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論　文　内　容　要　旨

報告番号	甲　先　第　187　号	氏　名	北島 孝弘
学位論文題目	Study on Maximum Power Control System for Small Wind Turbine Using Wind Speed Prediction （風速予測を用いた小型風力発電機の最大出力制御システムに関する研究）		

内容要旨

In recent years, renewable and clean natural energy has attracted much attention as a solution to depletion of fossil fuels and global warming due to the emission of carbon dioxide. Therefore, wind turbines are being rapidly introduced as alternative electric power generation systems using renewable energy worldwide. However the output of wind turbines fluctuates widely depending on the cube of the wind speed. In particular, the output of small wind turbines located at urban area including houses, apartments, and office buildings is apt to fluctuate because of turbulence as well as remote areas. In such area, it is desired that wind turbines efficiently convert wind energy to electrical energy. Variable speed wind turbines are generally characterized as having higher efficiency than fixed speed wind turbines. Moreover fixed pitch with variable speed wind turbines are becoming more popular for lower installation cost compared with variable pitch wind turbines.

Thus there are a variety of maximum power control methods to improve power generation efficiency. In those preceding researches, hill climbing methods are usually used. Yaoqin et al. proposed a maximum power point tracking control with hill climbing of variable step for rotational speed to track ramp variation of wind speed from 0 m/s to 12 m/s. As other hill climbing methods, variable step of load resistance and duty cycle are presented by Tanaka et al., Koutroulis et al., respectively. In those methods, Kazmi et al. reported that there are two serious problems with hill climbing method which significantly decreases performances under rapidly changing wind speed. The one is that a large step size causes oscillations around a maximum power point for fast tracking. The second is misleading of hill climbing by wind speed changing, because the direction of the climbing is decided only by the increase or decrease of generating power. Therefore Kazmi et al. proposed a control algorithm based on searching the non-unique optimal power curve in online depending on the wind speed, and use it as a reference for control to improve those problems. Here, because of the large inertia

moment of wind turbines, a fast tracking control is desired. Reference Kim et al. focuses on reduction the influence of the inertia moment of the wind turbines by employing a proportional controller for fast control performance. Also, Chen et al. propose fasten maximum power point tracking method by using aerodynamic power observer. In those preceding researches, the control systems use only current information such as wind speed, rotational speed, current, and voltage, and operate wind turbines.

Until now we have studied about wind speed prediction systems from 10 minutes to several hours ahead for applying to operation of power system and wind turbine control. Those prediction system are consisted by using a complex-valued neural network (called here, CVNN), a real-valued neural network (called here, RVNN), or self-tuning fuzzy reasoning. And we confirmed the effectiveness of those systems. The prediction system consisting of the CVNN can take into account wind dynamics in two dimensional space by expressing wind data as a vector, which has both magnitude and direction, because the CVNN has a good ability for treating a complex number. Due to that kind of the capability of the CVNN, improvement of prediction accuracy was seen comparing with a prediction system using the RVNN.

In this dissertation, we propose a novel approach of maximum power control system for small wind turbines in wind variability environment by using predicted wind speed data. After confirming the validity of the proposed wind turbine control system, a wind speed prediction system by using a CVNN is proposed.

To extract maximum power from wind turbines, it is necessary that the rotational speed of wind turbines should be adjusted at optimal point in the real time. However wind turbines have a large inertia compared to the inertia of the generator. Therefore the time lag of the rotational speed control will occur in environment with turbulence. The features of the proposed control system are to use future information which is predicted wind speed and to set a reference trajectory of the rotational speed of the wind turbine based on both the predicted wind speed ahead of a few seconds and the mechanical time constant of the wind turbine. The effect of using the predicted data is that the controller can operate the wind turbine efficiently and stably so that the rotational speed of the wind turbine catches up with the reference speed at maximum power point. Then variable speed control of wind turbine is realized by using power converter control technique. The effectiveness of the proposed control system and the wind speed prediction system are demonstrated by computer simulations.

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論文審査の結果の要旨

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学位論文題目

Study on Maximum Power Control System for Small Wind Turbine Using Wind Speed Prediction
風速予測を用いた小型風力発電機の最大出力制御システムに関する研究

審査結果の要旨

本研究は，小型風力発電機を対象として，風速予測情報を用いた最大出力制御法による発電効率向上を目的としたものである．特に，その制御アルゴリズムにおいて，風速予測情報と風力発電機の応答を考慮した風車回転数の指令値を設定している点に特徴がある．従来手法では，現時点までに観測された風速情報のみに基づいて制御を行うが一般的であるが，風力発電はブレードが大きな慣性を持つため制御に遅れを生じる問題があった．そこで本研究では，風力発電機に流れ込む風速を計測できること，また，風力発電機の各パラメータが既知であると仮定し，風速予測情報を用いた最大出力制御システムを提案している．提案手法においては，風力発電機の応答を考慮した風車回転数の指令値を設定し，その指令値に風車回転数が追従するように負荷に供給する電力を調整することにより，最大出力制御を実現している．また，不連続に変化する指令値ではなく，連続的に変化する指令値を設定することで制御性能の向上を実現している．

提案手法の有用性は，シミュレーション解析により従来手法を含む複数の手法と比較することで検討している．その結果，予測風速が精度よく得られる場合は提案手法の有用性が高いことが確認された．また，風速の予測精度が発電量に与える影響についても検討し，短時間先風速予測で一般的に用いられる持続モデルにより得られた予測風速に基づいたシミュレーション解析も行っている．さらに，提案する制御システムに関連して，複素ニューラルネットワークを用いた風速予測システムも提案している．複素ニューラルネットワークを用いた長時間先予測では，多地点の数値予報データを入力情報として用いることにより，予測精度の向上を実現している．また，実数ニューラルネットワークを用いた風速予測システムに対する優位性を示すために，t検定を用いて統計的に証明している．さらに，短時間先の風速予測システムも併せて構築し，予測精度の検討を行っている．

今後は，提案する制御手法の有用性を実験により評価することと，風速の予測精度向上が課題として挙げられているが，本研究の成果は意義深く，今後の発展が十分期待できる．

以上の結果より，本論文は博士（工学）の学位授与に値するものと判定する．