13th Int. Workshop on Generalized Nets
London, 29 October 2012, 83–90

Generalized net model of hydro power plants load distribution. Part 1

Lyubka Doukovska[1] and Krassimir Atanassov[2]

[1] Intelligent Systems Department,
Institute of Information and Communication Technologies, Bulgarian Academy of Sciences
2 Acad. G. Bonchev Str., 1113 Sofia, Bulgaria
e-mail: doukovska@iit.bas.bg

[2] Bioinformatics and Mathematical Modelling Department,
Institute of Biophysics and Biomedical Engineering, Bulgarian Academy of Sciences
105 Acad G. Bonchev Str., 1113 Sofia, Bulgaria
e-mail: krat@bas.bg

Abstract: It is very popular to say that power generation is the lifeblood of any economy. It is a branch of the national economy, which development provides sustainable growth. Guarantee for that is the safe, affordable and reliable supply of electricity. Proper operation of the system leads to increased energy security, which provides not only economic security but is also a guarantor for the national security. The ambition of the authors in this paper is the object of the study to be one of the branches of the power system - hydro power plants in Bulgaria. For Bulgaria, as EU Member State, the results obtained could be considered as guidelines for ensuring European security and stability. As a result of the analysis held, solutions leading to higher efficiency of hydro power plants, using generalized net models will be presented. The first one is described here.
Keywords: Generalized net, Hydro Power Plant (HPP), Modelling.
AMS Classification: 68Q85.

1 Introduction

One of the oldest methods for power generation is the conversion of water energy in electrical power. About 20 percent of worldwide electricity is produced by Hydro Power Plants (HPPs), and about 88 percent of the energy generated from renewable sources is hydroelectric, [5]. Depending on natural water sources the capacity of the hydro power units varies from kilowatts to several megawatts and their efficiency exceeds 80 percent. Although investment costs can reach 5,850 Euro/kW, the cost of electricity remains low. The largest share of electricity from renewable sources is on HPP located on large dams.

Cheapest electricity comes from hydro power plants, as they use the cheapest material. These plants are environmentally friendly, but their construction is expensive. Most of the HPP are built on natural running waters as they require smaller investments. HPP built on dams are a fewer in number, but they are more powerful. Another type of hydro power plants is the Pumped Storage HPPs (PSHPPs). The water from the lower basin is pumped to the upper one to be re-used during peak demand periods.

In Bulgaria there are 30 HPP (including the PSHPP) owned by the state, with a total installed capacity of 2,713 MW in turbine mode and 937 MW in pumping mode. In 2011, total production of electric power plants reached up to 2,847 GWh, and consumption when operating in the pumping mode is 1199 GWh, [4].

The main part of the generated power comes from fifteen large HPP, with total installed capacity of 2,630 MW, [4]. They are grouped into four cascades "Belmeken-Sestrimo-Chaira", "Batak", "Vacha" and "Dolna Arda" and are designed to cover peak loads and to control the power system parameter (frequency and active power).

2 Features of HPP operation

The National Power system Operator plans, coordinates and controls the power system of Republic of Bulgaria locally and working in parallel with the power systems of the other countries. It provides maintenance and safe operation of the grid.

Successful exploitation of HPP aims to achieve the following major results:

- Increase the installed capacity of hydro power unis;
- Increasing the efficiency of the turbines and reducing the harmful effects of the cavitation;
- High quality power generation, in accordance to the modern requirements for minimizing frequency and active power deviations;
- Increase the control range of active power and voltage;
- Unites taking part in primary frequency control;
- Ability to implement the "Black Start", "Island mode" and "Energy Corridor";
- Visualization of all processes;
- Ability for remote control from headquarters control center;
- Automatic units startup and switching on to the grid within 4-5 minutes.

Technical operation and maintenance of dams and HPP include implementation of technical control, maintenance and repairment of: dams (perennial, annual, seasonal, weekly and daily) water catchments, non-pressurized and pressurized derivations. Most of the dams have complex designation and in this sense they are essential for the economy as a whole. Operation of such potentially dangerous and complex hydro power objects is extremely responsible task which has to be held on modern technical level with the necessary expertise and responsibility.

One of the main objectives of efficient utilization of the facilities is increasing hydro power and pumped storage capacity and reducing the amount of greenhouse gases and other pollutants from Thermal Power Plants (TPP). This is accomplished through the use of flexible mechanisms of the Kyoto Protocol, under which the joint implementation of energy projects will lead to positive environmental effect on the development of the energy sector. Contribution to improving the environmental policy is the priority purchasing of electricity from renewable energy sources as well as from low-carbon energy sources.

Modern approach to achieve the desired effect is the supervisory control. In its development for about 40 years, it went from a centralized then to decentralized and now to network. The last type of supervisory control introduces new advanced features to meet the requirements of the business. Direct acquisition and processing of all technological and information relations on the basic control levels allows for using management approaches, significantly expanding the ones existing in DCS and SCADA systems. It is considered that modern supervisory control of power facilities and systems should be an upgrade of the established structures and systems of governance in DCS and SCADA. This allows for preserving the achieved reliability, transparency and trust in the existing systems while keeping moderate costs for design, installation, operation and reengineering.

Of particular interest is the theory of supervisory control based on finite automata and Petri nets. Finding such an adequate apparatus for continuous systems is a task of great interest to the specific needs of the project and related platforms for synthesis of supervisory control that take into account the current state of information technology - standards of language structures, protocols, performance. The trend is supervisory control to expand rapidly and successfully, taking its place as a bridge between technology and operational controls in HPP.

3 Generalized net model

A Generalized Net (GN; see [1, 2, 3]) model will be described (see Fig. 1).

Token κ permanently stays in place l_{12} with a characteristic

"status of the electricity company"

Tokens ρ_1, ρ_2 and ρ_3 permanently stay in places l_5, l_{17} and l_{25} with characteristics

"current status of the first reservoir",

"current status of the second reservoir",

"current status of the third reservoir", respectively.

Tokens ε_1 and ε_2 permanently stay in places l_8 and l_{20} with characteristics

"current status of the first PS",

"current status of the second PS",

respectively.

At each time moments tokens from type ω_1, ω_5 and ω_{10} enter places l_1, l_9 and l_{21} with characteristics

"quantity of the wather of the tributaries of the first reservoir",

"quantity of the wather of the tributaries of the second reservoir",

"quantity of the wather of the tributaries of the third reservoir",

respectively. ε_1 and ε_2 permanently stay in places l_8 and l_{20} with characteristics, respectively, "current status of the first PS" and "current status of the second PS".

At each time moments tokens from type ω_1, ω_5 and ω_{10} enter places l_1, l_9 and l_{21} with characteristics "quantity of the wather of the tributaries of the first reservoir", "quantity of the wather of the tributaries of the second reservoir", and "quantity of the wather of the tributaries of the third reservoir", respectively.

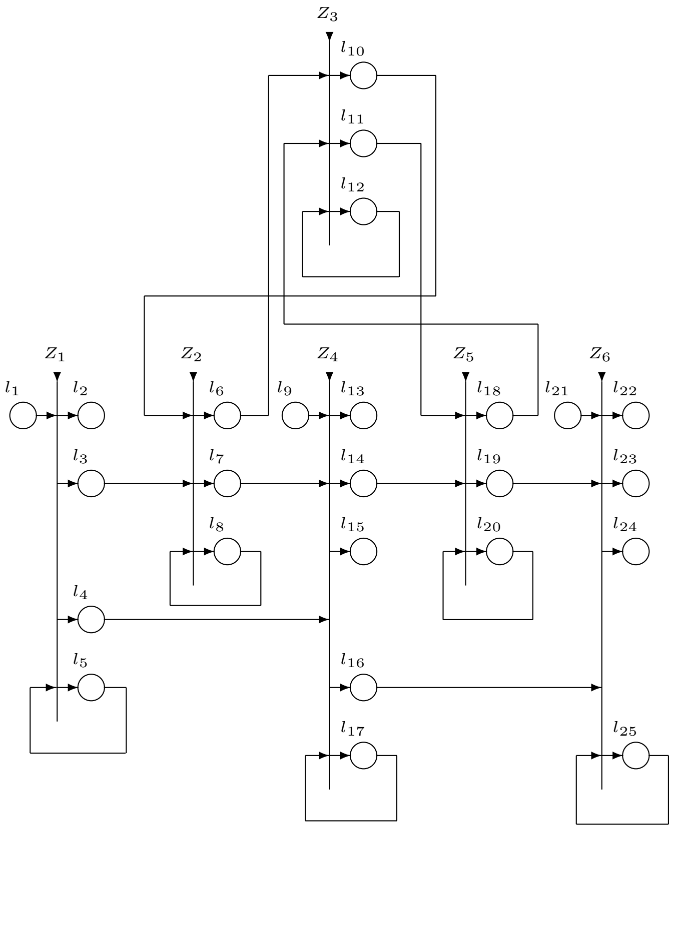

Fig. 1: Generalized net model

$$Z_1 = \langle \{l_1, l_5\}, \{l_2, l_3, l_4, l_5\},
\begin{array}{c|cccc}
 & l_2 & l_3 & l_4 & l_5 \\
\hline
l_1 & false & false & false & true \\
l_5 & true & W_{5,3} & W_{5,4} & true
\end{array} \rangle,$$

where

$W_{5,3} =$ "there is a necessity of water for the first PS",

$W_{5,4} =$ "there is a necessity a part of the water to be directed to the second reservoir".

At each time moment token ω_1 enters place l_5 and unites with token ρ_1 that stays there. On the other hand, the later token splits to two, three or four tokens: the same token ρ_1 that continues to stay in place l_5 with the above mentioned chatacteristic, and tokens ω_1, ω_2 and ω_3 that enter places l_2, l_3 and l_4 with characteristics

"quantity of the evaporated wather from the first reservoir",

"quantity of the wather directed to the first PS",

"quantity of the wather directed to the second reservoir",

respectively.

$$Z_2 = \langle \{l_3, l_8, l_{10}\}, \{l_6, l_7, l_8\},
\begin{array}{c|ccc}
 & l_6 & l_7 & l_8 \\
\hline
l_3 & false & true & false \\
l_8 & true & false & true \\
l_{10} & false & false & true
\end{array} \rangle.$$

When in place l_{10} there is a κ_1-token, it enters place l_8 and unites with the token ε_1, staying there permanently with the above mentioned characterstic. Token ω_3 enters place l_7 with a characteristic

"quantity of the wather flowed through the first PS",

while at each time-moment token ε_1 splist to the same token ε_1 and token ε_2 with a characteristic

"quantity of the generated electricity by the first PS"

and the later token enter place l_6.

$$Z_3 = \langle \{l_6, l_{12}, l_{18}\}, \{l_{10}, l_{11}, l_{12}\},
\begin{array}{c|ccc}
 & l_{10} & l_{11} & l_{12} \\
\hline
l_6 & false & false & true \\
l_{12} & W_{12,10} & W_{12,11} & true \\
l_{18} & false & true & false
\end{array} \rangle,$$

where
$W_{12,10}$ = "there is a necessity of a change ot the first PS status",
$W_{12,11}$ = "there is a necessity of a change ot the second PS status".

Tokens ε_2 and ε_4 from places l_6 and l_{18}, respectively, enter place l_{12} and unite with the token κ, that permanently stays there with the above mentioned characteristic. In some moments, token κ splits to two or three tokens: the same token κ and to tokens $\kappa_1 1$ and κ_2, that enter places l_{10} and l_{11} with characteristics

"order for change ot the first PS status",

"order for change ot the second PS status",

respectively.

$$Z_4 = \langle \{l_4, l_7, l_9, l_{17}\}, \{l_{13}, l_{14}, l_{15}, l_{16}, l_{17}\},
\begin{array}{c|ccccc}
 & l_{13} & l_{14} & l_{15} & l_{16} & l_{17} \\
\hline
l_4 & false & false & false & false & true \\
l_7 & false & false & false & false & true \\
l_9 & false & false & false & false & true \\
l_{17} & true & W_{17,14} & W_{17,15} & W_{17,16} & true
\end{array} \rangle,$$

where
$W_{17,14}$ = "there is a necessity of water for irrigation",
$W_{17,15}$ = "there is a necessity of water for the second PS",
$W_{17,16}$ = "there is a necessity a part of the water to be directed to the third reservoir".

At each time moment tokens ω_3, ω_4 and ω_5 enter place l_9 and unites with token ρ_2 that stays there. On the other hand, the later token splits to two, three, four or five tokens: the same token ρ_2 that continues to stay in place l_{17} with the above mentioned chatacteristic, and tokens $\omega_6, \omega_7, \omega_8$ and ω_9 that enter places l_{13}, l_{14}, l_{15} and l_{16} with characteristics

"quantity of the evaporated wather from the second reservoir",

"quantity of the wather directed for irrigation",

"quantity of the wather directed to the second PS",

"quantity of the wather directed to the third reservoir",

respectively.

$$Z_5 = \langle \{l_{11}, l_{14}, l_{20}\}, \{l_{18}, l_{19}, l_{20}\},
\begin{array}{c|ccc}
 & l_{18} & l_{19} & l_{20} \\
\hline
l_{11} & false & false & true \\
l_{14} & false & true & false \\
l_{20} & true & false & true
\end{array} \rangle.$$

When in place l_{11} there is a κ_2-token, it enters place l_{20} and unites with the token $\varepsilon 2$, staying there permanently with the above mentioned characterstic. Token ω_7 enters place l_{19} with a characteristic

"quantity of the wather flowed through the second PS",

while at each time-moment token ε_2 splist to the same token ε_2 and token ε_4 with a characteristic

"quantity of the generated electricity by the second PS"

and the later token enter place l_{18}.

$$Z_6 = \langle \{l_{16}, l_{19}, l_{21}, l_{25}\}, \{l_{22}, l_{23}, l_{24}, l_{25}\},
\begin{array}{c|cccc}
 & l_{22} & l_{23} & l_{24} & l_{25} \\
\hline
l_{16} & false & false & false & true \\
l_{19} & false & false & false & true \\
l_{21} & false & false & false & true \\
l_{25} & true & W_{25,23} & true & true
\end{array} \rangle,$$

where

$W_{25,23} =$ "there is a necessity of water for irrigation".

At each time moment tokens ω_7, ω_9 and ω_{10} enter place l_{25} and unites with token ρ_3 that stays there. On the other hand, the later token splits to two, three or four tokens: the same token ρ_3 that continues to stay in place l_{25} with the above mentioned chatacteristic, and tokens ω_{11}, ω_{12} and ω_{13} that enter places l_{22}, l_{23} and l_{24} with characteristics

"quantity of the evaporated wather from the second reservoir",

"quantity of the wather directed for irrigation",

"quantity of the wather going out the third reservoir",

respectively.

4 Conclusion

The last few years have marked a historic change in political commitment around the world for the use of Renewable Energy Sources (RES). This is due to the increasing evidence of high environmental, economic and social costs imposed by the centralized energy models that rely on fossil fuels. The European Union and Japan, and more recently the United States and China show determination to adopt "green" models for the development of their economies, hoping to slow and / or reverse the process of global warming and ensure greater energy security for users. As a result the EU set mandatory targets and action plans to the Member States to reduce emissions of carbon dioxide (CO2), reduction of energy intensity and increasing the share of RES in energy consumption.

The purpose of this article is the presented results to be used for raising the level of performance and reliability of hydro power plants by achieving excellent stability maintenance, optimization of performance and minimizing the non utilized discharge.

Acknowledgement

The research work presented in this paper is partially supported by the FP7 grant AComIn No. 316087, funded by the European Commission in Capacity Programme in 2012–2016.

References

[1] Alexieva, J., E. Choy, E. Koycheva. Review and bibloigraphy on generalized nets theory and applications. In:- *A Survey of Generalized Nets* (E. Choy, M. Krawczak, A. Shannon and E. Szmidt, Eds.), Raffles KvB Monograph, No. 10, 2007, 207–301.

[2] Atanassov, K. *Generalized Nets.* World Scientific, Singapore, New Jersey, London, 1991.

[3] Atanassov, K. *On Generalized Nets Theory,* "Prof. M. Drinov" Academic Publishing House, Sofia, 2007.

[4] NEK EAD, Annual Report, 2011.

[5] Renewables Global Status Report, 2006 (Update).