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Christian A. Hans

Operation control of islanded microgrids

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SHAKER VERLAG

OPERATION CONTROL OF ISLANDED MICROGRIDS

vorgelegt von
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PREDICTION IS VERY DIFFICULT, ESPECIALLY ABOUT

THE FUTURE.

DANISH PROVERB

Abstract

Islanded microgrids (MGs) are small electric power networks that have no connection to a larger grid. They typically comprise storage units, renewable and conventional generators as well as loads. The central question of this work is: How to operate islanded MGs with high renewable share, i.e., how to control the energy of the storage units, and how to maximize infeed from uncertain renewable sources without compromising a safe operation?

To answer this question, different model predictive control (MPC) schemes for the operation of MGs are deduced. These are derived based on a generic model of an islanded MG with high renewable share. The schemes can be distinguished by the way they handle the uncertain load and renewable infeed: (i) certainty equivalence MPC, where a nominal forecast is fully trusted; (ii) minimax MPC, where time-varying forecast intervals are assumed; (iii) risk-neutral stochastic MPC, where a forecast probability distribution is fully trusted; and (iv) risk-averse MPC, where a forecast probability distribution is *not* fully trusted.

All schemes are posed in computationally tractable ways and compared in a numerical case study. The results of this study indicate that (i) certainty equivalence MPC can compromise a safe operation; (ii) minimax MPC leads to a safe operation at the expense of higher costs; (iii) risk-neutral stochastic MPC leads to a safe operation and low costs if the forecast probability distribution is accurate; and (iv) risk-averse MPC provides robustness to misestimated forecasts and unlikely events which leads to a safe operation at low costs.

In conclusion, how uncertain load and renewable infeed are modeled has a significant impact on safety and performance. Overall, risk-averse MPC was identified to be most suitable for the operation of islanded MG as it provides robustness to misestimated forecasts and unlikely events which translates into low costs and a safe operation.

Kurzfassung

Microgrids (MGs) im Inselbetrieb sind kleine elektrische Netze ohne Verbindung zu einem größeren Netz. Sie beinhalten typischerweise Speicher, erneuerbare und konventionelle Einheiten sowie Verbraucher. Die zentrale Frage dieser Arbeit lautet: Wie können MGs mit hohem Anteil erneuerbarer Erzeuger als elektrische Insel betrieben werden, d. h., wie sollte die gespeicherte Energie geregelt werden, und wie kann man erneuerbare Einspeisung maximieren, ohne die Versorgungssicherheit zu gefährden?

Um diese Frage zu beantworten, werden unterschiedliche Ansätze zur modellprädiktiven Regelung (englisch model predictive control, MPC) hergeleitet. Diese basieren auf einem gemeinsamen mathematischen Modell eines MGs. Die Ansätze unterscheiden sich darin, wie unsichere erneuerbare Erzeugung und Last modelliert werden: (i) Sicherheitsäquivalente MPC, bei der die nominelle Vorhersage als sicher angenommen wird; (ii) Robuste MPC, bei der zeitvariante Vorhersageintervalle angenommen werden; (iii) Risikoneutrale stochastische MPC, bei der die Wahrscheinlichkeitsverteilung der Vorhersage als sicher angenommen wird; und (iv) Risikoaverse MPC, bei der die Wahrscheinlichkeitsverteilung der Vorhersage als unsicher angenommen wird.

Alle Ansätze werden so hergeleitet, dass sie mit existierenden Verfahren numerisch gelöst werden können und in einer Simulationsstudie miteinander verglichen. Die Ergebnisse der Studie legen nahe, dass (i) die sicherheitsäquivalente MPC zu verringerter Versorgungssicherheit führt; (ii) die robuste MPC zu einem sicheren Betrieb und erhöhten Kosten führt; (iii) die risikoneutrale stochastische MPC zu einem sicheren Betrieb und niedrigen Kosten führt, wenn die angenommene Wahrscheinlichkeitsverteilung korrekt ist; und (iv) die risikoaverse MPC robust gegenüber fehlerhaften Wahrscheinlichkeitsverteilungen und unwahrscheinlichen Ereignissen ist, was zu einem sicheren Betrieb und niedrigen Kosten führt.

Zusammenfassend lässt sich sagen, dass die Modellierung von unsicherer erneuerbare Erzeugung und Last einen großen Einfluss auf Versorgungssicherheit und Kosten hat. Alles in allem wurde die risikoaverse MPC als tauglicher Ansatz für den Betrieb von MGs im Inselbetrieb identifiziert, da sie robust gegenüber fehlerhaften Vorhersagen und unwahrscheinlichen Vorfällen ist und zu einen sicheren Betrieb mit niedrigen Kosten führt.

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