Identification of Maximum Loadability in Power System with Line Outages using Chaotic Mutation Immune Evolutionary Programming

Sharifah Azma Syed Mustaffa , Ismail Musirin, and Muhammad Murtadha Othman

***Abstract*— Recently, the sudden rise of demand for electricity leads to the voltage instability in power system which consequently affects the maximum loadability of the system. Therefore, it is crucial to solve the voltage stability problem and keep the voltage profile within the limit. The presence of line outage contingency also affects the voltage stability of the system. This paper proposes a new algorithm namely Chaotic Mutation Immune Evolutionary Programming (CMIEP) for maximum loadability under *N-1* contingency in a transmission system. The formulation of the contingency analysis and the constraints are initially presented. Next, the ranking process was performed based on the pre-developed voltage stability index termed as Fast Voltage Stability Index (*FVSI*) to identify the most critical line outage for the system during *N-1* contingency. IEEE 30-bus Reliability Test System (RTS) was utilized to test the proposed technique. The obtained results show the effectiveness of the proposed optimization technique and successively able to compute maximum loadability of the optimal bus during *N-1* contingency.**

***Index Terms*— Contingency Analysis, Maximum Loadability, Chaotic Mutation**

I. Introduction

VOLTAGE collapse in power system usually initiated by the occurrence of voltage instability that normally associates to very low voltage profile. The system will be heavily loaded and faced voltage instability. Furthermore, the constantly increment in reactive power loading towards its maximum point would lead to a sudden voltage drop consequently inducing the incidence of voltage instability in power system. The limit of security margin in the power system is normally estimated by calculating the difference of reactive power in the base case and the maximum acceptable load. The maximum acceptable load indicates the point before a system starts to develop the instability conditions. Maximum loadability is measured as the reactive power loading close to maximum permissible load and directly affects the voltage stability of the system. Thus, maximum loadability and voltage stability is a crucial factor to be considered during various stages of planning, operation and control of power system in order to refrain from voltage collapse and blackout. Several techniques have been proposed to solve this issue. Differential Evolutionary (DE) technique was used and Voltage Stability Index (L_{mn}) was applied as a tool to identify the weakest bus in the system in [1]. Currently, the used of flexible AC transmission (FACTS) devices technology has been proposed for the improvement of voltage stability in power system [2][3].

Contingency caused by line outages is one of the incidents that lead to failure of electric supply to the utilities. Therefore, contingency analysis technique is a must in order to evaluate various effects of contingencies such as the breakdown of transformers, transmission lines and generators. This will help to plan the remedial control action to maintain power system security and stability. Currently, contingency analysis is done by using the computerized application in the planning management system to indicate to the engineers the situation of the power system network with the presence of unplanned line or equipment outages. In the past few years, many techniques have been developed to encounter contingency problem [4]–[6].

In [7], an algorithm using Newton-Raphson load flow has been developed for contingency analysis with line outages. The contingency selection was performed by calculating the active power performance index (PIP) and reactive power performance index (PIV). This study concluded that with a higher value of PIV, the maximum loadability of the system will decrease. However, the traditional contingency analysis using power flow methods required numerous load flow calculations as Jacobian matrix becomes singular when it approaches its loadability limit [7]. Hence, metaheuristic optimization techniques are widely used in finding the optimal value of maximum loadability of a system [8][9]. In [10],

This manuscript is submitted on 18 January 2018 and accepted on 6th March 2018. This papers explained about identification of maximum loadability in power system using a new technique known as Chaotic Mutation Immune Evolutionary Programming (CMIEP) with line contingencies. This work was supported in part by Universiti Teknologi MARA under the scholarship. This paper is submitted on 13nd March 2017. Accepted on 7th September 2017.

Sharifah Azma Syed Mustaffa is a PhD student in Electrical Engineering at Faculty of Electrical Engineering, Universiti Teknologi MARA (UiTM) 40450, Shah Alam, Selangor. (email: sharifahazma@uniten.edu.my)

Ismail Musirin is a Professor at Faculty of Electrical Engineering, Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor. (email: ismailbm@salam.uitm.edu.my).

Muhammad Murtadha is an Associate Professor at Faculty of Electrical Engineering, Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor. (email: murtadha@salam.uitm.edu.my)

Security Constraint Genetic Algorithm is successfully applied to solve maximum loadability and at the same time to identify the weak buses of different IEEE bus systems.

In this paper, the aim is to find the maximum loadability of the optimal bus in power system taking *FVSI* as the indicator for the voltage stability. The optimal maximum loadability of a load bus under *N-1* contingency is determined using a new proposed algorithm namely Chaotic Mutation Immune Evolutionary Programming (CMIEP). The contingencies are ranked according to their severity. The IEEE 30 Reliability Test System (RTS) is used to test the effectiveness of the techniques. CMIEP is compared to traditional load flow. Results indicate that CMIEP outperformes the traditional load flow in term of computational time. The CMIEP also gives better accuracy in achieving maximum loadability with maximization of *FVSI* value.

II. Problem Formulation

A chaotic based mutation optimization technique, formulated with several constraints, is used to determine the optimal maximum loadability of an optimal bus under scheduled line outage contingency. A line based voltage stability index, *FVSI* developed by I. Musirin *et al.* [11] is used to measure the closeness of the system to voltage collapse. The maximum value of *FVSI* is set at 0.95 where the system tends to become unstable if *FVSI* of the system exceeding this value. The objective function is to maximize the maximum *FVSI* of the system. The objective function can be expressed as equation (1):

$$f = max\left(FVSI_{i,max}\right) \quad for\ \forall i \in nr \qquad (1)$$

Where f is the objective function, $FVSI_{i,max}$ is the maximum *FVSI* of the system and nr is the number of transmission lines.

The *FVSI* formulation was derived from a voltage quadratic equation on a two-bus system and defined by the following equation:

$$FVSI_{ij} = \frac{4Z^2 Q_j}{V_i^2 X} \qquad (2)$$

where Z is line impedance
X is line reactance
Q_j is reactive power at the receiving end
V_i is voltage at the sending end

The maximum system *FVSI* should be maximized to achieve maximum loadability of the corresponding optimal bus under the contingency. In this work, the occurrence of line outage contingency is simulated by removing the respective line from the line data one at a time prior to executing the load flow program. At the same time, the optimal bus location, x_1 and reactive power, x_2 were randomly generated during the contingency event in order to get the maximum loadability, x_{2max} of the optimal selected bus, x_1. The results from the post-outage load flow will be used to compute the *FVSI* values. The highest *FVSI* value from each line outage is recorded and sorted in descending order to rank the severity of each line outage in terms of voltage stability condition. This process is repeated for all the lines in the system. The optimization problem is formulated subjects to the following operational and system constraints.

A. Equality Constraints

The equality constraints of this problem are real and reactive power, given by the balance equations of:

$$P_i = \sum_{j=1}^{N} |V_i||V_j|\left(G_{ij}\cos(\theta_i - \theta_j) + B_{ij}\sin(\theta_i - \theta_j)\right) \qquad (3)$$

$$Q_i = \sum_{j=1}^{N} |V_i||V_j|\left(G_{ij}\sin(\theta_i - \theta_j) - B_{ij}\cos(\theta_i - \theta_j)\right) \qquad (4)$$

$i=1,2,\ \ldots .N$

Where N is the number of buses, Q_i is the reactive power generation at bus i, G_{ij} and B_{ij} are the real part and imaginary part of admittance between bus i and bus j, respectively, V_i and V_j are the voltage magnitude at bus i and bus j respectively, and θ_i and θ_j are the voltage angles at bus i and bus j respectively.

B. Inequality Constraints

The inequality constraints are referring to the value of which the magnitude and condition must be kept within acceptable limits throughout the optimization process. The bus voltage constraint is defined as follows:

$$v_{min} \le v_i \le v_{max} \quad \forall i \in N \qquad (5)$$

Where V_{min} and V_{max} are the lower and the upper bound of bus voltage limit respectively and V_i is the voltage magnitude at bus i for all the N bus. The range of limit is between 0.95 and 1.05.

For stable operation, the range of maximum loadability of optimal bus of the participant line should be within the loadability limit of the load bus as shown below:

$$Q_{i,min} \le Q_i \le Q_{i,max} \quad \forall i \in N \qquad (6)$$

Where $Q_{i,min}$ and $Q_{i,max}$ are the minimum and maximum value of reactive power loadability of a bus, i and $Q_{i,}$ is the optimal maximum loadability. A simplified curve of reactive loading versus *FVSI* of transmission line with maximum loadability range is shown in Fig.1. Exceeding the maximum value, $Q_{i,max}$, the system will enter the unstable region that can lead to voltage collapse.

For optimal location of maximum loadability, the increment of reactive power will happen only in optimal load bus as given in the equation (7):

$$2 \le Location\ Q_{i,} \le N_{Load} \qquad (7)$$

Where N_{Load} is the load bus.

For contingency analysis, the IEEE 30 bus RTS with 41 lines is used in this study. The single line outages are simulated automatically for all the lines in offline mode. Several lines are excluded to avoid islanding issue. Practically, the power plants have the islanding mode enable, which automatically isolate the plant and protecting the plant from external disturbance only during a severe disturbance in the grid such as voltage dip and frequency change. Therefore, the selection for the line is given by:

$$\forall nr \;\wedge nr \;\neq 13,\, 16,\, 34 \tag{8}$$

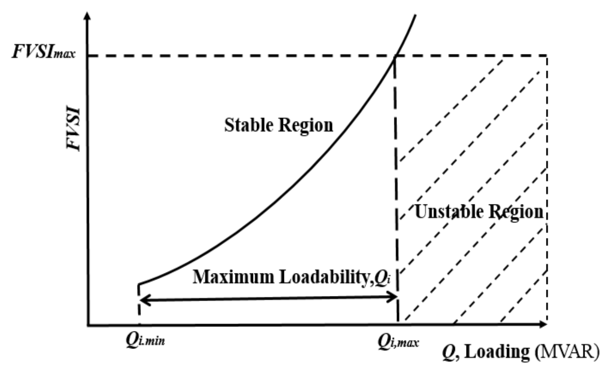

Fig. 1 Maximum Loadability Region

III. Chaotic Mutation Immune Evolutionary Programming (CMIEP)

CMIEP is a new proposed algorithm based on evolutionary programming (EP), artificial immune system (AIS) and chaotic theory to solve for numerical optimization problems [11]. This algorithm is used to find the optimal maximum loadability based on maximization of the objective function during *N-1* contingency for all the transmission lines. CMIEP is unique in term of its chaotic element; applied in the mutation which enables it to successfully solve the optimization problem faster than the traditional EP. CMIEP can be explained by dividing its functions into the following operations: initialization, cloning, fitness 1 calculation, chaotic mutation, fitness 2 calculation, combination and selection. The computational procedures of CMIEP technique are as follows:

a. The initialization of the population P is done using the following equation:

$$x_{i,k} = U\;(L_k, U_k) \tag{9}$$

For i=1,2, 3,…N and k=1,2,3…,M, where L_k and U_k are the lower and upper boundaries of the problem component respectively. While N and M are population size and the problem component respectively, U is the uniform distribution and x_i is an individual of population P.

b. CMIEP cloning is determined by using predefine E which is a clone multiplier. In this process, the each of the individual, x_1, x_2,..x_N in the population P is cloned to produce a set of new individual, $x_{i,clone}$. This creates a new population, P_{clone}. The cloning process is given by the following equation:

$$x_{i,clone} = x_i \times E \tag{10}$$

c. Fitness 1 calculation is performed using equation (2) for P_{new}.

d. In mutation process, the chaotic mapping is used to evolve the population, P_{new} and created the offspring population, $P_{off.}$. The mutation process was implemented based on the following equation:

$$mutation = C_i \times \left(0, \beta\;\left(x_{i,clone}^{max} - x_{i,clone}^{min}\right)\frac{f_{i,clone}}{f_{max}}\right)^2 \tag{9}$$

Where β is the mutation rate, $x_{i,clone}^{max}$ and $x_{i,clone}^{min}$ are the max and minimum value of all individuals in the population, P_{clone}; $f_{i,clone}$ and f_{max} are fitness for i^{th} individual and maximum fitness respectively. The chaotic element of piecewise linear mapping, C is embedded in the mutation to reduce the search steps in order to find the global minima value and to achieve better convergence. The equation of chaotic element, C is given by:

$$C_{n+1} = F(C_n, p) = \begin{cases} \dfrac{C_n}{p}, & 0 \le C_n < p \\ \dfrac{(C_n - p)}{(0.5 - p)}, & p \le C_n < 0.5 \\ \dfrac{(1 - p - C_n)}{0.5 - p}, & 0.5 < C_n < (1 - p) \\ \dfrac{1 - C_n}{p}, & (1 - p) < C_n < 1 \end{cases} \tag{10}$$

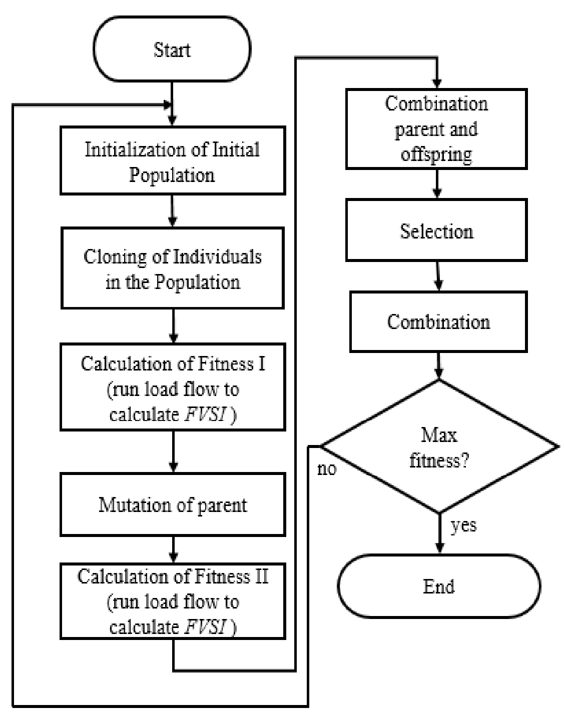

Fig. 2 Flowchart of Proposed CMIEP

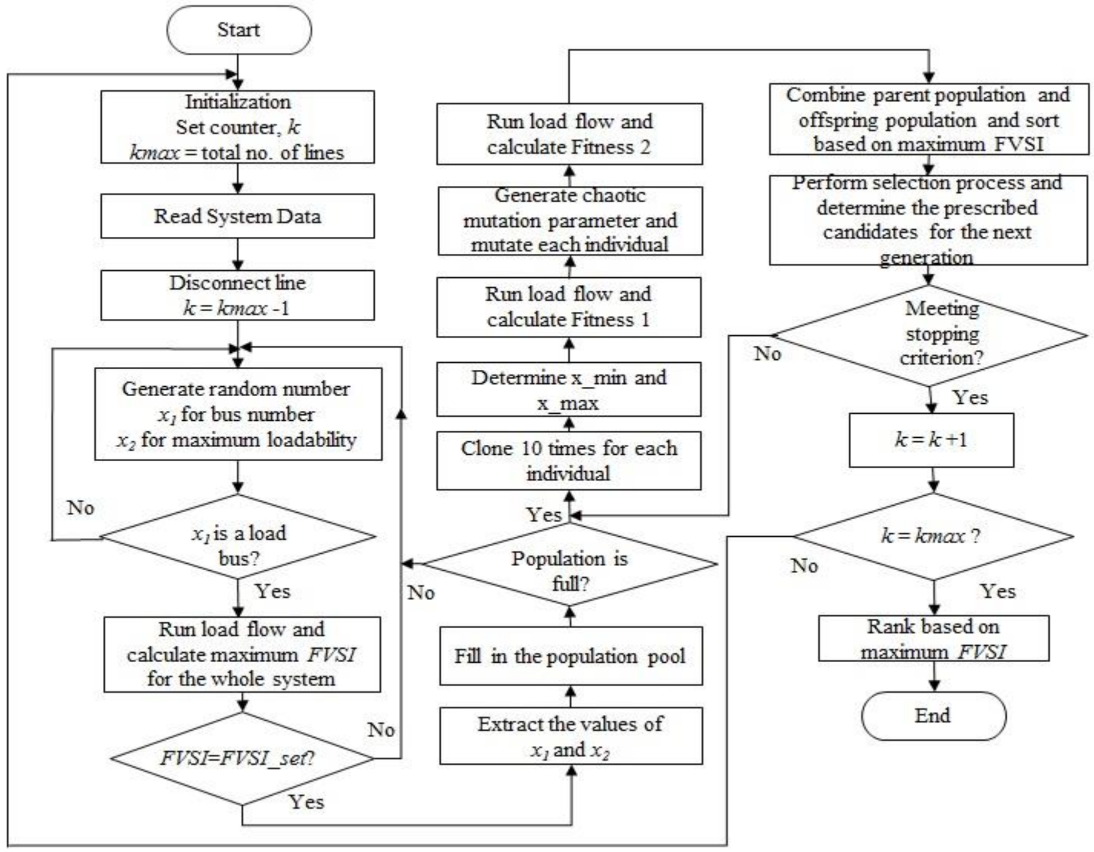

Fig 3 Flowchart of CMIEP technique to determine maximum loadability of optimal bus with maximization of maximum system *FVSI*

Where $C_n \in [0,1]$ is the initial state of the chaotic variable and $p \in [0,0.5]$ is the control parameter that can be set manually by the user. As the essence of chaotic search is finding a better solution in user-defined search space by its ergodicity, the start point does not make great sense. Using *rand* function to generate an initial value for the chaotic map is superior to the carrier method both in its simplicity and robustness [12].

After the mutation process, the individual in P_{off} is given as:

$$x_{i,off} = x_{i,clone} + N[0,mutation] \quad (11)$$

Where *N [0,1]* is the standard normal distribution range between 0 and 1.

e. Fitness 2 calculation is calculated using equation (2) for P_{off}.
f. Combination of the parent population, P_{new} and the offspring population, P_{off}.
g. Selection of new generation population, P_{update}. All individual in P_{update} will be ranked based on best fitness value and a set of fittest individuals are chosen for next generation population.

The general flowchart of proposed CMIEP is shown in Fig. 2, while the detailed CMIEP technique to determine maximum loadability of the optimal bus with maximization of maximum system *FVSI* is shown in Fig.3

The detailed steps of the flowchart in Fig.3 are described as follows:

Step 1: CMIEP initialization.
- a) Set iteration counter t=0 and maximum iteration t_{max}.
- b) Set population size.
- c) Set the constraints.

Step 2: Input line data and bus data.
Step 3: Disconnect a line from the system.
Step 4: Generate bus location, x_1 and loadability, x_2.
Step 5: Update the iteration counter.
Step 6: Run load flow and evaluate the fitness function in equation (2).
Step 7: Extract the selected individual.
Step 8: Fill in the population pool.
Step 9: Clone the individuals.
Step 10: Mutate the individuals using equation (9).
Step 11: Run load flow and evaluate the fitness function in equation (2).
Step 12: Combine the population.
Step 13: Perform selection process.
Step 14: If t reaches t_{max} go to Step 15. Otherwise, go to Step 9.
Step 15: Combine parent and offspring. Sort based on maximum fitness function.

Step 16: Selection process for next generation.
Step 17: Repeat the process until meeting stopping criterion and the best solution is achieved.
Step 18: Repeat the process for all the lines
Step 19: Rank the best solution.

IV. RESULTS AND ANALYSIS

The application of CMIEP techniques has been demonstrated for obtaining the maximum loadability of optimal bus under line contingency. The result for the application of CMIEP is shown in Table 1. Based on the results obtained using developed CMIEP, the most severe line outage occurs during the outage of line 4, given the highest value of *FVSI* which is 0.9498. Comparatively, by using traditional load flow, during the contingency of line 4, the highest *FVSI* was experienced by line 24 connecting bus 19 and bus 20. It is noted that implementation using CMIEP indicate that bus 20 optimally determine, as the bus connected to the line which exhibits the highest *FVSI* value. This implies that the result given by CMIEP agrees with the result using traditional load flow. On the other hand, line 38 ranked last with a *FVSI* value of 0.9335. The maximum loadability of bus 24 is around 110 MVar. Based on the result, the severity of this line outage is not critical compared to others. Furthermore, Bus 20 has been optimally selected the most followed by bus 25 and bus 24 which is 10, 8 and 7 times respectively for maximum loadability calculation. This shows that the lines with bus 20, bus 25 and 24 always tends to become unstable during *N-1* contingency compared to other lines. The maximum loadability and FVSI for the line contingency are displayed in Fig.4. Based on the results, the highest maximum loadability is achieved by bus 28 when line 41 is disconnected with the value of 113.1MVar. When line 40 is disconnected, bus 30 has the least maximum loadability compared to other buses. The value is 34.06 MVar.

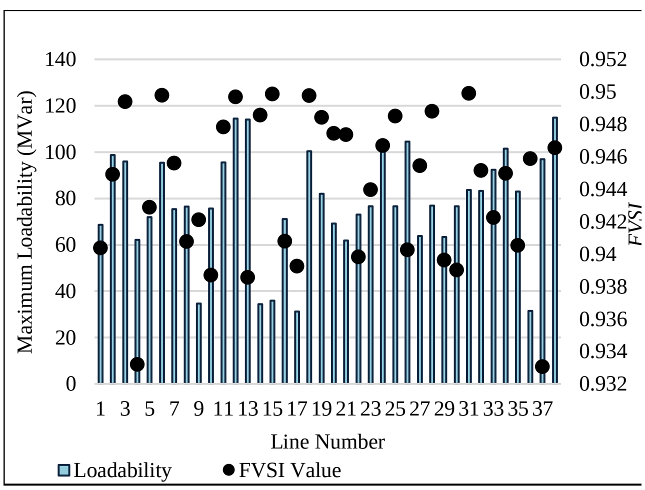

Fig. 4 Maximum loadabillity and *FVSI* for line contingency

Table 1: Comparison of contingency ranking using CMIEP

Rank	CMIEP				Traditional Load Flow	
	Line Outage (no)	Bus, x_1	Maximum loadability, x_2	FVSI	Highest FVSI Location (Line)	From bus-to bus
1	**4***	**20**	**99.02**	**0.9498**	**24**	**19-20**
2	28	24	104.70	0.9497	32	23-24
3	36	14	76.13	0.9494	20	14-15
4	21	20	100.00	0.9493	24	19-20
5	19	20	83.14	0.9491	24	19-20
6	39	20	101.72	0.9489	25	27-20
7	17	24	109.22	0.9489	31	22-24
8	20	20	100.32	0.9488	24	19-20
9	14	24	86.98	0.9488	31	22-24
10	26	16	75.16	0.9485	19	12-16
11	7	25	63.65	0.9485	34	25-26
12	12	25	65.14	0.9483	34	25-26
13	24	25	65.16	0.9480	34	25-26
14	11	25	65.61	0.9479	34	25-26
15	23	27	73.27	0.9478	37	25-27
16	8	24	110.33	0.9475	32	23-24
17	31	20	101.60	0.9474	25	10-20
18	1	20	95.33	0.9466	24	19-20
19	22	25	65.56	0.9465	34	25-26
20	6	25	63.22	0.9465	34	25-26
21	5	20	99.66	0.9458	24	19-20
22	**40**	**30**	**34.06**	**0.9458**	**38**	**27-30**
23	2	27	70.86	0.9456	35	25-27
24	41	28	113.12	0.9449	40	8-28
25	35	23	83.17	0.9435	32	23-24
26	37	20	101.38	0.9434	25	27-20
27	33	24	96.02	0.9425	31	22-24
28	29	27	37.46	0.9422	35	25-27
29	15	23	78.18	0.9419	31	22-24
30	32	14	76.74	0.9413	20	14-15
31	27	24	96.02	0.9408	32	23-24
32	10	25	63.54	0.9404	34	25-26
33	3	25	64.10	0.9394	34	25-26
34	18	18	73.33	0.9385	22	15-18
35	30	27	68.80	0.9376	35	25-27
36	25	27	72.65	0.9365	35	25-27
37	9	20	101.61	0.9354	24	19-20
38	**38***	**24**	**110.59**	**0.9335**	**33**	**23-24**

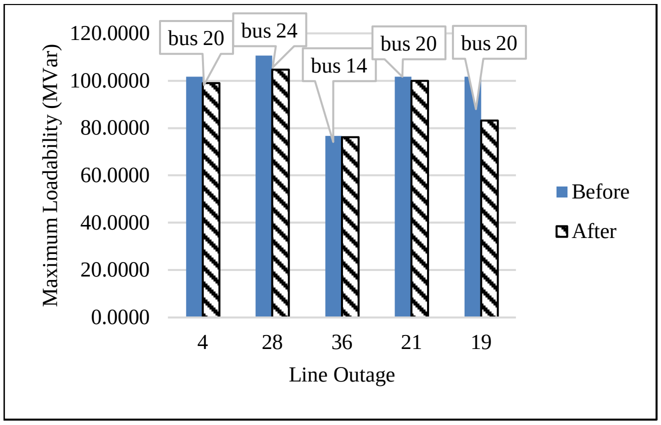

Fig 5 . Maximum Loadability Before and After Contingency

Fig. 5 shows a comparison of the maximum loadability of the optimal bus for the top five ranked before and after the contingency. All the bus experienced the reduction in maximum loadability. The outage at line 19 has caused the highest reduction of loadability in bus 20 with 18.25%. The reduction is very small for bus 14 with 0.65% during the outage of line 36. The most severe case which is the outage of line 4, shows a reduction of only 2.63%.

V. Conclusion

This paper has presented the Chaotic Mutation Immune Evolutionary Programming (CMIEP) for maximum loadability identification under line outage contingency. In this study, the severe line outage contingencies are conducted in accordance with the highest *FVSI* value during a contingency. The index provides information on the maximum loadability of the selected bus during a contingency. A comparative study is conducted with respect to the traditional load flow and the results show a close agreement in terms of the maximum loadability of the selected bus during the outage, in which it can be a useful information in the load variation monitoring process. Therefore, it can be concluded that CMIEP is able to find the optimal value of maximum loadability with maximization of *FVSI*.

Acknowledgment

The authors would like to acknowledge The Institute of Research Management and Innovation (IRMI) UiTM, Shah Alam, Selangor, Malaysia and Ministry of Higher Education (MOHE) for the financial support of this research. This research is supported by MOHE under the Fundamental Research Grant Scheme (FRGS) with project code: 600-RMI/FRGS 5/3 (0102/2016)

References

[1] M. Amroune, A. Bourzami, and T. Bouktir, "Weakest Buses Identification and Ranking in Large Power Transmission Network by Optimal Location of Reactive Power Supports," *TELKOMNIKA Indonesia. Journal Electrical Engineering*, vol. 12, no. 10, pp. 7123–7130, 2014.

[2] G. Deb, K. Chakrabo, and S. Deb, "Voltage Stability Analysis using Reactive Power loading as indicator and its improvement by FACTS Device," in *1st IEEE International Conference on Power Electronics. Intelligent Control and Energy Systems (ICPEICES-2016)*, 2016, pp. 1–5.

[3] D. Kumar, V. Gupta, and R. C. Jha, "Implementation of FACTS Devices for Improvement of Voltage Stability using Evolutionary Algorithm," in *1st IEEE International Conference on Power Electronics. Intelligent Control and Energy Systems (ICPEICES-2016)*, 2016, pp. 1–6.

[4] N. Balu *et al.*, "On-line power system security analysis," *Proceeding IEEE*, vol. 80, no. 2, pp. 262–282, 1992.

[5] Y. Y. Hsu and H. C. Kuo, "Fuzzy-Set Based Contingency Ranking," *IEEE Transaction Power System*, vol. 7, no. 3, pp. 1189–1196, 1992.

[6] I. Musirin and T. K. A. Rahman, "Evolutionary programming based optimal reactive power planning for voltage stability improvement and loss minimization in power system," *International Journal Power Energy System*, vol. 29, no. 1, pp. 1–9, 2009.

[7] S. D. Naik, M. K. Khedkar, and S. S. Bhat, "Effect of line contingency on static voltage stability and maximum loadability in large multi bus power system," *International Journal Electrical Power Energy System*, vol. 67, pp. 448–452, 2015.

[8] S. A. S. Mustaffa, I. Musirin, and M. Murthada, "Load Management for Voltage Stability Control in Multi-Area Power System," in *6th IEEE International Conference on Control System, Computing and Engineering*, 2016, no. November, pp. 25–27.

[9] P. Acharjee, S. Mallick, S. S. Thakur, and S. P. Ghoshal, "Detection of maximum loadability limits and weak buses using Chaotic PSO considering security constraints," *Chaos, Solitons and Fractals*, vol. 44, no. 8, pp. 600–612, 2011.

[10] P. Acharjee, "Identification of maximum loadability limit and weak buses using security constraint genetic algorithm," *International Journal Electrical. Power Energy System*, vol. 36, no. 1, pp. 40–50, 2012.

[11] S. A. S. Mustaffa, I. Musirin, M. M. Othman, and H. Mansor, "Chaotic Mutation Immune Evolutionary Programming for Voltage Security with the Presence of DGPV," *Indonesian Journal Electrical Engineering Computer Science*, vol. 6, no. 3, pp. 721–729, 2017.

[12] T. Xiang, X. Liao, and K. Wong, "An improved particle swarm optimization algorithm combined with piecewise linear chaotic map," *Applied Math. Computing*, vol. 193, no. 1, pp. 231–239, 2007.

Sharifah Azma Syed Mustaffa received her B.Eng degree from Universiti Tenaga Nasional (UNITEN), Malaysia, in 2002 and M.Eng. degree from Universiti Teknologi Malaysia (UTM) Malaysia, in 2006, both in electrical power. She is currently pursuing her Ph.D. degree with the Faculty of Electrical Engineering, Universiti Teknologi MARA (UiTM), Malaysia. Her research interest includes voltage stability, and evolutionary programming.

Prof. Ir. Dr Ismail Musirin obtained Bachelor of Electrical Engineering (Hons) in 1990 from Universiti Teknologi Malaysia, MSc Pulsed Power Technology in 1992 from University of Strathclyde, United Kingdom and PhD in Electrical Engineering from Universiti Teknologi MARA (UiTM), Malaysia in 2005. He is currently a Professor of Power System at the Faculty of Electrical Engineering, UiTM and the Director, Community of Research (CoRe), Advanced Computing and Communication (ACC) at UiTM. He has authored and co-authored 2 books, over 300 papers in international journal indexed conference. He is also an international journal reviewer for IEEE Transactions, Elsevier Science, WSEAS, John Wiley, IET and some other publishers. He has been the organizing chair for International Power Engineering and Optimization Conference (PEOCO) for the past eight years since 2007. He has delivered keynote

speeches at Cambridge University, United Kingdom, Dubai, Korea and Malaysia. His research interest includes artificial intelligence, optimization techniques, power system analysis, renewable energy, distributed generation and power system stability. He is a senior member of International Association of Computer Science and Information Technology (IACSIT), member of Artificial Immune System Society (ARTIST) and member of International Association of Engineers (IAENG).

Muhammad Murtadha Othman received Bachelor of Electrical Engineering (Hons) in 1998 from The Staffordshire University, UK, MSc in Electrical Engineering in 2000 from Universiti Putra Malaysia and PhD in Electrical Engineering in 2006 from Universiti Kebangsaan Malaysia. He is currently a lecturer at The Faculty of Electrical Engineering, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia. He has authored and co-authored more than 100 technical papers published in the international journals, national and international conferences. His research interest includes power system optimization, artificial intelligence application in power system, biological computing techniques, voltage stability studies, available transfer capability and power system reliability. He is also appointed as international journal reviewers.