Journal of Theoretical and Applied Information Technology
31st May 2021. Vol.99. No 10

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

VOLTAGE STABILITY ANALYSIS USING CONTINUATION POWER FLOW UNDER CONTINGENCY

MADHAVI GUDAVALLI[1], HARIKA VEMULAPALLI[2], KUMAR CHERUKUPALLI[3]

[1,2]Assistant Professor, Department of EEE, PVP Siddhartha Institute of Technology, India
[3]Associate Professor, Department of EEE, PVP Siddhartha Institute of Technology, India
[1]gudavalli.madhavi@gmail.com, [2]vemulapalliharika2312@gmail.com, [3]kumarcherukupalli77@gmail.com

ABSTRACT

This paper presents the knowledge of a continuation power flow (CPF) analysis to be used in a voltage stability analysis (VSA) to regulate the power in huge systems. Prominent feature of the continuation power flow is that it remains well-conditioned at and around the critical point. As significance, divergence due to ill conditioning is not encountered at the critical point, even when solitary meticulousness computation is used**.** It begins with a few basic values of the process and leads to a critical stage. The quiescent attribute of this approach is that it ruins fit at the anticipated stage, even though a particular estimation is used. In this paper system voltage, active power losses, reactive power losses and voltage stability are analyzed using a continuation power flow algorithm with and without contingency under load changing condition.

Keywords: *Continuation Power Flow, Contingency, Corrector, Critical Point, Predictor, Stability Index, L- Index, Jacobian, Tangent Vector*

1. INTRODUCTION

As power systems turn out to be further multifaceted and profoundly loaded, voltage stability is becoming an incredibly thoughtful issue. Voltage issues became a major worry during the preparation and maintenance of electricity systems owing to the bulk number of severe letdowns assumed to be triggered by this phenomenon. On that account it is important to evolve tools for VSA in today's electricity management systems (EMS) [1, 2].

Undeniably, a number of researchers have suggested voltage stability indices focused on basic forms of power flow analysis [3-7]. A specific challenge faced in those analyses is that the Newton-Raphson Jacobian load flow becomes divergent at a steady state stability limit (SL). In fact, this SL also referred to as the critical point (CP), which is interpreted as the point where the Jacobian flow of power is divergent. As a result, efforts at power flow solutions close to the CP are susceptible to deviation and inaccuracy [8, 9].

General theory associated with the continuous flow of electricity is uncomplicated. It incorporates a predictor-corrector pattern for estimate a key resultant path for a set of load flow equations that could be reconstituted that contain a load constraint [10-12]. As presented in Figure 1, it begins with a familiar resolution analogous to an altered load parameter value [13].This calculation is then amended by the resources of the alike Newton-Raphson method used for traditional power flow [14]. The confined parameterization described above affords a resource of describing individual point along the solution lane and shows a fundamental part in eluding the divergence of the Jacobian.

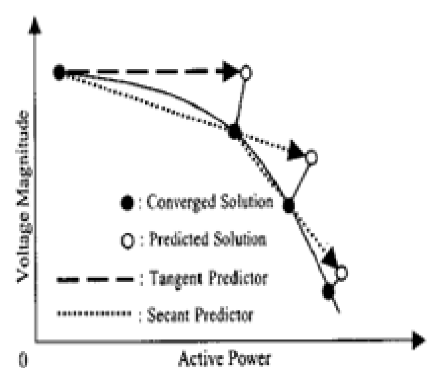

Figure 1: The sketch of the continuation power flow [13]

Journal of Theoretical and Applied Information Technology
31st May 2021. Vol.99. No 10

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

The divergence in the Jacobian can be resisted by faintly rearranging the load flow equations and implementing a narrowly considered follow-up method. During the consequential, continuous flow of electricity, the modified mathematical model ruins well-conditioned, subsequently the deviation and inaccuracy due to the special Jacobian are not encountered.

In the previous research studies, it is focused only on continuation power flow with load change under normal conditions without considering contingency and stability index. In the proposed research paper it is focused on how the voltage stability, active power loss, reactive power loss, voltage magnitude, voltage angle, L-index varies with respect to load changes for different test systems under normal condition and contingency condition (i.e. when one or more lines are removed) using continuation power flow method. Based on the L-index and stability index, the line to be removed is selected for creating the contingency. For the considered IEEE test systems, single and multiple contingency cases for various load changes are investigated.

2. Mathematical formulation

Intending to relate a locally parameterized adopt practice to the load flow problem, a load constraint is essentially introduced with in the equalizations. Although these could have been achieved in several ways, only a basic illustration adopting a constant load model will be computed at this stage.

Initially adopt λ represent the load constraint in order that $0 \le \lambda \le \lambda_{critical}$ Where $\lambda = 0$ relates to the base load and $\lambda = \lambda_{critical}$ relates to the critical load. We wish to integrate λ amongst to

$$0 = P_{Geni} - P_{Loadi} - P_{Transi} \quad (1)$$

$$P_{Transi} = \sum_{k=1}^{n} V_j V_k y_{jk} \cos(\delta_j - \delta_k - v_{jk}) \quad (2)$$

$$0 = Q_{Geni} - Q_{Loadi} - Q_{Transi} \quad (3)$$

$$Q_{Transi} = \sum_{k=1}^{n} V_j V_k y_{jk} \sin(\delta_j - \delta_k - v_{jk}) \quad (4)$$

For each bus i of an n bus system, where the subscripts *Load, Gen*, and *Trans* indicate bus burden, produced power and transmitted correspondingly. Then voltages at buses j and k are $V_j \angle \delta_j$ and $V_k \angle \delta_k$ correspondingly and $y_{jk} \angle v_j$ is the $(j,k)^{th}$ constituent of Y_{BUS}.

In order to pretend a burden transition, the terms P_{Loadi} and Q_{Loadi} must be changed. This can be achieved by splitting every single term into halves. One part refers to the original burden on bus i and the other part reflects a load shift induced by a variation in the load constraint. Consequently,

$$P_{Loadi} = P_{Loadi0} + \lambda(K_{Li} S_{\Delta base} \cos\psi_i) \quad (5)$$

$$Q_{Loadi} = Q_{Loadi0} + \lambda(K_{Li} S_{\Delta base} \sin\psi_i) \quad (6)$$

However the following characterizations are made;

$\boldsymbol{P_{Loadi0}}$, $\boldsymbol{Q_{Loadi0}}$ – foremost burden at bus i, watt-full and watt-less respectively.

$\boldsymbol{K_{Li}}$ - measurement to entitle the proportion of burden variation at bus i as λ deviations.

$\boldsymbol{\Psi_i}$ - power factor angle of burden variation at bus i.

$\boldsymbol{S_{\Delta base}}$ - a specified measure of complex power which is preferred to afford an applicable scaling of λ.

In accumulation, the true power generation term can modified to

$$P_{Geni} = P_{Geni0}(1 + \lambda K_{Geni}) \quad (7)$$

Where P_{Geni} is the watt-full generation at bus i in the base case and K_{Geni} is a constant used to specify the rate of change in generation as λ varies.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

If these new expressions are substituted into the power flow equations, the result is

$$0 = P_{Gnio}(1+\lambda K_{Gni}) - P_{Loadi0} - \lambda(K_{Li}S_{\Delta base}Cos\psi_i) - P_{Ti} \quad (8)$$

$$0 = Q_{Gnio} - Q_{LoadiO} - \lambda(K_{Loadi}S_{\Delta base}Cos\psi_i) - Q_{Ti} \quad (9)$$

The values of K_{Li}, K_{Gi}, and ψ_i can be distinctively quantified for all the buses in the network. This permits an explicit discrepancy of burden and electric power as λ changes.

3.THE APPLICATION OF A CONTINUATION ALGORITHM

In the former conversation, the load flow equations for the specific bus j have been reframed to include the burden constraint λ. The subsequent stage is to relate a continuation algorithm to the reframed load flow equation. If F_t is used to signify the whole set of equations, it can be articulated as a problem.

$$F_t(\delta, V, \lambda) = 0, 0 \leq \lambda \leq \lambda_{critical} \quad (10)$$

Where δ represents the vector of bus potential angles and V represents the vector of bus potential magnitudes. As stated, the fundamental situation solution $(\delta_o, V_o, \lambda_o)$ is known via a conventional load flow and the answer path is being pursued during the series of λ variations. In general, the dimensions of F_t will $2n_1 + n_2$, where n_1 and n_2 are the number of *P-Q* and *P-V* buses respectively.

To resolve the difficulty, the continuation algorithm initiates with a recognized resolution and uses the predictor-corrector pattern to estimate the successive resolutions at dissimilar load stages. Even though the corrector is not anything other than a marginally reformed Newton-Raphson load flow, here predictor is precise superior to the whole thing established in the traditional load flow and justifies the thoughtfulness.

3.1 Predicting the Next Solution

If a customary resolution have been found (λ= 0), an estimate of the succeeding resolution can be accomplished by fascinating an adequate proportions step in the direction of tangent to the resolution path. Therefore, the notable job in the predictor method is to estimate the tangent vector. This tangent measure is taken from the derivative of the load flow equations on both sides.

$$d[F(\underline{\delta}, \underline{V}, \lambda)] = F_{\underline{\delta}}\, d\underline{\delta} + F_{\underline{V}}\, d\underline{V} + F_\lambda\, d\lambda = \underline{0} \quad (11)$$

Factorizing

$$\begin{vmatrix} F_\delta & F_V & F_\lambda \end{vmatrix} \begin{vmatrix} d\underline{\delta} \\ d\underline{V} \\ d\lambda \end{vmatrix} = \underline{0} \quad (12)$$

There is a matrix of partial derivatives multiplied with a vector of differentials on the left side of this equation. The earlier one is the standard Jacobian load flow amplified by one column (F_λ), although the advanced one is the tangent vector being investigated. There is, however, a substantial obstacle to be resolved formerly by a distinctive resolution can be originated for the tangent vector. The problem ascends from the fact that one supplementary unfamiliar was introduced when λ was incorporated into the load flow equations, nevertheless the quantity was not specified.

This problematic condition can be resolved by electing a non-zero magnitude (say one) for individual of the constituents belongs to the tangent vector. In other words, if ***t*** is used to signify the tangent vector;

$$\underline{t} = \begin{vmatrix} d\underline{\delta} \\ d\underline{V} \\ d\lambda \end{vmatrix}, \quad t_k = \pm 1 \quad (13)$$

This result in

$$\begin{vmatrix} \underline{F_\delta} & \underline{F_V} & F_\lambda \\ & \underline{e}_k & \end{vmatrix} \begin{vmatrix} \underline{t} \end{vmatrix} = \begin{vmatrix} \underline{0} \\ \pm 1 \end{vmatrix} \quad (14)$$

Where e_k is an aptly dimensioned row vector, with all components equivalent to zero except kth value which is equals to one. If the index 'k' is selected aptly, permitting $t_k = \pm 1$ accomplishes a non-zero custom on the tangent vector and assertions that the amplified Jacobian will be non-divergent at the grave point. Whether +1 or -1 is used can be governed by what resources the k^{th} state variable is altering as the resolution path is being drawn. If it is cumulating a +1 ought to be used and if it is diminishing a-1 ought to be used. To categorize further about the state variables, refer to [15].

Just the once the tangent vector has been established by resolving, the estimate can be prepared by means of subsequent equivalent conditions.

$$\begin{vmatrix} \delta^* \\ V^* \\ \lambda^* \end{vmatrix} = \begin{vmatrix} \delta \\ V \\ \lambda \end{vmatrix} + \sigma \begin{vmatrix} d\,\delta \\ d\,V \\ d\,\lambda \end{vmatrix} \tag{15}$$

Where "*" implies the expected resolution for a consequent value of λ (loading) besides σ is a scalar that entitles the step dimension. The step dimension ought to be picked out so that the expected resolution is constrained by the convergence of the corrector even though a fixed magnitude of σ can be used throughout the continuation practice [16, 17].

3.2 Parameterization and the Corrector

After the estimate has been finished, a technique is mandatory to precise the estimated resolution. In fact, the finest technique to represent this corrector is to encompass the parameterization that is crucial to the operation.

Every single sequel practice ought to be an explicit parameterization arrangement. The parameterization compromises a scheme for outlining every single resolution in conjunction with the path to be identified. The system used in this paper is indicated as the local parameterization.

In the local parameterization, the most primitive set of equalities is amplified by equality that standardizes the assessment of every individual of the state variables. The reframed load flow equalities entailed the parameters such as determining the size of the bus potential, the angle of the bus potential, or the constraint of the burden. This can be articulated in the equation form as:

Let

$$\underline{x} = \begin{vmatrix} \delta \\ V \\ \lambda \end{vmatrix}, \quad \underline{x} \in R^{2n_1+n_2+1} \tag{16}$$

and let $x_k = \eta$

Where η is an apt value for the k^{th} component of x. then the renewed set of equations would be

$$\begin{vmatrix} F(\underline{x}) \\ x_k - \eta \end{vmatrix} = |\underline{0}| \tag{17}$$

Now, as soon as the prerequisite index k and value of η are designated, a slightly reformed N-R technique can be used to resolve the set of equalities. This offers the corrector prerequisite to alter the intended resolution contained in the aforementioned segment.

In fact, the index k used in the corrector is the indistinguishable to that implemented in the forecaster, and η is equivalent to x_k*, the foreseen value of x_k. The state variable x_k is then termed as the continuation parameter. A non-zero differential shift is made in the predictor ($dx_k = t_k = \pm 1$) and its value is well-defined in the corrector so that the values of other state variables can be initiated.

3.3. Choosing the critical point

There are plentiful techniques to elucidate in what manner the continuation constraint to be preferred. Mathematically, it resembles to the state variable that has the leading tangent vector. In other words this will lead to the state variable that ought to be the uppermost rate of improvement adjoining the resolution. The burden constraint λ is conceivably the preeminent optimal when initiated from the fundamental resolution. This is primarily accurate if the elementary case is not categorized by ordinary or light loading.

During such circumstances, the potential magnitudes and angles endure equitably stable during the change of burden. Though subsequently the load has been amplified by a numerous continuation steps and the resolution direction attains the grave stage, the potential magnitudes and angles are estimated to go through foremost deviations. It would be a deprived choice of continuation parameter at this point, since it can merely modified by a slight quantity associated to other state variables. For

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

this persistence, the selection of the continuation parameter ought to be re-framed at each stage. If the selection has been prepared for the initial step, a good way to follow the subsequent steps is to make use of it.

$$x_k : |t_k| = \max\{ |t_1|, |t_2|, \ldots\ldots |t_m| \} \qquad (18)$$

Wherever t is the tangent vector with a dimension $m=2n_1 + n_2 + 1$ and the index k narrates the constituent of the tangent vector. As soon as the continuation parameter is picked, the sign of its corresponding tangent constituent ought to be renowned so that the suitable value of +1 or -1 can be assigned to t_k in the subsequent tangent vector calculation.

3.4 Sensing the critical point

The ultimate step in this is to realize whether the grave point has been passed or not. This can be acknowledged as soon as we preserve in observance that grave point is nothing but the loading reaches its boundary condition and initiate to diminish. As a consequence the tangent associated to λ is nullified at the CP and negative further than the CP.

4. Voltage Stability Index- L

The study of voltage stability comprises the deduction of an index identified as a voltage failure contiguity indicator. This index is a predictable quantity of the contiguity of the system to the failure of the voltage [18]. Numerous methodologies are used to consider the contiguity voltage failure forecaster. The L-index scheme suggested in Kessel and Glavitsch is one of those methods. It is established on the learning of the load flow. Its assessment ranges from 0 (no loading) to 1 (voltage failure). The bus with the highest value of the L-index

$$I_{bus} = Y_{bus} . V_{bus} \qquad (19)$$

By separate out the load controlled buses (PQ) from the voltage controlled buses (PV),

Directly above Equivalence can arrange as

$$\begin{bmatrix} I_{Gen} \\ I_{Load} \end{bmatrix} = \begin{bmatrix} Y_{GenGen} & Y_{GenLoad} \\ Y_{LoadGen} & Y_{LoadLoad} \end{bmatrix} \begin{bmatrix} V_{Gen} \\ V_{Load} \end{bmatrix} \qquad (20)$$

Where I_{Gen}, I_{Load} and V_{Gen}, V_{Load} represents currents and voltages at the generator buses and load buses respectively.

Rearranging the above equation we get:

$$\begin{bmatrix} V_{Load} \\ I_{Gen} \end{bmatrix} = \begin{bmatrix} Z_{LoadLoad} & F_{LoadGen} \\ K_{GenLoad} & Y_{GenGen} \end{bmatrix} \begin{bmatrix} I_{Load} \\ V_{Gen} \end{bmatrix} \qquad (21)$$

$$F_{LoadGen} = -[Y_{LoadLoad}]^{-1}[Y_{LoadGen}] \qquad (22)$$

The L-index of the j^{th} node is given by the expression

$$L_j = \left| 1 - \sum_{i=1}^{N_g} F_{ji} \frac{V_i}{V_j} \angle(\theta_{ji} + \delta_i - \delta_j) \right| \qquad (23)$$

The stability index is given by minimum value of jacobian.

$$L_j = \left| 1 - \sum_{i=1}^{N_g} F_{ji} \frac{V_i}{V_j} \angle(\theta_{ji} + \delta_i - \delta_j) \right| \qquad (24)$$

5. Results and Disussions

In this paper CPF is performed on IEEE 30 and IEEE 75 bus systems.The proposed algorithm is implemented by using MATLAB-R2013a in the operating systems of windows 8 on an Intel core i5-3.20 GHZ personal computer.

5.1. Test system 1:

In this test case IEEE-30 bus system is considered as the input case and the voltage magnitude, voltage angle are observed at bus -30. The voltage magnitude and angle are going to be changed with the change in load (λ). Up to the knee point the value of λ increases after that it decreases.

Table 1: The Change in Voltage Magnitude, Voltage Angle, Maximum L-Index, L-Index, Stability Index, Active and Reactive Power Losses With Change in The Load without Contingency at Bus-30.

Without contingency							
Change in load (λ)	Voltage magnitude	Voltage angle	Maximum L-index	L-index	Stability Index	Active power loss	Reactive power loss
0.0015	0.9864	-0.2055	0.1456	0.1456	0.0518	0.0533	-0.3608
0.0045	0.9871	-0.2198	0.1488	0.1488	0.0517	0.0558	-0.3503
0.0090	0.9883	-0.2411	0.1552	0.1552	0.0516	0.0610	-0.3280
0.0150	0.9900	-0.2696	0.1650	0.1650	0.0514	0.0696	-0.2915
0.0225	0.9924	-0.3053	0.1784	0.1784	0.0511	0.0823	-0.2372
0.0285	0.9949	-0.3414	0.1955	0.1955	0.0507	0.1002	-0.1602
0.0330	0.9974	-0.3781	0.2134	0.2134	0.0503	0.1206	-0.0718
0.0360	0.9999	-0.4154	0.2319	0.2319	0.0500	0.1437	0.0283
0.0375	1.0026	-0.4531	0.2510	0.2510	0.0496	0.1694	0.1404
0.0375	1.0053	-0.4914	0.2707	0.2707	0.0492	0.1980	0.2651
0.0360	1.0082	-0.5302	0.2908	0.2908	0.0488	0.2295	0.4026
0.0330	1.0112	-0.5696	0.3114	0.3114	0.0484	0.2641	0.5537
0.0285	1.0143	-0.6095	0.3370	0.3323	0.0480	0.3020	0.7186
0.0225	1.0175	-0.6500	0.3663	0.3536	0.0476	0.3432	0.8979
0.0150	1.0209	-0.6911	0.3971	0.3752	0.0472	0.3880	1.0922
0.0060	1.0245	-0.7328	0.4293	0.3972	0.0468	0.4365	1.3021
0.0045	1.0284	-0.7750	0.4630	0.4194	0.0464	0.4889	1.5282

Table 2: The Change in Voltage Magnitude, Voltage Angle, Maximum L-Index, L-Index, Stability Index, Active and Reactive Power Losses With Change in the Load When Line Connected between Buses 27-29 is Removed.

With contingency of line 27-29							
Change in load (λ)	Voltage magnitude	Voltage angle	Maximum L-index	L-index	Stability Index	Active power loss	Reactive power loss
0.0015	0.9510	-0.2428	0.2178	0.2012	0.0496	0.0572	-0.3521
0.0045	0.9513	-0.2599	0.2231	0.2056	0.0495	0.0599	-0.3411
0.0090	0.9519	-0.2856	0.2338	0.2146	0.0493	0.0656	-0.3179
0.0150	0.9531	-0.3200	0.2502	0.2283	0.0491	0.0748	-0.2800
0.0225	0.9550	-0.3631	0.2725	0.2470	0.0488	0.0885	-0.2236
0.0285	0.9565	-0.4081	0.3010	0.2708	0.0484	0.1078	-0.1434
0.0330	0.9576	-0.4549	0.3330	0.2971	0.0479	0.1299	-0.0511
0.0360	0.9584	-0.5037	0.3684	0.3258	0.0475	0.1552	0.0540
0.0375	0.9590	-0.5544	0.4072	0.3567	0.0470	0.1837	0.1725
0.0375	0.9593	-0.6072	0.4491	0.3898	0.0466	0.2156	0.3050
0.0360	0.9595	-0.6621	0.4942	0.4249	0.0461	0.2512	0.4522
0.0330	0.9597	-0.7191	0.5425	0.4621	0.0457	0.2908	0.6148
0.0285	0.9598	-0.7783	0.5937	0.5013	0.0452	0.3345	0.7937
0.0225	0.9600	-0.8399	0.6479	0.5425	0.0448	0.3826	0.9899
0.0150	0.9604	-0.9038	0.7050	0.5856	0.0445	0.4356	1.2042
0.0060	0.9612	-0.9703	0.7647	0.6305	0.0441	0.4938	1.4379
0.0045	0.9623	-1.0393	0.8269	0.6771	0.0439	0.5575	1.6922

Table.1 and 2 gives the change in voltage magnitude, voltage angle, stability index, maximum L-index, L-index, active and reactive power losses with change in the load without and with contingency respectively. All the values specified are in per unit. The variations of voltage magnitude, voltage angles, maximum L-index, L-index, stability index, active and reactive power losses are described by Figure 2 to 8.

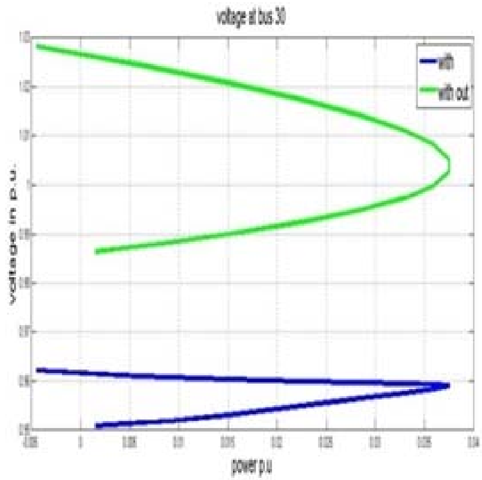

Figure 2: Voltage Magnitude at Bus 30 as Regards to Change in Load With and Without Contingency

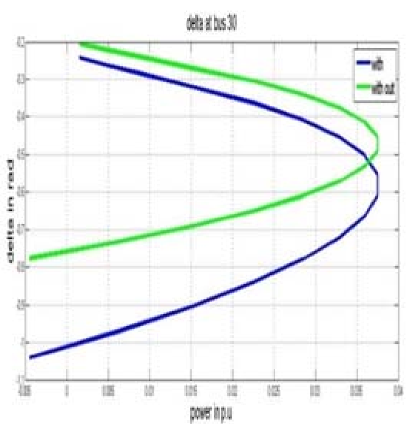

Figure 3: Voltage Angle at Bus 30 as Regards to Change in Load With and Without Contingency

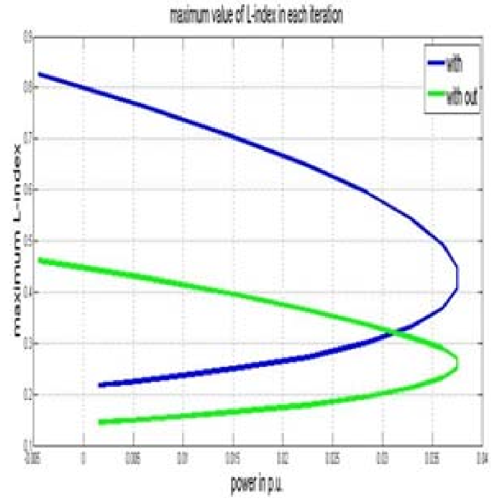

Figure 4: Maximum Value of L-Index as Regards to Change in Load With and Without Contingency

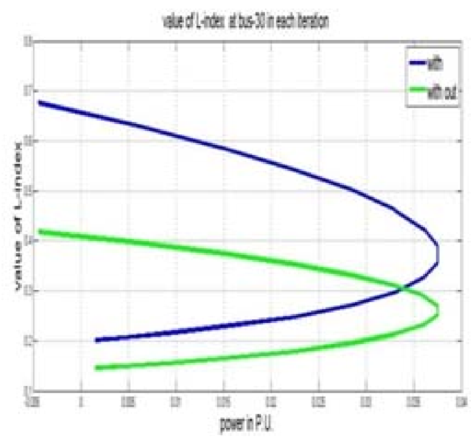

Figure 5: Value of L-Index at Bus 30 as Regards to Change in Load With and Without Contingency

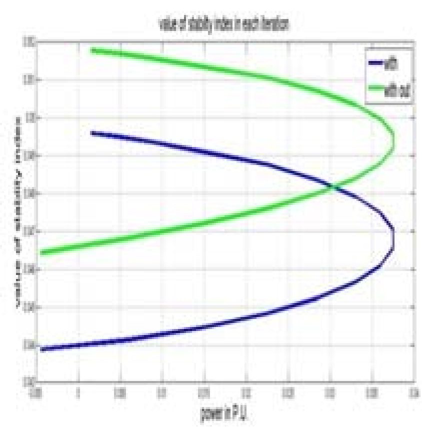

Figure 6: Value of Stability Index Regards to Change in Load With and Without Contingency

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

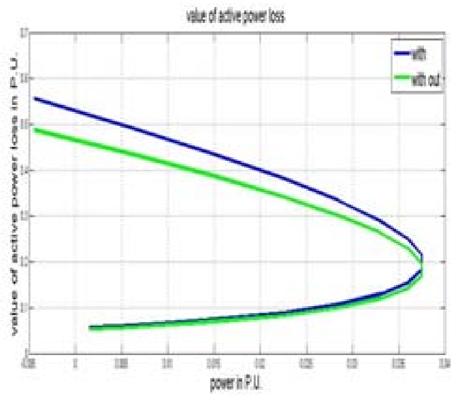

Figure 7: Value of Active Power Loss Regards to Change in Load With and Without Contingency

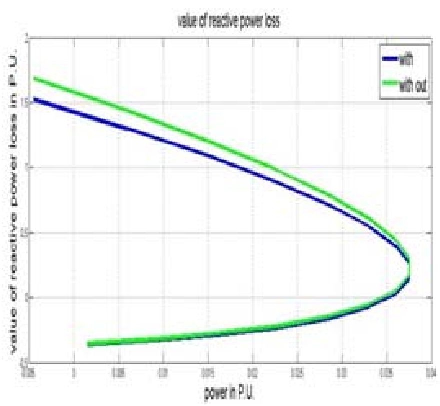

Figure 8: Value of Reactive Power Loss With Regards to Change in Load With and Without Contingency

By observing the above results we can conclude that due to the step change in the load parameter there will be variation in the potential magnitude, potential angles and watt-full and watt-less power losses. When contingency is created by removing the line connected between buses 27-29 there is increase in the watt-full and watt-less power losses and stability of the system is reduced.

5.2 Test case-2

In this test case Practical Indian 75 bus test system as taken as input. This practical test system represents uttarpradesh-75 bus system.

The voltage magnitude, voltage angle are observed at bus -75. The voltage magnitude and angle are going to be changed with the change in load (λ). Up to the knee point the value of *λ* increases after that it decreases. The variations of voltage magnitude, voltage angles, maximum L-index, L-index, stability index, active and reactive power losses are described by Figure 9 to 15.Table.3 and 4 gives the change in voltage magnitude, voltage angle, stability index, maximum L-index, L-index, active and reactive power losses with change in the load without and with contingency respectively.

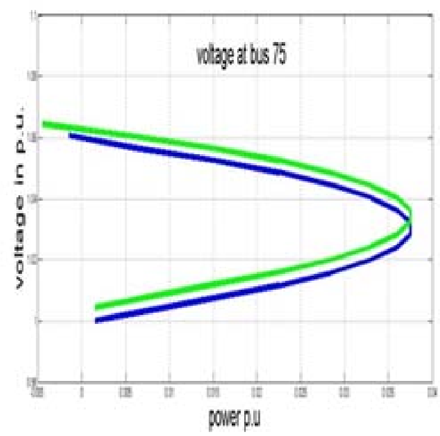

Figure 9: Voltage Magnitude at Bus 75 as Regards to Change in Load With and Without Contingency

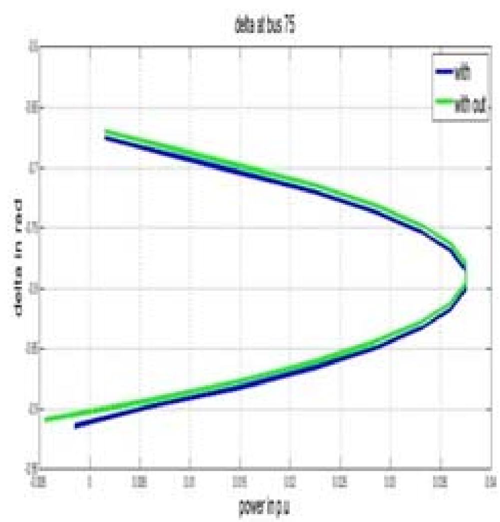

Figure 10: Voltage Angle at Bus 75 as Regards to Change in Load With and Without Contingency

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

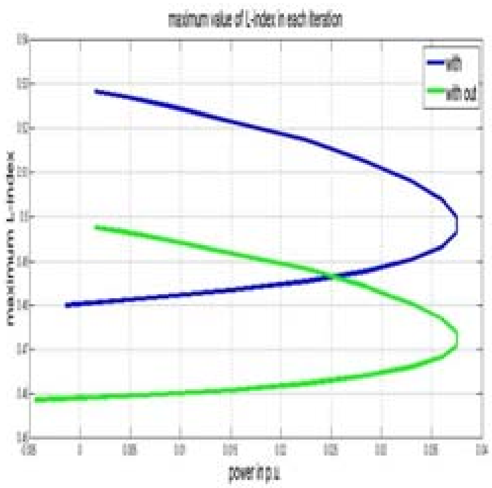

Figure 11: Maximum Value of L-Index as Regards to Change in Load With and Without Contingency

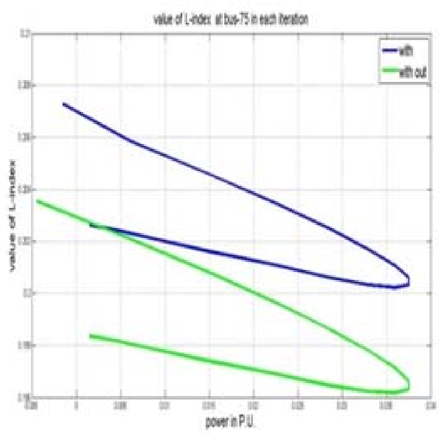

Figure 12: Value of L-Index at Bus 75 as Regards to Change in Load With and Without Contingency

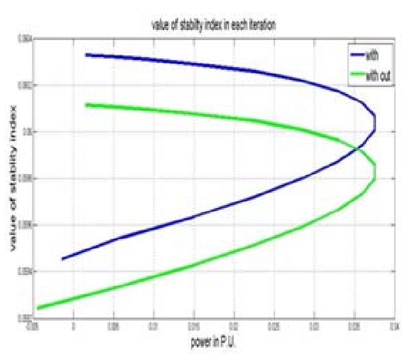

Figure 13: Value of Stability Index as Regards to Change in Load With and Without Contingency

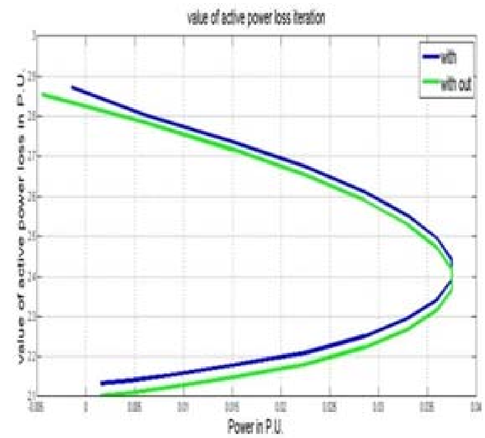

Figure 14: Value of Active Power Loss as Regards to Change in Load With and Without Contingency

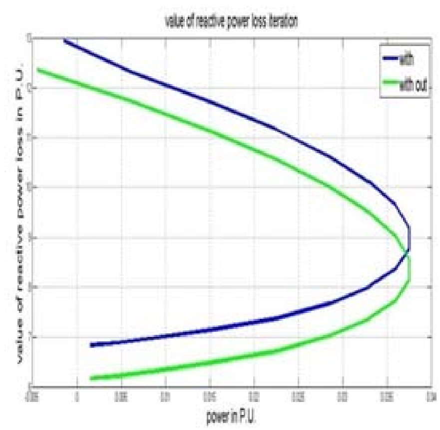

Figure 15: Value of Re Active Power Loss as Regards to Change in Load With and Without Contingency

By observing the results we can conclude that due to the step change in the load parameter there will be change in the potential magnitude, potential angles watt-full and watt-less power losses. When multiple contingency is created by removing the line connected between 39-31, 21-65, 18-71 there is increase in the watt-full and watt-less power losses and stability of the system is slightly reduced compared to the base case.

Table 3: The Change in Voltage Magnitude, Voltage Angle, Maximum L-Index, L-Index, Stability Index, Active and Reactive Power Losses With Change in The Load Without Contingency at Bus-75.

Without contingency							
Change in load (λ)	**Voltage magnitude**	**Voltage angle**	**Maximum L-index**	**L-index**	**Stability Index**	**Active power loss**	**Reactive power loss**
0.0015	1.0044	-0.6697	0.4976	0.1983	0.0601	2.1018	6.1706
0.0045	1.0060	-0.6762	0.4966	0.1982	0.0601	2.1092	6.2198
0.0090	1.0085	-0.6859	0.4946	0.1978	0.0601	2.1243	6.3216
0.0150	1.0118	-0.6988	0.4918	0.1974	0.0601	2.1477	6.4828
0.0225	1.0159	-0.7149	0.4883	0.1969	0.0600	2.1802	6.7136
0.0285	1.0200	-0.7311	0.4842	0.1965	0.0600	2.2230	7.0276
0.0330	1.0241	-0.7472	0.4804	0.1962	0.0600	2.2682	7.3700
0.0360	1.0282	-0.7634	0.4770	0.1962	0.0599	2.3159	7.7408
0.0375	1.0323	-0.7795	0.4739	0.1963	0.0599	2.3660	8.1401
0.0375	1.0364	-0.7957	0.4710	0.1966	0.0598	2.4185	8.5680
0.0360	1.0404	-0.8118	0.4685	0.1971	0.0597	2.4735	9.0244
0.0330	1.0445	-0.8280	0.4662	0.1978	0.0597	2.5310	9.5096
0.0285	1.0485	-0.8441	0.4642	0.1986	0.0596	2.5909	10.0234
0.0225	1.0525	-0.8603	0.4625	0.1997	0.0595	2.6533	10.5660
0.0150	1.0565	-0.8764	0.4610	0.2008	0.0594	2.7182	11.1374
0.0060	1.0605	-0.8926	0.4598	0.2021	0.0593	2.7855	11.7376
-0.0045	1.0645	-0.9088	0.4588	0.2036	0.0592	2.8553	12.3666

Table 4: The Change In Voltage Magnitude, Voltage Angle, Maximum L-Index, L-Index, Stability Index, Active and Reactive Power Losses at Bus-75 With Change in The Load When Line Connected Between Buses 39-31, 21-65, and 18-71are Removed.

With multiple contingency 39-31,21-65,18-71							
Change in load (λ)	**Voltage magnitude**	**Voltage angle**	**Maximum L-index**	**L-index**	**Stability Index**	**Active power loss**	**Reactive power loss**
0.0015	0.9999	-0.6755	0.5283	0.2026	0.0603	2.1327	6.8401
0.0045	1.0016	-0.6819	0.5272	0.2024	0.0603	2.1399	6.8880
0.0090	1.0041	-0.6916	0.5249	0.2021	0.0603	2.1546	6.9871
0.0150	1.0074	-0.7044	0.5216	0.2016	0.0603	2.1774	7.1442
0.0225	1.0116	-0.7205	0.5174	0.2011	0.0603	2.2091	7.3695
0.0285	1.0158	-0.7365	0.5126	0.2006	0.0602	2.2509	7.6768
0.0330	1.0199	-0.7526	0.5081	0.2003	0.0602	2.2952	8.0125
0.0360	1.0240	-0.7687	0.5039	0.2002	0.0601	2.3419	8.3768
0.0375	1.0281	-0.7848	0.5001	0.2003	0.0601	2.3910	8.7696
0.0375	1.0323	-0.8008	0.4966	0.2006	0.0600	2.4426	9.1910
0.0360	1.0364	-0.8169	0.4934	0.2011	0.0599	2.4967	9.6411
0.0330	1.0405	-0.8330	0.4905	0.2017	0.0599	2.5533	10.1199
0.0285	1.0446	-0.8491	0.4879	0.2025	0.0598	2.6124	10.6274
0.0225	1.0486	-0.8652	0.4855	0.2035	0.0597	2.6739	11.1638
0.0150	1.0527	-0.8813	0.4835	0.2046	0.0596	2.7380	11.7291
0.0060	1.0567	-0.8974	0.4817	0.2059	0.0595	2.8045	12.3233
-0.0045	1.0608	-0.9134	0.4802	0.2073	0.0595	2.8736	12.9463

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

6. CONCLUSION

In this paper the variation of voltage magnitude, voltage angle, active power loss, reactive power loss, stability index and L-index with respect to various load changes were analyzed using continuation power flow for base case. This concept is extended further for analyzing the stability of the test systems, whenever contingency has been occurred. Solution trails up to and beyond the CP has been identified for numerous burden variation consequences. By observing the results obtained it is concluded that even if load changes under contingency case the system is able to maintain the stability which cannot be attained by conventional Newton Raphson power flow. It demonstrates the capability and the effectiveness of the Continuation power flow.

REFRENCES:

[1] S. Sarkar, G. Saha, G. Pal, and T. Karmakar, "Indian experience on smart grid application in blackout control", in Proceedings of the 2015 National Systems Conference (NSC), Noida, India, December 2015.

[2] http://www.pserc.wisc.edu/. Blackout of 2003: Description and Responses [Online].

[3] X. Wang, G.C. Ejebe, J. Tong, & J.G.Waight, "Preventive/Corrective Control for Voltage Stability Using Direct Interior Point Method", IEEE Transaction on Power Systems, Vol. 13, No. 3, 1998, pp. 878-883.

[4] "Performance Indexes for Predicting Voltage Collapse", Electric Power Research Institute, EPRI EL-6461, Project 1999-10, 1989.

[5] B. Gao, G. K. Morison, and P. Kundur, "Voltage stability evaluation using modal analysis", IEEE Transactions on Power Systems, Vol. 7, No. 4, 1992,pp. 1529-1542.

[6] Dobson and H. D. Chiang, "Towards a theory of voltage collapse in electric power systems", Systems & Control Letters, 13, 1989, pp.253-262.

[7] R. A. Schlueter, A. G. costi, J. E. Sekerke. and H. L. Forgey, "Voltage Stability and Security Assessment", EPRI Report, Project,1988.

[8] W. C. Rheinboldt and J. V. Burkardt, "A Locally Parameterized Continuation Process", ACM Transactions on Mathematical Software, Vol. 9, No. 2, 1983, pp. 215-235.

[9] V.Ajjarapu, "Computational Techniques for Voltage Stability Assessment and Control", Power Electronics and Power Systems Series, Springer, 2010, pp.1-16.

[10] Veer Anjaneyulu.P, Dr. Purna chandrarao.B "Analysis of continuous power flow method, Model analysis, Linear Regression and ANN for voltage stability assessment for different Loading conditions", Procedia Computer Science No. 47, 2015 pp.168-178.

[11] Mehmet B. Keskin, "Continuation power flow and voltage stability in power systems", A Thesis submitted to the Graduate School of Natural and Applied Sciences of Middle East Technical University, 2007.

[12] Ajjarapu.V, and Christy, "The continuation power flow: A tool for steady state voltage stability analysis", IEEE Trans. Power Syst., 1992, 7, (1), pp. 416-423.

[13] Hiroyuki Mori, Souhei Yamada, "Continuation power flow with the Non-Linear Predictor of the Language's Polynomial Interpolation formula", Meiji University, 2002 IEEE.

[14] Saadat. H., "Power system analysis", (McGraw-Hill, Singapore, 1999)

[15] Chi-Tsong, Chen "Linear System Theory and Design",(Oxford University, 1999)

[16] Song, H., Kim, S., Lee, S., Kwon, H., and Ajjarap.V, "Determination of interface flow margin using the modified continuation power flow in voltage stability analysis", IEE Proc-Gene. Transm. Distrib. Vol. 148, No.2, 2001. pp 128-132.

[17] Haque. M. H, "Use of V-I characteristic as a tool to assess the static voltage stability limit of a power system", IEE Proc.-Gener. Transm. Distrib, Vol. 151, No. 1, 2004, pp 1-7.

[18] T.Van Cutsem and C.Vournas "Voltage Stability of Electric Power Systems, Power Electronics and Power Systems" International Series in Engineering and Computer Science, Springer, 2007.