Bloemfontein rural microgrids

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This work is organised as follows. In section 2 we shortly introduced the historical context situating the South African power grid, the ongoing load-shedding events, and we showcase the direct effects at the University of the Free State (UFS) in Bloemfontein. In section 3 we introduce both a low-level dynamical model of power grids affected by noise as well as Fokker-Planck approximation of the power-grid frequency statistics. From this basis, we present our theoretical and numerical results. In section 4 we discuss the outcomes and limitations of our data examination and present some thoughts on future work and the necessity to examine previously overlooked synchronous areas.

In this work, we focus on power-grid frequency recordings from the Continental European power grid, the Nordic Grid, and the South African power grid. It is the latter that interests us the most for this examination. The South African power grid is undergoing an unprecedented transformation.

The power sector in South Africa is dominated by the state-owned entity ESKOM, which both imports and exports energy from surrounding states with some input from nuclear and renewable energy (photovoltaic (PV), wind and concentrated solar power) [34]. Unfortunately, the South African power system has been experiencing an energy crisis since 2007 with electrical generation lagging the electrical demand, ultimately leading to implemented rolling blackouts in an effort to stabilise the national grid.

Due to extended periods of lack of maintenance and mismanagement resulted in an unpredictable and unreliable power system in South Africa, that during 2021 experienced load-shedding for 1169 h with 1775 GWh (with the upper limit of 2521 GWh) energy shed. The latter amounts to 13.3 of all h of 2021 being in the

state of, mostly, Stage 2 load-shedding (for details see table 1 in section 3.5) [10]. The power system remained coal powered during 2021, but with contributed by renewable energy (of which were variable sources) [2]. Concernedly, 3.2 TWh of energy was generated by using diesel.

Table 1. Total estimated load shed energy as reported by the Council for Scientific and Industrial Research--Energy Centre of South Africa (see p 171 in [10]) at different load-shedding stages (St. 1 to St. 6). Shown as well are the total number of hours under load-shedding in South Africa in 2019, 2020 and 2021.

With critical low reserve margins and increasing load-shedding, some consumers are considering the implementation of self-sufficient microgrids with some renewable input. The latter is preceded by the digitisation of the existing electrical network topology (i.e. smart grids) that requires initial capital input [35]. South African university campuses are naturally forced to evolve according to the constraints of the national utility, the ability to swiftly react to demand reduction signals being the most critical, see figure 1. In cases of severe loss of supply, self-sufficient microgrids are utilised that synchronise with available renewable supply to ensure supply continuity on campus. The latter typically being hybrid PV-diesel-based microgrids.