"The evolution of energy": the impact of the development of non-traditional renewable energy sources on the functioning of the traditional electric power system: technical and economic problems

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Abstract. Over the past 20 years, the trend in the development of non-traditional renewable energy sources around the world gives grounds to consider the prospects for each country, taking into account the existing traditional energy supply system and the potential for the development of other technologies and principles. With the increase in the share of renewable energy generation in the energy system, the problem of system stability appears. The neural network and the addition of a storage system can increase reliability and stability of the regional energy system. Both this systems can be considered not only as strategic investment projects, but safety measures as well.

Keywords: energy, renewables, stability

Introduction

At the International Economic Forum held in June 2021 in St. Petersburg, the following questions were repeatedly raised: what technologies can help traditional energy to move into a low-carbon age, whether the share of renewable sources in the global energy balance will continue to grow, and why the policy of reducing emissions can be a chance for small nuclear and hydro power. The relevance of the study of the risks of renewables development without taking into account the already emerging negative facts of reducing energy security has become even more obvious after the global outages of consumers in the United States occurred in the

region with a significant share of energy generation from renewables .In 2019 in California there were a series of blackouts that were caused by undersupplement of electricity. Experts doubt that the main reason is that unstable power output has caused these outages. [1]

Analysis

The authors have studied technological solutions that can reduce the risks of similar situations in any country [2]. Thus, the researchers distinguish two groups of the impact of the development of non-traditional renewable energy sources on the traditional electric power system: the reduction of CO_2 emissions and the changing dynamics of the system, which leads to new stability problems.

Based on data, provided by BP [3] we made a forecast using statistic methods of extrapolation of time distributed data. The results are shown below and shows upstreaming trends for renewables in all over the world.

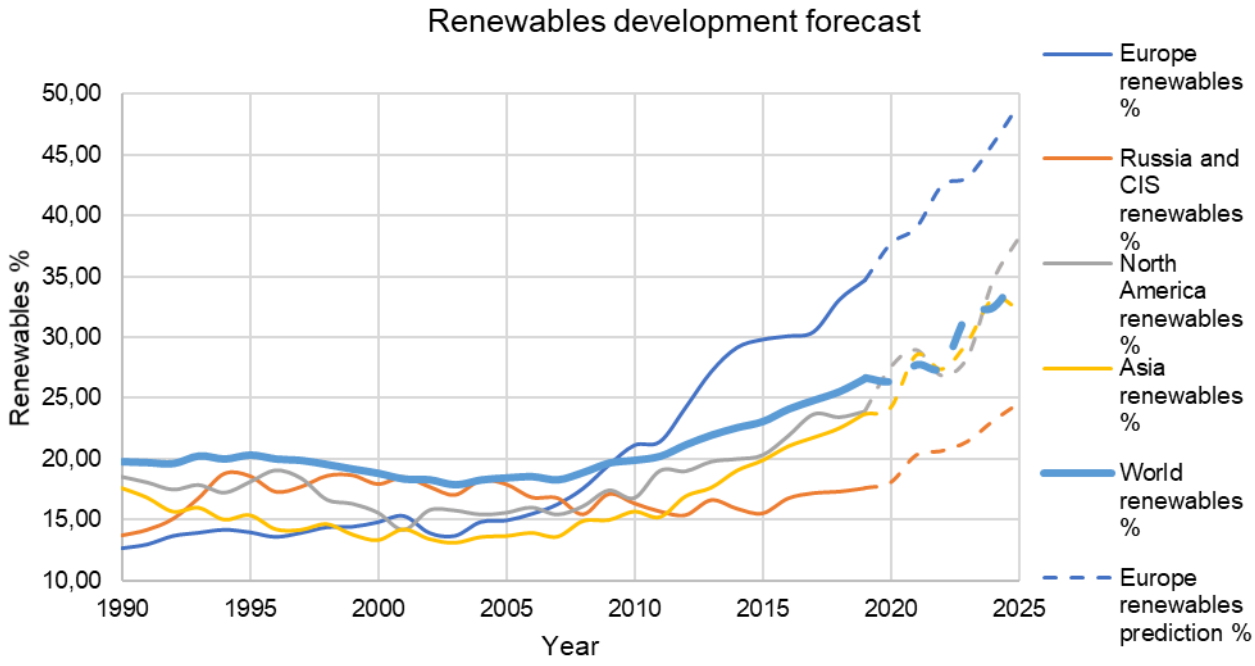

Figure 1 Renewable sources of energy development forecast

Today California's energy system consists of around 30% of renewable power supply that cause difficulties in terms of operation.

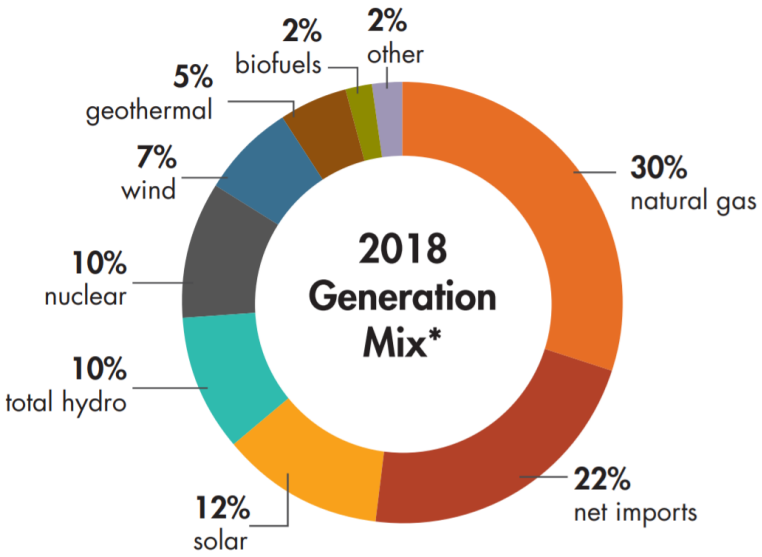

Figure 2 Energy generation in California

The main problem is that renewable sources such a wind and solar are too inconsistent, so it causes power shortage during peaks of a power demand. This leads to the next problem of imported electricity from other states, which in some cases couldn't be provided in time. This is the main reason of blackouts.

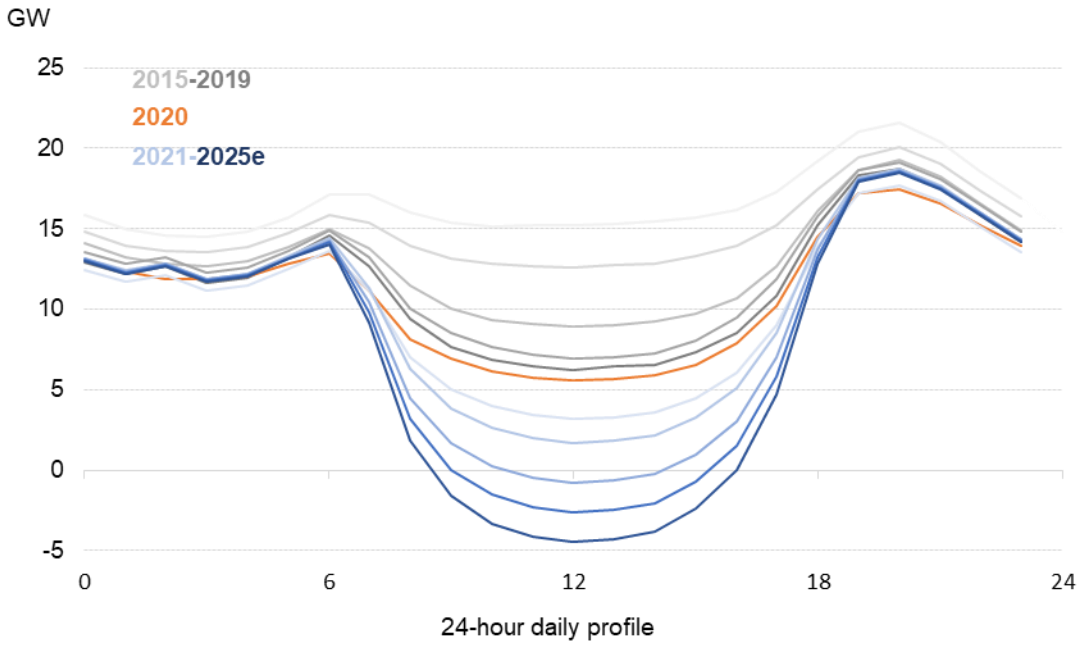

Figure 3 Daily electricity import in California

This leads us to the problem statement, which includes mismatching peaks of energy production and consumption. Moreover, it's not the only problem in the region. On a graph below in figure 2 it is shown that there is a high dependence on import electricity from neighboring states in California, which in some cases can cause a blackout due to a high load.

Figure 4 Import capacity throughout a year

Our research was based on a similar article [4] that showcase application of LSTM neural net to long-term time series data. For storage optimization we suggest using particle swarm optimization method that can solve non-linear dependences that will show up during the problem statement.

We made a research of the Californian whole scale energy market and picked out key features of this region, which we have taken into account as we proceed our solution. Data was provided by EIA [5]

Household optimization model

To solve the problems listed above, we propose a project of installing energy storage systems in houses in the form of lithium-ion batteries, which store excess energy generated by solar power plants during lower consumption hours, mainly from 8 am to 4 pm, to increase the stability of the network operation mode. Energy companies could benefit from this saving a huge amount of money on penalties for outages. Due to this we suggest that installation and some of the operation costs will be covered by this energy companies.

We developed a model for household energy storage optimization. It can be shown that usage of an energy storage can reduce peaks in daily electricity demand. However, this effect can be achieved, if a large number of households (around 40-60%) suggest installation of such systems.

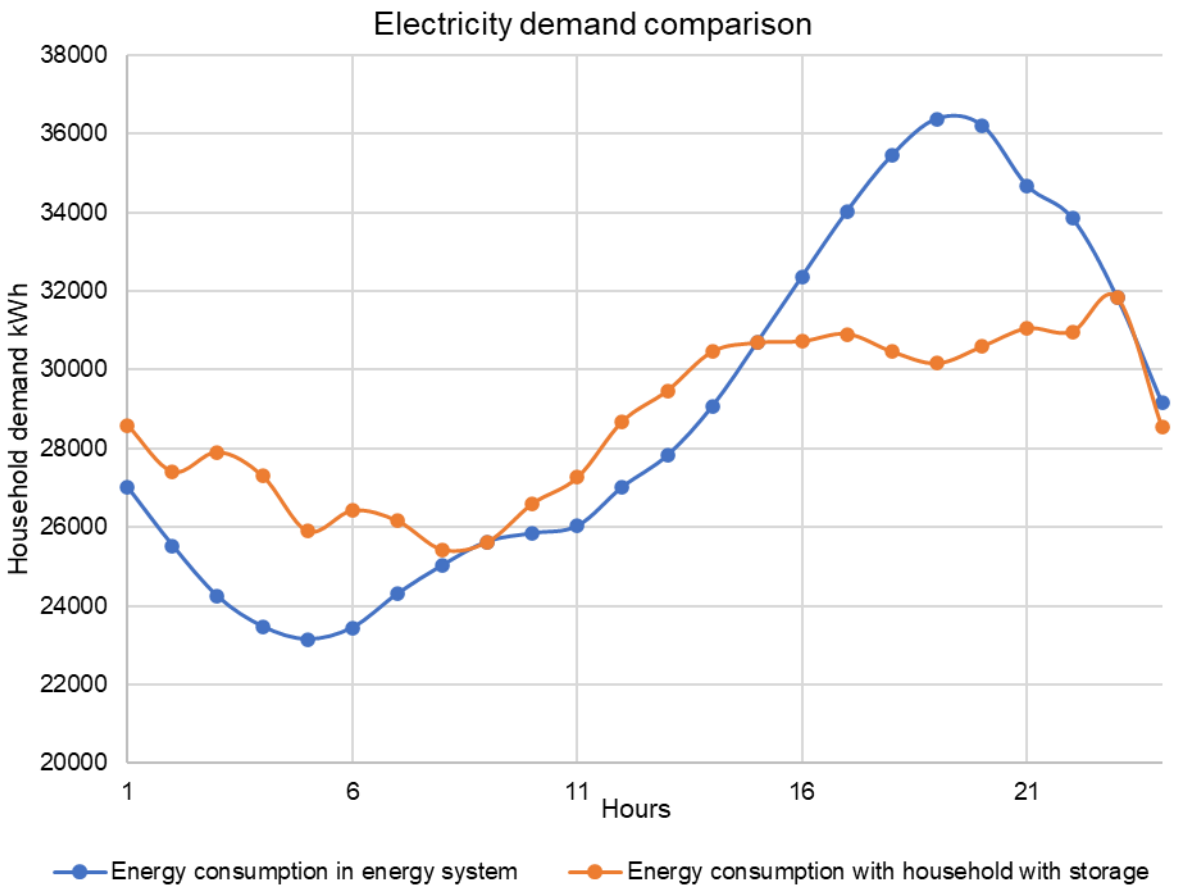

Figure 5 Energy demand comparison

Forecast model

To solve the problem of dependence from supplement from other regions we suggest using a neural network that will allow us to plan more precisely, and because of that minimize the demand in external sources of energy. The model includes different features of the region, for example: average temperature, amount of a sunlight during this period of time and generation output, which was differentiated to types of a power plants.

We made a research that lead us to a conclusion that current prediction energy demand model is not as accurate, so it can potentially cause undersupplement in the region. Using data provided by CISCO we developed a model, using neural networks and in terms of prediction it is much more accurate than the current model. In this case we used a day-ahead data to prove accuracy of the model. Our model has reached a 99% accuracy rate, which makes this model suitable for a future usage in forecasting and planning.

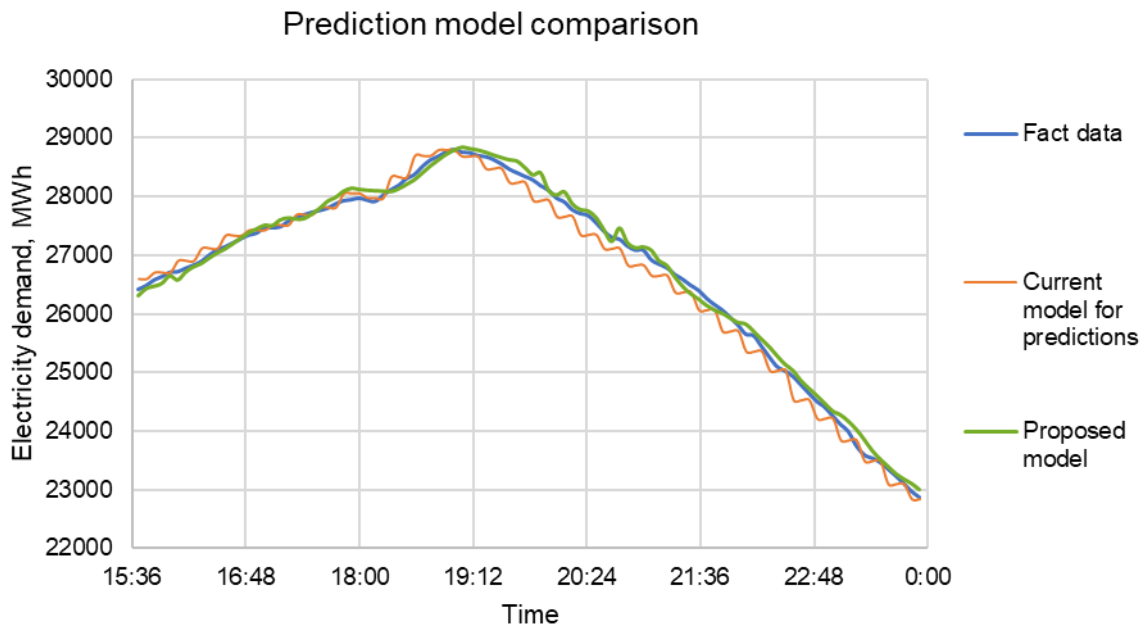

Figure 6 Prediction model comparison

Nowadays there is a hardware that can be implemented as a solution for household storages that meets needs of a developed project. Usage an artificial intelligence as well as data, that is collected by the software, could expand the current functions making current products more versatile and valuable on a market.

One of the positive sides of such project is to reduce penalties that companies have to pay for outages. In terms of modeling the variety of different scenarios for outages in California region, it can be proposed that there is a valuable effect for companies, so it can force them to invest in energy storage for households that will greatly reduce the cost for citizens.

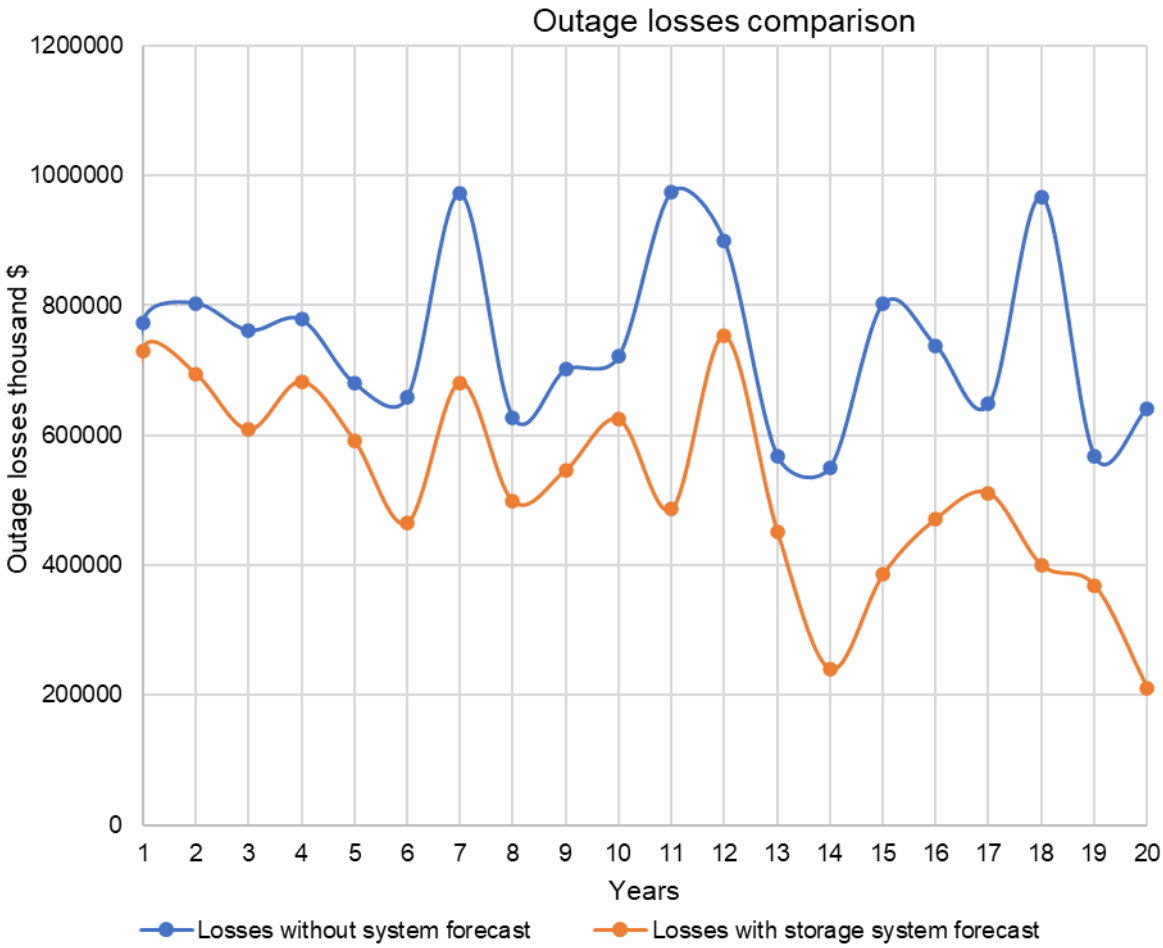

Figure 7 Potential losses of energy companies in California

The project is designed to have an implementation period of 15 years with capital expenses 2,1 billion $ in total throughout 20 years of simulation. One downside, however, is increased risk of investment, which is hedged by a source investment – WCI initiative and higher profitability index (1,36).

All economic indicators and project characteristics are based on mathematical simulation models of economy with addition of discounting method and were evaluated, using real data as a benchmark for comparison.

The neural network is an originally-developed project, designed to fit California's energy system special features as an example of the potential profit and sustainability of this technology. The joint use of our neural network and the Schneider Electric software will significantly enhance the effect of the implementation.

The economic efficiency of neural networks and storage devices may be calculated as a decrease in predicted consumption of 2%, which leads to everyday savings at least 233,7 thousand $.

Another beneficial factor, which is qualitative unlike the others, is the increased reliability and stability of the regional energy system. Both the neural network and the addition of a storage system can be considered not only as strategic investment projects, but safety measures as well.

Results

In the next 10 years, international technology transfers will be actively developed due to a common understanding of the mutual impact of environmental friendliness of the economy and energy systems around the world. This study confirms the relevance of the development of storage technologies and operational management of the energy system containing an increasing number of renewable energy sources, as well as operational international cooperation in the energy technology market, where China has long been established as an important participant.

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