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Smart Grid Forecasting and Infrastructure Models

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Abstract
The majority of recent research has been on smart grids as a clever method of controlling power generation and delivery. This pattern was appropriate during the ideation and development stage, but at the delivery stage, we will need to expand the concept and expand the use of it. More energy-related applications should be taken into account by smart grids, such as monitoring and integrating the natural gas grid and strengthening their support for peak load shifting applications. This article examines the integration of gas networks with smart power grids as part of ongoing efforts to promote the smart grid idea. Along with PHEVs, three potential integration strategies were provided, along with potential energy grid architecture. Forecasting models' significance.

Keywords: Models for forecasting, gas grids, smart energy grids, and grid infrastructure models.

I. INTRODUCTION

Electricity grids with cognitive behavior, such as communicating with consumers to limit energy usage and thus use fossil fuels more efficiently, are currently referred to as smart grids. Nevertheless, because of the ongoing growing energy use and the urgent need to reduce greenhouse gas emissions at the same time Smart gas grids and renewable energy products are two examples of the many energy supplies and grids that must be integrated into a smart grid. In this instance, "Smart Energy Grid (SEG)" would be a more appropriate moniker for this kind of interconnected system. To accommodate the newly needed features, this integration will necessitate an evolutionary shift and restructure in the current technological infrastructure [1]. For instance, the current energy supply system's operation needs be transformed to a suitable combination of power, gas supply chain infrastructure, contemporary telecommunications, and sensing technology is needed to completely integrate and deploy the gas grid and other components into the smart grid. At the moment, numerous studies Researchers are working to support the modeling, design, and realization of smart power grids. Research projects that take into account connecting the gas grid into the power grid are uncommon, nevertheless. For instance, the EU commission established Expert Group 4 to define the features and services of smart gas grids. This group came to the conclusion that smart gas grid development cannot be done in a vacuum; rather, it must be integrated with future electricity smart grid development to enable smart energy utilization. The team has determined a few prerequisites that will support the continued development of the National Institute for Standards and Technology's definition of the smart grid framework links the natural gas grid to the electrical grid via generating electricity [3]. This connection is one method of integration is currently included in the design of the electrical grid as it stands, but additional integration strategies should be looked at. Such research is necessary to demonstrate the possible role that the natural gas grid may play in sustaining and growing the smart power grid. To the best of the authors' knowledge, no prior work has examined the connection between smart power and the gas grid, either in terms of SEG architecture or the requirements of infrastructure models. This paper discusses the SEG architecture, integrated infrastructure components, and associated forecasting methods. Making use of this possible architecture, The remaining portion of this paper discusses three alternative approaches to integrate the gas and electricity grids, as well as a prospective energy grid architecture and associated KPIs, which were covered in section 2. The necessary smart grid infrastructure model is in section 3. Elements are displayed. Section 4 provides an explanation of the energy forecasting models pertaining to the flexible infrastructure. We will wrap up our findings and discuss the issues ahead in section 5.

II.Energy Grid Structures

2.1 Gas grid integration with smart grid

The natural gas grid's smartening and integration with the smart power grid, or SEG, may offer a number of financial and environmental benefits. The gas grid can be connected to the power grid in a number of ways. The ensuing subsections will cover three of these techniques.

2.1.1 Systems for Energy Hubs

Constructing energy hub systems with a transformer, a micro combined heat and power turbine (microCHP), and a furnace to aid in load shifting during peak hours is one method of integration. The following general equation of the energy hub defines the hub outputs as electricity and heat h. The hub inputs are electricity e and natural gas g.

2.1.2 Gas Power

As illustrated schematically in figure 1 [5], excess renewable power can be transformed to hydrogen through the use of water electrolysis technologies. Whenever necessary, the hydrogen can be transformed via a process with carbon dioxide (CO2) into synthetic methane. This methane can be stored with the elemental hydrogen in the current natural gas networks and related subterranean storage facilities, up to a certain capacity [6]. This conversion process has an efficiency of almost 80% [2]. Hydrogenics, a Toronto-based company, and Enbridge, a Calgary, Alberta-based company, have entered into a collaborative agreement to jointly develop utility-scale energy in Canada. This will involve combining Hydrogenics' expertise in water electrolysis with Enbridge's knowledge of natural gas pipeline networks and renewable energy generation this sustainable energy.

Fig 1. Power to Gas through water electrolysis (Source: German Energy Agency [5])

2.1.3 Appliances with two fuel sources

Using a dual fuel gas/electric appliance is one way to manage peak load shifting. Some of the technologies for dual appliances are currently available, although not yet broad. There are many different types of dual fuel/dual output appliances, including integrated heating and cooling systems, gas and electric dual fuel ranges, etc. Then, in order to allow the use of the less expensive fuel for cooking or home heating, smart grids should be able to send market data, including peak capacity pricing signals, to a home heating controller. Fig. 2 [2] provides a conceptual diagram of an in-house smart grid system that illustrates a potential system operation. The gas grid integration techniques covered above can result in a variety of energy grid scenarios. In Fig. 3, one of those circumstances is displayed. We have focused more on the integration of the gas grid system with the power grid in this architecture. The grid elements that are tinted in yellow indicate potential places of linkage between the two grids. As previously said, the variable electricity produced by renewable resources like solar and wind power is converted to gas and fed into the gas grid system. Given that they can run on both natural gas and electric batteries, plug-in hybrid electric vehicles (PHEVs) constitute a crucial and adaptable link in the proposed grid system. As a result, they can be charged at gas stations, electrical outlets, and As a result, employing dual fuel appliances, increasing the use of PHEVs, NGEVs, and EVs for transportation, injecting gas (from the conversion of electricity) into the gas grid, and making substantial use of energy hubs, such as CHP cogeneration will provide a great way to control greenhouse gas emissions and improve the energy networks' efficiency, enabling users to maximize their energy use.

2.3 Indicators of grid performance

Performance optimization is the basis for operating the target grid. Both the general grid architecture and each individual model block's performance are defined locally. This is accomplished. involves establishing key performance indicators (KPIs) for every grid model component, including the power line, building (such as the load), solar, wind, and energy storage systems. The definition of KPIs will make it possible to optimize grid performance overall based on the ranking of KPIs that is wanted. The definition of typical KPIs is determined by comparing the input to output ratio. The amount of energy produced for a given fuel, for instance, is a key performance indicator for generators. Model elements based on physical, dynamic, and control model aspects are used to develop the KPIs. This will enable the grid to be dynamically estimated.

III.Infrastructure model for smart grids

When SEG is fully utilized, conventional home appliance gadgets such The required smart meters and their related smart and dual appliances, such as refrigerators and heaters, must be replaced. The deployment of smart meters, which is either already planned or in the process of being implemented, is currently the primary responsibility of initiatives related to the smart grid. For instance, it was recently anticipated that 60 million smart meters are being installed in the US [1]. Apart from the components mentioned above and depicted in Fig. 3, additional factors are required to construct a dependable smart infrastructure model capable of facilitating the proper functioning of these components. Among those elements are:

1. Intelligent gas sensors,
2. A communications network, and
3. Advanced metering infrastructure
4. Optimizing the grid and responding to demand
5. Sophisticated forecasting models and control systems for utilities
6. Safety apparatus

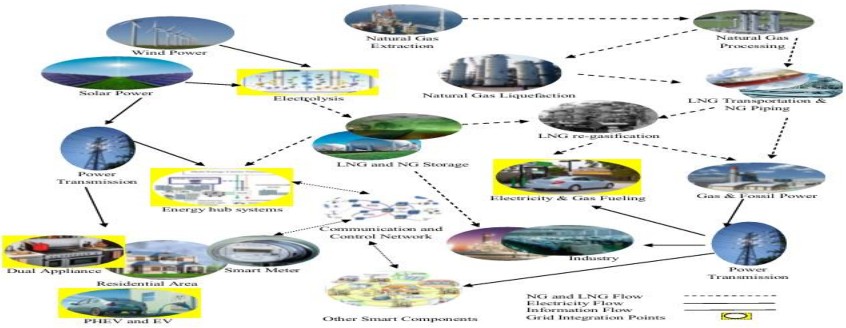

Fig. 3. Possible Scenario for Integrated gas and power smart grid

Because of the intricate relationships between its components, modeling an energy smart grid is a difficult undertaking. Controlling the charging of electric cars during peak hours, which can reduce their ability to transfer loads, is one of those difficulties. representative. Cost-benefit analysis was used to test the time-of-use control mechanism, and it was found to be beneficial in every scenario studied [8]. The difficulties in developing forecasting models appropriate for SEG and its varieties will be covered in the section that follows.

IV Forecasting models

The complexity of the relationships between the many components makes energy smart grid modeling a challenging task. One of those challenges is managing the charging of electric vehicles during peak hours, which can impair their capacity to transmit loads. exemplary. The time-of-use control mechanism was tested using cost-benefit analysis, and it was discovered to be advantageous in each of the scenarios examined [8]. The next section will address the challenges in creating forecasting models suitable for SEG and its variants. When calculating and implementing strategic plans for smart grid infrastructure, relying on such estimates might cause significant deviations from the most efficient use of available resources. The construction of such infrastructure will be extremely expensive; for example, PHEV supporting Infrastructure comprises the buildings, devices, and machinery required to operate a plug-in hybrid electric vehicle (PHEV), such as battery exchange or charging stations [10]. Customer demand and satisfaction models are a significant category of forecasting models that could have an impact on infrastructure estimates. Examples of such applications include developing models to address issues that may result from improper installation or malfunctioning smart meters, or employing forecasting models for joint pricing and demand prediction with data association mining methods [11]. About 78% of participants in a research designed to gauge societal acceptance of smart grids

4.1 Model for forecasting infrastructure

When time intervals increase, prior data used to build forecasting models loses their reference value, creating uncertainty that could be the cause of significant variations displayed in Fig. 4's predicting data. Using mixed forecasting models, which employ mid-term projections to realign the long-term forecasts, is one technique to get around those uncertainties. It is recommended to base the mid-term forecasting models on many "what-if" situations. In this manner, the forecasting model's corrective actions will aid in preventing resource waste that could result from strategic planning based on one-time forecasts. This model's concept is to use the following order to increase the long-term models' predicting accuracy:

1. Create several mid- and long-term forecasting models using various

Using high, medium, and low values for the market's EV diffusion rate, the modelling is based on assumptions and experiences.

2. Create strategic scenarios utilizing "what-if" tactics based on those models. Test changes in market demands using midterm models, then make necessary adjustments to plans and take corrective action.

4.2. Forecasting with Mixed Long-Term and Mid-Term

This section introduces the Mixed Long Term and Midterm Forecasting Model (LMFM), which is designed to forecast the rate at which various vehicles will become a part of the future market and the infrastructure that will support them. The integrated intelligent model serves as the foundation for the LMFM. With its many demand components and complicated environment, the model offers precise forecasts [13]. The moving average method and the Holt model, two popular statistical long- and mid-term forecasting models, will be used to compare the model. The data will also be used to test the models.

Conclusion

Smart grid deployment and full integration of the gas grid and other components need a suitable mix of contemporary telecommunications, electricity, gas distribution infrastructure, and sensing technology. This study has provided a a suggestion for a few potential ways to connect the smart power grid and the gas grid, such as energy hub systems, gas to power conversion, and dual fuel appliances in a single model. The three approaches for integrating the gas and power grid models have been applied in the suggested architecture. The key performance indicators (KPIs) for grid models will be created using potential architectures to allow for the optimization of the overall grid performance. There was also a general explanation of the forecasting models' shared characteristics and specifications a combination forecasting model utilizing mid-term.

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