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SHORT-TERM TREND OF PROCESS ORIENTED POWER SYSTEM SECURITY BASED ON LOAD PROFILE

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Abstract —*Power system analysis is necessary for planning, operation, economic scheduling and exchange of power between generation to load center. The primary information of power flow analysis is to find the magnitude and phase angle of the voltage at each bus and flowing of the real and reactive power in all transmission lines. This paper presents an introduction to the concepts and methods for " short-term trend security analysis" of power system". This work presents a solution methodology of process-oriented power system security using Taylor series expansion method for power flow for without the contingency. Also, determine the power flow analysis using NR, FDLF and Taylor method are applied to an IEEE14 node system and fast process oriented power system security using Taylor series expansion method than Traditional method and evaluate their performance and verify their accuracy.*

Keywords- *Power System security, process oriented power system security, tailor series expansion, load flow analysis, contingency.*

I. INTRODUCTION

The power system stability [1,2] has an important role that a secure system, economical and reliable operation. For power system instability, a major blackout occurs. According to a mathematical model, security analysis can be classified into dynamic analysis and static analysis. Dynamic analysis is rarely caused by a single apparatus failure. Security analysis is more focus on the behavior of the system to a contingency. This paper includes a static security analysis with ignoring contingency. The Security of Power System [3] depends on the system operating conditions and the contingent probability of disturbances. To determine the security level [4] of the Power system, not only a specific study case under certain contingency should be carried out, but also variations of the system state and different contingent probabilities of the power system. Therefore, power system security trend is defined as the future security performance index under certain contingency probability. Time process oriented[7] ideas are in the practical operation of power system such as the arrangement of operation schedule and often leads to much reserve capacity, low transmission efficiency.

The security trend of power system [3] can be divided into the (a) Long-term trend (b) Medium term trend (c) Short-term trend (d) Ultra short-term trend. However, from the perspective of operation and control, the system dispatcher or operator is mainly concerned with the short term trend rather than long-term trends. Therefore this paper focuses on the short term trend within the time frame of a few hours. so, it needs a fast process-oriented analysis method.

II. PROCESS ORIENTED POWER SYSTEM SECURITY[3]:-

Assume the Load variation is slow and transient process ignored. Hence the static equation can be used to describe the system state. The complex power injected by the source[4,5] in to the i^{th} bus of a power system is

$S_i = P_i + jQ_i = V_i I_i^*$ & i= 1,2,3-----n.

$S_i^* = P_i - jQ_i = V_i^* I_i$ & i= 1,2,3-----n .

$$S_i^* = P_i - jQ_i = V_i^* \left(\sum_{j=1}^{n} Y_{ij} V_j\right)$$

Thus we can write as

$$V_i(t) \sum_{j=1}^{n} Y_{ij}(t).V_j(t) = S_i(t)$$

and the value of admittance depends on contingency, So the equation is

$$\hat{\dot{V}}_i(t) \sum_{j=1}^{n} (Y_{ij}(t, c(t)).\dot{V}_j(t) = \hat{S}_i(t) \qquad (1)$$

Where $V_i(t)$= Voltage curve, $S_i(t)$= Load profile of Bus I & $Y_{ij}(t,c(t))$= The mutual admittance between bus i to Bus j, whose value depends on contingency C(t).

Here $\hat{S}_i(t)$ and $\hat{\dot{V}}_i(t)$ are the conjugation of $S_i(t)$ and $V_i(t)$ & dot notation means that the voltage is a phasor. Since the load curve $S_i(t)$ is composed of a series of discrete component $S_{i,k}$, K=1,2,3----N.

Equation (1) can be written as

$$\widetilde{\dot{V}_{i,k}}\sum_{j=1}^{n}(Y_{ij,ck}.\dot{V}_j(t) = \hat{S}_{i,k}(t) \text{ ,K=1,2,3-----N} \quad (2)$$

Where N is the number of the discrete cases including in the interval.
Equation (2) is a series of power flow equation and the problem is to efficiently solve this equation for fast calculation of the security indices. First, the Taylor series expansion of the power flow equation is introduced with and without contingency.

2.1.Taylor series expansion of power flow equation without Contingency[3]**:-**

In equation (1), ignore the contingency in the interval of $[t_0,t_m]$. Where t_0 is the initial Sample point and t_m is the final measured sample points. Separating the real & imaginary part and re-organizing in a matrix form. Here $V_{ix}(t)$ & $V_{iy}(t)$ are real and imaginary parts of the node voltage V_i and $V_{jx}(t)$ & $V_{jy}(t)$ are real and imaginary parts of the node voltage V_j.

$$\begin{bmatrix} V_{ix}(t) & V_{iy}(t) \\ -V_{iy}(t) & V_{ix}(t) \end{bmatrix} \sum_{j=1}^{N} \begin{bmatrix} G_{ij} & -B_{ij} \\ B_{ij} & G_{ij} \end{bmatrix} \begin{bmatrix} V_{jx}(t) \\ V_{jy}(t) \end{bmatrix} = \begin{bmatrix} P_i(t) \\ -Q_i(t) \end{bmatrix} \quad (3)$$

Taking m^th order derivative of both side of eq(3) and applying the Binomial theorem.

$$\sum_{k=0}^{m} C_m^k \begin{bmatrix} V_{ix}(t) & V_{iy}(t) \\ -V_{iy}(t) & V_{ix}(t) \end{bmatrix}^{(m-k)} * \sum_{j=1}^{N} \begin{bmatrix} G_{ij} & -B_{ij} \\ B_{ij} & G_{ij} \end{bmatrix} \begin{bmatrix} V_{jx}(t) \\ V_{jy}(t) \end{bmatrix}^{m} = \begin{bmatrix} P_i(t) \\ -Q_i(t) \end{bmatrix}^{m} \quad (4)$$

Let $\sum_{j=1}^{N} \begin{bmatrix} G_{ij} & -B_{ij} \\ B_{ij} & G_{ij} \end{bmatrix} \begin{bmatrix} V_{jx} \\ V_{jy} \end{bmatrix} = \begin{bmatrix} A_i \\ B_i \end{bmatrix}$ (5)

$$\sum_{j=1}^{N} \begin{bmatrix} G_{ij} & -B_{ij} \\ B_{ij} & G_{ij} \end{bmatrix} \begin{bmatrix} V_{jx} \\ V_{jy} \end{bmatrix}^{k} = \begin{bmatrix} A_{ik}^{k} \\ B_{ik}^{k} \end{bmatrix} \quad (6)$$

So equation (4) can be rewritten as

$$\begin{bmatrix} B_i & -A_i \\ A_i & B_i \end{bmatrix} \begin{bmatrix} V_{ix} \\ V_{iy} \end{bmatrix}^{m} + \begin{bmatrix} -V_{iy} & V_{ix} \\ V_{ix} & V_{iy} \end{bmatrix} \sum_{j=1}^{n} \begin{bmatrix} G_{ij} & -B_{ij} \\ B_{ij} & G_{ij} \end{bmatrix} \begin{bmatrix} V_{jx} \\ V_{jy} \end{bmatrix}^{m}$$
$$= \begin{bmatrix} -Q_i \\ P_i \end{bmatrix}^{m} - \sum_{k=1}^{m-1} C_m^k \begin{bmatrix} V_{ix}^{(m-k)} B_i^k - V_{iy}^{(m-k)} A_i^k \\ V_{ix}^{(m-k)} A_i^k + V_{iy}^{(m-k)} B_i^k \end{bmatrix} \quad (7)$$

an equation (7) can be obtained for each bus. If the bus is a PV bus, G_{ij} and B_{ij} are constant, so put $A_i=V_{iy}$ & $B_i=V_{ix}$. Then the equation (7) to Q is replaced by---

$$\begin{bmatrix} 2V_{ix} & 2V_{iy} \end{bmatrix} \begin{bmatrix} V_{ix}^m \\ V_{iy}^m \end{bmatrix} = -\left(\sum_{k=1}^{m-1} C_m^k V_{ix}^{m-k} B_i + \sum_{k=1}^{m-1} C_m^k V_{iy}^{m-k} A_i^k \right) \quad (8)$$

2.2. Calculation of Node Voltage[3]**:-**

After all derivatives of V_{ix} & V_{iy} known deduce the real and imaginary parts of the node voltage V_i.

$$V_{ix}(t) = V_{ix0} + \sum_{k=1}^{m} \frac{V_{ix}^k}{k!} \Delta t^k$$

$$V_{iy}(t) = V_{iy0} + \sum_{k=1}^{m} \frac{V_{iy}^k}{k!} \Delta t^k \quad (9)$$

If the load P_{i0}, Q_{i0} at the initial point is known, below equation can be used to obtain the higher derivatives of P and Q, $\begin{bmatrix} P_i \\ Q_i \end{bmatrix}^m = \begin{bmatrix} (P_{is} - P_{i0})/\Delta t \\ (Q_{is} - Q_{i0})/\Delta t \end{bmatrix}, m = 1$ (10)

$$= \begin{bmatrix} 0 \\ 0 \end{bmatrix}, m>1. \ ,$$

Eq(7) and ,(9) shows that V_{ix} and V_{iy} are independent of Δt, therefore, to increase the efficiency, Δt can be assigned as unity.

2.3. Steps for Taylor Series Expansion for power flow

- Read the slack bus voltages, real bus powers and reactive bus powers, bus voltage magnitudes and reactive power limits.
- Form the Y bus matrix with line charging admittance and shunt admittance.
- Assume initial values of bus voltages and phase angles of load buses and phase angles for PV buses. I set the assume voltage magnitude of bus and phase angle equal of slack bus quantities $V_1 = 1.0$, $\delta_1=0°$.
- Compute A_i, B_i, P_i and Q_i for each load bus from the Equations -6,7 and 8.
- Compute the scheduled errors, ΔP and ΔQ for each load bus. For PV buses, the exact value of Q*sp* is not specified, but its limits are known. If the calculated value of Q*sp* is within limits, only Δ*P* is calculated. If the calculated value of ΔQ is beyond the limits, then an appropriate limit is imposed and ΔQ*p* is also calculated by subtracting the calculated value of ΔQ from the appropriate limit.
- If the ΔP and ΔQ are less than the tolerance, Calculate real & reactive line flows in all the lines and more than the tolerance modify the voltage magnitude and phase angle at all loads Start the next iteration cycle at step 4.
- Continue until scheduled errors ΔP and ΔQ for all load buses are within a specified tolerance, where, ε denotes the tolerance level for load buses.
- Calculate line flows and power.

III. TREDITIONAL METHODS

3.1. Newton Raphson (NR)[5] method

Newton Raphson (NR)[5] method is a widely used for solving simultaneous nonlinear algebraic equations. A Newton-Raphson method is a successive approximation procedure based on an initial estimate of the one-dimensional equation given by series expansion. This method approach of Load Flow Solution is comparatively better reliable than the other load flow techniques. NR method is used at various buses with varying power flow. The main purpose of the load-flow solution is to calculate the individual phase voltages at all buses connected to the network corresponding to specified system situations. Its only drawback is the large requirement of computer memory. The Real and Reactive powers at bus i are,

$$P_i\,(\text{Real Power}) = \sum_{k=1}^{n} |V_i||V_k||Y_{ik}|\cos(\theta_{ik} + \delta_k - \delta_i)$$

$$Q_i\,(\text{Reactive Power}) = -\sum_{k=1}^{n} |V_i||V_k||Y_{ik}|\sin(\theta_{ik} + \delta_k - \delta_i)$$

The Jacobian is formulated in terms of $|V|$ and δ, we can use the matrix form,

$$\begin{bmatrix}\Delta P\\ \Delta Q\end{bmatrix} = \begin{vmatrix}H & N\\ M & L\end{vmatrix}\begin{bmatrix}\Delta\delta\\ \Delta|V|\end{bmatrix}$$

The off-diagonal and diagonal elements of the sub-matrices H, N, M, and L are determined and after Iteration process is going on.

- Power mismatch or power residuals, the difference in the schedule to calculated power

$$\Delta P_i^k = P_i^{sch} - P_i^k\,,\ \Delta Q_i^k = Q_i^{sch} - Q_i^k \qquad \text{----(11)}$$

- New estimated for the voltages,

$$\delta_i^{k+1} = \delta_i^k + \Delta\delta_i^k\,,\ |V|_i^{k+1} = |V|_i^k + \Delta|V|_i^k$$

3.2. Fast decoupled method

In Fast Decoupled method[5,8], When solving large-scale power transmission systems, an alternative strategy for improving computational efficiency and reducing computer storage requirements is the decoupled power flow method, which makes use of an approximate version of the Newton-Raphson procedure. The Fast decoupled power flow solution requires more iterations than the Newton-Raphson method but requires considerably less time per iteration and a power flow solution is obtained very rapidly.

For large scale power system, usually, the transmission lines have a very high X/R ratio. For such a system, real power changes Δ*P* are less sensitive to changes in voltage magnitude and are most sensitive to changes in phase angle Δδ.

Similarly, reactive power is less sensitive to changes in angle and most sensitive to changes in voltage magnitude. Incorporate of these approximations into the Jacobian matrix in the Newton-Raphson power flow solution makes the elements of the submatrices J_{12} and J_{21}zero.

- ➢ Transmission line & transformer have high X / R ratio.
- Real power change, ΔP is less sensitive to changes in the voltage magnitude, Δ|V|.
- Real power change, ΔP is more sensitive to change in the phase angle, Δδ
- Reactive power changes, ΔQ is less sensitive to changes in the phase angle, Δδ
- Reactive power changes, ΔQ is more sensitive to changes in the voltage magnitude, Δ|V|.

- Jacobian sub matrices J_{Qd} and J_{PV} tend to be much smaller in magnitude compared to J_{Pd} and J_{QV}.
- Jacobian sub matrices are $\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_{P\delta} & J_{PV} \\ J_{Q\delta} & J_{QV} \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix}$

III. RESULT

Bus/branch network models are most commonly used in power flow studies. The algorithms in this work have been tested by a standard IEEE14 bus test systems. In power system, the measurement set is usually a mixture of line power flow (both active and reactive), power bus injection (also active and reactive), and voltage magnitude measurement. The one-line diagram of the IEEE 14 bus network illustrated in Fig. A with a Standard data. Here the Process oriented power system security using Taylor series expansion method and traditional method like Newton Raphson (NR) and Fast Decouple Load flow(FDLF) method using MATLAB code for IEEE14 bus test system. Also, compare above all three methods.

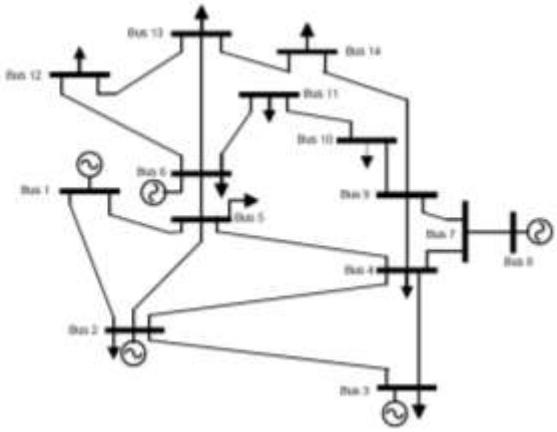


Fig.1 IEEE 14 Bus System

Bus No	V (p.u)	Angle (Degree)	Injection		Generation		Load	
			MW	MVar	MW	Mvar	MW	MVar
1	1.06	0	14.271	23.831	14.271	23.831	0	0
2	1.045	2.56	-7.005	-12.402	14.695	0.298	21.7	12.7
3	1.01	4.57	-7.086	-36.781	87.114	-17.781	94.2	19
4	1.0413	11.19	14.204	4.256	62.004	0.356	47.8	-3.9
5	1.0451	12.3	-1.621	23.647	5.979	25.247	7.6	1.6
6	1.0698	5.7	-20.228	-36.91	-9.028	-29.41	11.2	7.5
7	1.061	-3.85	3.954	-27.815	3.954	-27.815	0	0
8	1.09	0.33	0.104	17.905	0.104	17.905	0	0
9	1.0699	2.55	-12.881	-21.709	16.619	-5.109	29.5	16.6
10	1.0966	-4.38	5.122	41.257	14.122	47.057	9	5.8
11	1.082	-5.23	1.365	-2.405	4.865	-0.605	3.5	1.8
12	1.0921	-6.45	6.16	13.363	12.26	14.963	6.1	1.6
13	1.0767	-8.52	2.556	1.963	16.056	7.763	13.5	5.8
14	1.0626	-11.23	2.177	-8.207	17.077	-3.207	14.9	5
Total			1.091	-20.005	260.091	53.495	259	73.5

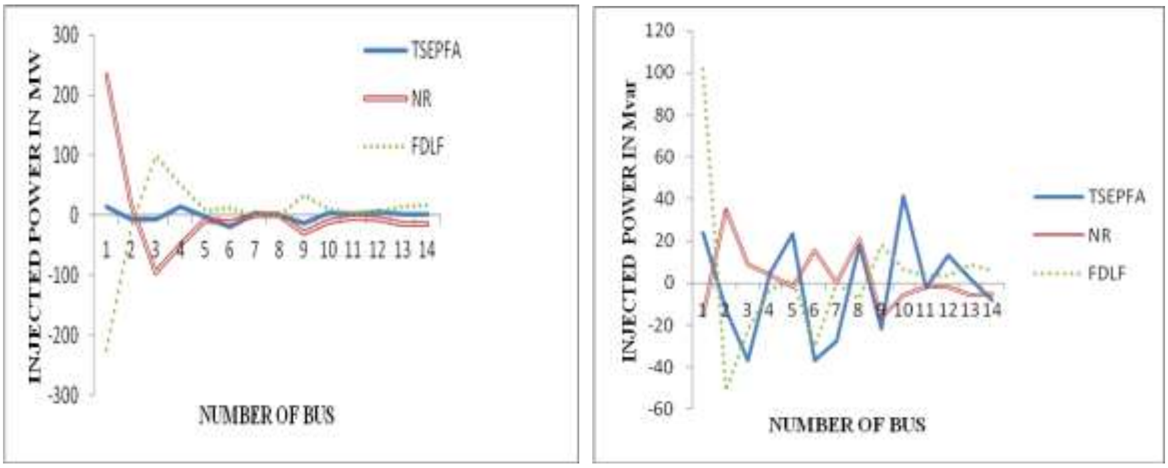
Table -1 Injected and Generated power : Taylor Series Expansion of power flow Analysis for IEEE-14 Bus System

From Bus	To Bus	Active Power	Reactive Power	From Bus	To Bus	Active Power	Reactive Power	Line Loss	
		MW	MVar			MW	MVar	MW	MVar
1	2	10.839	23.324	2	1	-10.725	-23	0.114	0.348
1	5	3.433	6.237	5	1	-3.408	-6.14	0.024	0.101
2	3	2.363	17.917	3	2	-2.222	-17.3	0.141	0.592
2	4	0.154	2.15	4	2	-0.152	-2.14	0.002	0.007
2	5	1.202	-0.473	5	2	-1.201	0.475	0.001	0.003
3	4	-4.864	-16.569	4	3	5.06	17.07	0.196	0.5
4	5	4.444	-10.908	5	4	-4.427	10.96	0.017	0.054
4	7	2.552	-10.064	7	4	-2.552	10.27	0	0.203
4	9	2.301	-5.524	9	4	-2.301	5.702	0	0.178
5	6	7.414	-11.007	6	5	-7.414	11.39	0	0.379
6	11	-3.496	-4.87	11	6	3.526	4.932	0.03	0.062
6	12	-3.41	-7.69	12	6	3.486	7.848	0.076	0.158
6	13	-5.907	-2.591	13	6	5.931	2.638	0.024	0.047
7	8	-0.104	-17.429	8	7	0.104	17.91	0	0.475
7	9	6.61	-8.541	9	7	-6.61	8.655	0	0.114
9	10	-2.615	-33.014	10	9	2.92	33.82	0.305	0.81
9	14	-1.355	3.533	14	9	1.371	-3.5	0.016	0.034
10	11	2.202	7.433	11	10	-2.161	-7.34	0.041	0.096
12	13	2.674	5.515	13	12	-2.604	-5.45	0.07	0.063
13	14	-0.771	4.778	14	13	0.806	-4.71	0.035	0.07
Total Loss								1.091	4.295

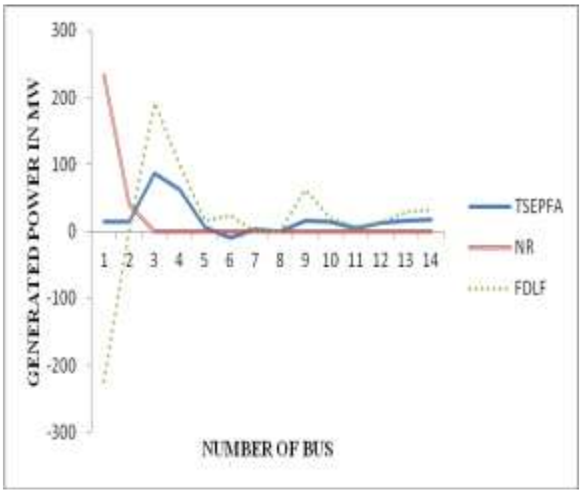
Table -2 (Line Flow and Losses): Taylor Series Expansion of power flow Analysis for IEEE-14 Bus System

Above table -1 shows that the amount of active and reactive power of different incoming bus to different outgoing bus, the Proposed method has line loss is very small as compared to the NR and FDLF.

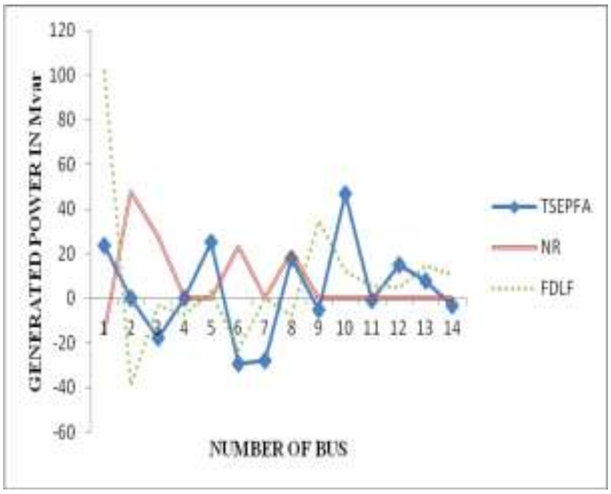
IV. GRAPH



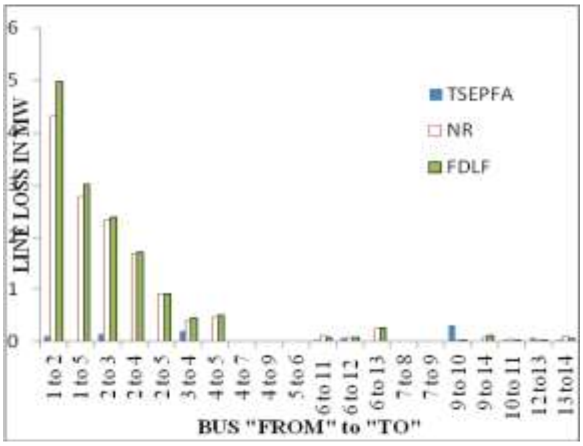
Graph-1(Comparision of Generated power in MW) **Graph-2(** Comparision of Generated power in Mvar)



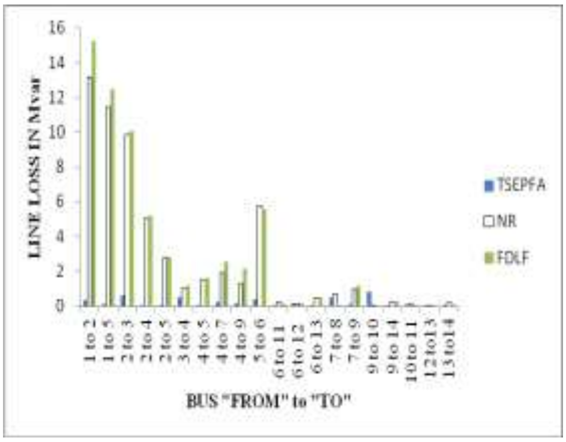
Graph-3 (Comparision of Generated power in MW)



Graph-4(Comparision of Generated power in MVar)



Graph-5 (Comparison of Line Loss in MW)



Graph-6 (Comparison of Line Loss in MVar)

These are different comparison graph without considering contingency. The Graph 1to 4 include injected power and Generated Power in MW and Mvar and Line loss in MW and Mvar for Taylor series expansion of power flow method. In above graph (1to4) shows that the minimum value of power in MW and Mvar in Taylor series expansion for power flow method as compared to traditional methods. In Graph 5 and 6, include Line loss in MW and Mvar for Taylor series expansion of power flow method , it shows the line loss in MW and line loss in Mvar is very low compared to another method. This proposed method is accurate and safe and reliable for load flow analysis.

Method	Computation Time (in seconds)	No. of Iteration
NR	0.5991	7
FDLF	0.4334	10
Taylor Series Expansion of Power Flow	0.3462	4

Table-3 (Comparison of Computation Time (in seconds) & No. of Iteration)

In table-3 shows that The Computation Time (in seconds) is small as compared to the traditional method, so this method is faster operation and highly effective for process calculation.

V. CONCLUSIONS

This paper introduces the concept, a methodology and fast algorithm for trend-oriented power system security. The traditional study based analysis, the proposed security Trend analysis method utilizes the load profile forecasts and contingency occurrence probability. The trend-oriented security analysis is a "forward-looking ' method and hence it can determine the system security in advance. Thus it can provide warning or control means to enhance the security of the power system. The results of the test show that the proposed method is feasible and efficient and faster.

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