Available *online* at: http://ajeeet.ft.unand.ac.id/

Andalas Journal of Electrical and Electronic Engineering Technology

ISSN 2777-0079

Research Article

# The Study of the Effect of Capacity Increase and Photovoltaic Placement on Power Loss, Voltage Profile by Considering THDv

*Syukri Yunus [1], R. H. Sukma [1]*

[1] *Department of Electrical Engineering, Faculty of Engineering, Andalas University, Limau Manis Campus Padang 25163 Indonesia[2]*

ARTICLE INFORMATION

Received: July 7, 2021
Revised: December 12, 2021
Available online: December 27, 2021

KEYWORDS

Photovoltaic, Power Loss, Voltage Profile, Total Harmonic Distortion, Loss Sensitivity Factor, Voltage Sensitivity Index

CORRESPONDENCE

Phone: -

E-mail: syukriyunus@eng.unand.ac.id

ABSTRACT

Photovoltaic (PV) application is one solution to the increasing demand for electrical energy. However, photovoltaic (PV) application must be in the right location and capacity so that the power losses to be reduced are large, and the voltage profile is good. An inverter is needed to convert DC voltage to AC voltage. The inverter is a non-linear load that produces harmonics. Harmonics in an electric power system can be known from Total Harmonic Distortion (THD). The purpose of this research is to determine the optimal placement (PV) location and its maximum capacity so that the power losses are smaller. The resulting voltage and the THD profile conform to the permitted standards. The methods used to determine the optimal photovoltaic (PV) location are Loss Sensitivity Factor (LSF) and Voltage Sensitivity Index (VSI). ETAP 16 software is used for power and harmonic flow simulation. From this research, the most optimal photovoltaic (PV) placement is on bus 10 (bus 283 T), with a maximum capacity of 3255 kVA. This placement location provides minimal power loss and a suitable voltage profile considering the permitted standard THDv.

## INTRODUCTION

Population growth that is increasing has brought many influences in life, one of which is in the field of electrical energy. This has resulted in an increasing demand for electrical energy [1]. One alternative to increase the supply of electrical energy, is to apply photovoltaic (PV) [2]. However, the application of this photovoltaic (PV) must be appropriate. If the installation of photovoltaic (PV) capacity and location is not right, it will cause a reduction in power loss that is smaller than the optimal location. Likewise, the voltage profile will be worse than its optimal location [3], [4].

Photovoltaic generates DC voltage which is then converted into AC using an inverter. Inverter is one type of non-linear load which is one source of harmonics [5]. Harmonics in an electric power system can be known from Total Harmonic Distortion (THD).

In this study, the exact location of the photovoltaic (PV) placement and the maximum photovoltaic (PV) capacity that can be installed on the Wahidin feeder were determined so that the power reduction was greater, the voltage profile was good and the THD obtained was according to the standard

### *Photovoltaic (PV)*

Photovoltaic (PV) is a power plant that can convert solar energy into electrical energy. Photovoltaic cells are basically composed of two layers of semiconductors [6]. On-grid Photovoltaic (a photovoltaic system integrated with the electricity grid) is a Green Energy solution for urban residents, both housing and offices.

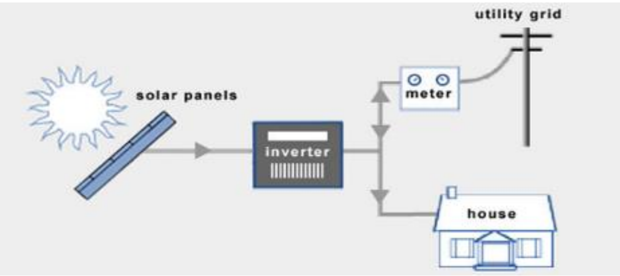


Figure 1. On-grid Photovoltaic

Figure 1. describes the working principle of a photovoltaic system that is integrated with the power grid. Photovoltaic converts sunlight into direct current (DC) electrical energy. Then it is converted into alternating electric current (AC) using an inverter, then it is used to supply various equipment [7], [8].

### *Effect of Photovoltaic (PV) on Distribution Networks*

Photovoltaic (PV) interconnection in the electric power network will change the active power flow, so that it will affect the voltage drop and power losses along the network. Power injection from photovoltaic (PV) into the power system will replace the load current so as to reduce the voltage drop and power loss in each component [9].

### *Total Harmonic Distortion (THD)*

Total Harmonic Distortion (THD) is a parameter needed to determine how much influence harmonics have on the electric power system. THD is an index that shows the large deviation of the voltage or current wave which is the ratio of the individual harmonic components to their fundamental components, expressed in percent.

The THD for the voltage waveform is [10]

$$THD_V = \frac{\sqrt{\sum_{h=2}^{h_{\max}} V_h^2}}{V_1} x100\% \qquad (1)$$

Where :
THDv = *Total Harmonic Distortion for voltage waveform (%)*
$I_1$ = Fundamental current (Ampere)
$I_h$ = hth harmonic current (Ampere)

The THD for the current wave is:

$$THD_i = \frac{\sqrt{\sum_{h=2}^{h_{\max}} I_h^2}}{I_1} x100\% \qquad (2)$$

Where :
THDi = *Total Harmonic Distortion for current waveform (%)*
$I_1$ = Fundamental current (Ampere)
$I_h$ = hth harmonic current (Ampere)

### *Loss Sensitivity Factor (LSF)*

One type of sensitivity analysis is loss sensitivity factor whose function is to find a factor value. And the goal is to reduce power loss. The advantage of this method is that it can find the location of the largest power loss on the bus quickly [11]

$$.LSF = \left(\frac{2 \times P[j] \times R[k]}{V[j]^2}\right) \qquad (3)$$

#### *Voltage Sensitivity Index* (VSI)

VSI aims to find the performance of the voltage index in a system. The method is that each bus is injected with DG, by injecting 15% of the total maximum load of the feeder. After placing the DG on each bus, the VSI can be calculated by the equation below [12].

$$VSI_i = \sqrt{\frac{\sum_{i=1}^{n}(1-V_k)^2}{n}} \qquad (4)$$

## METHODS

This research uses Loss Sensitivity Factor (LSF) and Voltage Sensitivity Index (VSI) methods to determine the optimal location for photovoltaic (PV) placement. The same formula is also used for the determination of PV injection power. Then later it will be divided into 15%, 30%, 45%. 60%, 75% and 90%

$$P_{DG} = P_L x P_T \qquad (5)$$

Where:

$P_L$ = power injection rate (%)
$P_{DG}$ = photovoltaic injection power (kVA)
$P_T$ = total feeder load (kVA)

### *Flowchart Metode LSF*

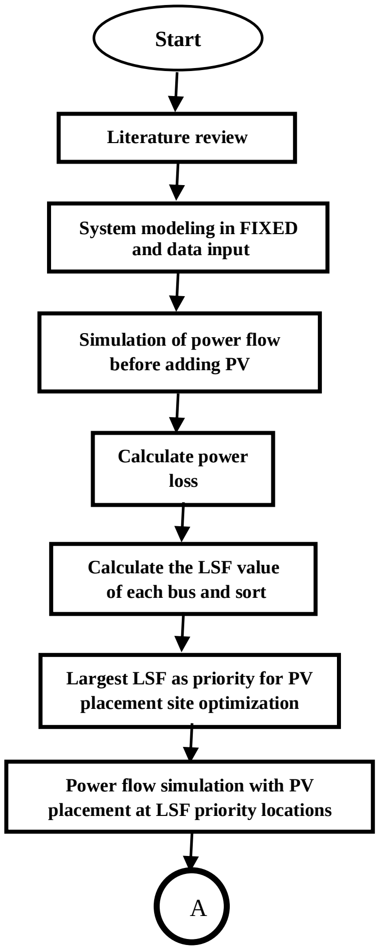


Figure 2. Flowchart Metode LSF

 https://doi.org/10.25077/ ajeeet.v1i2.13

### *Flowchart Metode VSI*

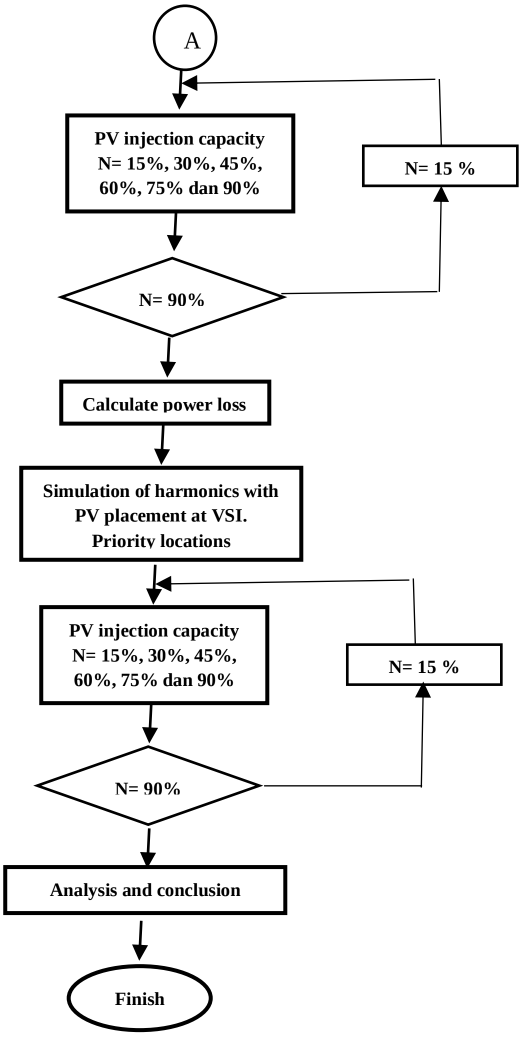


Figure 3. *Flowchart* Metode VSI

### *Comparison of the LSF method and the VSI method*

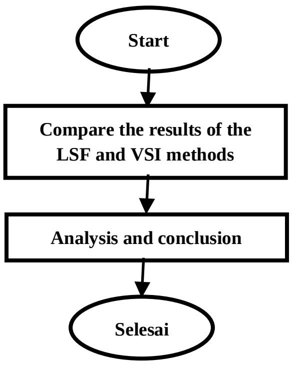


Figure 4. Comparison Flowchart of LSF and VSI Methods

## RESULTS AND DISCUSSION

### *Analysis of Power Loss, Voltage Profile and Harmonics before Placement Photovoltaic*

In Figure 5 can be seen the voltage profile before the addition of PV.

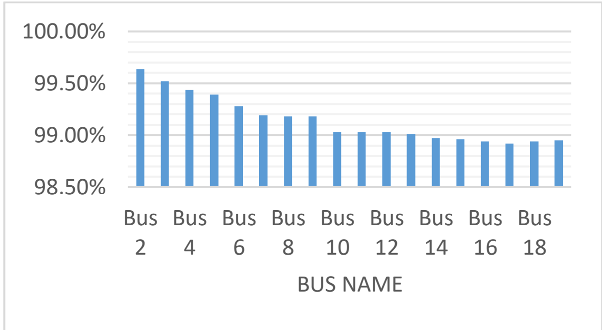


Figure 5. Voltage Profile before Addition of PV

In Table 1 can be seen the power loss in the system before the addition of PV.

Table 1. Power loss in the system before the addition of PV.

| From Bus | To Bus | W Losses |
|---|---|---|
| Bus-2 | Bus-3 | 3180 |
| Bus-3 | Bus-4 | 2255 |
| Bus-4 | Bus-5 | 1407 |
| Bus-5 | Bus-6 | 2701 |
| Bus-6 | Bus-7 | 2159 |
| Bus-7 | Bus-8 | 8 |
| Bus-8 | Bus-9 | 6 |
| Bus-7 | Bus-10 | 3167 |
| Bus-10 | Bus-11 | 4 |
| Bus-10 | Bus-12 | 98 |
| Bus-12 | Bus-13 | 211 |
| Bus-13 | Bus-14 | 517 |
| Bus-14 | Bus-15 | 144 |
| Bus-15 | Bus-16 | 146 |
| Bus-16 | Bus-17 | 61 |
| Bus-16 | Bus-18 | 1 |
| Bus-15 | Bus-19 | 8 |
| | Total | 16073 |

### *Determination of Photovoltaic (PV) Capacity*

The Wahidin feeder has a total load of 4340 kVA. Determination of PV capacity is determined from the formula:

$$P_{DG} = PL \times P_T$$

so that the PV capacity is obtained in table 4.2

Table 2. Injection Power in Determination of Photovoltaic Capacity

| PL (%) | Injection powers (kVA) |
|---|---|
| 15% | 651 |
| 30% | 1302 |
| 45% | 1953 |
| 60% | 2604 |
| 75% | 3255 |
| 90% | 3906 |

### *Photovoltaic Placement with Loss Sensitivity Factor (LSF)*

The LSF value on each bus can be seen in Figure 6. The largest LSF value is found on buses 5 and 10 so that it becomes a priority for PV placement.

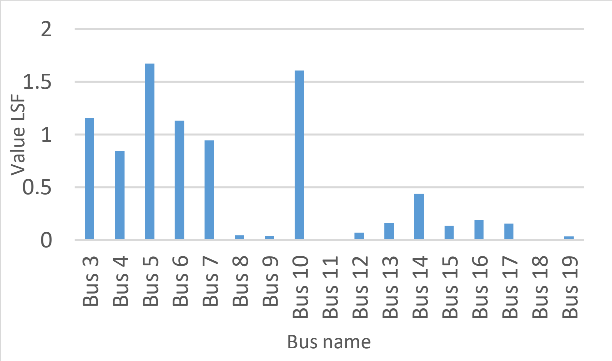


Figure 6 LSF Value on Each Bus

The value of power loss on bus 5 and bus 10 can be seen in Figures 7 and 8.

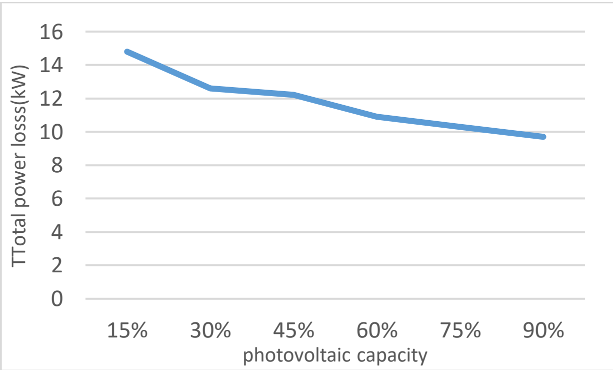


Figure 7. Value of Power Loss on Photovoltaic Capacity on Bus 5 (Bus 328T)

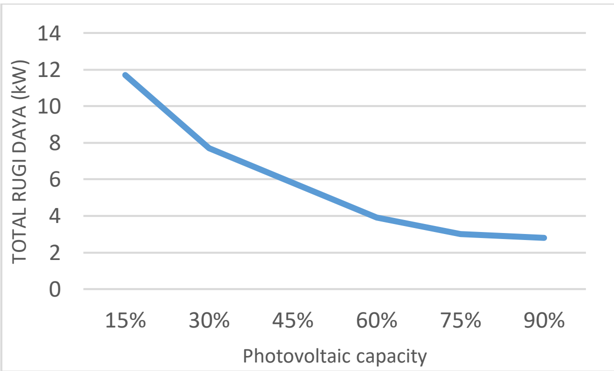


Figure 8. Value of Power Loss on Photovoltaic Capacity on Bus 10 (Bus 283T)

The value of the power loss on bus 10 is smaller, so the research is more focused on bus 10. The value of the voltage profile and THDv when placing PV on bus 10 can be seen in Figures 8 and 9.

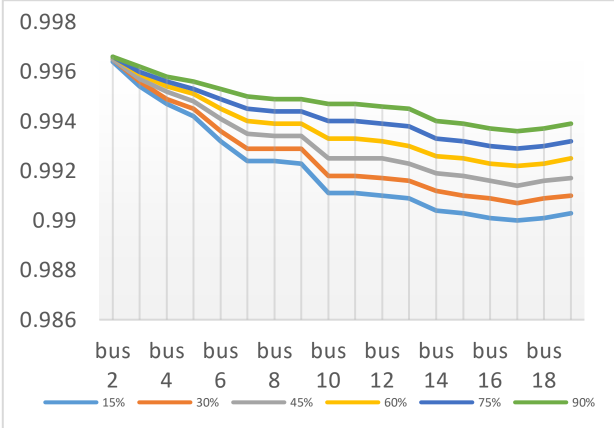


Figure 9. Effect of Photovoltaic Capacity on Voltage Profile with Placement on Bus 10 (Bus 283T) as Priority LSF Method

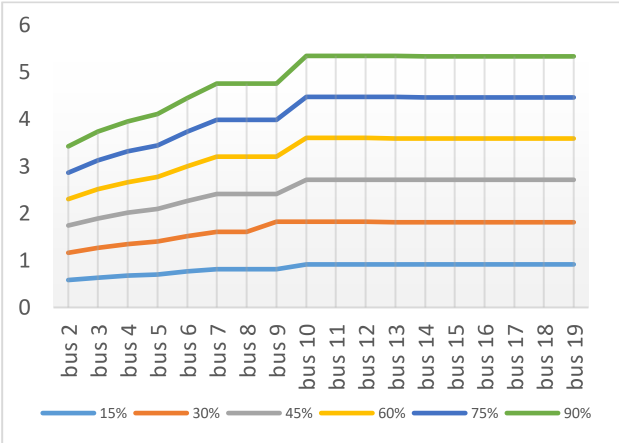


Figure 10. Effect of Photovoltaic Capacity on THDv with Placement on Bus 10 (Bus 283T) as the First Priority LSF Method

Based on the research that has been done, the most optimal capacity for power loss is 90% capacity and 90% for voltage profile, but 75% for harmonics. Therefore, because these three parameters must be met, the most optimal placement using the LSF (Loss Sensitivity Factor) method is on bus 10 (bus 283T) with a power capacity of 75% (3255 kVA).

### *Photovoltaic Placement with Voltage Sensitivity Index*

The VSI value on each bus can be seen in Figure 11. The smallest VSI value is on bus 17 so it becomesa priority for PV placement.

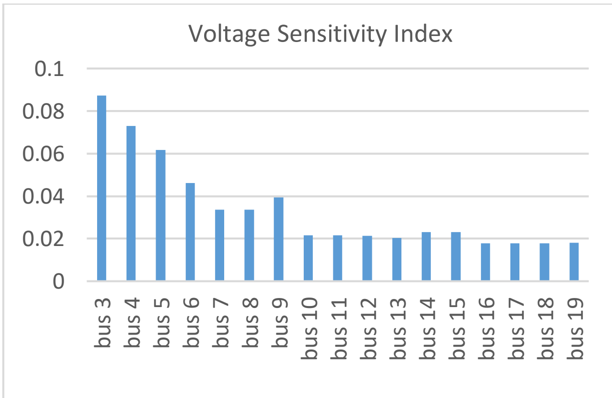


Figure 11 VSI Value on Each Bus

 https://doi.org/10.25077/ ajeeet.v1i2.13

The value of power loss, voltage profile, and THDv on bus 17 can be seen in Figures 12, 13, 14.

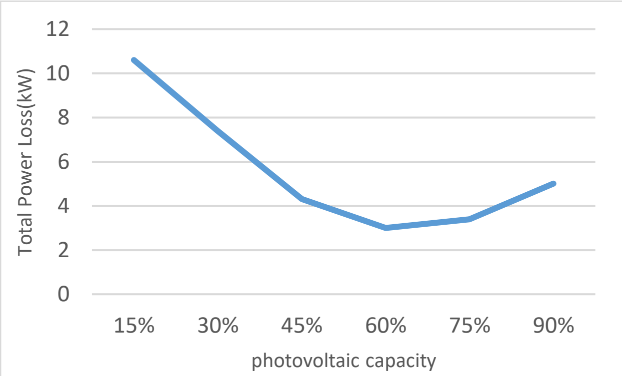


Figure 12 Value of Power Loss on Photovoltaic capacity on bus 17 (bus 180B) as a Priority VSI method Metode

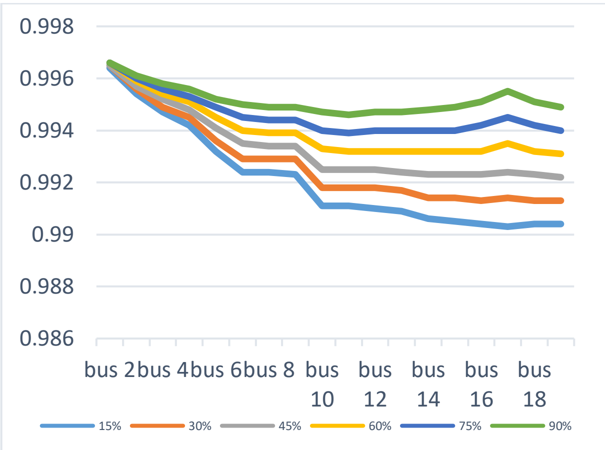

Figure 13 Effect of Photovoltaic Capacity on Voltage Profile with Placement on Bus 17 (Bus 180B) as Priority VSI Method

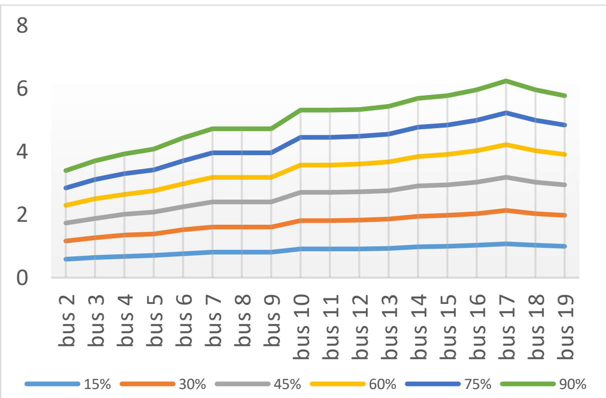

Figure 14 Effect of Photovoltaic Capacity on THDv with Placement on Bus 17 (Bus 180B) as Priority VSI Method

Based on the research that has been done, the most optimal capacity for power loss is 60%, for voltage profile 90%, and for THDv is 60%. Therefore, because these three parameters must be met, the most optimal placement using the VSI (Voltage Sensitivity Index) method is on bus 17 (bus 180B) with a power capacity of 60% (2604 kVA).

### *Comparison of LSF (Loss Sensitivity Index) and VSI (Voltage Sensitivity Index) Methods*

In the LSF method, the most optimal PV placement is on bus 10 (180B) with a capacity of 75% (3255 kVA). At the same time, the VSI method found the most optimal placement on bus 17 (283T) with a capacity of 60% (2604 kVA). Comparing the value of power loss, voltage profile and THDv between bus 10 with a capacity of 75% (3255 kVA) and bus 17 with a capacity of 60% (2604 kVA), bus 10 with a capacity of 75% is the most optimal. Although it has the same amount of power loss, the voltage profile is better on bus 10 and THDv on bus 10 is still within the permissible standard.

## CONCLUSIONS

From the results of the discussion on the effect of increasing photovoltaic capacity and its placement on power losses, the voltage profile by considering THDv can be concluded that the addition of photovoltaic in the distribution network can reduce power losses. So if the greater the photovoltaic capacity to its optimal capacity, the lower the power loss. Likewise, the voltage profile in the distribution network can be increased by adding photovoltaic to the network. And if the THDv is getting bigger, then the photovoltaic capacity is also getting bigger. The THDv value will be greater the closer it is to the harmonic source.

## ACKNOWLEDGMENT

The authors would like to thank colleagues who have helped so that this research can be completed. In particular, the authors would like to thank the Department of Electrical Engineering and the Faculty of Engineering, Andalas University, who have assisted in funding this research.

## REFERENCES

[1] S. Yunus and I. Ismail, “Studi Penempatan Dan Kapasitas Pembangkit Tersebar Terhadap Profil Tegangan Dan Rugi Daya,” *J. Nas. Tek. Elektro*, vol. 7, no. 1, pp. 8–17, 2018.

[2] R. Prasetya, “Rekomendasi Penempatan Distributed Generation (DG) Dengan Kapasitas Yang Aman Terhadap Koordinasi Proteksi Yang Sudah Ada,” Universitas Andalas, 2016.

[3] A. Parizad, A. Khazali, and M. Kalantar, “Optimal placement of distributed generation with sensitivity factors considering voltage stability and losses indices,” in *2010 18th Iranian Conference on Electrical Engineering*, May 2010, pp. 848–855, doi: 10.1109/IRANIANCEE.2010.5506959.

[4] M. Yahyazadeh and H. Rezaeeye, “Optimal Placement and Sizing of Distributed Generation Using Wale Optimization Algorithm Considering Voltage Stability and Voltage Profile Improvement, Power Loss and Investment Cost Reducing,” *Iran. J. Sci. Technol. Trans. Electr. Eng.*, vol. 44, no. 1, pp. 227–236, Mar. 2020, doi: 10.1007/s40998-019-00224-4.

[5] B. Trisno and I. W. Ratnata, “Perencanaan Sistem Mekanik PLTB,” in *Modul MK Pendalaman 2 Teknik Energi Surya dan Angin (2)*, Jakarta: Kementerian Riset, Teknologi dan Pendidikan Tinggi, Kementerian Pendidikan dan Kebudayaan, 2017.

[6] J. Heri, “Pengujian Sistem Pembangkit Listrik Tenaga

Surya Solar Cell Kapasitas 50Wp," *Eng. J. Bid. Tek.*, vol. 3, no. 1, pp. 47–55, 2012.

[7] Fernando, "Rancang Bangun Sistem Monitoring Online untuk Pemantauan Kerja dari Suatu Photovoltaic," Universitas Andalas.

[8] K. A. Alboaouh and S. Mohagheghi, "Impact of Rooftop Photovoltaics on the Distribution System," *J. Renew. Energy*, vol. 2020, pp. 1–23, Jan. 2020, doi: 10.1155/2020/4831434.

[9] M. A. Mahmud, M. J. Hossain, and H. R. Pota, "Analysis of Voltage Rise Effect on Distribution Network with Distributed Generation," *IFAC Proc. Vol.*, vol. 44, no. 1, pp. 14796–14801, Jan. 2011, doi: 10.3182/20110828-6-IT-1002.01305.

[10] M. Syahwil, M. Tola, and S. Manjang, "Studi Dampak Harmonisa terhadap Susut Teknis pada Industri Semen (Kasus Industri Semen Tonasa)," *Media Elektr.*, vol. 5, no. 2, pp. 1–12, 2010.

[11] G. Naik, D. K. Khatod, and M. P. Sharma, "Optimal Allocation of Distributed Generation in Distribution System for Loss Reduction," 2012.

[12] N. Singh, S. Ghosh, and K. Murari, "Optimal Sizing And Placement Of DG In A Radial Distribution Network Using Sensitivity Based Methods," *Int. Electr. Eng. J.*, vol. 6, no. 1, pp. 1727–1734, 2015.

## NOMENCLATURE

THDv = *Total Harmonic Distortion for voltage waveform (%)*

THDi = *Total Harmonic Distortion for current waveform (%)*

$I_1$ = Fundamental current (Ampere)

$I_h$ = hth harmonic current (Ampere)

$P_L$ = power injection rate (%)

$P_{DG}$ = photovoltaic injection power (kVA)

$P_T$ = total feeder load (kVA)

## AUTHOR(S) BIOGRAPHY

**Syukri Yunus**

Born in Padang, June 24, 1959. He earned a Bachelor of Engineering (Ir) from the Bandung Institute of Technology (ITB) in 1985. Then a Post graduate at Maryland University in 1989 and then a Master's degree (MSc) from the University of Indonesia in 1990.

Currently serving as a Lecturer in the Department of Electrical Engineering, Faculty of Engineering, and Andalas University.

The author can be contacted at the email address: syukriyunus@eng.unand.ac.id