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SIGNATURE RELIABILITY EVALUATION OF RENEWABLE ENERGY SYSTEM

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Abstract: In this paper, a real-life renewable energy-based system is considered and the reliability function of this system is evaluated with the help of Universal Generating Function technique. The renewable energy-based system is considered from the project in Germany where the wind turbine and hydro power plant are combined. The wind turbines are set at the top of the hills and the reservoirs are allowed to filled with river water. This paper presents a renewable energy-based system where the wind turbine and hydro power plant are combined together to produce electricity in bulk. Universal generating function technique is used to obtain the reliability function of the proposed system. Also tail signature, signature, expected cost rate, expected lifetime and Barlow-Proschan Index are estimated.

Keywords: Universal generating function; signature; tail signature; independent identically distributed; Barlow-Proschan Index; Expected Lifetime.

MSC: 90B25, 68M15.

1. INTRODUCTION

In recent times, due to the rapid growth of population and reduction in the fossil fuels because of over usage and exploitation, the need or demand of sustainable energy has been increased. This increase in demand can be completed by the renewable energy sources. Renewable energy sources are the sources that can be used over and over again to produce energy in the form of electricity, clean water etc. These energy sources cannot be exhausted over time. To meet the increasing demands of electricity, these energy sources are established. There are different ways to produce electricity with the help of renewable energy sources such as wind turbine, hydro-electric power plant, solar panel etc.

The different characters affecting the thermal power plant's efficiency was analyzed and other factors affecting Rankine cycle's deviation from ideal working is also evaluated [8]. Author also improved the efficiency of simple Rankine cycle by using Intermediate reheat cycle where the thermal conditions of the working fluid was also enhanced. The unpredictable electricity production with the help of wind sources and how the producers of electricity had to face loss due to the imbalance in the production of electricity, was discussed [1]. The authors had presented a stochastic optimization technique to maximize the profit when the hydro and wind generators were combined together in a pool-based market of electricity, where the wind power was kept unpredictable . The combination of wind and hydro generators for the maximum and more predictable production of electricity was introduced. The Maximum power point tracking (MPPT) technique for Wind energy conversion system (WECS) was analysed [7]. Authors had given an in-depth evaluation of the above technique and discussed the strength and drawbacks of the MPPT for WECS. The solar panel array, PV inverters and EPUs in a PV system on very large scale were represented by the reliability models with the help of Universal Generating Function (U.G.F) technique [4]. Authors had also calculated an expected unit cost of electricity for the future optimal decisions. The electricity provided by that system was used for water purification. The environmental situation of the two high altitude locations in Nepal were investigated [2]. Those locations were The Lama Hotel in Raseewa district and Thingam in Makawanpur district. Authors proposed two practical and economical hybridization methods for small off-grid systems for those locations and both these systems consists of completely renewable energy sources. The thermal power plant including its importance for the healthy environment and its relevance for application from waste heat energy produced by various sources such as petrochemical plant, cement plant, refinery etc was discussed [19]. Author also talk over the benefits of these type of thermal power plant which could help in the recent environmental issues such as global warming.

In the context of UGF and signature reliability, a multistate system with common cause failure had considered and solved with the help of UGF technique [12]. Here a 2-stage approach was suggested where in first stage the system performance distribution was considered with considering the elements of system subjected to common cause failure and in second stage the contribution of the system elements which were subjected to common cause failure were correctly included. A new technique for solving the problems related to a family of multistate system reliability optimization was presented [14]. Some examples that had been taken for multistate system optimization were structure optimization, optimal multistate modernization, maintenance optimization etc. The presented technique was the combination of UGF technique and genetic algorithm technique. The models for series and parallel systems were developed and these models were discrete and continuous [6]. The models were based on UGF technique and system was considered as multistate system where the elements consist of multistate components and the elements were considered to be identical but correlated. For the complex system and binary Sliding Window System (SWS) [9] the characteristics of signature reliability was evaluated by using UGF. Also, other measures were calculated such as tail signature, signature etc. SWS and its nature was revisited by [10] and interval-valued reliability was evaluated with the help of UGF technique. The reliability of a natural gas pipeline was discussed [21]. The compressor system of that gas pipeline was considered long distanced. The system was a multistate system and the reliability of the system was provided with the help of UGF technique. Here two models were considered, in model 1 the reliability of each compressor was considered and in second model the whole system was considered as a multistate component. A-within-B-from-D/G SWS was proposed by [11] and multiple failure case was considered with the system. UGF technique and Owen's method were used for the evaluation of reliability function and signature of the system. A SWS with the criteria of two failures was considered [15]. In the system x number of multistate elements were taken which were arranged linearly. The elements had varying rates of performance. The failure condition was if total k number of groups failed and each group contained r consecutive elements and if the gap between any two adjacent failed groups was less then m number of groups which were working and the group also contained r number of elements which were consecutive. The work in UGF was extended and corresponding algorithm was suggested.

As discussed above about renewable energy and UGF technique, an example based on the above topic is proposed and solved. In section 2 the description of the model is given where the structure model is explained. In section 3 the working of the wind turbine and hydro power plant is explained briefly. In this section the construction of wind turbine and hydro power plant is shown in details. The algorithm for evaluation of the reliability function using UGF technique is discussed in section 4. In section 5 the algorithms for calculating the other various measures are discussed and also the formulas are given. In section 6 an example based on the above renewable energy is taken and solved with the help of UGF technique and other measure are also calculated as discussed in section 4 and 5. The application of this real life based renewable energy system is discussed in section 7. In section 8 the results are discussed and the conclusion of the proposed system is drawn.

2. MODEL DESCRIPTION

A real-life based energy sector model is proposed. In this model a wind turbine and hydro power plant are combined with each other in a parallel arrangement. So, in a working state the wind turbine will work and produce electricity. The electricity produced by the wind turbine will be used for two work simultaneously i.e., for filling reservoir which is connected to the nearby flowing river and for other household purposes. The capacity of the reservoir is 1.6 million gallons.
So, when the wind turbine stops due to any reason the reservoir will start to spill out the water and by this the hydro power plant will start to work and if the wind starts flowing again, then the wind turbine will start working and produce electricity and start filling the reservoir again. By this method the electricity can be produced very efficiently and continuously. This model can minimize the failure chances and electricity can be produced with the help of renewable sources which will not harm our environment.
In this paper, the blades are connected to the turbine and generator which will produce the electricity and these are connected to the transformer for the stabilized electricity for household uses. Turbine and generator are considered as one element and transformer is connected to it in series. There are three sets of turbine generator and transformer connected in parallel so that if one set fails then the other will work and the wind mill fails if all three sets of turbine generator and transformer fail. If the wind turbine fails then the hydro power plant will start working. The mechanism of the hydro power plant is same as the wind mill. The turbine and generator are considered as one element and the transformer is connected to it in series. There are three sets of turbine generator and transformer and these three sets are connected to each other in parallel arrangement. Therefore, the hydro power plant fails when the third set of turbine generator and transformer fails.

3. WORKING OF A WIND TURBINE AND HYDRO POWER PLANT

Basically, wind turbine or hydro power plant are the machines that convert mechanical energy into electrical energy. Wind turbines generally consists of three blades mounted on a big tower which is made up of tubular steel. The blades are connected to the rotor which rotates the blades when the wind starts to flow. Then there is a box like structure called nacelle behind the rotor which is generally called the heart of the turbine. Outside the nacelle, on behind there is an anemometer which measures the wind speed and there is also a wind vane on the nacelle that measures the wind direction and this helps in the orienting the turbine in the direction of the wind accordingly to capture the maximum energy. In nacelle, there is a low speed drive shaft which rotates when the blades rotate due to moving wind. This low speed drive shaft generally rotates at a slow speed of 10 to 60 rotation per minute (rpm) and this speed is too low to create electricity. Then the Low speed drive shaft is generally connected to the gearbox which is used to raise the speed through the high-speed drive shaft which is directly connected to the gearbox. Sometimes, in small wind turbines the gearbox is not present and these type of wind turbines have very low capacity. The gearbox raises the speed of high-speed drive shaft by over a 100 times and then the shaft rotates at the speed of around 1500 rpm. This high-speed drive shaft is connected to a generator which is used to convert the kinetic energy of the high-speed drive shaft to electrical energy.

Now, the electricity produced by the generator is in the form of wild alternating current and is unusable in this form because of highly variable voltage and frequency. Then the generator is connected to the wind charge controller which is used to smoothen or stabilize the highly unstable current which was collected from the generator. This wind charge controller converts the destabilize alternating current into direct current. This produced direct current is allowed to flow down from the cables through tower and these cables are connected to an inverter which again converts the direct current into alternating current. At last the inverter is connected to the transformer and the electricity reach the house.

The working of a hydro power plant is almost the same as the wind mill. In hydro power plant the level of the water is raised from the level of the river for creating a falling water. This water is conserved in dams or reservoirs. When the water from the reservoir falls into the river, it pushes the blades of turbine and allow the turbine to rotate. The turbine of hydro power plant and wind mill is almost same but the only difference is that in wind mill the turbine rotates because of wind force and in hydro power plant the turbine rotates because of the force of falling water. Then the turbine converts the kinetic energy of the falling water to the mechanical energy. Then the turbine is connected to the generator which converts the mechanical energy to the electrical energy. Further processes are the same as the wind mill and the electricity can be collected with these above processes.

4. CALCULATION OF RELIABILITY FUNCTION

The reliability function of the proposed model is calculated with the help of UGF technique [13]. In the system, the different units are taken which are known as elements. These elements cannot be divided further. The system and its elements are binary and can be in only two states i.e., in working state or in failure state. X_c is the random binary variable which represents the state of the j^{th} element. This means $X_j = 1$ if the j^{th} element is in working condition and $X_j = 0$ if the j^{th} element is in failure mode. X is the random binary variable assigned for the system as a whole. For the system of n number of elements, the element state vector can be shown as $(X_1, X_2, \ldots, X_n)$ which can definitely determine the state of the system. The relationship between the vector X and X_j can be written as

$$X = \phi(X_1, X_2, \ldots, X_n)$$

where, ϕ is the deterministic function.

For the proposed model in this paper, the following alogorithm is used.

The reliability of any element j can be calculated by

$$P_j = P_r(X_j = 1).$$

The reliability vector of the elements can be written as

$$p = (p_1, p_2, \ldots, p_n).$$

By this formula, the reliability of the whole sysytem can be calculated as

$$R = P_r X = 1.$$

Then,

$$R = R(p) = R(P_1, P_2, \ldots, P_n).$$

For each random variable X_i the z-transformation represents its p.m.f.$(x_{i0}, \ldots, x_{ik_i}), ((p_{i0}, \ldots, p_{ik_i})$ in the form of polynomial as

$$= \sum_{j=o}^{k_i} p_{ij} z^{x_{ij}}.$$

For the variables $X_1, X_2, \ldots, X_n$ the product of the z-transform polynomials determines the p.m.f. of the sum of these variables. Now the formula for z-transform for a general composition operator $\underset{\varphi}{\otimes}$ is

$$\underset{\varphi}{\otimes}\left(\sum_{j_i=0}^{k_i} p_{ij_i} z^{x_{ij_i}}\right) = \sum_{j_1=0}^{k_1}, \sum_{j_2=0}^{k_2}, \ldots, \sum_{j_n=0}^{k_n}\left(\prod_{i=0}^{n} p_{ij_i z^{\varphi(x_{ij_1}, \ldots, x_{nj_n})}}\right) \tag{1}$$

The u-function of the random variable X_i is $u_i(z)$ and the u-function of the function $\varphi(X_1, \ldots, X_n)$ is $U(z)$. Now according to the above notations

$$U(z) = \underset{\varphi}{\otimes}(u_1(z), \ldots, u_n(z))$$

Also

$$U(z) = \underset{\varphi}{\otimes}(u_1(z), u_2(z)) = (u_1(z) \underset{\varphi}{\otimes} u_2(z))$$

The reliability vector $(p_1, p_2, \ldots, p_n)$ can be represented in the form of u-functions as $u_i(z) = p_i z^1 + (1 - p_i) z^0$, for $0 \leq i \leq n$.

5. PROCEDURE FOR EVALUATING SIGNATURE AND OTHER MEASURES FROM RELIABILITY FUNCTION

The signature of the considered system is calculated with the help of reliability function in the following manner. Firstly, by using Boland's formula [3] the signature of the system is evaluated. For the calculation, the reliability function is to be taken into account. So, the formula for the estimation of signature is

$$B_a = \frac{1}{\binom{s}{s-a+1}} \sum_{k\subseteq[s]|k|=s-a+1} \phi(K) + \frac{1}{\binom{s}{s-1}} \sum_{k\subseteq[s],|k|=s-a+1} \phi(K) \quad (2)$$

Compute the reliability polynomial for above complex structure using
$K(P) = \sum_{j=1}^{s} e_j \binom{s}{j} P^j q^{n-1}$ where , $e_i = \sum_{i-s-j+1}^{s} w_i, j = 1, 2, \ldots, s$.
The reliability function of the system is to be obtained with the help of Taylor evolution at w=1 from the polynomial form, which we get from the above algorithm for the calculation of reliability function. So, the formula for reliability function is

$$P(w) = w^s K(\frac{1}{w}) \quad (3)$$

Then the estimation of the values of tail signature for the complex system with $(p+1)$ -tuple $W = (W_0, \ldots, W_n)$ is done with the following formula

$$W_a = \sum_{i=a+1}^{s} w_i = \frac{1}{(\ s-a\ )} \sum_{|H|=s-a} \phi(K). \quad (4)$$

Now by using [16] and equation (3) the tail signature of the system is calculated by using the formula given below.

$$W_a = \frac{(s-a)!}{s!} d^a P(1), a = 0, 1, \ldots, s. \quad (5)$$

With the help of tail signature of the system, finally we can calculate the signature of the system as follows

$$w = W_{a-1} - W_a, a = 1, 2, \ldots, s. \quad (6)$$

Calculation of the expected lifetime for the system is done with the help of minimal signature. The elements of the system are considered to be independent and identically distributed (i.i.d) and the MTTF is to be calculated for the elements which have exponentially distributed element with mean $(\mu = 1)$.
Then by using the formula given in [17], estimate E(T) of the system with the help of given formula

$$E(T) = \mu \sum_{i=1}^{n} \frac{e_i}{i} \quad (7)$$

where, $e = (e_1, e_2, \ldots, e_n)$ is a vector coefficient we obtain with the help of minimal signature.
Using [20] and [18] the Barlow Proschan Index is calculated with the help of the

reliability function of the complex system where the elements of the system are i.i.d. So, the following formula is used to estimate the Barlow Proschan Index

$$I^a{}_{BP} = \int_0^1 (\delta_a K)(w)dw, a = 1, 2, \ldots, n \quad (8)$$

where, K are reliability functions of system.
Next the expected value is to be calculated for the elements of the proposed system [5]. The formula used for the expected value for the elements is given below

$$E(X) = \sum_{i=1}^{n} iw_i, i = 1, 2, \ldots, n \quad (9)$$

Then two measures are to be calculated at last. One E(X) and second is E(X)/E(T) for the proposed renewable energy-based system.

6. EXAMPLE OF THE RENEWABLE ENERGY-BASED SYSTEM

Here, in the considered case the wind mill is in parallel with the hydro power plant. In wind mill and hydro power plant turbine generator and transformer are in series and there are three pair of this connected in parallel to maximize the reliability. Elements 2 and 3 are in series and so are 4, 5 and 6, 7. All these pair are in parallel with each other, means 2, 3 and 4, 5 are in parallel and 4, 5 and 6, 7 are in parallel with each other. These three sets are together is in series with element 1 as shown in figure 1. The random variable X_{19} denotes the arrangement of these elements. Then, elements 9 and 10, 11 and 12, 13 and 14 are in series and they are also in parallel with each other. This arrangement is in series with element 8. The random variableX_{24} denotes the arrangement of the elements. At last, the random variableX_{19} and $X_{24}$are connected in parallel with each other and random variable X_{25}denotes the arrangement of all the components of the system. Here, the operator min is for elements in series and operator max for the elements in parallel. Now the u-function of the following elements can be written as

$$u_i(z) = p_i z^1 + (1 - p_i)z^0,$$

for i=(1,...,14).
So, from figure 1, the element's arrangement can be simplified into series parallel structure and following equations can be drawn

$$X_{15} = min(X_2, X_3) \quad (10)$$
$$X_{16} = min(X_4, X_5) \quad (11)$$
$$X_{17} = min(X_6, X_7) \quad (12)$$
$$X_{18} = max[min(X_2, X_3), min(X_4, X_5), min(X_6, X_7)] \quad (13)$$
$$X_{19} = min[max[min(X_2, X_3), min(X_4, X_5), min(X_6, X_7)]] \quad (14)$$

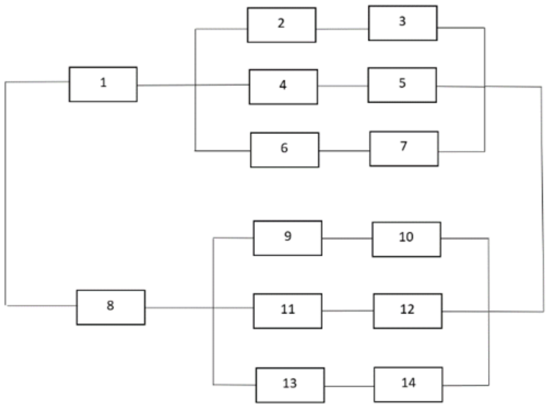

Figure 1: Wind mill and hydro power plant

Similarly,

$$X_{20} = min(X_9, X_{10}) \tag{15}$$

$$X_{21} = min(X_{11}, X_{12}) \tag{16}$$

$$X_{22} = min(X_{13}, X_{14}) \tag{17}$$

$$X_{23} = max[min(X_9, X_{10}), min(X_{11}, X_{12}), min(X_{13}, X_{14})] \tag{18}$$

$$X_{24} = min[max[min(X_9, X_{10}), min(X_{11}, X_{12}), min(X_{13}, X_{14})]] \tag{19}$$

$$X_{25} = max[min[max[min(X_2, X_3), min(X_4, X_5), min(X_6, X_7)]] \\ min[max[min(X_9, X_{10}), min(X_{11}, X_{12}), min(X_{13}, X_{14})]] \tag{20}$$

So, from the above expression the reliability function of the proposed renewable energy-based model is calculated as follows

$$R = P_1P_2P_3 + P_1P_4P_5 + P_1P_6P_7 - P_1P_2P_3P_4P_5 - P_1P_2P_3P_6P_7 \\ - P_1P_4P_5P_6P_7 + P_1P_2P_3P_4P_5P_6P_7 + P_8P_9P_{10} + P_8P_{11}P_{12} \\ + P_8P_{13}P_{14} - P_8P_9P_{10}P_{11}P_{12} - P_8P_9P_{10}P_{13}P_{14} - P_8P_{11}P_{12}P_{13}P_{14} \\ + P_8P_9P_{10}P_{11}P_{12}P_{13}P_{14} - P_1P_2P_3P_8P_9P_{10} - P_1P_4P_5P_8P_9P_{10} \\ - P_1P_6P_7P_8P_9P_{10} + P_1P_2P_3P_4P_5P_8P_9P_{10} + P_1P_2P_3P_6P_7P_8P_9P_{10} \\ + P_1P_4P_5P_6P_7P_8P_9P_{10} - P_1P_2P_3P_4P_5P_6P_7P_8P_9P_10 - P_1P_2P_3P_8P_{11}P_{12} \\ - P_1P_4P_5P_8P_{11}P_{12} - P_1P_6P_7P_8P_{11}P_{12} + P_1P_2P_3P_4P_5P_8P_{11}P_{12} \\ + P_1P_2P_3P_6P_7P_8P_{11}P_{12} + P_1P_4P_5P_6P_7P_8P_{11}P_{12} \\ - P_1P_2P_3P_4P_5P_6P_7P_8P_{11}P_{12} - P_1P_2P_3P_8P_{13}P_{14} - P_1P_4P_5P_8P_{13}P_{14} \\ - P_1P_6P_7P_8P_13P_{14} + P_1P_2P_3P_4P_5P_8P_{13}P_{14} + P_1P_2P_3P_6P_7P_8P_{13}P_{14} \\ + P_1P_4P_5P_6P_7P_8P_{13}P_{14} - P_1P_2P_3P_4P_5P_6P_7P_8P_{13}P_{14} \\ + P_1P_2P_3P_8P_9P_{10}P_{11}P_{12} + P_1P_4P_5P_8P_9P_{10}P_{11}P_{12} \\ + P_1P_6P_7P_8P_9P_{10}P_{11}P_{12} - P_1P_2P_3P_4P_5P_8P_9P_{10}P_{11}P_{12}$$

$- P_1P_2P_3P_6P_7P_8P_9P_{10}P_{11}P_{12} - P_1P_4P_5P_6P_7P_8P_9P_{10}P_{11}P_{12}$
$+ P_1P_2P_3P_4P_5P_6P_7P_8P_9P_{10}P_{11}P_{12} + P_1P_2P_3P_8P_9P_{10}P_{13}P_{14}$
$+ P_1P_4P_5P_8P_9P_{10}P_{13}P_{14} + P_1P_6P_7P_8P_9P_{10}P_{13}P_{14}$
$- P_1P_2P_3P_4P_5P_8P_9P_{10}P_{13}P_{14} - P_1P_2P_3P_6P_7P_8P_9P_{10}P_{13}P_{14}$
$- P_1P_4P_5P_6P_7P_8P_9P_{10}P_{13}P_{14} + P_1P_2P_3P_4P_5P_6P_7P_8P_9P_{10}P_{13}P_{14}$
$+ P_1P_2P_3P_8P_{11}P_{12}P_{13}P_{14} + P_1P_4P_5P_8P_{11}P_{12}P_{13}P_{14}$
$+ P_1P_6P_7P_8P_{11}P_{12}P_{13}P_{14} - P_1P_2P_3P_4P_5P_8P_{11}P_{12}P_{13}P_{14}$
$- P_1P_2P_3P_6P_7P_8P_{11}P_{12}P_{13}P_{14} - P_1P_4P_5P_6P_7P_8P_{11}P_{12}P_{13}P_{14}$
$+ P_1P_2P_3P_4P_5P_6P_7P_8P_{11}P_{12}P_{13}P_{14} - P_1P_2P_3P_8P_9P_{10}P_{11}P_{12}P_{13}P_{14}$
$- P_1P_4P_5P_8P_9P_{10}P_{11}P_{12}P_{13}P_{14} - P_1P_6P_7P_8P_9P_{10}P_{11}P_{12}P_{13}P_{14}$
$+ P_1P_2P_3P_4P_5P_8P_9P_{10}P_{11}P_{12}P_{13}P_{14}$
$+ P_1P_2P_3P_6P_7P_8P_9P_{10}P_{11}P_{12}P_{13}P_{14}$
$+ P_1P_4P_5P_6P_7P_8P_9P_{10}P_{11}P_{12}P_{13}P_{14}$
$- P_1P_2P_3P_4P_5P_6P_7P_8P_9P_{10}P_{11}P_{12}P_{13}P_{14}$

So, the reliability function of the system, when all the elements of the system are i.i.d, that means when

$$P_1 = P_2 = \cdots = P_{14} = P$$

is as follows

$$R = 6P^3 - 6P^5 - 9P^6 + 2P^7 + 18P^8 - 15P^{10} + 6P^{12} - P^{14}.$$

6.1. SIGNATURE OF THE CONSIDERED STRUCTURE

To get the reliability function of the considered energy sector system the Owen's method is being used and from this method the reliability will comes out to be in the form of p as follows

$$H(p) = 6P^3 - 6P^5 - 9P^6 + 2P^7 + 18P^8 - 15P^{10} + 6P^{12} - P^{14}.$$

Now using the above equation (3) from the section 5 the polynomial function of the above reliability function is as follows

$$P(v) = P^{14}H(\frac{1}{P}) = -1 - 6p^2 - 15p^4 + 18p^6 + 2p^7 - 9p^8 - 6p^9 + 6p^{11}.$$

Now using the equation (4) to evaluate the tail signature P of the system, the tail signature of the system is

$$P = (1, 1, \frac{90}{91}1, \frac{88}{91}, \frac{934}{1001}, \frac{883}{1001}, \frac{1778}{3003}, \frac{1282}{3003}, \frac{3729}{14014}, \frac{365657}{2270268}, \frac{396}{7007}, \frac{256633}{18162144}, 0, 0, 0)$$

Now using the above values of tail signature, the calculation for the signature is being done with the help of the procedure mentioned above in the 5th section. So, the signature reliability of the system is as follows

$$P = (0, \frac{1}{91}, \frac{2}{91}, \frac{3094}{91091}, \frac{51}{1001}, \frac{871871}{3006003}, \frac{496}{3003}, \frac{6767761}{42084042}, \frac{3341512174}{31815535752}, \frac{1663132471}{15907767876}, \frac{5393981593}{127262143008}, \frac{256633}{18162144}, 0, 0).$$

6.2. Barlow-Proschan Index of Complex Structure System

Now with the help of equation (8) calculate the Barlow-Proschan index for the considered complex structure as follows

$$I^1{}_{BP} = \int_0^1 (3P^2 - 3P^4 - 9P^5 + P^6 + 18P^7 - 15P^9 + 6P^{11} - P^{13})dp = \frac{61}{140}$$

Similarly, we obtain Barlow-Proschan index $I^K{}_{BP}$ for K=(1,2,...,14) of all elements such as

$$I_{BP} = (\frac{61}{140}, \frac{39}{840}, \frac{39}{840}, \frac{39}{840}, \frac{39}{840}, \frac{39}{840}, \frac{39}{840}, \frac{61}{140}, \frac{39}{840}, \frac{39}{840}, \frac{39}{840}, \frac{39}{840}, \frac{39}{840}, \frac{39}{840})$$

6.3. Expected Lifetime of the System

Now, using Equation (7) from above we get the minimal signature M of the renewable energy-based system as
minimal signature $(0, 0, 6, 0, -6, -9, 2, 18, 0, -15, 0, 6, 0, -1)$.
Using minimal signature, obtain expected such as

$$E(t) = 0.764285.$$

6.4. Expected Cost Rate

Using equation (8), the expected value of the system is determined as

$$E(X) = 7.2880102588,$$

the expected cost rate for the system using the formula in (8) is

$$= 9.5357233.$$

7. CONCLUSION

The characteristic of a real-life renewable energy-based system is studied in this paper. In Germany a renewable energy project is build where the wind mill and hydro power plant are combined together to produce electricity from natural resources. In this paper, the reliability function of this system is evaluated with the help of UGF technique. With the help of reliability function various measures such as tail signature, signature, expected cost etc are evaluated. After solving the proposed system with the help of the algorithms and formulas discussed above in this paper, some following results are drawn. The tail signature of the considered system is

$$P = (1, 1, \frac{90}{91} 1, \frac{88}{91}, \frac{934}{1001}, \frac{883}{1001}, \frac{1778}{3003}, \frac{1282}{3003}, \frac{3729}{14014}, \frac{365657}{2270268}, \frac{396}{7007}, \frac{256633}{18162144}, 0, 0, 0)$$

The signature reliability of the system is as follows

$$P = (0, \frac{1}{91}, \frac{2}{91}, \frac{3094}{91091}, \frac{51}{1001}, \frac{871871}{3006003}, \frac{496}{3003}, \frac{6767761}{42084042}, \frac{3341512174}{31815535752}, \frac{1663132471}{15907767876}, \frac{5393981593}{127262143008}, \frac{256633}{18162144}, 0, 0).$$

The Barlow-Proschan Index is

$$I_{BP} = (\frac{61}{140}, \frac{39}{840}, \frac{39}{840}, \frac{39}{840}, \frac{39}{840}, \frac{39}{840}, \frac{39}{840}, \frac{61}{140}, \frac{39}{840}, \frac{39}{840}, \frac{39}{840}, \frac{39}{840}, \frac{39}{840}, \frac{39}{840})$$

and expected cost rate of the system by using Owen's method is 9.53572

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