

RBF Networks for Power System Topology Verification

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INTRODUCTION

A necessary condition for monitoring and control of a Power System (PS) is possessing a credible model of this system. The PS model for a need of dispatchers in national control centre is created in real time. An important element of such a model is a topology model. PS Topology Verification (PSTV) is an important problem in PS engineering. Often this problem is solved together with PS state estimation (Lukomski, & Wilkosz, 2000; Mai, Lefebvre, & Xuan, 2003). Methods, that enable such a solution of the problem, are sophisticated and usually time consuming. They require successful state estimation performance but convergence problems may occur in the case of certain Topology Errors (TEs). Thus, a robust method for PSTV before a state estimation is desired.

BACKGROUND

Now, the growth rate of Artificial Neural Networks (ANNs) application in some PS subjects is observed (Haque, & Kashtiban, 2005). One of such a subject is PSTV. It can be considered as a pattern recognition problem and then also utilization of ANN technique for solution of PSTV can be taken into account (Alves da Silva, & Quintana, 1995; Souza, Leite da Silva, & Alves da Silva, 1996, 1997, 1998). There are many references in which PSTV with use of ANNs is described. In (Tian, Zhu & Zhang, 1995) use of ANN as a part of an expert system to rule extraction is presented. One of the first method for such PSTV has assumed utilization of one ANN for whole PS (Vinod Kumar, Srivastava, Shah, & Mathur, 1996). In the case of this method the complexity of the ANN structure grows rapidly with the size of a power network. There are the problems

with learning and classification process in a case of large ANNs. In other attempts to solve the problem of PSTV with use of ANNs one can observe utilization of additional knowledge on PS (Garcia-Lagos, Joya, Marin, & Sandoval, 2003; Delimar, Hebel, & Pavić, 2001, 2002, 2003a, 2003b). Such approach allows reducing size of utilized ANNs. The learning and classification process become more effective and the verification method is more efficient. The considered approach is also utilized in the case of the method, which is further presented.

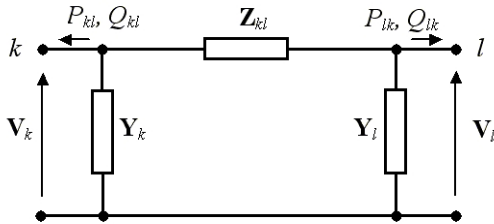
DESCRIPTION OF THE CONSIDERED SOLUTION

To ensure that in the described method a larger knowledge on PS will be utilized than it is in other methods for PSTV, so-called unbalance indices are introduced. Taking into account the nature of the solved problem and to accomplish the best features of the PSTV, Radial Basis Function Networks (RBFNs) are utilized.

Power System Model

Elements of the PS topology model are nodes (representing electrical nodes) and branches (representing power lines, transformers, loads etc.). The assumption, that every branch in a PS model is modeled as the π -equivalent circuit (Fig. 1), is adopted. It is assumed that there is an accessible credible measurement data set of such quantities as: active and reactive power flows at the ends of each branch, power injections, loads and voltage magnitudes at each node. Usually, if a branch is not included in PS model the measurement data related to the branch are not taken into account in carried out analyses.

Figure 1. The assumed π model of the branch, $\mathbf{Z}_{kl} = R_{kl} + j X_{kl}$, $\mathbf{Y}_k = jB_{kl}$, $\mathbf{Y}_l = jB_{lk}$, $B_{kl} = B_{lk} = B$. B is a half of the capacitive susceptance of the branch.



Unbalance Indices

Using Kirchhoff's and Ohm's Laws, PS can be described by many relationships among measured quantities. If there are no TEs, all these relationships are fulfilled. When TE occurs some of the relationships become unfulfilled. It should be underlined that if a branch is not included in the PS model, the relationships for this branch are not considered, because measurement data for it are not taken into account. In the described approach to have possibility of examination of relationships for all nodes and all branches independently of their correct or incorrect inclusion in the PS model the so-called unbalance indices for nodes and branches are introduced (Lukomski, 2002). These indices are shown in Table 1.

It should be noted that the nodal unbalance indices instead of power flow measurement data are taken into account when branch unbalance indices are calculated. This fact allows considering branch unbalance indices independently of correct or incorrect inclusion of branches in the PS model.

Unbalance indices create characteristic sets of values for different cases of modeling PS. If the topology model is correct and there are no errors burdening measurement data, all nodal unbalance indices are equal to zero and branch unbalance indices are near to zero, as well. The same situation is, when there is a branch that is actually out of operation but it is included in the topology model (the inclusion error). If a branch is actually in operation in PS but it is not included in the topology model (the exclusion error), then; (i) the unbalance indices for terminal nodes of this branch considerably differ from zero, (ii) the unbalance indices for the considered branch are equal to zero, (iii) absolute values of the unbalance indices for other branches, that are incident to the nodes mentioned under (i), have especially large values.

It should be stressed that the behavior of unbalance indices for active power and for reactive power is the same for the same TE.

Analyzing unbalance indices for nodes and branches one can observe that the exclusion error of the branch j has no influence on: (i) unbalance indices for nodes, that are not terminal nodes of the branch j , (ii) unbalance indices for branches that are not incident to the

Table 1. Active and reactive power unbalance indices for nodes and branches

	Node	Branch
Active power	$W_{Pk} = \sum_{i \in I_k} P_{ki}$	$W_{Pkl} = -W_{Pk} - W_{Pl} + R_{kl}W$
Reactive power	$W_{Qk} = \sum_{i \in I_k} Q_{ki}$	$W_{Qkl} = -W_{Qk} - W_{Ql} + X_{kl}W - B_{kl}(V_k^2 + V_l^2)$
Description: W_{Pk} , W_{Qk} – unbalance indices for the node k for active and reactive power respectively; W_{Pkl} , W_{Qkl} – unbalance indices for the branch connecting the nodes k and l for active and reactive power respectively; I_k – a set of the nodes connected to the node k ; P_{ki} , Q_{ki} – active and reactive power flows in the branch connecting the nodes k and i at the node k ; R_{kl} , X_{kl} , B_{kl} – π model parameters for the branch connecting the nodes k and l (Fig. 1); V_k , V_l – voltage magnitudes at the nodes k and l respectively; $W = \frac{W_{Pk}^2 + (W_{Qk} + B_{kl}V_k^2)^2}{V_k^2}$		

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