Smart Dispatch of Generation Resources for Restructured Electric Power Systems

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Abstract--**This paper addresses the vision of a new generation dispatch system for restructured power systems. As distributed generation, demand response and renewable energy resources become significant portions of overall system installed capacity, a better system dispatch tool for system control centers is required in order to cope with the increasing amount of uncertainties being introduced by the new resources. A Smart Dispatch (SD) framework for regional transmission organizations and transmission system operators to manage large power grids is proposed. In particular, the ability of the new dispatch system to provide a better holistic and forward-looking view of system conditions and generation patterns will be discussed in detail. Such features are deemed critical for the success of efficient system operations in the future.**

***Index Terms*—Economic dispatch, system security, system operations, electricity market, smart grid, generation control**

I. INTRODUCTION

THE restructured electric power industry has brought new challenges and concerns for the secured operation of stressed power systems. Energy systems whether in developed or emerging economies are undergoing fundamental changes due to the emphasis of low carbon energy mix and the demand responsiveness. This will lead to a profound transition from the current centralized infrastructure towards the massive introduction of distributed generation, responsive and controllable demand and active network management throughout the system. At the same time regulators and market participants appetite for market liquidity and transparency naturally drives towards larger trading areas as well as new incentive for end users to consume their energy smartly.

Unlike conventional generation resources, outputs of many of the renewable resources do not follow traditional generation/load correlation but have strong dependencies on weather conditions or demand for heat, which from a system prospective is posing new challenges associated with the monitoring and controllability of the demand-supply balance.

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As distributed generations, demand response and renewable energy resources become significant portions of overall system installed capacity, a smarter dispatch system for generation resources is required to cope with the new uncertainties being introduced by the new resources. Regional transmission organizations (RTOs) and transmission system operators (TSOs) managing large geographical regions of resources need better tools to support operator's decision-making. The ability of the new dispatch system to provide a better predictive, forward-looking holistic view of system conditions and generation patterns is deemed critical for the success of efficient system operations.

Around the world very large power grid operators like PJM, Midwest ISO or North China Grid are fundamentally reliant on some generation-dispatching systems to optimally dispatch generation resources to serve the native load in large geographical regions [1]. Facing the challenges posed by the smart grid, RTOs/TSOs are in the process of designing the next generation of dispatch systems with broader and higher capability to handle the uncertainties ever before. For example, the limited dispatchability and intermittent nature of wind and solar generation could require grid operators to supply additional ancillary services needed to maintain reliability and operational requirements. The new dispatch system will need to somehow economically manage rapid changes in load, generation, interchange and transmission security constraints simultaneously on a real-time and near real-time basis. It is also expected that the system will flexibly incorporate various power forecast data sources including demand forecast and renewable generation forecast. A new time-coupled dynamic dispatch engine will provide a desired dispatch profile for any specified time frame. The scheduling solutions of different time frames addressing different system scenarios are consolidated to form a continuum of comprehensive operating plan (COP). COP provides operators with a holistic forward-looking view and continually updated view of trends and dynamics of generation profile and system conditions hours ahead of real-time.

The rest of the paper will be presented as follows. An overview of the evolution of economic dispatch is given in Section II. Section III discusses the functional framework and the vision for Smart Dispatch from a system operator perspective. Section IV describes the newly proposed dispatch system called generation control application (GCA) which is a key part of the overall smart dispatch vision. Conclusions are drawn in Section V.

II. THE EVOLUTION OF ECONOMIC DISPATCH

Economic dispatch is about the operation of generation facilities to produce energy at the lowest cost to reliably serve consumers, recognizing any operational limits of generation and transmission facilities. The problem of economic dispatch and its solutions have evolved over the years. The evolution timeline of it could be divided into the following three major periods:

1. Classical dispatch (1970's – 1990's)
2. Market-based dispatch (1990's – 2010's)
3. Smart dispatch (2010's –)

Classical dispatch [2]

Since the birth of control center's energy management system, classical dispatch monitors load, generation and interchange (imports/exports) to ensure balance of supply and demand. It also maintains system frequency during dispatch according to some regulatory standards, using Automatic Generation Control (AGC) to change generation dispatch as needed. It monitors hourly dispatch schedules to ensure that dispatch for the next hour will be in balance. Classical dispatch also monitors flows on transmission system. It keeps transmission flows within reliability limits, keeps voltage levels within reliability ranges and takes corrective action, when needed, by limiting new power flow schedules, curtailing existing power flow schedules, changing the dispatch or shedding load. The latter set of monitoring and control functions is typically performed by the transmission operator. Traditionally, generation scheduling/dispatch and grid security are separate independent tasks within control centers. Other than some ad hoc analysis, classical dispatch typical only addresses the real-time condition without much consideration of scenarios in the past or the future.

Market-based dispatch [3,4,5]

Ensuring reliability of the physical power system is no longer the only responsibility for the RTO/ISOs. A lot of the RTOs/ISOs are also responsible for operating wholesale electricity markets. To facilitate market transparency and to ensure reliability of the physical power system, an optimization-based framework is used to provide an effective context for defining comprehensive rules for scheduling, pricing, and dispatching. Taking advantage of the mathematical rigor contained in formal optimization methodology, the rules are likely to be more consistent, and thus more defensible against challenges that invariably arise in any market. Congestion management via the mechanism of locational marginal pricing (LMP) becomes an integral part of design of many wholesale electricity markets throughout the world and security-constrained economic dispatch (SCED) becomes a critical application to ensure the transmission constraints are respected while generation resources are being dispatched economically. The other important aspect of market-based dispatch is the size of the dispatch system. A typical system like PJM or Midwest ISO is usually more than 100GW of installed capacity. Advances in mathematical algorithms and computer technology really make the near real-time dispatch and commitment decisions a reality.

Smart dispatch

Smart dispatch (SD) is envisioned to be the next generation of resource dispatch solution particularly designed for operating in the smart grid environment [6]. The "smartness" of this new era of dispatch is to be able to manage highly distributed and active generation/demand resources in a direct or indirect manner. With the introduction of distributed energy resources such as renewable generations, PHEVs (Plug-in Hybrid Electric Vehicles) and demand response, the power grid will need to face the extra challenges in the following areas:

- Energy balancing
- Reliability assessment
- Renewable generation forecasting
- Demand forecasting
- Ancillary services procurement
- Distributed energy resource modeling

A lot of the new challenges are due to the uncertainties associated with the new resources/devices that will ultimately impact both system reliability and power economics.

One way to cope with uncertainties is to create a better predictive model. This includes better modeling of transmission constraints, better modeling of resource characteristics such as capacity limits and ramp rates, and more accurate demand forecasting. It is our belief that providing a forward-looking view of system conditions and generation patterns to system operators is deemed critical for the success of efficient system operations in the future.

Another way to cope with uncertainties is to address the robustness of dispatch solutions. Optimality or even feasibility of dispatch solutions could be very sensitive to system uncertainties. Reserve requirements and "n-1" contingency analysis are traditional ways to ensure certain robustness of a given system. Scenario-based (Monte-Carlo) simulation is another common technique for assessing economic or reliability impact with respect to uncertainties such as demand forecast.

When compared to the classical dispatch which only deals with a particular scenario for a single time point, smart dispatch addresses a spectrum of scenarios for a specified time period (Figure 1). Thus the expansion in time and scenarios for SD makes the problem of SD itself pretty challenging from both a computational perspective and a user interface perspective. For example, effective presentation of multi-dimensional data to help system operators better visualize the system is crucial. Beside a forward-looking view for system operators, SD should also allow after-the-fact analysis. System analysts should be able to analyze historical data systematically and efficiently, establish dispatch performance measures, perform root-cause analysis and evaluate corrective