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RELIABILITY EVALUATION OF WIND POWER PLANT – A CASE STUDY

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ABSTRACT

Rapid technological progress, combined with falling costs, a better understanding of financial risk and a growing appreciation of wider benefits, means that renewable energy is increasingly seen as the best solution. Today's world needed uninterrupted qualitative electrical power with high reliability. Electrical energy that is derived from fossil fuels produces high pollution one side and on the other side electrical energy demand is continuously increasing . To tackle this typical twin problem alternative resources such as wind, solar and bio mass energy sources are to be preferred. In order to reduce the utilization of fossil fuels that is to save the fossil fuel reserves {coal, diesel e.t.c}, it is very essential to see towards the above mentioned alternative sources.

A Realistic cost benefit analysis requires evaluation models that can recognize the highly erratic nature of wind energy source and it's interdependence of random variables inherent in them.

The proposed paper immensely narrate the probabilistic reliability evaluation of wind power systems for gaining a better insight in system construction , operation and maintanance before they are built. The paper presents a case study of a **Kakulakonda, Tirumala** wind power plant with capacity 6MW for reliability assessment.

The Reliability indices such as LOLE, LOEE , SAIFI, CAIFI, SAIDI, CAIDI e.t.c are evaluated and numerically analysed to check the system performance.

KEYWORDS: Renewable Energy, Reliability, wind, LOEE, LOLE e.t.c.

INTRODUCTION

Renewable energy:

Renewable energy is reliable and plentiful and will potentially be very cheap once technology and infrastructure improve. It includes solar, wind, geothermal, hydropower and tidal energy, plus bio fuels that are grown and harvested without fossil fuels. Non-renewable energy, such as coal and petroleum, require costly explorations and potentially dangerous mining and drilling, and they will become more expensive as supplies dwindle and demand increases. Renewable energy produces only minute levels of carbon emissions and therefore helps combat climate change caused by fossil fuel usage.

Renewable energy can be locally produced and therefore is not vulnerable to distant political upheavals. Many of the safety concerns surrounding fossil fuels, such as explosions on oil platforms and collapsing coal mines do not exist with renewable energy.

Renewable energy is far cleaner than fossil fuels. Coal mining and petroleum exploration and refinement produce solid toxic wastes, such as mercury and other heavy metals. The burning of coal to produce electricity uses large quantities of water often discharges arsenic and lead into surface waters and releases carbon dioxide, sulphur dioxide, nitrogen oxides and mercury into the air . Gasoline and other petroleum products cause similar pollution. These pollutants cause respiratory illnesses and death in humans, produce acid rain that damages buildings and destroys fragile ecosystems, and deplete the ozone layer.

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Strong consensus in the scientific community states that climate change and global warming are occurring and are caused by human production of carbon dioxide and other greenhouse gases. Climate change may also damage agriculture, because widespread extinctions imperil clean water supplies and aid the spread of tropical diseases.

Wind power generation:
Wind power is extracted from air flow using wind turbines or sails to produce mechanical or electrical power. Windmills are used for their mechanical power, wind pumps for water pumping, and sails to propel ships. Wind energy as an alternative to fossil fuels, is plentiful, renewable, widely distributed, clean, produces no green house gas emissions during operation and uses little land. The effects on the environment are generally less problematic than those from other power sources.

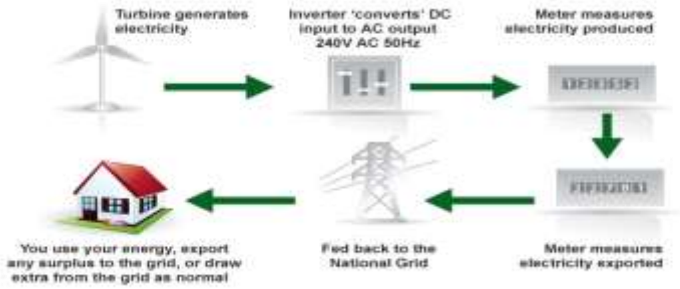

Fig 1.1 Integration of wind farm to grid

Large wind farms can consist of hundreds of individual wind turbines which are connected to the electric power transmission network. Gansu Wind Farm, the largest wind farm in the world, has several thousands of turbines. A hierarchy of wind farm of integration is shown in Fig 1.1. Onshore wind is an inexpensive source of electricity, competitive with or in many places cheaper than coal, gas or fossil fuel plants. Offshore wind is steadier and stronger than on land, and offshore farms have less visual impact, but construction and maintenance costs are considerably higher. Small onshore wind farms can feed some energy into the grid or provide electricity to isolated off-grid locations.

Need for reliability study:
It is needed to get the information we need to cut operating costs, improve efficiency and reliability, and improve system maintenance . Risk analysis and reliability studies are essential tools in designing continuous process plant power systems. Emerson Network Power's power system reliability study provides the information we need to upgrade and maintain our power delivery infrastructure.

We engineers can conduct a thorough assessment of your system's design to identify points of failure within your system. We'll investigate the number of redundancies designed into your electrical system, and determine the likelihood of a power interruption under normal or compromised power conditions. Once the assessment is complete, we provide recommendations on how to improve your system design to ensure continuous operation under all foreseeable circumstances.

We must do an economic assessment in addition with the reliability assessment in determining suitable transmission facility to deliver solar power from the PV Arrays to a power grid system. The evaluation of sufficient system facilities is essential in providing adequate and acceptable continuity of supply.

Power system reliability evaluation:
Modern electrical power systems have the responsibility of providing a reliable and economic supply of electrical energy to their customers. The economic and social effects of loss of electric service can have significant impacts on both the utility supplying electric energy and the end users of the service. Maintaining a reliable power supply is therefore a very important issue in power system design and operation.

The term "reliability" when associated with a power system is a measure of the ability of the system to meet the customer requirements for electrical energy. The general area of "reliability" is usually divided into the two aspects of system adequacy and system security [1, 2], as shown in the Fig1.2

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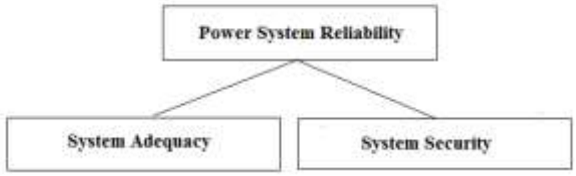

Figure 1.2: Attributes of power system reliability

CASE STUDY (KAKULA KONDA , TIRUMALA WIND POWER PLANT (6MW):

In the present paper a case study of a wind plant of capacity 6 MW located at kakula Konda, Tirumala, Andh is considered for Reliability study.
Arrangement of wind units at kakulakonda is shown in fig 2.1

Fig 2.1 Wind units at kakulakonda

Reliability Analysis

Reliability analysis of a power system can be conducted using either deterministic or probabilistic techniques. The early techniques used in practical application were deterministic and some of them are still in use today. The essential weakness of deterministic criteria is that they do not respond to the stochastic nature of system behaviour, customer demands or component failures. System behaviour is stochastic in nature, and therefore it is logical to consider probabilistic methods that are able to respond to the actual factors that influence the reliability of the system [1]. Limited computational resources, lack of data and evaluation techniques have limited the use of probability methods in the past. These factors are not valid today, and there has been a wealth of publications dealing with the development and application of probabilistic techniques in power system reliability evaluation [2-8]. This paper extends the probabilistic evaluation of power systems incorporating wind energy.

Reliability evaluation of kakula konda , tirumala wind power plant (6mw):

Table1. YEAR WISE AVERAGE GENERATION DATA

GENERATION DETAILS		
YEAR'S	AVERAGE POWER (MW)	PEAK POWER (MW)
2012	45.466	116.6075
2013	44.92541	121.405
2014	39.3666	88.0325

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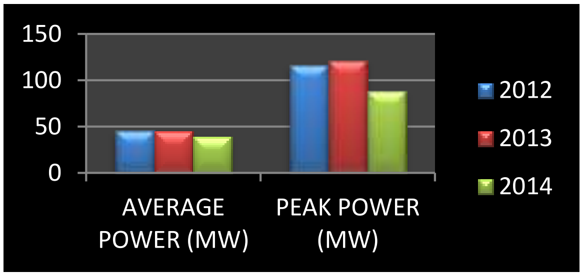

Fig 2.2 Annual Avarage And Peak Generation

The plant consists of 6 units of each capacity 1 MW. The annual average and peak power generations is shown in table 1.

Capacity outage probability table:

For calculation of reliability indices it is assumed that Availability (A) =0.98, Unavailability (U) =0.02

Table 2:Capacity Outage Probability

CAPACITY OUTAGE PROBABILITY TABLE					
STATE	**O**	**C_{IN} MW**	**C_{OUT} MW**	**P**	**E**
1	0 OUT	6	0	0.88584	0
2	1 OUT	5	1	0.018078	8760
3	2 OUT	4	2	0.003689	17520
4	3 OUT	3	3	0.00000752	26280
5	4 OUT	2	4	0.000000153	35040
6	5 OUT	1	5	3.13E-09	43800
7	6 OUT	0	6	6.4E-11	52560

Where O : Outage status of units

C_{IN}: Capacity IN in MW

C_{OUT}: Capacity OUT in MW

P: Probability of outage

E : Energy Cu rtailed in MWH

By using system annual generation data Capacity Outage Probability is evaluated and it is shown in Table 2. The variation of Energy curtailed with capacity outage is shown in Fig 2.3

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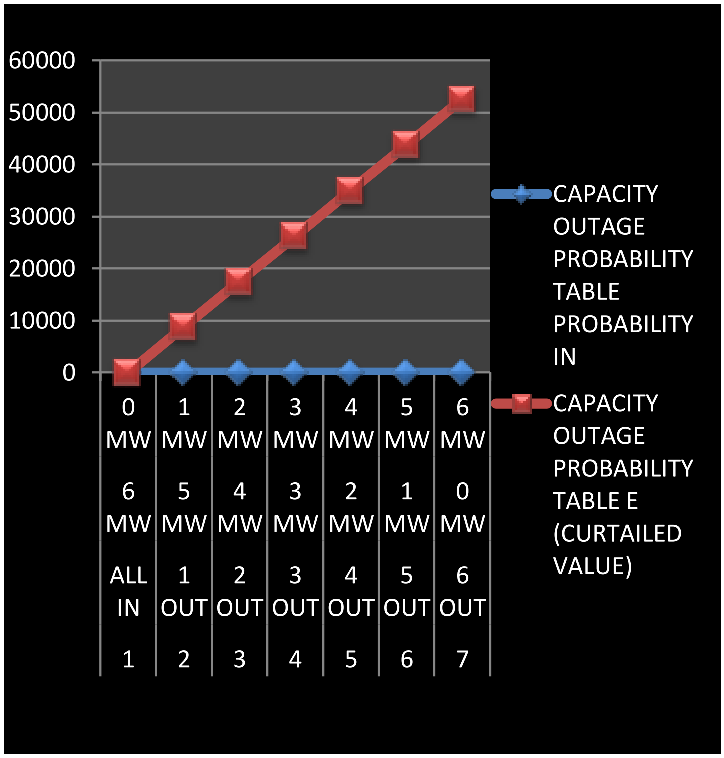

Fig 2.3 Energy curtailed VS Capacity Outage

Loss of energy indices:

Evaluation of energy indices:

The probable energy curtailed is EkPk. The sum of these products is the total expected energy curtailment or loss of energy expectation LOEE where:

LOEE $=\sum_{K=1}^{n} EkPk$

This can then be normalized by utilizing the total energy under the load duration curve designated as E.

$LOEE_{P.U.} =\sum_{K=1}^{n} EkPk/ E$

$LOEE=\sum E_K.P_K=E_1P_1+E_2P_2+E_3P_3..........E_6.P_6$

$=0\times0.88584+8760\times0.018078+17520\times0.003689+26280\times7.5210^{6}+35040\times1.5310^{7}+43800\times3.1310^{9}+52560\times6.410^{1}$
^{1} =164.6255 MWH

$LOEE_{PU} = \sum (E_K P_K) / E$

$LOEE_{PU}$ = 164.6255 / 52560

=0.003132

Energy Index Of Reliability:

The per unit LOEE value represents the ratio between the probable load energy curtailed due to deficiencies in available generating capacity and the total load energy required to serve the system demand. The energy index of reliability, EIR, is then

EIR = 1 – LOEE p.u.

EIR = 1 - 0.00313 =0.9968.

Loss Of Load Expectation:

The standard LOLE approach utilizes the daily peak load variation curve or the individual daily peak loads to calculate the expected number of days in the period that the daily peak load exceeds the available installed capacity. A LOLE index can also be calculated using the load duration curve or the individual hourly values.

Table 3: LOLE

EVALUATION OF (LOLE)				
C_{OUT}	C_{IN}	(P_K)	TOTAL TIME(T_K)	LOLE=$(\sum P_K \times T_K)$
0MW	6MW	0	0	0
1MW	0MW	0	0	0
2MW	4MW	0.0003689	33.33	0.012295
3MW	3MW	0.00000752	66.66	0.0005012
4MW	2MW	0	0	0
TOTAL LOLE=0.01279				

LOLE is evaluated for a peak load of 5MW is shown in Table 3.

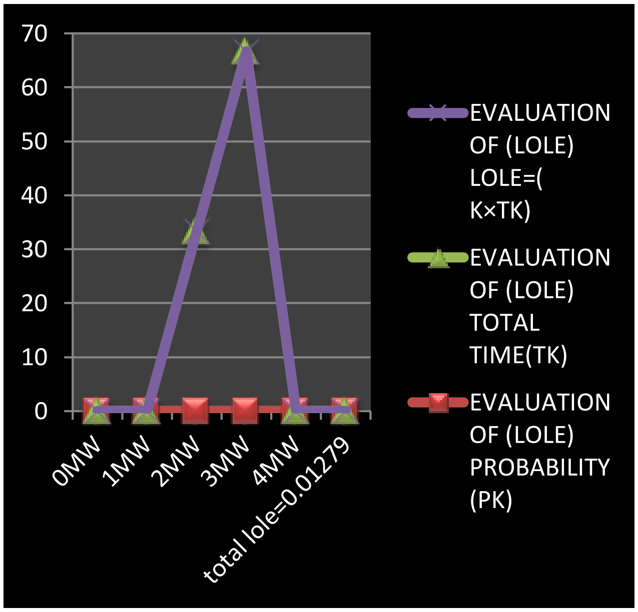

Fig 2.4 LOLE VS Capacity outage

The variation of LOLE with capacity outage and probability is shown in Fig 2.4

Customer oriented Indices

There is a lot of discussion today on improving reliability in customer service. There are partially standardized methods and calculations for calculating reliability indices. Reliability analysis that identifies the real problem areas is what is important so effective action can be taken to improve customer service. The reliability analysis begins with selection of reliability measures that actually reflect the needs of customers.

Table 4 : LOAD FEEDERS DETAILS

LOAD FEEDERS DETAILS			
S.NO	LOADS (KVA)	POWER FACTOR	TOTAL LOAD (KW)
Load1	7055 (KVA)	0.8	5644
Load2	2445 (KVA)	0.8	1956
Load3	5075 (KVA)	0.8	4060
Load4	6625 (KVA)	0.8	5300

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- Total number of customers connected to load point 1=21
- Total number of customers connected to load point 2=10
- Total number of customers connected to load point 3=18
- Total number of customers connected to load point 4=20
- Total number of customers $=\sum n=69$
- Total number of customers affected $=\sum n_a=49$
- Total number of customer interruption $=\sum n_c=59$

Table 5: Load interruption duration details

INTERRUPTION DURATIONS				
INTERRUPION CASE	L_P	N_C	**d**	L_a
LOAD 1	1	21	2	5644
LOAD 2	2,3	10,18	3,2.5	1956
LOAD 3	2	10	1	4060
TOTAL NO OF CUSTOMERS INTERRUPTION $=\sum N_C = 59$				

L_P :Load point Affected
N_C: Total no of customer interruptions
d: customer interruption duration in Hrs
L_a : Average energy not supplied in KWH

Table 6: Load interruption indices

CUSTOMER INDICES		
S.NO	INDICES	VALUES
1	SAIFI	0.955
2	CAIFI	1.2
3	SAIDI	1.84
4	CAIDI	2.15

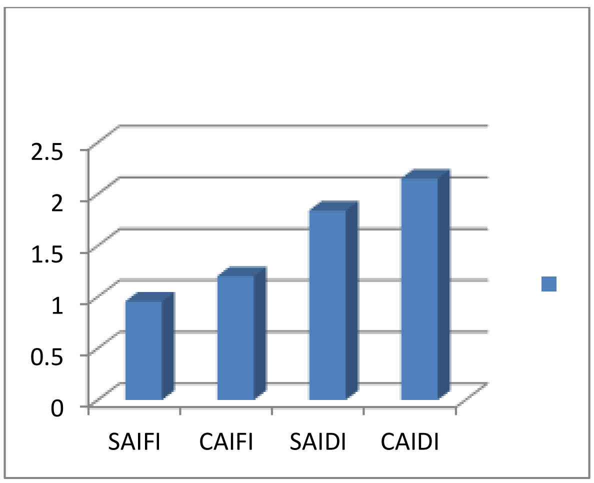

Fig 2.5 Variation of interruption frequency & duration indices

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Table 7: Availability indices

CUSTOMER INDICES		
S.NO	INDICES	VALUES
1	ASAI	0.955
2	ASUI	1.2

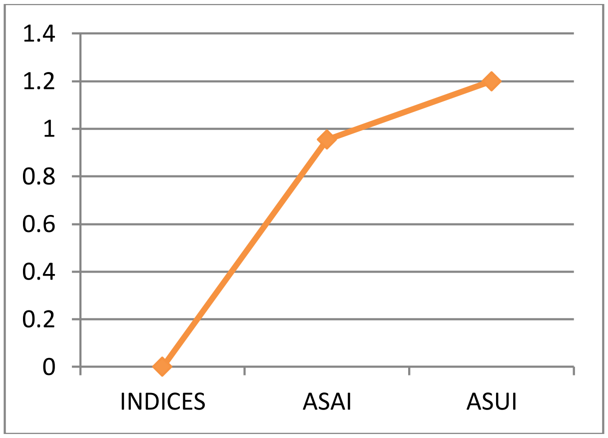

Fig 2.6 Variation of Availability indices

Table 8: Curtailment indices

CUSTOMER INDICES		
S.NO	INDICES	VALUES
1	ENS	0.955
2	AENS	1.2
3	ACCI	1.84

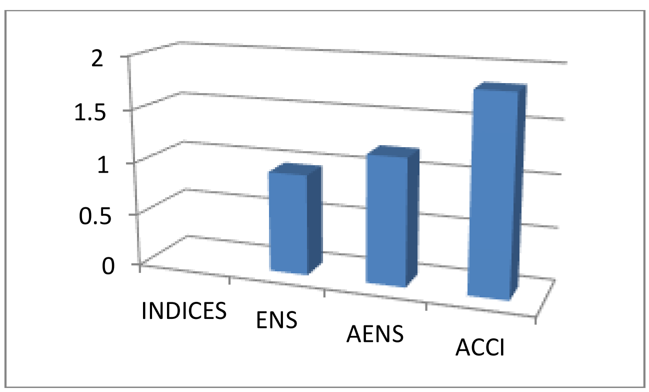

Fig 2.7 Variation of Curtailment indices

CONCLUSIONS

The principal objective of power system planner is to design reliable and economical system facilities. This objective becomes great challenging
when considering transmission system facility to deliver wind power.

A probabilistic method is presented for evaluating for contribution of wind power system to overall system reliability.

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LOLE &LOEE are useful energy indices which can provide significant information on adequate transmission line size for wind power delivery.

IEEE RTS system reliability increases with the transmission line size when wind power is integrated to a conventional system .The incremental reliability benefits are however decreased with increasing in line capacity.

Wind power generation can contribute to overall system reliability and help in reducing costumer cost of electric power interruptions offsetting the conventional fuel consumption means reducing harm full emissions produced by fuel and therefore providing environmental benefits.

By the results the loss of load energy probability of Kakulakonda wind plant is 1.279%. It indicates better delivery of load and the interruption duration is very less. The method illustrated in this paper can be used for any wind site located at any distance from a grid system, and for any level of wind power penetration in a power system.

However the reliability study of Kakulakonda wind power plant is carried and its performance is checked with suitable indices.

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