Journal of Advanced Research in Applied Mechanics

Journal homepage:
https://semarakilmu.com.my/journals/index.php/appl_mech/index
ISSN: 2289-7895

Optimizing Voltage Profile and Mitigating Power Losses in Distribution Network Reconfiguration Via the Integration of Distributed Generation Penetration in Malaysia

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ARTICLE INFO

Article history:
Received 1 January 2025
Received in revised form 31 January 2025
Accepted 7 February 2025
Available online 28 February 2025

Keywords:
Distribution networks; power losses; voltage profile; Distribution Network Reconfiguration (DNR); Distributed Generations (DGs); PSS ADEPT 5.3.2

ABSTRACT

Radial distribution networks face challenges such as voltage drop and power losses, which are significant concerns. The objective of reconfiguration in a distribution network is to determine the optimal combination of switching system branches that maximizes a specific goal function while adhering to defined limitations. This process improves the quality of electrical power and enhances the performance of the distribution network. This research paper presents optimal techniques for optimizing the reconfiguration of the distribution system and the installation of DG units to minimize active power losses and improve the bus voltage profile. These techniques are based on technical analysis conducted using the Power System Study ADEPT (PSS ADEPT) software in an industrial setting. The load flow calculations are performed using technical analysis technique simulated by PSS ADEPT. The proposed methods are evaluated in the distribution system of the 145-bus test system. Furthermore, the distribution system model incorporates the solar DGs and load profile. The simulation results demonstrate the effectiveness of the proposed method in reducing active power losses and improving the system bus voltage. Additionally, it successfully addresses the system reconfiguration problem and enhances the performance of the distribution system. These improvements are particularly advantageous when integrating distributed generation (DG) into the distribution network to accommodate load growth over the next 5 years. The results confirm the effectiveness and success of the proposed methodology in determining the most suitable placement and dimensions of solar distributed generators (DGs) to minimize power losses and enhance voltage profiles.

1. Introduction

The impact of global warming and environmental pollution has brought about a significant transformation in the modern energy structure [1]. Thankfully, renewable energies and electric vehicles (EVs) provide practical solutions for energy production and consumption [2]. The distribution

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https://doi.org/10.37934/aram.133.1.120134

network now incorporates various decentralized renewable generation sources like wind power (WP) and photovoltaic power (PV), resulting in reduced network loss and improved voltage quality [3]. One promising technology, the battery swapping station (BSS), can recharge an EV in just minutes and contribute to the distribution network by flexibly charging and discharging stored batteries. This not only maximizes the utilization of renewable energies but also strengthens the system's resilience [4,5].

The increased demand for electricity has posed challenges for the power grid, leading to difficulties in maintaining stability and reliability. As a result, the smart grid concept is shifting from centralized generating units to distributed units located directly at load buses. These smaller units, which are part of the distribution network and situated close to end-users, are incorporating renewable energy sources like wind and solar. These sources are preferred in the smart grid due to their low maintenance requirements, long lifespan, and environmental friendliness. However, their unpredictability presents technical challenges [6-8]. To ensure system reliability and stability, it is crucial to have reserved energy allocation. By integrating a battery energy storage system into the distribution network, costs can be reduced, power loss can be minimized, and quick responses to critical loads can be achieved [9,10]. This versatile system can be utilized in electric vehicles and offers various applications, including powering different sectors, load sharing, peak shaving, and energy storage [11-14].

The methods proposed in [15-18] aim to find the most suitable allocation of distributed generators (DGs) and ensure optimal reconfiguration for the distribution system. These approaches primarily focus on determining the appropriate capacities of solar distributed generators (DGs) and analyzing their coordinated operation within a distribution network (DN). Solar DGs exhibit power generation patterns that are unpredictable and may not align with the load demand. Therefore, estimating DG capacities based on average or peak load demands is not feasible. To optimize DG capacities, the method considers the timing of maximum power generation for solar and wind DGs. However, uncertainties in power generation may cause the actual capacities of DGs to exceed the optimized capacities. To estimate the actual capacities of DGs, the study considers the panel generating factor for solar DGs and the efficiency of DGs. The primary objective of this research is to minimize active power loss and voltage deviation in the DN. Network reconfiguration is another technique employed to achieve this objective. By reconfiguring the DN, the voltage profile at bus nodes is improved, network reliability is enhanced, and the burden on heavily loaded lines as well as power losses are reduced [19,20].

1.2 Review of Related Work
1.2.1 Distributed Generation (DGs)

DERs have become more prevalent in electric distribution networks in the last two decades due to affordable technology, increased customer demand for reliable electricity, and the liberalization of the electricity market [21]. However, the integration of DERs into the distribution system can pose challenges such as voltage rise and bidirectional power flow [22]. To tackle these challenges, there is a need to improve the management approach of the distribution system [23]. Traditionally, distribution systems were designed for one-way power transmission from substations to customers. However, the high penetration of DERs has led to reverse power flows, which can create reliability challenges that distribution system operators (DSOs) must address [24].

In the study conducted by the researchers mentioned that, the Salp Swarm Algorithm was utilized in [25] to forecast the distribution of Distributed Generation (DG) and carry out network reconfiguration. The main objective of this research was to minimize power loss and voltage fluctuations. Similarly, the researchers employed the Water cycle algorithm to identify the most suitable network reconfiguration, DG sizing, and optimal placement in the Distribution Network (DN) [26]. The main focus was on improving the power factor of the DG to minimize power loss. Conversely, concentrated on a multi-objective management process that involved the simultaneous operation of network reconfiguration, placement of renewable DG, and optimal sizing to decrease power loss, total annual investment cost, and polluting gas emissions [27]. To tackle this challenge, a practical genetic approach based on the Pareto Evolutionary Algorithm was utilized. Moreover, employed the genetic algorithm approach to optimize the DG location, followed by network reconfiguration, while considering the P and PQV bus in the DN [28].

1.2.2 Distribution Network Reconfiguration (DNR)

NR is commonly used for minimizing losses, improving voltage profiles, balancing loads, and enhancing reliability. The achievement of NR involves altering the status of switches that connect or disconnect branches, with the aim of improving system reliability [29,30]. A methodology was presented for evaluating the optimal network configuration after a failure [31]. An algebraic model was proposed in [32] to assess the reliability of the DS, while Tabares *et al.,* [33] introduced a multistage analytical model that considers network reliability for network expansion. [34] proposed a mathematical model for planning the expansion of multistage distribution networks, considering reliability. Additionally, [35] described a method for optimizing the reconfiguration of distribution networks to enhance reliability and network performance. The modifications in existing reliability indices have been brought about by the redefinition of failure rates in the context of underground feeders. An instance of this can be seen in the Deep-Learning (DQL) approach suggested by [36], which focuses on effectively tackling the reconfiguration issue while considering the reliability factor in the presence of distributed generators (DG). Furthermore, [37] presented a method for planning multi-period reconfiguration in distribution networks that incorporate remotely controlled and supervised switches, commonly referred to as automated switches.

To recapitulate the study proposed to address the research gap mentioned earlier, the significance of this research can be summarized as follows:

i. The PSS ADEPT software is used with technical analysis to determine the most suitable locations for DGs.
ii. The network reconfiguration method is implemented with the objective of enhancing the voltage profile and minimizing power losses in the DN.
iii. Five (5) years trending of load growth will be considered in this study with adjustment of DGs penetration so that the system can optimize voltage profile and reduce real power losses.

2. Methodology

This research concentrated on the technical performance of the distribution network and does not consider complex factors like environmental and economic issues that could complicate the models. By narrowing the focus, the study aims to maintain clarity and highlight technical efficiency. It may have been difficult to find or measure data on environmental and economic aspects, which is why the emphasis is on technical metrics. The intended audience is likely technical professionals or engineers, leading to a focus on technical details instead of broader sustainability or economic topics. Although environmental and economic factors may have become more significant recently, the researchers might not have been aware of these changes during their study. The assumption is that improving technical performance will also enhance environmental and economic results, so these areas are not explicitly discussed.

The main focus of this section is to present the research framework that outlines the overall procedure of this study. To carry out the simulation, the research utilizes the Power System Study (PSS ADEPT) software [38]. The comprehensive research framework is divided into three sections, as shown in flowchart Figure 1. The first part of the process involves the modelling of the practical 145-bus radial distribution system with the standard load. Following this, the backward-forward load flow analysis is utilized to determine the voltage and current levels at all buses and lines. Moving forward, the second section focuses on the placement and sizing of Distributed Generation (DG) that will have an impact on the load side of the distribution system. Finally, the third section concentrates on the reconfiguration of the distribution network to identify the optimal placement of switches, taking into account the projected load growth for the next five years. This reconfiguration aims to improve the voltage profile and reduce active power losses in the distribution system [39].

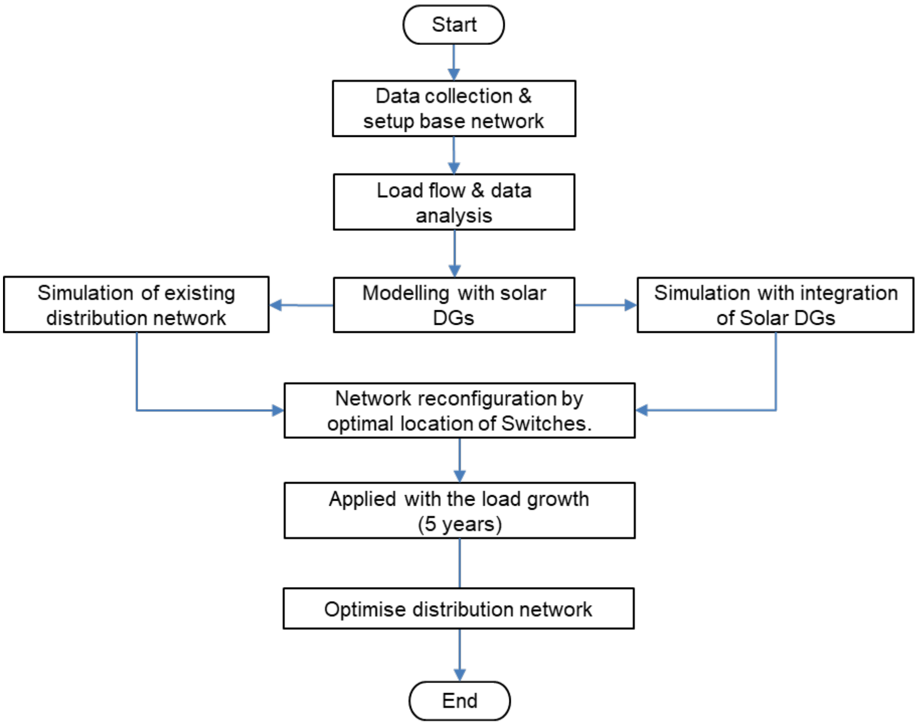

Fig. 1. Research flowchart

Before implementing the proposed methodology, it is of utmost importance to ascertain the appropriate number of Distributed Generators (DGs) in order to maximize the benefits of the system. To determine the suitable DG number, it will be based on the typical range of solar installations in Malaysia. The study encompasses a total of six variables, which include three options for placement and three different sizes of DGs. Each of these parameters will have specific constraints that need to be satisfied. The placement of DGs will be determined by minimizing power loss and improving the voltage profile at various bus locations. Since this involves two objective functions, a multi-objective approach will be adopted using weight summation. The essential formulas for the multi-objective analysis can be seen in Eq. (1) and Eq. (2) below:

$$OBJ = \omega_1 Losses_{rel} + \omega_2 V_{profile} \tag{1}$$

$$\omega_1 = \omega_2 = 0.5 \tag{2}$$

where OBJ is referred to multi-objective function, ω_1 and ω_2 are weighted coefficient, $Losses_{real}$ is active power losses of distribution network and $V_{profile}$ is voltage at all busses

3. System Modelling

The subsequent sections will focus on the modeling of the distribution system, incorporating distributed generation (DG), and the prediction of load growth. Following that, the emphasis will transition to determining the appropriate formula for calculating power loss, voltage profile, and load growth. Ultimately, the attention will be directed towards the technical analysis conducted using the PSS ADEPT software in this research.

3.1 Distribution System Modelling

Considering the standard load and operation of distributed generators (DGs), the distribution system has been developed. It is specifically designed to replicate the actual distribution system utilized by the utility company in Malaysia, which caters to a diverse range of areas including residential, commercial, and industrial zones. To assess the integration of solar DGs into the distribution system, the 11kV 145-bus radial distribution system has been chosen for utilization and simulation, as illustrated in Figure 2. The practical distribution system typically consists of a greater number of branches due to customer demand and the distance from the nearest bus. The load data is based on the peak load observed during the afternoon, as indicated in Figure 3.

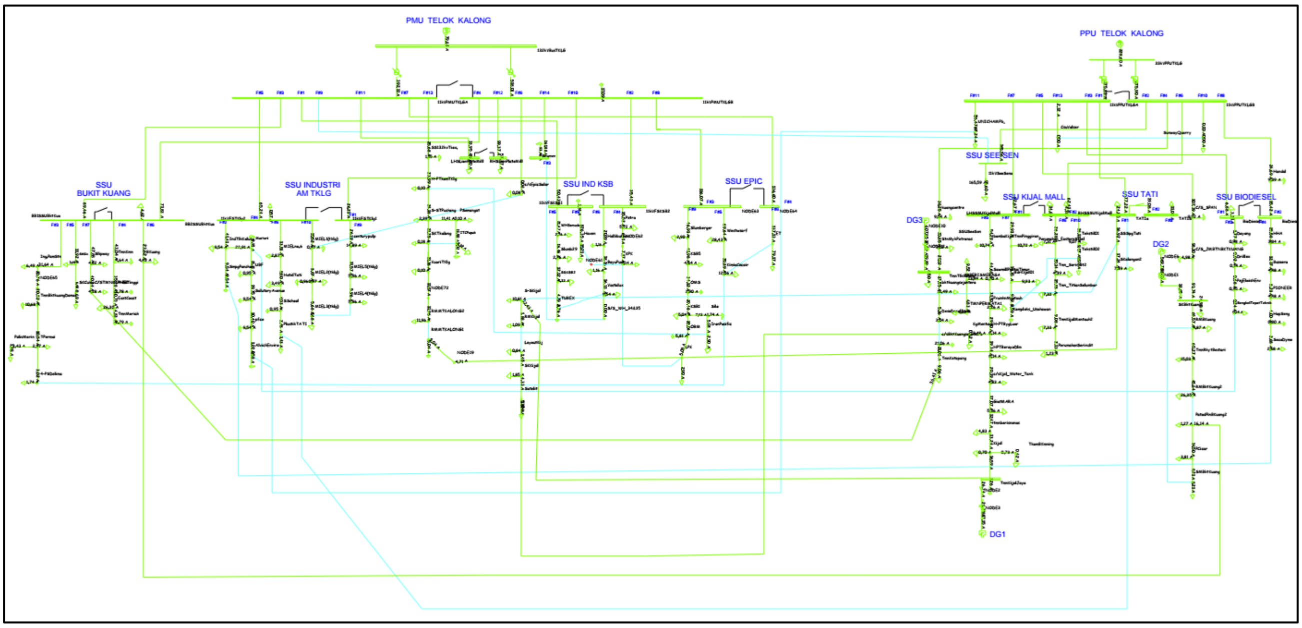

Fig. 2. 11 kV practical 145-bus radial distribution system

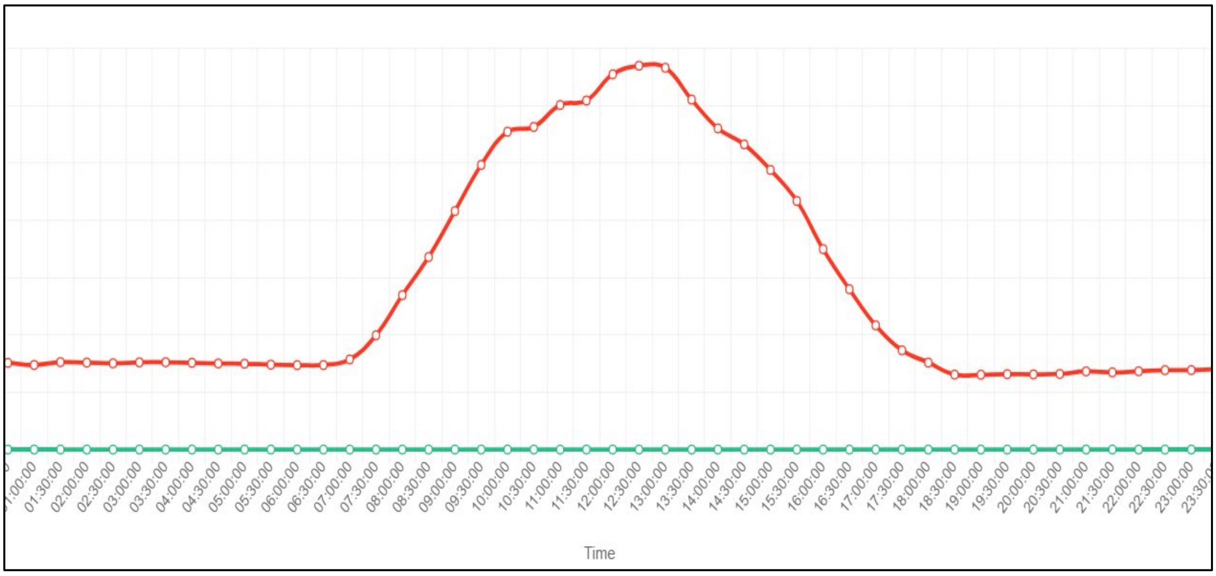

Fig 3. Peak hour of DGs penetration (highest at 12:30 at noon)

Detailed information regarding the load and line data can be found in Table 1 and Table 2. The existing load of the distribution network is recorded as 28.292 MW and 14.570 MVAr. This research incorporates three distributed generation (DG) units within a distribution system, serving distinct purposes that are often aligned with the specific objectives of the study or project. This approach facilitates a more manageable analysis by simplifying calculations and enhancing the understanding of fundamental interactions without introducing excessive complexity. Furthermore, these units can act as benchmarks for evaluating performance and impacts, enabling straightforward assessments of various configurations. This methodology also allows for a more thorough examination of interactions between different types of DG units and the distribution network, particularly in terms of load sharing and voltage regulation. By concentrating on a limited number of models, stakeholder engagement in discussions regarding potential impacts and benefits becomes more feasible, avoiding the confusion that may arise from an abundance of options. However, it is crucial to acknowledge the advantages of potentially expanding the number of units as the study or project progresses

Table 1
Load data for 145-bus radial distribution system

bus no.	load (mw)	load (mvar)	bus no.	load (mw)	load (mvar)	bus no.	load (mw)	load (mvar)
1	0.540	0.270	26	0.016	0.008	51	0.023	0.012
2	0.075	0.038	27	0.004	0.002	52	0.011	0.005
3	0.039	0.020	28	0.005	0.003	53	0.039	0.019
4	0.032	0.016	29	0.018	0.009	54	0.039	0.019
5	0.025	0.013	30	0.010	0.005	55	0.017	0.009
6	0.018	0.009	31	0.018	0.009	56	0.009	0.004
7	0.007	0.004	32	0.006	0.003	57	0.106	0.053
8	0.098	0.049	33	0.051	0.025	58	0.035	0.017
9	0.062	0.031	34	0.204	0.102	59	0.024	0.012
10	0.034	0.017	35	0.205	0.103	60	0.021	0.011
11	0.032	0.016	36	0.046	0.023	61	0.012	0.006
12	0.030	0.015	37	0.043	0.022	62	0.063	0.032
13	0.016	0.008	38	0.044	0.022	63	0.052	0.026
14	0.002	0.001	39	0.017	0.009	64	0.045	0.023
15	0.014	0.007	40	0.017	0.009	65	0.007	0.004
16	0.016	0.008	41	0.024	0.012	66	0.238	0.119
17	0.013	0.007	42	0.025	0.012	67	0.171	0.085

18	0.008	0.004	43	0.025	0.013	68	0.069	0.035
19	0.020	0.010	44	0.007	0.004	69	0.062	0.031
20	0.015	0.007	45	0.763	0.382	70	0.050	0.025
21	0.006	0.003	46	0.053	0.026	71	0.043	0.022
22	0.004	0.002	47	0.030	0.015	72	0.022	0.011
23	0.080	0.040	48	0.027	0.013	73	0.007	0.004
24	0.047	0.024	49	0.024	0.012	74	0.012	0.006
25	0.031	0.016	50	0.001	0.000	75	0.007	0.004
76	0.103	0.051	101	0.108	0.054	126	0.077	0.038
77	0.031	0.015	102	0.095	0.047	127	0.074	0.037
78	0.146	0.073	103	0.091	0.045	128	0.073	0.036
79	0.000	0.000	104	0.080	0.040	129	0.073	0.037
80	0.028	0.014	105	0.061	0.031	130	0.066	0.033
81	0.107	0.053	106	0.054	0.027	131	0.053	0.027
82	0.581	0.291	107	0.023	0.012	132	0.047	0.023
83	0.464	0.232	108	0.010	0.005	133	0.001	0.001
84	0.036	0.018	109	0.003	0.001	134	0.046	0.023
85	0.023	0.011	110	0.001	0.001	135	0.038	0.019
86	0.023	0.011	111	0.001	0.000	136	0.022	0.011
87	0.018	0.009	112	0.000	0.000	137	0.020	0.010
88	0.012	0.006	113	0.157	0.079	138	0.018	0.009
89	0.006	0.003	114	0.143	0.072	139	0.014	0.007
90	0.004	0.002	115	0.137	0.068	140	0.001	0.001
91	0.092	0.046	116	0.101	0.050	141	0.021	0.010
92	0.039	0.019	117	0.088	0.044	142	0.007	0.004
93	0.030	0.015	118	0.067	0.033	143	0.171	0.086
94	0.023	0.012	119	0.000	0.000	144	0.018	0.009
95	0.013	0.007	120	0.154	0.077	145	0.019	0.009
96	0.003	0.002	121	0.044	0.022			
97	0.027	0.013	122	0.028	0.014			
98	0.013	0.007	123	0.014	0.007			
99	0.241	0.121	124	0.112	0.056			
100	0.000	0.000	125	0.097	0.049			

Table 2
Line data for 145-bus radial distribution system

From bus	To bus	R (ohms)	X (ohms)	From bus	To bus	R (ohms)	X (ohms)
132kVBusTKLG	11kVPMUTKLA	0.000	0.000	11kVFSKSB2	Petra	0.161	0.152
11kVFSKSB1	11kVPMUTKLGA	0.161	0.152	Petra	KPK	0.265	0.160
11kVFSKSB1	Haven	0.195	0.083	11kVPMUTKLGB	11kVFSTKlg1	0.161	0.152
11kVFSKSB1	WHSamudera	0.161	0.152	centurypulp	11kVFSTKlg1	0.161	0.152
Slumb29	WHSamudera	0.161	0.152	centurypulp	MIEL5(tklg)	0.161	0.152
Slumb29	SSKSB2	0.161	0.152	MIEL5(tklg)	MIEL4(tklg)	0.161	0.152
SSKSB2	TUBEX	0.161	0.152	BB2SSUBktKua	11kVPMUTKLGB	0.161	0.152
11kVPMUTKLGA	11kVFSTKlg2	0.161	0.152	BB2SSUBktKua	BKuang	0.195	0.083
11kVFSTKlg2	IndTlkKalung	0.161	0.152	BKuang	PatodPinBKuang2	0.568	0.117
IndTlkKalung	Mustari	0.161	0.152	PCicar	PatodPinBKuang2	0.195	0.083
Mustari	UBF	0.161	0.152	BB2SSUBktKua	TmnKmn	0.161	0.152
UBF	SalutaryAvenue	0.161	0.152	SMBktKuang	PCicar	0.265	0.160
SalutaryAvenue	pfce	0.161	0.152	4-PBTinggi	TmnKmn	0.161	0.152
pfce	AlvichEnviro	0.161	0.152	4-PBTinggi	EastCoast	0.161	0.152
IndTlkKalung	SmpgPanchor	0.265	0.160	EastCoast	TmnMeriah	0.161	0.152
MIEL1(tklg)	11kVFSTKlg2	0.161	0.152	11kVPMUTKLGB	Bitumen	0.161	0.152
MIEL1(tklg)	MIEL2(tklg)	0.161	0.152	11kVPMUTKLGB	NODE63	0.195	0.083
MIEL3(tklg)	MIEL2(tklg)	0.161	0.152	NODE63	Slumberger	0.161	0.152
MIELno.6	11kVFSTKlg2	0.161	0.152	Slumberger	KSB5	0.161	0.152
MIELno.6	HotelTati	0.161	0.152	KSB5	OMS	0.161	0.152
HotelTati	SSchool	0.161	0.152	OMS	KSB1	0.195	0.083
SSchool	PlastikTATI	0.265	0.160	KSB1	OBM	0.265	0.160
BB1SSUBktKua	11kVPMUTKLA	0.161	0.152	OBM	LPK	0.265	0.160

BB1SSUBktKua	Ing.PamStn	0.195	0.083	PIONEER	HapSeng	0.161	0.152
TmnBktkuangDamai	Ing.PamStn	0.195	0.083	SecaDyme	HapSeng	0.161	0.152
TmnBktkuangDamai	TPermai	0.265	0.160	11kVPPUTKLGB	RHSSSUKijalMall	0.080	0.095
4-PSDelima	TPermai	0.195	0.083	Baseera	PIONEER	0.161	0.152
PolisMerin	TPermai	0.195	0.083	Handal	BioDiesel2	0.161	0.152
BB1SSUBktKua	SMSis	0.265	0.160	BioDiesel1	Dayang	0.161	0.152
SKCukai	SMSis	0.195	0.083	HHA	Baseera	0.161	0.152
BB1SSUBktKua	Slipway	0.265	0.160	11kVPPUTKLGB	Handal	0.161	0.152
Slipway	C/STMNKTPNG2	0.265	0.160	Perumahan_EasternSteel	RHSSSUKijalMall	0.161	0.152
11kVPMUTKLGA	LHSLionPlateMill	0.161	0.152	Perumahan_EasternSteel	Tmn_Serindit2	0.161	0.152
11kVPMUTKLGA	NODE64	0.161	0.152	Tmn_Serindit2	Tmn_TitianSelumbar	0.161	0.152
ET	NODE64	0.265	0.160	TmnKijalMentauh2	Tmn_TitianSelumbar	0.161	0.152
11kVPMUTKLGA	SS132kvTiox.	0.161	0.152	TmnKijalMentauh2	PerumahanSerindit	0.161	0.152
H-PTkomTKlg	SS132kvTiox.	0.161	0.152	Tekstil01	RHSSSUKijalMall	0.161	0.152
H-PTkomTKlg	S-STPuchong	0.195	0.083	Tekstil02	Tekstil01	0.161	0.152
KimiaCecair	4-PSDelima	0.265	0.160	SSUSeeSen	11kVPPUTKLGB	0.080	0.097
PSemangat	ITCPupuk	0.265	0.160	11kVPPUTKLGB	SunwayQuarry	0.161	0.152
S-STPuchong	SKTkalong	0.195	0.083	kuangcentre	11kVPPUTKLGB	0.161	0.152
SKTkalong	ITCPupuk	0.265	0.160	StnMykPetronas	kuangcentre	0.161	0.152
KuariTKlg	RMMTKALONG2	0.265	0.160	StnMykPetronas	TmnTlkKalong	0.265	0.160
RMMTKALONG1	RMMTKALONG2	0.265	0.160	TmnTlkKalong	bktkuangsejahtera	0.265	0.160
11kVPMUTKLGA	SSUSeeSen	0.080	0.095	DesaDarulIman	bktkuangsejahtera	0.265	0.160
11kVPMUTKLGB	11kVFSKSB2	0.161	0.152	DesaDarulIman	c/sBktKuangsejahtera	0.265	0.160
SKTkalong	KuariTKlg	0.195	0.083	c/sBktKuangsejahtera	TmnKetapang	0.265	0.160
Halliburton	BayuPurn	0.265	0.160	11kVPPUTKLGA	BioDiesel1	0.161	0.152
Vastalux	BayuPurn	0.265	0.160	HHA	BioDiesel2	0.161	0.152
S/S_WH_34&35	Vastalux	0.161	0.152	Dayang	Drillex	0.161	0.152
Silo	KSB1	0.195	0.083	PejElwishEnv	Drillex	0.161	0.152
IronPasific	Silo	0.195	0.083	BengkelTepatTeknik	PejElwishEnv	0.161	0.152
NODE63	Westwsarf	0.161	0.152	11kVPPUTKLGA	C/S_SPAN	0.161	0.152
Westwsarf	KimiaCecair	0.161	0.152	C/S_SPAN	C/S_JMBTNBKTKUANG	0.161	0.152
11kVPMUTKLGB	RHSLionPlateMill	0.161	0.152	C/S_JMBTNBKTKUANG	SKBktKuang	0.161	0.152
c/sEpicSolar	11kVPMUTKLGB	0.161	0.152	SKBktKuang	RMBKuang	0.265	0.160
PlastikTATI	TATIa	0.265	0.160	RMBKuang	TmnRkytBestari	0.159	0.105
11kVPPUTKLGA	TATIa	0.080	0.095	TmnRkytBestari	RMBktKuang2	0.265	0.160
CsuValser	11kVPPUTKLGA	0.161	0.152	H-PTBygLuar	HPTBerayoDlm	0.265	0.160
11kVPPUTKLGA	LHSSSUKijalMall	0.080	0.095	c/sKjal_Water_Tank	HPTBerayoDlm	0.265	0.160
S-STPuchong	PSemangat	0.524	0.094	c/sKjal_Water_Tank	GiatMARA	0.265	0.160
TmnPinggiran	LHSSSUKijalMall	0.161	0.152	tmnberisnenas	GiatMARA	0.265	0.160
TmnPinggiran	BdrKijal01	0.161	0.152	Kijal	tmnberisnenas	0.265	0.160
Kompleks_Usahawan	BdrKijal01	0.161	0.152	TkomBKmning	Kijal	0.524	0.094
RMKijal	S-SKijal	0.265	0.160	TmnKijalJaya	Kijal	0.265	0.160
LHSSSUKijalMall	bombaKijal	0.161	0.152	S-SKijal	TmnKijalJaya	0.265	0.160
bombaKijal	SawmillPantaiTimur	0.161	0.152	S-SKijal	SSSpgTati	0.195	0.083
SawmillPantaiTimur	PrumhnMentauh	0.195	0.083	RMKijal	LayoutKij	0.265	0.160
H-PTBygLuar	PrumhnMentauh	0.195	0.083	LayoutKij	SKKijal	0.265	0.160
SKKijal	Satelit	0.265	0.160	SKBERISMERAGA	SawmillPantaiTimur	0.265	0.160
H-PTBygLuar	KgMentauh	0.195	0.083	TMNPERMATA1	SKBERISMERAGA	0.265	0.160
11kVPPUTKLGA	UNICHAMPb,	0.161	0.152	SSSpgTati	TATIa	0.265	0.160
SKalongan2	SSSpgTati	0.195	0.083				

3.2. DGs Modelling

The impact of solar distributed generators (DGs) on power losses and voltage profile depends on the number of DGs and their power output ratings. The unique attributes of every solar distributed generation (DG) system are shaped by the technology employed in its construction, along with the design of active and reactive power generation for the distribution network. The modeling of solar DGs entails the generation of active or reactive power, depending on their technological characteristics. This research primarily concentrates on power loss and voltage profile; thus, each DG will exclusively produce active power with a power factor of unity. The placement and size of the DGs will be determined through optimization results. Table 3 as display below showed the model of the photovoltaic systems.

Table 3
Photovoltaics (PV) module characteristics

No.	Description	Value
1.	Maximum power (Pmax)	340W
2.	Power tolerance	0 to +3%
3.	Maximum power voltage (Vmp)	38.7V
4.	Maximum power current (Imp)	8.79A
5.	Open circuit voltage (Voc)	47.1V
6.	Open circuit current (Isc)	9.24A
7.	Nominal operating cell temp (NOCT)	45 ± 2%
8.	Maximum system voltage	1500VDC
9.	Maximum series fuse rating	20A
10.	Operating temperature	-40 °C to +85 °C
11.	Application class	A
12.	Fire class	C
13.	Weight	22.5 (kg)
14.	Dimension	1956 x 992 x 40 (mm)
15.	Standard Test Conditions (STC)	1000 W/m², AM1.5, 25°C

3.3. Power Loss and Voltage Profile

The study focuses on two primary objectives: power loss and voltage profile. In distribution systems, a cable or overhead line is commonly linked to two buses. The mathematical representation of power loss can be expressed as either Eq. (3) or Eq. (4) [40,41].

4. Optimal Planning of Distribution Networks with Consideration DGs

To enhance the energy supply to feeder loads in distribution networks, the integration of Distributed Generators (DGs) can be employed to implement efficient strategies during the network optimization procedure. The optimization of economic objectives encompasses the reduction of investment and operational expenses, mitigation of energy losses, and reliability costs. Technical limitations involve equipment capacity, reliability indicators, voltage drop, and the utilization of multi-objective algorithms to accommodate the radial network structure [42].

$$P_{loss} = \left(\frac{P_{ij}^2 + Q_{ij}^2}{V_i}\right) R_{ij} \tag{3}$$

$$P_{loss} = \sum_{i=1}^{24} I_{rel,ij}^2 R_{ij} \tag{4}$$

where n_n is total number of busses in the distribution network R_{ij} are the resistance of the network, $I_{rel,ij}$ are real current of power network.

The equation provided in [43] offers a comprehensive explanation for determining the voltage profile at all buses. This equation is denoted as Eq. (5). Furthermore, it is crucial to enforce the constraint that all bus voltages fall within the acceptable range [44]. The acceptable voltage range spans from 0.95 pu to 1.05 pu.

$$V_{profile} = \sum_{t=1}^{24} \sum_{i=1}^{n} |V_i(t) - V_{nom}| \tag{5}$$

where $V_i(t)$ is the bus voltage in p.u., V_{nom} is the rated voltage in the p.u. and n is the number of buses

4.1. Technical Analysis Using PSS ADEPT

This research project will primarily focus on two types of technical analysis. The first type involves the integration of Distributed Generators (DGs) into the distribution network. The second part of the analysis aims to perform network reconfiguration by determining the optimal location for switches. The technical analysis approach is inspired by mathematical equations used for power flow analysis, employing PSS ADEPT software. The proposed location for connecting solar DGs will be chosen based on the bus with the highest power losses. Subsequently, a more comprehensive study will be conducted to identify areas with significant line losses. These high line losses will be considered as constraints for the reconfiguration process, with the goal of enhancing voltage and reducing active power losses [45].

Modelling and analysis of DGs will focuses on a single point in time which the system can be checked to see how well it is working, how efficiently it operates, or how it connects with the grid without considering changes over time. Engineers can evaluate if a specific distributed generation (DG) setup or technology works well under certain conditions, which helps confirm designs before making any changes or expansions. A one-time simulation helps optimize resources at that moment, supporting decisions about energy distribution, load management, or investing in more DGs. Utilities may need to show they meet regulations based on the current system state, which can be effectively assessed through these one-time simulations. Knowing how a DG operates under present grid conditions can reveal any weaknesses in the system that need fixing. Time-based simulations can be complex, so focusing on a single moment makes the analysis easier while still offering useful insights.

5. Results

The primary purpose of the initial simulation is to identify the ideal range of solar Distributed Generators (DGs) connected to the distribution system, with the objective of minimizing active power losses. Each selected bus will accommodate 3 DG units. The previous simulation revealed a power loss of 350.97KW for a system without DGs. Consequently, the initial simulation, as depicted in Table 3, indicates that the most suitable range for solar DGs in Malaysia is between 0.5 MW and 2 MW. Considering the percentage of penetration level of DGs, which the tested DGs consumed the power between 200 kW to 500 kW only as presented in Table 4.

The initial scenario involved conducting a study based on the assumption that the load in the current distribution system would remain constant. Following this, three types of Distributed Generators (DGs) were utilized and randomly simulated in a practical 145-bus radial distribution system. The main objective was to determine the appropriate placement and sizes of five solar DGs. To achieve this, the simulation was carried out using PSS ADEPT software, which commenced with load flow strategies to identify the suitability of three location buses and three units of solar DGs capacity.

Table 4
Real power losses on tested distribution network

No.	Tested on Distribution Network (DN)	Capacity of DGs (kW)			Real power losses	Reduction
		DG1	DG2	DG3	kW	
1.	Existing DN	0	0	0	350.97	-
2.	DN with DGs	500	200	250	344.92	1.72%
3.	DN with DGs and reconfiguration	500	200	250	343.65	2.09%

The second part of the analysis by implement the 5 years load growth to the distribution network (Figure 4). According to the distribution planning cycle and trending of the load growth in sampling area, the load growth of the distribution network increasing 1.83% to 1.95% annually. Contribution of load growth will be affected and increase the real power losses as presented in Table 5 and Table 6 below. In order to benefit the network in terms of power losses, the adjustment of DGs capacity need to be done in this study. The power losses showed some reduction by setting up capacity of DG2 and DG3 to 220 kW as presented Table 5 and Table 6.

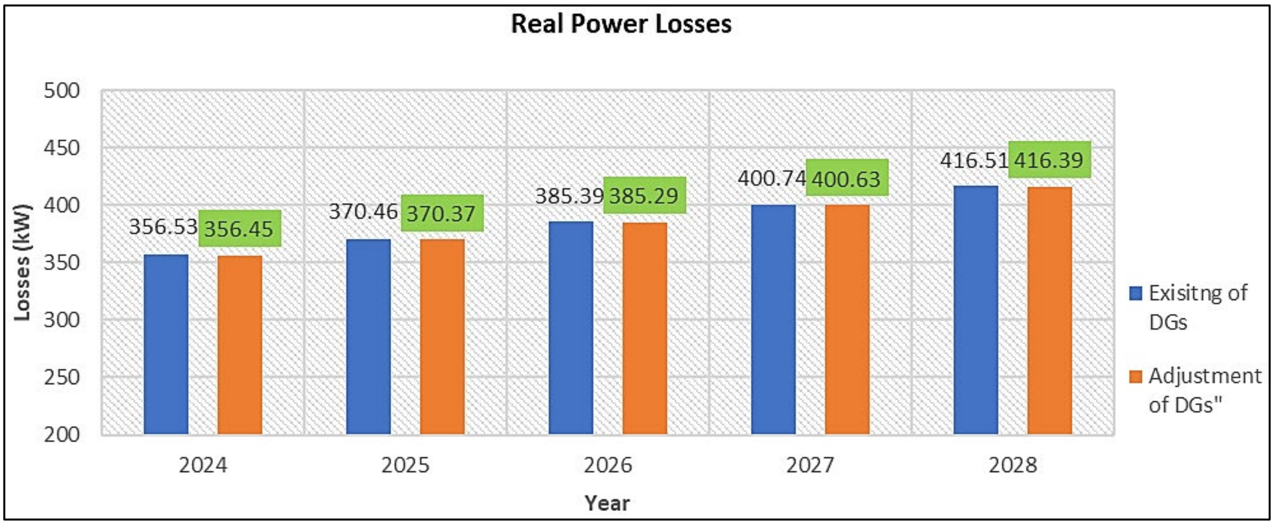

Fig. 4. Trending real power losses with existing DGs and adjustment DGs in 5 years

Table 5
Existing network with DGs applied for 5 years load growth

No	Year	Growth (%)	Real power losses without DGs and DNR	Capacity of DGs (kW)			DNR	Real power losses (kW)	Reduction
				DG1	DG2	DG3			
1.	2024	1.83	365.04	500	200	250	Yes	356.53	2.23%
2.	2025	1.90	380.24	500	200	250	Yes	370.46	2.57%
3.	2026	1.95	393.67	500	200	250	Yes	385.39	2.10%
4.	2027	1.92	410.26	500	200	250	Yes	400.74	2.32%
5.	2028	1.89	427.29	500	200	250	Yes	416.51	2.52%

Table 6
Existing network with adjusted DGs capacity for 5 years load growth

No	Year	Growth (%)	Real power losses without DGs & DNR	Capacity of DGs (kW)			DNR	Real power losses (kW)	Reduction
				DG1	DG2	DG3			
1.	2024	1.83	365.04	500	220	220	Yes	356.45	2.23%
2.	2025	1.90	380.24	500	220	220	Yes	370.37	2.60%
3.	2026	1.95	393.67	500	220	220	Yes	385.29	2.13%
4.	2027	1.92	410.26	500	220	220	Yes	400.63	2.35%
5.	2028	1.89	427.29	500	220	220	Yes	416.39	2.55%

As presented in Table 7, the location of DGs contributed to reduction of the power losses and improve voltage profile in Distribution Network. By using technical analysis, the optimal location of DGs has been addressed above which DG1 is placed at Bus no. 104, DG2 is placed at Bus no. 135 and DG3 is placed at Bus no. 116. Furthermore, it is of utmost importance to ensure that the voltage deviation at each bus adheres to the prescribed upper and lower limits to maintain both voltage stability and power quality. To achieve this, load buses in the distribution system are subject to voltage limits of ±5% of the rated voltage. Through the implementation of specific technical analysis techniques, the voltage profile at all terminal buses, including those connected to solar DGs, has been significantly enhanced. As a result, the voltage values at these buses have been improved and now meet the desired levels of 1.00 pu., 1.01 pu, and 1.03 pu. The comparison of voltage profiles before and after the distribution network reconfiguration involving DGs is depicted in Figure 5.

Table 7
Optimal location of DGs integrated with distribution network

No.	DGs No.	Location of DGs	
		Before Optimization	After Optimization
1.	DG1	121	104
2.	DG2	47	135
3.	DG3	16	116

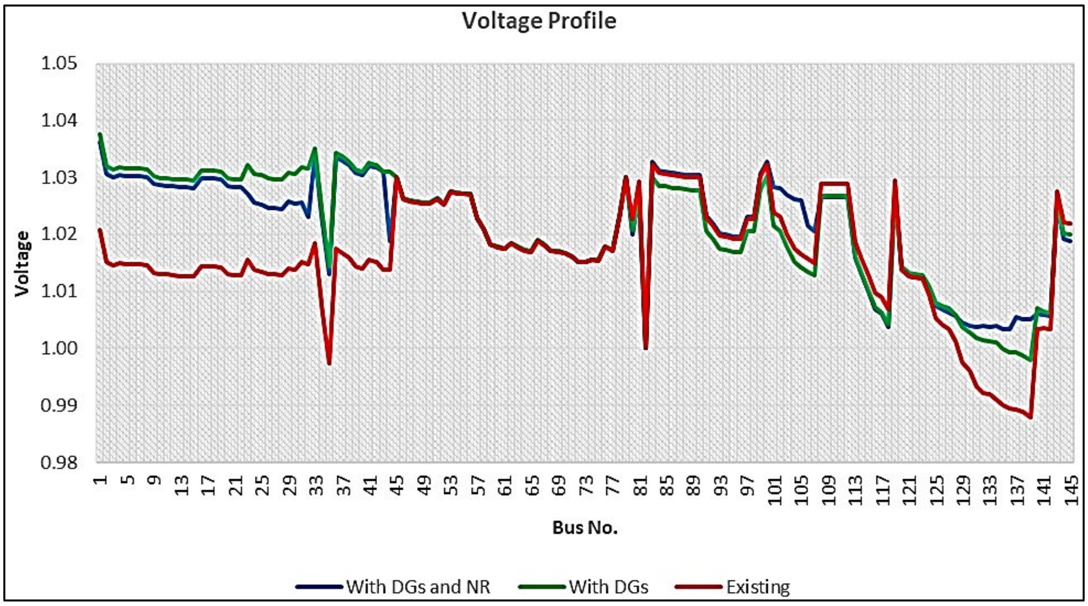

Fig. 5. Voltage profile before and after DNR connected with DGs

6. Conclusions

This research paper showcases the successful implementation of a method on a 145-bus network to enhance the voltage profile and reduce real network losses. By coordinating the operation of distributed generators (DGs), the appropriate sizes of DGs were determined using PSS ADEPT simulations while ensuring all constraints were met. Furthermore, a distribution network reconfiguration was conducted to compare the voltage and real power losses in the original and modified network. The installation of DGs resulted in a decrease in real power losses and an improvement in the voltage profile at the buses. Additionally, the network reconfiguration, with strategically placed and sized DGs, significantly improved the minimum bus voltage profile. This study represents a significant advancement in integrating renewable energy sources and network reconfiguration to accommodate load growth in our power system. The configuration of DGs is tailored to meet the specific requirements of the distribution network system. The findings of this research highlight that accurately sized and properly positioned DGs can effectively mitigate power losses and enhance the voltage profile within the distribution network system, especially considering the load growth experienced by the distribution network.

In the coming years, the research will progress by incorporating Battery Energy Storage Systems (BESSs) into the planning of distribution network systems (DNSP) to enhance the efficiency of the existing network, considering the significant integration of Distributed Generators (DGs) [46]. Moreover, different approaches, including heuristic, analytical, and metaheuristic techniques, are commonly employed to determine the most suitable placement and sizing of DGs and DNR [47]. As a valuable contribution to this study, the adoption of metaheuristic technique is justified due to its superior ability to achieve the optimal solution when compared to alternative techniques.

Acknowledgement
This work was supported by the Geran Putra Berimpak - Universiti Putra Malaysia (GPB-UPM) under Grant UPM/800-3/3/1/GPB/2019/9671700

References
[1] Wang, Shukun, Lu Zhang, Chao Liu, Zuming Liu, Song Lan, Qibin Li, and Xiaonan Wang. "Techno-economic-environmental evaluation of a combined cooling heating and power system for gas turbine waste heat recovery." *Energy* 231 (2021): 120956. https://doi.org/10.1016/j.energy.2021.120956
[2] Jirdehi, Mehdi Ahmadi, and Vahid Sohrabi Tabar. "Risk-aware energy management of a microgrid integrated with battery charging and swapping stations in the presence of renewable resources high penetration, crypto-currency miners and responsive loads." *Energy* 263 (2023): 125719. https://doi.org/10.1016/j.energy.2022.125719
[3] Fathabad, Abolhassan Mohammadi, Jianqiang Cheng, Kai Pan, and Feng Qiu. "Data-driven planning for renewable distributed generation integration." *IEEE Transactions on Power Systems* 35, no. 6 (2020): 4357-4368. https://doi.org/10.1109/TPWRS.2020.3001235
[4] Revankar, Swapnil R., and Vaiju N. Kalkhambkar. "Grid integration of battery swapping station: A review." *Journal of Energy Storage* 41 (2021): 102937. https://doi.org/10.1016/j.est.2021.102937
[5] Sui, Quan, Feiyu Li, Chuantao Wu, Zhongnan Feng, Xiangning Lin, Fanrong Wei, and Zhengtian Li. "Optimal scheduling of battery charging–swapping systems for distribution network resilience enhancement." *Energy Reports* 8 (2022): 6161-6170. https://doi.org/10.1016/j.egyr.2022.04.060
[6] Elkadeem, Mohamed R., Mohamed Abd Elaziz, Zia Ullah, Shaorong Wang, and Swellam W. Sharshir. "Optimal planning of renewable energy-integrated distribution system considering uncertainties." *IEEE Access* 7 (2019): 164887-164907. https://doi.org/10.1109/ACCESS.2019.2947308
[7] Schainker, Robert B. "Executive overview: energy storage options for a sustainable energy future." In *IEEE Power Engineering Society General Meeting, 2004.*, p. 2309-2314. Ieee, 2004. https://doi.org/10.1109/PES.2004.1373298
[8] Xu, Xiaokang, Martin Bishop, Donna G. Oikarinen, and Chen Hao. "Application and modeling of battery energy storage in power systems." *CSEE Journal of Power And Energy Systems* 2, no. 3 (2016): 82-90. https://doi.org/10.17775/CSEEJPES.2016.00039
[9] Palizban, Omid, and Kimmo Kauhaniemi. "Energy storage systems in modern grids—Matrix of technologies and applications." *Journal of Energy Storage* 6 (2016): 248-259. https://doi.org/10.1016/j.est.2016.02.001
[10] Rosewater, David M., David A. Copp, Tu A. Nguyen, Raymond H. Byrne, and Surya Santoso. "Battery energy storage models for optimal control." *IEEE Access* 7 (2019): 178357-178391. https://doi.org/10.1109/ACCESS.2019.2957698
[11] Jani, Vahid, and Hamdi Abdi. "Optimal allocation of energy storage systems considering wind power uncertainty." *Journal of Energy Storage* 20 (2018): 244-253. https://doi.org/10.1016/j.est.2018.09.017
[12] Fu, Qiang, Luis F. Montoya, Ashish Solanki, Adel Nasiri, Vijay Bhavaraju, Tarek Abdallah, and C. Yu David. "Microgrid generation capacity design with renewables and energy storage addressing power quality and surety." *IEEE Transactions on Smart Grid* 3, no. 4 (2012): 2019-2027. https://doi.org/10.1109/TSG.2012.2223245
[13] Zhao, Haoran, Qiuwei Wu, Shuju Hu, Honghua Xu, and Claus Nygaard Rasmussen. "Review of energy storage system for wind power integration support." *Applied Energy* 137 (2015): 545-553. https://doi.org/10.1016/j.apenergy.2014.04.103
[14] Castillo, Anya, and Dennice F. Gayme. "Grid-scale energy storage applications in renewable energy integration: A survey." *Energy Conversion and Management* 87 (2014): 885-894. https://doi.org/10.1016/j.enconman.2014.07.063
[15] Essallah, Sirine, and Adel Khedher. "Optimization of distribution system operation by network reconfiguration and DG integration using MPSO algorithm." *Renewable Energy Focus* 34 (2020): 37-46. https://doi.org/10.1016/j.ref.2020.04.002

[16] Pegado, Raoni, Zocimo Ñaupari, Yuri Molina, and Carlos Castillo. "Radial distribution network reconfiguration for power losses reduction based on improved selective BPSO." *Electric Power Systems Research* 169 (2019): 206-213. https://doi.org/10.1016/j.epsr.2018.12.030
[17] Merzoug, Yahiaoui, Bouanane Abdelkrim, and Boumediene Larbi. "Distribution network reconfiguration for loss reduction using PSO method." *International Journal of Electrical and Computer Engineering* 10, no. 5 (2020): 5009. https://doi.org/10.11591/ijece.v10i5.pp5009-5015
[18] Ma, Caoyuan, Chunxiao Li, Xuezi Zhang, Guoxin Li, and Yonggang Han. "Reconfiguration of distribution networks with distributed generation using a dual hybrid particle swarm optimization algorithm." *Mathematical Problems in Engineering* 2017, no. 1 (2017): 1517435. https://doi.org/10.1155/2017/1517435
[19] Gupta, Nikhil, Anil Swarnkar, and K. R. Niazi. "Reconfiguration of distribution systems for real power loss minimization using adaptive particle swarm optimization." *Electric Power Components and Systems* 39, no. 4 (2011): 317-330. https://doi.org/10.1080/15325008.2010.528532
[20] Onlam, Arun, Daranpob Yodphet, Rongrit Chatthaworn, Chayada Surawanitkun, Apirat Siritaratiwat, and Pirat Khunkitti. "Power loss minimization and voltage stability improvement in electrical distribution system via network reconfiguration and distributed generation placement using novel adaptive shuffled frogs leaping algorithm." *Energies* 12, no. 3 (2019): 553. https://doi.org/10.3390/en12030553
[21] Al-Jaafreh, Mohammad AA, and Geev Mokryani. "Planning and operation of LV distribution networks: a comprehensive review." *IET Energy Systems Integration* 1, no. 3 (2019): 133-146. https://doi.org/10.1049/iet-esi.2019.0013
[22] Yoldaş, Yeliz, Ahmet Önen, S. M. Muyeen, Athanasios V. Vasilakos, and Irfan Alan. "Enhancing smart grid with microgrids: Challenges and opportunities." *Renewable and Sustainable Energy Reviews* 72 (2017): 205-214. https://doi.org/10.1016/j.rser.2017.01.064
[23] Aljohani, Tawfiq Masad. "Distribution system reliability analysis for smart grid applications." Master's thesis, University of Southern California, 2014.
[24] Karafotis, Panagiotis A., Vasileios A. Evangelopoulos, and Pavlos S. Georgilakis. "Reliability-oriented reconfiguration of power distribution systems considering load and RES production scenarios." *IEEE Transactions on Power Delivery* 37, no. 6 (2022): 4668-4678. https://doi.org/10.1109/TPWRD.2022.3153552
[25] Sambaiah, Kola Sampangi, and T. Jayabarathi. "Optimal reconfiguration and renewable distributed generation allocation in electric distribution systems." *International Journal of Ambient Energy* 42, no. 9 (2021): 1018-1031. https://doi.org/10.1080/01430750.2019.1583604
[26] Muhammad, Munir Azam, Hazlie Mokhlis, Kanendra Naidu, Adil Amin, John Fredy Franco, and Mohamadariff Othman. "Distribution network planning enhancement via network reconfiguration and DG integration using dataset approach and water cycle algorithm." *Journal of Modern Power Systems and Clean Energy* 8, no. 1 (2019): 86-93. https://doi.org/10.35833/MPCE.2018.000503
[27] Hamida, Imen Ben, Saoussen Brini Salah, Faouzi Msahli, and Mohamed Faouzi Mimouni. "Optimal network reconfiguration and renewable DG integration considering time sequence variation in load and DGs." *Renewable energy* 121 (2018): 66-80. https://doi.org/10.1016/j.renene.2017.12.106
[28] Das, Sangeeta, Debapriya Das, and Amit Patra. "Reconfiguration of distribution networks with optimal placement of distributed generations in the presence of remote voltage controlled bus." *Renewable and Sustainable Energy Reviews* 73 (2017): 772-781. https://doi.org/10.1016/j.rser.2017.01.055
[29] Karafotis, Panagiotis A., Vasileios A. Evangelopoulos, and Pavlos S. Georgilakis. "Reliability-oriented reconfiguration of power distribution systems considering load and RES production scenarios." *IEEE Transactions on Power Delivery* 37, no. 6 (2022): 4668-4678. https://doi.org/10.1109/TPWRD.2022.3153552
[30] Conti, S., R. Nicolosi, and S. A. Rizzo. "Generalized systematic approach to assess distribution system reliability with renewable distributed generators and microgrids." *IEEE Transactions on Power Delivery* 27, no. 1 (2011): 261-270. https://doi.org/10.1109/TPWRD.2011.2172641
[31] Li, Zihao, Wenchuan Wu, Boming Zhang, and Xue Tai. "Analytical reliability assessment method for complex distribution networks considering post-fault network reconfiguration." *IEEE Transactions on Power Systems* 35, no. 2 (2019): 1457-1467. https://doi.org/10.1109/TPWRS.2019.2936543
[32] Tabares, Alejandra, Gregorio Munoz-Delgado, John F. Franco, Jose M. Arroyo, and Javier Contreras. "An enhanced algebraic approach for the analytical reliability assessment of distribution systems." *IEEE Transactions on Power Systems* 34, no. 4 (2019): 2870-2879. https://doi.org/10.1109/TPWRS.2019.2892507
[33] Tabares, Alejandra, Gregorio Muñoz-Delgado, John F. Franco, José M. Arroyo, and Javier Contreras. "Multistage reliability-based expansion planning of AC distribution networks using a mixed-integer linear programming model." *International Journal of Electrical Power & Energy Systems* 138 (2022): 107916 https://doi.org/10.1016/j.ijepes.2021.107916

[34] Gitizadeh, Mohsen, Ali Azizi Vahed, and Jamshid Aghaei. "Multistage distribution system expansion planning considering distributed generation using hybrid evolutionary algorithms." *Applied Energy* 101 (2013): 655-666 . https://doi.org/10.1016/j.apenergy.2012.07.010

[35] Agrawal, Praveen, Neeraj Kanwar, Nikhil Gupta, Khaleequr Rehman Niazi, Anil Swarnkar, Nand K. Meena, and Jin Yang. "Reliability and network performance enhancement by reconfiguring underground distribution systems." *Energies* 13, no. 18 (2020): 4719. https://doi.org/10.3390/en13184719

[36] Malekshah, Soheil, Ali Rasouli, Yaser Malekshah, Afsaneh Ramezani, and Arezoo Malekshah. "Reliability-driven distribution power network dynamic reconfiguration in presence of distributed generation by the deep reinforcement learning method." *Alexandria Engineering Journal* 61, no. 8 (2022): 6541-6556. https://doi.org/10.1016/j.aej.2021.12.012

[37] Popović, Željko N., and Neven V. Kovački. "Multi-period reconfiguration planning considering distribution network automation." *International Journal of Electrical Power & Energy Systems* 139 (2022): 107967. https://doi.org/10.1016/j.ijepes.2022.107967

[38] Silva, James A., Hamed B. Funmilayo, and Karen L. Bulter-Purry. "Impact of distributed generation on the IEEE 34 node radial test feeder with overcurrent protection." In *2007 39th North American Power Symposium*, p. 49-57. IEEE, 2007. https://doi.org/10.1109/NAPS.2007.4402285

[39] Nguyen, Ha Duc, and Ilgiz Mirgalimovich Valeev. "Improvement methods for solving the distribution network reconfiguration problem." *Energetika* 64, no. 4 (2018): 174-185 https://doi.org/10.6001/energetika.v64i4.3892

[40] Satrio, Reza Indra, and Subiyanto Subiyanto. "Reduction technique of drop voltage and power losses to improve power quality using ETAP Power Station simulation model." In *AIP Conference Proceedings*, 1941, no. 1. AIP Publishing, 2018. https://doi.org/10.1063/1.5028088

[41] Wilms, Yakov, Sergey Fedorovich, and Nikolay Aleksandrovich Kachalov. "Methods of reducing power losses in distribution systems." In *MATEC Web of Conferences. Vol. 141: Smart Grids 2017.—Les Ulis, 2017.*, 1412017, p. 1050. EDP Sciences, 2017. https://doi.org/10.1051/matecconf/201714101050

[42] Sultana, U., Azhar B. Khairuddin, Beenish Sultana, Nadia Rasheed, Sajid Hussain Qazi, and Nimra Riaz Malik. "Placement and sizing of multiple distributed generation and battery swapping stations using grasshopper optimizer algorithm." *Energy* 165 (2018): 408-421. https://doi.org/10.1016/j.energy.2018.09.083

[43] Khasanov, Mansur, Salah Kamel, and Hussein Abdel-Mawgoud. "Minimizing power loss and improving voltage stability in distribution system through optimal allocation of distributed generation using electrostatic discharge algorithm." In *2019 21st International Middle East Power Systems Conference (MEPCON)* p. 354-359. IEEE, 2019. https://doi.org/10.1109/MEPCON47431.2019.9007943

[44] Imani, Mahmood Hosseini, Payam Niknejad, and M. R. Barzegaran. "Implementing Time-of-Use Demand Response Program in microgrid considering energy storage unit participation and different capacities of installed wind power." *Electric Power Systems Research* 175 (2019): 105916. https://doi.org/10.1016/j.epsr.2019.105916

[45] Nasir, SN Syed, A. F. Othman, R. Ayop, and J. J. Jamian. "Power loss mitigation and voltage profile improvement by optimizing distributed generation." In *Journal of Physics: Conference Series*, 2312, no. 1, p. 012023. IOP Publishing, 2022. https://doi.org/10.1088/1742-6596/2312/1/012023

[46] Maddina, Suresh Babu, R. Thirunavukkarasu, and N. Karthik. "Optimization of energy storage unit size and location in a radial distribution network to minimize power loss using firefly algorithm." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 31, no. 3 (2023): 25-42. https://doi.org/10.37934/araset.31.3.2542

[47] Ali, Mirna Fouad, Eman Beshr, Almoataz Y. Abdelaziz, and Mohamed Ezzat. "Hybrid Siting and sizing of distributed generators and shunt capacitors with system reconfiguration using wild horse optimizer." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 38, no. 2 (2024): 196-213. https://doi.org/10.37934/araset.38.2.196213