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Optimal Two-Tier Forecasting Power Generation Model in Smart Grids

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There has been an increasing trend in the electric power system from a centralized generation-driven grid to a more reliable, environmental friendly, and customer-driven grid. One of the most important issues which the designers of smart grids need to deal with is to forecast the fluctuations of power demand and generation in order to make the power system facilities more flexible to the variable nature of renewable power resources and demand-side. This paper proposes a novel two-tier scheme for forecasting the power demand and generation in a general residential electrical gird which uses the distributed renewable resources as the primary energy resource. The proposed forecasting scheme has two tiers: long-term demand/generation forecaster which is based on Maximum-Likelihood Estimator (MLE) and real-time demand/generation forecaster which is based on Auto-Regressive Integrated Moving-Average (ARIMA) model. The paper also shows that how bulk generation improves the adequacy of proposed residential system by canceling-out the forecasters estimation errors which are in the form of Gaussian White noises.

Keywords : Adequacy Analysis, ARIMA Model, Forecasting Model, Maximum Likelihood Estimation, Smart Grids.

1. INTRODUCTION

In recent years, increasing awareness about environmental issues and sustainable energy supply introduced modern power system, called smart grid (SG), to upgrade conventional power system by utilizing novel technologies. There are many influential elements in the SG which helps power grid to achieve a more reliable, sustainable, efficient and secure level, such as distributed renewable resources (DRRs), advanced metering infrastructure (AMI), energy storage devices, electric vehicles, demand response programs, energy efficiency programs, and home area networks (HANs) [1,2]. Furthermore, recent advances in deploying communication networks in SG provide two-way communication between utility and electricity consumers and improve market efficiency [3]. In a related context, conventional generation resources mostly use fossil fuel as their energy source which is a major environmental concern. To overcome this problem, SG will experience a high penetration of DRRs which has two main advantages: 1) cost-effective because the main energy source is free (wind energy, sunlight, etc), 2) produce no hazardous pollution. Additionally, DRR utilization helps power system to become dispersed. Therefore, not only SG is more distributed than conventional power system but power generation units are trying to implement green-based energy resources [4].

One of the most challenging issues in future power system design and implementation is the flexibility of power system devices to adapt the stochastic nature of demand and generation [5,6]. In other words, high penetration of DRRs, such as wind power and photovoltaics, is not sufficient to achieve an acceptable level of reliability in terms of adequate supply of elecergy in different communities during the time. In the case that $\mathcal{S}(q,t) \leq s_q - \lambda$ for the q^{th} community, the controller asks the bulk generation to fill the gap and cancel out the noise $-\mathcal{W}_t$ by providing the community with $\mathcal{W}_t$ units of energy.

Here, we focus on what has to be done by the LLMU specified in Figure 1b. The recently explained scenario which specified the functionality of LLMU cannot be implemented in the real-world as the values of $\mathcal{G}(q,t)$ and $\mathcal{D}(q,t)$ are obtained from random processes. This urges us to forecast theses values in short term (for example, every 15 minutes). Algorithm 1 shows the practical way of implementing LLMU using forecasting models for the $q^t h$ community. As mentioned before, by forecasting (estimating) the power demand and generation using ARIMA model, we will obtain white noise errors added to the real values of $\mathcal{G}(q,t)$ and $\mathcal{D}(q,t)$ as the estimated values. These noises on the estimated power values will add some errors in the form of Brownian Motion processes to the estimated values of stored energy.

5. SUMMARY AND OUTLOOK

This paper proposed a novel hybrid scheme for forecasting the power demand and generation in a residential power distribution network. Our forecasting scheme had two tiers: long-term demand/generation forecaster which is based on Maximum-Likelihood Estimator (MLE) and real-time demand/generation forecaster which is based on Auto-Regressive Integrated Moving-Average (ARIMA) model. The paper also showed how bulk generation improves the adequacy of our residential system by canceling-out the forecasters estimation errors which are in the form of Gaussian White noises.

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