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An Innovative Reliability Oriented Approach for Restructured Power System Considering the Impact of Integrating Electric Vehicles and Renewable Energy Resources

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ABSTRACT Attributing to the irreplaceable quality of nil carbon footprints, the power system considering the integration of electric vehicles and renewable energy resources are appealing growing attention in the recent time, but the reliability of their associated components, is a main matter of concern nowadays. Therefore, in this paper, a novel incentive based fuzzy fault tree analysis (NIBFFTA) approach for restructured power system considering the influence of integrating Electric vehicles and Renewable energy resources-based hybrid wind-solar energy is presented. The approach combines the impacts of different components failure rate and the incentive Gaussian distribution effects under the inducement fuzzy fault tree atmosphere for the grid integrated Renewable energy resources and Electric vehicles configurations. In the basic fault tree analysis, the vague and inaccurate events such as system switches and low power component failures could not be identified competently. Moreover, the probability values of fault occurrences in the complete power system are not considered into account. Additionally, it is quite hard to have a precise assessment of the grid-connected wind energy power systems and EV configuration failure chances or the possibility of occurrence of undesired actions in the complete system because of data deficiency. To overwhelm these demerits, a novel incentive based fuzzy fault tree analysis based on the Gaussian distribution and fuzzy set model is recommended and used for the restructured power system considering the impact of integrating Electric vehicles and Renewable energy resources. Besides, the probability analysis of fault occurrence is also proposed to determine the impact of each basic event of the proposed system on the top event. Furthermore, the prediction analysis of fault occurrence is also done to know the effect of every basic action of the system on the top action. Whereas, prediction analysis factors for the different basic events of the proposed systems are evaluated and these can be used to obtain the real consequence of basic events on the proposed system. It is found that a novel incentive based fuzzy fault tree analysis approach is more significant and efficient than the conventional fault tree method for risk assessment of restructured power system with integrating the electric vehicles and renewable energy resources.

INDEX TERMS Solar energy, wind energy, electric vehicles, reliability analysis, failure rate, NIBFFTA, fuzzy fault tree analysis.

I. INTRODUCTION

Wind and solar power sources are taking up the role of power generation as their level of penetration increases day by day. The combined effect of wind and solar powered generator on entire power system sufficiency is dependent on many factors which includes the probabilistic demonstration of wind and solar power sources, reliability of the systems and capacity of wind and solar power systems [1]. A framework has been proposed in past to know the power

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system reliability including the impact of various components uncertainties and reliability model is formulated for power converters in the renewable energy system [2]. Whereas the trend of more power accountable travel is causing in increasing more towards the Renewable energy resources [3]. Moreover, with the growing permeation of Electric vehicles, more connections seem between the power system and transportation system, which may give new treats for the propagation of fault occurrence in the limits of various systems, hence risk assessment method is needed for the power system which includes the Electric vehicles and Renewable energy resources [4]. The reliability improvement of power systems including the effect of renewable power resources connected into the grid with different techniques has been proposed [5]. The Electric vehicles are connected to the artificial intellect and composite software stacks pointing to understand the real world, perform decisions tasks and make activities without the interference of human [6]. The supportive communication and Electric vehicles computation system has been proposed and stochastic design of the vehicle communication reliability has been also discussed with probability theory [7]. Whereas, the effect of connecting the solar-wind power system has also been investigated by using the distribution generation system and to make the power system more accurate, suitable non-linearity's are combined into conventional power system [8]. A tracking absorption method has been proposed for renewable power based on the interface between the demand side and supply side, which regulates the process of charging of Electric vehicles to understand the following captivation of renewable energy unrestricted electricity[9]. A method has been proposed for good allocation of charging station of Electric vehicles in the power system without compromising with the performance of the system [10]. If Renewable energy resources are included with the Electric vehicles, then there is need of doing the analysis of power system through demand of charging of Electric vehicles[11]. The changeable and unpredictable nature of solar and wind energy system can enhance the burden of the operator of the system to maintain the reliability of the different, therefore, stochastic risk-constrained outline has been presented to know the impact of demand response on the issue of reliability in the system [12]. With the integration of power electronic based technologies in the grid, this needs the assessment of reliability in the system and therefore impact of failure rate of equipment's in the power system on the reliability should be known [13]. The connection of different storage system in a distribution network can affect the distinct reliability and outcomes to utility [14], [15] and the present grid is undergoing an unique change from the original design, converting the way how power has been generated and consumed in the past [16]. Moreover, the uncertainties of wind-solar power can impacts the reliability of the system, hence, a new production rescheduling algorithm which regulates the outputs of production to lessen the deviations of energy flow and ease the overload probability [17] and with increasing the penetration of renewable power, many ISOs are introducing ramp ability products to achieve the challenge of matching real- time power [18]. Further, a novel approach has been presented to explore the effectiveness of applying reliability assessment to describe the standards of reliability for grid with huge penetration of power converter interfaced production [19] and design of different devices in the power system is important to improve the efficiency as well as reliability [20], [21]. With the enhancement of the Electric vehicles in the market, they should be design according the reliability based approach [22], therefore, a novel reliable motors, named as magnetic steering motor, has been presented to understand the idea of the magnetic discrepancy system for the electric vehicles[23]. The main advantages of the renewable power system is overcoming the carbon emissions at different level, therefore, by using the renewable energy power with grid can reduce the carbon footprints because the units generated from the wind-solar power system need not to taken by the thermal based plant [24]. Furthermore, a general structure of charging station of electric vehicles has been proposed to know the power electronics based elements reliability in Electric vehicles [25] and hybrid Electric vehicles reliability observation is also important for design, control, planning and management of Electric vehicles [26], [27]. Moreover, energy conversion methods have been introduced for renewable based generation that allow every element of renewable energy sources to operate as suitable point that gives maximum power [28]. Further, Latin hypercube sampling approach has been proposed for assessment of reliability of power systems which includes the wind-solar power sources, with a prominence on the bus loads changes and unpredictable behavior of wind–solar power productions [29] and a novel approach has been proposed to assess scheme generating capability reliability indices including the time reliant loads and power sources [30]. The goal of this article is to evaluate the influence of integrating wind energy with small hydropower plants on the power system's reliability [31] and many stochastic computational methods to fuzzy system have been introduced [32]–[34]. Whereas, Due to the continued rise of wind and solar generators, the contribution of renewable energies in power networks is increasing. Traditional reliability evalu ation methods are inapplicable because to the intermittency and uncertainty of these resources therefore new approaches have been introduced [35]–[37]. Through qualitative or quantitative research, fault trees are commonly used to analyze the unreliability of electrical or mechanical systems [38]–[40].

Hence different methodology is utilized to get the chosen operation of wind-solar power sources, Also, a reliability valuation framework has been proposed to know the impact of solar-wind power sources and electric vehicles integration into the power grid, because the data received is inadequate: therefore, the present approach is proposed. Previous methods have not provided the good outcomes because of the insufficient data and computational burden. Hence, in this article, an innovative reliability-oriented approach has been proposed for restructured power systems considering the impact of integrating Electric vehicles and renewable energy sources. This technique is based on novel incentive built fuzzy fault tree analysis to overcome the practical reliability investigation problem of solar-wind-electric vehicle connected power system. This approach is applied to obtain the different reliability indices and fault chances of the top event failure with varying the load as well. The obtained outcomes are compared with different previous methods like electrical loss minimization technique, chronological multiple state probability model, system state generating method and probabilistic minimal cut-set-based iterative methodology, but these techniques involve the lengthy process and need extra time to now the reliability of the system as compared with the proposed technique. Besides, prediction analysis factor for the different basic events is calculated and it could be used to get the real consequence of basic events on the proposed power system.

As found from the outcomes of the proposed system, it could be seen that the integration of wind and solar power system with electric vehicles into the grid can improve the reliability of the entire system, particularly when conventional thermal power plant is associated with the grid. So, it is important to increase more renewable energy sources to maintain the reliability of the system when Electric vehicles are associated to the distribution networks.

In this paper, solar-wind power and electric vehicles integrated grid-connected system is presented in Section II. In Section III, a novel incentive based fuzzy fault tree analysis (NIBFFTA) approach is proposed however, NIBFFTA based risk assessment approach for power system including the wind-solar energy systems and Electric vehicles is discussed in Section VI. In Section V, case study with the proposed NIBFFTA based risk assessment approach is presented. Finally, concluding statements are given in Section VI.

II. SOLAR-WIND POWER AND ELECTRIC VEHICLES INTEGRATED GRID-CONNECTED SCHEME

The present belongings of the conventional energy sources would be finished soon reason being the depletion of fossil fuel reserves and major portion of this reserve is being used by transportation sector, therefore, the power system is forced to use the Renewable energy resources. Hence, Electric vehicles electrification with grid connected solar-wind energy system is the best way to abate their reliance on fossil fuels. The use of renewable energy-based power system reduces the carbon footprints also, as their units need not to be consumed by thermal power plant. Therefore, electrification of electric vehicles with grid-connected wind-solar energy system plays a noteworthy role in decreasing the greenhouse effect. Though, Electric vehicles conversion increases the load and it affects the power system which would finally affect the system reliability. Therefore, the reliability assessment of restructured power system taking the impact of integrating Electric vehicles and renewable energy sources need to be investigated. Fig. 1 shows the solar-wind power and electric vehicles integrated grid-connected scheme [5]. In the spring and fall, wind power is at its peak. When solar panels are set off at night, wind turbines start in, hence it works both day and night. There is no need of adding the extra storage system in the proposed system, it would increase the overall cost. Moreover, the power from the grid can also be utilized when there is less power from the solar-wind energy systems.

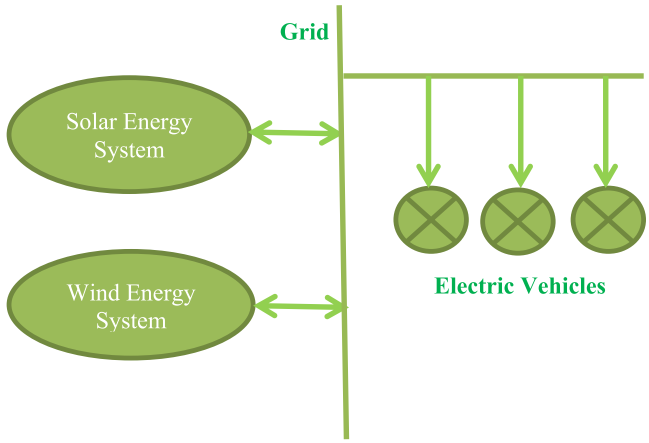

FIGURE 1. Solar-wind power integrated grid connected system with electric vehicles.

Different data of solar energy system, wind energy system and electric vehicles are used to investigate the proposed NIBFFTA approach. The electric vehicle is composed of a motor and as related controller of the motor. The motor is used to drive the vehicles wheel with the rear axle. According to the need of driving system, controller is used to control the direction, speed and torque of the associated motor. Moreover, the electric vehicles charging need may affect the power system, for prize limits, lower number of switches can be used with the drive controller system.

For installing the wind-solar energy-based system, firstly good area is chosen so that the system reliability could be enhanced. The area is selected where precise and significant solar irradiation and speed of wind is found. The different methods can be used to predict the solar radiation and wind speed. These can give the information about the sunlight receive and wind speed throughout the year and then the load can be calculated in accordance with that size of wind power system and solar power system. The particular site and size of the plant are important to feed the power to different users. Among the different energy resources available at present the wind and solar energy-based system are best suited reason being the abundant obtainability of wind and solar power and these sources generates less pollution, therefore these sources decrease the carbon footprints and hence, decrease the global warming. Hence, this work presents the risk assessment of the power system including the renewable energy resources and Electric vehicles. The key faults of the solar-wind power and Electric vehicles integrated grid-connected scheme are as follows:

A. SOLAR ENERGY SYSTEM FAULTS

Solar energy system consists of the solar panel, rectifier, converter, fuse, switches etc. Therefore the main faults in the solar energy systems are due to solar panel, converter, bus system, inverter, converter, ac and dc switches, connectors etc [41].

B. WIND ENERGY SYSTEM FAULTS

The faults in the wind power system are mainly due to the mechanism of rotation, gear teeth, deformation of body of wheel, disproportion misalignment, rise in oil temperature, stator winding, rotor winding, converter, DC switch, protection devices, phase, etc. [42].

C. ELECTRIC VEHICLES FAULTS

The faults in the Electric vehicles includes the stator core failure, stator winding failure, bearing failure, rotor failure, axis system fault, motor system fault, switches faults, controller and driving system faults etc. [43].

This work is focused on the grid-integrated wind-solar energy system and EVs. The components of the solar power system are enclosed within the system and it is located in different areas. Whereas, the wind energy system components are assembling near the tower. The drive system transfers power to the collector from the shaft of the rotor. Furthermore, the Electric vehicles faults are in stator, rotor, shaft and controller.

III. NOVEL INCENTIVE BASED FUZZY FAULT TREE ANALYSIS (NIBFFTA) APPROACH

Reliability model is the base and foundation for reliability assessment of the system. Therefore, a novel incentive based fuzzy fault tree analysis method has been proposed to know the reliability of power system taking the impact of wind-solar power systems and EVs. The solar-wind and Electric vehicles-based system configuration fault rate could define the discrete distribution firstly. The reliability of the system increases as the wind-solar and electric vehicles insertion increases in the power system. To know the reliability of the system firstly following process is adopted.

Phase 1 Know the real value of N(k) factor of every component of the grid connected wind-solar energy system and Electric vehicles.

$$N\left(k\right) = S_k W_k E_k SR_k WR_k ER_k (1) \tag{1}$$

$$N_2\left(k\right) = S_k^2 W_k^2 E_k^2 SR_k WR_k ER_k \tag{2}$$

$$N_3\left(k\right) = S_k^3 W_k^3 E_k^3 SR_k WR_k ER_k \tag{3}$$

$$N_4\left(k\right) = S_k^4 W_k^4 E_k^4 SR_k WR_k ER_k \tag{4}$$

$$N_5\left(k\right) = S_k^5 W_k^5 E_k^5 SR_k WR_k ER_k \tag{5}$$

$$N_6\left(k\right) = S_k^6 W_k^6 E_k^6 SR_k WR_k ER_k \tag{6}$$

$$N_7\left(k\right) = S_k^7 W_k^7 E_k^5 SR_k WR_k ER_k \tag{7}$$

$$N_8\left(k\right) = S_k^8 W_k^8 E_k^8 SR_k WR_k ER_k \tag{8}$$

$$N_9\left(k\right) = S_k^9 W_k^9 E_k^9 SR_k WR_k ER_k \tag{9}$$

$$N_{10}\left(k\right) = S_k^{10} W_k^{10} E_k^{10} SR_k WR_k ER_k \tag{10}$$

S_k, W_k, and E_k are the capacity of units in the solar energy system, wind energy system and Electric vehicles and SR_k, WR_k, and ER_k are failure rate of solar energy, wind energy and Electric vehicles units respectively.

Phase 2 Apply the consequences of phase 1 and estimate the various factors.

$$N = \sum_{k=1}^{i} S_k W_k E_k, \quad F = \sum_{k=1}^{j} F(k),$$
$$P_k\left(u\right) = \sum_{u=1}^{o} S_k(u) W_k(u)\, E_k(u) SR_k(u) WR_k(u)\, ER_k(u) - e_u \tag{11}$$

where, F and P are the force and prediction factor, u represents the number of units of system and e represents the forced outage value when extra units of different systems are added.

Phase 3 Apply the consequences of phase 1 phase 2 and assess the factors.

$$N_5\left(k\right) = \sum_{u=1}^{o} \left(N_3\left(u\right) N_4\left(u\right) N_5(u) - 7F_k^5\right) + \sum_{u=1}^{o} 9S_k(u) W_k(u)\, E_k(u) SR_k(u) WR_k(u)\, ER_k(u) - e_u \tag{12}$$

$$N_6\left(k\right) = \sum_{u=1}^{o} \left(N_4\left(u\right) N_5\left(u\right) N_6(u) - 11F_k^6\right) + \sum_{u=1}^{o} 12S_k(u) W_k(u)\, E_k(u) SR_k(u) WR_k(u)\, ER_k(u) - e_u \tag{13}$$

$$N_7\left(k\right) = \sum_{u=1}^{o} \left(N_5\left(u\right) N_6\left(u\right) N_7(u) - 14F_k^7\right) + \sum_{u=1}^{o} 15S_k(u) W_k(u)\, E_k(u) SR_k(u) WR_k(u)\, ER_k(u) - e_u \tag{14}$$

$$N_8\left(k\right) = \sum_{u=1}^{o} \left(N_6\left(u\right) N_7\left(u\right) N_8(u) - 17F_k^8\right) + \sum_{u=1}^{o} 18S_k(u) W_k(u)\, E_k(u) SR_k(u) WR_k(u)\, ER_k(u) - e_u \tag{15}$$

$$N_9\left(k\right) = \sum_{u=1}^{o} \left(N_7\left(u\right) N_8\left(u\right) N_9(u) - 19F_k^9\right) + \sum_{u=1}^{o} 21S_k(u) W_k(u)\, E_k(u) SR_k(u) WR_k(u)\, ER_k(u) - e_u \tag{16}$$

$$N_{10}\left(k\right) = \sum_{u=1}^{o} \left(N_8\left(u\right) N_9\left(u\right) N_{10}(u) - 22F_k^{10}\right)$$

$$+\sum_{u=1}^{o} 24S_k(u)W_k(u)\,E_k(u)SR_k(u)WR_k(u)\,ER_k(u) - e_u \tag{17}$$

Phase 4 Evaluate the failure rate for fuzzy fault tree by adding the effect of phase 1, phase 2 and phase 3.

$$S_1 = \frac{x - 0.5N}{L} \tag{18}$$

$$S_2 = \frac{x - 2.5N}{L} \tag{19}$$

$$W_3 = \frac{x - 3.5N}{L} \tag{20}$$

$$W_4 = \frac{x + 0.5N}{L} \tag{21}$$

$$E_5 = \frac{x + 2.5N}{L} \tag{22}$$

$$E_6 = \frac{x + 3.5N}{L} \tag{23}$$

By considering the values of above parameters different cases are formed then failure rate is calculated with joining the fuzzy fault tree analysis technique. For the proposed work, the reliability indices, loss of load expectation (LOLE), loss of load probability (LOLP), mean time to failure (MTTF), rate of failure, and expected energy not served (EENS) are calculated.

The fuzzy fault tree method is added with the above proposed technique after knowing the failure data from the above analysis, these data is used in fuzzy fault tree. Basically, the fuzzy fault tree technique is based on fuzzy sets theory.

The suspicious of rates of failure of the basic event and top event occurance chance, the fuzzy number is taken to know the probabilities of the different events and to lower the complexitity in the probability calculation. Many types of fuzzy number are used for this calculation but for easy algebra operation in this study, the triangular fuzzy number is chosen. The memebership function is used to know the probability of the different fault events. The proposed function is defined as

$$\omega_g(x) = \left\{ \begin{array}{cc} 0 & For\ x \leq \sigma \\ x - \sigma\big/ b - \sigma & For\ \sigma \leq x \leq b \\ \lambda - x\big/ \lambda - b & For\ b \leq x \leq \lambda \\ 0 & For\ \lambda \leq x \end{array} \right\} \tag{24}$$

The array (b, σ, λ) is used to define the proposed function, where mean of the number is b, and σ, λ are the distribution curve left and right end points respectively.

The event A in fuzzy number is defined as:

$$M_A = (b - \sigma, b, b + \lambda) \tag{25}$$

The event chance occurance for the specfic confidence level §($0 \leq § \leq 1$), is presented as:

$$M_A^{§} = (b - \gamma + §\gamma, b, b + \lambda - §\lambda) \tag{26}$$

where the confidence level is §.

The fuzzy operators of AND and OR gate are defined as:

$$\begin{aligned} M_{§}^{AND} &= \prod_{t=1}^{n} M_{t§} = F_{1§}F_{2§}F_{3§}\ldots\ldots, F_{n§} \\ &= (\lambda_1§\,(b_1 - \sigma_1) + \sigma_1§\,(b_1 + \delta_1) + \lambda_1§\sigma_1§), \\ &\quad (\lambda_2§\,(b_2 - \sigma_2) + \sigma_2§\,(b_2 + \lambda_2) + \lambda_2§\gamma_2§) \\ &\quad \ldots.(\lambda_n§\,(b_n - \sigma_n) + \sigma_n§\,(b_n + \lambda_n) + \lambda_n§\gamma_n§) \\ &= \left[\prod_{t=1}^{n}((\lambda_t§\,(b_t - \sigma_t)) + \sigma_t§, \prod_{t=1}^{n}((\lambda_t§\,(b_t - \lambda_t)) + \lambda_1§\sigma_1§\right] \end{aligned} \tag{27}$$

$$\begin{aligned} M_{§}^{OR} &= 1 - \prod_{T=1}^{n}(1 - F_{t§}) \\ &= 1 - (1 - (\lambda_1§\,(b_1 - \sigma_1) + \sigma_1§\,(b_1 + \delta_1) + \lambda_1§\sigma_1§), \\ &\quad (\lambda_2§\,(b_2 - \sigma_2) + \sigma_2§\,(b_2 + \lambda_2) + \lambda_2§\gamma_2§) \\ &\quad \ldots.(\lambda_n§\,(b_n - \sigma_n) + \sigma_n§\,(b_n + \lambda_n) + \lambda_n§\gamma_n§) \\ &= \left[1 - \prod_{k=1}^{n}(1 - (\lambda_t§\,(b_t - \sigma_t)) + \sigma_t§, - \prod_{k=1}^{n}(1 - (\lambda_t§\,(b_t - \lambda_t)) + \lambda_1§\sigma_1§\right] \end{aligned} \tag{28}$$

where AND gate and OR gate fuzzy operators are $M_{§}^{AND}$ and $M_{§}^{OR}$ respectively.

Additionally, information from the professional could be taken to get the effect of the different faults on the power system. This proposed technique is used for risk evaluation of grid-connected solar-wind energy system and Electric vehicles.

Furthermore, the fault tree digaram is made for the proposed power system which considers the effect of wind-solar based power systems and Electric vehicles that shows the procedure from the top event to bottom event for the entire proposed system.

After considering some records of failure and experts views, basic event failure is calculated. T he proposed approach provides the failure rates of rest events. Hence, this approach is used for risk analysis of the power system taking the effects of solar-wind energy systems and Electric vehicles and it is more adaptive and flexible for the reliability assessment.

IV. NIBFFTA BASED RISK ASSESSMENT APPROACH FOR POWER SYSTEM INCLUDING THE WIND-SOLAR ENERGY SYSTEM AND ELECTRIC VEHICLES

This method provides the probability of all the events from basic to the top, for this purpuse, ten types of systems are considered i.e. grid-connected power system with Renewable energy resources and different configurations

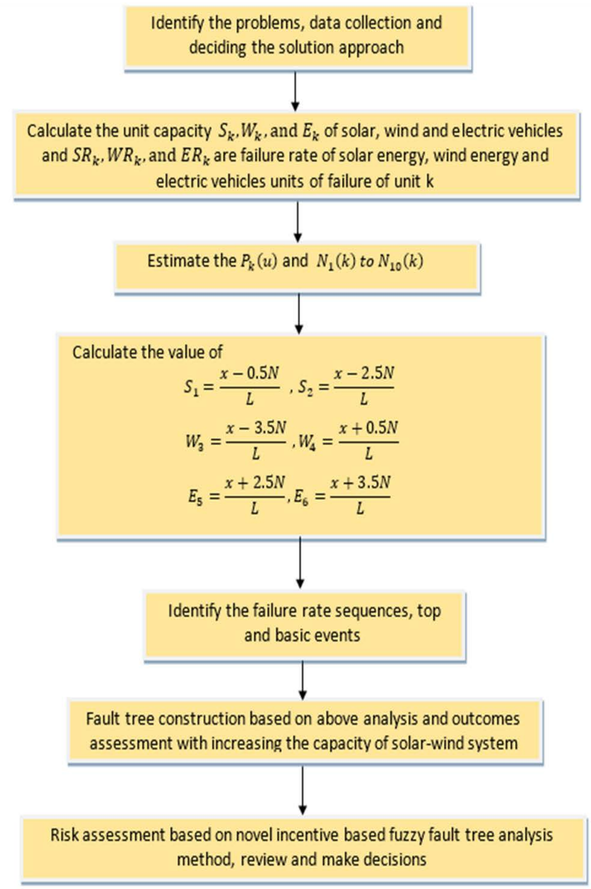

FIGURE 2. Flow chart of the novel incentive based fuzzy fault tree analysis-based grid-connected solar-wind and electric vehicles system risk assessment.

of grid–connected system with renewable power resouces and electric vehicles. Fig.2 represents the flow chart of the novel incentive based fuzzy fault tree analysis-based grid-connected solar-wind and Electric vehicles system risk assessment method [5]. The following steps have been taken for the application of proposed NIBFFT based risk assessment for the power system.

A. PROPOSED MODELING AND ORGANIZATION

The ten grid-connected solar-wind and electric vehicles system alternatives are chosen for the analysis purpose as shown in Table 1. IEEE 69 Node Test Feeder is used for this study and the optimal locations are found by algorithm of optimal placement of different energy sources and Electric vehicles, the solar power system is connected to bus 27, wind power system is connected to bus 29, and electric vehicles is connected to bus 40. The large-scale electric vehicles insertion in the distribution network increases the load in the system hence power quality and reliability are affected.

Therefore, the various factors related to the electric vehicles power demands are considered in this work. Different 10 alternatives have been taken in this work, P1 is original system with 15 MW solar power system and 15 MW wind

TABLE 1. Solar-wind and electric vehicles system energy system alternatives.

Choices	Proposed system configuration
P1	Original 15 MW wind system+15 MW solar system
P2	15 MW wind system+15 MW solar system+2 MW Electric vehicles
P3	25 MW wind system+25 MW solar system+2 MW Electric vehicles
P4	35 MW wind system+35 MW solar system+2 MW Electric vehicles
P5	45 MW wind system+45 MW solar system+2 MW Electric vehicles
P6	55 MW wind system+55 MW solar system+2 MW Electric vehicles
P7	65 MW wind system+65 MW solar system+2 MW Electric vehicles
P8	75 MW wind system+75 MW solar system+2 MW Electric vehicles
P9	85 MW wind system+85 MW solar system+2 MW Electric vehicles
P10	95 MW wind system+95 MW solar system+2 MW Electric vehicles

power system, alternative P2 is the 15 MW solar power systems, 15 MW wind power system and 2 MW Electric vehicles configurations. Similarly in the next alternative, 2 MW Electric vehicles are considered with increasing the capacity of solar and wind energy systems gradually.

Hence, firstly, problems identification, data collection and problem solution are investigated. After that different parameters and failure rates are calculated. The failure rate sequences, top and basic events are identified with the proposed approach. After that, fault tree is constructed based on the above analysis and risk analysis is done with increasing the solar and wind energy systems capacity. Finally, risk assessment is done based on the proposed NIBFFT method, reviews the results and made decisions.

Data collection are done by gathering information related to solar energy system, wind energy system and Electric vehicles by brush up old records, noticing the operation of the grid connected system with Renewable energy resources and electric vehicles, conducting the survey and taking the views of experts. The outcomes show that the damage in the solar panel, wind generation, electric vehicles motor is frequently happening failure in the system.

B. FAULT TREE CONSTRUCTION BASED ON THE PROPOSED METHOD AND IDENTIFICATION OF RISK FACTORS

The impacts of inserting the renewable energy resources and electric vehicles on the reliability of power system are discussed in the proposed work. It includes some advantages and disadvantages when these sources and Electric vehicles are inserted conventional electric power system. Though, the advantages are predominant because of unlimited and cost-effective solution. Reliability is the main factor for the researches in this field therefore after getting the previous failure data and expert's opinions, top and basic event failures are determined. The major events failures in the grid-connected solar-wind and Electric vehicles system are as follows:

- Solar power system faults (SPSF)
- Wind power system faults (WPSF)
- Electric vehicles faults (EVF)

Therefore, fault tree diagrams are constructed for the proposed power systems that show the top to basic events. Figure represents the fault tree diagram of the grid-linked power system with wind-solar energy resources without the Electric vehicles according the structure and different fault happened in the solar-wind power system. The top event is the solar-wind power system fault and basic faults in the subelements in the system are divided into the basic events.

In the proposed work the task period is chosen as 2 years relaibilty assesement of the entire system. Solar power system faults include the solar module fault, wring faults, junction box fault, front glass failure, solder bond fault, encapsulate fault, system balance faults (DC and AC switches), circuit breaker, connector, bypass diode, DC combiner, Inverter module fault, AC and DC contactor, fans for colling faults, operational fault, start up and stopping faults, converter faults, grid operation fault, faults due to weather. Whereas, the wind power systen include the rotor blades fault, generator fault, gearbox fault, mechanical brake fault, yaw system fault, hub fault, pitch sysetm failure, start upfault, blade damage, shell damge,tip damage, different angles fault,sensors fault, structural fault, moreover Electric vehicles faults includes charge controller failure, power converter failure, rotor shaft failure, start up faults, stopping fault, connector faults, battery module, stator winding open circuit, stator winding open circuit, eccentricity related issue, battery temperature issue, over charge issue, under charge issue,faults in bearing, slave controller of management system of battery, master controller of management system of battery, sensors in electric vehicles, stator winding abnormal connection, control modules failure, driver modules, communications module, discharging module, faults in transducer, failure in body hardware, paint issue, and power switches failure.

The key issue in calculating the chances of failure of the grid-connected wind-solar energy resources and Electric vehicles is the insufficient data of different element failures within the entire system. Therefore, the proposed technique is used to overcome the issue. The experts provide the failure probability of all evenets. There are known failure rates of 20 basic events from the research papers and database. The rest events failure rates are to be determined by the proposed method. Fig 3 shows the fault tree model of grid connected renewable energy system with the Electric vehicles according the structure and different fault happened in the solar-wind power system and Electric vehicles.

C. BASIC EVENT FAILURE INCIDENT VALUATION

The probability of occurrence of all the basic events is done and consequences are investigated to know the probability of

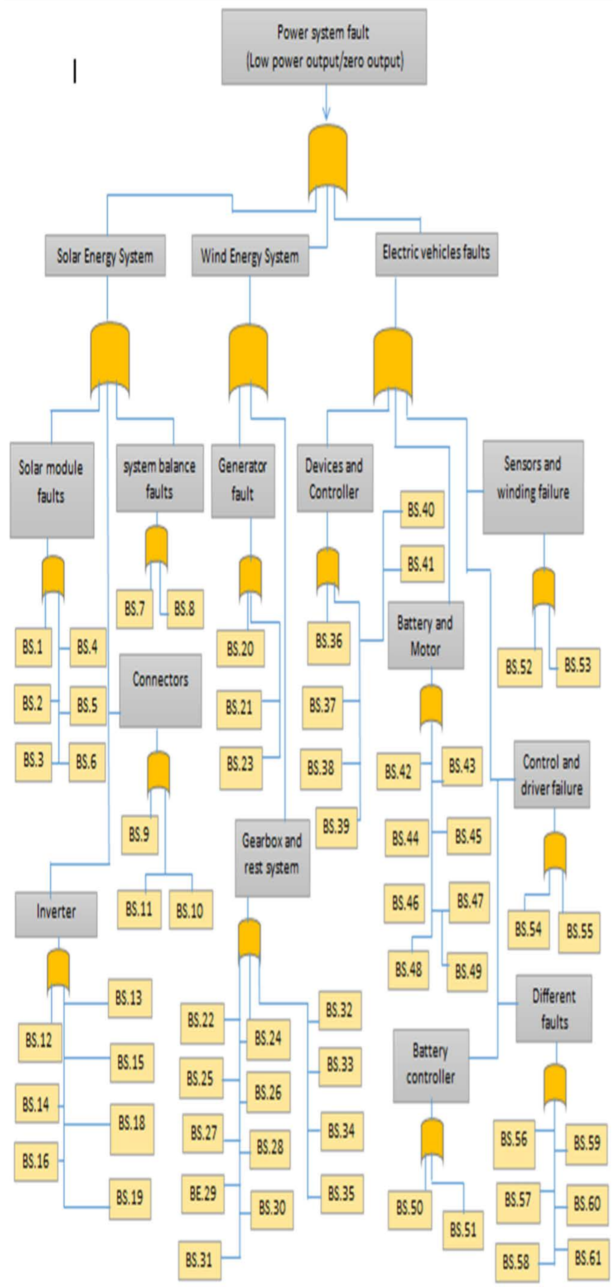

FIGURE 3. Power system faults with a novel incentive based fuzzy fault tree analysis risk assessment.

fault occurrence. The basic events failure rate is considered as fuzzy numbers and the outcomes are changed into the probability scores.

The ranking of fault occurrence can be calculated from the consequence. Therefore, this technique could be used for choosing the proper value of wind-solar and electric vehicles system. The proposed method is reliable and robust especially when most of data are unidentified. The failure risks and corresponding fuzzy numbers are determined and expert views are taken for knowing the rest failure rates.

TABLE 2. Fault tree analysis of the solar-wind-electric vehicles systems.

Top Event of the proposed power system with renewable power resources and the Electric vehicles	Basic Event of the proposed power system with renewable power resources and the Electric vehicles	Rate of failure	Identified event (λ) failure rate with previous records
Power system fault (low power output/zero output)	BS.1: solar module failure	Identified	4.6 [41]
	BS.2: Wiring fault	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.3: Junction box failure	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.4: Front glass failure	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.5: Solder bond fault	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.6: Encapsulate fault	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.7: DC switches failure	Identified	0.7 [41]
	BS.8: AC switches failure	Identified	0.034 [41]
	BS.9: Issue in circuit breaker	Identified	0.4 [41]
	BS.10: Connector failure	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.11: Bypass diode failure	Identified	3.5 [41]
	BS.12: DC combiner issue	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.13: Inverter module fault	Identified	11 [41]
	BS.14: Issue in AC contractor	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.15: Issue in DC contractor	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.16 Issue in cooling fans	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.17: Operational fault	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.18: Start up issue in inverter	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.19: Stopping issue in inverter	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.20: Rotor blades fault in wind rotor	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.21: Generator fault	Identified	0.651 [44]
	BS.22: Gearbox issue	Identified	0.698 [44]
	BS.23: Mechanical brake failure	Identified	0.588 [44]
	BS.24: Yaw system failure	Identified	0.74 [44]
	BS.25: Hub fault	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.26: Pitch system failure	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.27: Start up fault in wind system	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.28: Blade damage	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.29: Shell damage	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.30: Tip damage	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.31: Different angles issue	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.32: Sensor failure	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.33: Structural fault	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.34: Main shaft failure	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.35: Converter failure	Novel incentive based fuzzy fault tree analysis method	Unidentified

TABLE 2. ***(Continued.)*** **Fault tree analysis of the solar-wind-electric vehicles systems.**

	BS.36: Charge controller failure in Electric vehicles	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.37: Power converter failure in Electric vehicles	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.38: Rotor shaft failure in Electric vehicles	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.39: Start up faults in Electric vehicles	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.40: Stopping fault in Electric vehicles	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.41: Connector faults	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.42: Battery module failure	Identified	3.453 [45]
	BS.43: Stator winding open circuit in Electric vehicles	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.44: Stator winding open circuit in Electric vehicles	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.45: Eccentricity related issue	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BE.46: Battery temperature issue	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BE.47: Over charge issue	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BE.48: Under charge issue	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BE.49: Faults in bearing in electric vehicles	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.50: Slave controller of management system of battery	Identified	1.6324 [45]
	BS.51: Master controller of management system of battery	Identified	1.7010 [45]
	BS.52: Sensors in electric vehicles	Identified	1.544 [45]
	BS.53: Stator winding abnormal connection	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.54: Control modules failure,	Identified	1.888 [45]
	BS.55: Driver modules	Identified	1.495 [45]
	BS.56: Communications module	Identified	0.341 [45]
	BS.57: Faults in transducer,	Identified	0.258 [45]
	BS.58: Failure in body hardware	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.59: Paint issue	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.60: Power switches failure	Novel incentive based fuzzy fault tree analysis method	Unidentified
	BS.61: Discharging module	Identified	0.282 [45]
	BS.61: Grid protection issue	Identified	5.7 [41]

Table 2 displays fault tree analysis of the solar-wind-Electric vehicles systems. Whereas Table 3 shows failure risks of basic events by the opinion of skilled persons. It can be seen from the table that the expert's opinion is different of all basic events therefore aggregation calculation is carried out using the opinions of experts.

D. RISK ASSESSMENT BASED ON NOVEL INCENTIVE BASED FUZZY FAULT TREE ANALYSIS METHOD AND MANAGEMENT OF RISK ISSUES

Qualitative proposed fault tree method of different types of systems with probability of top event and basic fuzzy tree analysis is displayed in fig 3. Basic events fuzzy probability scores are calculated for the different basic events of the proposed systems (P1 to P10) and they are presented in Table 5 and Table 6. Defuzzification values based on NIBFFTA are also calculated and are presented in Table 7. After that proposed risk analysis technique is used to know the effect of different basic events on the entire system, it can damage the whole system. Hence, with the proposed NIBFFTA technique, top event probability can be known so the idea of entire system condition can be judged easily.

The probability analysis of fault occurrence is also done to know the effect of every basic action of the system on the top action. The prediction analysis factors for the different basic events of the proposed systems are calculated and it can be used to know the actual effect of basic events on the entire system.

The Prediction analysis factors for the different basic events of the proposed systems are presented in Table 2 and

TABLE 3. Risks of failure and corresponding fuzzy numbers.

Chances of failure	Corresponding Fuzzy Numbers
Extra low (EXL)	(0.01, 0.07, 0.10)
Normal low (NRL)	(0.18, 0.21,0.32)
Adequate low (ADL)	(0.25, 0.34,0.41)
Low (LW)	(0.31, 0.43, 0.48)
Reasonable (RES)	(0.42,0.53,0.68)
High (HH)	(0.58, 0.73,0.85)
Adequate high (ADH)	(0.62, 0.78,0.87)
Normal high (NRH)	(0.75, 0.88, 0.93)
Extra high (EXH)	(0.89,0.97,0.99)

Table 3. The prediction analysis factors for BS.12 is 5.45E-03, 4.57E-04, 3.72E-04, 4.28E-03, 3.94E-04, 5.10E-03 for the alternatives P1, P2, P3, P4, P5, P6, P7, P8, P9, and P10 respectively and it belongs to the DC combiner issue in the solar power system. Moreover, the prediction analysis factors for BS.34 are 2.85E-04, 3.41E-04, 1.79E-04, 2.18E-04, 6.89E-04, 4.62E-07, 3.95E-05, 3.27E-04, 2.76E-06, and 6.12E-04 for the alternatives P1, P2, P3, P4, P5, P6, P7, P8, P9, and P10 respectively and it belongs to the main shaft failure in the wind energy system, whereas, the prediction analysis factor for BS.48 are 5.79E-05, 6.38E-03, 3.91E-04, 6.14E-04, 3.47E-04, 4.82E-03, 7.26E-03, 4.52E-05 and 6.71E-04 for the alternatives, P2, P3, P4, P5, P6, P7, P8, P9, and P10 respectively and it belongs to the overcharge issue in battery of electric vehicles. This factor could lower the risk limit by knowing the critical issue. These presented values permit the manufacturer to make the suitable component of solar-wind energy system and Electric vehicles to lower the uncertainties and different risk issues. The proposed approach helps in getting the range of failures and to describe the failure rate. With this analysis, the most suitable and reliable solar-wind-Electric vehicles components could be chosen and hence the rates of failure of components could be lowered.

Therefore, from the reliability assessment consequences, top event probability for different kinds of proposed alternative systems is presented in Table 7. Fig.4 shows the top event probability along with basic FTA of proposed different alternatives systems [46]. The probability of top event with basic FTA method and proposed NIBFFTA method for the alternatives P1, P2, P3, P4, P5, P6, P7, P8, P9, 10 are 0.01247, 0.01143, 0.01125, 0.01105, 0.01097, 0.01085, 0.01073, 0.01068, 0.01052, 0.01042 and 0.02648, 0.02627, 0.02592, 0.02583, 0.02574, 0.02551, 0.02548, 0.02537, 0.02526, 0.02514 respectively. It could be seen, the proposed NIBFFTA techniques provides better outcomes and it can be used as choice care model for the selection of a suitable solar-wind energy systems and Electric vehicles.

TABLE 4. Failure risks of basic events by the opinion of skilled persons.

Basic Events	Skilled 1	Skilled 2	Skilled 3	Skilled 4	Skilled 5	Skilled 6
BS.2	EXH	HH	ADH	ADH	LW	NRL
BS.3	NRL	ADL	ADH	ADH	EXL	RES
BS.4	HH	RES	NRH	NRH	EXH	HH
BS.5	NRL	NRL	HH	EXL	NRH	LW
BS.6	LW	HH	NRL	ADL	ADH	HH
BS.10	LW	LW	ADL	NRL	ADL	NRL
BS.12	ADL	NRL	LW	LW	NRH	EXH
BS.14	EXH	ADH	NRL	HH	LW	ADL
BS.15	HH	NRL	ADL	EXH	ADH	ADL
BS.16	LW	ADH	HH	RES	ADL	RES
BS.17	RES	HH	LW	NRL	EXH	ADH
BS.18	RES	EXH	ADL	HH	LW	RES
BS.19	NRL	LW	ADH	RES	RES	HH
BS.20	ADL	ADH	HH	EXH	NRL	EXL
BS.25	EXH	LW	EXL	LW	HH	NRH
BS.26	ADH	HH	RES	LW	EXL	ADL
BS.27	HH	EXH	NRL	ADL	RES	NRH
BS.28	LW	ADL	LW	ADH	NRL	EXH
BS.29	NRH	ADH	EXL	HH	ADL	RES
BS.30	LW	NRH	EXH	ADL	ADH	NRL
BS.31	ADL	EXH	HH	EXL	RES	EXL
BS.32	ADH	NRH	RES	ADL	LW	NRL
BS.33	ADL	NRL	HH	LW	EXL	ADH
BS.34	NRL	NRH	ADH	LW	ADL	RES
BS.35	EXH	HH	ADL	NRL	NRH	NRL
BS.36	ADL	NRL	NRH	EXL	EXH	ADH
BS.37	LW	RES	EXH	NRL	HH	ADL
BS.38	HH	ADH	ADL	LW	RES	EXL
BS.39	NRL	ADL	NRH	RES	HH	NRH
BS.40	HH	EXH	LW	NRL	ADL	EXH
BS.41	ADL	LW	NRH	ADH	ADH	NRH
BS.43	EXH	EXL	ADH	HH	ADL	NRL
BS.44	ADL	NRH	EXL	LW	EXH	NRH
BS.45	HH	NRL	NRL	RES	ADH	LW
BE.46	RES	ADL	LW	NRL	ADL	HH
BE.47	NRL	ADH	NRH	HH	NRH	EXH
BE.48	NRH	NRH	NRL	ADL	NRL	LW
BE.49	ADH	EXH	EXL	LW	NRL	ADH
BS.53	ADL	ADL	HH	NRL	NRH	NRH
BS.58	EXH	NRH	RES	NRH	EXH	ADL
BS.59	EXL	NRL	ADH	LW	EXL	RES
BS.60	HH	LW	EXH	ADH	ADL	NRL

Hence, these results allow making a better setup on the solar-wind energy system and Electric vehicles configuration to lower the risk boundary.

V. CASE STUDY WITH THE PROPOSED NIBFFTA BASED RISK ASSESSMENT APPROACH

Grid-integrated solar- wind energy systems and Electric vehicles with the various components are taken for this work with the proposed NIBFFTA technique to know the system reliability while changing the capacity of solar, wind and Electric vehicles system. Total 10 alternatives are considered.

TABLE 5. Basic events fuzzy probability scores and prediction analysis factors for the different basic events of the proposed systems.

Basic Events	Fuzzy number	P1	P2	P3	P4	P5
BS.2	6.24E-03	5.52E-03	4.75E-03	5.21E-03	4.86E-04	5.16E-03
BS.3	6.68E-05	6.72E-05	7.29E-05	6.81E-05	5.24E-05	6.22E-04
BS.4	7.62E-03	7.46E-03	6.34E-03	7.45E-03	6.14E-04	3.62E-04
BS.5	8.27E-07	7.82E-07	7.14E-07	6.72E-07	7.68E-07	5.72E-07
BS.6	5.23E-03	3.26E-03	2.18E-03	3.98E-04	3.12E-03	4.56E-03
BS.10	6.19E-05	5.98E-05	5.14E-05	6.27E-05	8.35E-05	7.23E-05
BS.12	5.45E-03	4.57E-04	3.72E-04	4.28E-03	3.94E-04	5.10E-03
BS.14	8.37E-07	6.72E-07	6.15E-07	5.71E-07	4.93E-07	5.91E-07
BS.15	7.25E-05	5.81E-05	5.65E-05	4.62E-04	3.87E-05	7.98E-05
BS.16	8.48E-04	7.93E-04	9.25E-04	7.52E-03	6.27E-04	3.28E-04
BS.17	5.84E-03	3.84E-03	3.17E-03	2.25E-03	4.58E-03	4.96E-03
BS.18	4.28E-04	4.21E-04	3.63E-04	4.15E-04	4.17E-04	5.91E-04
BS.19	5.62E-03	4.61E-03	4.31E-03	3.28E-04	5.17E-03	5.93E-04
BS.20	6.92E-05	7.85E-05	6.65E-05	7.12E-05	5.18E-05	4.16E-05
BS.25	7.14E-04	7.63E-04	7.25E-04	6.82E-03	5.23E-04	2.89E-03
BS.26	7.92E-07	5.72E-07	6.73E-07	7.28E-07	4.27E-07	5.18E-07
BS.27	4.31E-04	3.45E-03	3.19E-04	5.28E-04	3.17E-04	6.62E-04
BS.28	6.23E-07	6.78E-07	4.82E-07	5.94E-07	6.16E-07	5.81E-07
BS.29	6.47E-05	5.37E-05	4.21E-05	5.12E-04	6.28E-05	9.17E-05
BS.30	8.26E-03	7.83E-04	7.61E-03	7.57E-03	8.04E-03	7.12E-04
BS.31	7.85E-04	7.12E-04	6.71E-04	7.81E-04	6.18E-03	5.37E-04
BS.32	8.17E-07	9.36E-07	9.32E-07	3.41E-07	7.16E-07	8.16E-07
BS.33	5.16E-03	3.75E-03	4.52E-03	3.17E-03	5.73E-03	4.93E-03
BS.34	4.48E-04	2.85E-03	3.41E-04	1.82E-04	2.23E-04	6.89E-04
BS.35	6.63E-05	7.63E-05	6.26E-04	5.17E-04	6.71E-04	9.93E-05
BS.36	4.92E-07	N/A	5.28E-04	3.90E-04	8.18E-04	6.26E-05
BS.37	4.81E-04	N/A	3.28E-07	5.17E-04	3.29E-06	7.17E-06
BS.38	6.71E-06	N/A	7.18E-04	5.21E-04	3.71E-06	9.19E-04
BS.39	5.95E-04	N/A	4.82E-04	4.35E-04	4.68E-04	7.13E-05
BS.40	4.26E-05	N/A	7.34E-05	7.14E-05	5.91E-06	4.84E-04
BS.41	6.13E-05	N/A	4.52E-07	2.96E-07	4.14E-05	6.73E-07
BS.43	7.55E-04	N/A	4.52E-05	5.69E-05	6.82E-04	5.29E-05
BS.44	6.50E-05	N/A	6.72E-04	5.79E-05	5.91E-05	6.70E-04
BS.45	7.36E-04	N/A	6.13E-04	8.94E-04	6.72E-04	5.62E-05
BE.46	3.62E-03	N/A	6.83E-07	7.10E-06	5.86E-04	3.62E-04
BE.47	4.83E-04	N/A	9.05E-06	7.73E-06	5.72E-05	5.94E-07
BE.48	6.92E-03	N/A	5.79E-05	6.38E-03	3.91E-04	6.14E-04
BE.49	8.46E-07	N/A	2.73E-06	5.18E-07	7.65E-06	5.13E-06
BS.53	4.82E-05	N/A	1.93E-05	4.68E-06	5.79E-05	8.32E-05
BS.58	5.64E-07	N/A	6.65E-03	4.13E-04	4.57E-03	7.12E-05
BS.59	6.92E-03	N/A	8.35E-07	7.32E-05	5.27E-07	4.18E-04
BS.60	3.56E-05	N/A	4.67E-07	3.11E-06	4.17E-06	9.86E-07

TABLE 6. Prediction analysis factors for the different basic events of the proposed systems.

Basic Events	P6	P7	P8	P9	P10
BS.2	5.25E-04	2.47E-05	3.81E-03	4.92E-03	5.73E-03
BS.3	7.83E-07	7.69E-05	3.57E-07	5.61E-03	7.28E-04
BS.4	8.26E-05	7.27E-03	6.29E-04	6.78E-03	3.28E-03
BS.5	8.93E-05	6.54E-07	5.63E-06	6.28E-06	5.56E-07
BS.6	4.82E-04	3.57E-03	4.82E-04	5.71E-05	6.16E-03
BS.10	4.79E-07	4.69E-07	5.74E-05	4.83E-07	5.94E-05
BS.12	6.73E-05	5.62E-04	4.76E-05	4.68E-03	5.98E-03
BS.14	9.82E-06	6.71E-07	3.79E-07	4.19E-06	6.92E-05
BS.15	4.82E-05	3.69E-04	4.78E-04	7.82E-04	6.84E-05
BS.16	7.16E-03	8.01E-03	7.63E-03	5.18E-04	2.85E-04
BS.17	4.84E-04	3.68E-04	3.81E-03	4.94E-05	6.17E-03
BS.18	5.70E-05	3.12E-04	6.71E-05	5.27E-04	5.18E-04
BS.19	3.26E-03	5.43E-04	3.72E-03	6.17E-04	5.25E-04
BS.20	6.18E-07	5.75E-07	7.72E-05	6.81E-05	3.27E-07
BS.25	7.18E-03	6.74E-03	5.72E-03	3.81E-04	3.86E-04
BS.26	5.19E-07	8.23E-05	6.29E-05	4.83E-07	9.16E-07
BS.27	6.28E-03	3.73E-03	2.81E-04	3.96E-03	9.12E-05
BS.28	7.32E-05	4.19E-05	4.78E-04	6.98E-07	7.45E-07
BS.29	5.98E-07	5.68E-06	6.92E-04	7.22E-07	9.63E-05
BS.30	7.83E-03	6.81E-04	7.96E-04	5.62E-05	8.94E-06
BS.31	6.87E-05	6.53E-05	7.93E-03	5.68E-03	4.87E-04
BS.32	7.39E-05	8.52E-05	3.68E-07	5.29E-07	8.91E-07
BS.33	3.76E-04	3.78E-04	3.29E-03	4.84E-04	6.21E-03
BS.34	4.62E-07	3.95E-05	3.27E-04	2.76E-06	6.12E-04
BS.35	7.13E-07	5.86E-05	4.37E-07	8.92E-05	6.73E-05
BS.36	5.61E-06	4.61E-03	3.16E-04	7.17E-05	6.98E-05
BS.37	6.73E-04	4.51E-06	5.98E-05	6.74E-06	7.83E-04
BS.38	7.84E-05	8.16E-03	6.27E-03	3.25E-06	7.15E-04
BS.39	4.53E-04	3.71E-06	4.71E-06	5.61E-05	7.93E-05
BS.40	6.27E-04	4.65E-07	7.27E-05	6.88E-07	3.17E-04
BS.41	5.68E-06	5.72E-07	3.47E-07	4.78E-05	6.12E-07
BS.43	3.41E-05	7.28E-06	6.72E-06	6.47E-04	5.71E-05
BS.44	7.69E-05	5.27E-07	7.37E-05	5.15E-06	7.82E-04
BS.45	6.83E-05	6.78E-03	7.25E-05	5.61E-03	8.35E-05
BE.46	4.67E-06	6.25E-05	8.31E-05	4.38E-04	3.13E-07
BE.47	8.15E-07	7.23E-06	7.26E-06	6.52E-05	8.14E-06
BE.48	3.47E-04	4.82E-03	7.26E-03	4.52E-05	6.71E-04
BE.49	5.72E-05	6.75E-07	5.73E-06	6.95E-05	5.35E-04
BS.53	3.49E-04	3.27E-04	4.93E-05	6.32E-04	7.26E-03
BS.58	5.23E-04	6.12E-06	7.27E-05	4.79E-05	6.25E-05
BS.59	4.15E-04	5.75E-05	8.84E-05	6.12E-05	4.72E-04
BS.60	4.86E-06	3.89E-07	3.52E-07	6.28E-06	7.37E-07

Alternative 1- Original arrangement, 15 MW wind power system is associated to bus 29 and 15 MW solar power system is associated to bus 27.

Alternative 2- Original arrangement with 15 MW wind power system is associated to bus 29 and 15 MW solar power system is linked to bus 27 and 2MW Electric vehicles is connected to bus 40.

TABLE 7. Top event probability for different kinds of proposed alternative systems.

Choices	Probability of top event	Defuzzification values based on NIBFFTA		Basic FTA
		Right score	Left score	
P1	0.01247	0.02745	0.96246	0.02648
P2	0.01143	0.02725	0.96136	0.02627
P3	0.01125	0.02698	0.96125	0.02592
P4	0.01105	0.02684	0.95983	0.02583
P5	0.01097	0.02673	0.95821	0.02574
P6	0.01085	0.02668	0.95769	0.02551
P7	0.01073	0.02654	0.95625	0.02548
P8	0.01068	0.02647	0.95419	0.02537
P9	0.01052	0.02632	0.95327	0.02526
P10	0.01042	0.02613	0.95147	0.02514

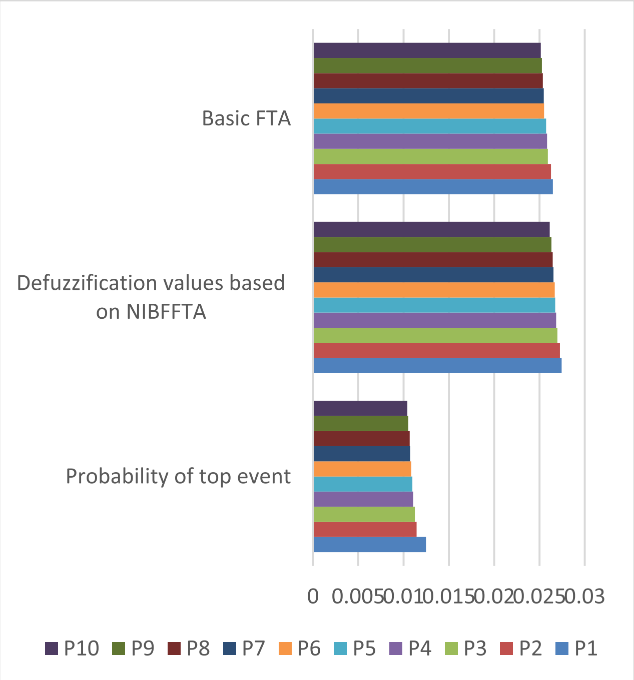

FIGURE 4. Top event probability along with basic FTA of proposed different alternatives systems.

Alternative 3- Total 25 MW wind power system is used and it is linked to bus 29 and 25 MW solar power system are taken and it is connected to bus 27 with original 2MW Electric vehicles

Alternative 4- Total 35 MW wind power system is used and it is connected to bus 29 and 35 MW solar power system are taken and it is connected to bus 27 with original 2MW Electric vehicles

Alternative 5- Total 45MW wind power system is used and it is connected to bus 29 and 45 MW solar power system are taken and it is connected to bus 27 with original 2MW Electric vehicles energy scheme is associated and it is linked with bus 22.

Alternative 6- Total 55 MW wind power system is used and it is connected to bus 29 and 55 MW solar power system are taken and it is connected to bus 27 with original 2MW Electric vehicles

Alternative 7- Total 65 MW wind power system is used and it is connected to bus 29 and 65 MW solar power system are taken and it is connected to bus 27 with original 2MW Electric vehicles

Alternative 8- Total 75 MW wind power system are used and it is connected to bus 29 and 75 MW solar power system are taken and it is connected to bus 27 with original 2MW Electric vehicles

Alternative 9- Total 85 MW wind power system is used and it is connected to bus 29 and 85 MW solar power system are taken and it is connected to bus 27 with original 2MW Electric vehicles

Alternative 10- Total 95 MW wind power system is used and it is connected to bus 29 and 95 MW solar power system are taken and it is connected to bus 27 with original 2MW Electric vehicles

The proposed work involves the solar power system with rating from 15MW to 95 MW, wind power system with rating from 15MW to 95 MW and 2 MW Electric vehicles. The alternative 1 is original system without adding the extra solar and wind power systems and Electric vehicles. Reliability indices are calculated for the different alternative as large Electric vehicles connection in the distribution network raises the load, therefore, reliability is affected. Hence, solar and wind power system are connected to different buses to enhance the reliability of the power system. Gradually, solar and wind power systems are inserted into the buses and reliability indices are monitored, it can be seen that by inserting the renewable power sources in the power system with Electric vehicles enhances the reliability of the system. The large-scale Electric vehicles insertion in the distribution network increases the load in the system hence power quality and reliability are affected. Therefore, the various factors related to the Electric vehicles power demands are considered in this work.

By using the proposed NIBFFTA technique, different reliability indices LOLP, LOLE, MTTF, rate of failure, EENS and failure probability of top event of grid-connected solar-wind systems and Electric vehicles with considering the different alternatives are calculated and these are presented in Table 8. Fig 5 and fig 6 show the reliability indices with proposed NIBFFTA technique for the different alternatives.

It could be seen from the Table 8 that LOLP is 0.1728 % with original arrangement i.e., 15 MW wind power system is connected to bus 29 and 15 MW solar power system is connected to bus 2 and LOLP is 0.1732% with 15 MW wind power system is linked to bus 29 and 15 MW solar power system is linked to bus 27 and 2 MW Electric vehicles is linked to bus 40. Therefore LOLP is increased with electric vehicle is linked to the system it affects the reliability but in alterative 3 when solar and wind power insertion into the power system increase with the same value of Electric

TABLE 8. Calculation of reliability indices with proposed NIBFFTA technique for the proposed different alternatives.

S. N.	LOLP	LOLE	MTTF (yr.)	Rate of failure (Failures/year)
Alternative 1	0.1728%	52.17	4.6	27
Alternative 2	0.1732%	54.62	4.3	28.1
Alternative 3	0.1712%	52.31	5.7	26.2
Alternative 4	0.1659%	52.24	6.8	25.6
Alternative 5	0.1625%	51.86	7.2	25.1
Alternative 6	0.1518%	51.62	7.9	24.4
Alternative 7	0.1439%	51.27	8.2	23.8
Alternative 8	0.1410%	50.97	8.7	22.5
Alternative 9	0.1362%	50.49	9.1	21.7
Alternative 10	0.1318%	50.16	9.8	20.6

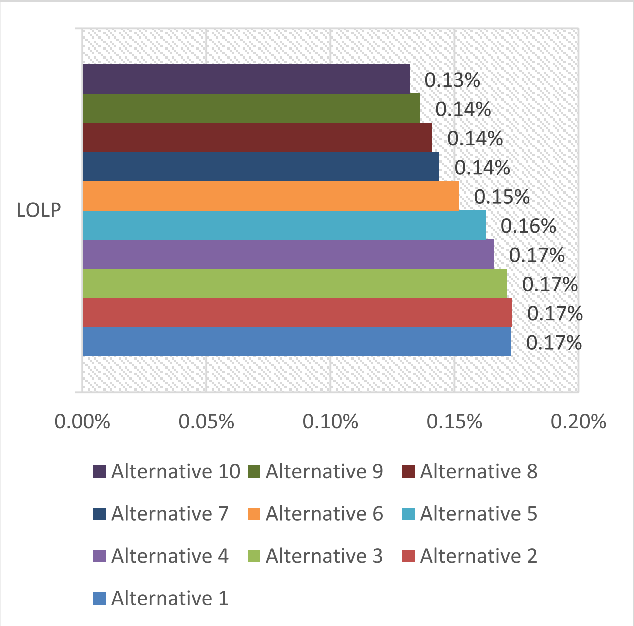

FIGURE 5. Reliability indices LOLP with proposed NIBFFTA technique for the proposed different alternatives.

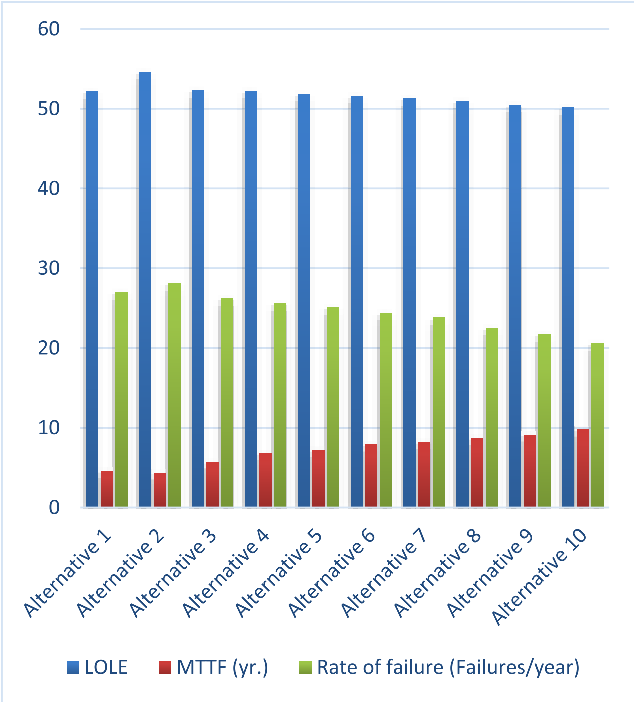

FIGURE 6. Reliability indices LOLE, MTTF and rate of failure with proposed NIBFFTA technique for the proposed different alternatives.

vehicles i.e. 25 MW wind power system are used and 25 MW solar power system are taken with original 2MW Electric vehicles, the LOLP is 0.1712%. Hence, when renewable energy sources insertion increases in the power system, the LOLP is decreased. Similarly, for the reliability indices LOLE, for alternative 1 when 15 MW solar and 15 MW wind energy systems are used with the grid, it is 52.17 but for alternative 2 when same value of renewable energy sources are used as in alternative 1 but 2 MW Electric vehicles are added, the LOLP is increased i.e., 54.62. However, for alternative 3, when wind and solar power systems values are increased, the LOLP is 52.31, therefore by insertion the more power from the renewable power resources, the realibility is increased. The MTTF is 4.6 for the alternative 1 i.e., without Electric vehicles, but it is 4.3 when extra Electric vehicles are added. Hence, Electric vehicles connection with the grid affects the reliability but for alternative 3, the MTTF is 5.7, therefore by inserting the more wind-solar energy systems the reliability of the system increases. Moreover, the rate of failure for alternative 1, 2, and 3 are 27, 28.1, 26.6 respectively. It can be seen from the values of rate of failure for alternatives 1, 2 and 3, firstly rate of failure increases when Electric vehicles are added in the system, but by giving more power from the renewable sources into the grid with the same Electric vehicles, the rate of failure is decreased. For better reliability of power system, the mean time failure should be lower and rate of failure should be higher.

As seen from the results of different alternative in Table 8, the consequences shows that the integration of wind and solar power system into the grid with Electric vehicles can enhance the reliability of the system, exclusively when conventional thermal power plant is connected with the grid.

Moreover, it can be seen from the Table 9 that the value of EENS is 38.5 with original system i.e., 15 MW wind power system is linked to bus 29 and 15 MW solar power system is linked to bus 2 and EENS is 38.8 with 15 MW wind power system, 15 MW solar power system and 2MW Electric vehicles are added in the power system. For alternatives 3, 4, 5,6, and 10, the values of EENS are 32.3, 27.6, 25.2,26.5, and 19.5 respectively.

Fig 7 and fig 8 represent the graphical representation of EENS and rate of failure with proposed NIBFFTA technique

TABLE 9. Reliability indices calculation with proposed NIBFFTA technique for the different alternatives of grid connected solar-wind-Electric vehicles systems.

S. N.	EENS MW	Top event Failure probability
Alternative 1	38.5	0.482
Alternative 2	38.8	0.497
Alternative 3	32.3	0.468
Alternative 4	27.6	0.462
Alternative 5	25.2	0.451
Alternative 6	26.5	0.446
Alternative 7	24.0	0.431
Alternative 8	23.5	0.419
Alternative 9	21.1	0.392
Alternative 10	19.5	0.385

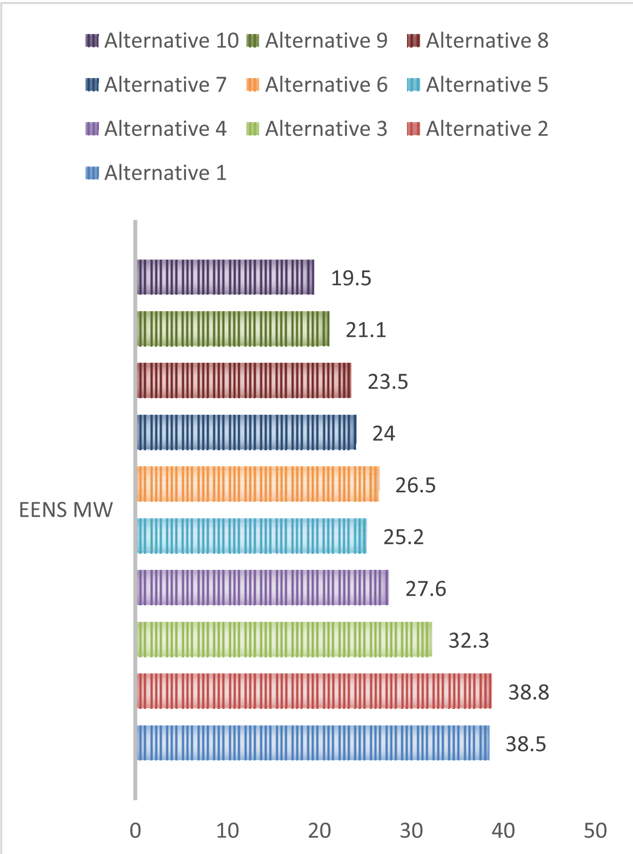

FIGURE 7. Reliability indices EENS with proposed NIBFFTA technique for the different alternatives.

for the different alternatives respectively. The reduction is more specially when integrating the solar-wind energy resources with more capacity.

The reduction in EENS is desirable, and therefore, the power system reliability increases with the connection of solar-wind power system with Electric vehicles Similarly for the probability of top event occurrences, for alternative 1, it is 0.482 when only solar and wind power systems are connected with the grid, the probability of top event occurrences for alternative 2 is 0.497, with the same solar-wind power systems are used as in case 1 with 2 MW Electric vehicles.

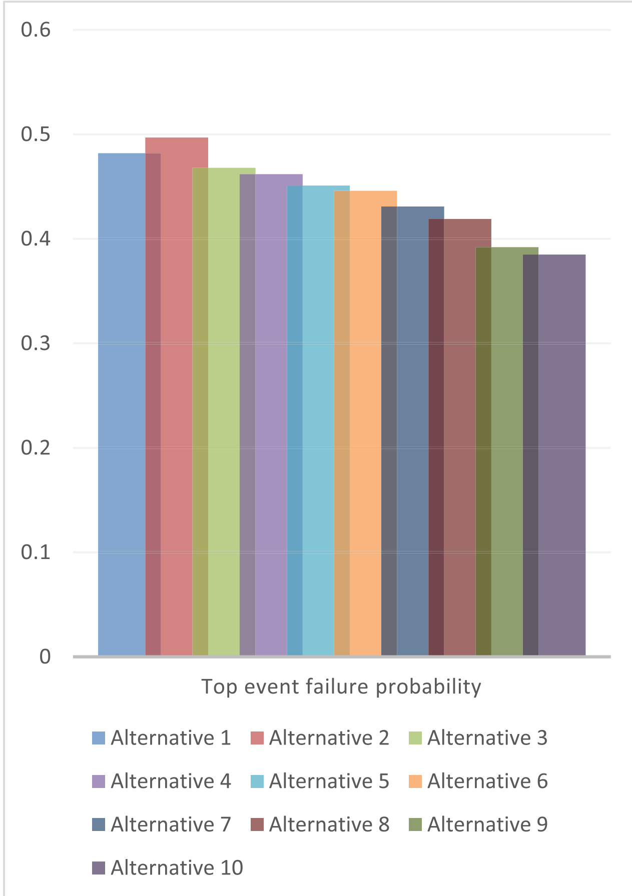

FIGURE 8. Rate of failure with proposed NIBFFTA technique for the proposed different alternatives.

Hence, the probability of top event increases with addition of Electric vehicles because the Electric vehicles conversion increases the load in the system and it affects the power system reliability.

For alternative 3, 4, 5,6,7,8,9 and 10, the value of probability of top event of the proposed system are 0.468, 0.462, 0.451, 0.446, 0.431, 0.419, 0.392 and 0.385 respectively. It could be seen from Table 9, that the probability of top event failure decreases with increasing the value of solar-wind power system. Hence, it can be determined form the values of reliability indices EENS, the renewable energy sources insertion in the power system could improve the reliability, especially when Electric vehicles are connected in the system.

Fig. 9 shows the reliability index EENS with changing the load with proposed NIBFFTA technique for the different alternatives and it can be seen form the Table 10 that when same value of solar-wind-Electric vehicles are changes as alternative 1 to alternative 10 and load is changed from 100 % to 105 %, 115 %, 125 % and 135 %, then EENS decreases. But it does not improve the LOLP and LOLE with the same solar and wind energy system used (alternative 1) with changing the load. The value of EENS for alternative 1 without including the Electric vehicles with 105 %, 115 %,

TABLE 10. Reliability indices EENS with proposed NIBFFTA technique for the different alternatives with changing the load.

S. N.	EENS MW With 105 % load	EENS MW With 115 % load	EENS MW With 125 % load	EENS MW With 135 % load
Original 15 MW wind system+15 MW solar system	37.2	36.8	36.1	35.6
15 MW wind system+15 MW solar system+2 MW Electric vehicles	38.4	38.2	37.9	37.3
25 MW wind system+25 MW solar system+2 MW Electric vehicles	31.6	31.3	31.1	30.7
35 MW wind system+35 MW solar system+2 MW Electric vehicles	26.8	26.2	25.3	24.9
45 MW wind system+45 MW solar system+2 MW Electric vehicles	24.5	23.8	23.2	23.0
55 MW wind system+55 MW solar system+2 MW Electric vehicles	25.1	24.6	24.1	23.7
65 MW wind system+65 MW solar system+2 MW Electric vehicles	23.6	23.1	22.6	22.2
75 MW wind system+75 MW solar system+2 MW Electric vehicles	22.6	22.2	21.7	21.5
85 MW wind system+85 MW solar system+2 MW Electric vehicles	20.9	20.3	19.6	19.1
95 MW wind system+95 MW solar system+2 MW Electric vehicles	18.6	18.4	18.1	17.8

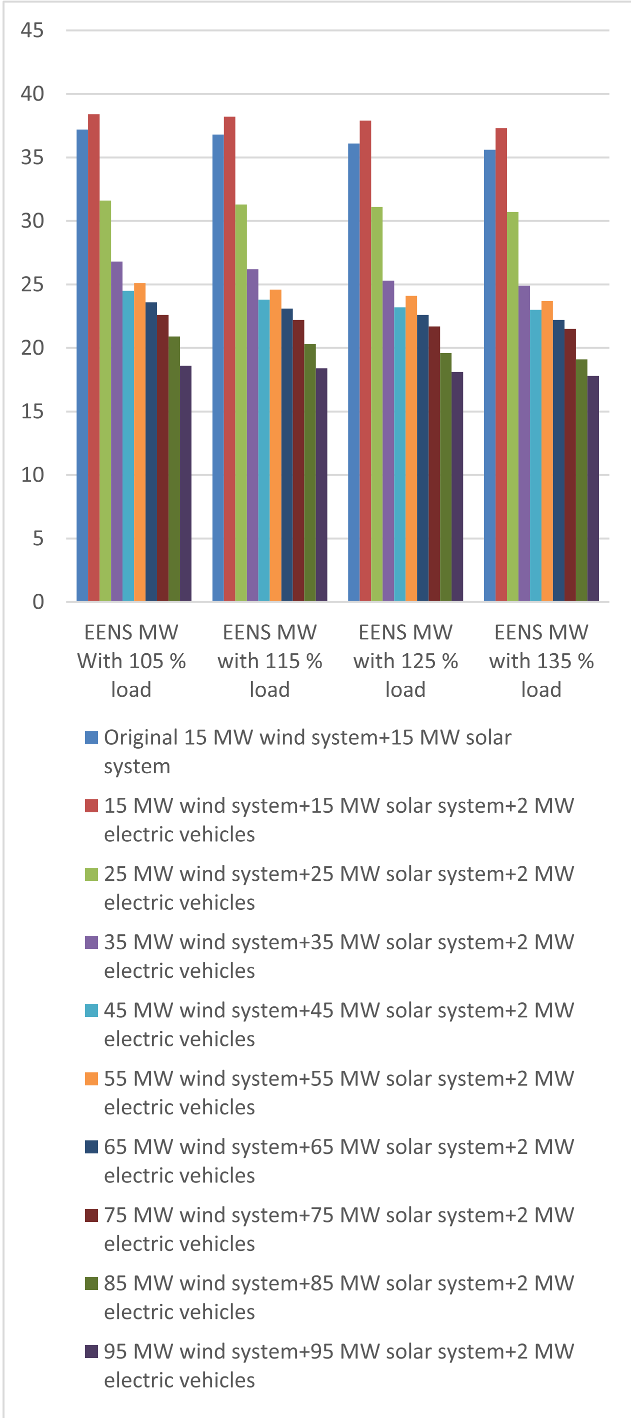

FIGURE 9. Reliability indices EENS with changing the load with proposed NIBFFTA technique for the different alternatives.

125 % and 135 % load are 37.2, 36.8, 36.1 and 35.6 respectively. Whereas with including the Electric vehicles in the distribution network, the value of EENS for alternative 2 without including the Electric vehicles a same renewable energy sources as used in alternative 1with 105 %, 115 %, 125 % and 135 % load are 38.4, 38.2, 37.9 and 37.3 respectively, hence, the insertion of Electric vehicles in the distribution network affects the reliability indices EENS. Similarly, for alternative 7 i.e., 65 MW wind system, 65 MW solar system, and 2 MW Electric vehicles, the values of EENS are 23.6, 23.1, 22.6 and 22.2 respectively.

Table 11 represents the reliability indices MTTF (yr.) and rate of failure with proposed NIBFFTA technique for the different components of proposed system. These are unidentified events, the mean to failure easily calculated by the proposed techniques. The rate of failure also changes with the proposed system. If the aggregated value of mean time to failure and failure rate are taken as shown in Table 8, then

TABLE 11. Reliability indices MTTF (yr.) and rate of failure with proposed NIBFFTA technique for the different components of proposed grid connected solar-wind Electric vehicles system.

Proposed grid connected solar-wind-Electric vehicles system components	MTTF (year)	Rate of failure (failures/ Year 10^{-6})
Solar energy system- Wiring fault	2.6	18
Junction box failure	4.2	6.3
Front glass failure	1.2	4.6
Solder bond fault	1.6	11.6
Encapsulate fault	3.7	16.4
Connector failure	0.26	4.8
DC combiner issue	3.6	5.8
Issue in AC contractor	1.3	0.78
Issue in DC contractor	1.2	0.96
Issue in cooling fans	2.7	2.9
Operational fault	4.8	15
Start up issue in inverter	0.37	2.8
Stopping issue in inverter	0.48	7.4
Wind energy system- Rotor blades fault in wind rotor	3.5	8.5
Hub fault	0.57	5.1
Pitch system failure	0.92	6.8
Start-up fault in wind system	1.2	9.2
Blade damage	2.8	10.4
Shell damage	0.94	5.7
Tip damage	0.86	8.5
Different angles issue	4.7	17.3
Sensor failure	4.1	18.8
Structural fault	0.27	5.1
Main shaft failure	1.6	8.2
Converter failure	2.6	12.4
Electric vehicles system- Charge controller failure in Electric vehicles	3.2	15.6
Power converter failure in Electric vehicles	2.4	6.4
Rotor shaft failure in Electric vehicles	1.7	8.2
Start up faults in Electric vehicles	1.9	9.6
Stopping fault in Electric vehicles	2.3	5.3
Connector faults	0.71	3.4
Stator winding open circuit in electric vehicles	1.3	11.6
Stator winding open circuit in electric vehicles	4.2	6.8
Eccentricity related issue	4.8	9.5
Battery temperature issue	2.5	14.6
Over charge issue	1.71	17.9
Under charge issue	1.3	5.1
Faults in bearing in electric vehicles	4.9	2.8
Stator winding abnormal connection	0.27	0.32
Failure in body hardware	0.12	0.56
Paint issue	5.2	4.5
Power switches failure	1.8	6.8

TABLE 12. Comparison table of reliability indices.

S.N.	Techniques	EENS
1.	Electrical Loss Minimization Technique [47]	34.38
2.	Chronological multiple state probability model with maximum charge power [48]	31.85
3.	System state generating method [49]	24.41
4.	Probabilistic minimal cut-set-based iterative methodology [50]	63.1
5.	Proposed novel incentive based fuzzy fault tree analysis method	19.5

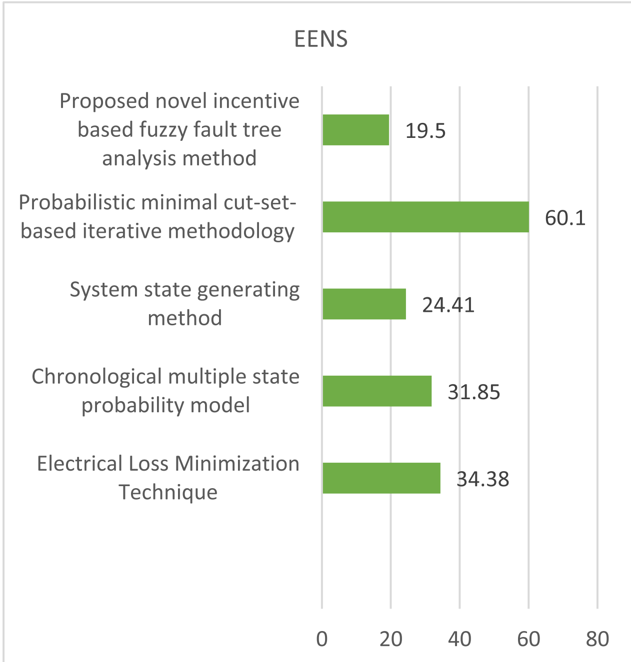

FIGURE 10. Graphical representation of EENS with different methods.

with increasing the value of solar and wind energy system, the value of MTTF increases and rate of failure is decreased. Hence, the different capacities of solar, wind and Electric vehicles systems are determined and integrated to the system to make the different alternatives.

Hence, it can be concluded form the values of reliability indices LOLE, LOLP, MTTF, rate of failure, and EENS, that the renewable energy sources insertion into the power system can improve the reliability, especially when Electric vehicles are connected in the system. Therefore, it is important to add more renewable energy sources to maintain the reliability of system when Electric vehicles are connected to the distribution networks.

The comparison of realibility indices is shown in Table 12, the EENS is basically related to the energy over a provided zone and during a provided time period which is probably low due to lack of resources to meet the required demand.

It shows a matrix which can be used as security measure of power supply and it is also used to set the standard of reliability in the power market. There are various features about the EENS cost, about the measurement of economics losses and in dealer money losses because of not providing the expected energy. Therefore, mainly the expanding the population density in terms of consumers caused the collective growth of power consumption, significance of the calculation of EENS becomes more essential. Here, in this analysis, the ENNS is taken as a reliability index for comparison and it could be low for better system reliability.

Whereas, Fig. 10 shows the graphical representation of EENS with different methods. The EENS using the different methods such as electrical loss minimization technique, chronological multiple state probability model, system state generating method, probabilistic minimal cut-set-based iterative methodology and the proposed novel incentive based fuzzy fault tree analysis method are 34.38, 31.85, 24,41,63.1 and 19.50 respectively. The comparison table shows that proposed novel incentive based fuzzy fault tree analysis method provide the better value of ENNS in comparison with the other existing approaches.

VI. CONCLUSION

In order to get a more reliable prediction of the overall power system considering the impact of integrating electric vehicles and renewable energy systems, a detailed investigation of the reliability problems in the proposed system is presented in this paper by using the novel incentive based fuzzy fault tree analysis (NIBFFTA) approach. The basic events fuzzy probability scores and prediction analysis factor for the different basic events of the proposed systems are calculated, furthermore, the probability analysis of fault occurrence is also proposed to determine the effect of each basic event of the system on the top event. The prediction analysis factor for the different basic events of the proposed systems is calculated and it can be used to get the real consequence of basic events on the proposed system.

Moreover, grid-integrated solar- wind energy systems and electric vehicles with the various components are considered with the proposed NIBFFTA method to know the reliability of system while changing the capacity of solar, wind and Electric vehicles system. Hence, total 10 alternatives are considered. Further, reliability indices such as LOLE, LOLP, EENS, MTTF, failure rate and top event failure probability with for the proposed different alternatives are calculated. Besides, the reliability index EENS with proposed NIBFFTA technique for the different alternatives with changing the load are also calculated. Furthermore, reliability indices MTTF (yr.) and rate of failure with proposed NIBFFTA technique for the different components of proposed grid connected solar-wind Electric vehicles system are also determined.

As found from the consequences of different alternative, it could be seen that the integration of wind and solar power system into the grid with electric vehicles can enhance the system reliability, particularly when conventional thermal power plant is linked with the grid. Consequently, it is important to add more renewable power sources to maintain the system reliability when electric vehicles are connected to the distribution networks. The proposed method is likely to be scalable to big grid-connected solar and wind power systems with Electric vehicles, changeable to different types of solar and wind power systems with other renewable energy resources where the reliability is the vital factor in the design of the system.

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