学位論文内容の要旨

Due to the various environmental issues and the limited reserve of the fossil fuel, people have been searching for a renewable source of energy that can be used as an alternative to the fossil fuel. Among the various sources of renewable energy, photovoltaics (PV) has proved its potentiality as a long-term, inexhaustible, environmentally friendly and reliable energy technology. Generally, photovoltaic systems are constructed using lead-acid batteries. But lead-acid batteries have some limitations, e.g., short lasting time, low power density etc. To overcome these problems of batteries, in this work, a distributed power generating system has been developed using PV panel and a new energy storage device, called Energy Capacitor System (ECS). The ECS is the combination of Electric Double Layer Capacitor (EDLC) and some electronic circuits, like, parallel monitors and current pumps. The ECS has very long lifetime, high power density, and very short charge/discharge time.

The proposed system consists of mainly six functional units. These are PV panel, Maximum Power Point Tracker (MPPT), Power Conversion System (PCS), EDLC bank, load unit, and the control unit. The PV panel has been constructed using nine modules and the peak output of the panel is 1296W at MPP (I_m=7.2A V_m=180V). To extract the maximum power from the PV panel a 1000W MPPT has been used. In order to supply the DC output of the MPPT and the EDLC to the load, and to charge the EDLC by grid power, a bi-directional Power Conversion System (PCS) has been incorporated in the system. Its maximum capacity is 1000W. The EDLC bank consists of four capacitor-modules and has a storage capacity of 2.3kWh. The control system consists of a microcomputer, a data acquisition unit and its necessary interfacing circuits. To simulate different load patterns, a resistive room heater of variable power is used. Its value is 50W ~1150W, but within this range the value can be set to any integer multiple of 50W.

Since, the performance of the PV system depends on the PV output and hence on the insolation, in this work, a procedure has been developed to estimate the PV output power by calculating solar radiation. To calculate the daily insolation, Hottel's equation and Liu-Jordan's equation have been used with some modifications. To verify the accuracy of the developed procedure, the calculated solar radiations for different months of the year have been compared with the 20 yeas' practically measured solar radiation in Kitami.

Using the calculated solar radiation a procedure is devised to estimate the daily PV output power. The estimated PV output is compared with the practically measured one to verify its accuracy. It is found that, for sunny day the error in estimation is 10% maximum. To use the procedure in cloudy/rainy weather, the characteristic of the PV output in different weather conditions has been studied using one-day-ahead weather forecasts for about 2 years.

A characteristic of the developed PV-ECS system is that, the amount of power to be taken from grid line should be set, before the system starts its daily operation. Hence, with an aim to set the optimum amount of this power, a simulation program has been made. This program can simulate the operations of the whole system. Using this simulation and the estimated PV output power, the optimum amount of the power to be taken from grid line could be set properly.

The performance of the system has been studied for several years in different weather conditions using different types of load profiles. In going to study the system performance, two modes of operation of the system, (I) optimal economic mode and (II) optimal load-leveling mode, have been described. A comparative study of the system performance in these modes of operations has also been done and presented in this thesis.

The performance of the system changes due to the weather conditions and the yearly variation of solar radiation. So, the effect of the weather condition and the yearly variation of solar radiation on the system performance have been investigated thoroughly.

As the system is operated using the one-day-ahead weather forecast, the forecast may not always be accurate. So, there is a probability of the estimated PV output to differ from the practical one. To overcome the effect of this inaccuracy on the system performance, two techniques have also been described in this thesis.

Finally, to evaluate the system performance, the power flow patterns, charging discharging characteristics of the ECS, financial benefit and load-leveling capacity of the system have been studied thoroughly. It is found that the system provides an excellent economic benefit for non-flat price of electricity and load-leveling facility with a good overall efficiency.

論文審査結果の要旨

天候への依存性のため太陽電池は安定した電源になり得ず、何らかの蓄電装置とのハイブリッド化が内外で検討されている。本論文は、新たな蓄電装置として電気二重層キャパシタシステム（ＥＣＳ）を用いた、系統連系型の次世代型太陽光発電システムを開発し（ＰＶ－ＥＣＳシステム）、同システムに様々な機能を付加することにより太陽光発電を安定したしかも制御の容易な分散型電源に高めることを目的とした、新エネルギー供給システムの開発について述べている。即ち、

先ず。①年間を通して、快晴日における直達および散乱日射強度の実用的推定式を開発し、実測値との比較から、３時間ごとのオンライン気象予想（晴れ、曇り、雨、雪）に対応する全天日射量、即ち、太陽電池出力推定方式を開発している。次いで、②太陽電池、ＥＣＳ、双方向インバータからなる電力供給システムを、負荷および配電系統に連系したＰＶ－ＥＣＳシステムを構築し、日間の負荷パターンの平準化を目的とするシステムの運用制御方式を開発している。更に、③太陽電池出力推定方式と翌日の気象予測から、負荷の平準化を実現するようなＥＣＳの充放電制御方式を確立し、長期間の連続運転からシステムの信頼性を検証している。ＩＣＥＥにおいて優秀論文賞を受賞するなど、本論文は内外で高い評価も受けており、博士の学位に相応しい内容を備えているといえる。