Journal of Mechatronics, Electrical Power, and Vehicular Technology 13 (2022) 201-213

Journal of Mechatronics, Electrical Power, and Vehicular Technology

e-ISSN: 2088-6985
p-ISSN: 2087-3379

mev.lipi.go.id

Component degradation and system deterioration: An overview of early termination of PV-DG microgrid system

Tinton Dwi Atmaja [a, b, c], Dalila Mat Said [a, c, *], Sevia Mahdaliza Idrus [a, c], Ahmad Fudholi [b, d], Nasarudin Ahmad [a], Dian Andriani [e, f], Ahmad Rajani [a, b, c], Sohrab Mirsaeidi [g], Haznan Abimanyu [h]

[a] *Faculty of Electrical Engineering, Universiti Teknologi Malaysia*
Block P19A, UTM Johor Campus, Johor Bahru, 81310 Johor, Malaysia

[b] *Research Centre for Energy Conversion and Conservation, National Research and Innovation Agency*
Kawasan Bandung Cisitu, Jl. Sangkuriang, Dago, Coblong, Bandung, 40135, Indonesia

[c] *Centre of Electrical Energy System, Institute of Future Energy, UTM*
Block P19A, Level 1, UTM Johor Campus, Johor Bahru, 81310 Johor, Malaysia

[d] *Solar Energy Research Institute, Universiti Kebangsaan Malaysia*
Level G Research Complex, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

[e] *Faculty of Civil Engineering, Universiti Teknologi Malaysia*
Block M46, UTM Johor Campus, Johor Bahru, 81310 Johor, Malaysia

[f] *Research Organization for Life Sciences & Environment, National Research and Innovation Agency*
Cibinong Science Center, Jl. Raya Jakarta-Bogor, Cibinong, Bogor, Jawa Barat 16915, Indonesia

[g] *School of Electrical Engineering, Beijing Jiaotong University*
X82W+H2F, Jiaoda E Rd, Beixiaguan Subdistrict, Haidian District, Beijing100082, China

[h] *Research Organization for Energy and Manufacture, National Research and Innovation Agency*
Gedung Manajemen Puspiptek, Gedung 720, Jl. Puspitek, Tangerang Selatan, Banten 15314, Indonesia

Received 17 November 2022; Revised 14 December 2022; Accepted 15 December 2022; Published online 29 December 2022

Abstract

Degradation of components and system failure within the microgrid system is deteriorating the performance of electrification. The aim of this study is to discuss the relationship and connections between issues resulting from degradation and deterioration in the microgrid system, in addition to introducing the prominent impacts which may eventually lead to the premature termination of the microgrid system. This study explored the microgrid degradation and deterioration issues within four microgrid sections: generation section, storage section, transmission section, and distribution section. Subsequently, this study analyzes, derives, and classifies all emerging issues into four types of prominent impacts. The degradation and deterioration invoked many component performance issues into four main damaging outcomes, namely (i) deteriorated transmission line yielded issues regarding expected energy not achieved; (ii) energy deficit and unpredicted blackout come after the depth of discharge (DOD) reduction and invoke a loss of power supply; (iii) a shorter battery life cycle, shorter transformer lifespan, and decreased DG lifetime concluded as a shorter microgrid life expectancy; and (iv) rapid microgrid broke down and the crash of the key component inadvertently fastened the time to failure and gave rise to the early failure of a microgrid system. It is envisaged that the discussion in this study can provide useful mapped information for the researcher, stakeholder, operator, and other parties for thoroughly addressing various degradation and deterioration issues and anticipating the early termination of the microgrid system.

Keywords: early failure; expected energy not achieved; loss of power supply; microgrid termination; shorter lifespan.

I. Introduction

Renewable electrification is one of the trending research projects to provide affordable, reliable, sustainable, and modern energy for all communities [1], as many countries are moving toward the

* Corresponding Author. Tel: +60 19 427 8761
E-mail address: dalila@utm.my

doi: https://dx.doi.org/10.14203/j.mev.2022.v13.201-213
2088-6985 / 2087-3379 ©2022 National Research and Innovation Agency

How to Cite: T.D Atmaja *et al.*, "Component degradation and system deterioration: An overview of early termination of PV-DG microgrid system," *Journal of Mechatronics, Electrical Power, and Vehicular Technology*, vol. 13, no. 2, pp. 201-213, Dec. 2022.

highest possible electrification ratio using renewable sources [2]. It is highly inevitable that the higher the electrification, the more poverty can be reduced, especially in developing countries [3]. Electrification projects are not only conducted in urban areas aiming for higher energy efficiency [4][5] but also applied in rural areas [6][7]. Thereof, a lot of microgrid projects have been initiated and conducted in both rural and urban areas [8].

There are usually four sections in a microgrid: generation, storage, transmission, and distribution. A number of previous studies discussed how each section could be improved. For example, increasing the power production [9][10], intensifying storage unit [11][12][13], optimizing transmission line [14][15][16], and improving distribution network [17][18][19].

It is commonly known that microgrid reliability is a trend in the publication, which is focused on enhancing the microgrid performance [20][21] or optimizing the configuration [22][23][24] and technological choice [25][26]. Research [3] tried to enhance the stability of the generation section performance using proper design and planning, while research [20] tried to enhance the performance at the energy source section using scheduling and upgrading.

Study [22] optimized configuration and sizing, while [23][24][27] see the optimization of redesigning techno-economic aspects. The approach in [25] focused on technological choice, while [26] focused on topological configuration. However, microgrid installations are occasionally followed by unique challenges both in the technical and social aspects [28]. For example, lower energy production than the expected level [29][30], expected energy not achieved [31][32], loss of power [33][34], etc. It is expected that technical issues were inaudibly disrupting the microgrid, which led to the deterioration of the microgrid and finalized with failure of the microgrid [35][36].

Microgrid failure has been studied previously by many institutions around the globe. Aside from system failure because of force majeure [37][38][39], microgrid failure usually starts at the operational condition level (such as unbalanced voltage [40][41]), followed by loss of power or thermal increase in the system [42], and finalized by component reliability decreased performance [43]. If the reliability reductions are not recovered, the microgrid system will completely fail, and termination is unavoidable.

The basics of microgrid failure were studied based on two main grounds, i.e., component degradation and system deterioration. The component degradation model has been long developed to predict the component time to failure based on critical environmental conditions [44][45]. Some studies are also concerned about component degradation which was based on the component's active disconnection among improper topology, which triggers a multi-state flow failure [46].

In a power plant with a rotating component, such as a wind farm, a worn-out component is a common cause of failure [47][48]; for example, the turbine gearbox. Deteriorated sections were commonly channeled in the storage section and transmission section. The network joint and grid connection has become the continuous attention of the researcher [49][50] They were vulnerable to deterioration and followed by reduced transmitted energy in the transmission line.

As mentioned, microgrid termination is a possible event targeting underperformed microgrids which are predicted to have more disadvantages than practical benefits. Microgrid termination is also one of the schemes for smart grid implementation [51]. Still and all, an underperforming microgrid was never designed in the first place but came in mid-operation because of the occurrence of component degradation and system deterioration. When the key component of the microgrid has deteriorated, it will be easily concluded that the microgrid shall face its early termination. Previous research [52][53] developed an early warning system to anticipate early microgrid failure. Nevertheless, it will be beneficial to learn how the failure is triggered and anticipate them long before the component degradation and deterioration occur.

Furthermore, both the researcher and the operator tend to occasionally neglect the potential degradation and deterioration aspect of the microgrid sections themselves, whereas the impact of their negligence would be an early termination of the microgrid system. If there is any paper with a discussion on microgrid-degradation topic [54][55][56], they are focused on one section of the microgrid, which omits the connection between entire microgrid sections. This study should combine the degradation from all sections into one framework scenario.

Based on the aforementioned issue, this paper aims to highlight the emerging issues related to degradation and deterioration in the whole microgrid sections, classify the degraded and deteriorated parameters, and correlate the parameters to one another. This paper shall provide a broad concept of microgrid degradation and deterioration based on the critical impact of each emerging issue.

The information gathered in this work hopefully will contribute as:

1. Valuable information for researchers, practitioners, designers, decision-makers, and stakeholders to be aware of the degradation and deterioration in sections of the power system.
2. A convenience assistant for microgrid operators/management to update their knowledge that collaborated degradation issues have a significant impact on the reduction of microgrid performance.
3. A thorough guideline on identifying and addressing the degradation deterioration issue and hopefully prevent the early termination of the microgrid system.

In order to address those termination challenges, Section 2 defines the methodology used in this study, Section 3 provides a thorough systematic exploration of component degradation and system deterioration, and finally, Section 4 discusses critical impacts derived from degradation and deterioration issues, as well as explain the collaborative scheme between issue's domains.

II. Methodology

This study conducts a thorough exploration of the electrification system, which is more presented in a microgrid system. The observation was made through literature studies across every aspect with potential degradation and deterioration inside the microgrid system.

A. Exploratory on microgrid system

The exploration of the electrification system is expressed in an overview shown in Figure 1. The electrification was established in a microgrid system which contained the generation section, storage section, transmission section, and ended up in a distribution system. The deterioration happened in every section of the microgrid and potentially affected one section to another. This study collaborates the potential impact between sections where the final consequence should be a termination of the whole microgrid system.

B. Analysis of potential impact of component degradation & performance deterioration

The analysis of the potential impact has been done based on two main roots; component degradation and system deterioration. These predicaments drive a lot of notable issues within the microgrid; for example, the occurrence of rising temperature, increased voltage, reduction of DOD, and so on.

Degradation and deterioration problems brough out particular emerging issues at the component level (Figure 2). The complex emerging issues decreased the microgrid component's performance and then brought forth the prominent impacts. There are four notable impacts in this study.

- Expected energy not achieved (EENA); the degradation and deterioration not only reduce the generation section but also alter the transmission line. This issue resulted in lower transmitted energy than expected.
- Loss of power supply probability (LPSP) is a significant parameter to evaluate the reliability of the microgrid. The smaller the LPSP, the higher the reliability. The degraded storage unit

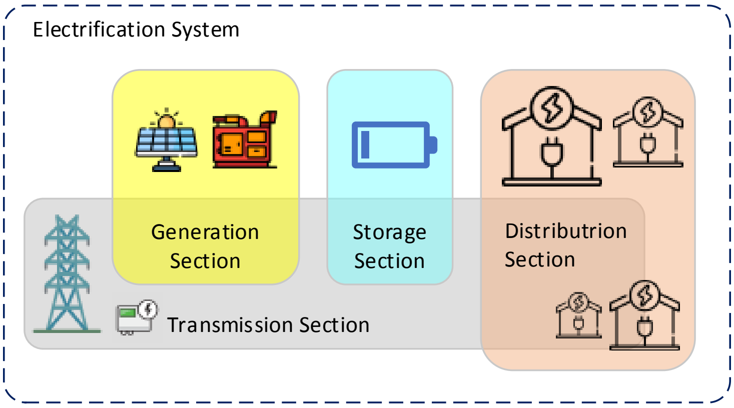

Figure 1. General overview of the electrification system

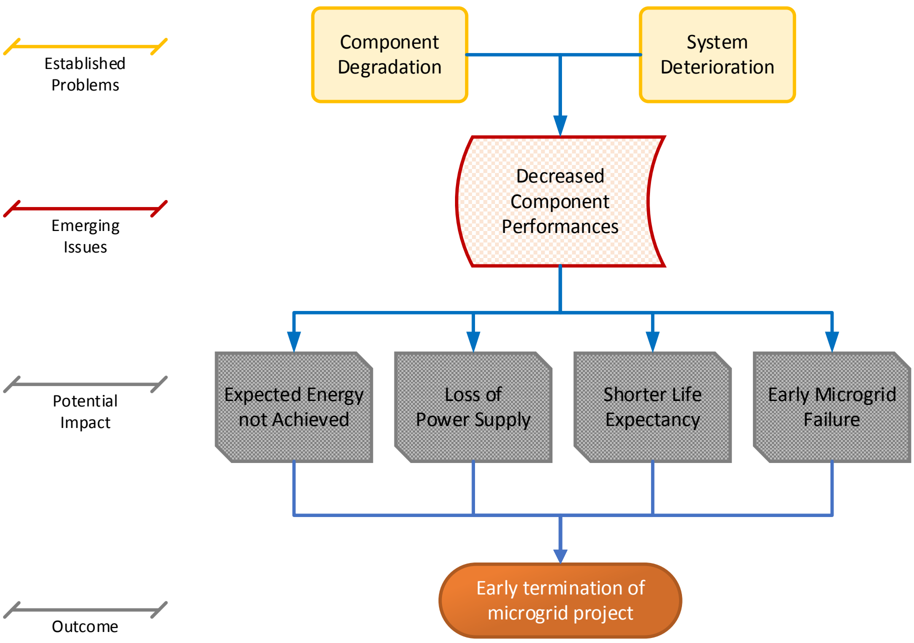

Figure 2. Potential impact scenario from the degradation and deterioration within the microgrid system

is the most impacted unit, which led to the loss of power supply.

- Shorter life expectancy: each component has been restricted to a certain manner, which concurs with the deterioration of its life expectancy. Not only in the generation section, but the storage section is also quite a sensitive section with a lot of potential reduction in lifespan.
- Early microgrid failure; each issue eventually led to an early component failure and then followed by a system breakdown. These component issues impacted on an earlier microgrid failure than a normal prediction. Thereof, the initial prediction is no longer reliable.

This study discussed the degradation and deterioration as the main reason for the reduction of microgrid lifespan. However, the termination of the microgrid system is evidently stimulated by many issues. Therefore, this study added several significant issues aside from those four, which are believed to unavoidably lead the microgrid into an early termination.

C. Constraints and limitations

The single-generation mode using PV is the favorite microgrid setup in urban areas; however, when it comes to rural areas, PV-DG is the most considered microgrid setup [22][57]. Therefore, this study focuses on PV-DG setup, which can represent both urban and rural areas. It is also because data on PV readiness to comply with DG are more well-founded [58][59]. Even though the PV-DG microgrid has been used in previous research [60][61][62], the previous more focused on component optimization but did not thoroughly analyze the deterioration factor.

It has been recently underlined that microgrid management is not only about the technical issue but also considering non-technical matters such as social (e.g., community involvement or stakeholder issues), economics (e.g., levelized cost of electricity or funding issues), local policy (e.g., incentives or investment policies issues), etc. [28][63]. However, this work only focused on the technical-related issue of correspondence to the degradation of the component and deterioration of the system within the power system area.

Since the issues regarding microgrid deterioration have emerged in the last decade, this work is mainly considering ten years of literature sources with several minor additions to the 20-year literature for specific matter discussion. Hence, it is expected that the topic discussed in this work is up-to-date enough with the current condition of the electrification system.

Since this study is overviewing the cause and framing the termination of the microgrid system, this study is not discussing any issue related to the microgrid optimization process. Instead, this study provided thorough qualitative information about the impact of component deterioration on microgrid performance.

III. Component Degradation and System Deterioration

Microgrid components usually come with a specific datasheet containing their operating condition in correspondence with the operating cycle. Default handling was provided with the manufacturer's experimental curve that expresses the nominal loss of performance on a certain operating cycle. For example, on the battery's product handling, it usually is provided with the DOD curve related to the operating cycle.

This curve was created under a controlled environment and was supposed to be anticipated for the approximation of real environment value difference. The value difference comes due to the real operation, such as charging or discharging on the battery or displacement damage by the surrounding shell on the photovoltaic module. The real environment value may differ from the test value. This varying value could be related to the weather condition, impact on the grid structure, robust control, or strange load behavior [64]. Nevertheless, it is unavoidable to have component degradation as well as system deterioration.

System performance deterioration is usually led by component degradation [65]. However, system deterioration may be invoked by other factors, such as human error or amiss maintenance. This section explores component degradation and system deterioration based on the recent decade of literature and research.

A. Component degradation

Each component ordinarily reduced its performance and affected the expected quality of the microgrid. For example, Figure 3 shows how photovoltaic cells were degraded along the operational process [66]. Each product has its own curve based on its materials and the system configuration. Table 1 contains the literature survey on previous research related to the degradation of the microgrid component.

It can be analyzed that the performance of the microgrid component is not merely based on the default datasheet. The uncontrolled environment value affected the initially predicted performance reduction and degraded faster. Table 1 shows the most visible degradation in the generation and storage sections. Improper design and installation of a PV module were followed by unexpected degradation and led to lower energy generation [67][68].

In the DG domain, unmanaged working time was found to be alarmed by the life cycle reduction and deficiency of energy supply [69][70]. Otherwise, the degradation comes from the amiss configuration of the DG itself, especially the CNC configuration [71].

Battery coupling with the grid was detected as one of many reasons for the occurrence of voltage spikes and temperature rise [72][73]. It also led to discharge activity anomaly, which degraded the DOD even faster. Without proper connection, the load requests a supply of energy with an unstable pattern, which invokes the improper charge and discharge

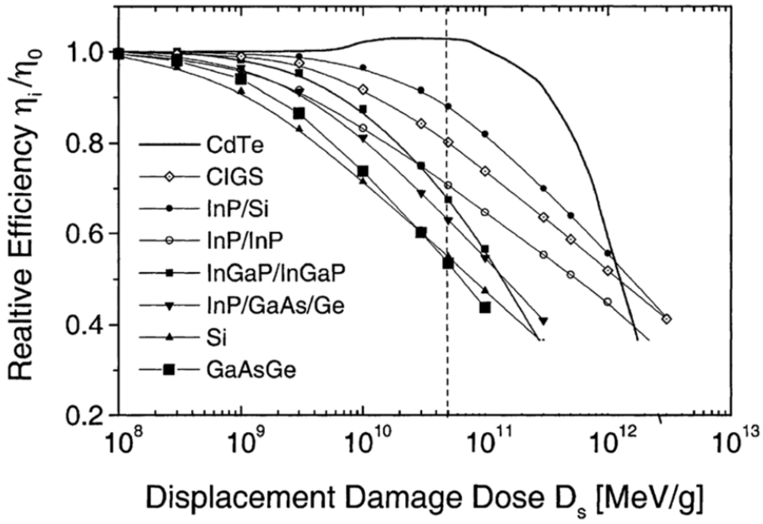

Figure 3. Example of degradation curves on various PV cells (Modified from ref. [66])

Table 1.
Degradation summary to introduce the decreased microgrid performance

Ref	Degradation scheme	Degradation issues	Classification
[67]	PV module degradation leads to lower energy generation	Degradation in the photovoltaic	Expected energy not achieved
[68]	PV-battery improper design	Degradation on generation section	Expected energy not achieved
[69]	A high amount of working time with a low energy supply	Shorter battery life cycle	Shorter unit lifespan
[70]	Long period operational on DG section	Energy production deterioration	Expected energy not achieved
[71]	Amiss configuration on the DG section led to deteriorated DG	Energy production below expectation	Expected energy not achieved
[72]	The occurrence of high voltage led to DOD degradation	Energy deficit is detected	Loss of power supply
[73]	High temperature and high voltage lead to unit damage	Early unit replacement affects the economic consideration	Shorter unit lifespan
[74]	Unexpected self-discharge in the storage section	Deficiency of energy supply	Loss of power supply
[75]	Improper charge-discharge sequence	Reduction of DOD	Loss of power supply
[76]	Battery capacity reduction	Reduction of DOD	Loss of power supply
[77]	Degradation of the key component, such as the battery or inverter	Early failure of the key component	Early microgrid failure
[78]	Cycle reduction on the storage section	Degradation of the storage section	Loss of power supply
[79]	Electrochemomechanical degradation	Reduced performance on DG section	Expected energy not achieved

sequence, even more, triggers an impulsive self-discharge [74][75]. These events triggered DOD reduction [76].

Once the reduction of batteries and the photovoltaic module has occurred, the other microgrid component will start failing. Microgrid management should directly address any key component malfunction to make sure that early microgrid failure is not happening.

B. System deterioration

Each component has not only degraded but also deteriorated because of the operational process in its continuous cycle. For example, Figure 4 shows how two battery modules deteriorated during the operational cycle [80]. Each system has a particular component with distinct characteristics. Those two battery modules were supposed to be having a clean degradation curve, but instead, they have a fluctuated deteriorated curve which perpetually decreases more than the predicted value. Moreover, Table 2 contains the literature survey on previous research related to system deterioration.

Distinctively operate than component degradation, Table 2 shows that system deteriorations happened more at transmission line and distribution network. The deteriorations were similarly begun at the design and installation stage, where the network topology and grid architecture slightly affect the transmitted energy. It is found that several transmission disturbances were triggered by improper design of topology and architecture [81][82].

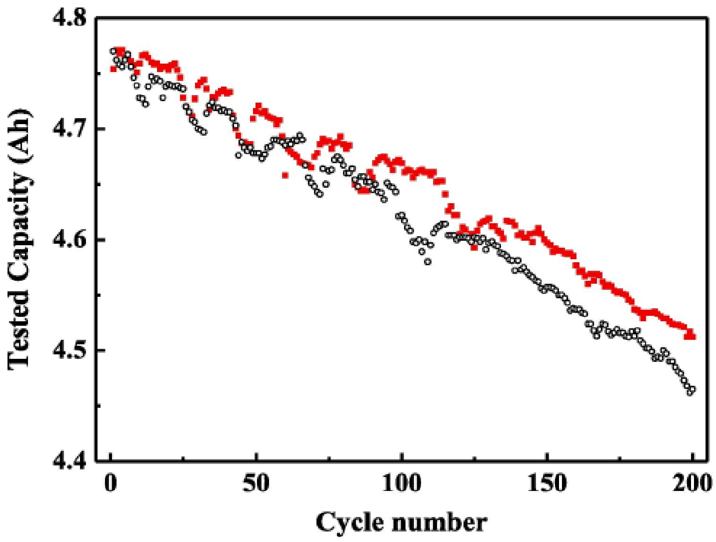

Figure 4. Example of capacity deterioration curves on two battery modules during. (Modified from ref. [80])

Table 2.
System deterioration survey to emerge the reduction of system performance

Ref	Deterioration scheme	Deterioration issues	Classification
[81]	Transmission network architecture improperly developed	The network has deteriorated, and the transmission is disturbed	Expected energy not achieved
[82]	Network topology set forth a degenerated transmission line	The network has deteriorated, and the transmission is disturbed	Expected energy not achieved
[83]	Unavoidable corrosion on microgrid component	Deterioration in the generation section and transmission line	Loss of power supply
[83]	Overloading at the transformer unit	Deterioration of transformer lifespan	Shorter unit lifespan
[84]	Improper working frequency	Reduced DG lifespan	Shorter unit lifespan
[85]	The transmission line setting cannot hold the voltage sensor threshold	A deteriorated sensor in the transmission line	Expected energy not achieved
[86]	Loop frequency led to DG failure	Energy production is disturbed	Expected energy not achieved
[87]	Unmanaged loss of power or blackout	Accumulated blackout deteriorated the component	Loss of power supply
[88]	Inapt CNC configuration within transmission and distribution line	The energy transmission has deteriorated	Expected energy not achieved
[89]	Insufficient maintenance schedule	Deteriorated component	Early microgrid failure

A transmission line design without considering the surrounding environment was found with an unexpected nuisance, e.g., component corrosion [83], overloading load [83], out of range working frequency [84], or underrated coupling between grid networks [85]. Most of these disturbances were led to expected energy not achieved and loss of power supply. A shorter lifespan potentially happens to sensitive components such as sensors along the transmission line.

Unmanaged activities will lead to an accumulated loss of power and result in an unpredicted blackout. Without proper maintenance, the line and the network shall fail and require an unnecessary re-design [86][87].

C. Other performance reduction factor

It is agreeable that the failure of the microgrid system is not only because of degradation and deterioration. Table 3 shows other potential factors that trigger performance reduction and lead to the early failure of the microgrid system.

Most of this subsection discusses the interference which comes from outside the microgrid domain. For instance, a microgrid connection with the main utility grid demands a proper fault connection because both the main grid and microgrid compensate each other with distinct characteristics. Once the compensation process is not properly conducted, the loss of power supply is conducted and followed with expected energy not transmitted [90][91].

Other unpredicted disturbances come from the human aspect. Within the microgrid area, human errors usually emerge without warning but have a tremendous impact. Whether it is an instant impact, such as the immediate failure of the equipment or is long deteriorated system, such as mishandling the worn-out component [92]. From outside the microgrid, the long-distance operator sometimes causes a ruckus in the cyber setting of the microgrid and disturbs the transmission line or distribution network [93][94].

Table 3.
Other factors thazt lead to the failure of the microgrid system

Ref	Reduction scheme	Reduction issues	Classification
[90]	Grid connection cannot compensate for the microgrid fault	The microgrid lost the power support	Loss of power supply
[91]	The transmission line setting is not properly conducted	Energy supply disturbance	Expected energy not achieved
[92]	Human error in DG operation led to DG Failure	Energy production is disturbed	Expected energy not achieved
[93]	The cyber failure led to a fault in the transmission line	Disturbance on the transmission network	Expected energy not achieved
[98]	Unsupportive policy on item procurement	Acquiring a low-quality item	Early microgrid failure

The last significant impact comes from the policy sector, whether it is concerning the policy at the beginning of the microgrid project or the ongoing policy for the continuous operation of the microgrid [95][96][97]. The policy maker could be the stakeholder, the donors, or probably the local governing body. Those policies will determine how much a proper design and installation can be done. They also determine how long the continuity of microgrid operation can be held. If the policies no longer support it, the microgrid will eventually terminate [98][99].

IV. The Impact on Performance Reduction of the Microgrid System

Each component of a microgrid system has a distinctive performance characteristic. They also have a certain factor that gives uncertain stresses over time. These stresses can be in any form, such as high temperature, improper joint, high usage rate, improper discharge, etc. Beyond datasheet coverage, the stress has increased the degradation value of the component and decreased the component performance as well. Figure 5 shows how the increased degradation brought down the performance value of the microgrid component [65].

At some point, after continuous deterioration and degradation, the component performance will fall beyond the tolerable performance threshold. Once the component performance is beyond the performance threshold, potential issues such as expected energy not achieved, loss of power supply, shorter life expectancy, and early microgrid failure will emerge. Each issue impacted the microgrid system, as discussed in the following sub-section.

A. Expected energy not achieved

The expected energy is given as an index to measure the minimum amount of required energy produced by the generation section. However, a lot of issues come up in the transmission section, which reduces the transmitted energy. In the generation section, PV production is not achieved mostly because of device degradation [67] which raises the index of expected energy not generated (EENG). Aside from the PV, the diesel generator was also acknowledged to have EENG [71] because of the degradation caused by amiss DG element configuration.

The expected energy is not achieved only because of the generation section but potentially also because of the delivery section. Expected energy not produced (EENP) mostly happened in the transmission line and, in most cases, was derived from the EENP case. Research by [71] contains one discussion about the failure to achieve the expected energy because of the performance deterioration of the transmission line. Transmission line setting constraints such as thermal limit or voltage threshold detection was also the potential trigger for an EENP [85].

Research by [91] showed that an improper design of the transmission network invokes the potential

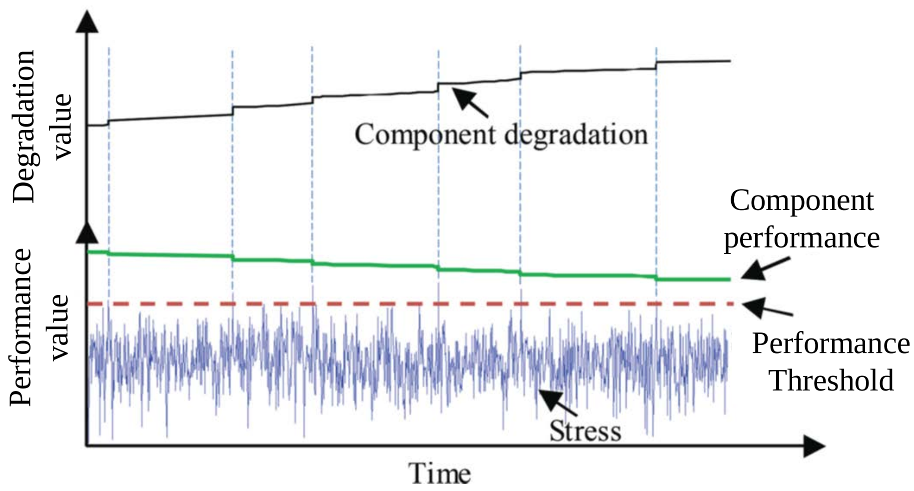

Figure 5. The impact of increased degradation value on the decreased performance value of the microgrid system (Modified from ref. [65])

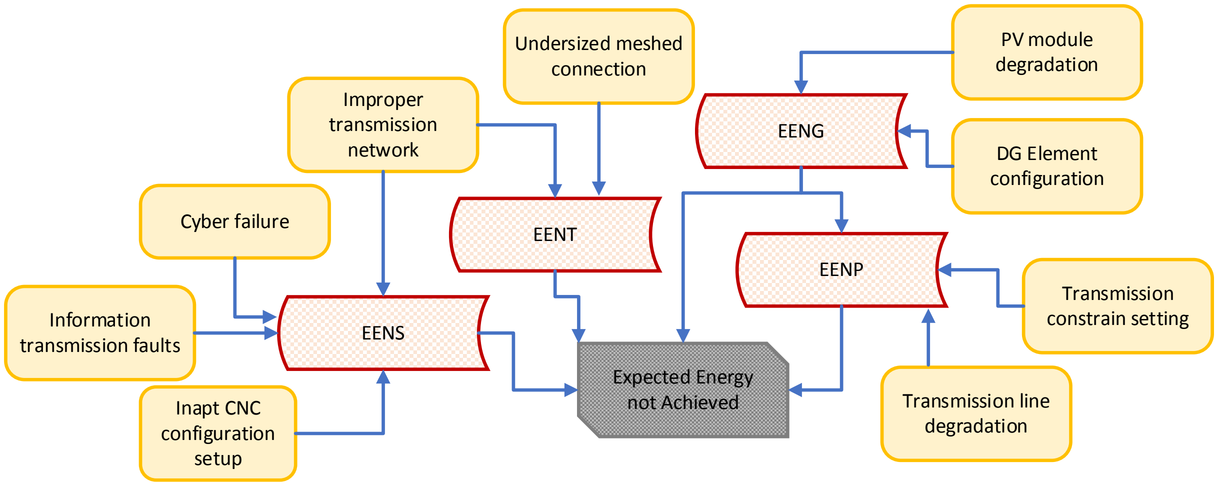

Figure 6. The schematic overview on the emerging issue of expected energy not achieved

expected energy not supplied (EENS). An architecture of a transmission line could deliver the generated energy but face a loss of power along the transmission line, and the delivered energy is slightly below the expected threshold. In other research by [81][82], topology degeneration also induced expected energy not transmitted (EENT).

Research by [93] confirmed that cyber failures and information transmission faults lead to an occurrence of 5.7 % expected energy not supplied (EENS) error. Moreover, inapt CNC configuration generated up to 70 MW EENS per year [88].

Figure 6 mapped the connection between each issue with the potential expected energy disturbance. All the EENG, EENP, EENT, and EENS will come to EENA with uncertain time exposure. The unattended EENA later be followed by possible early failure of the microgrid.

B. Loss of power supply

High voltage was turned up as one of the roots of power loss. Whether it directly invokes energy deficit in the transmission line or the distribution network, high voltage surely could also induce a 25 % battery DoD degradation [72]. Battery deterioration itself can directly cause a loss of power, influence an energy deficit, and subsequently trigger a loss of power. Another account that generates an energy deficit is self-discharge [74]. Self-discharge was an unpredicted event that happened in an unpredicted time that caused a continuous deficit of the power supply until it went beyond the minimum tolerable threshold [100].

Another study also found that the reduction of DoD was triggered by the increase in the use of battery units, the unpreserved rising temperature, and an improper charge-discharge sequence. Those issues shall later introduce the loss of power on the distribution level [75]. Moreover, corrosion was also listed as the cause of the battery deterioration, which surely reduced the supply of power to the transmission line [83].

Figure 7 resumes the loss of power supply which comes from the failure of the transmission line and the significant reduction of the storage unit. Under a high ratio loss of power, the microgrid could fail before time and the supplied energy to the user will be instantly stopped.

For the on-grid microgrid system, the grid connection fault is the primary reason for the loss of

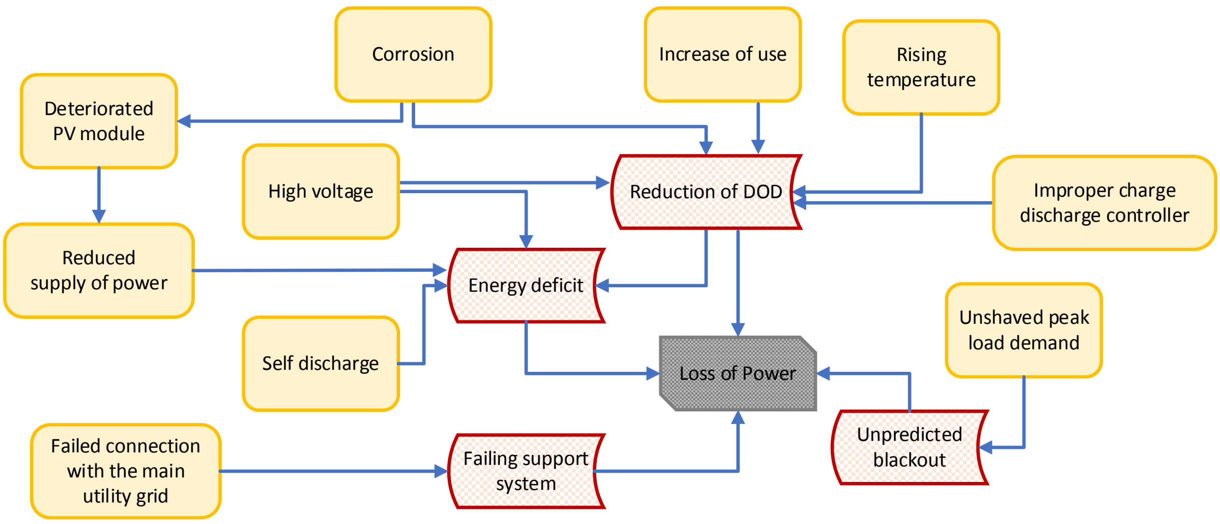

Figure 7. The schematic overview of the emerging issue of power loss

power [90]. The on-grid microgrid usually depends on the utility grid to cover the energy deficit. However, when a significant fault disturbance happened, the connection was supposed to supply proper energy to the microgrid. However, when the ride-through instrument fails to connect, the microgrid shall lose its power.

Lastly, peak load shaving is giving a significant effect on preventing blackouts. Without proper peak shaving management, an unpredicted high peak load can trigger an unpredicted blackout and lead to a total loss of power [87].

C. Shorter life expectancy

It's about the depreciation of energy storage, power generation, and transmission components. The whole microgrid system depends on the surrounding parameter. Some areas in which the microgrid was installed could have a lack of energy sources. Consequently, some components such as energy storage or gird sensor face a high amount of working time and unexpectedly run out of energy. This scenario led to a shorter life cycle of the component [69].

In other cases, storage units face a continuously rising temperature [73]. High temperatures trigger a component to overheat, followed by a significant performance reduction. Moreover, an early unit replacement can be further related to economic losses.

It is also known that the reduced battery lifespan was correlated with capacity reduction. As the battery capacity is reduced, the battery lifespan decreases [76]. Following that event, the number of DG startups increased in correspondence with the DOD of the battery. Afterward, the DG lifetime will decrease, and the microgrid lifespan will also be shortened.

The working frequency was also one of the grounds which triggered a lot of dynamic stress over the component [84]. Each component usually came with a proper range of working frequency. Special interference can raise the working frequency over the upper threshold and bring about stress on the component. Continuous dynamic stress means that the lifespan of the component would be reduced.

Overloading and corrosion were found in previous research [83][87], which led to a deteriorated transformer. This condition shall later reduce the transformer lifespan and affect the other section of the microgrid system.

A shorter life expectancy of the microgrid component is mapped in Figure 8. It is mostly dominated by the wrongdoing at the storage unit, but also because of the reduction at the generation unit. A shorter component lifespan will result in an early failure of the microgrid.

D. Early microgrid failure

The degradation of the key component is always the main reason for early microgrid failure. A degraded key component, such as a deteriorated battery or broken inverter, brings deals to the whole system on the microgrid site [77].

Another event that stirred the early microgrid failure was the rapid system breakdown. It is mostly because the component is aging or worn out. Previous studies mentioned that Insufficient maintenance mostly leads to worn-out and aging components [89][98].

Local policies could also come as a challenge. For example, forced policy to apply the local content can coerce the under-standard local component or poor-quality nearby component. Both types of components will trigger the rapid system breakdown and failure of the key component [94].

Figure 9 concludes the early failure of the microgrid system. The previous disturbance comes as a broken, aging, or worn-out component. Those will lead to the system breaking down and then the microgrid shall be out of function. Early termination will be an immediate consideration.

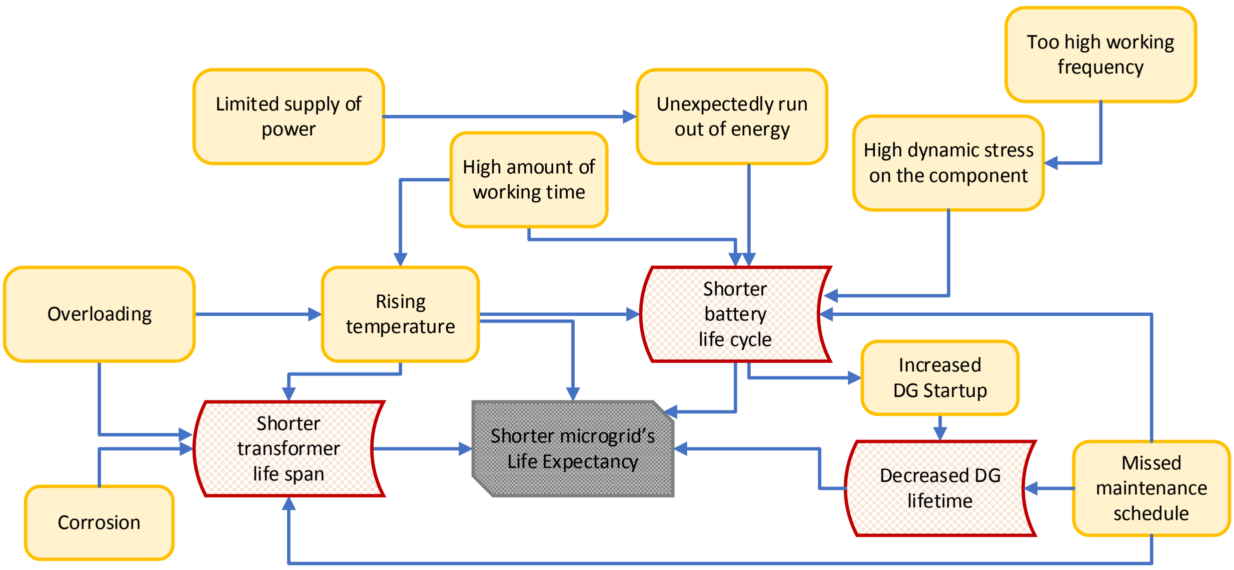

Figure 8. The schematic overview of the emerging issue of shorter life expectancy

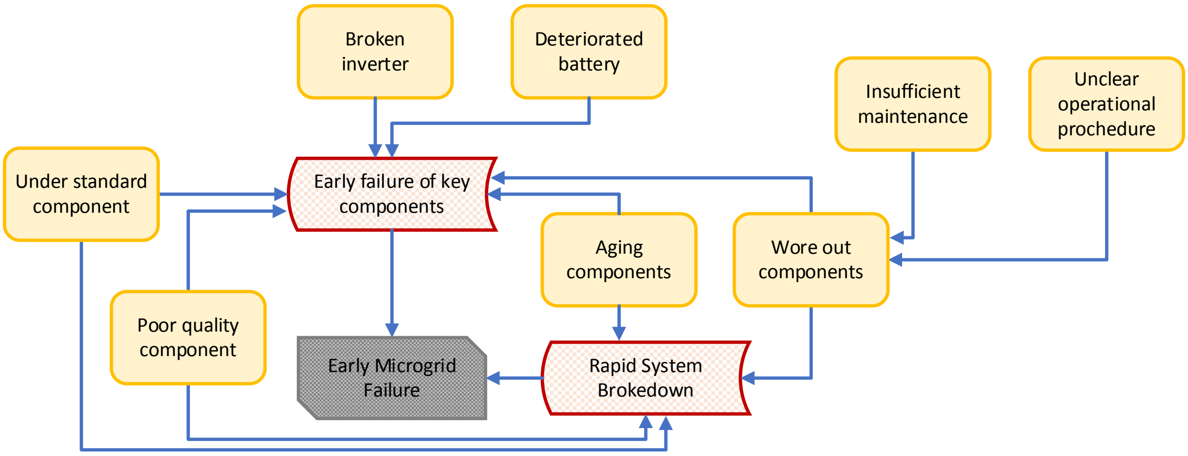

Figure 9. The schematic overview of the emerging issue of early microgrid failure

E. Open issues on early termination of microgrid system

It is agreeable that all four microgrid issues directed the reasoning for the termination of the said microgrid. When the expected energy on the transmission line is not achieved, the primary objective of the microgrid will be in question, and the distribution network will soon decide to consider other electrification systems. When a loss of power continuously happens, the record of unmet load will be accumulated. Significant accumulation will be considered as a potential material for an early microgrid termination. After a shorter life expectancy on the microgrid component is predicted, the economic calculation will weigh the cheaper alternative. An expensive microgrid operation will call out an early project termination. And finally, if an early failure is convincingly forecasted, the community and the stakeholder should consider early action of no longer continuing the microgrid project and focus on the potential alternative electrification system.

It has become notable that the discussed issues, which are capable of introducing degradation and deterioration, should be addressed immediately. Future work should be initiated to anticipate those four domains. However, besides those four domains, there are more factors to study. Some factors also include economic analysis, cultural discussion, donor availability, social engagement, community involvement, proper management framework, policy agreement, incentive scheme, continuous funding, and other non-technical domains.

V. Conclusion

Component degradation and deterioration within the electrification system pose a threat to the microgrid's performance. Furthermore, it can lead to the early termination of the said microgrid. This study addresses the further issues derived from the degradation and deterioration of the electrification system. The degradation and deterioration invoked many component performance issues, which led to four main damaging impacts on the microgrid system. The transmission line was found degradation and deterioration bringing up several issues in the form of EENS, EENT, EENG, and EENP, which finalized as expected energy not achieved. The energy storage section also addresses the degradation and deterioration with the occurrence of DOD reduction issues where energy deficit and unpredicted blackout invoke a prominent loss of power supply. Degradation and deterioration additionally come up with shorter lifespan issues which have a lot of attention because its shorter battery life cycle, shorter transformer lifespan, and decreased DG lifetime have resulted in shorter microgrid life expectancy. The last impact is the early failure of the microgrid system. Rapid broke down, and the crash of key components inadvertently fastened the time to failure. It is envisaged that the discussion in this study can provide a piece of useful information for the researcher, stakeholder, operator, and others to thoroughly consider the emerging issues of degradation and deterioration to prevent the early termination of the microgrid system. There are still a lot of unexplored emerging issues because of the deterioration and degradation of the microgrid component. It is expected that further study should be conducted to cover more non-technical issues.

Acknowledgments

The authors would like to thank Badan Riset dan Inovasi Nasional and Universiti Teknologi Malaysia for facilitating all the data collection and providing sophisticated literature on the completion of this work. The author would also like to thank all the UTM lecturers, BRIN researchers, staff, and students who helped in the accomplishment of this study.

Declarations

Author contribution

All authors contributed equally as the main contributor of this paper. All authors read and approved the final paper.

Funding statement

This work was conducted as a part of Universiti Teknologi Malaysia (UTM) and Badan Riset Inovasi Nasional, Indonesia (BRIN) Collaborative Research Grant vot R.J130000.7351.4B734.

Competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Additional information

Reprints and permission: information is available at https://mev.lipi.go.id/.

Publisher's Note: National Research and Innovation Agency (BRIN) remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

[1] United Nation, "Ensure access to affordable, reliable, sustainable and modern energy," *United Nations Sustainable Development Goals*, 2015. (accessed Aug. 20, 2022).

[2] The World Bank, "Report: Universal access to sustainable energy will remain elusive without addressing inequalities," *World Bank Press Release*, 2021. (accessed Aug. 20, 2022).

[3] M. Sandelic, S. Peyghami, A. Sangwongwanich, and F. Blaabjerg, "Reliability aspects in microgrid design and planning: Status and power electronics-induced challenges," *Renew. Sustain. Energy Rev.*, vol. 159, p. 112127, May 2022.

[4] T. D. Atmaja, R. Darussalam, and D. Andriani, "Vertical facade PV installation to optimize microgrid system on high rise EV parking lot with AC and DC charging station," in *2017 International Conference on Sustainable Energy Engineering and Application (ICSEEA)*, pp. 164–171, Oct. 2017.

[5] L. Martirano, S. Fornari, A. Di Giorgio, and F. Liberati, "A case study of a commercial/residential microgrid integrating cogeneration and electrical local users," in *2013 12th International Conference on Environment and Electrical Engineering*, pp. 363–368, May 2013.

[6] O. Babayomi, T. Shomefun, and Z. Zhang, "Energy efficiency of sustainable renewable microgrids for off-grid electrification," in *2020 IEEE PES/IAS PowerAfrica*, pp. 1–5, Aug. 2020.

[7] A. Ghasemi-Marzbali, R. Ahmadiahangar, S. G. Orimi, M. Shafiei, T. Haring, and A. Rosin, "Energy management of an isolated microgrid: A practical case," in *IECON 2021 – 47th Annual Conference of the IEEE Industrial Electronics Society*, pp. 1–6, Oct. 2021.

[8] Y.-O. Udoakah, E. Mudaheranwa, and L. Cipcigan, "Dynamic modeling of energy consumption pattern of a typical nigerian average urban and rural household for microgrid pv design," in *2019 IEEE PES Innovative Smart Grid Technologies Europe (ISGT-Europe)*, pp. 1–5, Sep. 2019.

[9] M. Effendy, N. Mardiyah, and K. Hidayat, "Efficiency improvement of photovolatic by using maximum power point tracking based on a new fuzzy logic controller," *J. Mechatronics, Electr. Power, Veh. Technol.*, vol. 9, no. 2, pp. 57–64, Dec. 2018.

[10] S. S. Reddy and C. Yammani, "Odd-even-prime pattern for PV array to increase power output under partial shading conditions," *Energy*, vol. 213, p. 118780, Dec. 2020.

[11] A. Iranmanesh, "Intensifying the melting process of a triple-tube latent heat energy storage unit via inserting a middle plate into the phase change material container," *J. Energy Storage*, vol. 56, p. 105982, Dec. 2022.

[12] T. D. Atmaja and G. Pikra, "Absorber layer addition and thermal storage media comparison for concentrated solar power plant optimization," *Energy Procedia*, vol. 32, pp. 74–83, 2013.

[13] E. Riyanto *et al.*, "A review of atomic layer deposition for high lithium-ion battery performance," *J. Mater. Res. Technol.*, vol. 15, pp. 5466–5481, Nov. 2021.

[14] V. M. Gonçalves, E. M. Baptista Bolonhez, G. E. Mendes Campos, and L. H. Sathler, "Transmission line routing optimization using rapid random trees," *Electr. Power Syst. Res.*, vol. 194, p. 107096, May 2021.

[15] V. Rexhepi and P. Nakov, "Condition assessment of power transformers status based on moisture level using fuzzy logic techniques," *J. Mechatronics, Electr. Power, Veh. Technol.*, vol. 9, no. 1, pp. 17–24, Jul. 2018.

[16] M. Abasi, A. Rohani, F. Hatami, M. Joorabian, and G. B. Gharehpetian, "Fault location determination in three-terminal transmission lines connected to industrial microgrids without requiring fault classification data and independent of line parameters," *Int. J. Electr. Power Energy Syst.*, vol. 131, p. 107044, Oct. 2021.

[17] Z. Li, H. Wang, Q. Ai, and Y. Zhang, "Interactive optimization between active distribution network with multi-microgrids based on distributed algorithm," *Energy Reports*, vol. 6, pp. 385–391, Dec. 2020.

[18] J. Gao, J.-J. Chen, Y. Cai, S.-Q. Zeng, and K. Peng, "A two-stage Microgrid cost optimization considering distribution network loss and voltage deviation," *Energy Reports*, vol. 6, pp. 263–267, Feb. 2020.

[19] E. Ganji and M. Mahdavian, "Improvement of power grid stability and load distribution using diesel excitation controller," *J. Mechatronics, Electr. Power, Veh. Technol.*, vol. 13, no. 1, pp. 36–47, Jul. 2022.

[20] A. Younesi, H. Shayeghi, Z. Wang, P. Siano, A. Mehrizi-Sani, and A. Safari, "Trends in modern power systems resilience: State-of-the-art review," *Renew. Sustain. Energy Rev.*, vol. 162, p. 112397, Jul. 2022.

[21] A. O. Yakub, N. N. Same, A. B. Owolabi, B. E. K. Nsafon, D. Suh, and J.-S. Huh, "Optimizing the performance of hybrid renewable energy systems to accelerate a sustainable energy transition in Nigeria: A case study of a rural healthcare centre in Kano," *Energy Strateg. Rev.*, vol. 43, p. 100906, Sep. 2022.

[22] B. Akbas, A. S. Kocaman, D. Nock, and P. A. Trotter, "Rural electrification: An overview of optimization methods," *Renew. Sustain. Energy Rev.*, vol. 156, p. 111935, Mar. 2022.

[23] G. Veilleux *et al.*, "Techno-economic analysis of microgrid projects for rural electrification: A systematic approach to the redesign of Koh Jik off-grid case study," *Energy Sustain. Dev.*, vol. 54, pp. 1–13, Feb. 2020.

[24] A. Haghighat Mamaghani, S. A. Avella Escandon, B. Najafi, A. Shirazi, and F. Rinaldi, "Techno-economic feasibility of photovoltaic, wind, diesel and hybrid electrification systems for off-grid rural electrification in Colombia," *Renew. Energy*, vol. 97, pp. 293–305, Nov. 2016.

[25] T. D. Atmaja, D. Andriani, and R. Darussalam, "Smart grid communication applications: measurement equipment and networks architecture for data and energy flow," *J. Mechatronics, Electr. Power, Veh. Technol.*, vol. 10, no. 2, p. 73, Nov. 2019.

[26] K. Cabana-Jiménez, J. E. Candelo-Becerra, and V. Sousa Santos, "Comprehensive analysis of microgrids configurations and topologies," *Sustainability*, vol. 14, no. 3, p. 1056, Jan. 2022.

[27] M. Günther, "A hybrid PV-battery/diesel electricity supply on Peucang island: an economic evaluation," *J. Mechatronics, Electr. Power, Veh. Technol.*, vol. 7, no. 2, pp. 113–122, Dec. 2016.

[28] International Energy Agency (IEA), "World energy outlook 2021," 2022.

[29] G. Xavier de Andrade Pinto, L. P.Costa, H. F. Naspolini, and R. Rüther, "Evaluation of technical feasibility and financial attractiveness of a 1MWp solar photovoltaic generator on ground and building rooftops at the Federal University of Santa Catarina - Brazil," in *Proceedings of the ISES Solar World Congress 2021*, pp. 1–12, 2021.

[30] S. Tabish and I. Ashraf, "Simulation of partial shading on solar photovoltaic modules with experimental verification," *Int. J. Ambient Energy*, vol. 38, no. 2, pp. 161–170, Feb. 2017.

[31] G. Celli, E. Ghiani, G. G. Soma, and F. Pilo, "Pseudo sequential Monte Carlo to plan the integration of RES in active distribution networks," 2011.

[32] M. Tamoor, M. Abu Bakar Tahir, M. A. Zaka, and E. Iqtidar, "Photovoltaic distributed generation integrated electrical distribution system for development of sustainable energy using reliability assessment indices and levelized cost of electricity," *Environ. Prog. Sustain. Energy*, vol. 41, no. 4, Jul. 2022.

[33] M. M. Baiek, A. E. Esmaio, M. Nizam, M. Anwar, and H. M. S. Atia, "Derivative load voltage and particle swarm optimization to determine optimum sizing and placement of shunt capacitor in improving line losses," *J. Mechatronics, Electr. Power, Veh. Technol.*, vol. 7, no. 2, pp. 67–76, Dec. 2016.

[34] R. Hou, A. Maleki, and P. Li, "Design optimization and optimal power management of standalone solar-hydrogen system using a new metaheuristic algorithm," *J. Energy Storage*, vol. 55, p. 105521, Nov. 2022.

[35] S. Peyghami, F. Blaabjerg, and P. Palensky, "Incorporating power electronic converters reliability into modern power

system reliability analysis," *IEEE J. Emerg. Sel. Top. Power Electron.*, vol. 9, no. 2, pp. 1668–1681, Apr. 2021.

[36] J. Peters, M. Sievert, and M. A. Toman, "Rural electrification through mini-grids: Challenges ahead," *Energy Policy*, vol. 132, pp. 27–31, Sep. 2019.

[37] R. K. Asyuri and E. A. Setiawan, "Optimization and integration of renewable energy sources with regional tourism potentials to improve the welfare of local communities," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1050, no. 1, p. 012007, Jul. 2022.

[38] G. Dimov, S. Tzvetkova, A. Petleshkov, and Y. Lozanov, "Change of power supply continuity indices due to force majeure circumstances," in *2020 12th Electrical Engineering Faculty Conference (BulEF)*, pp. 1–5, Sep. 2020.

[39] Q. Li, L. Wang, and S. Hou, "Microgrid reliability evaluation based on condition-dependent failure models of power electronic devices," in *2018 2nd IEEE Conf. on Energy Internet and Energy System Integration (EI2)*, pp. 1–6, Oct. 2018.

[40] A. Ostrowska *et al.*, "Power quality assessment in a real microgrid-statistical assessment of different long-term working conditions," *Energies*, vol. 15, no. 21, p. 8089, Oct. 2022.

[41] Q. Xiao *et al.*, "An improved power regulation method for a three-terminal hybrid AC/DC microgrid during module failure," *Int. J. Electr. Power Energy Syst.*, vol. 123, p. 106330, Dec. 2020.

[42] A. M. Nakhaee, S. A. Hosseini, S. H. H. Sadeghi, and A. Nasiri, "A framework for assessing the impact of operational uncertainties on the reliability of adaptive microgrid protection schemes," *Arab. J. Sci. Eng.*, Oct. 2022.

[43] W. Zhong, L. Wang, Z. Liu, and S. Hou, "Reliability evaluation and improvement of islanded microgrid considering operation failures of power electronic equipment," *J. Mod. Power Syst. Clean Energy*, vol. 8, no. 1, pp. 111–123, 2020.

[44] A. Turnbull, J. Carroll, and A. McDonald, "Combining SCADA and vibration data into a single anomaly detection model to predict wind turbine component failure," *Wind Energy*, vol. 24, no. 3, pp. 197–211, Mar. 2021.

[45] Y. H. Yang, Y. L. Xin, J. J. Zhou, W. H. Tang, and B. Li, "Failure probability estimation of transmission lines during typhoon based on tropical cyclone wind model and component vulnerability model," in *2017 IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC)*, pp. 1–6, Nov. 2017.

[46] G. Wu and Z. Li, "A cascading failure model of power systems considering components' multi-state failures," in *2019 Prognostics and System Health Management Conference (PHM-Qingdao)*, pp. 1–6, Oct. 2019.

[47] L. Gigoni, A. Betti, M. Tucci, and E. Crisostomi, "A scalable predictive maintenance model for detecting wind turbine component failures based on SCADA data," in *2019 IEEE Power & Energy Society General Meeting (PESGM)*, pp. 1–5, Aug. 2019.

[48] M. Fischer, S. Tenbohlen, M. Schafer, and R. Haug, "Determining power transformers' sequence of maintenance and repair in power grids," in *2010 IEEE International Symposium on Electrical Insulation*, Jun., pp. 1–6, 2010.

[49] V.-H. Bui, A. Hussain, and H.-M. Kim, "A strategy for optimal operation of hybrid AC/DC microgrid under different connection failure scenarios," *Int. J. Smart Home*, vol. 10, no. 12, pp. 231–244, Dec. 2016.

[50] M. Pompili, L. Calcara, and S. Sangiovanni, "MV Underground Power Cable Joints Premature Failures," in *2020 AEIT International Annual Conference (AEIT)*, Sep. pp. 1–4, 2020.

[51] J. Weichold, R. Calone, I. Gentilini, G. Bolcato, F. Giammanco, and M. Stalder, "The smart termination: an innovative component to enable smart grids development," in *22nd International Conference and Exhibition on Electricity Distribution (CIRED 2013)*, pp. 0598–0598, 2013.

[52] R. Zhao, J. Chen, Z. Hou, B. Li, M. Lin, and M. Duan, "A security early warning method of power grid based on failure risk assessment," in *2021 IEEE Sustainable Power and Energy Conference (iSPEC)*, Dec., pp. 1627–1633, 2021.

[53] Q. Yu, Z. Jiang, Y. Liu, G. Long, M. Guo, and D. Yang, "Research of early warning of failure with load tendency based on non-intrusive load monitoring in microgrid," in *2020 IEEE 6th International Conference on Control Science and Systems Engineering (ICCSSE)*, Jul., pp. 232–236, 2020.

[54] J. Han, L. Zhang, and Y. Li, "Hotspots, flaws and deficiencies of research on rural energy upgrading: A review," *Energy Strateg. Rev.*, vol. 38, p. 100766, Nov. 2021.

[55] F. Gonzalez-Longatt, C. Adiyabazar, and E. V. Martinez, "Setting and testing of the out-of-step protection at mongolian transmission system," *Energies*, vol. 14, no. 23, p. 8170, Dec. 2021.

[56] P. Aaslid, M. Korpås, M. M. Belsnes, and O. B. Fosso, "Stochastic operation of energy constrained microgrids considering battery degradation," *Electr. Power Syst. Res.*, vol. 212, p. 108462, Nov. 2022.

[57] A. Yahiaoui, K. Benmansour, and M. Tadjine, "Control, analysis and optimization of hybrid PV-Diesel-Battery systems for isolated rural city in Algeria," *Sol. Energy*, vol. 137, pp. 1–10, Nov. 2016.

[58] F. Fodhil, A. Hamidat, and O. Nadjemi, "Potential, optimization and sensitivity analysis of photovoltaic-diesel-battery hybrid energy system for rural electrification in Algeria," *Energy*, vol. 169, pp. 613–624, Feb. 2019.

[59] S. M. Shaahid and I. El-Amin, "Techno-economic evaluation of off-grid hybrid photovoltaic–diesel–battery power systems for rural electrification in Saudi Arabia–A way forward for sustainable development," *Renew. Sustain. Energy Rev.*, vol. 13, no. 3, pp. 625–633, Apr. 2009.

[60] S. Yilmaz and F. Dincer, "Optimal design of hybrid PV-diesel-battery systems for isolated lands: A case study for Kilis, Turkey," *Renew. Sustain. Energy Rev.*, vol. 77, pp. 344–352, Sep. 2017.

[61] H. Rezzouk and A. Mellit, "Feasibility study and sensitivity analysis of a stand-alone photovoltaic–diesel–battery hybrid energy system in the north of Algeria," *Renew. Sustain. Energy Rev.*, vol. 43, pp. 1134–1150, Mar. 2015.

[62] T. D. Atmaja *et al.*, "Fuel saving on diesel genset using pv/battery spike cutting in remote area microgrid," *MATEC Web Conf.*, vol. 164, p. 01045, Apr. 2018.

[63] F. Almeshqab and T. S. Ustun, "Lessons learned from rural electrification initiatives in developing countries: Insights for technical, social, financial and public policy aspects," *Renew. Sustain. Energy Rev.*, vol. 102, pp. 35–53, Mar. 2019.

[64] A. Qashou, S. Yousef, and E. Sanchez-Velazquez, "Mining sensor data in a smart environment: a study of control algorithms and microgrid testbed for temporal forecasting and patterns of failure," *Int. J. Syst. Assur. Eng. Manag.*, vol. 13, no. 5, pp. 2371–2390, Oct. 2022.

[65] Y. Zhang, J. Liu, B. Song, and T. Yu, "Reliability modeling for dependent competing failure processes between component degradation and system performance deterioration," in *Safety and Reliability – Safe Societies in a Changing World*, London: CRC Press, pp. 2475–2482, 2018.

[66] D. L. Bätzner, A. Romeo, M. Terheggen, M. Döbeli, H. Zogg, and A. N. Tiwari, "Stability aspects in CdTe/CdS solar cells," *Thin Solid Films*, vol. 451–452, pp. 536–543, Mar. 2004.

[67] S. G. Kumar and K. S. R. K. Rao, "Physics and chemistry of CdTe/CdS thin film heterojunction photovoltaic devices: fundamental and critical aspects," *Energy Environ. Sci.*, vol. 7, no. 1, pp. 45–102, 2014.

[68] D. Azuatalam, K. Paridari, Y. Ma, M. Förstl, A. C. Chapman, and G. Verbič, "Energy management of small-scale PV-battery systems: A systematic review considering practical implementation, computational requirements, quality of input data and battery degradation," *Renew. Sustain. Energy Rev.*, vol. 112, pp. 555–570, Sep. 2019.

[69] G. Liu, Y. Zhang, F. Luo, and J. Yuan, "Design of wireless sensor network routing for renewable energy microgrid," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 366, p. 012022, Jun. 2018.

[70] Y. Liu, H. Shi, L. Guo, T. Xu, B. Zhao, and C. Wang, "Towards long-period operational reliability of independent microgrid: A risk-aware energy scheduling and stochastic optimization method," *Energy*, vol. 254, p. 124291, Sep. 2022.

[71] Y. V. Makarov, "Probabilistic assessment of the energy not produced due to transmission constraints," in *2003 IEEE Bologna Power Tech Conference Proceedings*, vol. 4, pp. 435–437, 2003.

[72] F. J. V. Fernández, F. Segura Manzano, J. M. Andújar Márquez, and A. J. Calderón Godoy, "Extended model predictive controller to develop energy management systems in renewable source-based smart microgrids with hydrogen as backup. theoretical foundation and case study," *Sustainability*, vol. 12, no. 21, p. 8969, Oct. 2020.

[73] Y. García-Vera, R. Dufo-López, and J. Bernal-Agustín, "Optimization of isolated hybrid microgrids with renewable energy based on different battery models and technologies," *Energies*, vol. 13, no. 3, p. 581, Jan. 2020.

[74] S. Kharel and B. Shabani, "Hydrogen as a long-term large-scale energy storage solution to support renewables," *Energies*, vol. 11, no. 10, p. 2825, Oct. 2018.

[75] N. Shirzadi, H. Rasoulian, F. Nasiri, and U. Eicker, "Resilience enhancement of an urban microgrid during off-grid mode operation using critical load indicators," *Energies*, vol. 15, no. 20, p. 7669, Oct. 2022.

[76] T. M. Layadi, G. Champenois, M. Mostefai, and D. Abbes, "Lifetime estimation tool of lead–acid batteries for hybrid power sources design," *Simul. Model. Pract. Theory*, vol. 54, pp. 36–48, May 2015.

[77] M. Derks and H. Romijn, "Sustainable performance challenges of rural microgrids: Analysis of incentives and policy framework in Indonesia," *Energy Sustain. Dev.*, vol. 53, pp. 57–70, Dec. 2019.

[78] K. Takeno, M. Ichimura, K. Takano, and J. Yamaki, "Influence of cycle capacity deterioration and storage capacity deterioration on Li-ion batteries used in mobile phones," *J. Power Sources*, vol. 142, no. 1–2, pp. 298–305, Mar. 2005.

[79] S. Zhang, K. Zhao, T. Zhu, and J. Li, "Electrochemomechanical degradation of high-capacity battery electrode materials," *Prog. Mater. Sci.*, vol. 89, pp. 479–521, Aug. 2017.

[80] Y. Lv, X. Yang, and G. Zhang, "Durability of phase-change-material module and its relieving effect on battery deterioration during long-term cycles," *Appl. Therm. Eng.*, vol. 179, p. 115747, Oct. 2020.

[81] S. Hardy, D. Van Hertem, and H. Ergun, "A techno-economic analysis of meshed topologies of offshore wind hvac transmission," in *2021 IEEE Madrid PowerTech*, Jun., pp. 1–6, 2021.

[82] S. Hardy, H. Ergun, and D. Van Hertem, "A greedy algorithm for optimizing offshore wind transmission topologies," *IEEE Trans. Power Syst.*, vol. 37, no. 3, pp. 2113–2121, May 2022.

[83] J. M. Lujano-Rojas, R. Dufo-López, and J. L. Bernal-Agustín, "Technical and economic effects of charge controller operation and coulombic efficiency on stand-alone hybrid power systems," *Energy Convers. Manag.*, vol. 86, pp. 709–716, Oct. 2014.

[84] P. Singh and J. S. Lather, "Accurate power-sharing, voltage regulation, and SOC regulation for LVDC microgrid with hybrid energy storage system using artificial neural network," *Int. J. Green Energy*, vol. 17, no. 12, pp. 756–769, Sep. 2020.

[85] Y. V. Makarov, R. C. Hardiman, and D. L. Hawkins, "Risk, reliability, cascading, and restructuring," in *IEEE Power Engineering Society General Meeting, 2004.*, vol. 2, pp. 383–395, 2004.

[86] A. Volkanovski, A. Ballesteros Avila, and M. Peinador Veira, "Trend analysis of loss of offsite power events," Jun. 2016.

[87] D. F. Lizondo, V. A. Jimenez, P. B. Araujo, and A. Will, "Conceptual microgrid management framework based on adaptive and autonomous multi-agent systems," *J. Comput. Sci. Technol.*, vol. 22, no. 1, p. e01, Apr. 2022.

[88] M. Hamzeh and B. Vahidi, "The impact of cyber network configuration on the dynamic-thermal failure of transformers considering distributed generator controller," *Int. J. Electr. Power Energy Syst.*, vol. 137, p. 107786, May 2022.

[89] E. C. X. Ikejemba, P. B. Mpuan, P. C. Schuur, and J. Van Hillegersberg, "The empirical reality & sustainable management failures of renewable energy projects in Sub-Saharan Africa (part 1 of 2)," *Renew. Energy*, vol. 102, pp. 234–240, Mar. 2017.

[90] A. M. Moheb, E. A. El-Hay, and A. A. El-Fergany, "Comprehensive review on fault ride-through requirements of renewable hybrid microgrids," *Energies*, vol. 15, no. 18, p. 6785, Sep. 2022.

[91] S. Paul and Z. H. Rather, "A novel approach for optimal cabling and determination of suitable topology of MTDC connected offshore wind farm cluster," *Electr. Power Syst. Res.*, vol. 208, p. 107877, Jul. 2022.

[92] D. Kančev, A. Duchac, B. Zerger, M. Maqua, and D. Wattrelos, "Statistical analysis of events related to emergency diesel generators failures in the nuclear industry," *Nucl. Eng. Des.*, vol. 273, pp. 321–331, Jul. 2014.

[93] M. Aslani, H. Hashemi-Dezaki, and A. Ketabi, "Analytical reliability evaluation method of smart micro-grids considering the cyber failures and information transmission system faults," *IET Renew. Power Gener.*, Jul. 2022.

[94] S. K. Akula and H. Salehfar, "Risk-based classical failure mode and effect analysis (fmea) of microgrid cyber-physical energy systems," in *2021 North American Power Symposium (NAPS)*, Nov., pp. 1–6, 2021.

[95] D. Akinyele, J. Belikov, and Y. Levron, "Challenges of microgrids in remote communities: A STEEP model application," *Energies*, vol. 11, no. 2, p. 432, Feb. 2018.

[96] O. Babayomi and T. Okharedia, "Challenges to Sub-Saharan Africa's renewable microgrid expansion - A CETEP solution model," in *2019 IEEE PES/IAS PowerAfrica*, Aug., pp. 617–621, 2019.

[97] D. Xu and Y. Long, "The impact of government subsidy on renewable microgrid investment considering double externalities," *Sustainability*, vol. 11, no. 11, p. 3168, Jun. 2019.

[98] S. D. Negara, "The impact of local content requirements on the indonesian manufacturing industry," 2016.

[99] D. E. Ighravwe and D. Mashao, "Development of a techno-economic framework for renewable energy project financing," in *2019 IEEE 2nd International Conference on Renewable Energy and Power Engineering (REPE)*, Nov., pp. 120–124, 2019.

[100] Y. Pu *et al.*, "Optimal sizing for an integrated energy system considering degradation and seasonal hydrogen storage," *Appl. Energy*, vol. 302, p. 117542, Nov. 2021.