Design Development and Simulation of Mobile Substation for Distribution Network

Ankit M. Malvi[1] Mr. Gopal K. Sharma[2]
[1,2]Department of Electrical Engineering
[1,2]Pacific University, Udaipur

Abstract— With the increase in population, the growing demand for energy in urban areas is compelling the utilities to expand their supply network. Higher levels of demand for power must be met at short notice and physical space available used to an optimum. One solution to such cases is a mobile substation. This does away with costly construction work and if necessary, the substation can move location in container, together with its foundation which includes switchgear as an assembly of equipment, transformer and control panel cabin. When mobile substation is used to restore electrical service, it function as part of the permanent grid system. The purpose of this thesis is to evaluate the Design parameters for Mobile and/or Compact Substation for different Applications and identify the situations needing the mobile and/or compact substation.

Key words: Coductor, Insulator, Circuit Breaker

I. Introduction

In this paper concept of mobile substation and also design, development, and simulation of mobile substation have been presented.

The growing demand for energy in urban areas is compelling the utilities to expand their supply networks. Higher levels of demand for power must be met at short notice and the physical space available used to an optimum. Increasing use is being made in such cases of gas insulated high-voltage switchgear housed in buildings. SF6 Gas Insulated switchgear is widely used for construction of compact substation. Their compact design also allows them to be used in very confined spaces. There are, however, also cases in which the construction of a permanent, solid building for gas-insulated high-voltage substation is too costly or nearly impossible. For specific application as well as for compaction it is necessary to construct mobile substation.

For example big rural conventions, exhibitions, kumbhmela, construction power for big power projects, industrial projects, road construction etc. may need temporary power supply. Deployment of D.G. sets may become expensive. If the H.V. or E.H.V. transmission network is available nearby, installation of mobile substation is the answer.

Many underdeveloped countries in African sub-continent electrical power is not available in far flung areas. D.G. sets are deployed for supplying lightning loads at night. Mobile distribution substation can come as a blessings for such regions. The solar energy is catching attention of the world now. A mobile substation with battery storage scheme and a mobile substation can provide steady and stable power in a Stand Alone mode.

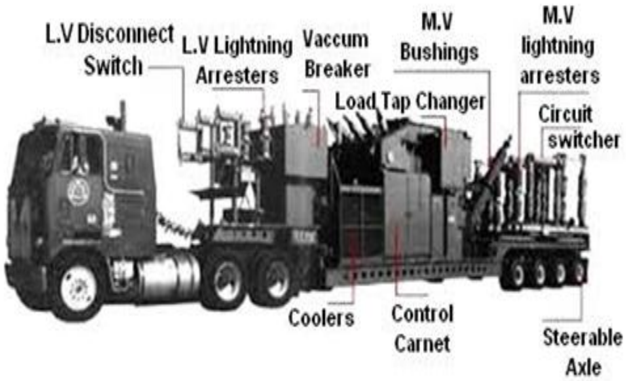

Fig. 1: Layout of Mobile Substation

II. Selection of Proposed Mobile Substation Equipment

Deciding substation equipments and their ratings is important task of substation design. Selection of voltage level plays an important role in designing substation and its equipments. Major parameter considered in selection of voltage level depends on amount of power to be transferred. Depending upon requirement, mobile substation is placed for temporary service, which has to match the system voltage level.

Main switchyard equipments:

1) Conductor
2) Insulator
3) Lightning arrester
4) Bushings
5) Current transformers
6) Voltage transformers
7) Disconnector / Earthing switches
8) Circuit breaker
9) Central control cubide
10) Drive mechanism
11) Power transformer
12) Vaccum circuit breaker
13) Battery
14) Air conditioner.

A. *Selection of Trailer*

In the mechanical layout and the choice of equipment however there are essential differences due to the limitations in the dimentions and also weight of the trailer. Those will determine the maximum height, width and length of the trailer which may vary from country to country between 2.6 and 3.5 m width, 4.4 and 4.8 m height and 14 to 25 m length.

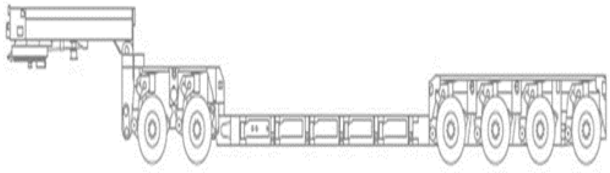

Fig. 2: Layout of Low-bed semi-trailer

The maximum weight depends on the type of trailer. Consider type of trailer Low bed Semi-trailer/ Semi low loaders, Trailer length -17 m, Trailer Width - 3.4m, Operating Platform height - 1.2m, Gross Load Capacity - 100tons,Steering Angle - 600max.

III. ENGINEERING DETAILS

A. Voltage Regulation

These calculations are required to quantify the behavior of the transmission line with reference to the tower configuration and the conductor material. They also help in deciding the efficiency of the transmission line. As a matter of fact, before positioning of the mobile substation, it will be necessary to ascertain that voltage regulation on the feeder is within limit

$$\text{Voltage Regulation} = \frac{|V_s| - |V_r|}{|V_r|} \times 100$$

B. Inductance And Capacitance Calculation

These calculations are required to determine the losses occurred in the line. Once the losses in the line is known it helps in deciding the efficiency of the line and the tap setting of the transformer to compensate losses occurred in the line.

Equivalent GMD:

$$D_{eq} = \sqrt[3]{GMD_R \times GMD_Y \times GMD_B}$$

Calculation of GMR:

$$GMR = 0.7788 \times r$$

$$\text{Inductance L} = 2 \times 10^{-7} \ln(\frac{D_{eq}}{GMR}) H/m$$

$$\text{Capacitance C} = \frac{2 \times \pi \times \epsilon}{\ln(\frac{D_{eq}}{GMR})} F/m$$

Conductor Type	Single AAAC Dog
Conductor Diameter D (mm)	12.78
Inductance L (H/phase/km)	0.001308
Capacitance C (μF/phase/km)	0.0088375
Total Inductance L (H/phase)	0.003924
Total Capacitance C (μF/phase)	0.0265125

Table 1: Inductance and Capacitance of AAAC Dog Conductor

C. Line Parameter Calculation

The total reactance of the line X = 2πfl
The total impedance of the line Z = R + Xj
Voltage Drop in line V = Z × I

D. Sag and Tension Calculation

The case in which the existing line is some kms away from the proposed location of mobile substation, one has to take tapping and bring it to proposed location with the help of pole structure and hence calculation for sag and tension becomes necessary. Specification of AAAC Dog conductor for 66kV line.

Specification	Unit	Value
Overall Diameter	m	1.28×10^{-2}
Cross-sectional area	*m*2	9.95×10^{-5}
Ultimate Tensile Strength	Kg	2.984×10^{3}
Weight of conductor	Kg/m	0.273
Modulas of elasticity	Kg/m^2	6.42×10^{9}
Coefficient of linear expansion	/^{0}C	2.30×10^{9}
Span	m	125

Table 2: Data for AAAC Dog Conductor

$$\text{Sag S} = \frac{w \times L^2}{8 \times T}$$

Tension T= f ×A

E. Direct Stroke Lightning Protection

For preparation of DSLP [20] diagram of this substation, Fixed angle method is used in which protected distance from shield wire can be calculated. In this method, Angle of Protections, between shield wires = 600 and outside shield wire = 450 are considered as shown in figure,

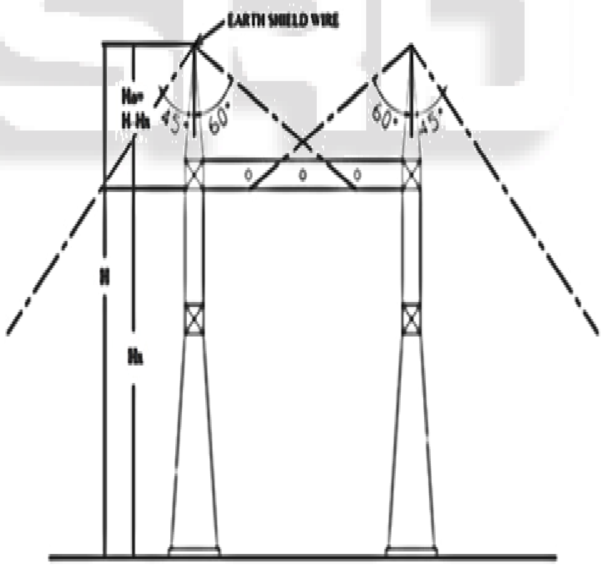

Fig. 3: Direct Stroke Lightning Protection Diagram

The calculations for the Lightning protection by shielding wire are based on IS:2309 for lightning protection.

- Height of Shield wire = h meter
- Height of the object to be protected = hx meter
- Height of the lightning conductor ha = h – hx

The protective angle of shielding for parallel shield wires at outer side is considered as 450.

$$\tan 45^0 = \frac{r_x}{h - h_x}$$

$$\text{Radius of protective zone } r_x = \tan 45^0 (h - h_x)$$

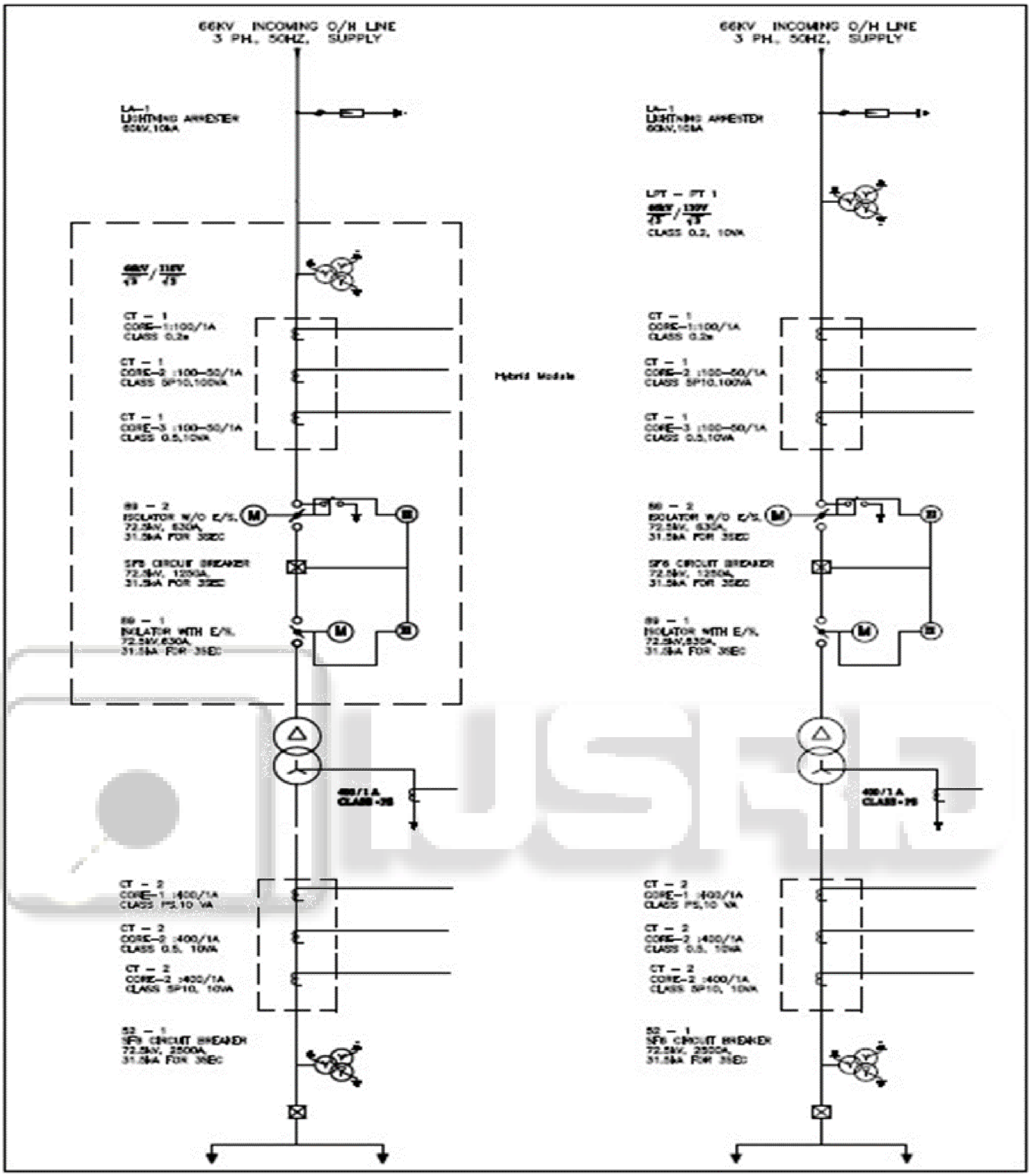

Fig. 4: SLD of Mobile substation

IV. SIMULATION AND RESULT FOR MOBILE SUBSTATION

In Model-Based Design, a system model is at the center of the development process, from requirements development, through design, implementation, and testing. The model is an executable specification that is continually refined throughout the development process. After model development, simulation shows whether the model works correctly. The Simulation is carried out on the proposed mobile substation model in order to ensure the proper selection of the mobile substation equipment. The simulation is carried out for various normal operating condition and fault condition. The given simulation model comprises several elements like, an infinite voltage source, feeder, circuit breaker, power transformer and load. The above model represents the normal operating condition of proposed substation, in which all the equipment are in their normal operating range and the entire system is healthy.

A. Simulation Result At Normal Operating Condition

Under normal operating condition, it is desired to have nominal rated voltage and current in the system. The given simulation results shows the nominal rated voltage and current on 66kV side in the system and also on 11kV side in the system. The nominal rated voltage and current are matching the theoretical values.

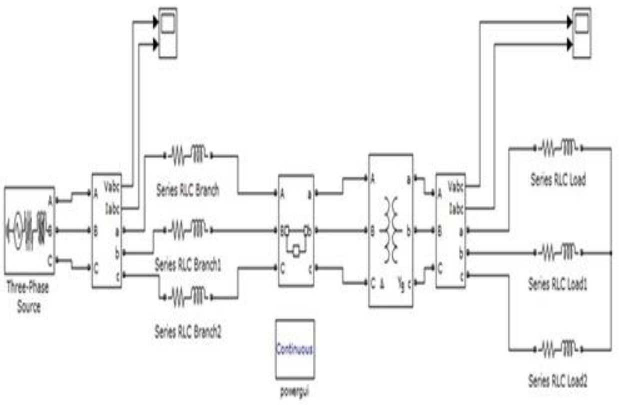

Fig. 5: Model for normal operating condition

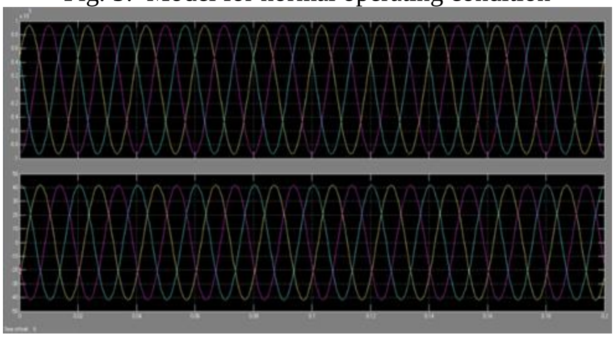

Fig. 6: Result of normal operating condition on 66kV Side

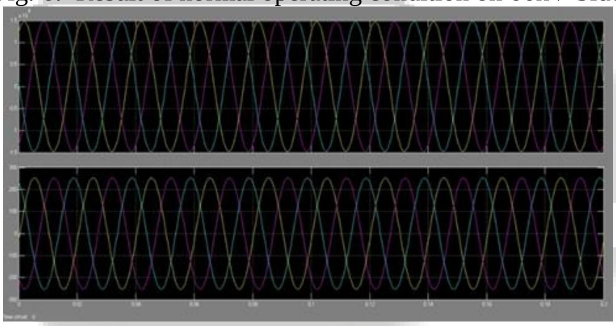

Fig. 7: Result of normal operating condition on 11kV side

Parameter	Theoretical Value	Simulation result
Voltage on 66kV (peak voltage)	93.06 kV	93.00 kV
Voltage on 11kV (peak voltage)	15.51 kV	14.85 kV
Current on 66kV side	43.80 A	42.5 A
Current on 11kV side	262.74 A	254.5 A

Table. 3: Comparison of theoretical value and simulation result

B. Simulation Result At Fault Condition

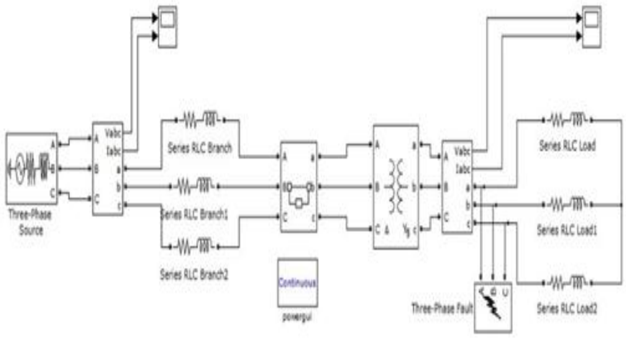

Fig. 8: Model for fault condition

The above model represents the fault condition of proposed substation in which the severe three-phase fault take place. The given three phase fault involves ground and it take place on 11kV side. In three phase fault it is desired that operation of circuit breaker should be proper. It can be concluded from simulation result that the selection of design parameters of 66kV and 11kV circuit breaker are proper, as they carry nominal rated current and perform operation on fault condition. It is derived from simulation result at fault condition, that the short circuit current can be dissipated to ground easily, if ground resistance is maintained 1Ω and after operation of circuit breaker the system comes to normal operating condition.

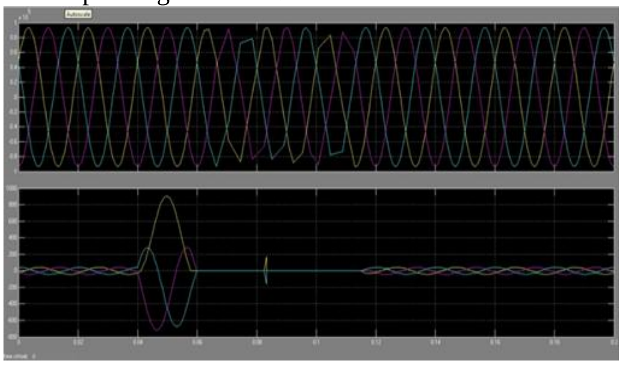

Fig. 9: Result of S.C. condition on 66kV side

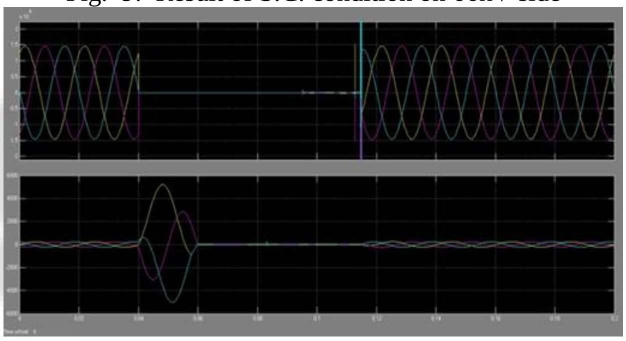

Fig. 10: Result of S.C. condition on 11kV side

V. CONCLUSION

Mobile substation is one of the unique idea for temporary arrangement of power supply. Mobile substation can be tailor made or readymade depending upon the application. Mobile substation can serve a vital role in protecting the Nations electrical infrastructure. Their flexibility allows them to switch from one purpose to another relatively easily. When needed, the Mobile substation enables temporary restoration of grid service while circumventing damaged substation equipment, allowing time to procure certain long lead-time grid components. From the presentation given in the project work, the following recommendations are made.

- The utilities should design mobile substation for distribution and transmission network for various application enumerated in the project report.
- The disasters management should also opt such mobile substation.
- For construction power mobile substation should be used to save the cost of makeshift power installation.
- For remote and inaccessible areas or renewable source of energy in a stand-alone mode use of mobile substation should be encouraged.

- The work carried out during this dissertation work can be improved further with following work.
- Design of heavy duty mobile substation with the implementation of SCADA system which can be synchronized with the protection scheme.
- The transformer is the most important part of the substation, but also the biggest and heaviest part. Therefore a compact and lightweight transformer design would contribute to the mobility of a mobile substation.

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