Minimum Distance, a Quick and Simple Method of Determining the Static ATC

Mostafa Eidiani

Islamic Azad University, Bojnourd Branch, Bojnourd, Iran. Email: info@eidiani.ir

D. Yazdanpanah

Khorasan Region Electric Co., Planning and Research, Mashad, Iran. Email: dariush_yaz@yahoo.com

Abstract— In this paper, a quick, simple and precise method has been introduced for determining the static ATC, considering the real limitation of the network. It has also taken into account the limitation of the over load of all the elements, the over and lower voltage for all buses and terminals. In fact, (Minimum Distance) MD method is a kind of Continuation Power Flow (CPF) which converges to the response fast and with a few Load Flow (LF) from the distance between the operation point and desired point with approximation quadratic equation and only utilizes the LF to obtain the results. The algorithm presented here has been tested on 270 buses in Khorasan network and 449 buses in Iran network and has been compared with the CPF.

Keywords—CPF, Static ATC, Khorasan Network, Iran Network, Voltage Stability, DIgSILENT Software

I. INTRODUCTION

Determining the maximum authorized consumption power in a way to satisfy the regarded limitation of the power system operator, is more important for electricity company users than determining the maximum consumption power leading to the system voltage instability. Different methods have been suggested for determining voltage instability or determining voltage collapse point [1-4]. These methods, in specifying voltage collapse point, make use of changes in different parts of Jacobian matrix, such as determinant [4], eigenvalues and eigenvectors or reduced/increased Jacobian matrix [4]. However, since most of the limitation such as loading of the power system elements and bus voltage limitations is practical and empirical and not mathematical, for determining the static ATC, there is no mathematical index for specifying the maximum consumption or transmission power [4]. Although a variety relations have been offered for determining voltage crisis.

In this paper a simple, quick and precise method called Minimum Distance (MD) is introduced for specifying the static ATC, considering the real system limitation. The program written in DIgSILENT Programming Language (DPL) [5], 5kb of size can be performed by all power systems supplied with DIgSILENT software. In the second part of the paper, MD method and algorithm are presented. In the third section, MD method has been performed on Khorasan and Iran networks through DIgSILENT software. It has been tested by the classic load flow method and in the fourth section, the final results of the paper is presented..

II. MD METHOD

Three important limitations have been taken into account in MD method of determining the static ATC:

$$
\begin{aligned}
V_i &\geq V_{min} & i &= 1:n \\
V_i &\leq V_{max} & i &= 1:n \\
L_j &\leq L_{max} & j &= 1:m
\end{aligned}
\tag{1}
$$

in which:

n: no. of buses plus no. of terminals.

m: no. of lines plus no. of transformers, generators and asynchronous motors.

V_i: the ith buses and terminals voltage.

L_j: the ith loading on the lines, transformers, generators and motor asynchronous.

V_{min}: minimum authorized bus or terminal voltage (in this paper assumed 0.95 p.u.)

V_{max}: maximum authorized bus or terminal voltage (in this paper assumed 1.05 p.u.)

L_{max}: maximum authorized loading (in this paper assumed 100%)

Now we can define the distance between the operation point and the mentioned limitation, as an index.

$$
MDV_{min\,i} = K_{min}(V_i - V_{min}) \qquad i = 1:n
\tag{2}
$$

$$
MDV_{max\,i} = K_{max}(V_{max} - V_i) \qquad i = 1:n
\tag{3}
$$

$$
MDL_{max\,j} = L_{max} - L_j \qquad j = 1:m
\tag{4}
$$

$$
\begin{aligned}
MD &= \\
&Min(MDV_{min\,i}, MDV_{max\,i}, MDL_{max\,j}) \ \forall i, j
\end{aligned}
\tag{5}
$$

K_{max} and K_{min} factors have been define for equalizing the voltage and loading and in this paper their amounts have been assumed 1000. Equation (5) is calculated for all buses, terminals, lines, generators, transformers and asynchronous motors and it is shown for a sample network of 9 buses, 3 generators, 3 transformers and 6 lines, in Fig. 1 from the operation point to the boundary.
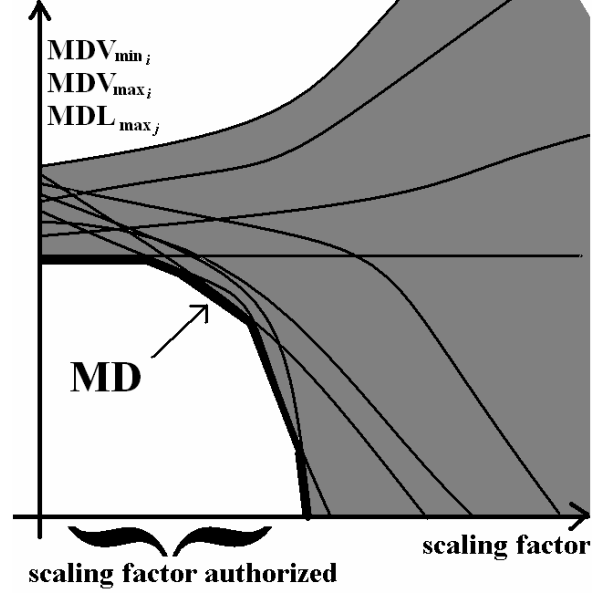

Fig1. The direction of (2) to (5) for a 9 bus system, following the change of operation point on the basic of load scaling factor.

To determine the maximum authorized load scaling factor in such a way that the system obtains at least one of the equation limitations of an element and MD of (5) becomes zero or nearly zero, it is modeled on quadratic equation. To determine the quadratic equation, three operation points should be utilized. These three points are specified in a way that the obtained MDs are not equal, so that we are able to use a degree of approximation of 2 for the direction of MD.

The precise algorithm of MD can be seen in Fig. 4. Following this algorithm, you can write MD program in any languages, but since for the time being, the precise data about Khorasan and also Iran networks are available through DIgSILENT software, MD method has been written on the software in DPL. The

advantages of MD method written in DPL over other methods are in abstract as follows:

1. It only makes use of the LF.

2. It takes into account all the practical and real limitations of the system, such as the dependence of load on voltage.

3. It can be applied on all networks, without requiring any specific training [4].

4. The algorithm presented on the average network of Khorasan including 270 buses and the network of Iran having 449 buses, possesses a quick and clear response.

5. The program written in DPL is applicable to all power system that use DIgSILENT software.

6. MD method can be used as a prerequisite for calculation of the dynamic ATC [4].

III. APPLYING MD TO KHORASAN AND IRAN NETWORKS

Since the information on Khorasan network 2011 (Fig. 2) and Iran network (Fig. 3) were available via DIgSILENT software, the static ATC of all Khorasan buses and some of Iran network buses have been obtained through installing the ATC program written in DPL with MD algorithm on these networks and its amount has been compared with the CPF (performed by the user). Calculation time of MD program has been 7 seconds in Khorasan network and 9 seconds in Iran network. This comparison is made in Table 1. In this analysis, the calculation error has been assumed 1% for load scaling factor. With this precision, on average, only 5 iterations of load flow were enough to get the results. In case the precision decrease, the speed of calculation increase; however, precision of 1% seems acceptable for the load scaling factor.

In Table 1 it is assumed that the load scaling factor is increased through the constant power factor. In this table it can be observed that Tabas bus has got the minimum authorized load scaling factor and next is Chenaran bus. However, in previous analysis [4] based on voltage stability limit to load flow divergence, Chenaran bus has been identified as the most critical one and this fact shows the difference between these two analysis.

A. Determining the static ATC of Khorasan and Iran network in emergency cases

The written program, MD is in fact a subprogram of another main program called CMD, "Network static ATC determination, considering limitations of the operation in emergency case", which calculates the network static ATC via MD subprogram, through disconnecting all the elements of the system one by one including the transformers, generators and lines. This work has been done for all buses Khorasan network and Iran network. Here as an example, the static security of Bardeskan buses has been analyzed in emergency case based on disconnecting the generators (Table 2) and disconnecting the lines (Table 3). In Tables 2 and 3 it is observed that in the worst condition which is the disconnection of Qaenat generator, the maximum load scaling factor is 1.13 and in the normal case (Table 1) this factor is 1.80 which indicates the reduction of the maximum loading considering at least one contingency.

TABLE I.

CALCULATION OF THE MAXIMUM LOAD SCALING FACTOR IN DIFFERENT BUSES OF KHORASAN NETWORK 2011 AND IRAN NETWORK, VIA MD AND CPF. (IN THIS TABLE SCMD IS THE CALCULATED LOAD SCALING FACTOR BY MD)

Network	Bus	CPF		SCMD
		Stable	Unstable	
Khorasan	Nehban	2.90	2.91	2.91
Khorasan	Boj 2	3.85	3.86	3.86

Khorasan	Khalil	2.92	2.93	2.92
Khorasan	Tor Jam	1.78	1.79	1.78
Khorasan	Pardis	1.92	1.93	1.92
Khorasan	Tor her	1.7	1.71	1.70
Khorasan	Kashmar	1.81	1.82	1.81
Khorasan	Ferdows	2.00	2.01	2.00
Khorasan	Tabas	1.59	1.60	1.59
Khorasan	Bardescan	1.79	1.80	1.80
Khorasan	Boj 1	1.69	1.70	1.69
Khorasan	Gochan	2.15	2.16	2.15
Khorasan	Dargaz	2.73	2.74	2.73
Khorasan	Shirvan	2.28	2.29	2.29
Khorasan	Gazi	2.32	2.33	2.33
Khorasan	Jajarm	2.59	2.60	2.60
Iran	Tehran	3.32	3.33	3.32
Iran	Shahrod	3.02	3.03	3.03
Iran	Sardrod	2.45	2.46	2.45
Iran	Behrang	2.8	2.81	2.81
Iran	Bandar ab	2.39	2.40	2.39
Iran	Shahab	3.56	3.57	3.56
Iran	Sepidrod	3.28	3.29	3.28
Iran	Iranshhr	1.80	1.81	1.81

TABLE II.
CALCULATION OF THE MAXIMUM LOAD SCALING FACTOR IN BARDESKAN BUS IN SYSTEM OF KHORASAN NETWORK 2011 WITH THE CMD METHOD AND THE CPF IN EMERGENCY CASE (DISCONNECTING ALL THE GENERATORS ONE BY ONE) (IN THIS TABLE SCMD IS THE LOAD SCALING FACTOR CALCULATED VIA MD METHOD)

Disconnecting Generator	CPF		SCMD
	Stable	Unstable	
Toos	1.39	1.40	1.40
Nyshabour	1.69	1.70	1.69
Shirvan	1.37	1.38	1.38
Mashad	1.76	1.77	1.76
Toos 2	1.32	1.33	1.33
Shariati	1.59	1.60	1.60
Gaen	1.73	1.74	1.73
Qaenat	1.13	1.14	1.13

TABLE III.
CALCULATION OF THE MAXIMUM LOAD SCALING FACTOR IN BARDESKAN BUS IN SYSTEM OF KHORASAN NETWORK 2011 WITH THE CMD METHOD AND THE CPF IN EMERGENCY CASE (DISCONNECTING ALL THE LINES ONE BY ONE) (IN THIS TABLE SCMD IS THE LOAD SCALING FACTOR CALCULATED VIA MD METHOD)

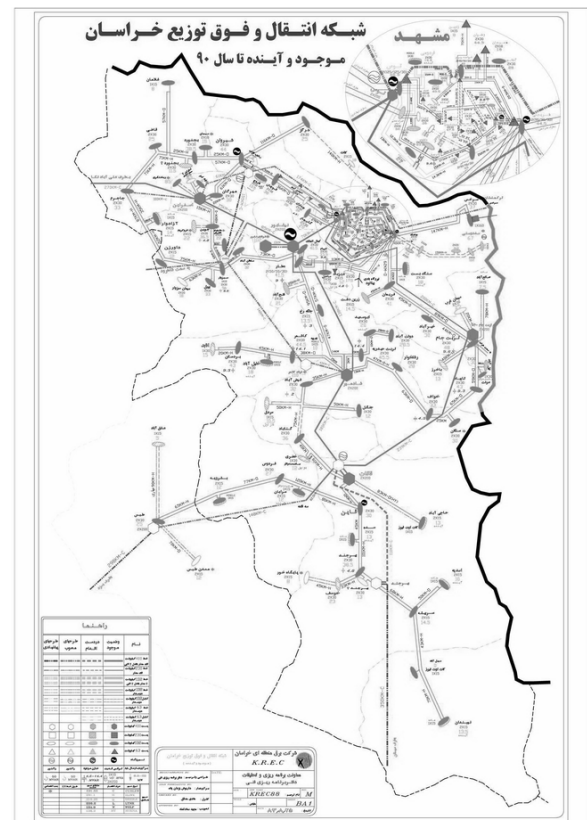| Disconnecting Line	CPF		SCMD
	Stable	Unstable	
Line 1	1.77	1.78	1.77
Line 2	1.71	1.72	1.71
Line 3	1.56	1.57	1.57
Line 4	1.72	1.73	1.72
Line 5	1.68	1.69	1.68
Line 6	1.72	1.73	1.72
Line 7	1.68	1.69	1.68
Line 8	1.73	1.74	1.73
Line 9	1.35	1.36	1.36
Line 10	1.51	1.52	1.52
Line 11	1.66	1.67	1.66
Line 12	1.70	1.71	1.70
Line 13	1.69	1.70	1.69
Line 14	1.67	1.68	1.67
Line 15	1.70	1.71	1.70
Line 16	1.62	1.63	1.62
Line 17	1.74	1.75	1.74

Fig2. Khorasan network 2011 [6]

Fig3. Iran network [7]

IV. CONCLUSION

In this paper an algorithm is introduced holding the title of MD, which can calculate the static ATC, while considering the real and practical limitations of the network, before the network become collapse. By expanding the given limitations, the voltage collapse point of the network can be also obtained. MD algorithm has been tested on the average network of Khorasan (270 bus) and Iran (449 bus) and has had an acceptable speed and precision. The other noticeable point at this method is the presentation of MD algorithm in DPL in such a way that is becomes applicable to all regional electricity networks which use DIgSILENT software.

REFERENCES

[1] P. Kundor, *Power System Stability and Control*, Englewood Cliffs, NJ: Prentice-Hall, 1996.

[2] C. W. Taylor, *Power System Voltage Stability*, McGraw-Hill, 1993.

[3] A. C. Zambroni and de Souza, "Discussion on some voltage collapse indices", *Electric Power System Research,* No. 53, 2000, pp: 53-58.

[4] M. Eidiani and M.H.M. Shanechi, "FAD-ATC, a new method for computing dynamic ATC*", International Journal of Electrical Power & Energy Systems,* Vol. 28, Issue 2 , Feb. 2006, pp: 109-118.

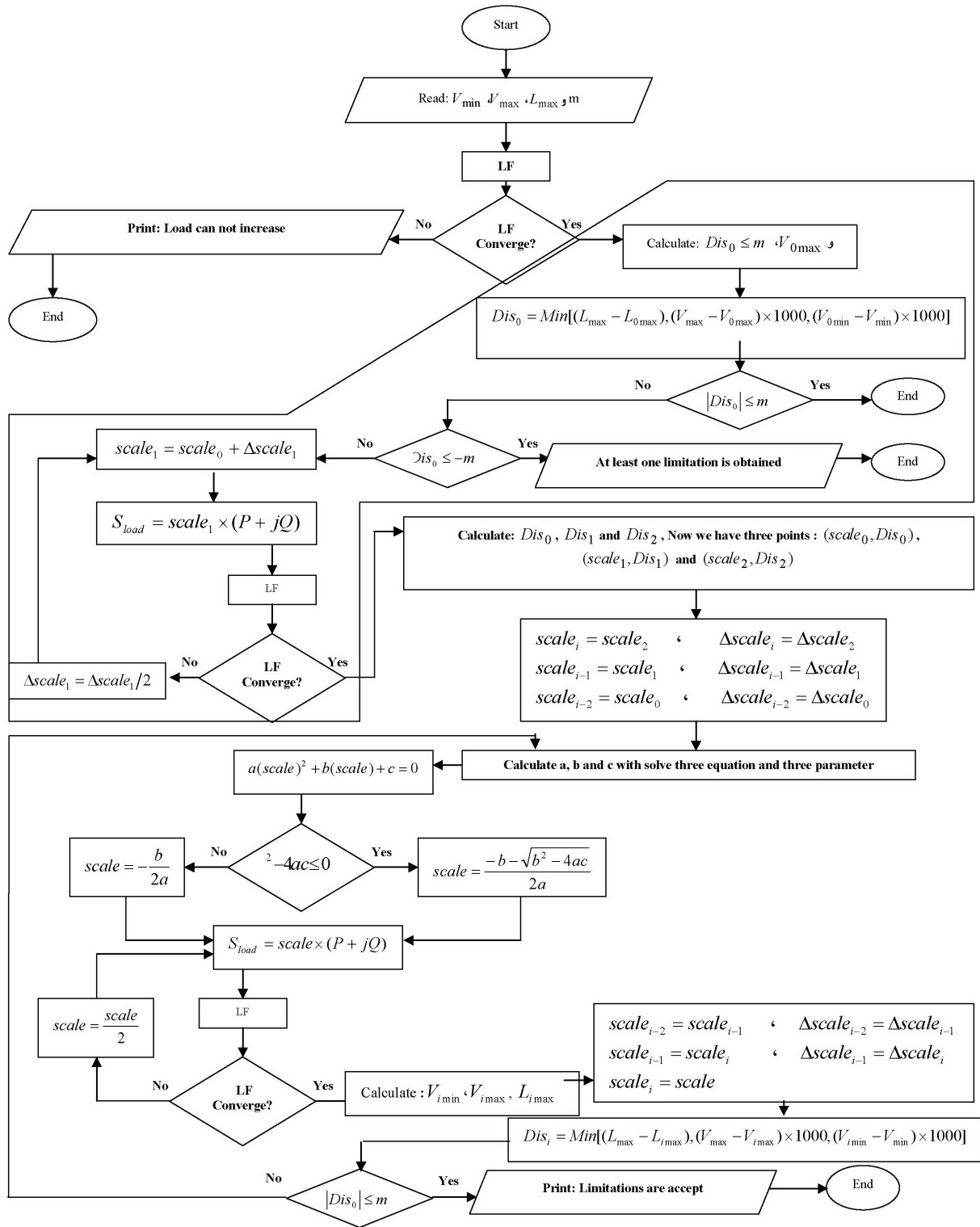[5] www.DIgSILENT.de, narsys.eidiani.com

[6] www.Krec.ir

[7] www.IGMC.ir

Start

Read: $V_{\min}$ 、$V_{\max}$ 、$L_{\max}$ 、m

LF

LF Converge?

No → Print: Load can not increase → End

Yes → Calculate: $Dis_0 \leq m$ 、$V_{0\max}$ 、

$Dis_0 = Min[(L_{\max} - L_{0\max}), (V_{\max} - V_{0\max}) \times 1000, (V_{0\min} - V_{\min}) \times 1000]$

$|Dis_0| \leq m$ No / Yes → End

$Dis_0 \leq -m$ Yes → At least one limitation is obtained → End

No → $scale_1 = scale_0 + \Delta scale_1$

$S_{load} = scale_1 \times (P + jQ)$

LF

LF Converge?

No → $\Delta scale_1 = \Delta scale_1 / 2$

Yes → Calculate: Dis_0 , Dis_1 and Dis_2 , Now we have three points : $(scale_0, Dis_0)$, $(scale_1, Dis_1)$ and $(scale_2, Dis_2)$

$scale_i = scale_2$ ，$\Delta scale_i = \Delta scale_2$
$scale_{i-1} = scale_1$ ，$\Delta scale_{i-1} = \Delta scale_1$
$scale_{i-2} = scale_0$ ，$\Delta scale_{i-2} = \Delta scale_0$

Calculate a, b and c with solve three equation and three parameter

$a(scale)^2 + b(scale) + c = 0$

$^2 - 4ac \leq 0$

No → $scale = -\dfrac{b}{2a}$

Yes → $scale = \dfrac{-b - \sqrt{b^2 - 4ac}}{2a}$

$S_{load} = scale \times (P + jQ)$

LF

LF Converge?

No → $scale = \dfrac{scale}{2}$

Yes → Calculate : $V_{i\min}$ 、$V_{i\max}$, $L_{i\max}$

$scale_{i-2} = scale_{i-1}$ ，$\Delta scale_{i-2} = \Delta scale_{i-1}$
$scale_{i-1} = scale_i$ ，$\Delta scale_{i-1} = \Delta scale_i$
$scale_i = scale$

$Dis_i = Min[(L_{\max} - L_{i\max}), (V_{\max} - V_{i\max}) \times 1000, (V_{i\min} - V_{\min}) \times 1000]$

$|Dis_0| \leq m$ No / Yes → Print: Limitations are accept → End

Fig5. The MD algorithm