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Analysis of power and frequency control requirements in view of increased decentralized production and market liberalization

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Abstract

This paper presents a systematic approach of the analysis of the minimum control requirements that are imposed on power producing units in the Netherlands, especially in the case when decentralized production increases. Also some effects of the liberalization on the control behavior are analyzed. First an overview is given of the amount and type of power production in the Netherlands, followed by a review of the control requirements. Next models are described, including a simplified model for the UCTE power system. The model was tested against frequency and power measurements after failure of a 558 MW production unit in the Netherlands. Agreement between measurements and model predictions proved to be good. The model was subsequently used to analyze the primary and secondary control requirements and the impact of an increase in decentralized power production on the fault restoration capabilities of the power system. Since the latter production units are not actively participating in primary and secondary control, fault restoration takes longer and becomes unacceptable when only 35% of the power producing units participate in secondary control. Finally, the model was used to study the impact of deregulation, especially the effect of "block scheduling", on additional control actions of the secondary control.

Keywords: Power transient; Frequency transient; Simplified model; Primary control; Secondary control; Deregulation; Block scheduling

1. Introduction

In the Netherlands about 70% of the electricity production is supplied by the large production companies. This is often called centralized power generation. About 30% is generated by decentralized or dispersed generation consisting of combined heat and power (chp), wind turbines, photo voltage, etc. In the years to come, decentralized generation will increase and constitute a larger part of the total electricity demand.

Control requirements are imposed on centralized and decentralized generation. The control requirements for centralized generation are more stringent than those for decentralized generation. By increasing decentralized generation it may be necessary to review the control requirements imposed on centralized and decentralized generation, in order to deal with power unbalance in a fast and effective way. The situation can become even more pressing due to the liberalization of the electricity market. This paper will review the control requirements for these situations. First an overview of the power production will be given, followed by a description of the control strategy/requirements, a description of the simulation model, analysis and conclusions.

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2. Power generation units

Table 1 gives a survey of the maximum available nominal power generation in the Netherlands. The table shows the units under secondary control separately. This controller will be explained in a later section.

After the Dutch Electricity Act of August 1998 came into force, power generation is divided into three classes: small contributors ($P_{nominal} < 5$ MW), medium sized contributors ($5 < P_{nominal} < 60$ MW) and large contributors ($P_{nominal} > 60$ MW). Table 2 shows power generation according to the new situation.

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Table 1
Overview of centralized and decentralized power generation capacity

Centralized power under secondary control	11190 MW	62.6%
Centralized power not under secondary control	1930 MW	10.8%
Decentralized power, $P < 5$ MW (exclusive agricultural sector)	80 MW	0.5%
Decentralized power, 5 MW $< P <$ 60 MW	830 MW	4.6%
Decentralized power, $P > 60$ MW	3230 MW	18.1%
Power from waste	320 MW	1.8%
Wind turbines	290 MW	1.6%

Table 1

Table 2
Power generation capacity according to size of unit

	Category	Total nominal power (MW)	Decentralized (MW)	Under secondary control (MW)
0	$P < 5$ MW[a]	80	80	
1	$5 < P < 60$ MW	1120	830	
2	$P > 60$ MW	16670	3230	11190

[a] Exclusive agricultural heat and power installations.

3. Control strategy for power generation

In the normal situation there will be a balance between power production, load and power-exchange with neighboring countries. Due to disturbances, uncertainties in prognoses, an unbalance can exist, manifesting itself in a deviation of the frequency from its setpoint and a mismatch in the desired power exchange with neighboring countries. In order to ensure that the power production is controlled in a coordinated way, a control strategy with control requirements has been established by the UCTE (Union pour la Coordination de la Transport de l'Electricity, 1998). The control strategy consists of three types of control: primary control, secondary control and tertiary control.

A principle of the strategy is that all countries contribute to the elimination of a disturbance through primary control. This type of control is activated in the 0–30 s time frame and must be able to sustain for several minutes. This control action is locally installed on the unit level and is proportional to the frequency deviation.

Secondary control is used to eliminate the disturbance in the country where the disturbance occurred. This type of control is active during the time frame from 30 s to 15 min.

Tertiary control could be active, e.g. every 10 min and is used to create sufficient controllability for secondary control and calculates the economically optimal distribution of setpoints over the power generating units.

4. UCTE requirements

For every country participating in the UCTE power system, a minimum amount of primary power is prescribed relative to the amount of power generation in respect to the total production of the UCTE; for the Netherlands this is 110 MW (for 1998). The total primary reserve power has to cope with a worst case disturbance in the power system of 3000 MW in such a way that no load need to be switched off (frequency does not drop below 49 Hz).

In order to realize the 110 MW, Sep (Dutch Board for Power Production) and EnergieNed (Dutch Board for Power Distribution) defined specifications which are given in Table 3.

UCTE pose that after a disturbance in a particular country, secondary control should increase power to eliminate the disturbance within 15 min. The maximum rate of change of the secondary control is in the Netherlands 0.5% per minute of the nominal power output of the power plant.

5. Modeling assumptions

The complexity of a model depends on the objectives that have been set and the application of the model. In this case the objectives are to develop a simple model that is capable of quantitatively predicting maximum power and frequency changes on a power disturbance in the local power system and qualitatively predicting the power and frequency transients.

In the literature much attention has been paid to modeling of power plants and systems, e.g. (Welfonder, Lampert, & Heilemann, 1980; Colombo, De Marco, Ferrari, & Magnani, 1983). Also detailed software tools are available (e.g., PSS/E). However, for this study a simplified model was found to be adequate enough to study the most important dynamic characteristics: power exchange transients and frequency transients under changing conditions and the impact of primary and secondary control. In view of the modeling objectives, a simplified semi-empirical model was developed in Simulink/ Matlab using the following assumptions:

- the law of conservation of energy has been applied to the active power balance,
- only phenomena which impact the power balance have been modeled,