Visualization and Image Analysis of Power Transmission Network Using Mathematical Morphology Techniques

S.U.Prabha, C.Venkataseshaiah and M.Senthil Arumugam
FET,Multimedia University, Melaka Campus, Malaysia

Abstract- **Morphological decimation technique is proposed to visualize and analyze the power transmission network image. A 24 bus Reliability Test System is considered for this purpose. A graphical image of the power network, with thickness of the lines proportional to their respective MVA capacity is created in two-dimensional discrete space. Based on ac load flow solution, another image is drawn which represents the power flow (in MW) between the buses. Proper scaling is done to represent the MVA capacity and the MW flow. Using mathematical morphology technique the spatially represented line flows, between the buses are decimated into nine categories. They are represented in different colors. This image which is obtained with different colors is superimposed on the image which is created with the MVA capacity of the network. For better visualization and to easily remember the color coding, it is further regrouped into 3 categories. The second approach is to analyze the real power losses as it is one of the important parameter in the power system. The operators are interested to focus on the system with respect to the losses. An image is constructed such that the width of the lines is proportional to the MW losses for a modified IEEE 30 bus test system and it is decimated. The processed image will help the planner and operator to get a better visualization of the power system network and to analyze the same in terms of the behavior of the network.**

Index terms — Image processiong, power system monitoring, power system planning, visualization

I. INTRODUCTION

The electrical power systems are very large, interconnected and complicated networks. The power network planner and operator should have a bird's eye view of the network. Power system operators need to interpret and integrate multiple measured parameters. They then use that information to perform tasks typical of process control, requiring consistent monitoring of the network flow and detection of faults due to transmission line overloads. Various methods for load flow tracing have been reported in [1]. In [2], a morphological approach is presented which introduces some new techniques to visualize the strongly connected sub networks. As an extension of this idea, in [3], multi-color visualization is used to find the optimal path for power transfer from one bus to other using power flow analysis[5]. The purpose of the present work is to use the morphological decimation techniques to visualize and analyze the power transmission system. Regrouping of the decimated image is proposed for better visualization and it enables better understanding for the operator. Further, real power loss analysis has been carried out and the results are found to be useful for the planners and operators to get abstract information of the network under consideration.

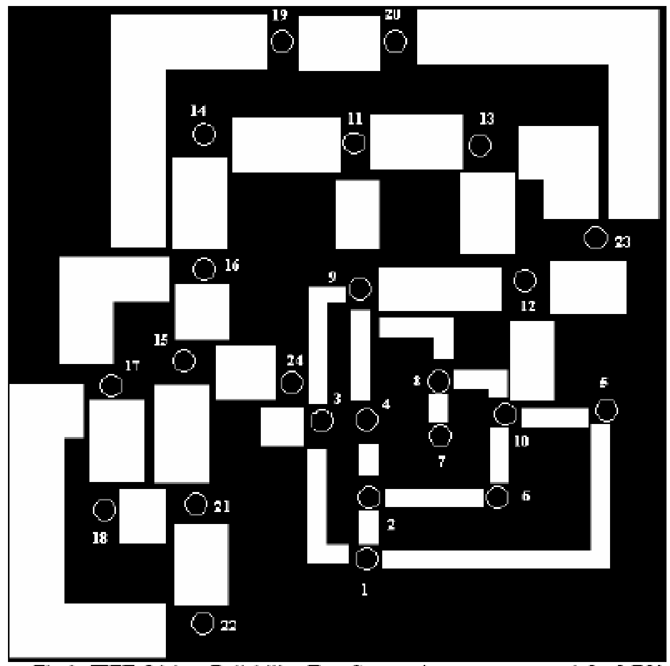


Fig.1. IEEE 24 bus Reliability Test System image constructed for MVA capacities (Set A) available between the buses (Set P). Buses are represented with open circles. This diagram is obtained by taking the logical union of sets A and P. The larger the widths of the network-segments, larger are the available capacity.

The original principle of Mathematical Morphology (MM) stems from set theory. MM provides an algebraic formulation to apply neighborhood operations [4]. Erosion and dilation are two basic operators of MM, which are derived from the definitions of Minkowski's addition and subtraction. The basic morphological operations, namely erosion, dilation, opening, closing etc. are used for decimating the network image. By using these techniques, it is possible to analyze and understand any network under consideration. A single line diagram of the network is drawn to scale. This diagram is converted into a bitmap image. This image is then decimated through a series of morphological transformations. The features of this proposed approach are multi-color visualization of the available power transfer capability in a transmission network and analysis of the network image for an IEEE 30 bus test system which is created with respect to the real power losses.

Section II explains image construction technique for the power network. The mathematical morphology tools, the basic transformations and processes using morphological tools are discussed in Section III. Section IV presents the test results and conclusions are drawn in Section V.

II. IMAGE CONSTRUCTION TECHNIQUE

Two IEEE test systems are considered in this paper. In order to have a multi-color visualization and to analyze the network with respect to the available power in the lines, IEEE 24 bus Reliability test system is considered. To perform the analyses with respect to the MW losses in the lines, IEEE 30 bus test system is considered. Two different systems are considered in order to appreciate the usefulness of the proposed technique.

A. Image construction for IEEE 24 bus reliability test system

The single line diagram is drawn for both the systems under consideration. Figure 1 shows the single line diagram which represents the rated mega-volt ampere (MVA) capacity. A power flow analysis, using fast decoupled load flow technique is performed using MATLAB. By using the results of the analysis, another image is constructed for the megawatt (MW) flow in the lines and is shown in Fig.2. These images were translated into bitmap images.

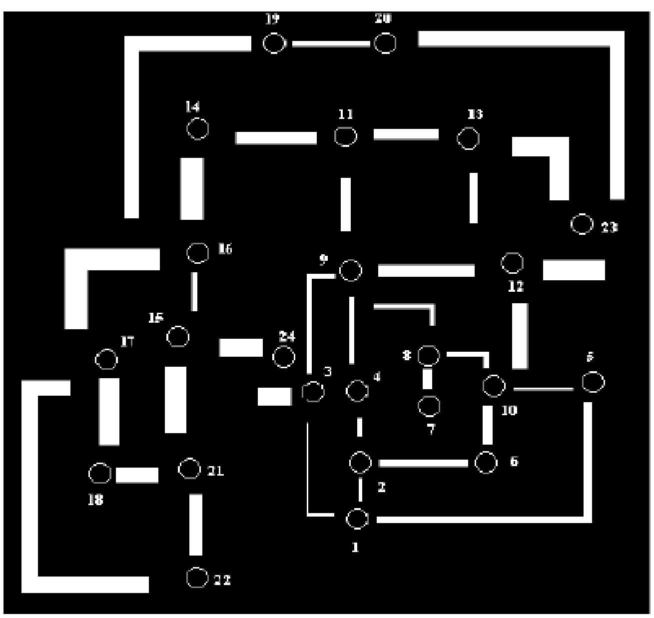


Fig.2. Image created with MW flow in line. (Set M). The utilized capacity is depicted in terms of varied line widths. The line width is proportional to the utilized capacity. This diagram is obtained by taking the logical union of sets M and P.

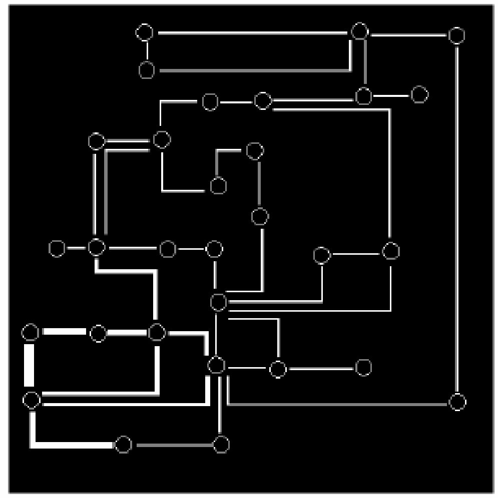


Fig.3. Image created with real power losses in lines for a IEEE 30 bus test system

Fig.2 is decimated through a multiscale morphological opening transformation and the decimated image is represented as color coded image with 9 different categories. In order to have better understanding and to enable the operator to remember the categories, these 9 categories are further reduced into 3 categories by re-grouping the ranges. This is done by following the multiple threshold values. This is further discussed in result section.

B. Image construction for IEEE 30 bus test system

IEEE 30 bus system was considered as an example to analyze the network with respect to the MW losses in the lines. A single line diagram is drawn and a bit map image is constructed such that the line widths are proportional to the MW losses in the lines. The input diagram for this analysis is shown in Fig.3.

III.MORPHOLOGICAL APPLICATIONS FOR POWER GRID DECIMATION PROCESS

The images that are constructed by the process explained in section II yield a bitmap image of the power grid. These images provide a synoptic understanding of power flow in lines with their total available capacity and the capacity being utilized. It would be appropriate if these spatially distributed capacity and power flow diagrams are decimated according their potentialities. This paper addresses this aspect by employing binary morphologic opening transformation. The required basic morphologic transformations are briefly explained in the section that follows

A. Morphological Transformations

Let A, P, and M denote sets representing total available power capacity, buses (open circles) and the power being utilized respectively over two-dimensional discrete space on black background (Figs. 1, 2). These sets depicting the important features in spatial form are created interactively with white pixels and background space with black pixels. In these sets foreground with white shade (color 15) depicts available capacity, buses, and power being utilized. In these figures set P representing buses (with open circles) is superposed. Fig.1 is obtained through logical union of sets A and P. It is also obvious from figures 1 and 2 that the set M, being the map denoting spatial distribution of the load being utilized, is a subset of set A.

In the information that follows, set M is subjected to decimation process by employing multiscale morphologic opening transformation. Morphologic transformations are explained with an image represented in discrete space (M) (e.g. Fig. 2) and a template (B) that would be used as a probing rule to make modifications in M. The basic binary morphologic transformations include erosion (Eq. 1) and dilation (Eq. 2).

Erosion: $M \ominus B$ (1)
Dilation: $M \oplus B$ (2)

where $\ominus$, and + respectively denote erosion and dilation symbols, and B denotes a symmetric square structuring element of primitive size 3 X 3. Opening transformation (Eq. 3) is performed by performing erosion transformation followed by dilation transformation on M with respect to B.

Opening : $M \ominus B \oplus B = MoB$ (3)
Closing : $M \oplus B \ominus B$ (4)

[illegible] $\oplus B$ [illegible] illustrated in Fig.4.

While creating this power grid network (M), the following technically viable assumptions are taken into account.

- the higher the power flow, the wider the network segment connecting the buses.
- width of the network segments is subjected to filtering process performed in a multiscale opening transformation, but not the segment length
- each segment of network is bounded between the button-like buses.
- this power grid network, in binary form, is denoted by set M .

As a whole, M (Fig. 2) is the set that consists of network segments with varied widths in Euclidean two-dimensional discrete space (Z^2) providing a synoptic (bird's eye) view. This network is drawn to scale. The scale parameters considered to create this discrete binary network include the line power flows obtained from the load flow calculations.

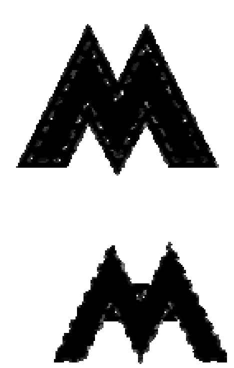
B. Color-coded Morphological Transformations

The process of color coding of the decimated set (M) is presented in this section. For better visualization in a single image, each isolated power grid line of n^{th} category ($n = 1,2,3...N$) is color-coded with intensity value denoted by (i), where $n = i$. Each nth-category grid-segment ($n = [1,2,...N]$) decimated for 24 bus system is color-coded as follows (Eq. 5):

$$\bigcup_{\substack{n=0 \\ i=n+1}}^{\substack{9 \\ N}} [GSn]^i , \qquad (5)$$

where N is the maximum number of segments that could be decimated and i denotes the color employed to assign n^{th} [illegible] the proposed algorithm, the color-coded image is obtained and [illegible] is shown in Fig.5.

[illegible] defined as $B \oplus B \oplus$ [illegible] morphological transformations [illegible]



ormations
(d) closing

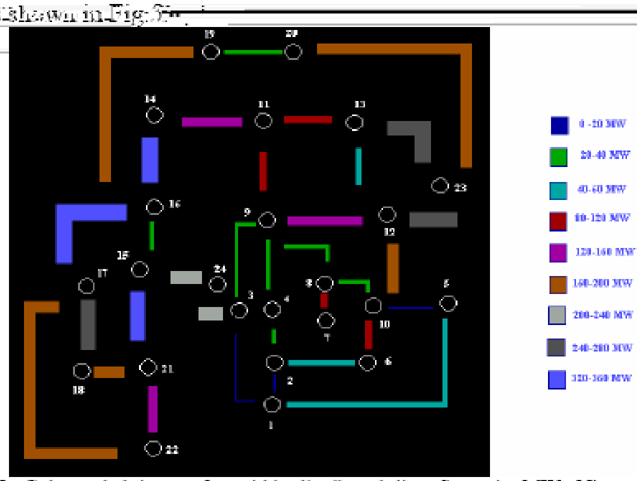


Fig.5. Color-coded image for width distributed line flows in MW. Nine different categories are decimated according to MW units represented with proportional widths in terms of pixel units.

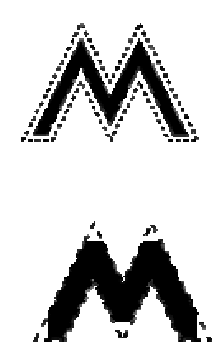


Fig.4. Basic Morphological Transf
(a) Erosion (b) Dilation (c) opening

IV. RESULTS

In order to test the proposed algorithm, several structuring elements have been tried. They are square, octagon and rhombus shaped elements. The octagon-shaped structuring element gave the best result for the first case (IEEE 24 bus test system) and square shaped structuring element gave the best result for the second case (IEEE 30 bus test system). It is because of the reason that the application is different for each case.

A. Regrouping of the Color-coded image for IEEE 24 bus test system

In order to have better visualization, the power grid with color-coding scheme shown in Fig.5 is further regrouped by following multiple threshold values. As there are nine different categories, regrouping these categories is addressed in order to identify strong flow pattern within the system. The processed image is shown in Fig.6. This analysis helps us to identify the power-flow patterns within the system and coupling between generation and demand. The nine categories are obvious with different colors, the representation of which ranges from 1to 9. While regrouping this network, we consider the threshold values as given in Table 1.

TABLE I. THRESHOLD VALUES FOR REGROUPING

	Threshold values	Value of line flow (MW)	Color
1	From 1 to 3	Up to 40 MW	Blue
2	From 4 to 6	40 MW to 160 MW	Green
3	Above 6	Above 160 MW	White

B. Image created with MW losses for IEEE 30 bus test system

The real power loss in a power network is an important operational parameter and need to be estimated for every line in the network. The width of the lines is set proportional to the MW losses and the network image is constructed and is shown in Fig.3.

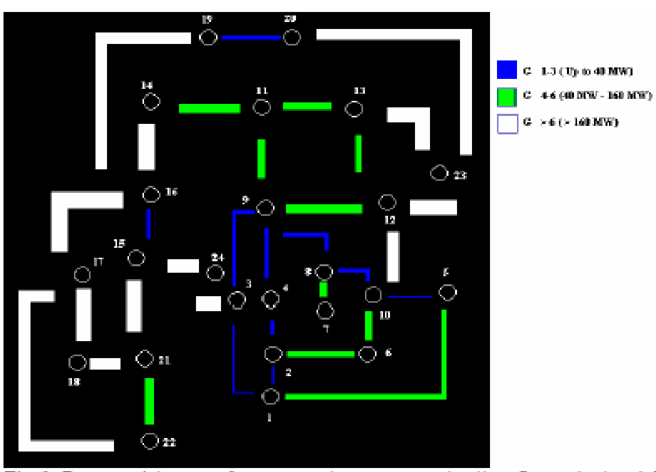


Fig.6. Processed image after regrouping, w.r.t to the line flows depicted in blue, green and white colors.

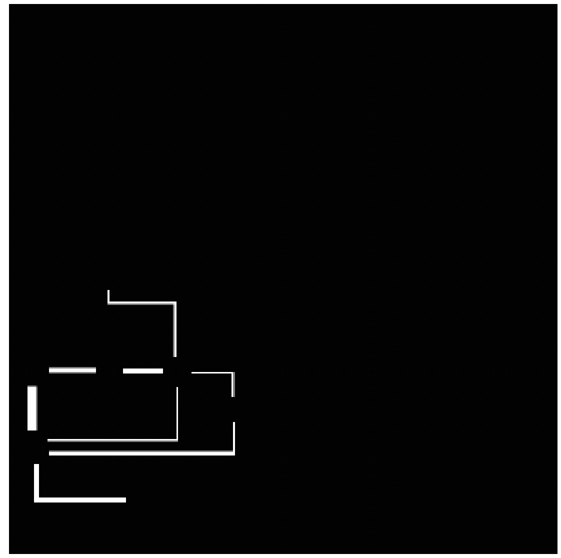


Fig.7. Processed image created with real power losses in lines for a IEEE 30 bus test system

This is then converted into bit map image. The decimation of this image brings out the lines causing higher losses in the system. Fig.7 shows the decimated image of the IEEE 30 bus test system. The results of this analysis give an overall idea about the lines which causes higher losses in the system under consideration.

V. CONCLUSION

The proposed technique was successfully implemented on IEEE 24 bus test system and IEEE 30 bus test system and the results are presented. This is a novel approach which enables the planners and operators to have a bird's eye view of any power network under consideration. The application of mathematical morphology in power system analysis is promising and could be extended for different operational parameters in future. Through these techniques, the power system planner and operators may easily visualize the functioning of the network and the knowledge obtained might be used to predict the behaviour of the network.

REFERENCES

[1] Wu F.F, Y.Ni and P.Wei. Power transfer allocation for open access using graph theory-fundamentals and applications in systems without loopflow *IEEE Trans. Power Syst.*,vol.15,no. 3, pp.923-929, Aug.2000

[2] P.Radhakrishnan, B.S.D.Sagar and,B.Venkatesh, "Morphological Image Analysis of Transmission Systems, " *IEEE Trans. On Power delivery*,vol. 20, no.1, pp.219-223, Jan 2005

[3] S.U.Prabha, B.S.Dayasagar and C.Venkataseshaiah, "Visualization of Available Power Transfer Capability in a Transmission System Using Morphological Techniques", American Journal of Applied Sciences, 6(2) : 247-250, 2009

[4] J. Serra, Image Analysis and Mathematical Morphology, Academic Press (London), p. 610.

[5] B.Stott and o.Alsac,"Fast de-coupled load flow,"IEEE Trans.Power App.Syst.,vol.PAS-93, no.3,pp.859-869, May-Jun.1974.