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Effect of Weather and the Hybrid Energy Storage on the Availability of Standalone Microgrid

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Abstract- This paper presents a model for availability analysis of standalone hybrid microgrid. The microgrid used in the study consists of wind, solar storage and diesel generator. Boolean driven Markov process is used to develop the availability of the system in the proposed method. By modifying the developed model, the relationship between the availability of the system with the fine (normal) weather and disturbed (stormy) weather durations are analyzed. Effects of different converter technologies on the availability of standalone microgrid were investigated and the results have shown that the availability of microgrid increased by 5.80 % when a storage system is added. On the other hand, the availability of standalone microgrid could be overestimated by 3.56 % when weather factor is neglected. In the same way 200, 500 and 1000 hours of disturbed weather durations reduced the availability of the system by 5.36%, 9.73% and 13.05 %, respectively. In addition, the hybrid energy storage cascade topology with a capacitor in the middle maximized the system availability.

Keywords Microgrid; renewable energy; availability; wind; PV; hybrid energy storage system.

1. Introduction

The practice of generating electricity from central large-scale steam power stations is getting weaker by the day. This is due to the global concern about the environment as a result of centralised coal-fired generation. Different factors such as emissions, economy and technology are the main drivers towards a decentralised power system. This decentralisation could be achieved with the help of a microgrid. The proposed decentralised system may be one of the inputs to achieving the Kyoto agreement of a 50% reduction in greenhouse gas emissions by 2050.

Recently, the World Energy Council (WEC) has shown that about 1.5 billion people are known to have no access to electricity. Similarly, about three billion people are forced to use fuel for their day-to-day activities [1]. A greater percentage of these people are from Sub-Saharan Africa, India and South Asia [2]. Most of these people live in rural areas where extension of the grid may be challenging and relied solely on the use of diesel generator. People living in isolated communities are still in search of cost-effective means of power generation. The WEC estimated that if all the stakeholders are not committed, there could still be about 880 million people by 2030 and 530 million people by 2050 without electricity. Therefore, more commitment is of paramount importance in order to increase the number of people with access to electricity across the globe. Due to these, the United Nations general assembly declared the decade of 2014-2024 as the decade of sustainable energy for all [3].

Integrating an existing diesel generator with renewable energy such as wind and solar in the form of a microgrid is being planned for isolated loads. A microgrid is a small electrical distribution system that connects multiple customers to multiple distributed sources of generation and storage through power electronic devices that provide the necessary interface [4]-[5]. A microgrid can be DC, AC or a combination of both (hybrid mode) depending on the application. It can be in single or three phases and sometimes can be connected to a low voltage or medium voltage distribution network [6]. In some cases it can be operated in a standalone mode. In each case, the system requirements differ in control, stability and reliability, etc.

Battery storage may be added to reduce the variations in power from the renewable energy and this amount to a critical part of the microgrid. Moreover, the power and energy density of energy storage determines its capability. Battery storage has a high power density and low energy density. On the other hand, ultra-capacitor has a high energy density with low power density. This leads to the development of hybrid energy storage system in the next generation power systems. Based on the new storage system, a trade-off between power and energy density is achieved with help of converter interface. The operation of the future power systems with new hybrid energy battery storage may have effects on the economy and availability of the system. This makes the development of strategies for maximising the benefits of these units an important priority for system planners.

Authors in [7] compared different control techniques according to three topologies of hybrid energy storage (HES). Similarly, basic operating strategies of microgrid consisting of battery-superconducting storage system have been presented in [8]. Another control method for the enhancement of power and efficiency of a standalone microgrid has been proposed in [9]. Vanadium-redox flow battery and superconductor improved the performance of wind turbine generator in [10]. Also, it is possible to smooth the output power of a PV microgrid using battery and superconductor [11]. Another work in [12] showed that the flywheel battery and storage battery can support each other by proper control scheme to support a DC microgrid. Possibility of microgrid to operate using battery and electrical double layer capacitor has been demonstrated experimentally in [13]. Method for the sizing of microgrid in the presence of HES has been proposed in [14]. In all these papers, the system availability has not been analysed. Therefore the main objective of this paper is to investigate the effect of HES on the system availability. The proposed method is based on the network topology and it depends on the renewable energy resources which may be affected by weather conditions. This may in turn have considerable effect on the availability of the system. Therefore, with the help of the developed methods, the effect of fine weather and duration of disturbed weather conditions on the system availability are investigated.

The rest of the paper is organized as follows. The proposed microgrid configuration is briefly explained in section 2. The microgrid system availability analysis is presented in section 3. The effect of weather on the availability of microgrid is investigated in section 4. Section 5, explore the relationship between hybrid storage energy system with the availability of the network. Finally, conclusion drawn is presented in section 6.

2. System operation

A schematic diagram of the proposed hybrid system is presented in Figure 1. The proposed system has six major building blocks. These include wind energy conversion system (WECS), solar energy conversion system (SECS), storage system, diesel generator, static energy conversion system and the load unit. These components are operated in parallel to guarantee continuous power supply to the load. The storage system is connected to reduce the fluctuations and store the excess power produced by the renewable energy sources. When the power produced by the two renewable energy sources is less than the demand, the battery supply the deficit. On the other hand, when the power supplies by both renewable energy sources and the battery is less than the demand, the diesel generator operates to supply the deficit.

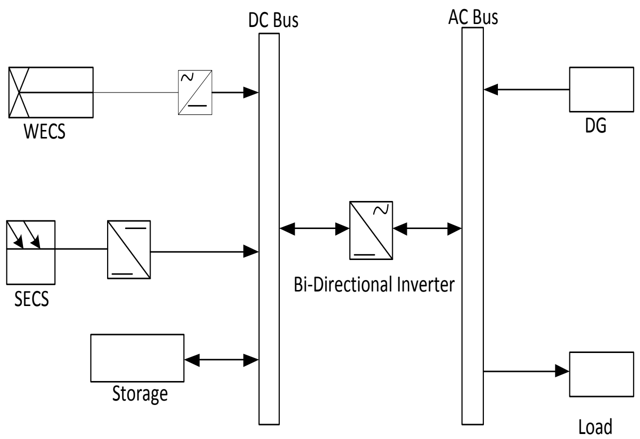

Fig.1. Proposed hybrid microgrid

3. Analysis of system availability using the Boolean logic driven Markov process

A hybrid renewable energy microgrid has many systems connected in standby mode. Therefore the availability model of the system is very difficult to obtain using Monte Carlo simulation because it is time-consuming and the precision of the results cannot be determined. Due to the dependence of the proposed microgrid on the weather, conventional methods such as a fault tree may not be suitable. To solve these problems usually rely on dynamic models such as Markov processes. The weaknesses of the existing techniques can be addressed by the proposed method of combining the application of the Markov process and the fault tree called Boolean logic driven Markov process (BDMP). This method has created a compromise among the three available techniques. It has also provided a new graphical representation of the fault tree augmented by a new link represented by a dotted arrow [15], [16].

The proposed BDMP process uses state transition rates and it also assumes that the system or equipment failure follows an exponential distribution. Similarly, other parameters, such as switching and repair rates, are within the exponential distribution [17]. One of the benefits of the proposed method is that it is applicable to any size and complexity. The state transition rate or probability is obtained by using the differential equation

$$\frac{\partial p_i(t)}{\partial t} = p_i(t) \tag{1}$$

where

$p_i(t)$ is the probability of system state i at time t in general. Eq. (1) can be written in matrix form as

$$\dot{p} = Tp \tag{2}$$

with a solution in form of

$$p(t) = p_o \ell^{At} \tag{3}$$

where p_o is the initial vector of all states.

On the other hand, the exponential of Eq. (3) converges absolutely and uniformly to a finite interval of time. In this case, it is assumed that all states with all components in upstate have unity probability while the rest have zero. Therefore, the exponent can be defined as

$$\ell^{At} = I + AI + A^2 \frac{t^2}{2!} + ... + \sum_{k=1}^{\infty} A^k \frac{t^k}{k} \tag{4}$$

Since our interest is on the final value, the derivative of Eq. (4) will be zero. Finally, we have a system of algebraic Equations as

$$0 = Tp \tag{5}$$

The determinant of T is zero, meaning that the equations are linearly dependent. Hence one of the Equations can be discarded and substituted with Eq. (6)

$$\sum_{t=1}^{n} p_i = 1 \tag{6}$$

The system transition matrix can be written as

$$T = \begin{bmatrix} t11 & t12 & \cdots & t1n \\ t21 & t22 & \cdots & t2n \\ \cdots & \cdots & \cdots & \cdots \\ tn1 & tn2 & \cdots & tnn \end{bmatrix} \tag{7}$$

where the off-diagonal elements of T are the failure and repair rates that represent the transitions between the states of the system. The diagonal elements are the transitions out of states with a negative sign. Substituting the nth row of the T matrix, a new equation is obtained as

$$T_n = \begin{bmatrix} t11 & t12 & \cdots & t1n \\ \cdots & \cdots & \cdots & \cdots \\ t(n-1)^1 & (n-1)^2 & \cdots & (n-1)^n \\ \cdots & \cdots & \cdots & \cdots \end{bmatrix}$$

and a new steady state equation becomes,

$$\begin{bmatrix} t11 & t12 & \cdots & t1n \\ \cdots & \cdots & \cdots & \cdots \\ t(n-1)^1 & (n-1)^2 & \cdots & (n-1)^n \\ 1 & 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} p_1 \\ \cdots \\ p_{n-1} \\ p_n \end{bmatrix} = \begin{bmatrix} 0 \\ \cdots \\ 0 \\ 1 \end{bmatrix} \tag{9}$$

Since the right hand side is no longer zero, it is possible to write the final solution of the steady state as Eq. (10)

$$p = T_n^{-1} b \tag{10}$$

Finally, Eq. (10) gives the probability of every state in the model.

Since the microgrid network may be exposed to weather fluctuations, the environment may have considerable effects on system availability. The proposed model can be installed in an environment having fine or disturbed weather conditions. To achieve this, an exponential distribution is assumed first, on a single unit with a two state failure. Figure 2 shows the state space diagram of the single unit with a state fluctuating environment.

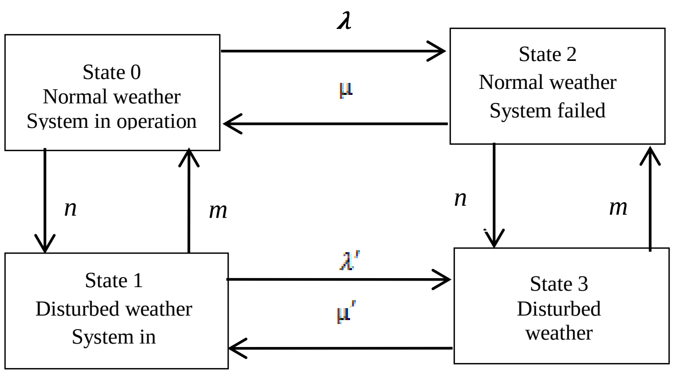

Fig. 2. State space diagram of the single unit

The differential equation of the model is defined as

$$\begin{bmatrix} p_0(t)' \\ p_1(t)' \\ p_2(t)' \\ p_3(t)' \end{bmatrix} = \begin{bmatrix} -(\lambda+n) & n & \lambda & p' \\ m & -(\lambda'+m) & 0 & \lambda' \\ \mu & 0 & -(n+\mu) & n \\ 0 & \mu' & m & -(\mu'+n) \end{bmatrix} \begin{bmatrix} p_0(t) \\ p_1(t) \\ p_2(t) \\ p_3(t) \end{bmatrix} \qquad (11)$$

$$-(n+\lambda)\,p_o + m\,p_1 + \mu\,p_2 = 0$$

$$n p_o - \left(m+\lambda'\right) p_1 + \mu' p_3 = 0$$

$$n\,p_o - (n+\mu)\,p_2 + m\,p_3 = 0$$

$$\lambda' p_1 + n p_2 - \left(m+\mu'\right) p_3 = 0$$

and

$$p_0 + p_1 + p_2 + p_3 = 1$$

P (system availability) = $p_0 + p_1$

P (system unavailability) = $p_2 + p_3$

The proposed procedure is applied to a hybrid microgrid, and the solution is presented. Initially, it is assumed that the system consists of a diesel generator. This is because isolated loads and communities relied on diesel generators. In this case, the availability of the system is the availability of the diesel generator. The proposed methodology takes into consideration that the system is integrated with wind and solar. Therefore, the model can be presented in the form of the state space model shown in Figure 3. Application of the procedure above to a microgrid yields the differential equation in matrix form presented in Eq. (12). The failure and repair rates assumed are given in the Table 1. Finally, the differential equation is solved and the result is presented in Eq. (13).

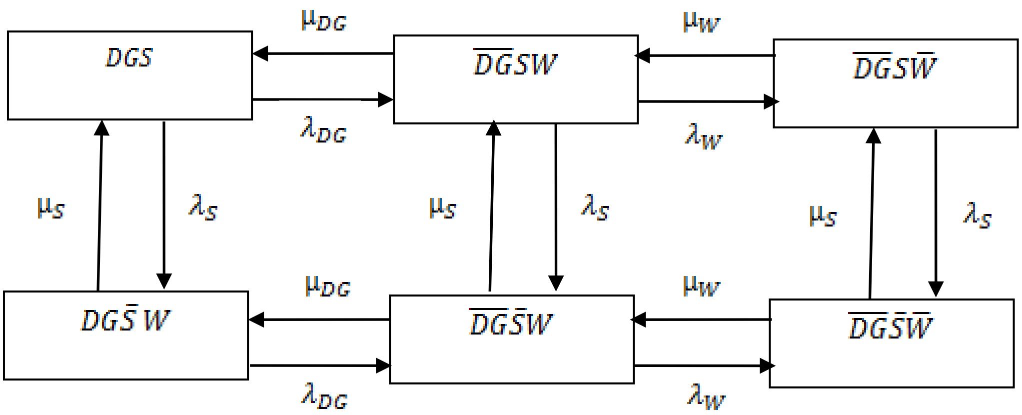

Fig. 3. State space of the microgrid without storage

$$\begin{bmatrix} p_0(t)' \\ p_1(t)' \\ p_2(t)' \\ p_3(t)' \\ p_4(t)' \\ p_5(t)' \end{bmatrix} = \begin{bmatrix} -(\lambda_S+\lambda_{DG}) & \mu_{DG} & \mu_S & 0 & 0 & 0 \\ \lambda_{DG} & -(\mu_{DG}+\lambda_S+\lambda_W) & 0 & \mu_S & \lambda_W & 0 \\ \lambda_S & 0 & -(\mu_S+\mu_{DG}) & \mu_{DG} & 0 & 0 \\ 0 & \lambda_S & \mu_{DG} & -(\mu_{DG}+\mu_S+\lambda_W) & 0 & \mu_W \\ 0 & \lambda_W & 0 & 0 & -(\lambda_S+\lambda_W) & \mu_S \\ 0 & 0 & 0 & \lambda_W & \lambda_S & -(\mu_S+\mu_W) \end{bmatrix} \begin{bmatrix} p_0(t) \\ p_1(t) \\ p_2(t) \\ p_3(t) \\ p_4(t) \\ p_5(t) \end{bmatrix} \qquad (12)$$

$$\begin{bmatrix} p_o \\ p_1 \\ p_2 \\ p_3 \\ p_4 \\ p_5 \end{bmatrix} = \begin{bmatrix} 0.91611 \\ 0.0226 \\ 0.04554 \\ 0.00087 \\ 0.01421 \\ 0.00067 \end{bmatrix} \qquad (13)$$

Table 1. Failure and repair rates of each unit

Failure rate	Normal weather	Stormy weather	Repair rate
Bat	0.1	0.13	0.25
RE	0.13	0.169	0.2667
DG	0.1	0.13	0.4
TR	0.34	0.442	0.0167

It can be seen that the availability of the power supply to the consumer connected to the microgrid is $p_o + p_1 + p_2 + p_3 =$ 0.9993308. The unavailability of the network is $p_4 + p_5 =$ 0.000669. Based on the procedure presented, it is also possible to realise the influence of the storage on the system availability. This is achieved by modifying the network diagram shown in Figure 3, such that a new equation is obtained and solved. Integration of the storage system results into a new state space model of the microgrid network. From the state space model, it is possible to show the system differential equation in matrix form as in equation (14). The availability of the network is obtained by solving Eq. (14) and the solution is given by Eq. (15),

$$\begin{bmatrix} p_o \\ p_1 \\ p_2 \\ p_3 \\ p_4 \\ p_5 \\ p_6 \\ p_7 \\ p_8 \\ p_9 \\ p_{10} \end{bmatrix} = \begin{bmatrix}
-(\lambda_{DG}+\lambda_T) & \mu_{DG} & \mu_T & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\lambda_{DG} & -(\lambda_T+\lambda_B+\mu_{DG}) & 0 & 0 & \mu_T & 0 & \mu_B & 0 & 0 & 0 & 0 \\
\lambda_T & 0 & -(\lambda_{DG}+\lambda_B+\mu_T) & \mu_B & \mu_{DG} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \lambda_B & -(\lambda_{DG}+\lambda_R+\mu_B) & 0 & \mu_{DG} & 0 & 0 & \mu_R & 0 & 0 \\
0 & \lambda_T & \lambda_{DG} & 0 & -(\mu_T+\lambda_B+\lambda_R+\mu_{DG}) & \mu_B & 0 & 0 & 0 & \mu_R & 0 \\
0 & 0 & 0 & \lambda_{DG} & \lambda_B & -(\mu_T+\mu_B+\lambda_R+\mu_{DG}) & \lambda_T & 0 & 0 & 0 & \mu_R \\
0 & \lambda_B & 0 & 0 & 0 & \mu_T & -(\lambda_T+\lambda_R+\mu_B) & \mu_R & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & \lambda_R & -(\lambda_T+\mu_R) & 0 & 0 & \mu_T \\
0 & 0 & 0 & \lambda_R & 0 & 0 & 0 & 0 & -(\lambda_{DG}+\mu_R) & 0 & \mu_{DG} \\
0 & 0 & 0 & 0 & \lambda_R & 0 & 0 & 0 & 0 & -(\lambda_B+\mu_R) & \mu_B \\
0 & 0 & 0 & 0 & 0 & \lambda_R & 0 & \lambda_T & \lambda_{DG} & \lambda_B & -(\mu_R+\mu_T+\mu_{DG}+\mu_R)
\end{bmatrix} \begin{bmatrix} p_o \\ p_1 \\ p_2 \\ p_3 \\ p_4 \\ p_5 \\ p_6 \\ p_7 \\ p_8 \\ p_9 \\ p_{10} \end{bmatrix} \qquad (14)$$

$$\begin{bmatrix} p_o \\ p_1 \\ p_2 \\ p_3 \\ p_4 \\ p_5 \\ p_6 \\ p_7 \\ p_8 \\ p_9 \\ p_{10} \end{bmatrix} = \begin{bmatrix} 0.0260 \\ 0.0069 \\ 0.5231 \\ 0.1225 \\ 0.1388 \\ 0.0356 \\ 0.0016 \\ 0.0011 \\ 0.0398 \\ 0.0781 \\ 0.0265 \end{bmatrix} \tag{15}$$

For the hybrid microgrid consisting of wind, solar, diesel generator and storage, the availability of the power supply is $p_o + p_1 + p_2 + p_3 + p_4 + p_5 + p_6 + p_7 + p_8 + p_9 =$ 0.9735. Similarly, system unavailability is $p_{10} =$ 0.0265. Therefore, it is possible to compare the impact of the storage system on the reliability of the hybrid microgrid as shown in Figure 4.

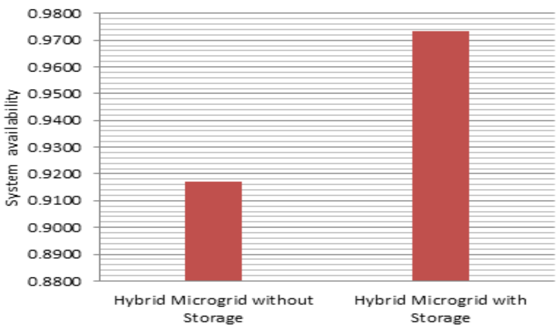

Fig. 4. Availability of the hybrid microgrid with and without storage

The comparison between hybrid microgrid with storage system and without storage system results in increased availability of the network power supply by 5.80 %. Hence the viability of the proposed methodology in analysing the impacts of storage system on the availability of the power supplied. The result is important for the system planners to note that adding a storage system to the microgrid increase the system availability. Another factor that may affect the availability of the system is the condition of weather. The effect of this factor on the availability of the system is analysed in the next section.

4. Effect of weather on the availability of a standalone microgrid

This section investigates the availability of the microgrid while considering weather conditions. The BDMP model presented in section 3 is modified to accommodate weather factors. Figure 5 shows the new model that considers fair and disturbed weather condition's fluctuations. The differential equation of the network can be defined in Eq. (16).

$$\dot{p}(t) = p(t)\begin{bmatrix} D1 & n[I] \\ m[I] & D2 \end{bmatrix} \tag{16}$$

D_1 is the differential equation described in Eq. (17) , and $D2$ is defined in Eq. (18).

$$D1 = \begin{bmatrix} -(\lambda_s + \lambda_{DG} + n) & \mu_{DG} & \mu_s & 0 & 0 & 0 \\ \lambda_{DG} & -(\mu_{DG} + \lambda_s + \lambda_w + n) & 0 & \mu_s & \lambda_w & 0 \\ \lambda_s & 0 & -(\mu_s + \mu_{DG} + n) & \mu_{DG} & 0 & 0 \\ 0 & \lambda_s & \mu_{DG} & -(\mu_{DG} + \mu_s + \lambda_w + n) & 0 & \mu_w \\ 0 & \lambda_w & 0 & 0 & -(\lambda_s + \lambda_w + n) & \mu_s \\ 0 & 0 & 0 & \lambda_w & \lambda_s & -(\mu_s + \mu_w + n) \end{bmatrix} \tag{17}$$

$$D2=\begin{bmatrix} -\left(\lambda_S'+\lambda_{DG}'+m\right) & \mu_{DG}' & \mu_S' & 0 & 0 & 0 \\ \lambda_{DG}' & -\left(\mu_{DG}'+\lambda_S'+\lambda_W'+m\right) & 0 & \mu_S' & \lambda_W' & 0 \\ \lambda_S' & 0 & -\left(\mu_S'+\mu_{DG}'+m\right) & \mu_{DG}' & 0 & 0 \\ 0 & \lambda_S' & \mu_{DG}' & -\left(\mu_{DG}'+\mu_S'+\lambda_W'+m\right) & 0 & \mu_W' \\ 0 & \lambda_W' & 0 & 0 & -\left(\lambda_S'+\lambda_W'+m\right) & \mu_S' \\ 0 & 0 & 0 & \lambda_W' & \lambda_S' & -\left(\mu_S'+\mu_W'+m\right) \end{bmatrix} \quad (18)$$

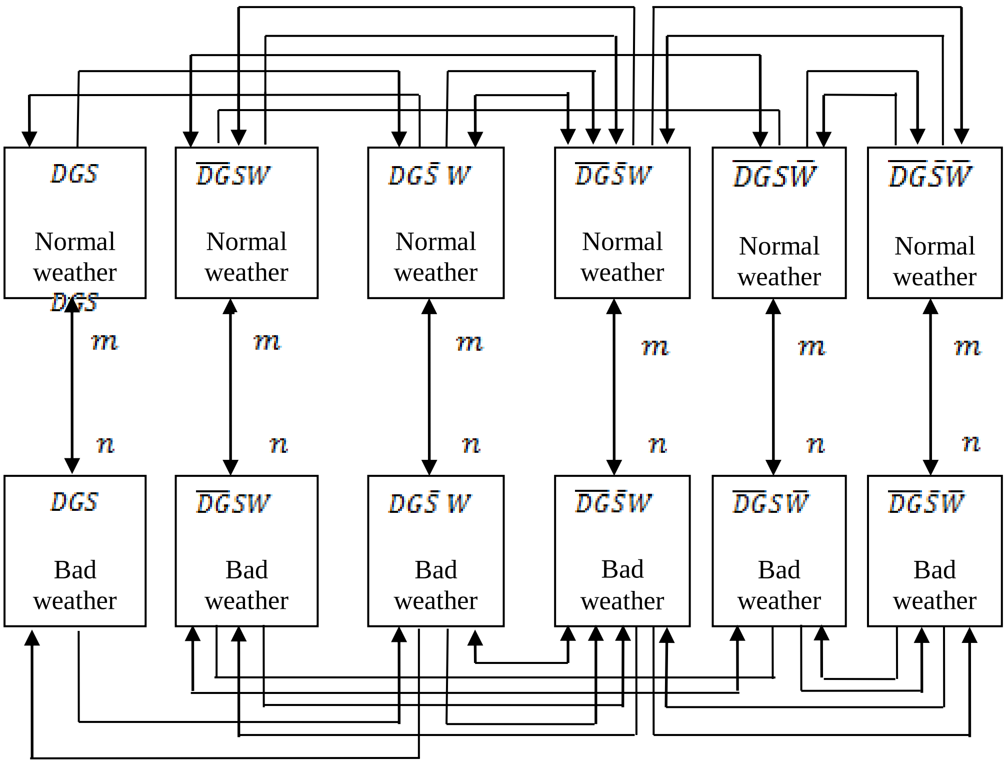

Fig.5. BDMP of the standalaone microgrid

$$\begin{bmatrix} p_o \\ p_1 \\ p_2 \\ p_3 \\ p_4 \\ p_5 \\ P_o' \\ P_1' \\ P_2' \\ P_3' \\ P_4' \\ P_5' \end{bmatrix} = \begin{bmatrix} 0.916140174 \\ 0.022595273 \\ 0.045529393 \\ 0.000872001 \\ 0.014194694 \\ 0.000668463 \\ 0.465353508 \\ 0.100503732 \\ 0.232149035 \\ 0.040907294 \\ 0.126312556 \\ 0.034773875 \end{bmatrix} \quad (19)$$

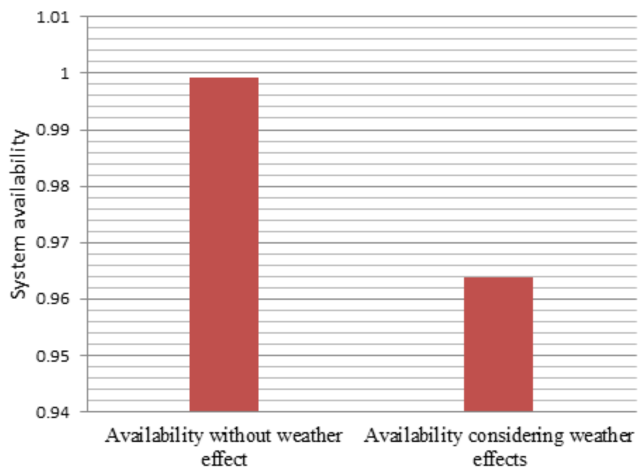

Fig. 6. Effects of weather on the availability of a hybrid microgrid

Hence the availability of the network is obtained by solving the steady state equation. Figure 6 compared the availability of the two models. It can be observed that neglecting weather and its duration could lead to overestimation of system availability.

Another factor that affects the availability of the system is the duration of the normal and disturbed weather, as shown in Eq. (16). The effects of periods of 200, 300, 500 and 1000 hours were studied. The system availability variation with the duration of disturbed weather is shown in Figure 7. It is observed that the availability of the system is very sensitive to the duration of disturbed weather. The result shows that increase in disturbed weather durations decrease the availability of the system by 5.3596%, 9.7291% and 13.0549%, respectively. Hence system availability is sensitive to the duration of disturbed weather.

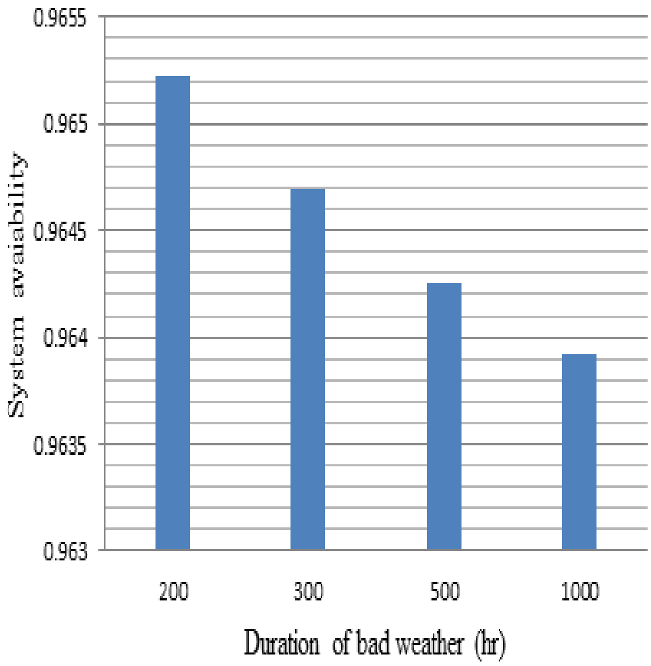

Fig. 7. Variation of the system availability with disturbed weather

5. Effects of hybrid energy storage system on the availability of the system

Due to the dependence of the proposed system on the weather and other external factors, storage system is a very critical. Unfortunately, battery storage system has a high energy density with a low power density. On the basis of this, present researches are proposing a new storage system that will solve the problem in power systems. A compromised is need as shown in the Rogane diagram [18]-[19].

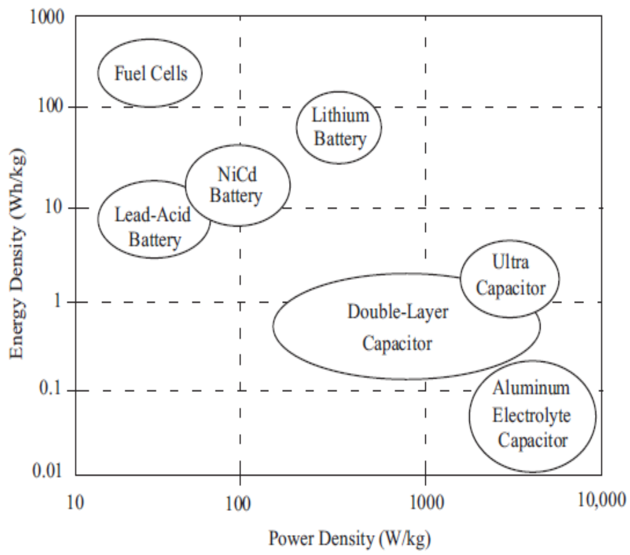

Fig. 8. Rogan diagram

Careful examination of the diagram shows that ultra-capacity has a high power density and low energy density. Hence combination of lithium battery and ultra-capacitor solve the problem of energy and power densities. The new hybrid energy storage will have high energy and power densities. Various topologies exist for the possible combination of the ultra-capacitor and battery storage proposed in this work.

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In order to test the application of the procedure, cascade topology with ultra-capacitor in the middle is analysed. The circuit diagram of the topology is shown in Figure 10. The converter connected between the battery and ultra-capacity is used to interface them while the second converter is needed to regulate the DC bus voltage.

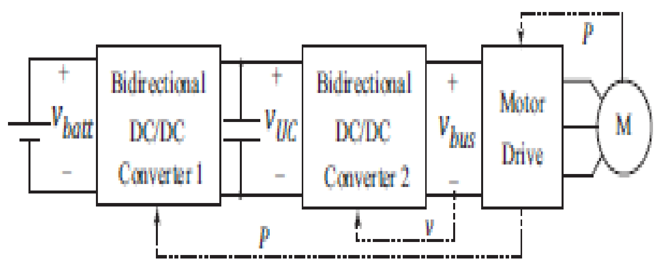

Fig. 9. Circuit diagram of cascade topology with capacitor in the middle

Assuming that the network has fault detection isolation and reconfiguration (FDIR) mechanism. This block has the capability to isolate and configure the topology when the need arise. In the Markov chain of Figure 10, it is assumed that λ_{uc}, λ_{bat} λ_{c1} and λ_{c2} represents the failure rates of ultra-capacitor, battery, DC/DC converter 1 and DC/DC converter 2 respectively. By inspection the whole system failed in state three. That is, battery and DC-DC converter 1 and 2 failed. The occupational probability of each state can be obtained in Eq. 20.

It is assumed that the system starts from state one, the imposed initial condition is also defined in the Eq. (21). Finally, the HES failure rate of the topology is defined in Eq. (22).

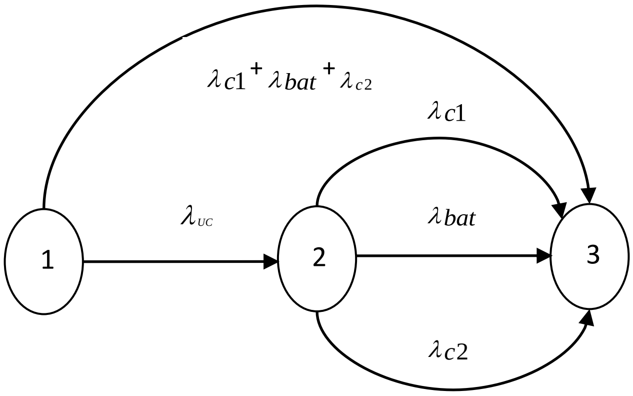

Fig. 10. Markov chain of cascade topology with capacitor in the middle

$$\frac{\partial}{\partial t}\begin{bmatrix} p_1(t) \\ p_2(t) \\ p_3(t) \end{bmatrix} = \begin{bmatrix} -\left(\lambda_{uc}+\lambda_{bat}+\lambda_c+\lambda_{c2}\right) & 0 & 0 \\ \lambda_{uc} & -\left(\lambda_{bat}+\lambda_{c1}+\lambda_{c2}\right) & 0 \\ \left(\lambda_{bat}+\lambda_{c1}+\lambda_{c2}\right) & \left(\lambda_{bat}+\lambda_{c1}+\lambda_{c2}\right) & 0 \end{bmatrix}\begin{bmatrix} p_1(t) \\ p_2(t) \\ p_3(t) \end{bmatrix} \tag{20}$$

$$p(o) = \begin{bmatrix} 1 & 0 & 0 & \ldots & 0 \end{bmatrix}^T = \tag{21}$$

$$\lambda_T = \lambda_{bat} + \lambda_{c1} + \lambda_{c2} = \tag{22}$$

The epicacy of the proposed procedure is that other factors could be obtained. This includes the mean time to failure of each topology etc. Having obtained the failure rate of the model it is possible to obtain the repair rate of the unit. Also the analysis is repeated for each of the proposed topology and the result of the system availability is shown in the Figure 11.

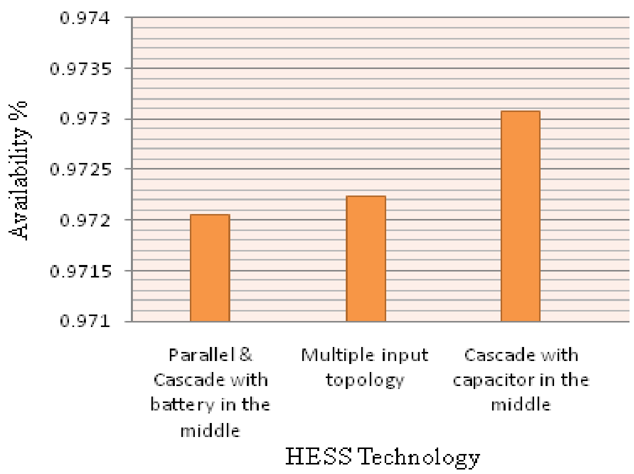

Fig. 11. Availability of different topology

Figure 11 shows that the availability of the microgrid is different in each case. In the case of each topology, the HES with cascade topology with a capacitor in the middle has the highest system availability compared to other topology. Hence this topology recommended for the proposed application. Therefore, this section shows that introducing HES in the microgrid increases the system power density and charge density at the expense of system cost. Other topology analysed are not shown here for the sake of beravity.

6. Conclusion

The paper compared the availability of standalone microgrid with and without storage unit. In the same way, the relationship between fine weather, disturbed weather durations and the availability of the system has been investigated. The effects of different HES on the availability of standalone microgrid considering have been analysed. The HES employed in the analysis is multiple input converter topology. The result has shown that the availability standalone microgrid increased by 5.8% when a storage system is added. Similarly, the HES increased both the power and energy density at the expense of system cost. This is as a result of increased in the number of component. Also, the converter technology affects the availability of the hybrid renewable energy microgrid. In the same way, neglecting weather factors may lead to inaccurate availability analysis of the system.

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