

Reliability Analysis of Smart-Grid Generation Pools

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Abstract — A smart grid comprises of several genres of generating units; DG sets, wind turbines, solar plants and the like. Depending on the contingent power situation at any given time, it is expedient on the part of the system operator to extract optimum generation from all the units. Unit Commitment (UC) techniques can be applied in such a situation. Each of these units has associated variables like continuous ratings, start-up and shut-down characteristics, failure and repair rates, reliability indices etc. UC has been explored in depth for many years. Its application to smart grids is complex owing to the disparate characteristics of the different power plants within the smart grid. It is proposed to reduce the complexity by introducing redundant state analysis. It weeds out the redundant states that arise by the combination of failures and repairs on this pool of machines. It is based on the concept of sequential machines in the context of digital electronics.

Keywords- Unit Commitment problem, Smart grid, Reliability constraints, generator scheduling, sequential machines, finite state machines, redundant states

I. INTRODUCTION

Smart grids are the precursor to the evolving distributed generation scene in the coming years. They are much more than conglomerated power systems. They address the point-to-point generation modes that are integral to distributed load demands that are specific to smart grids. Such grids are further dependent on generation models, transmission networks and downstream distribution among industrial, commercial and domestic customers, at different voltage levels. This paper leans towards the generation models and the corresponding analysis of state related problems.

In a particular generation model, a generation block typically consists of several generating units of varying hierarchy, ratings and ages. These are interconnected to assign a specified power rating to the block. Several such blocks cohere to form a smart grid, often classified according to the geography of the region. Unit commitment (UC) is an important problem in the daily operation and planning of the power system. The objective of UC is to determine the optimal set of generating units to be in service during each interval of the scheduling period (a day or a week ahead), to meet system demand and reserve requirements at minimal production cost, subject to

satisfying a large set of operating constraints [1,2]. The solution of the UC problem is a complex optimization problem with both discrete (unit commitment) and continuous (generation levels) variables. Generation levels for each feasible combination of units can be obtained by the economic dispatch procedure. The optimal solution to the problem can be found by exhaustive enumeration of all feasible combinations of generating units. The computer execution time for this method is usually too immense for practical systems. Research efforts have concentrated on efficient, suboptimal UC algorithms which can be applied to realistic power systems [3]. This is done by the analysis of the different states that are formed by the multiple failures and repair activities of the units. However, this apparently crude method of enumeration lends itself excellently to the proposed method of redundancy analysis of these states.

II. PROBLEM STATEMENT

The overall objective function of the UCP of N generating units for a scheduling time horizon T is given by [2].

$$\text{Min.} \sum_{i=1}^N \sum_{t=1}^T [U_i F_i(P_i) + V_i S_i] \quad (1)$$

U_i = Units status variable

P_i = Output power of unit i at time t.

$F_i(P_i)$ = Production cost of a committed unit i (considered in quadratic form)

V_i = Start-up/shut-down variable

S_i = Start-up/shutdown variable (function of the down time of unit i)

PD_t = System peak demand at hour t (MW)

Subject to the primary constraints

(a) Load demand constraints:

$$\sum_i U_i P_i = PD_t \quad (2)$$

(b) Spinning reserve:

Spinning reserve, R_t is the total amount of generation capacity specified by the system operator, when load demand rises excessively, from all

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