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To Study the Adequacy Assessment of Chitradurga distribution substation using MCS

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Abstract: Power system has dynamic behavior as it faces various disturbances like sudden variation in load, sudden variation in generation and different faults. Due to the variation of load demand, the operation, maintenance and control of power system have become a challenging task. To meet the load requirements, many noticeable research activities are going on in the field of deregulation, restructuring of power system, utilization of renewable energy sources and installing small generators at the load centre referred to as Distributed Generation (DG) etc. Furthermore, among many different types of DG units, renewable DG units are widely accepted. In this paper, adequacy evaluation of the 220kV distribution system with DG has been proposed. This concept deals with installation of additional capacity with the existing capacity for supplying load, which is provided by renewable DG units. Reliability index such as average unsupplied load (AUL) is calculated using Monte Carlo simulation (MCS).

Keywords: Adequacy Assessment, Renewable wind energy, MCS, IPP, Distribution system, Distributed generation.

I. INTRODUCTION

The basic function of a power distribution system is to supply customers with electrical energy as economical as possible. The reliability performance of the power distribution system plays an important role. For reliability assessment, the system is divided into three hierarchical levels. 1st level (HL1) consists of evaluation of generation system, 2nd level (HL2) consists of combined evaluation of generation and transmission systems, 3rd level (HL3) consists of combined evaluation of all the main sectors of power system (Generation, Transmission and Distribution system). Due to the complexities in HL3, only distribution system is taken into account for analysis of reliability evaluation of power system. Fig 1 represents hierarchical levels of reliability assessment.

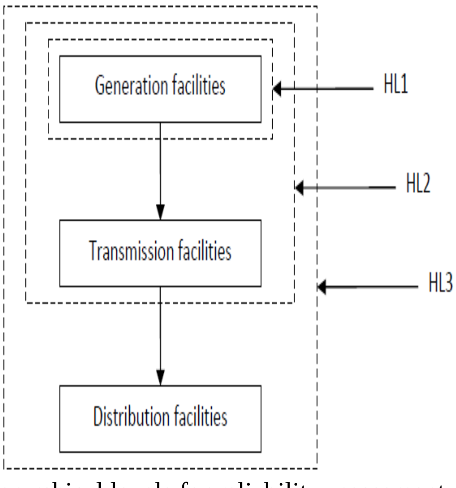

Fig 1: Hierarchical levels for reliability assessment

The reliability assessment of a distribution system can be evaluated by two attributes: adequacy and security. Adequacy evaluation specifies the ability of the system to supply the accumulated electrical energy requirements of customers within component ratings and voltage limits, even when scheduled and unscheduled component outages occur. Security evaluation specifies to the ability of power system to withstand the disturbances arising from faults or equipment outages. Most of the research work is carried out considering security as an aspect of reliability evaluation with DG and only a few are operated considering adequacy requirement.

Adequacy assessment can be operated using either an analytical technique or the Monte Carlo method. Many papers involving analytical techniques have been proposed. Present paper focuses on operation of the Monte Carlo method in distribution system adequacy assessment.MCS can be considered to be more superior to an analytical approach in situations, which cover, for example, the subsequent considerations.

1. Time reliant or sequential issues are considered.
2. The duty cycle of peak units are modeled.
3. Non exponential component state duration distributions are considered.
4. Distributions of reliability indices are required.
5. A large unacceptable set of states (unfeasible range) in multi- area generation system studies is involved.

Quantitative reliability assessments not only prefer the actual physical elements in a system in terms of their function and random behavior, but also perceive overall system operating conditions. The indices determined should be easily understandable and it should easily interpret. There are many techniques and resulting indices are applicable in the adequacy assessment of power systems.

All the techniques are commonly classified into two section, Analytical methods and Monte Carlo simulation methods. A mathematical and probabilistic model has been modeled in form of equation in analytical method

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and typically enumerates and combines the probabilities and frequencies of system states to arrive at the reliability indices. A Monte Carlo simulation delights the problem as a series of substantive experiments, the result depend on the operating characteristics of the system. The reliability indices are then predicted by performing number of experiments, universally reliability evaluation of engineering system focus on analytical methods but MCS used as an alternative solution.

Distributed generation (DG) is commonly used in small-scale (1 KW–50 MW) electric power generators that produce electricity at a site close to customers or that are connected to an electric distribution system. It includes combustion gas turbines, fuel cells, solar, wind turbine and electric vehicles etc.

Due to the improvements in distributed generation technology, some amount of spare capacity is also added at the customer sites. DG assures sufficient and acceptable continuity of supply, in the event of failure in the Generation, Distribution, and Transmission systems.

The degree of redundancy has to be proportionate with the requirement, that the supply should be as profitable as possible. It is necessary that maximum reliability is achieved within a given set of economic constraints. DG units are closer to customers so that transmission and distribution costs are avoided or reduced. It is straight forward to find sites for small generators than for large ones.

This paper abode the random nature of the distribution system operation when DG units are operating laterally within the system. Based on load requirement DG are manage to operate, the mechanism of turning on and off each DG unit will be a random process. The random on and off cycle of each DG will result in a random contribution of this DG to the system overall power capacity. Therefore, the overall system power capacity will vary randomly and the determination of this capacity requires proper modeling of the random operation state of the system.

II. PROBLEM FORMULATION

In this section, adequacy evaluation of an electrical distribution system with DG is described. The assumptions considered are,

1. Renewable DG used is wind power generation.
2. Hourly load characteristic of Distribution system is known a priory.
3. Due to future load growth, distribution systems may not be able to supply required load and hence additional energy is required. To avoid expansion of substation, DG installed close to them.

The interpretation of ability of a distribution system for satisfying the total system load is done as a part of adequacy assessment. Certainly the average amount of energy not supplied is given as adequacy index. MCS is used for distribution system adequacy assessment to endure the randomness of power generation in wind turbines.

The subsequent control strategies are applied throughout the study

- Unit power factor is maintained for all wind based DG.
- Wind-based DG output power is regulated and used for satisfying load. Extra energy will be stepped up to grid.
- All DG ratings are considered in Million units.

III. DESCRIPTION OF THE MONTE CARLO METHOD FOR ADEQUACY ASSESSMENT

In MCS a random value is selected for each of the tasks, based on the range of estimates. The model is predicted based on this random value. The outcome of MCS are recorded and performed for different random values. A typical MCS calculates the model hundreds or thousands of times, every time using distinct randomly generated values. The random values can be generated with the help of some random generators. After completion of simulation large number of results are obtained from the model, each value based on random input values.

A. Algorithm for Adequacy Calculation
Step 1: Consider peak load data of simulated year
Step 2: Select DG as Wind Generator
Step 3: Calculate AUL indices without adding DG.
Step 4: For with DG, Add substation power with IPP power expressed as

$$P_S = P_T + P_{DG}$$

Where P_T is substation power, P_{DG} is IPP generated power, P_S is the Total power with DG.
Step 5: Calculate Average unsupplied load as indices.

During AUL calculation the energy from the substation (P_T) curve is superimposed on the peak load curve of substation, to obtain the available margin. A positive margin reveals that the substation generation is sufficient to meet the substation load, although a negative margin reveals that the substation demand is not satisfied, extra energy is required to fulfill the demands. The average amount of the unsupplied load during each year (AUL) is estimated by running MCS for a large number of sample years and using the following equation:

$$\text{AUL} = \left|\frac{\sum \text{Negative Margin in MW}}{8760*\text{M}}\right| \quad (2)$$

M is the number of Monte Carlo experiments.

IV. STUDY AREA

For the adequacy analysis 220/66/11kV SRS Chitradurga distribution substation of state electricity board has been selected. The main supply for this network comes from 440kV station located at Guttur and from 440kV PGCIL. Substation consists of five power transformers, three are of 220/66kV 100MVA, other two transformer is of 66/11kV 12.5MVA. The two 220 kV incoming lines from Guttur and PGCIL step down voltage at 66 kV. The 66 kV bus transmits power to Hiriyur, Challakere, Turuvanur, Chitradurga and Holakere 66 kV Substation.

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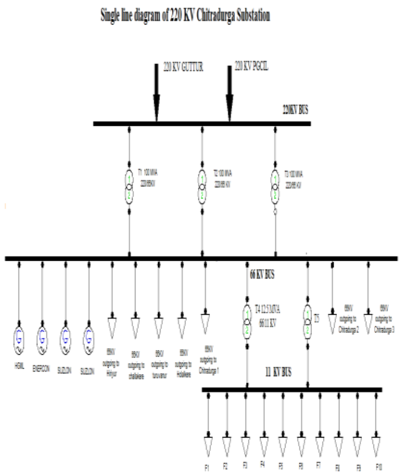

Fig 2: Single line diagram of 220/66/11 kV SRS Chitradurga substation.

The Power from Chitradurga substation is delivered through two 12.5 MVA 66/11kV transformers to 10 feeder. This Substation consists of all protective devices and measuring meters and The Independent power production (IPP) from different companies like Suzlon, Enercon, HGML, FIZA, Micon, Jindal, Pioneer, Reliance, NSL Jagallur, and Pallagata are connected to substation. Figure 2 shows the single line diagram of 220/66/11 kV SRS Chitradurga substation. For the study purpose Chitradurga 66 kV Substation is chosen for adequacy analysis. The single line diagram of 66 kV substations is shown in figure 3. The 66 kV Chitradurga bus is step down the voltage at 11 KV by using the two 66/11 kV transformer. Each transformer has 12.5 MVA rating. The 11 KV bus feed the power to 10 different feeders. The details of feeder are presented in table 1. The three IPP HGML, Suzlon, Enercon have been connected. The total consumption data required for simulation is shown in table2 and the collected data is from 2014 year. Simulation model have been developed in MATLAB software.

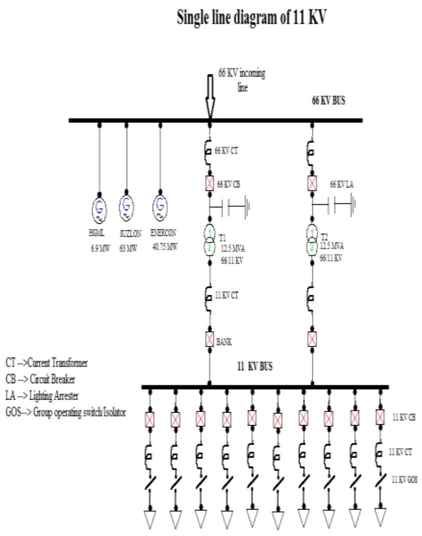

Fig 3. Single line diagram of 66 kV Chitradurga substation.

Number	Feeder name
F1	COPPER MINES
F2	KYADIGERE
F3	J.N. KOTE
F4	KASAVARATTI
F5	AUX. TRANSFORMER 1
F6	AUX. TRANSFORMER 2
F7	PALLAVAGERE
F8	STADIUM
F9	INDUSTRIAL AREA
F10	SARASWATHIPURAM

Table 1. Feeder Details.

The analysis of the case study is done in two phases. In the first phase, the adequacy assessment is performed on only its substation capacity. In the second phase, the distributed generation is included in the analysis.

Phase I: Analysis without DG

This phase is concerned with the estimation of the available substation capacity of the distribution system in the absence of the DG. The goal of this phase is to decide, whether the substation received power will be enough to cover the demand of the system all year round or there is a need for a substation expansion. To achieve this goal Energy from grid is subtracted with Total energy consumption. The details are shown in table 2. From the figure 4 it is clear that the system encountered several hours where the substation energy is not enough to satisfy the required demand, and therefore, there is a need for an increase of the overall substation available capacity

Month	Energy from grid (MU)	Total energy consumption (MU)
January	31.635	69.5034
February	47.2242	63.1324
March	43.6347	69.27218
April	39.3214	55.6192
May	15.9246	35.4214
June	3.421	46.8582
July	1.245	44.3739
August	4.431	33.5051
September	8.7314	34.7726
October	13.7823	27.485
November	14.247	33.8494
December	29.3672	50.7654

Table2. Energy from grid and Total Energy Consumption.

This result, shows a high insufficiency of the substation in each month, which is not meeting system load and cannot be used to assess the system adequacy because the analysis was performed for one sample year.

During this sample year, the energy from substation is considered to be a random variable (80 to 100% of nominal values). Therefore, different margin patterns will be expected for different sample years.

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In order to estimate average amount of the unsupplied load for any sample year, MCS was performed for a large number of sample years. The average amount of unsupplied load for each year was calculated using (2). Fig. 5 portrays the Monte Carlo convergence process. The average unsupplied load (AUL) is estimated to be 25.879 MU/year. This figure reflects the great need for substation capacity increase and the inadequacy of the system in its current structure to meet the installed demand. In the later section, the effects of running some DG in parallel with the existing substation are explained.

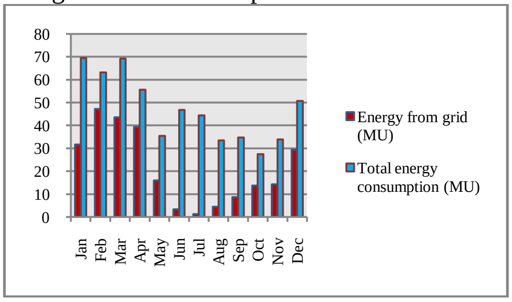

Fig 4: Grid energy and Total energy consumption.

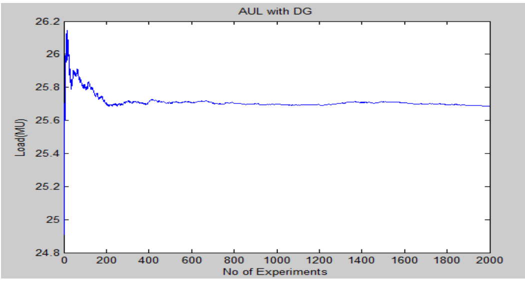

Fig.5. AUL is 25.879 MU

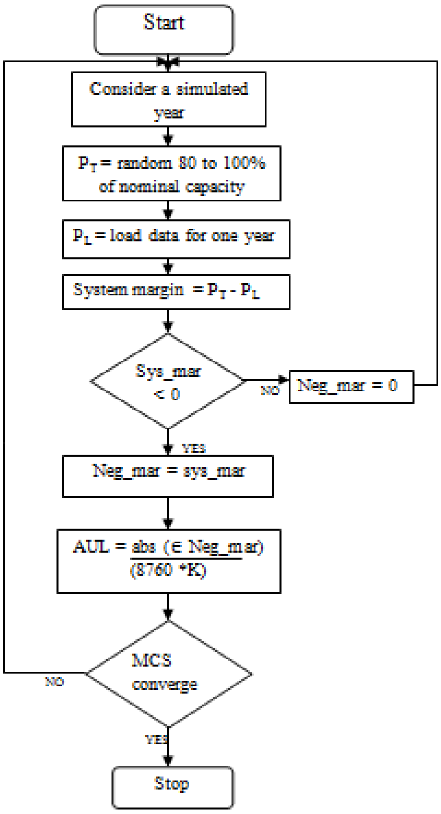

Fig 6.Flow chart for calculating AUL

Phase II: Analysis with DG

In this phase, DG units are run in parallel with the existing substation. The total energy generated from IPP is given in table 3. In order to calculate total available power, P_T is superimposed on the available P_{DG} (IPP energy) to determine the overall P_S, in this study P_T is the energy from the grid, P_{DG} is the energy from IPP. P_S is the total energy.

$$P_S = P_T + P_{DG}$$

Month	Total ipp generation (MU)
Jan	41.763
Feb	18.018
Mar	26.406
April	19.262
May	29.204
June	66.741
July	100.21
Aug	61.34
Sep	53.366
Oct	22.328
Nov	33.06
Dec	21.857

Table 3: Total IPP Generation from Enercon, Suzlon, HGML

Month	Energy from Grid+ IPP generation (MU)	Total energy consumption (MU)	Extra Energy to Grid (MU)
Jan	73.398	69.5034	3.8946
Feb	65.2421	63.1324	2.1097
Mar	70.0406	69.2721	1.1257
April	58.5833	55.6192	2.9692
May	45.129	35.4214	10.0534
June	70.162	46.8582	23.3054
July	101.45	44.3739	57.4034
Aug	65.771	33.5051	32.0657
Sep	62.0978	34.7726	28.3589
Oct	36.1103	27.4857	8.4478
Nov	47.307	33.8494	13.9569
Dec	51.2241	50.7654	0.4587

Table 4: with DG power and extra energy

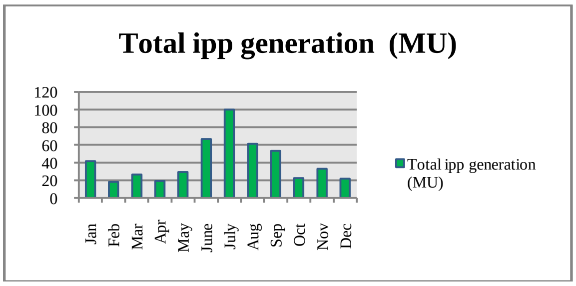

Fig.7. Total IPP Generation in MU

The comparison between the values with DG and without DG, Reveal that, DG running parallel with the substation has eliminated most of the negative margins during the

2014 year. However, the criteria to judge the adequacy of the system in this case are still the AUL per year. In this substation extra energy generated will be exported to grid. Hence if 5% Uncertainty occurs in the generation AUL is shown in figure 8 and it is estimated by running Monte Carlo simulation and similar procedure is carried out for different uncertainty. The details are shown in table 5.

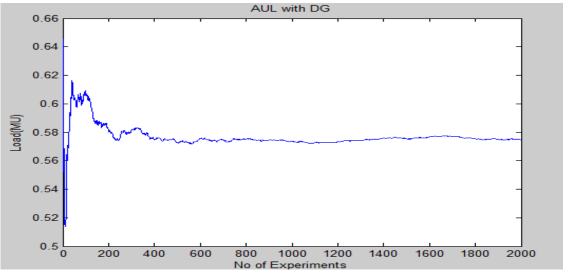

Fig 8: AUL with 5 % Uncertainty is 0.5876MU.

Uncertainty (%)	AUL (MU)
5	0.587
10	1.317
20	5.556
30	9.457

Table 5: Different ranges of Uncertainty

The conclusion drawn directly from this result is that distributed generation units, if well managed, can give a good support to the existing system.

V. CONCLUSION

In this work adequacy evaluation of the distribution system has been performed by considering wind energy based DG. Monte Carlo simulation technique is used for calculation of adequacy index. Application of the proposed approach for real system notifies that wind energy based distributed generation can provide positive margin and could be a very good value addition to minimize the curtailment of unsupplied load value as distribution system adequacy.

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BIOGRAPHIES

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