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Analysis of Distribution Losses in Network Reconfiguration Method

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Abstract

This paper presents the analysis of distribution losses in real time distribution network using Network Reconfiguration (NRC) method. There are three types of losses in power system network namely technical, non-technical, and commercial losses. The accurate loss reduction and voltage profile improvement are the critical components for efficient electricity distribution system. The distribution losses in network reconfiguration method are an important tool for the planning and operation of power system utility. Usually, the power system utilities can use multiple criteria regarding the observation of regulation policies and public awareness to drive the network topological system. The several research scholars are looking for new optimization methods, as the complexity of this combinatorial issue is high in large systems and the classic optimization methods are failing to address the problem of various reasonably. Additionally, there is possibility to explore the automation equipment applying the new concept in Chennai Electricity Distribution Control Centre (CEDCC). The network topology of reconfiguration method is real time and automatically performed by means of remote-controlled isolating or tie line switches. The network reconfiguration includes a validation by computer simulations based on a multiple criteria decision-making method. The main objective of this paper is to reduce the distribution losses in existing Low-Tension (LT) as well as High Tension (HT) distribution networks with the help of NRC Methods. A sample case study conducted in large power system of 33/11-KV Integral Coach Factory Sub-Station, CEDCC network, TANGEDCO, Tamil Nadu state and India considered using Network Manager-WS5001 power station software program. The benefit of this paper is to increase the good quality of power factor, reducing the voltage drop at tail end of distribution networks, compare energy losses in kilowatts and calculates percentage voltage regulation in existing and proposed networks, annual energy saving are also calculated. In this sample case study was conducted based on constitution of Indian Electricity act-2003 and follow up TNEB Rules and Regulation [1].

Key Words:Annual energy saving, distribution losses, network manager-WSS5001 power station software, network reconfiguration, and percentage voltage regulation.

1. Introduction

The term energy losses in power system are difference between the amount of actual energy delivered to the distribution system and the amount of actual energy consumed by total customers. The existing Transmission and Distribution (T&D) losses in India during period of 2008-09 are extremely high about 28.44%. However, as per system previous case study conducted by Central Government of India these losses has been calculated to be as very high about 50% in many states. In a recent last year case study conducted by Central Government of India, T&D losses about 58% reached some territorial states. In present electricity distribution system overall percentage efficiency is very low due to heavy losses occurred in LT distribution network. The peak power shortfall is 10-14% between 18:00 hrs to 23:00 hrs due to electric welding, the theft of energy by non-customer and pilferage by existing customer, shortage of electricity, load shedding, Routine maintenance work carried out in generating station, T&D wing and power cuts are common throughout India; this has adversely affected in our Country Economic Growth (CEG). The annual energy losses analyzed in 11KV feeder distribution network with various capacities of electric power components in underground cable networks and transformers using load and load duration curve methods [2]. The energy losses in existing distribution networks reduced by load transferring the overloaded feeders, that load as transferred to adjoining under-loaded distribution networks from peak period to off-peak period [3]. The transmission and distribution losses in power sector calculated by replacing the Over Head (OH) conductors to Under Ground (UG) cable network and then higher capacity of distribution transformers replaced to smaller capacity of distribution transformers installed nearer to customer load point [4]. The calculation of no load to full load losses in distribution transformer using feeder no.12 at 220/22KV-Pune electricity distribution network using actual and analytical methods are discussed [5]. The calculate energy losses in existing and proposed high voltage distribution system are discussed with the help of Turbo C++ programming language [6]. The main causes of distribution losses and subsequent loss rectification techniques discussed. Then higher capacity of distribution transformer replaced in to smaller capacity of distribution transformers installed nearer to customer load points [7]. The network reconfiguration method is an important tool for the planning and operation of power systems. Usually, the main aims are the reduction of distribution losses, the enhancement of voltage stability, and the reliability levels. Moreover, recently, the reconfiguration method considered as context of the Smart Grids, which characterized by a series of integrated technologies, and procedures for planning and operation of distribution systems. Some desired features in a smart grid are the low operating, maintenance costs, and the ability to self-reconfiguration methods [8]. In this context, the automation of distribution networks plays an important role, e.g., using remotely controlled by isolating and closing tie line switches. In general, reconfiguration problem cannot optimally solved without considering following events are

(i) The proper modelling and analysis of the distribution system
(ii) The algorithms to handle reconfiguration changes in the line network in a timely manner
(iii) The load flow and power flow analysis
(iv) The composition of the objective functions and constraints
(v) The optimization and the decision-making techniques used to define the ideal electrical reconfiguration.

The Several research scholars have subscribed by various reconfiguration methods. Baran [9], Hong [10], Nara [11], and Su [12] describe concepts and new concepts applied to this problem. The minimization of distribution losses and maximization of the load balance equation are the two most common criteria used to reconfiguration methods. The reconfiguration method has also to consider radial or ring main distribution networks, limits on voltage profile, and current limits constraints. Additionally, one important and convenient aspect refers to uncertainty on the input analogue data's or in the degree of components when multi criteria take place in the reconfiguration methods, as Das [13], Dugan [14], and Venkatesh [15] assumed in their approaches. This paper represents a new technology and computer program for automatic reconfiguration of distribution network using smart grid concepts. The network topology defined, automatically performed by means of remote-controlled isolating and tie line switches. The network topology includes a validation by computer simulations program that indicates the ON or OFF isolating switches to operate and that ensure the technical feasibility of the manoeuvre, for each load rate. Since there may be many reconfiguration options with different gains, an algorithm based on a multiple criteria decision making methods are applied. The Bellman-Zadeh method [16] chosen for the fuzzy logic research methodology, as it has been successfully applied to multi criteria problems and it promotes final resolutions belonging to the Pareto objective spaces [17]. The algorithm can be reconfigured according to the needs of the power utilities, helping in the prompt decision making process.

2. Problem Formulation of Power Flow Analysis

The basic principal of information obtained from the power flow analysis is magnitude of voltage and phase angle at each bus, and the real and reactive power injected in each bus system. One of the main sources of losses in the distribution system contains overhead conductor as well as underground cables, since these losses are a functioning of current flows through the line conductor or underground cable networks. These losses also reduced by network reconfiguration methods. A sample case study conducted in large power system of 33/11-KV Integral Coach Factory Sub-Station, CEDCC, TANGEDCO, Tamil Nadu state and India considered using Network Manager-WS5001 power station software program. This has chosen as case study, areas of domestics, industrial, commercial, other departments and non-residential loads. The Network Manager WS5001 power station software program applied for load flow calculations of before and after reconfiguration methods. This allow the proper distribution layout for the existing networks in Chennai city to be made in the form of single line diagram which enables a better understanding the loss evaluation of the distribution network in a more precise way. The load flow analysis for three methods in exhaustive search methods needed to manage optimal switching reconfiguration of test systems. Real power, reactive power and volt drop of each bus evaluated by using Network Reconfiguration Method of load flow solutions. It is more suitable for large-scale power system because it is more practical and efficient. The formulation of load flow equation (1), equation (2), equation (3) and equation (4), are

Load Flow equation: F(x, u) = 0 (1)

$$P_{i,n} = \sum_{j=1}^{N_B} \left| Y_{ij} V_{i,n} V_{n,j} \right| \cos\left(\theta_{ij} + \delta_{j,n} - \delta_{i,n}\right) \quad (2)$$

$$Q_{i,n} = \sum_{j=1}^{N_B} \left| Y_{ij} V_{i,n} V_{n,j} \right| \sin\left(\theta_{ij} + \delta_{j,n} - \delta_{i,n}\right) \quad (3)$$

Bus Voltage Constraint: $V_{Min} \le V \le V_{Max}$ (4)

The total power loss of individual feeders may then be determined by summing up the losses of all branches of line section and electrical components of the feeder, which equation (5) and equation (6), are:

$$\text{Real Power loss} = \sum_{mn=1}^{K} \left| I_{mn} \right|^2 * R_{mn} \quad (5)$$

$$\text{Reactive Power loss} = \sum_{mn=1}^{K} \left| I_{mn} \right|^2 * X_{mn} \quad (6)$$

Where

I_{mn} = Current through in the branch (m, n)

R_{mn} = Resistance in the branch (m, n)

X_{mn} = Reactance in the branch (m, n)

3. Overview of 33/11-KV Integral Coach Factory Distribution System

Chennai Electricity Distribution Control Centre (CCDCC) is the largest load centre in TANGEDCO of Tamil Nadu State, India. The prepared systems under case study of the 11KV Villivakkam-II, 11KV Pumping Station and 11KV Ayanavaram feeder of 33KV Integral Coach Factory (ICF) Sub-Station. The two power transformer ratings and the values of power factor are 16MVA and 0.85. The two incoming line segment (33KV) received from 110KV Anna Nagar SS and 110KV Padi SS, and each underground XLPE AL cable size of 630sqmm. 120sqmm XLPE AL cable and 7/3.35-ACSR and 7/2.59-ACSR overhead conductors combine the eight numbers 11KV outgoing feeders' networks. The entire distribution system covered under AC ring main groups and some radial wing portions are covered. The single line diagrams of 33/11-KV ICF Sub-Station as shown in Figure1. The entire power system of 11KV Villivakkam feeder-II of 33KV ICF Sub-Station, that energy consumptions of connected loads are full load capacity. That overloading capacity of existing feeder network may reconfigure and some quantum of load may transfer to adjoining 11KV Pumping Station and 11KV Ayanavaram feeders of same 33/11-KV ICF Sub-Station.

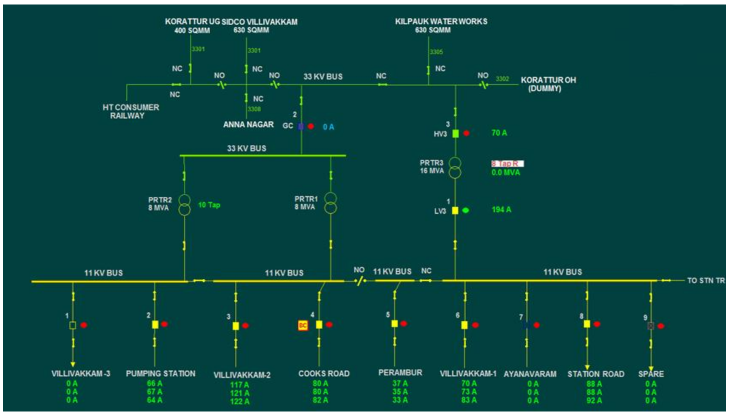

Figure 1: Single Line Diagram for 33KV Integral Coach Factory Sub-Station

The 11KV Villivakkam feeder-II networks are mutual interlinked with adjoined 11KV feeder networks. They are twenty-six numbers distribution transformers are covered and supply to the whole consumers. The receiving end value of power factor is 0.78. Although installed capacities for 11KV Villivakkam Feeder-II is 8000KVA, because of all distribution transformers are full load capacity as shown in Figure2. Therefore, the total power consumption of connected loads for feeder is 7.60 MW and receiving the voltage 388V at tail end. A long distance low-tension distribution networks and huge capacity of distribution transformers, resulting in increase the I^2R losses in both no-load and full load condition as well as frequent fuse brownout in LT pillar-boxes. The predominating low voltage in the LT networks is also a impressing the efficiency of the electrical instruments and continuous fuse blown out in LT networks. In addition, there is tendency of illegal connections to tapping of LT lines, which results in over loading of the distribution transformers. Before implementation of network reconfiguration method, the actual energy losses are 45911.35-Kilowatts and percentage voltage regulation is 10.45% obtained in 11KV Villivakkam feeder-II as shown in Table.1

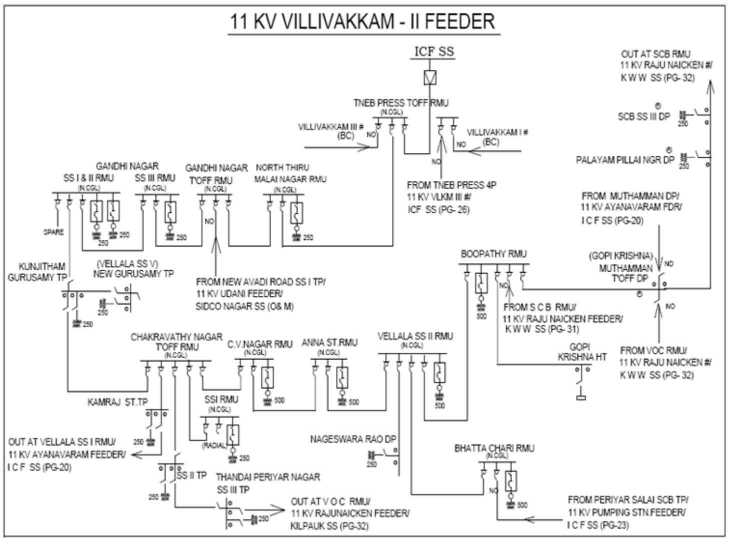

Figure 2: Single Line Diagram for 11KV Villivakkam Feeder-II of 33KV ICF Substation

Table 1: Actual Energy Losses and Percentage Voltage Regulation in 11KV Villivakkam Feeder-II

BEFORE LOAD BIFURCATION OF 11KV VILLIVAKKAM # II: VOLTAGE REGULATION AND POWER LOSS CALCULATION									
SL. NO	11 KV Cable Size	Distance in KM	Distribution Transformer	Capacity in KVA	Cumulative Load	Momentum	% Voltage Regulation	Current in (Amp)	Power Loss (KW)
1	3x120	0.25	INTEGRAL COACH FACTORY	250	8000	2000	0.56	419.90	3345.65
2	3x120	0.28	TNEB PRESS RMU	500	7750	2170	0.60	406.78	3516.59
3	3x120	0.70	NORTH THIRUMULLAI NAGAR RMU	250	7250	5075	1.41	380.54	7693.69
4	3x120	0.67	GANDHI NAGAR 'T'OFF RMU	250	7000	4690	1.31	367.42	6864.86
5	3x120	0.50	GANDHI NAGAR SS III RMU	250	6750	3375	0.94	354.29	4763.63
6	3x120	0.76	GANDHI NAGAR SS I & SS II RMU	500	6500	4940	1.37	341.17	6714.30
7	3x120	0.49	KUNJITHAM GURUSAMY TP	500	6000	2940	0.82	314.93	3688.58
8	3x120	0.45	CHAKRAVATHY NGR 'T'OFF RMU	1000	5500	2475	0.69	288.68	2846.42
9	3x120	0.51	CV NAGAR RMU	500	4500	2295	0.64	236.20	2159.51
10	3x120	0.38	ANNA ST RMU	500	4000	1520	0.42	209.95	1271.35
11	3x120	0.82	VELLALA SS II RMU	1250	3500	2870	0.80	183.71	2100.44
12	3x120	0.62	BOOPATHY RMU	1250	2250	1395	0.39	118.10	656.32
13	3x120	0.75	MUTHURAMAN 'T' OFF DP	250	1000	750	0.21	52.49	156.83
14	3x120	0.80	PALAYAM PILLAI NGR DP	250	750	600	0.17	39.37	94.10
15	3x120	0.56	SCB SS III DP	250	500	280	0.08	26.24	29.27
16	3x120	0.75	SCB RMU	250	250	188	0.05	13.12	9.80
17	**Total**	**9.29**		**8000**			**10.45**		**45911.35**

4. Implementation of Loss Reduction Technique in NRC Method

The implementations of loss reduction technique in NRC method, which are mutually, interconnect with various buses in a power system network. The interconnection of Ring Main Units (RMU) Opening and closing isolators are connecting or disconnecting with line segments to the existing networks. The Network reconfiguration in distribution systems performed by opening (sectionalizing) and closing of tie line (closed) switches. These line switches are performing in such a way that ring main group of all distribution networks. A normal operating condition open line switches are closed and transfer the load from over excited feeder (11KV-Villivakkam feeder-II) to alternating under loaded feeder networks, while appropriate sectionalizing switches are opened to restore the supply by existing transformers. The tie lines switch pairs chosen through exhaustive formulas for the change in distribution losses. A ring main group can represent by two numbers of alternating feeders (11KV-Pumping Station feeder and 11KV-Ayanavaram feeder) by meshed loops. This is because, when it is connected, one tie line can only make one loop at that time mobile as well as manual mode of operation, the number of loops is equal to the number of tie line switches. The benefits of this network reconfiguration technique include:

(i) Immediate restore power supply to any outage partitions of a feeder network,
(ii) Immediate relieving over capacity feeders by shifting the load to adjacent feeders without any major capital investment, and
(iii) Immediate reducing resistive line losses in feeder network

The network reconfiguration involves the selection of the best set of branches are opened, one each from each loop, for reducing resistive line losses, and reliving overloads on feeders by shifting the load to adjacent feeder networks. This method commonly used for ring main group of distribution networks.

5. Proposed NRC Method

The NRC method is done by minimize distribution losses in existing network. An optimal placement of NRC method is to configure the distribution networks and reduces the distribution losses under normal operating conditions. By reducing these losses in the distribution systems, costs saving for these network can achieve various techniques are involved. This paper focuses on reconfiguration of a ring main group of distribution network to optimize the power distribution process in the existing network, improve the voltage profile and reduce the energy losses. There are three types involved in loss reduction techniques, they are Minimum Branch Current (MBI), Minimum Voltage Difference (MVD) and Voltage Difference (VD) based opening and closed of isolators in RMG and RMU groups. The proposed approach is suitable for both operational and planning studies, as it is computationally efficient. In this paper, three different methods, proposed with initial configuration and meshed topological system. The initial meshed topology gives the minimum distribution loss configuration for the system and as the network is reconfigure, the ring main configuration of distribution network with minimum loss will occur. The reduction in distribution losses can easily computed from the results of two load flow and power flow studies of the system configuration before and after the feeder reconfiguration methods. The load flow solutions of both cases are modeled and simulated by using Network Manager-WS5001 power station software program. The flow charts for the combined algorithm are manual and mobile mode of operation in NRC Method as illustrated in Figure3.

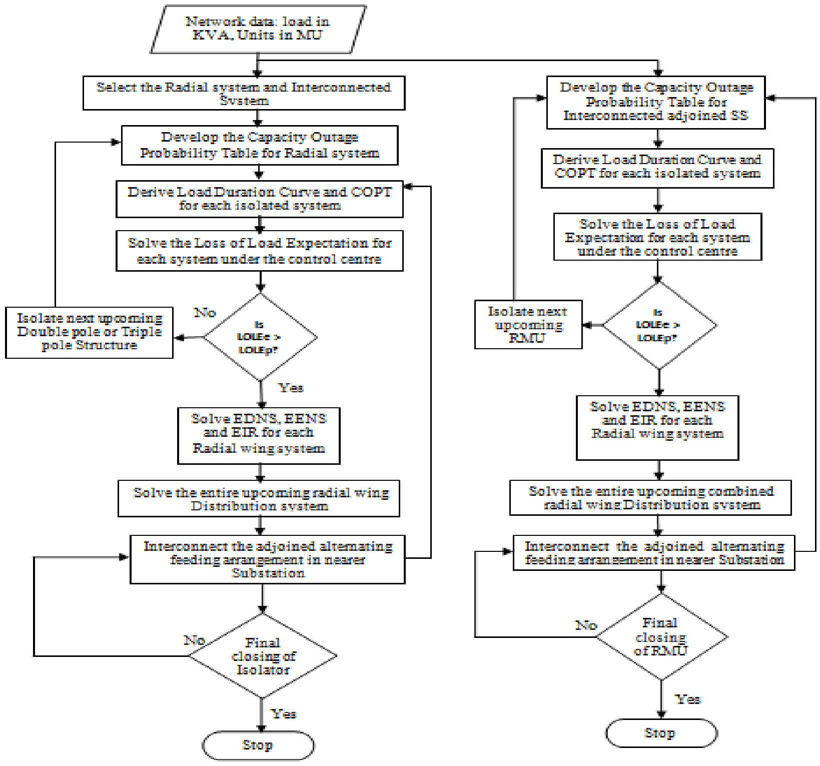

Figure 3: Flowchart Process of the Combined Algorithm of Manual Mode of Operation in NRC Method

6. Simulation Process and Results

There are four tie line switches operated before network reconfiguration method, because of voltage reduction, long length and overloaded lines in the existing ring main distribution system. In addition, that minimum operating voltage is nearly from 9.62KV and 9.58KV occurred in the existing distribution network. The single line diagram for 11KV Villivakkam feeder-II along with meshed topology of distribution systems as

Demonstrated in Figure4, after using exhaustive proposed new techniques in network reconfiguration method, there are four sectionalizing switches are achieve minimum loss switching configuration. The step by steps procedure of network reconfiguration in existing distribution networks calculated according to the above flowchart Figure2. Among three techniques of exhaustive research methods, the best solutions for voltage difference based opening and closing of isolators in RMG and RMU groups.

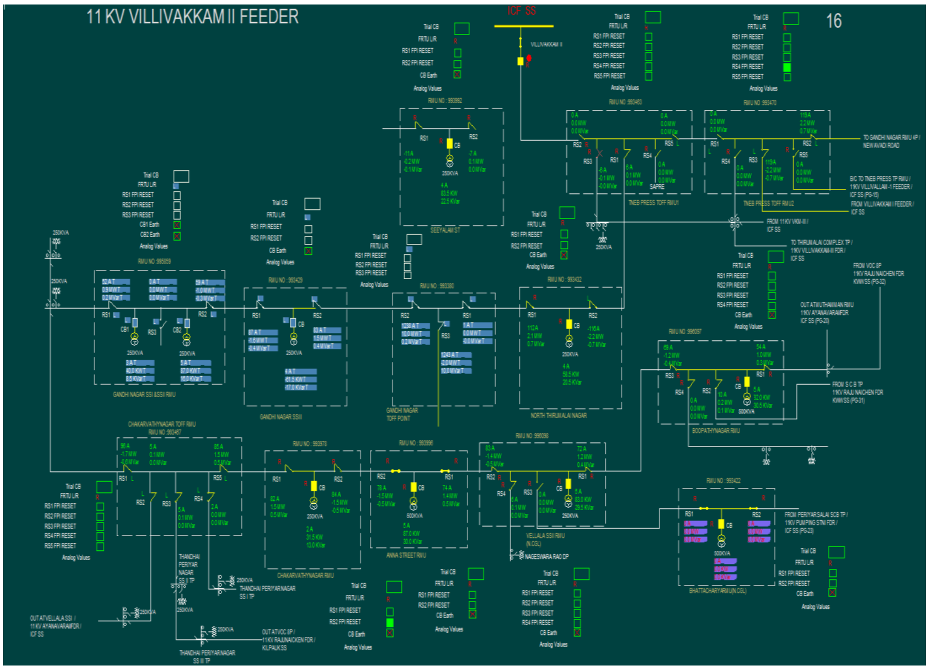

Figure 4: Single Line Diagram for 11KV Villivakkam feeder-II along with Meshed Topology Distribution System

The 11KV Villivakkam feeder-II of 33KV ICF SS meshed topology distribution system; Voltage Difference (VD) based opening and closed of isolators in RMG and RMU group based loss reduction technique method is the best solution for network reconfiguration practice. Finally, the ring main groups of equal load distributed adjoined network systems for the best method in case study as demonstrated in Figure5. Then, voltage profile improvement and reduction of energy losses in present distribution network after reconfiguration of the test system as shown in Table2 and Table3. Subsequently in Table1, Table2 and Table3 energy losses in present system, before reconfiguration condition expressed in blue, Red and green indicated for after implementation of exhaustive search technique in reconfiguration process as shown in Figure6. In this condition, all operating bus voltages dramatically increased above 10.58KV. By comparing three methods, method 3 or voltage difference based opening and closing of isolators in RMG and RMU group based loss reduction technique is an excellent method because the bus voltages increased from 9.58 KV to 10.58 KV of the three distribution systems for that operating condition. Moreover, real and reactive power losses gradually reduced. The following figures show the equivalent voltage difference based opening and closing of isolators in RMG and RMU groups of distribution system are best method in network reconfiguration.

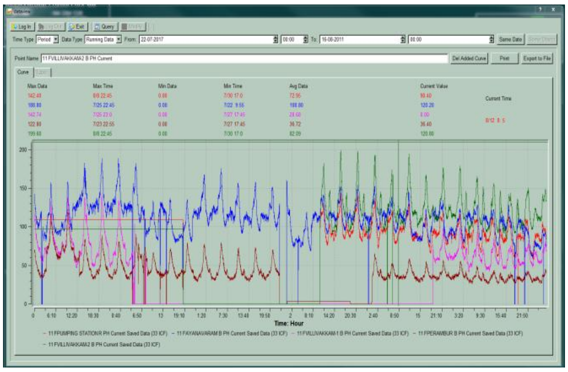

Figure 5: Load Curve for Voltage Difference based Opening and Closing of Isolators in Loss Reduction Technique

Table 2: After Strengthening Cable in 11KV Villivakkam # II: Voltage Regulation and Power Loss Calculation

AFTER STRENGTHENING CABLE IN 11KV VILLIVAKKAM # II: VOLTAGE REGULATION AND POWER LOSS CALCULATION									
SL. NO	11 KV Cable Size	Distance in KM	Distribution Transformer	Capacity in KVA	Cumulative Load	Momentum	% Voltage Regulation	Current in (Amp)	Power Loss (KW)
1	3x240	0.25	INTEGRAL COACH FACTORY	250	8000	2000	0.28	419.90	1652.99
2	3x240	0.28	TNEB PRESS RMU	500	7750	2170	0.30	406.78	1737.45
3	3x240	0.70	NORTH THIRUMULLAI NAGAR RMU	250	7250	5075	0.70	380.54	3801.23
4	3x240	0.67	GANDHI NAGAR 'T'OFF RMU	250	7000	4690	0.64	367.42	3391.73
5	3x240	0.50	GANDHI NAGAR SS III RMU	250	6750	3375	0.46	354.29	2353.57
6	3x240	0.76	GANDHI NAGAR SS I & SS II RMU	500	6500	4940	0.68	341.17	3317.34
7	3x120	0.49	KUNJITHAM GURUSAMY TP	500	6000	2940	0.76	314.93	3688.58
8	3x120	0.49	CHAKRAVATHY NGR 'T'OFF RMU	1000	5500	2695	0.70	288.68	3099.43
9	3x120	0.76	CV NAGAR RMU	500	4500	3420	0.88	236.20	3218.10
10	3x120	0.51	ANNA ST RMU	500	4000	2040	0.53	209.95	1706.28
11	3x120	0.82	VELLALA SS II RMU	1250	3500	2870	0.74	183.71	2100.44
12	3x120	0.62	BOOPATHY RMU	1250	2250	1395	0.36	118.10	656.32
13	3x120	0.75	MUTHURAMAN 'T' OFF DP	250	1000	750	0.19	52.49	156.83
14	3x120	0.80	PALAYAM PILLAI NGR DP	250	750	600	0.16	39.37	94.10
15	3x120	0.56	SCB SS III DP	250	500	280	0.07	26.24	29.27
16	3x120	0.75	SCB RMU	250	250	188	0.05	13.12	9.80
17	**Total**	**9.71**		**8000**			**7.50**		**31013.47**

Table 3: After Load Bifurcation of 11KV Villivakkam # II: Voltage Regulation and Power Loss Calculation

AFTER LOAD BIFURCATION OF 11KV VILLIVAKKAM # II: VOLTAGE REGULATION AND POWER LOSS CALCULATION									
SL. NO	11 KV Cable Size	Distance in KM	Distribution Transformer	Capacity in KVA	Cumulative Load	Momentum	% Voltage Regulation	Current in (Amp)	Power Loss in (KW)
1			**BRANCH-I**						
2	3x120	0.25	INTEGRAL COACH FACTORY	250	8000	2000	0.37	419.90	2071.75
3	3x120	0.28	TNEB PRESS RMU	500	7750	2170	0.40	406.78	2177.60
4	3x120	0.70	NORTH THIRUMULLAI NAGAR RMU	250	7250	5075	0.94	380.54	4764.21
5	3x120	0.67	GANDHI NAGAR 'T'OFF RMU	250	7000	4690	0.87	367.42	4250.97
6	3x120	0.50	GANDHI NAGAR SS III RMU	250	6750	3375	0.63	354.29	2949.81
7	3x120	0.76	GANDHI NAGAR SS I & SS II RMU	500	6500	4940	0.92	341.17	4157.74
8	3x120	0.49	KUNJITHAM GURUSAMY TP	500	6000	2940	0.55	314.93	2284.10
9	3x120	0.67	CHAKRAVATHY NGR 'T'OFF RMU	1000	5500	3685	0.68	288.68	2624.32
10	3x120	0.49	CV NAGAR RMU	500	4500	2205	0.41	236.20	1284.81
			BRANCH-II				**5.77**		**26565.30**
11	3x120	0.38	ANNA ST RMU	500	4000	1520	0.28	209.95	787.26
13	3x120	0.82	VELLALA SS II RMU	1250	3500	2870	0.53	183.71	1300.67
14	3x120	0.62	BOOPATHY RMU	1250	2250	1395	0.26	118.10	406.42
15	3x120	0.75	MUTHURAMAN 'T' OFF DP	250	1000	750	0.14	52.49	97.11
16	3x120	0.80	PALAYAM PILLAI NGR DP	250	750	600	0.11	39.37	58.27
17	3x120	0.56	SCB SS III DP	250	500	280	0.05	26.24	18.13
18	3x120	0.75	SCB RMU	250	250	188	0.03	13.12	6.07
19	**Total**	**9.49**		**8000**			**1.41**		**1886.67**
20			**NETT POWER LOSS IN PROPOSED NETWORK IS**				**7.18**		**28451.96**

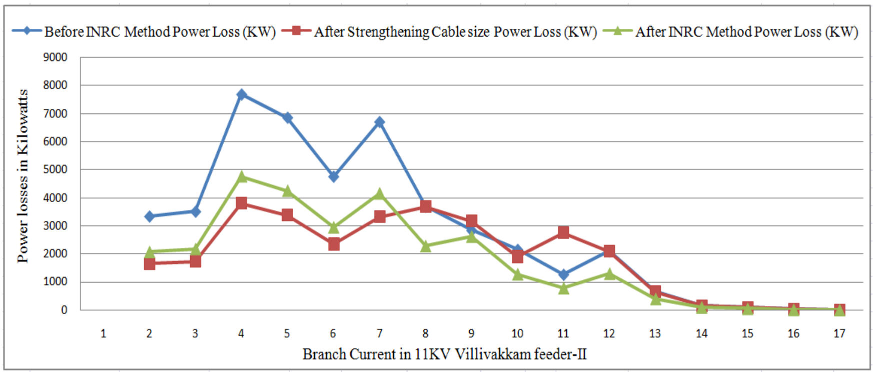

Figure 6: Implementation of NRC Method in 11KV Villivakkam Feeder-II at 33KV Integral Coach Factory Substation, Before and After Power Loss Curve

7. Conclusion

The Exhaustive technique used to find the optimal switching reconfiguration and power loss calculation of this work is very efficient. Network Manager-WS5001 power station software program applied for load flow solutions of these methods to manage the optimal switching scheme with minimum loss calculation. According to the calculation results, before strengthening of cable size and NRC method in 11KV Villivakkam feeder II of 33KV ICF SS, voltage regulation and power loss calculation about 10.45% and 45911.35KW. After strengthening of cable size 120sqmm XLPE AL to 240sqmm XLPE AL, that may reduced to 7.5% voltage regulation and 31013.47 KW energy losses. After implementation of NRC method that may further more reduced to 7.18% voltage regulation and 28451.86 KW energy losses. Therefore, **249.238 million units** saved by after adaptation of network reconfiguration in 11KV Villivakkam feeder-II at 33KV Integral Coach Factory substation. These energy saving is equivalent to saving of about that may properly utilized in Chennai city for five days energy consumption. After network reconfiguration, all operating bus voltages dramatically increased test result from **9.58KV** to **10.58KV.** However, the aim of our proposed work is to reducing the real and reactive power losses in existing system without any capital investments cost. In addition, reducing the reactive power losses is also increasing the voltage profile of existing system.

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