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A novel method to identify critical Voltage Control Areas

***Streszczenie**. Systemy elektroenergetyczne całego świata doświadczane są awariami, które zwykle prowadzą do całkowitego zaniku napięcia tzw. blackout'u. Poniższy artykuł przedstawia automatyczną metodę systemowego zapobiegania utracie stabilności napięciowej. Metoda VCA określa krytyczne obszary regulacji napięcia, tzw. obszary VCAs w systemie (z uwzględnieniem topologii, warunków i ograniczeń przesyłu oraz oblicza wymagane źródła mocy biernej, potrzebne dla zapewnienia bezpieczeństwa. Metoda przeszła pomyślnie wstępne testy dla krajowych sieci przesyłowych. **(Nowa metoda identyfikacji obszarów zagrożonych utratą stabilności napięciowej)**.*

***Abstract**. The power system all over the world experience from time to time big failure leading to total lack of voltage over a large area - called blackout. This paper presents an automated method for preventing the voltage collapse. This method called VCA (Voltage Control Area) allows to calculate reactive power necessary to mitigate the grid and point out the weak knots where the reactive power should be injected. This method was applied and tested with Polish transmission network.*

Słowa kluczowe: stabilność napięciowa systemu elektroenergetycznego, symulacja pracy, niezawodność pracy, regulacja mocy biernej.
Keywords: Power system voltage stability, Power system simulation, Power system reliability, Reactive power control.

Introduction

Assessing and mitigating problems associated with voltage security remains a critical concern for many power system planners and operators. Since it is well understood that voltage security is driven by the balance of reactive power in a system, it is of particular interest to find out what areas in a system may suffer reactive power deficiencies under some conditions. If those areas prone to voltage security problems, often called Voltage Control Areas (VCAs), can be identified, then the reactive power reserve requirements for them can also be established to ensure system secure operation under all conditions. A number of attempts have been made in the past to identify those areas, including a wide range of academic research and efforts toward commercial applications. A brief review of methods for determining VCA groups is presented in [1], where the author developed the Voltage Stability Security Assessment and Diagnostic (VSSAD) method. The VSSAD method breaks up any power system into non-overlapping set of coherent bus groups (VCAs), with unique voltage stability problems. There is a Reactive Reserve Basin (RRB) associated with each VCA, which is composed of the reactive resources on generators, synchronous condensers, and other reactive power compensating devices, such that its exhaustion results in voltage instability initiated in this VCA. The VCA bus group acts like a single bus and can't obtain reactive power supply at the same level of reactive power load no matter how it is distributed among the buses in that group. Finding VCAs and their associated RRB's in VSSAD method is based on QV curve analysis performed at each test VCA. It involves the placement of a synchronous condenser with infinite limits at VCA buses and observing the reactive power generation required for different set point voltages. QV curve analysis can be time consuming if curves have to be found for every bus in the system. Finding VCA's and their associated RRB's in VSSAD method is based on QV curve analysis performed at each test VCA. It involves the placement of a synchronous condenser with infinite limits at VCA buses and observing the reactive power generation required for different set point voltages. QV curve analysis can be time consuming if curves have to be found for every bus in the system. Thus another method has been proposed by Schlueter [2,3], which reduces the number of QV curves that need to be found for determining system's RRBs. Coherent bus groups can be found by this method that have similar QV curve minima's and share a similar set of exhausted generators at these minima's. This method, however, involves a fairly high degree of trial and error and requires the computation of QV curves at higher voltage buses before the QV curves for each individual bus group can be found.

A modal analysis technique has been applied to evaluate voltage stability of large power systems [4]. Although it has proven, when combined with PV analysis, to be an effective tool for determining areas prone to voltage instability for individual selected system scenarios, it has not been used directly as an approach to automatically determine VCAs when numerous contingencies or system scenarios are involved. In summary, the existing methods have had only a limited success in commercial application because they cannot produce satisfactory results for practical systems. This, in general, is because of the following difficulties:

- *The problem is highly nonlinear*: To examine the effects of contingencies the system is repeatedly stressed in some manner by increasing system load and generation. The process of stressing the system normally introduces a myriad of non-linearities and discontinuities between the base case operating point and the ultimate instability point
- *The VCAs must be established for all expected system conditions and contingencies*: Finding VCAs is a large dimensioned problem because many system conditions and contingencies need to be considered. It may not be possible to identify a small number of unique VCAs under all such conditions. The VCAs may also change in shape and size for different conditions and contingencies.

To deal with those issues, a more practical approach is needed that can clearly establish the VCAs for a given system and all possible system conditions. The approach is based on a QV Curve method combined with Modal Analysis [5,7]. Typically, a QV curve is created by increasingly stressing the system and solving a power flow at each new loading point. When the power flow fails to converge, the nose of the QV curve has been reached and this point corresponds to the stability limit for that particular imposed stress. Contingencies can also be applied at points along the QV curve to generate post-contingency.

Technical approach

The proposed approach is based on a PV curve method combined with Modal Analysis. The general approach is as follows:

- A system operating space is defined based on a wide range of system load conditions, dispatch conditions, and defined transactions (source-to-sink transfers).

- A large set of contingencies is defined which spans the range of credible contingencies.
- Using PV curve methods, the system is pushed through every condition, under all contingencies until the voltage instability point is found for each condition.
- To identify the VCA for each case using modal analysis: At the point of instability for each case (nose of the *PV* curve) modal analysis is performed to determine the critical mode of instability as defined by a set of bus participation factors corresponding to the zero eigenvalue (bifurcation point).
- The results of the modal analysis will is placed in a database for analysis using data mining methods to identify the VCAs and track them throughout the range of system changes.
- The reactive reserve requirements for selected VCA will then be established.

While the concept of *V-Q* sensitivity is a familiar one (the effect on voltage of a reactive injection at a bus), the concept of modal analysis, as used to determine area prone to voltage instability, is less widely understood. Therefore, it is useful to relate the two concepts to classify the meaning of modal analysis results.

The network constraints are expressed in the following linearized model around the given operating point [6,8]:

(1) $$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_{P\theta} & J_{PV} \\ J_{Q\theta} & J_{QV} \end{bmatrix}$$

where: ΔP – incremental change in bus real power, ΔQ – incremental change in bus reactive power, $\Delta\theta$ – incremental change in bus voltage angle, ΔV – incremental change in bus voltage magnitude, $J_{P\theta}$, J_{PV}, $J_{Q\theta}$, J_{QV} – are Jacobian sub-matrices.

The elements of the Jacobian matrix give the sensitivity between power flow and bus voltage changes. While it is true that both *P* and *Q* affect system voltage stability to some degree, we are primarily interested in the dominant relationship between *Q* and *V*. Therefore, at each operating point, we may keep *P* constant and evaluate voltage stability by considering the incremental relationship between *Q* and *V*. This is not to say that we neglect the relationship between *P* and *V*, but rather we establish a given *P* for the system and evaluate, using modal analysis, the *Q-V* relationship at that point.

Based on the above consideration the incremental relationship between *Q* and *V* can be derived from Equ.1 by letting $\Delta P=0$:

(2) $$\Delta Q = J_R \cdot \Delta V$$

where J_R is the reduced *Q-V* Jacobian sub-matrix:

(3) $$J_R = \left[J_{QV} - J_{Q\theta} J_{P\theta}^{-1} J_{PV} \right]$$

From Equ. 2 we can write:

(4) $$\Delta V = J_R^{-1} \cdot \Delta Q$$

where the inverse matrix J_R^{-1} is the *V-Q* sensitivity matrix:

(5) $$J_R^{-1} = \left[\partial V / \partial Q \right]$$

The i^{th} diagonal element of matrix J_R^{-1} is the *V-Q* sensitivity at bus i, which represents the slope of the *V-Q* curve at the given operating point. A positive *V-Q* sensitivity is indicative of stable operation: the smaller the sensitivity the more stable the system. The sensitivity becomes infinite at the stability limit. Sensitivity matrix J_R^{-1} is a full matrix whose elements reflect the propagation of voltage variation through the system following a reactive power injection in a bus.

V-Q sensitivity Analysis

V-Q sensitivities provide information regarding the combined effects of all modes of voltage reactive power variations. The relationship between bus *V-Q* sensitivities and eigenvalues can be derived from the general Equ. 4. Using the eigenvalues and eigenvectors of the reduced Jacobian matrix J_R we can write:

(6) $$J_R = \xi \Lambda \eta$$

where: $\xi = \left[\xi_1, \xi_2, ..., \xi_N \right]$ is the right eigenvector matrix of J_R; $\eta = \left[\eta_1, \eta_2, ..., \eta_N \right]$ is the left eigenvector matrix of J_R and Λ is the eigenvalue matrix of J_R.

Since $\xi = \eta^{-1}$ we can also write:

(7) $$J_R^{-1} = \xi \Lambda^{-1} \eta$$

Substituting Equ. 6 in Equ. 4 gives:

(8) $$\Delta V = \xi \Lambda^{-1} \eta \cdot \Delta Q \qquad \text{or:}$$

(9) $$\Delta V = \sum_i \frac{\xi_i \eta_i}{\lambda_i} \cdot \Delta Q$$

where λ_i is the i^{th} eigenvalue of J_R and ξ_i and η_i are its corresponding right and left eigenvectors. Bus *V-Q* sensitivities can be derived from Equ. 9 as follows. Let $\Delta Q = e_k$ where e_k has all zero elements except for the k^{th} element that is equal to 1. The *V-Q* sensitivity at bus k is then given by:

(10) $$\frac{\partial V_k}{\partial Q_k} = \sum_i \frac{\xi_{ki} \eta_{ik}}{\lambda_i}$$

where ξ_{ki} and η_{ik} are the k^{th} elements of the right and left eigenvectors respectively corresponding to eigenvalue λ_i.

The *V-Q* sensitivities provide information regarding the combined effects of all modes on voltage-reactive power variation. The magnitudes of the eigenvalues can provide a relative measure of the proximity to voltage instability. When the system reaches the voltage stability critical point, the modal analysis is helpful in identifying the voltage stability critical areas and buses, which participate in each mode. The relative participation of bus k in mode i is given by the bus participation factor:

(11) $$\mathbf{P_{ki}} = \boldsymbol{\xi}_{\mathbf{ki}} \boldsymbol{\eta}_{\mathbf{ik}}$$

From Equation 10 we could see that bus participation factor P_{ki} determines the contribution of eigenvalue λ_i to the *V-Q* sensitivity at bus k.

VCA Identification Procedure

In the proposed approach, the power system is stressed to its stability limit for various system conditions under all credible contingencies. At the point of instability (nose of the *PV* curve) modal analysis is performed to determine the critical mode of voltage instability for which a set of bus participation factors (PFs) corresponding to the zero eigenvalue (bifurcation point) is calculated. Based on these PFs, the proposed method identifies the sets of buses and generators that form the various VCAs in a given power system. It is assumed that for a given contingency case, buses with high PFs including generator terminal buses, form a VCA. This suggests that each contingency case might produce its own VCA. In practice, however, the large number of credible contingency cases generally will produce only a small number of VCAs because several contingencies are usually related to the same VCA. The proposed identification procedure applies heuristic rules to (a) group contingencies that are related to the same VCA; and (b) identify the specific buses and generators that form each VCA (see Figure 1).

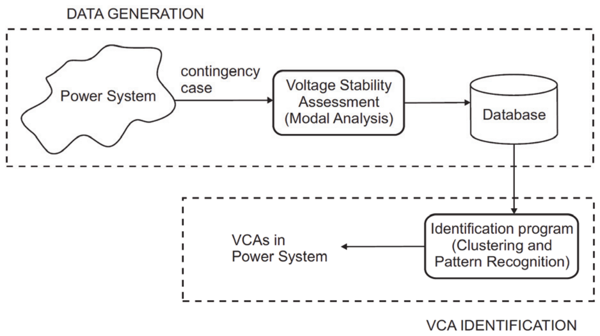

Fig. 1. VCA identification in a Power System

The VCAs are identified based on the results of the analysis of all credible contingencies and different power system conditions. Each VCA identified is related to a cluster of contingencies; these cases are the so-called “support” of that VCA. This means that first “similar” contingency cases are clustered and then the specific buses and generators that form the VCAs are identified. Before clustering contingency cases, however, a preliminary selection of buses and generators is done at an earlier stage of the VCA identification process as indicated in Figure 2.

Step 1: Selection of Buses for VCA Identification

From each contingency modal analysis results, a subset of buses with high PF is selected for further analysis (remaining buses are discarded). Several strategies to select such subset can be applied. For instance, one could predefine a PF threshold and then select the buses with PFs above this threshold. Such approach would assume that it is meaningful to compare PFs values among various contingencies. However, such assumption may be false because the PFs calculated for each contingency are normalized with respect to the maximum PF value of each mode. Therefore, because different contingencies use different references for their PFs, they cannot be compared. Since each contingency case is unique, a better approach to select the Set for Further Analysis (SFA) buses is to base it on the characteristics of each contingency. Generator terminal buses are PV type buses and thus are not included in the reduced Jacobian matrix. Therefore, PF cannot be calculated for a generator terminal bus until the generator exhausts its reactive reserves, which is marked as a Q-limited (QL) bus, and it becomes a PQ type bus. The number of QL buses, characteristic for each contingency, determines the selection of SFA buses. The selection for SFA buses includes all generators QL buses and a subset of buses with the highest PFs. The pseudo-code for this step is as follows:

```
Set PF_threshold=PF_T
For each contingency case i:
   Determine Xi=number of generators at
   their limit in contingency case I;
   Select the buses with PFs >= PF_T;
   Denote the selected buses as set SFAi;
   Include the corresponding Xi generator
   buses, if any, into SFAi;
End.
```

Note: A SFAi set consists of:

a. buses with PFs >= PF_T, selected for analysis,
b. Xi generator buses that have exhausted their reactive reserves.

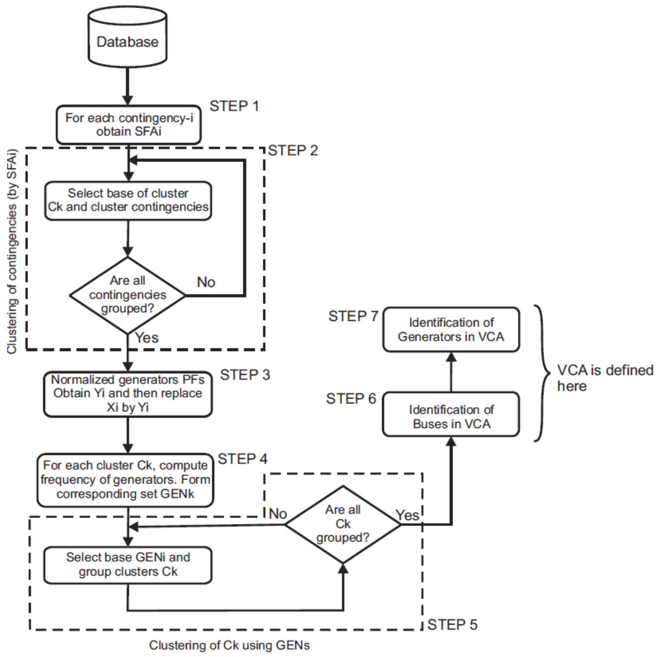

Fig. 2. Data Flow Diagram for VCA Identification Procedure

Step 2: Clustering of Contingency Cases based on SFAs.

In this step only the buses having high PFs are used for comparison (generators which are at their reactive power limit are not considered at this stage). Several contingency clusters Ck are constructed in this step. Later on, these clusters will be used to identify the VCAs in the power system (Steps 6 and 7). The first step in a clustering process is the selection of a particular SFAx as the base for the cluster (heuristic rules for selecting the base are given in next section). Then every SFAi is compared against this base set. If predetermined percentage of SFAi buses are members of the SFAx set, then those sets are consider being similar and are grouped together. After grouping the SFAs similar to SFAx base set a new base set SFAz is selected for the remaining SFAs. Then the process is repeated until all SFAs are grouped (groups of a single SFA are allowed). The pseudo-code for this step is as follows:

```
Set k=1 (counter for number of clusters Ck)
Repeat until all SFAs are grouped
   Create empty cluster Ck;
   From SFAs not yet grouped select base set
   SFAx.;
   Include SFAx in Ck (SFAx → Ck)
       - For every SFAi not yet grouped:
       If buses in SFAi are similar to buses
       in SFAx then include SFAi in Ck
       - End for every SFAi not yet grouped
   If every SFAi has been grouped then STOP;
   otherwise increase k and repeat the
   procedure.
End
```

Step 3: Normalization of Generator Buses PFs.

For every SFAi in cluster Ck, the generator buses PFs are normalized. If a given SFAi contains Xi generator buses then the maximum PF value of those Xi buses is used as a normalization factor. Then, a subset of Yi generator buses with the highest normalized PFs is selected for further analysis (remaining generator buses are eliminated from SFAi). The pseudo-code for this step is as follows:

```
For each cluster Ck
   For each SFAi in Ck
       Normalized the PFs of the Xi
       generator-buses;
       Select the Yi generator buses with
       normalized PFs>=β;
       In SFAi: replace set Xi by set Yi;
   End for each SFAi in Ck;
End for each cluster Ck.
```

Note: The β factor is used to select only the most significant generator buses; β is a threshold for the generator buses normalized PFs below which the generator buses are excluded from SFAs.

Step 4: Selection of Generators in Cluster Ck.

For each cluster Ck, the frequency of generator bus participations in this Ck is calculated as the number of SFAs in which a given generator bus is present. The generator buses with the highest frequencies are selected to represent the cluster Ck reactive reserves and are denoted as GENk. The pseudo-code for this step is as follows:

```
For each cluster Ck
   For each generator-bus-z in Ck
       Compute frequency Fz for generator
       bus z:
          Fz=number of SFAs where generator
          bus z is present;
   End for each generator bus z;
   Select set of gen. buses with Fz>= δ;
   Denote this set of gen. bus set as GENk;
   Remove generator buses from each SFAi in
   cluster Ck;
End for each cluster Ck.
```

Note: The factor δ is a frequency threshold used for the selection of generator buses. The higher the frequency of a generator bus, the higher the possibility of selecting the generator bus. The value for δ depends on the number of SFAs in a given Ck.

Step 5: Clustering of Ck based on GENs.

In this step, Ck are grouped together if their corresponding GEN sets are similar. Two GENs are considered similar if certain percentage of generator buses are matched. If GENi (from Ci) and GENj (from Cj) are similar, then Ci and Cj are grouped together into a preliminary VCA, say VCAm. This VCAm is associated with a set of generator buses GENm that consists of the generator buses of the combined GENi and GENj. The pseudo code for this step is as follows:

```
Set m=1 (counter for number of preliminary
VCAs);
Repeat until all clusters Ck have been
grouped:
      Create empty preliminary VCAm
      Create empty GENm
      From Ck not yet grouped select base
      set GENx.
      Include all SFAs, from corresponding
      Cx, into the VCAm:
          SFA(Cx) → VCAm
          Update GENm = GENx ∩ GENm I
      For each Ci not yet grouped:
          If corresponding GENi is similar
          to GENx then
              SFA(Ci) → VCAm
              Update GENm = GENi ∩ GENm I
      End for each Ci not yet grouped
      If all Ck have been grouped then
      STOP;
        otherwise increase m and repeat the
        procedure;
End.
```

After this step, a set of preliminary VCAs is established. Each preliminary VCAm relates to a unique set of generator buses GENm.

Step 6: Selection of buses. For each preliminary VCAm, compute the frequency of each bus. Then select the buses with a frequency greater than 50% the number of SFAs in that VCAm. These are the buses that form VCAm of the given power system.

Step 7. Selection of generators. For each GENm, get the frequency of each generator bus. Then select the generator buses with a frequency greater than 50% the number of SFAs in the corresponding VCAm. The generators associated with these generator buses are the ones that form controlling generators associated with VCAm of the given power system

Heuristic Rules for Base Selection and Similarity Measurement

(a) Selection of a base for clustering process

From the VCA identification process, as mentioned earlier, we can observe that clustering is carried out twice:

- Clustering contingency cases based on SFAs (Step 2),
- Clustering Ck based on GENs (Step 5).

Each clustering process starts with the selection of a base set for the cluster. Then any other set is compared to this base to evaluate whether they are similar. In Step 2, two different criteria for the selection of a base SFAx set were tested:

- Largest contingency (SFA). After the SFAs are found in Step 1, the number of buses in each SFA is counted. The SFA with the highest number of buses is selected as the SFAx base for a cluster and then similar SFAs are grouped together.
- Most severe contingency (SFA). As part of the voltage stability assessment of the system, we also compute the margin for each contingency case. The SFA corresponding to the contingency with the smallest margin is selected as the base of the cluster. Then similar SFAs are grouped together.

The second criterion was found more suitable and therefore it is applied in the VCA identification process. For clustering in Step 5, the GEN set with the highest number of generator-buses is selected as the base GENx of a cluster. Then similar GENs are grouped together.

(b) Measure of similarity between sets

Whether we are dealing with SFAs or GENs the measure of similarity is the same. First the numbers of buses in the base sets SFAx or GENx as well as the SFAs or GENs sets for all cases are counted. Then the elements of set-i (either SFAi or GENi) are compared with the elements of the base set (either SFAx or GENx). The number of common elements C is counted and compared with the similarity threshold T. If the number of common elements C is greater than the threshold T, then set-i and the base set are considered being similar. The similarity threshold T is set as a percentage of the number of elements of in the largest set (set-i or the base set). If all elements of the smaller set (base or set-i) are included in the larger set then those sets are considered being similar.

Analysis of VCA Buses

Let's assume that the total number of buses in the system equals four (n=4). Let's also assume that two contingency cases are considered and that their PFs are those given by:

Bus PFs:

CntgA=[B1 B2 B3 B4] =[1.0 0.8 0.7 0]

CntgB=[B1 B2 B3 B4] =[0.4 1.0 0 0]

To rank the buses listed above one proceeds as follows. For a given contingency, the bus with the highest PF is mapped/ranked into n=4. Then the bus with the second highest value is mapped into (n-1), then the next one into (n-2) and so on. Buses with PFs=0 are mapped into 1 (minimum ranking value). That is, the buses listed above are ranked as follows.

Bus Ranking:

CntgA=[B1 B2 B3 B4] =[4 3 2 1]

CntgB=[B1 B2 B3 B4] =[3 4 1 1]

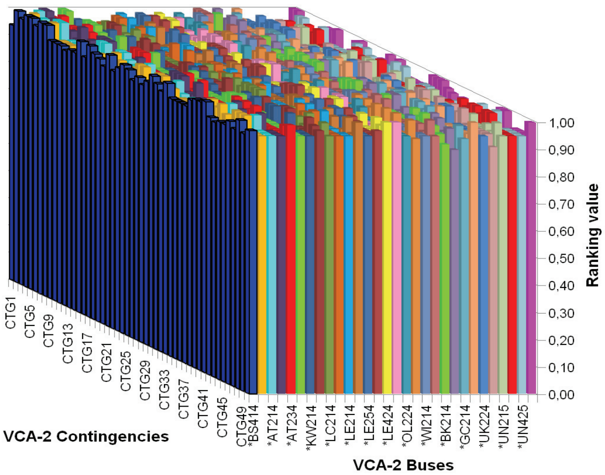

Fig. 3. Ranking values VCA-2 Buses (30 Buses and 50 contingency cases)

Then, ranking values are normalized with respect to n:

Normalized Ranking:

CntgA=[B1 B2 B3 B4] =[1 0.75 0.5 0.25]

CntgB=[B1 B2 B3 B4] =[0.75 1 0.25 0.25]

The normalized ranking values are not the same as the PFs. For instance, the bus with the second highest PF is always ranked to the same normalized ranking value (0.75 in the example given); i.e., this ranking is independent of how different the PFs of these buses are for the different contingencies. These normalized ranking values are used to evaluate the identified VCA buses. Figure 3 shows the ranking values of a set of 30 buses across 50 contingency cases; these buses and contingencies are related to VCA-2. On the other hand, Figure 4 shows the ranking values of a set of non-VCA buses. Comparing Figure 3 versus Figure 4, one can observe that the ranking values of the VCA buses are higher than those of the non-VCA buses. That is, the identified VCA buses are indeed the most important buses prone to voltage instability problems.

Analysis of VCA Generators

"VCA generators" are those generators that initiate the instability of the VCA once their reactive power reserves have been exhausted. That is, VCA generators are the location where reactive power reserves should be kept so that voltage instability is avoided. In the previous section, buses are ranked in order to identify how important they are. Such an approach is not suitable for the generators since we are not interested on how important (rank) they are, but rather how effective they are in preventing voltage instability.

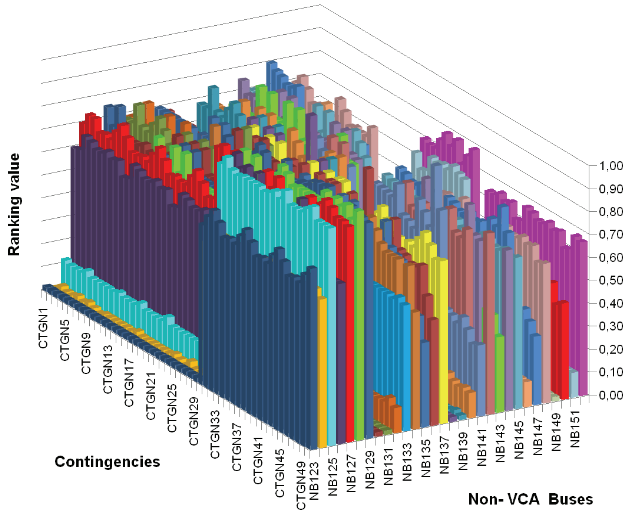

Fig. 4. Ranking of Non-VCA Buses (30 Buses and 50 contingency cases)

For a single contingency case, for instance, a generator that is ranked in second place might not be as effective in avoiding voltage instability as the generator ranked in the first place. In other words, reactive power reserves in the generator ranked second will not produce the same system improvement as if these reserves were allocated to the generator ranked first instead. A per-contingency generator-PF-normalization metric can measure how effective generators are. It is expected that VCA generators have higher normalized PFs than those of non-VCA generators.

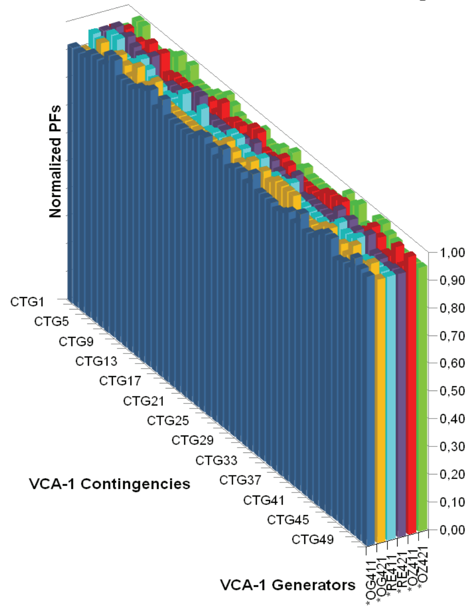

Fig. 5. Normalized PFs of VCA-1 Generators (6 Generators and 50 contingency cases)

An example of how to normalized generators PFs follows. Consider the following contingencies cases and generators PFs.

PFs of QL generators (generators that are at their reactive power limit):

CntgA=[G1 G2 G3 G4] = [0.4 0.2 0.1 0]   (max=0.4)
CntgB=[G1 G2 G3 G4] = [0.1 0.2 0.1 0.3] (max=0.3)

Then, one normalizes the PFs with respect the highest PF of the corresponding contingency; that is,

Normalized PFs of QL generators:
CntgA=[G1 G2 G3 G4] =[1   0.5 0.25 0]
CntgB=[G1 G2 G3 G4] =[0.3 0.6 0.3   1].

Figure 5 shows the normalized PFs of the VCA-1 generators; these values are higher than those of the non-VCA generators. That is, the set of identified VCA generators are the most effective to avoid voltage instability if reactive reserves are kept in.

Performance of VCA-1 Generators when reactive power reserves are increased

In order to evaluate the effectiveness of the identified VCA generators, for VCA-1, the following test was carried out. An additional 50 MVAR reserve was uniformly distributed on the set of the VCA-1 generators. Then the points of voltage instability of the associated contingencies were computed. These voltage instability points were compared against those when there is no increase in reserves. The objective of this test is to measure how the power transfer increases, for the various contingencies considered, when the reactive reserves in this set of VCA-1 generators is increased. The above increment in power transfer was compared against that obtained when a 50 MVAR reserve is distributed on each of two other sets of generators. Based on experience, these two other sets of generators were identified as the most promising for a high power transfer increment. Figure 6 shows the MW-Transfer increase obtained when an additional 50 MVAR reactive power reserve is distributed on various sets of generators. The mean MW transfer increase (M-MW-Inc) is higher for the set of VCA-1 generators than that for the other two sets. That is, the identified VCA-1 generators are the most effective in securing voltage stability since the points of voltage instability, for the various associated contingencies, occurs farther ahead than that at the other two sets of generators tested.

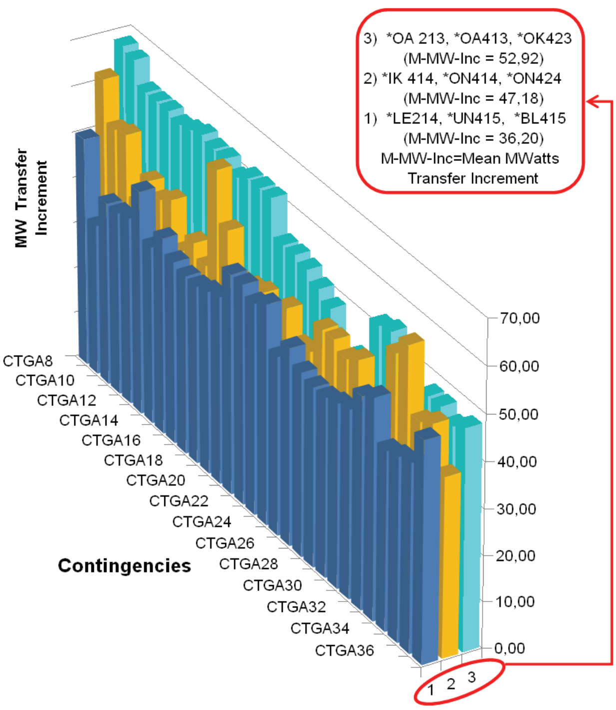

Fig. 6. Transfer Increase Comparison: Set of VCA-Generators Versus Other Sets. MW Transfer-Increment vs. Reactive Reserve Increment (50MVars)

Conclusion

In normal operating conditions the control system manage to adjust generation of reactive power in power plants and to control the voltages. If the location of reactive power sources is inadequate, the control system may lead the power grid to a blackout. For ensuring appropriate reliability of supply in electrical energy are responsible network-companies, which usually do not own any generation. Thus, they have to achieve their task by control of contracted reserves and generation-load balancing. Since customers are free to change their power demand at any time, the balancing consists in requesting a change in generation. In market economy all contracts are profit oriented. A term of the common good or wealth is not appealing to companies desperately needed income. The reliability of supply in market environment is on one hand more important due to customer expectation and on the other hand more difficult and more expensive to achieve. An overview of the state-of-the-art of on-line VSA has been presented and a new method for the identification of voltage control areas is described. For a wide range of system conditions and contingencies, the technique can identify the buses in each VCA and identify VCAs which are common for a set of contingencies and/or conditions. In addition, the method identifies the generators which are critical to maintaining stability for a given VCA. Voltage control areas describe the regions in a power system that under specific conditions are prone to voltage instability. Intelligent systems hold promise to improve VSA speed, provide adaptive learning capabilities and offer the ability to identify key system parameters.

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