

# A Review of Probabilistic Reliability Analysis of Wind-PV Hybrid Power Systems

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## Abstract

The Utilization of renewable energy for energy generation is growing at a high rate nowadays due to rapid decrease in fossil fuel resources and serious environmental concerns. In this context wind and solar energies are of the most successfully utilized. This Paper will discuss benefits of wind-PV hybrid system, comparison of various reliability indices for different power generation system (Wind alone, Wind-PV hybrid, Solar alone etc.) Brief review of probabilistic reliability evaluation of wind-PV hybrid power system is given.

**Keywords: Probabilistic Approach, Reliability Indices, Solar, Wind, Wind-PV Hybrid System**

## I. INTRODUCTION

The energy requirement of the world is ever increasing. The increasing energy demand put a lot of pressure on the conventional energy source (oil, gas and coal). But the fossil fuel-based energy sources are limited in quantity and also cause environmental pollution. Also the formation of these fuels takes a very long time.

Table – 1

Current reserve and current production rate of coal, oil and gas.

| Resource | Unit            | Current Reserve | Current Production rate | Availability (No. of years) |
|----------|-----------------|-----------------|-------------------------|-----------------------------|
| Oil      | Billion barrels | 1047.7          | 26                      | 40.2                        |
| Gas      | Trillion scf    | 5501.5          | 102.2                   | 53.8                        |
| Coal     | Billion tons    | 984             | 4.8                     | 205                         |

Therefore, development of clean, secure, sustainable and affordable energy source should be our priority. Renewable energy sources are the best option for this. Solar and wind energies, among the renewable energy sources are most available and distributed in all over the world. Worldwide, 1000 times more energy reaches the surface of the earth from the sun than it released today by all fossil fuel consumed. The time-dependent and intermittent feature of wind speed and solar illumination but high degree of complementarity between the two sources made us choose the wind-PV hybrid system. It is also an excellence solution for electrification of remote rural areas where grid extension is difficult and uneconomical.

Brief analysis of wind-PV Hybrid system using probabilistic reliability evaluation is given. Morteza Aien, Ahad Biglari and Masoud Rashidinejad [1] proposed the application of revised capacity outage probability table (RCOPT) for hybrid wind-PV power system and also described the multi-state model for reliability evaluation. Nabina Pradhan and Nava Raj Karki [2] give the analysis of hybrid system reliability for the electricity supply for off-grid application with focus on solar photovoltaic-wind hybrid system based on current load profile of a real system. Yuan Zhu, Ping Jiang and Shaojin Yang [3] proposed a probabilistic production simulation based on the equivalent energy and frequency function method to analyze the power supply reliability and the production cost of a wind-photovoltaic (PV) hybrid generation system. Simultaneously, the optimization method of the wind and solar hybrid generation system capacity is proposed, which target to achieve a minimum production cost. S. H. Karki, R. B. Chedid and R. Ramadan [4] described the development of a general probabilistic model of an autonomous solar-wind energy conversion system (SWECS) composed of several wind turbines, several photovoltaic (PV) module and a battery storage feeding a load. The model takes into consideration outage due to the primary energy fluctuations and hardware failure.

The organization of this paper is as following. Section II explains the benefits of hybridization to reduce the uncertainties. Section III gives the comparison of various reliability indices for different power generation system. This paper concludes in section IV.

## II. HYBRIDIZATION TO REDUCE THE UNCERTAINTIES

Variability and intermittency are the most dominant properties of renewable energies. Wind speed varies with both in time and place. It varies instantaneously, therefore has a much more uncertainty rather than the other kind of energies. The solar radiation is also varies both in time and place. Many factor such as weather conditions affect the quantity of solar radiation, so this kind of energy is also faced with different uncertainties but less than the wind speed. Figure 1 shows typical curve for the variation of wind speed and solar radiation in a day.

Figure 1 depicts that in this region, when the wind speed is in its maximum, the solar radiation is in its minimum and vice versa; also it illustrates that in times which the wind speed is increasing, the solar radiation is decreasing and vice versa. It can be deduced that the combination of wind and solar energy resources can reduce the uncertainties of this kind of energies in some hours of the day.

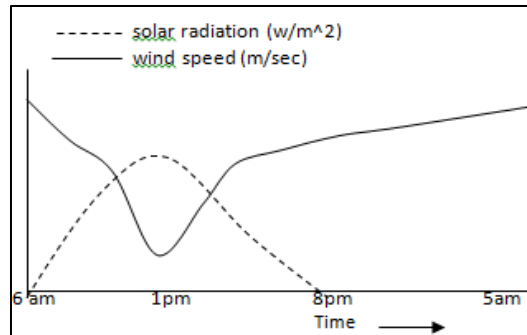


Fig. 1: Typical variation of wind speed and solar radiation in a day.

In figure 2, the comparison of the output variation for three different kinds of renewable energies utilization is presented.

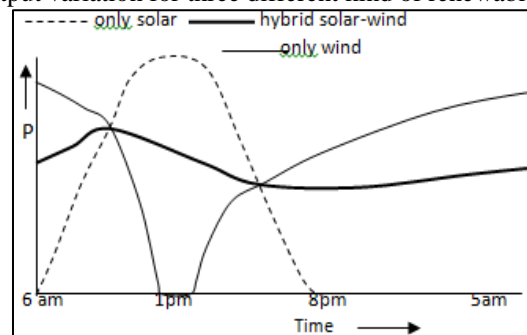


Fig. 2: Typical variation of three different kinds of renewable energy utilization.

It shows that a hybrid system has less variation compared with a solar or a wind system with the same installed capacity. In the night time, as the solar radiation becomes zero, the hybrid system behaves like a half rating wind farm. The usage of energy storage technologies such as batteries is a complementary option to reduce the hybrid power system uncertainty in both day and night times. The variation of these energies may reduce the stability of the power system, if these energies feed a big share of load; therefore, they must have a certain penetration in the whole system or efficient compensating strategies such as more primary and secondary reserves should be procured.

### III. COMPARISON OF VARIOUS RELIABILITY INDICES FOR DIFFERENT POWER GENERATION SYSTEM

Compared with the wind power generation system that has the same installed capacity, the wind-PV hybrid generation system increases the value loss of load probability (LOLP) and expected energy not supplied (EENS), but reduces the output and frequency of generator start-stop of unit capacity (FGSUC) due to complementary nature between wind and solar energy. So the production cost can be reduced.

The seasonal reliability evaluation is more complicated than the hourly reliability evaluation. Among all the seasons, only spring can fulfill the loads to fullest and hence better reliability indices. Then follow summer, winter and lastly autumn in a hierarchical order. Addition of battery storage in wind-PV hybrid will increase the reliability of system. Means without battery storage, wind-PV hybrid system is less reliable compared to the presence of battery.

### IV. CONCLUSION

Due to environmental and economic considerations, the utilization of renewable energies, especially wind and solar energies are growing with a highly increasing rate. These kinds of energies are variable and intermittent. The hybridization of energy resources can increase the versatility of the power system. Wind and solar energy can cover the uncertainty of each other in day times. The output power of renewable energies technologies is related to availability of primary energy (wind speed and solar radiation) and also the good performance of conversion devices such as wind turbine generators (WTGs) or solar cell generators (SCGs).

Compared to the wind power connect to the grid, the wind-PV hybrid system can reduce the fluctuation of the output power of the system, so that the frequency of generator start-stop of unit capacity associated with the production cost are decreased.

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