Energy Policy 39 (2011) 6220–6233

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Peak loads and network investments in sustainable energy transitions

Erik Blokhuis [a,*], Bart Brouwers [a], Eric van der Putten [b], Wim Schaefer [a]

[a] Eindhoven University of Technology, Department of Architecture, Building and Planning, Vertigo 8.11, P.O. Box 513, 5600MB Eindhoven, The Netherlands
[b] Endinet, Gas and Electricity Network Operations, P.O. Box 2005, 5600CA Eindhoven, The Netherlands

ARTICLE INFO

Article history:
Received 23 December 2010
Accepted 11 July 2011
Available online 27 July 2011

Keywords:
Energy transition
Peak load
Network investments

ABSTRACT

Current energy distribution networks are often not equipped for facilitating expected sustainable transitions. Major concerns for future electricity networks are the possibility of peak load increases and the expected growth of decentralized energy generation. In this article, we focus on peak load increases; the effects of possible future developments on peak loads are studied, together with the consequences for the network. The city of Eindhoven (the Netherlands) is used as reference city, for which a scenario is developed in which the assumed future developments adversely influence the maximum peak loads on the network. In this scenario, the total electricity peak load in Eindhoven is expected to increase from 198 MVA in 2009 to 591–633 MVA in 2040. The necessary investments for facilitating the expected increased peak loads are estimated at 305–375 million Euros. Based upon these projections, it is advocated that – contrary to current Dutch policy – choices regarding sustainable transitions should be made from the viewpoint of integral energy systems, evaluating economic implications of changes to generation, grid development, and consumption. Recently applied and finished policies on energy demand reduction showed to be effective; however, additional and connecting policies on energy generation and distribution should be considered on short term.

1. Introduction

The energy sector faces numerous problems, e.g. climate change, environmental and human accidents, reliability of energy supply, and oil dependency. It is therefore time to launch a fundamental course change with respect to our energy supply. The drivers for such a change originate in broad societal ambitions, and materialize in policy that is mostly formulated at national and cross-border level. For instance, the European Commission has formulated major objectives for future energy systems, e.g. to reduce carbon emissions by 20%, to increase the share of renewable energies by 20%, and to increase the energy efficiency by 20% before 2020 (CoEC, 2008a, 2008b). This fundamental course change implies transitions towards new sustainable energy systems (Verbong and Geels, 2010).

The introduction of a sustainable energy system will alter the current patterns of electricity demand and generation (Shaw et al., 2010), necessitating investments in the distribution network. The existing distribution networks do not have the quantitative and qualitative capacity to support the large-scaled introduction of sustainable energy generation and end-use technologies. Two major concerns for future electricity networks can be distinguished. The first concern is the possibility of increases in peak loads. This could either be caused by an increased total electricity use or by changing usage profiles. In case of increasing peak loads, additional investments in the network will be necessary to prepare the network for the future. Factors influencing the total electricity use and the usage profiles are economical growth, social developments (e.g. the increase in the number of single person households), energy system developments (e.g. the introduction of new smart balancing systems), and choices in end-use technologies like electric vehicles. The second concern is a large-scaled introduction of intermittent decentralized generation (DG). The current system is based on one way load flows and centralized system balancing. When DG contributes a relatively small part of the total production capacity, the system can still be stabilized at a central level. However, the decentralized generated power should never exceed the demand at any given time; this implies the requirement of a different method of balancing.

The consequences of the introduction of DG on energy networks are studied extensively, from the perspectives of finance (Raineri et al., 2005; Harrison et al., 2007), regulation (de Joode et al., 2009; Cossent et al., 2009), network control (Lehtonen and Nye, 2009), and policy making (Pepermans et al., 2005; Niesten, 2005). However, to date, the consequences of increases in peak loads – caused by sustainable energy generation and consumption – on energy distribution networks are not studied in detail. Additionally, it is expected that peak loads in the network constitute the main problem for urban environments (van Lumig, 2009). Therefore,

* Corresponding author. Tel.: +31402473349; fax: +31 40 243 8488.
E-mail address: e.g.j.blokhuis@tue.nl (E. Blokhuis).

0301-4215/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enpol.2011.07.021

this article will focus on the effects of peak load increases on the necessity for electricity network extensions and the accompanying required financial investments. The central issue in this article is the statement that a higher level of sustainability in the energy system leads to a growing share of the energy carrier electricity compared to other energy carriers like solid, fluid, and gaseous fuels, and heat. Electricity has several advantages when comparing it to other energy carriers: the level of flexibility, the absence of waste, and the easy and safe way of connection. From a production point of view, electricity is the prevalent carrier for energy from important sustainable sources like hydropower, wind, and sun. Therefore, it is expected that electricity will play an important role in societies with a sustainable energy system, resulting in increasing peak loads on the electricity networks.

In order for cities, regions, and countries to be able to make more efficient, economical, and sustainable choices on future network developments, it is important to have an estimate of what the required investments are in different sustainable policy scenarios (Sheblé, 1999; Shahidehpour et al., 2002). When discussing future energy systems, this information is essential yet lacking. Currently, the consequences of the implementation of sustainable measures on the necessity to invest in the electricity network are not considered in accompanying policy debates. In this article, the possible consequences of sustainable policy choices on the future electricity use and related network capacities in cities are explored. We want to show that apparent economical and sustainable policy choices can have severe financial and economical consequences for networks, in order to stress that choices regarding sustainable transitions should be made from the viewpoint of the integral energy system. To illustrate this, a worst case electricity use scenario is developed for the city of Eindhoven (the Netherlands), in which the upper limits for necessary network investments are explored.

2. Structure of the Dutch electricity sector

As most electricity networks in Europe, the Dutch network is a conventional electricity grid. The electricity system is dominated by large controllable generators. The centralized production in the Netherlands is based on numerous coal and gas power plants and a single nuclear facility, and is controlled by commercial energy companies. Furthermore, the network – locally owned by network operating companies – has very little storage capacity. Balancing generation and electricity use is currently executed by controlling production at the central generation facilities.

2.1. Generation technology

The search for more sustainable resources has led to the introduction of a number of alternative generation technologies. In 2005, renewable electricity covered 6.1% of the Dutch national electricity production (CBS, 2010). In 2009, this has grown to 8.9% of the total national electricity production (CBS, 2010). It is expected that this percentage will continuously increase to somewhere between 35% and 40% in 2020 due to policy aimed at achieving the EU targets. For the Netherlands, the target is to cover 14% of the total national energy production with renewable energy technologies (European Parliament, 2009).

2.2. Infrastructure

The Dutch national transfer network is owned and operated by TenneT. High voltage; high capacity circuits are used for cross country bulk transfer of electricity. Recently, a number of high voltage direct current (HVDC) connections have been realized connecting the Dutch network to England, Norway, and Denmark, which are used to solve national surpluses or shortages. TenneT delivers the electricity from central generation facilities to several regional network operators. These operators distribute it through medium and low voltage systems to the end user.

The existing infrastructure represents a huge financial value. In 2005, the economic value of the electricity and gas networks in the Netherlands was estimated at 24–30 billion Euros (Sequoia, 2005). The replacement value of the networks may even be many times higher, because the energy networks are largely integrated in the built environment; the majority of the network components are underground cables in urban areas. To replace or add components, extensive construction activities will be needed in the public domain.

2.3. Eindhoven infrastructure

In the city of Eindhoven, the distribution network is operated by Endinet. The local network consists of three feed-in stations that are supplied by the network operator Enexis. From these stations, 10 kV is distributed from nine main distribution stations, through 30 neighborhood distribution stations, to about 1100 electricity substations, where the electricity is converted into 400 V. From these substations, the electricity is distributed to over 105,000 LV client connections in Eindhoven. There are about 570 clients directly connected to the MV network. The network in Eindhoven is laid out in MV rings that feed the transformer stations. Within these rings, the LV network is a mesh. The entire system is dimensioned to an '$n-1$' specification; any cable may break down or be switched off without delivery to the clients being influenced. The same goes for transformer stations on the MV rings. Any of these may be switched off without delivery being interrupted (see Fig. 1).

The existing grid does have some margins and options for expansion. New grid sections in Eindhoven are designed for peak loads of approximately 2 kW per connections while the actual peak load is averagely 1 kW per connection. In addition, the design often offers features that allow easy capacity expansion to an average of 2.5 kW per connection during peak times. Older

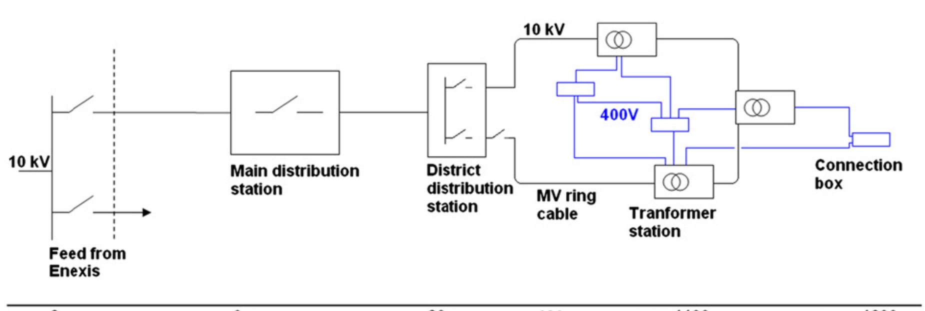

Fig. 1. Schematic electricity network in Eindhoven.