Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 132 (2017) 610–615

Energy Procedia

www.elsevier.com/locate/procedia

11th Nordic Symposium on Building Physics, NSB2017, 11-14 June 2017, Trondheim, Norway

Analysis of the impact resolution has on load matching in the Norwegian context

Kari Sørnes[a], Eyvind Fredriksen[a], Ketil Tunheim[a], Igor Sartori[a]

[a]*SINTEF Byggforsk, P.O.Box 124 Blindern, NO-0314 Oslo*

Abstract

Generation of energy at building level has an increasing interest in Norway, as in rest of Europe. Load matching is the correlation between the buildings generation and load, which in most cases aims at optimization of the amount of self-consumption. When analysing generation in relation to load, it is of interest to study the choice of resolution and what impact this has on load match indicators. This study analyses the importance of choosing the right resolution, starting with hourly measurements, and going down towards one-minute resolution.

Monitoring resolution has a significant impact on both the type of monitoring equipment and the data storage capacity needed. If the impact of lower resolution is small, less complex monitoring systems can be installed in projects that are not sensible to the uncertainty caused by the lack of minute-based data.

Norwegian case studies with solar power production gives data to the analysis, studying a nursing home in Oslo called Økern Sykehjem. The nursing home has been a pilot building in the European Fp7 research project ZenN, Nearly Zero Energy Neighbourhood (2012-2017), which led to the installation of 130 kW solar power panels while going through a large renovation process. Generation and load have been monitored with high-resolution since 2015 and this gives useful insight into the effect of high-resolution data monitoring compared to hourly-resolution monitoring.

Resulting graphs shows that by collecting data on a daily basis will give a wrong impression on self-consumption and self-generation by about 20% compared to hourly based data. The difference between minute based and hourly based resolution is relatively small (6%).

Keywords: Photovoltaic, nZEB, load matching, resolution

10.1016/j.egypro.2017.09.683

1. Introduction

In recent years there has been a growing attention towards ZEBs, buildings that are producing its own energy. The Norwegian government proposed in 2012 that the requirements for the energy efficiency and demand in new buildings in Norway should be at near ZEB-level by 2020 [1], in accordance with the EU Energy Performance of Buildings Directive. More knowledge of how to monitor self-producing buildings (prosumers) is needed and this has been a topic of concern in the European Fp7 research project ZenN, Nearly Zero Energy Neighbourhood (2012-2017) which this paper is based on. One of the pilot buildings in the project is a nursing home called Økern, which went through a full renovation becoming an energy efficient and self-producing building. Generation and load have been monitored with high-resolution since 2015, which has given useful insight on what choice of resolution has on the degree of load matching indicators such as self-consumption and self-generation.

The most common choice of resolution when performing a detailed energy simulation related to a building is one hour. One reason for this is that the simulations usually run for one or several years, and with a shorter time-step the data processing needs more comprehensive analysis tools due to the large amount of data to be processed.

When using hourly data while studying energy generation from PV panels, fluctuations related to moving clouds may be neglected which can give a wrong impression of degree of generation on a sub-hourly level. Electrical demand of especially households can also change rapidly every minute because of inhabitant behaviour. The timing of power peaks that can occur due to this is critical to the matching of load and generation, and the question in this paper is to what extent this has an effect.

Several previous studies have investigated the impact of time resolution on generation and load curves, with a general conclusion that sub-hourly resolution is needed to get the right picture of how the curves correspond with each other [2-4], but the load matching figures was not considered in those studies. One study focusing on this topic was conducted by Cao et.al [5] which studied the effect of choice of resolution has on load matching figures in two residential cases simulating power generation by PV panels using TRNSYS. The focus was the degree of error of daily matching results with coarser resolutions than 1-min resolution. There was no fixed conclusion regarding which coarser resolution should be selected to achieve results close to those with one-minute resolution, but one of the conclusions is that the characteristics of generation and demand profiles influences the results.

In this study, the time-span is one year and based on real monitoring data. Another difference from previously studies is that the pilot building is a nursing home and not a residential building.

2. Net Zero Energy Buildings and load matching

Sartori, Napolitano and Voss [6] proposes a definition of the net ZEB-balance as a condition that is satisfied when weighted supply meets or exceeds weighted demand over a period of time, nominally a year. This is given by Eq.1.

$$\boldsymbol{Net\ ZEB\ balance = |weighted\ supply| - |weighted\ demand| \geq 0} \quad (1)$$

The weighted demand is the sum of all delivered energy (or load) obtained summing all energy carriers each multiplied by its respective weighting factor. The weighted supply is the sum of all exported energy (or generation) obtained summing all energy carriers each multiplied by its respective weighting factor.

In Norway, a net ZEB with PV for energy generation has net export of energy in the summer months and net import in the winter months. Also, there is a large hourly variation in generation and load throughout the day. The correlation between on-site generation and the building loads can be analyzed by looking at the load matching of the system. The term load matching (LM) refers to the degree of matching of the on-site generation with the building load profiles [7]. This can be analyzed by studying the degree of self-generation (load cover factor) and self-consumption (supply cover factor). Self-generation is the share of energy demand covered by on-site energy production. Self-consumption is the share of on-site generated energy used by the building. Equation 2 and 3 gives the mathematical expression of this [7].

$$\gamma_D = \frac{\int_{\tau_1}^{\tau_2} min[P_D,P_S]dt}{\int_{\tau_1}^{\tau_2} P_D dt} \qquad \text{(self-generation)} \tag{2}$$

$$\gamma_S = \frac{\int_{\tau_1}^{\tau_2} min[P_D,P_S]dt}{\int_{\tau_1}^{\tau_2} P_S dt} \qquad \text{(self-consumption)} \tag{3}$$

Where P_S is the onsite generation (supply) of energy in [W], P_D is the load (demand) in [W] and τ_1, τ_2 delimit the observation period.

When Eq. 1 is zero the net ZEB balance is reached, and there is a perfect annual balance between on-site generation and demand. This is a special case where self-generation (Eq. 2) is equal to the self-consumption (Eq. 3).

3. Method

Electrical demand profiles and PV generation is obtained from a nursing home called Økern. Økern nursing home was built in 1975 and contains 140 dwellings for senior citizens. In 2014 the building was retrofitted according to Passive House principles: highly insulated and highly airtight building with ventilation heat recovery and solar gains control. The heat demand for space heat and domestic hot water is covered by district heating, so the electricity demand is relative stable through the day. Ventilation, lighting, hot water, heating cables on bathrooms floors, lifts and appliances are main loads. Fig.1 shows a summer day in July from 08.00 AM to 04.00 PM. Although the generation is large in the summer, it does not exceed the demand (load).

The PV installation at Økern is 130 kW_p yielding annually 93.2 MWh and 86.7 MWh in 2015 and 2016 respectively. No battery is installed, so storage to make a buffer between generation and demand influencing the level off mismatch, have not been taken into consideration.

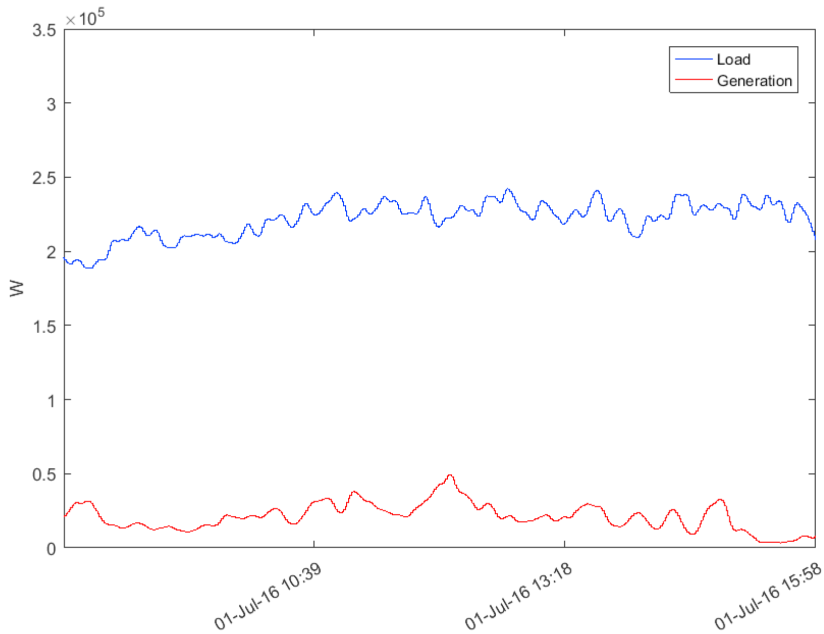

Fig. 1 Average power measurements (1 min resolution)

High-resolution data has been gathered from Økern nursing home since 2015. The data related to this paper focuses on a duration of one year, which means that t_1 and t_2 in Eq. 2 and 3 are respectively the starting and ending points for a one year time-span. ''Dt'' is equal to the selected resolution levels of 1 min, 1 h and 24h.

Data is collected from the buildings SCADA system by discretized values for real time monitoring and is processed and analyzed by using Matlab.

Økern is far from reaching the net ZEB balance since its annual generation equal ca. 10% of its annual consumption. However, for the purpose of this study the total generation data collected through 2016 has been scaled up to net ZEB level to show the effect resolution has on the load match indicators on a wide range of generation capacity. The results are presented by two different graphs; a carpet plot showing net export in Fig. 2 and by the net ZEB load matching graph in Fig. 3.

Results

Fig. 2 shows a carpet plot of possible net export (kW) to the grid at net ZEB level. Since this is a building with a photovoltaic power production it has the typical "eye" shape in the middle, which means high export in summer/day and high import in winter/night. There are about 7 days in November with lack of data which explain the white line at the upper part.

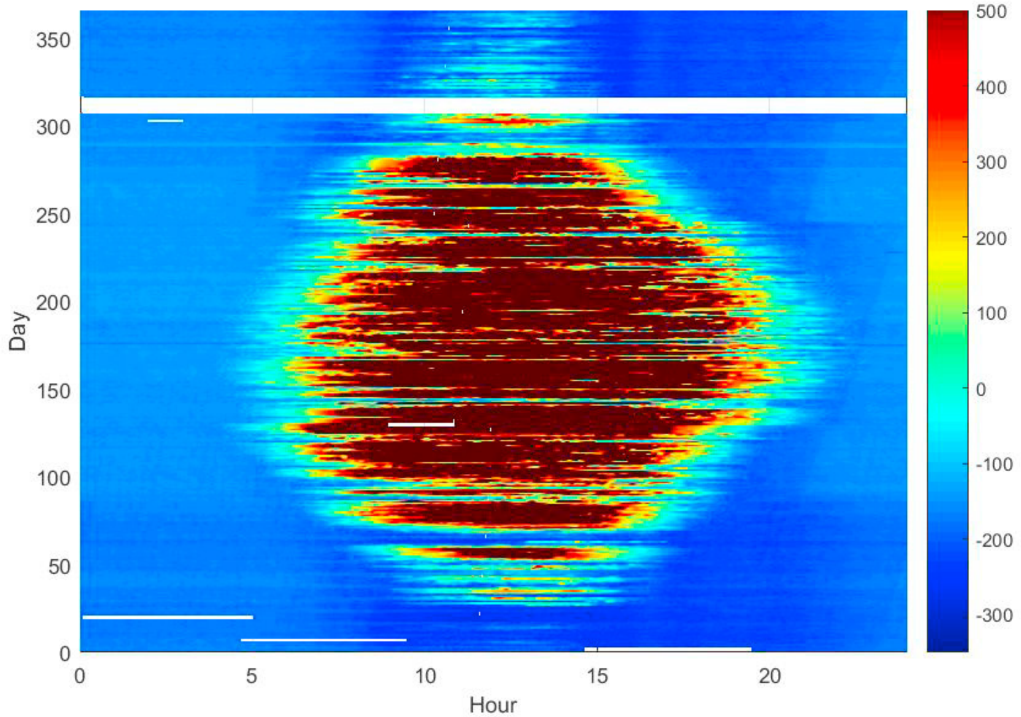

Fig. 2. Export profile (kW)

Fig. 3 shows net ZEB load matching graphs, with self-generation and self consumption with different resolution levels; minute (blue lines), hour (orange lines) and day (green lines) in relation to yearly PV production normalized by yearly electricity production. Net ZEB point occurs when yearly PV production normalized by yearly electricity production is one.

Data on a daily basis would give a significant overestimate of both self-consumption and self-generation, giving a value of 56% at net ZEB, compared to the 37% obtained from hourly based monitoring. Another finding is that the difference between minute based and hourly based resolution is relatively small, with the cross-point of the two curves being 31%.

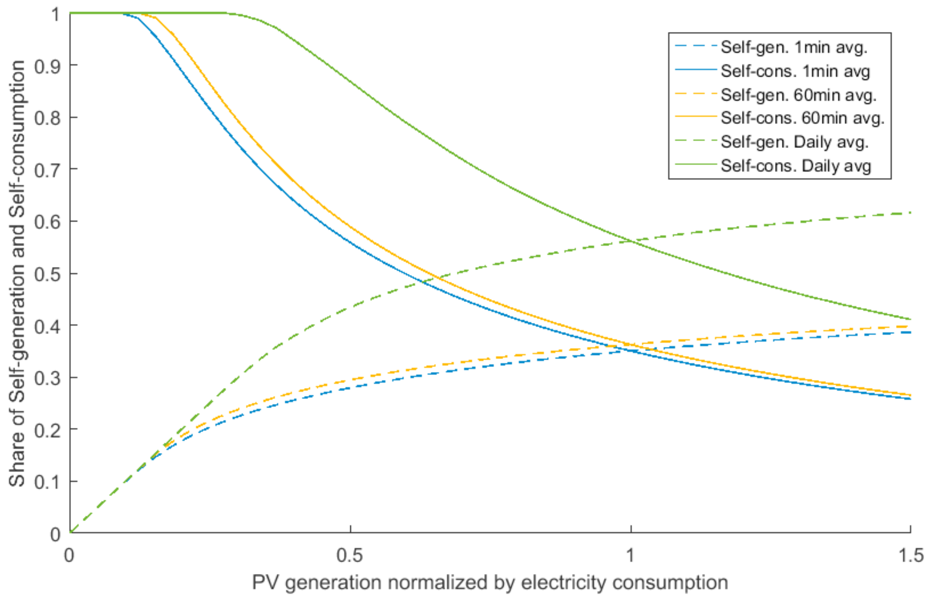

Fig. 3. Effect of resolution on load matching factors at net ZEB point

4. Discussion

Self-consumption and self-generation of a building is determined from data series of average power generation and demand, typically hourly values. It is a general understanding that lower resolution will lead to an overestimation of the self-consumption since fluctuations causing mismatch between the generation and load profiles are evened out and averaged into more flat profiles. The magnitude of the exported and imported electricity will then both be underestimated. In this study the emphasis was to go from hourly to sub-hourly resolution and see the effect on load matching figures. As can be seen from the graphs, the effect of changing from daily to hourly measures is large, but by changing to minute based monitoring the effect is small. The frequency of data collection influence the data storage size and complexity of monitoring, and for these metrics, in this particular case, it is questionable if minute based resolution is really needed.

The reason for the small difference between hourly and minute based resolution (6%) can partly be explained by a relatively stable electricity demand since space heating is covered by district heating and electrical demand results in a rather flat consumption curve.

The factors describing self-consumption and self-generation defined in eq. 2 and 3 are part of a wider range of metrics describing different aspects of the interplay between on-site power generation and demand. These load matching indicators is based solely on on-site profiles and is therefore used to study and quantify energy over a longer period of time. Other indicators, like Generation Multiple (GM) [7], are metrics defined to study the instantaneous power imported from or exported to the grid. In other words, grid interaction refers to the exchange of energy between the building and the grid, whereas load matching refers to how the local energy generation correspond with the building load. Grid interaction flexibility is the ability to respond to signals from the grid (smart grids), e.g. price signals, and consequently adjust load, generation and storage control strategies in order to serve the grid needs together with the building and user needs, and/or adjust to favourable market prices for energy exports or imports. Since load matching considers only the building load and generation, it is easier to calculate than grid interaction. The question is whether there is a strong enough correlation between the two so that it is possible to evaluate the grid interaction based on calculations of the load matching. Further research might give an answer this.

One of the main reasons why self-consumption is important is that due to asymmetric prices of purchased (imported) and feed-in (exported) electricity, there is an economic incentive for the user to improve self-consumption. If electricity imported from the grid costs 1 kr/kWh (spot price + grid tariff + taxes) and electricity exported to the grid receives 30 øre/kWh (spot price only) there is an incentive to maximise self-consumption.

An aspect related to mismatch between generation and demand is also a potential security risk for the electrical grid, as large amounts of distributed electrical generation with a severe mismatch characteristic significantly increase the probability to destabilise the voltage and capacity limitations of the grid.

This study was carried out to get a better understanding of how load matching figures relates to resolution at Økern nursing home. In this case space heating was based on district heating, but different heating system technology tend to have different matches with the PV generation, therefore different levels of self-consumption.

The study is only taking into account one building, and to conclude on this topic more buildings of this type must be analyzed and compared to each other.

5. Conclusion

The nursing home Økern is used to study the effect resolution has on load matching figures. Resulting graphs shows that by collecting data on a daily basis will give a wrong impression on self-consumption and self-generation by about 20% compared to hourly based data. The difference between minute based and hourly based resolution is relatively small (6 %). More buildings with high-resolution data on on-site generation and load must be analyzed to be able to conclude if this apply for all similar cases.

References

1. Regionaldepartement, D.K.K.o., *«Meld.St.28: Gode bygg for eit betre samfunn. Ein framtidsretta bydningspolitikk,»*. 2012: Oslo.
2. A., W. and F. S., *The nature of domestic electricity-loads and effects of time averaging on statistics and on-site generation calculations.* Applied Energy, 2007. **84**: p. 389–403.
3. J., W., et al., *Impacts of different data averaging times on statistical analysis of distributed domestic photovoltaic systems.* Sol Energy, 2010. **84**: p. 492–500.
4. EJ., H. and C. CA., *Implications of temporal resolution for modeling renewables-based power systems.* Renewable Energy, 2012. **41**: p. 285–93.
5. Cao, S. and K. Sirén *Impact of simulation time-resolution on the matching of PV production and household electric demand*. 2014. **124**, 192–208.
6. Sartori, I., A. Napolitano, and K. Voss, *Net zero energy buildings: A consistent definition framework.* Energy and Buildings, 2012. **48**(0): p. 220-232.
7. IEA, *ANALYSIS OF LOAD MATCH AND GRID INTERACTION INDICATORS IN NET ZERO ENERGY BUILDINGS WITH HIGH-RESOLUTION DATA* in *Subtask A*, I.T.A.T.N.Z.E.S. Buildings, Editor. 2014, International Energy Agency.