N-1 contingency analysis on distribution system

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***Abstract*—(N-1) contingency analysis can be defined as the ability of the system to operate in stable position after outage of anyone component (transformer, generator, line) of transmission network. [1] Distribution system networks often operate with a radial topology, but, ideally, should have more than one route to deliver energy to any node of the network for reliable supply. In case of outage, alternate routes are activated by closing switches located at specific points of the network. This paper proposes a method to evaluate the power supply capability (PSC) of the distribution system. Simulation is done on 6 buses and 9 switches (Circuit breakers). MATPOWER package is used in MATLAB for the simulation.**

***Index Terms*—(N-1) Contingency analysis,Distribution system,Power transfer capability, load-ability**

I. Introduction

Distribution network is modelled as a radial system, consisting of six Distribution transformers feeding the load connected to same bus where transformers are present.The circuit breakers connected between the transformers form an interconnection network.

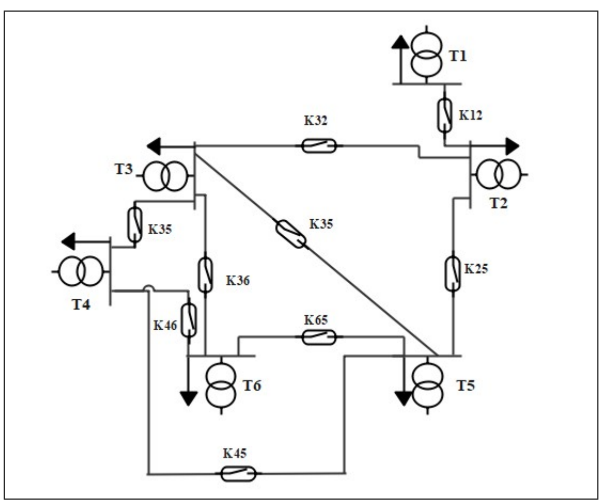

Fig. 1. Proposed 6 bus system

II. Basic terms:

A. *Power supply capability (PSC)*

PSC is defined as maximum capability of the distribution system within a certain power region that satisfies the users electricity consumption under N-1 reliability guidelines It is usually composed of two parts, one is the substation supply capability(SSC) and the other is the network transfer capability(NTC).

B. *Substation supply capability (SSC)*

Maximum capability of the equipment in a substation that satisfies the users electricity consumption under N-1 reliability guidelines.

C. *Network transfer capability (NTC)*

Network transfer capability is adopted to describe the maximum load that could be transferred from one transformer to other transformers in the neighboring substations.

III. Procedure to evaluate N-1 contingency analysis

A. *Interconnection linkage matrix (ILM)*

ILM elements define the interconnection between the two transformers. Lij=1 represents the connection between transformer (i) to transformer(j) Lij=0, represents no connection between the transformer i and j
For given system L_{Link} matrix is:

$$\mathrm{L}_{Link} = \begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 & 1 \end{bmatrix}$$

B. *Maximum average load ability analysis of interconnected transformer*

Based on the L_{link} matrix the maximum average load-ability of the transformers interconnected with the i^{th} transformer can be derived from following equation.

$$T_{ij} = \left(\frac{\sum_{j=1}^{N} L_{ij} R_{ij} - R_i}{\sum_{j=1}^{N} L_{ij} - R_j} \right) L_{ij} \tag{1}$$

T_{link}matrix measures the maximum capability of interconnected transformer

$$\mathrm{T}_{Link} = \begin{bmatrix} 0.50 & 0.50 & 0 & 0 & 0 & 0 \\ 0.78 & 0.78 & 0.78 & 0 & 0.78 & 0 \\ 0 & 0.84 & 0.84 & 0.84 & 0.84 & 0.84 \\ 0 & 0 & 0.81 & 0.81 & 0.81 & 0.81 \\ 0 & 0.74 & 0.74 & 0.74 & 0.74 & 0.74 \\ 0 & 0 & 0.69 & 0.69 & 0.69 & 0.69 \end{bmatrix}$$

C. Maximum permissible loadability analysis of transformers

The i^{th} column in the matrix T_{link} represent the different permissible maximum loadability of the i^{th} transformer in different interconnected groups. To solve the N-1 reliability guideline,only the minimum values is feasible in the practical operation mode. To guarantee transformer T_i to satisfy the N-1 security guideline when any interconnected transformer fails, the feasible maximum loadability of T_i has to be as given below,
$T_{i(N-1)}$ =min(ith column of T_{link})

$$\mathrm{T}_{N-1} = \begin{bmatrix} 50\% & 50\% & 69\% & 69\% & 69\% & 69\% \end{bmatrix}^T$$

D. Maximum power supply capability (MPSC)

MPSC is the sum of all the maximum permissible supplying loads of transformer
$S_{N-1} = \sum_{i=1}^{N} T_{i(N-1)} R_i$
=20*50%+20*50%+20%69+20%69+31.5*69%+31.5*69%
=91.5MVA

Total capacity of all the substations=20*4+31.5*2
=143MVA

IV. Algorithm for N-1 contingency

General calculation procedure for power supply capability of distribution system

1) *Simplification of topology:* The complex distribution network is reduced to radial system, transformer and load connected at each bus

2) *Analysis of interconnection relation of transformers:* The interconnection relation if formed using L_{link} matrix

3) *Maximum average loadability analysis of interconnected transformers:*The maximum permissible loadability of each transformer can be find out using T_{link} matrix (Different permissible maximum loadabilities of the i th transformer in different interconnected transformer)

4) *Maximum permissible loadability of the transformers:*: The maximum permissible loadability vector T_{N-1} can be formed which consisted of each transformer's maximum permissible loadability in the distribution system

5) *Calculation of PSC:*Calculate maximum power supply capability of distribution systems S_{N-1} based on all transformers maximum permissible loadability vector.

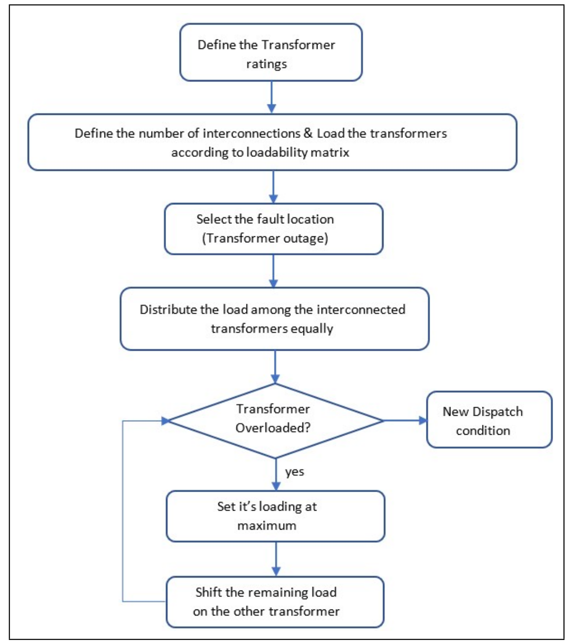

Fig. 2. Flow chart of algorithm

Mode	Interconnection between	Pre-optimized PSC MVA	PSC after Optimization
1	K16	91.5	104.689
2	K15	104.689	107.094
3	K26	107.094	111.5

A. Sample example

1) Present interconnection matrix

$$\mathrm{L}_{Link} = \begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 & 1 \end{bmatrix}$$

Total capacity of the system:143 MVA

2) State the number of extra interconnections to be made: **2**

Interconnecting 6 and 1
Interconnecting 5 and 1

The available MVA Capacity considering N-1 contingency is **107.0944**

3) New Interconnected matrix:

$$\mathrm{L}_{Link} = \begin{bmatrix} 1 & 1 & 0 & 0 & \mathbf{1} & \mathbf{1} \\ 1 & 1 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 & 1 \\ \mathbf{1} & 1 & 1 & 1 & 1 & 1 \\ \mathbf{1} & 0 & 1 & 1 & 1 & 1 \end{bmatrix}$$

4) Power flow under normal operating condition:

BUS	Voltage(V)	Generation(MW)	$P_{load}(MW)$
1	1	14.88	14.88
2	1	15.59	15.59
3	1	14.88	14.88
4	1	14.88	14.88
5	1	23.43	23.43
6	1	23.43	23.43
Total		107.09	107.09

5) The transformer on which fault is simulated: **3**
New dispatch condition:

BUS	Voltage(V)	Generation(MW)	$P_{load}(MW)$
1	1	14.88	14.88
2	1	**19.31**	15.59
3	1	**0**	14.88
4	1	**18.60**	14.88
5	1	**27.15**	23.43
6	1	**27.15**	23.43
Total		107.09	107.09

V. Assumptions

1) High impedance used in place of open circuit breaker

2) Load considered as locally connected

VI. Challenges:

1) For distributed load power flow doesn't converges
2) For NR power flow reactive power became unpredictable

VII. Observation and conclusions

1) Adding extra interconnection in the system increases the available power transfer capability of the network

2) Reduces the cost of installing devices of higher ratings

3) Very unlikely to attain the loadability equal to total capacity of substation, even after interconnecting all the transformers

4) TSC saturates to a certain value after a certain number of interconnections

VIII. References

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