Performance Analysis of Distribution System in Ohntaw Substation

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Abstract- The main function of a distribution system is to receive electric power from large, bulk power sources and to distribute electric power to consumers at various levels with acceptable degrees of reliability. This paper is intended to design and analysis of distribution system for existing distribution system of Ohntaw substation. The main aim of this paper is to analyze the distribution system, to study the function of components, to improve the continuity of supply to prevent the disturbance fault in distribution system and to calculate the voltage regulation, line lossess and line efficiency in this substation. And then, the study of daily load utilization for Ohntaw substation.

Indexed Terms- Voltage Regulation, Line, Efficiency, Lossess, Demand Power.

I. INTRODUCTION

Distribution system can be defined as portion of the electric power system which links the bulk power source or sources to the end user facilities. Power system which is includes three parts such as generation, transmission and distribution. It consists of sub transmission circuits, distribution substation, primary feeders, distribution transformer station, secondary circuits, and consumer connections. In generation system, electricity generations or power stations which are very important to make energy available wherever needed.

The three main processes necessary for electricity supply are generation, transmission and distribution of electric power. Any AC power system begins with a generating source. Electric generators are devices that convert energy from a mechanical form into an electrical form. Power is generated in power stations and is transmitted over many different distances depending on the location of the stations relative to their consumers. The distribution system can be either overhead or underground. It is usually overhead, though for higher load densities in cities or metropolitan areas, it is underground. The voltage regulation of the underground cable system is more efficient as compared with the overhead.

II. MAIN PARTS OF DISTRIBUTION SYSTEM

Distribution system can be divided into six parts:

1) sub-transmission circuits
2) distribution substations
3) distribution or primary feeders
4) distribution transformers
5) secondary circuits
6) Consumers' service connecting and meters or consumers' services.

Figure 1 is a schematic diagram of a typical distribution system showing these parts. Power would be taken from the sub-transmission station or stations to distribution sub-stations by means of primary distribution or feeders. There may be need for a primary distribution system to supply a few large loads such as industrial loads in the area at high voltage. The sub-transmission substation steps down the transmission voltage to primary distribution levels. The distribution transformers are located at the distribution substation to change the primary distribution voltage to the secondary distribution voltage. The distribution substations are the feeding points for the secondary distribution system.

The distributions are run from the distribution substations or feeding points. These are conductors which are tapped to supply the various loads of the consumers by service mains [3].

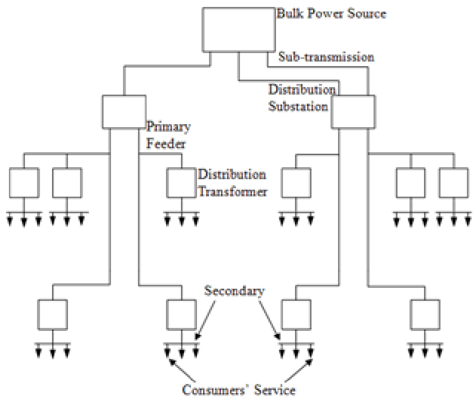

Figure 1. Typical Distribution System Showing Component Parts

A. Classification of Distribution Systems

1) According to voltage: the distribution system may be primary or secondary. The primary distribution is done at 33kV, 66kV and the secondary at 11kV.
2) According to the kind of currents: it may be carrying DC or AC.
3) According to service: it may serve a house (domestic) or an industry.
4) According to construction: it may go along roads with poles, insulators, etc., or underground in trenches.
5) According to connection schemes: the distribution scheme may be of three types are radial, ring main and interconnection scheme [3].

B. Requirements of a Good Distribution Scheme

1. Reliability of supply should be maintained. If there is a breakdown, it should be for the least possible time.
2. The voltage drop at any consumer terminal should remain within ± 5 % of the declared voltage.
3. The efficiency of the system should not be less than 90 %.
4. The insulation resistance of the system is high so that there is no leakage.
5. The system should be economical [3].

C. Calculation of Distributor Sizes

Distributors are conductors that are tapped for supplying loads to consumers. The main requirement of these conductors is to supply power to consumers at the rated voltage within the permissible voltage variation. The voltage at the last consumer connected across the distributors should not fall below the minimum prescribed value.

The distributors are fed from the feeding points or substations. The types of load on the distributors are concentrated loads at various points of tapping of the service mains. If the loads are uniformly distributed such as street lighting loads of equal sizes at equal distances, they may be represented as uniformly distributed load per unit length of the distributor.

In practice, it may be that the loads are both concentrated at various points as well as uniformly distributed. The voltage drops that occur due to such loads can be worked out and the voltage at the terminals of the last consumer can be found out [4].

D. Types of Fault

The types of fault that can occur depends on the distribution system-single line to ground fault, double line to ground fault and line to line fault are common to single phase, two phase and three phase systems. The three phase faults are (very rare) characteristic only of three phase systems (less than about 5% to total faults).

A fault in an electrical power system is the unintentional and undesirable creation of a conducting path (a short-circuit) or a blockage of current (an open-circuit). The short-circuit fault is typically the most common and is usually implied when most people use the term fault.

The causes of faults include lightning, wind damage, trees falling across lines, vehicles colliding with towers or poles, birds shorting out lines, aircraft colliding with lines, vandalism, small animals entering switchgear, and line breakers resulting from excessive ice loading. Power system faults can be categorized as one of four types. The single line to ground faults result when one conductor falls to ground or contacts the neutral wire. Single line to ground faults is relatively frequent (more than about 70%). Double line to ground faults result when two conductors fall and are connected through ground, or when two conductors contact the neutral of a three phase/two phase grounded system.

Line to line faults result when conductors of a two phase or three phase system are short circuited. Balanced three-phase and the first three types constitute severe unbalanced operating conditions [1].

E. Voltage Regulation

The regulation is the change in voltage at the receiving end when full load is thrown off, the sending end conditions remaining constant. It is usually expressed as a percentage of the voltage at the receiving end.

The method of voltage regulation used on distribution systems are:

1) Transformer taps, 2, 5, 7 % taps are generally used.
2) Automatic-control induction-type voltage regulators.
3) Boosters.
4) Automatic tap-changers and boosters.
5) Shunt capacitors.

Automatic voltage boosters are less expensive than induction regulators and are important in improving the service in low-density areas, particularly on long, rural lines.

Automatic tap changing on-load is also used with large distribution transformers and power transformers in substations to control the voltage on a bus or feeder.

For satisfactory operation, operation of regulators on distribution circuit must be coordinated with the system design and the regulator setting may be determined to give the best results.

The distribution system may be designed with the following limitations:

1) 1.1.8% voltage drop is allowed between the primary of the first transformer and end of the secondary of last transformer with maximum load on the circuit and the maximum load on the last transformers and secondary.
2) 2. Regulators are set up to provide a voltage, at the primary of the first transformer of about 4 % more than the normal voltage.

When automatic control is used for the distribution System, the contact making voltmeters are set to the Value of the standard voltage to be maintained.

$$V.R = \frac{V_S - V_R}{V_R} \times 100 \quad (1)$$

If the receiving end voltage is much less than the sending end voltage, the regulation is said to be poor [2].

F. Substation Grounding System

The following information is mainly concerned with personnel safety. The information regarding the grounding system resistance, grid current, and ground potential rise can also be used to determine if the operating limits of the equipment will be exceeded.

Safe grounding requires the interaction of two grounding systems:

1. Intentional ground, consisting of grounding systems buried at some depth below the earth’s surface.

2. Accidental ground, temporarily established by a person exposed to a potential gradient in the vicinity of a grounded facility.

Earth resistance is the total resistance of electrode to the current. The resistance of the earth becomes smaller and smaller as its distance from the electrode increases.

III. ELECTRICAL PARAMETERS OF SUBSTATION

A. Types of Conductors

Different types of aluminium conductors are

AAC – all aluminium conductors

AAAC – all aluminium alloy conductors

ACSR – aluminium conductors, steel-reinforced

ACAR – aluminium conductors, alloy-reinforced

B.Choice of Circuit Breaker

The value of the kA rating determines how much current the circuit breaker can withstand under fault conditions. The circuit breaker only has to withstand this for a brief period of time, usually the time it takes for the circuit breaker to trip.

The maximum amount of current that can flow through a circuit is determined by the size of the transformer feeding the circuit and the length of the cable run from the transformer. This is often called the downstream short circuit current. This will determined the maximum kA rating required for the main circuit breaker.

Under fault conditions (such as a short circuit) much more current flows through the circuit than what it was designed for. A circuit that was designed for a maximum of 20A may suddenly be drawing hundreds, if not thousands of amps. The circuit breaker will trip if this occurs.

C.Resistance

The effective resistance of a conductor is

$$R = \frac{\text{Power loss in conductor}}{|I|^2}$$

Directive current resistance is given by the formula

$$R_o = \frac{\rho L}{A} \qquad (2)$$

Where,

ρ = resistivity of conductor (Ω-m) or (Ω-cmil/ft)

L = length (m) or usually given in ft

A = cross- sectional area (m^2) (or)

A = circular mil; (cmil)

At 20°C for hard-drawn copper ρ is 10.66 Ω-cmil/ft (or) 1.77×10^{-8} Ω-m.

At 20°C for aluminum at 20°C ρ is 17.00 Ω-cmil/ft (or) 2.83×10^{-8} Ω-m.

The resistance can be calculated by

$$\frac{R_2}{R_1} = \frac{T + t_2}{T + t_1} \qquad (3)$$

Where,

R_1, R_2 = the resistances of the conductor at temperatures t_1 and t_2

T = Operation temperature of conductor

t_1, t_2 = Conductor temperature

T = 234.5 for annealed copper of 100% conductivity

T = 241 for hard-drawn copper of 97.3% conductivity

T = 228 for hard-drawn aluminum of 61% conductivity [3]

D. Skin Effect

The resistance of non-magnetic conductors varies not only with temperature but also with frequency. As the frequency of alternating current increases, the non-uniformly of distribution becomes more pronounced. As increase in frequency causes non-uniform current density. This phenomenon is called skin effect. Skin effect is due to the current flowing nearer the outer surface of the conductor as results of non-uniform flux distribution in the conductor. This increases the resistance of the conductor by reducing the effective cross-section of the conductor through which the current flows.

Skin effect is a function of conductor size, frequency, and relative resistance of the conductor material. The following formula should be used to consider the skin effect in resistance calculation [3].

$$R_{ac} = kR_{dc} \qquad (4)$$

Where,

K is a function of X.

$$X = 0.063598 \sqrt{\frac{\mu f}{R_{dc}}} \qquad (5)$$

Where,

f= frequency (Hz)

μ = permeability (1.0 for non- magnetic material)

R_{dc}=dc resistance in ohms per mile

E. Line Losses

Line losses are a result of passing current through an imperfect conductor such as copper. The conducting material has characteristic impedance that produces a voltage drop along the line proportional to the current flow.

The resistive component (R) of the impedance (Z) contributes to active power losses (P_{loss}).

The line losses can be calculated based on the measured current load as:

$$P_{loss} = I^2R \qquad (6)$$

Where,

I = current

R= resistance

For a three phase system, the losses for each phase are calculated separately according to the measured current as:

$$P_{loss} = 3 \; I^2R \qquad (7)$$

F. Efficiency

When the load is impressed on a line, along with V.D, power loss occurs in the line due to impedance. This causes the power at the receiving end to be less than the power at the sending end. The ratio of the receiving end power to the sending end power of a line is called its efficiency. This is also expressed as percentage.

$$\text{Efficiency} = \frac{V_R \cos\phi}{V_R \cos\phi + \sqrt{3}IR} \times 100 \qquad (7)$$

The line efficiency should be high. So, means are adopted to keep line losses as small as possible [8].

IV. DISTRIBUTION SYSTEM OF OHNTAW SUBSTATION

In Ohntaw substation, incoming lines are 230kV and outgoing lines are 33kV and 66kV. Incoming lines are Belin 1 and Belin 2. They are overhead lines. Outgoing lines 33kV are Sagaing, Industrial Zone, Ohntaw-Sadaung, Texitile Mill and Myinmu-Myaung. Outgoing lines 66kV are Tat Ywa, Aradaw-2, Sin Tat and Pway Ywa.

The 230kV bus stepped down to 33kV and 11kV by 60 MVA stepped down transformer. And then, it is stepped down to 66 kV and 11kV by 100MVA stepped down transformer. After stepping down the high voltage to the required voltage level, the lines at this voltage would be leaving substation as outgoing feeders.

V. DESIGN AND CALCULATION OF ELECTRICAL PARAMETERS

A.Selection of Cable Sizes

The cable size is varied according to the size of load. The maximum current is calculated by 369.59 A. So,ACSR 120mm^{2}cable can be chosen and it maximum current carrying capacity is 420A for 33 kV lines and ACSR 200mm^{2}cable can be chosen and it maximum current carrying capacity is 590A for 66kV lines.

B.Fault Calculation and Choice of Circuit Breakers

The installed interrupting capacity of 33 kV gas circuit breaker is 36kV, 1600A,I_s=31.5kA,1964MVA.The actual fault current is calculated as 9229.5A and fault MVA is 527.54MVA.

The installed interrupting capacity of 66 kV gas circuit breaker is 72.5 kV, 2000 A, I_s=31.5kA, 3956 MVA. The actual fault current is 6930.7 A and fault MVA is 792.29 MVA.

C. Selection of the Current Transformer and Potential Transformer

The CT ratio of current transformer is calculated as 200:5 for 33kV lines. So, The size of current transformer is 200 – 400/5/5/5 A. The voltage transformers ratio is calculated as:

$$\frac{19.0526\times 10^3}{110} = \frac{173.2054}{1}$$

So, The selection of the voltage transformer ratio is 33kV/$\sqrt{3}$: 110 V/$\sqrt{3}$.

The CT ratio of current transformer is calculated as 300:1 for 66 kV lines. So, The size of current transformer is 200 – 400/1/1/1 A. The voltage transformers ratio is calculated as:

$$\frac{38.1051\times 10^3}{110} = \frac{346.41}{1}$$

So,The selection of the voltage transformer ratio is 66kV/$\sqrt{3}$: 110 V/$\sqrt{3}$.

D. Calculation of Voltage Regulation, Line Losses and Line Efficiency

In Ohntaw substation, all feeders are overhead ACSR cables. There are five (33kV) outgoing feeders and three (66kV) outgoing feeders.

Table 1 Results from Selection of Cable Size

Feeder Name	Rated Voltage (kV)	Conductor Size (mm^2)	Types of conductor
Sagaing	33	120	ACSR
Industrial Zone	33	120	ACSR
Ohntaw-Sadaung	33	120	ACSR
Textile Mill	33	120	ACSR
Myinmu-Myaung	33	120	ACSR
Tat Ywa	66	200	ACSR
Aradaw-2	66	200	ACSR
Sin Tat	66	200	ACSR

Table 2 Results from Calculation of Voltage Regulation, Line Losses and LineEfficiency (33kV)

Feeder Name	Conductor Size (mm^2)	Rated Voltage (kV)	Max Load (MW)	Voltage Regul; %	Line Loss (kW)	Line Effi; %
Sagaing	120	33	16.9	10.51	1294.49	92.2
Industrial Zone	120	33	10.7	5.9	489.4	95.4
Ohntaw-Sadaung	120	33	14.7	-31.39	12406.3	63.3
Textile Mill	120	33	0.7	1.06	5.92	99.2
Myinmu-Myaung	120	33	5.9	7.19	631.11	89.7

Table 3 Results from Calculation of Voltage Regulation, Line Losses and LineEfficiency (66kV)

Feeder Name	Conductor Size (mm^2)	Rated Voltage (kV)	Max Load (MW)	Voltage Regul; %	Line Loss (kW)	Line Effi; %
Tat Ywa	200	66	1.2	0.48	3.45	99.7
Aradaw-2	200	66	1.7	2.54	25.68	98.5
Sin Tat	200	66	1.5	0.03	0.31	99.9

E. Load Utility

Ohntaw substation has two incoming lines and eight outgoing lines. Belin 1 and Belin 2 are incoming lines. Sagaing, Industrial Zone, Ohntaw-Sadaung, Textile Mill and Myinmu-Myaung are 33kV outgoing lines. Tat Ywa, Aradaw-2 and Sin Tat are 66kV outgoing lines. Daily load of Ohntaw substation is shown in Figure 1.

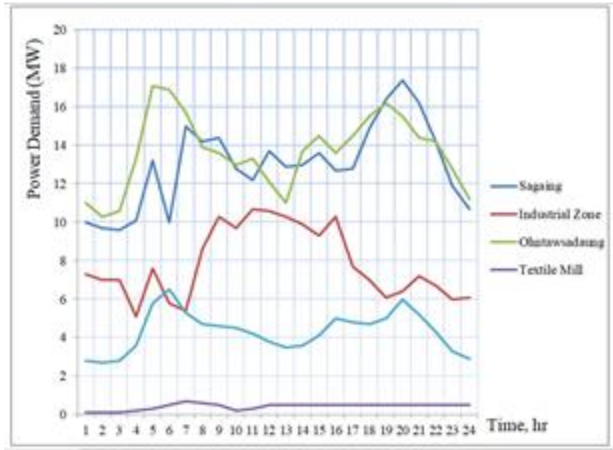

Figure 2.Daily Load Utility Curve of Outgoing Feeders of Ohntaw Substation 33 kV side

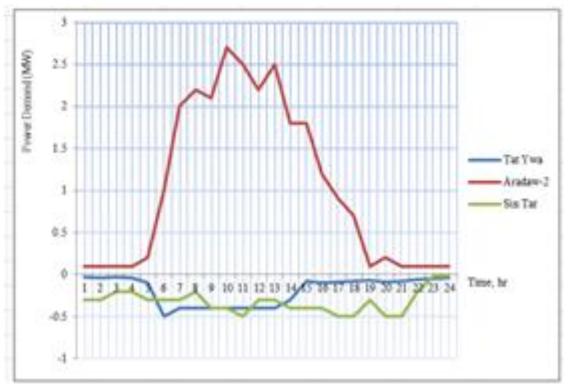

Figure 3.Daily Load Utility Curve of Outgoing Feeders of Ohntaw Substation 66 kV side

VI. CONCLUSIONS

This paper expresses the function of distribution system.The calculation of faults, conductor sizes, voltage regulation, line losses and line efficiency for outgoing feeders are expressed.Circuit breakers can be chosen from fault calculations. Conductor sizes can also be chosen from maximumload current. The larger conductor size decreases the line losses and increases the line efficiency.Current transformers are selected according to the current ratio and voltage transformers are selected according to the voltage ratio. The result of voltage regulation, line losses and line efficiency of each outgoing feeders are calculated and described in this paper.This paper emphasizes the distribution system of substation. Moreover, daily load utility shows the curve in this paper.

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REFERENCES

[1] T.A. SHORT : Electric Power Distribution Handbook, (2004)

[2] Wallace S.Read : Power Distribution for Industrial Plant, IEEE Standard Board, (1997)

[3] EP-2016 Transmission, Distribution, Switch Gear and Protection

[4] EP-4036 Power System Design

[5] A. Helseth, "Modelling Reliability of Supply and Infrastructural Dependency in Energy Distribution Systems," 2008.

[6] R. Billinton and R. N. Allan, Reliability evaluation of power systems, Second ed. Springer Science & Business Media, 1996.

[7] H. L. Willis, Power distribution planning reference book. CRC press, 2004.