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# Probabilistic demand forecasting to minimize overtaking the transmission contract

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ABSTRACT

This paper presents a new methodology for electricity demand forecasting on very short-term horizon based on a discrete probabilistic model (Markov Chain). The modeling process is automated by a feature extraction tool, the Self-Organizing Map, considering historical data of climate variables (air temperature, relative humidity and wind speed) and load behavior, related through the thermal discomfort index and wind chill. Thus, it is possible to estimate the probability of a certain demand level occur given a current climatic condition, as well as the number of time intervals (hours) until this occurs. The forecast is then used to control the decentralized dispatch of a small hydroelectric power plant, aiming to minimize overtaking the transmission contract.



## 1. Introduction

In Brazil, some small utilities that have distributed generation (*DG*) can make cheaper supply contracts considering this asset under its control. Therefore, it is vital that these come into operation during periods when there is forecast that energy demand will exceed the contract, in order to avoid paying an overtaking fee. Thus, considering restricted resources, a method of load forecasting in the very short-term horizon is of great value to this type of company.

This paper proposes a methodology that results in an important tool to decision support for the decentralized dispatch of a Small Hydropower Plant (SHP) of 1 MW connected in a distribution system, which the operation is limited to the small storage capacity of the reservoir (Fig. 1). There are usually constraint generation in the dry season (summer–autumn in the southern hemisphere), since there is not enough water to generate continuously. For this reason, it is necessary to define the best moment to enable the generation as well as the required amount of power.

It can be seen in the literature that the projections of electricity demand are basic for power system studies such as expansion, planning and operation. However, it can be held on different time horizons like long-term (1–10 years), medium-term (several months to a year), short-term (a day ahead) and very short-term (hours and minutes ahead), depending on the planning objectives [1]. The estimation of future behavior of electric loads is directly linked to the task of decision making and achievement of management actions on both the demand and supply side. Thus, a projection beyond the scope of any forecast horizon may go far wrong, since an underestimation could result in overtaking the transmission contract, while overestimation leads to idleness of the electric system [2]. Therefore, several methodologies have been proposed for forecasting electricity demand on different projection horizons [2–11]. However, the implementation of these methodologies seems limited to medium and large electrical systems, which have a greater inertia, and their forecast abilities do not estimate a variation of the load behavior.

In the electricity demand forecasting on the very short-term, the climatic variables have a strong impact on the electric load evolution and should be incorporated into the projection model [12–15]. An important topic related to the consumption of electric power is the “thermal comfort”, which expresses the human satisfaction with the thermal environment. The potential impact of climate change on electricity demand can be seen daily through the fluctuation of demand with weather conditions. In this sense, electricity demand is affected not only by environment temperature but also wind speed, relative humidity, precipitation and evaporation level, transpiration of human body, solar radiation, atmospheric pressure and cloud cover [12,16,17].

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**Fig. 1.** Small Hydropower Plant's reservoir, penstock and housing.

The paper is organized as follows. In Section 2, the proposed methodology for the probabilistic demand forecasting on the very short-term horizon, that involves the use of the thermal Discomfort Index (*DI*) and Wind Chill (*WC*), and the creation of a discrete probabilistic model (Markov Chain) from the classification of historical climatic variables data in a Self-Organizing Map (SOM) is presented. Section 3 presents the simulations and results, including a case with a well-known data set and compared to the state-of-the-art short-term load forecasting algorithms. It also shows how the probability of a given demand level is being used to aid the dispatch of a small hydroelectric power plant to avoid overtaking the transmission contract. Lastly, Section 4 gives conclusions.

The main innovation of this paper is the global methodology proposed for a probabilistic demand forecasting on the very short-term horizon, including:

- climate variables influence and the use of the thermal Discomfort Index and Wind Chill;
- methodology using SOM to automatic build a Markov Chain, that forecasts the probabilities of the demand exceeds a threshold in the next hours;
- the forecasted probabilities are used to control a small hydropower plant to avoid overtaking the transmission contract.

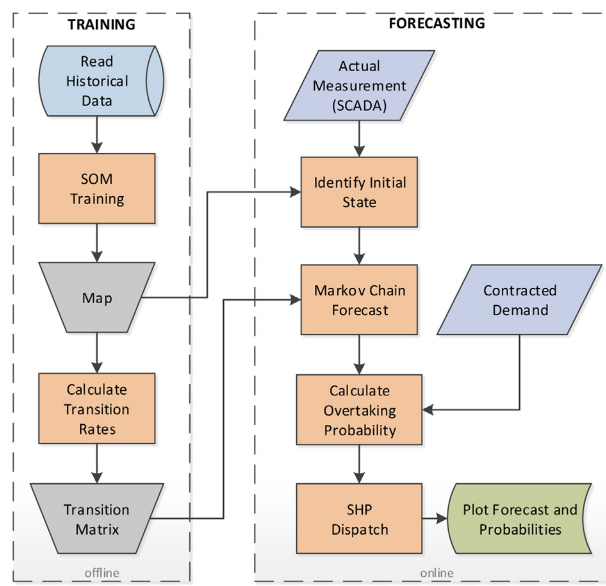


**Fig. 2.** Flowchart of the proposed methodology for probabilistic demand forecast and decentralized dispatch.

## 2. Probabilistic demand forecasting on very short-term horizon

This work proposes a new computational tool for electricity demand forecasting through two stages. The first one consists in an analysis of the influence of climatic variables using the Discomfort Index (*DI*) and Wind Chill (*WC*), which are used to train a Self-Organizing Map that is used to automatically build a discrete probability model (Markov Chain). This is made once, in an offline process, or whenever the user wants to update the model with new historical data. Then, the second stage runs continuously (online) acquiring the climatic variables with the Supervisory Control and Data Acquisition system (SCADA). Each measurement leads to a state of the Markov Model, that runs a very-short term demand forecast in order to evaluate the probability of the transmission contract be overtaken. Fig. 2 shows a flowchart of this methodology, and the next subsections will describe its steps.

### 2.1. Climate variables influence

The climate variables have great relevance in terms of its effects on the electricity demand evolution on the very short-term horizon, since that act directly on the thermal comfort sensation of the humans. Thus, air temperature, relative humidity, wind speed and solar radiation also control the thermal comfort of the human body [12]. The thermal comfort definition involves the personal factors that make its definition subjective. Thermal comfort can be analyzed from two perspectives: the personal and the environment, where the personal perspective can be defined as a mind condition, which expresses satisfaction with thermal environment [17].

The Air Temperature (*AT*) is the climate variable most significant on the electric load in the context of the residential and commercial customers. A small deviation from the *AT* in relation to its normal value (23 °C) generates a significant variation in electricity consumption. Table 1 presents the positive correlation of electric load with relation to *AT* variation. The Relative Humidity (*RH*) is another climate variable that affects the electricity demand level. It can be observed that the electricity demand increases with the increasing of relative humidity related to very cloudy or rainy days, which require more lighting. On the other hand, the wind speed decreases the perceived air temperature felt by the body, the wind chill, generating a negative correlation with the electricity demand on hot days, as shown in Table 1, calculated with data measured at the site of the case study presented at Section 3.