Observability and Decision Support for Supervision of Distributed Power System Control -
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Analyses of past disturbances and blackouts have shown that lack of situation awareness of control room operators led to
wrong or suboptimal decisions. Two main issues are associated with lack of situation awareness. On the one hand,
operators do not get the information needed to fully understand the current state of the grid. On the other hand, the
information is not correctly interpreted. Along with the enhancement of existing tools, complementary monitoring methods
must be developed for increased observability and situation awareness. To facilitate the decision process, tools that
provide specific operational information, relevant to the current grid condition, need to be developed. This dissertation
covers three areas where specific challenges for improved observability and decision support in future control rooms are
addressed: Classical large power system stability issues, innovative data-driven techniques for voltage estimation at the
distribution level, and
aggregation functions for geographically dispersed time-dependent distributed energy resources are investigated. In
particular, this dissertation proposes a decision support tool for transient stability preventive control, a neural-network-
Based approach for real-time voltage estimation in active distribution grids, and a modeling approach to harness the
flexibility of an aggregation of electric vehicles. For improved monitoring and maintaining power system stability, a decision
support tool for transient stability preventive control, based on time-domain simulations, is proposed. The approach
employs a critical bus screening and a fast critical contingency screening prior to the assessment to reduce the
computational burden. In addition, a fast-converging technique to determine the required dispatch for re-establishing a
predefined stability margin is presented. The approach delivers a near optimal solution in terms of cost minimization due to
its sequential nature and shows to be robust when applied to larger power systems. The general problem of low
distribution grid observability is addressed by proposing a data-driven
approach for real-time voltage estimation in active distribution grids utilizing existing real-time and non-real-time
measurements. The framework to establish such a neural real-time voltage estimator is described. Then, the capabilities
and limitations of the approach under practical considerations are analyzed by means of field data. This includes a
methodology to select the most relevant input variables and find a tradeoff solution between achievable performance and
number
of inputs and a sensitivity analysis of the performance and number of neurons. Moreover, the quantity of historical data
which is needed to train an adequately functioning model is analyzed. In order to maintain the accuracy of the trained
model, the impact of the retraining interval on the model performance is determined. Additionally, the sensitivity of the
model to distributed generation is investigated. The growth of electric vehicles results in additional demand for charging
which will require large investments in power distribution, transmission, and generation. However, this demand is often
also flexible in time and can be actively managed to reduce the required investments and to enhance power system
operation. Harnessing this flexibility requires forecasting and controlling electric vehicle charging at thousands of stations.
A model to aggregate and forecast the flexible demand from tens to thousands of electric vehicle supply equipments is
proposed. From an
operational perspective, the aggregated EVs are represented as an equivalent time-variant storage model whose
parameters can be easily aggregated and forecasted using autoregressive models. The forecastability of the uncontrolled
demand and the storage parameters is evaluated using an extensive dataset from 1341 non-residential electric vehicle
supply equipments located in Northern California. Two possible applications of the model are presented: peak reduction
compared to
uncontrolled charging, and an energy arbitrage scenario. Overall, it is shown that a combination of classical and innovative
approaches can contribute to improved situation awareness of control room operators. In addition, complementary
decision support tools can further aid the control room operator in determining appropriate operational actions. However,
observability and decision support tools must be integrated to allow optimal operational decisions that satisfy all
constraints.

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