学位論文内容の要旨

This thesis optimizes the operation planning of a photovoltaic system (PV) with a diesel engine generator or a combined fuel cell. The proposal systems allow for the construction of a power supply system with low environmental impact that uses renewable energy. The production of electricity from the photovoltaic system continues to attract interest as a power source for distributed energy generation. It is important to be able to estimate a photovoltaic power to optimize system energy management. The neural network has been proposed as suitable for statistical approaches for classifications and prediction problems. A layered neural network is made to learn and teach based on the weather data of amount of solar radiation and outside air temperature. Fuel cell power generation is another attractive option for providing power for electric utilities and commercial buildings because of its high efficiency and environmentally benign feature. The fuel cells have recently been the focus of great interest as a distributed generation technology. The solid-oxide fuel cell (SOFC) and a proton-exchange membrane fuel cell (PEFC) are two types of fuel cells and particularly suitable for distributed power generation and cogeneration systems. Moreover, energy supply characteristics of a PV and a diesel engine generator combined system are studied. Two operating cases are examined in this system: one with and one without a power storage facility. The operation of the diesel engine generator is based on the fluctuation of the load in the operation of Case 1, and a battery is not used.

Therefore, because the engine is operated over a wide area from a low to a high load, the average engine operation efficiency is low. On the other hand, in the operation of Case 2, a battery is used to supply the demand when the PV power generation is less than the demand, and the diesel engine generator operates at 25% or less of the battery residual quantity to work in safety mode in the proposed system. Furthermore, operation of the engine generator is based on the charge or discharge of the battery, with maximum engine efficiency at maximum output power. Comparisons are presented of the results from the two cases with respect to the actual calculations of output power and the predicted electricity production from the photovoltaic. Energy is supplied to a demand side of three households in Sapporo city, Japan from the proposed system, and no external sources are used. The analysis error of the operation prediction is considered.

A photovoltaic and SOFC-PEFC combined system is developed in this study. The proposed system consists of a SOFC-PEFC combined system and a PV as the energy supply to a micro-grid of 30 residences in Sapporo, Japan. The operation plan of the system has three cases: without solar power, with 50% and with 100% of solar output power. Furthermore, three types of system operation of using the SOFC independent operation, PEFC independent operation and SOFC-PEFC combined system are used to supply the demand side. A comparative study between the types of system operation is presented. The power generation efficiency is investigated for different load patterns: average load pattern, compressed load pattern and extended load pattern.

The operation results the PV and the diesel engine combined system shows that, when the NN production-of-electricity prediction is introduced, the engine

generator operating time is reduced by 12.5% in December and 16.7% for March and September. The engine generator operation time is shortened by introducing a NN prediction algorithm. Furthermore, the operation results of the PV and SOFC-PEFC combined system show that, the difference between the SOFC independent system and the PEFC independent system is small. The fuel consumption of the SOFC-PEFC combined system is reduced 10 to 35% compared with the SOFC or PEFC systems independently. The power generation efficiency of the SOFC-PEFC combined system considering the three load patterns of the proposed system is 27% to 48%. When photovoltaic generation is not introduced into the SOFC-PEFC combined system, the change in the power generation efficiency is small.

Considering all the results of this thesis, it is found that the optimized operation of an energy system with a photovoltaic power generation reduced the time operation of the diesel engine generator and the energy cost of the proposal systems. In addition, the proposed energy systems with a PV power generation are proved to be effective to achieve the purpose supplying energy to a micro-grid with high performance without any external source.

論文審査結果の要旨

本論文は，2つの研究成果から構成されている。最初は，ニューラルネットワークを用いた気象予測情報から太陽光発電の発電量を推定して，マイクログリッドの運用を最適化する研究である。次に，SOFC（固体酸化物形燃料電池）とPEFC（固体高分子膜形燃料電池）の複合システムを導入することで，環境負荷の小さなマイクログリッドを構築できるという提案である。

最初の研究では，マイクログリッドに接続した従来型発電機（ディーゼルエンジン発電機）の運用時間をおよそ13から17%減らすことに成功した。気象予測情報に基づくシステムの運用は，蓄電および蓄熱の運用計画に有効であることを示している。また，次の研究では，SOFCの高温排熱をPEFCの燃料改質装置に供給して，改質ガスを製造することの優位性について明らかにした。年間を通した提案システムの平均発電効率はおよそ43～49%であり，各燃料電池の単独運転に比べて有利である。さらに，マイクログリッドの電力負荷変動が大きくなる際の，燃料電池の負荷率および発電効率の低下量の知見について示された。

これを要するに，申請者は，太陽光発電を伴う複合エネルギーシステムについて運用最適化問題の新知見を得たものであり，自然エネルギーを伴うエネルギーシステムの構築に際して環境負荷の改善に貢献するところ大なるものがある。

よって，申請者は，北見工業大学博士（工学）の学位を授与される資格があるものと認める。