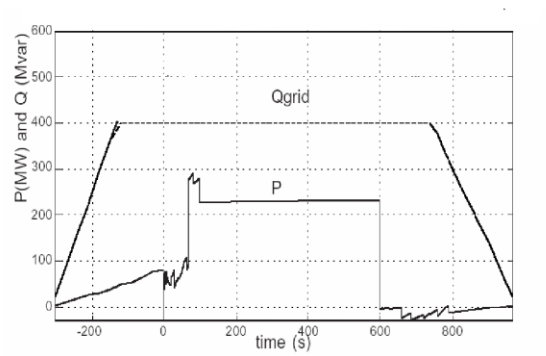


Fig.2. Start-up power load of ITER

Figure 1 shows the simplified model of the electricity grid with several sources such as renesables, thermal or nuclear, storage with inverse dam, and fusion plant. Impacts on the grid is estimated on the various hypothetical relatively small grids of capacity around 10 GWe. Figure 2 is the typical load for starting fusion plant, assuming ITER sized plant. If the plant is far larger, particularly effects become more significant.

3. Results and Discussion

A typical result of the analysis is shown in the figure 3. Assumed grid capacity is 12GW, and

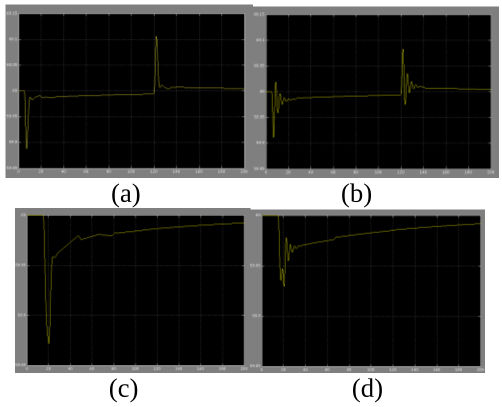


Fig.3. Typical fluctuation of frequency in the grids induced by fusion reactor
(a) start-up without storage (b)start-up with storage, (c)disruption without storage, (d)disruption with storage.

start up power was 230MW, with 200MW/s of rapid draw. Fluctuation of the frequency was respectively 0.12 and 0.09Hz, without and with storage, respectively. Sudden loss of 500MW electricity loss gave 0.13 and 0.06 Hz fluctuation.

The results suggests that the fluctuation can be suppressed by storage, but also strongly affected by the capacity of the grid, time constant of other generators controlled with governers. When other sources are unchanging nuclear or unchangeable renewables, effects of storage is more significant.

4. Conclusion

This study describes some case studies for the fusion deployment, and suggests that majority of sales of fusion, if it would be viable, is in the developing countries rather than the mature markets where growth is not expected, and thus encompassing such a business model could justify the investment for fusion development.