



## DC- Versus AC Minigrids for Sub-Saharan Africa

Opiyo, N. (2019). *DC- Versus AC Minigrids for Sub-Saharan Africa*. Poster session presented at 36th European Photovoltaic Solar Energy Conference, Marseille, France.

[Link to publication record in Ulster University Research Portal](#)

### Publication Status:

Published (in print/issue): 11/09/2019

### Document Version

Publisher's PDF, also known as Version of record

### General rights

The copyright and moral rights to the output are retained by the output author(s), unless otherwise stated by the document licence.

Unless otherwise stated, users are permitted to download a copy of the output for personal study or non-commercial research and are permitted to freely distribute the URL of the output. They are not permitted to alter, reproduce, distribute or make any commercial use of the output without obtaining the permission of the author(s).

If the document is licenced under Creative Commons, the rights of users of the documents can be found at <https://creativecommons.org/share-your-work/licenses/>.

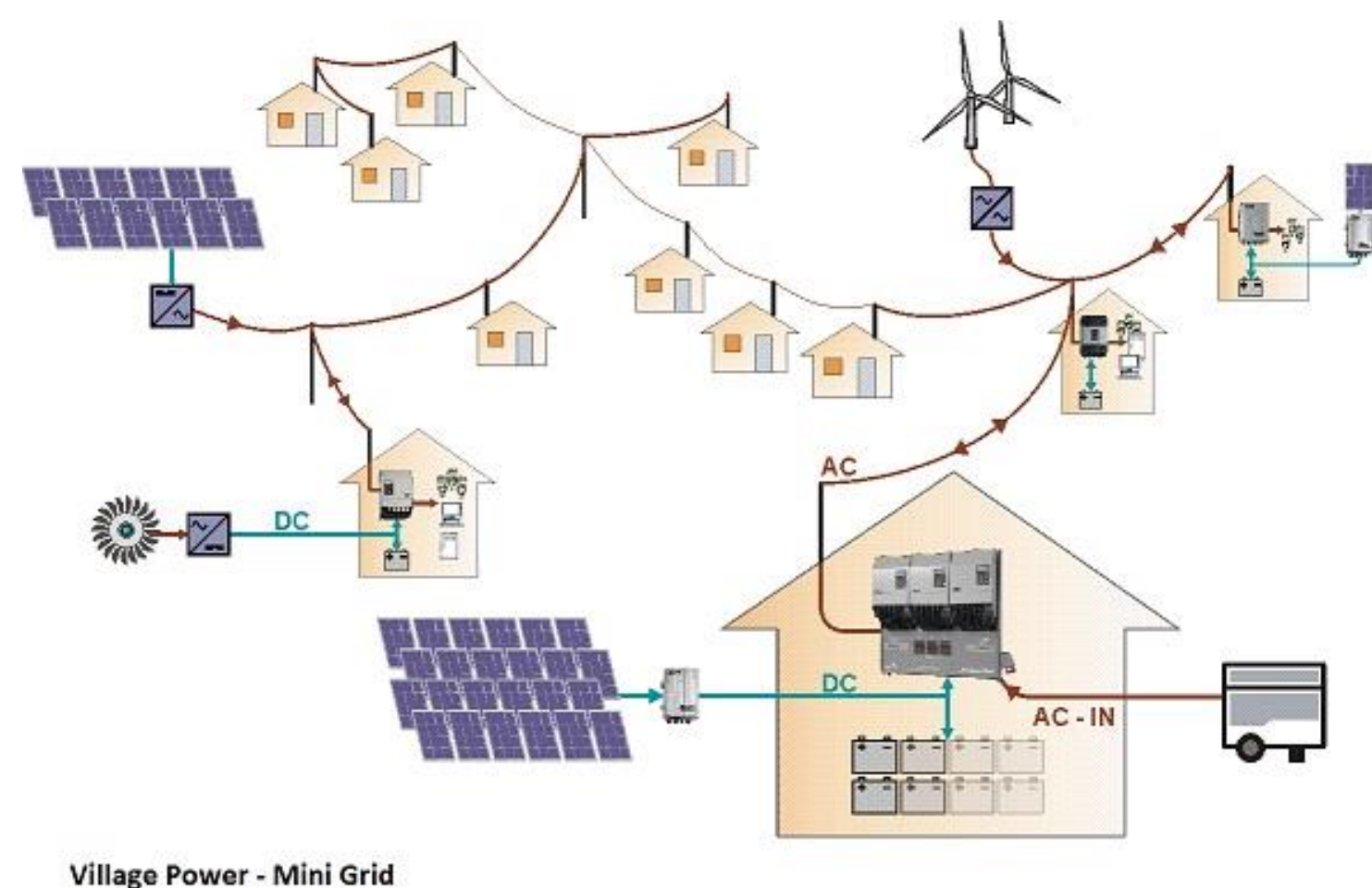
### Take down policy

The Research Portal is Ulster University's institutional repository that provides access to Ulster's research outputs. Every effort has been made to ensure that content in the Research Portal does not infringe any person's rights, or applicable UK laws. If you discover content in the Research Portal that you believe breaches copyright or violates any law, please contact [pure-support@ulster.ac.uk](mailto:pure-support@ulster.ac.uk)

# DC- Versus AC Minigrids for Sub- Saharan Africa

## Introduction:

A Minigrid is defined as a locally confined and independently controlled electric power grid in which a distribution architecture integrates distributed loads and distributed energy resources



Village Power - Mini Grid

Fig. 1: A PV-Based Hybrid Minigrid

Power losses in minigrids are mainly due to cable losses, voltage (IR) drops, and rectifier (conversion) power losses. In DC systems, these can be modelled as [1]:

$$\Delta P_{DC} = 2 \cdot R \cdot \frac{P^2}{V_{DC}^2} \quad (1)$$

Where  $P$  is the transmitted power,  $R$  is the resistance per core, and  $V_{DC}$  is the voltage level.

In single-phase AC systems, power losses are modelled as [1]:  
Where  $\phi$  is the phase angle.

$$\Delta P_{1\phi} = 2 \cdot R \cdot \frac{P^2}{V_{rms}^2 \cdot \cos^2 \phi} \quad (2)$$

The ratio of (1) to (2) is given by:

$$\frac{\Delta P_{DC}}{\Delta P_{1\phi}} = \frac{V_{rms}^2}{V_{DC}^2} \cos^2 \phi \quad (3)$$

From (3), we can infer that DC systems perform better than AC systems with guaranteed equal transmitted power for the same load with very low stress on the dielectric.

## Methodology:

Four different minigrids of same size are modelled and simulated in MATLAB/Simulink to compare their costs and ease of expansion based on the total; number of conversion stages. The minigrids are classified as: a) DC minigrid with decentralised storage, b) DC minigrid with centralised storage, c) AC minigrid with decentralised storage, and d) AC minigrid with centralised storage. Figure 2 shows a DC coupled minigrid with decentralised storage.

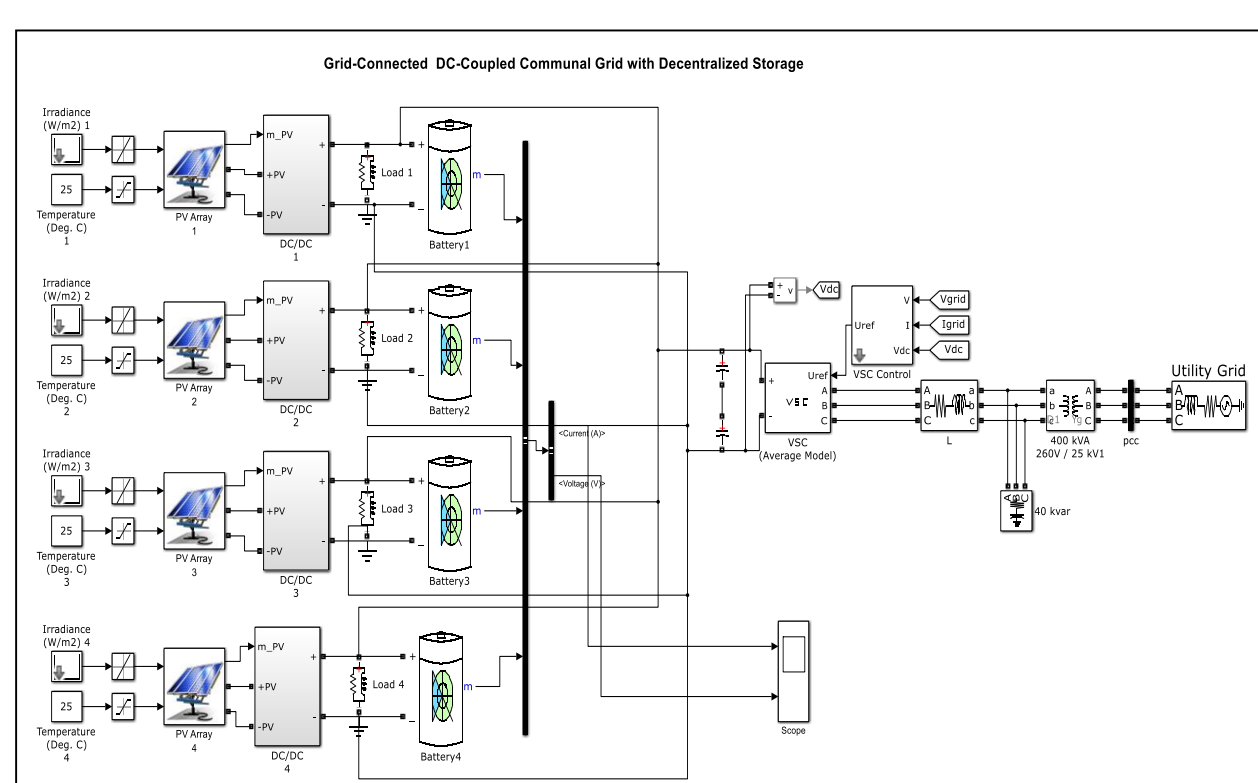


Fig. 2: Simulink Model of a DC-Coupled Minigrid

## Results and Discussion:

After 25 years, 2,410 consumers would have joined minigrids with decentralised storage systems, representing 24.6% of all consumers. This is higher than the 2,011 consumers that would have joined networks with centralised storage systems, representing 20.5% of all households.

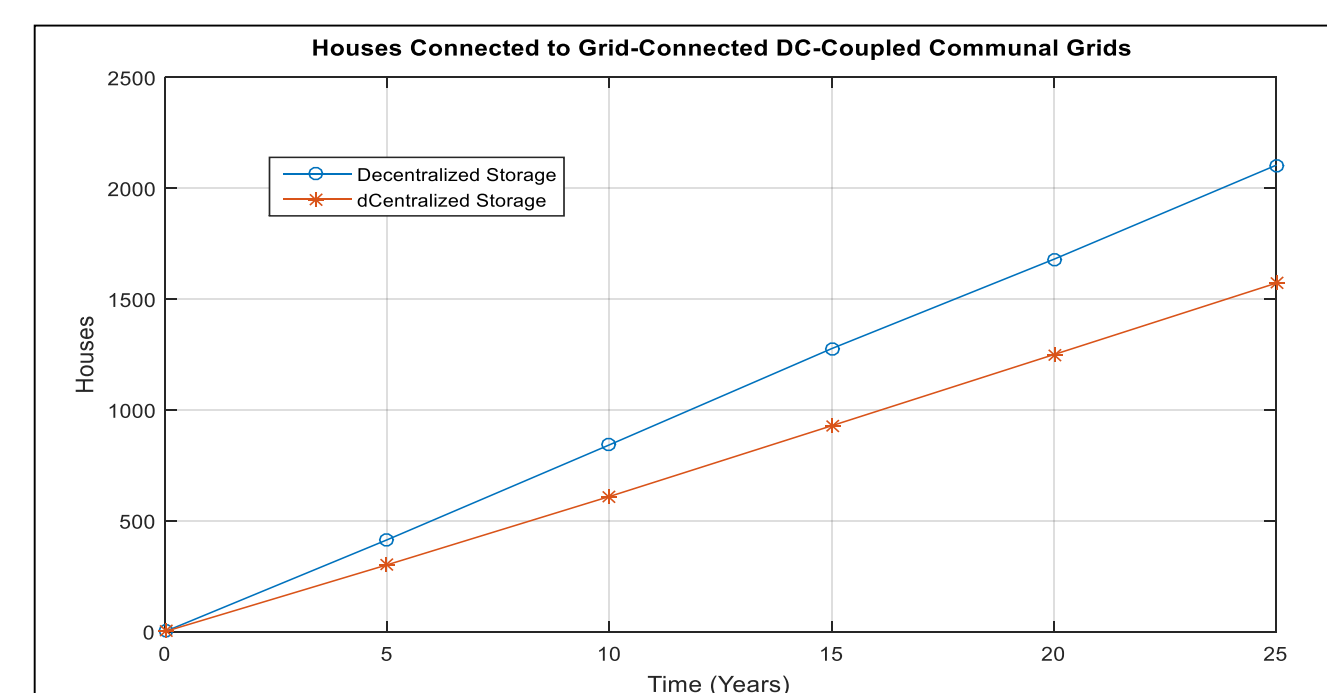


Fig. 3: Consumers Connected to Islanded DC-Coupled Networks

After 25 years, 2,179 consumers would have joined minigrids with decentralised storage systems, representing 22.2% of all consumers. This is higher than the 1,728 consumers that would have joined networks with centralised storage systems, representing 17.6% of all consumers.

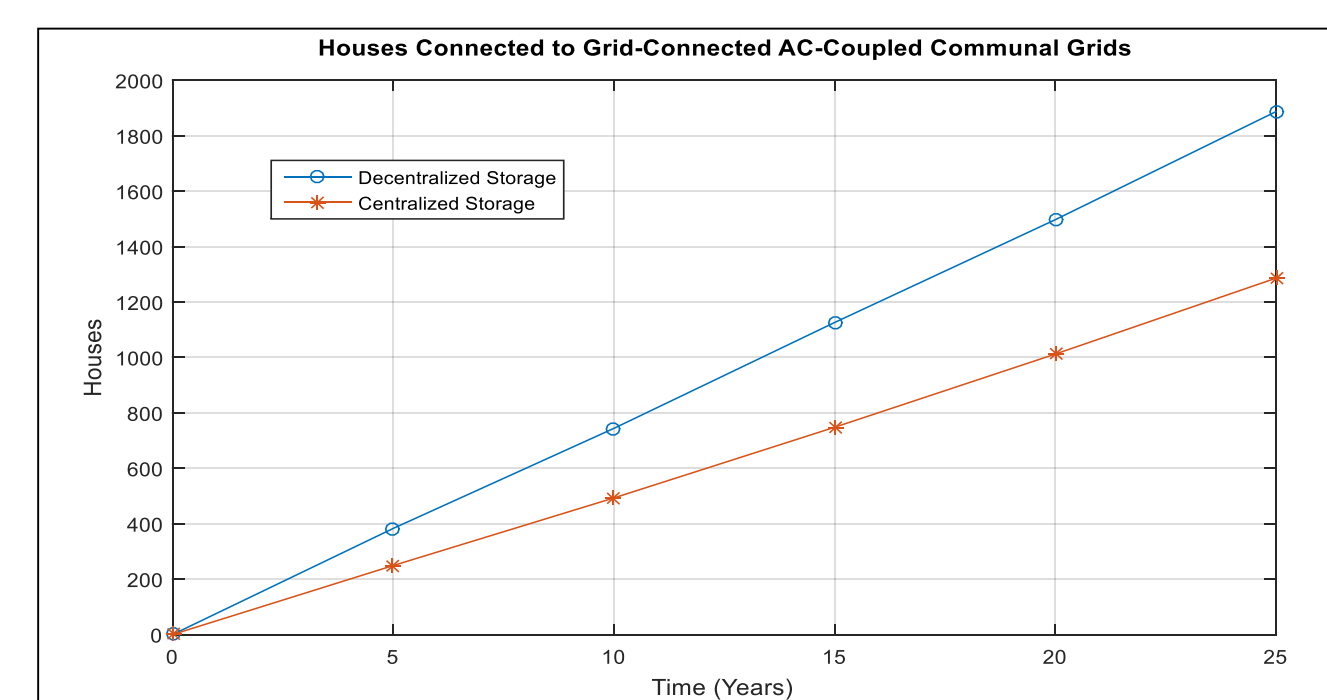


Fig. 4: Houses Connected to AC-Coupled Networks

## Conclusion:

Generally, DC-coupled networks seem to fair better than AC-coupled networks in all categories. This is mainly due to cost and ease of set-up of such networks; DC systems are more modular and scalable than AC systems because DC converters are easier to control and to parallel. This allows for more flexibility in system design and expansion, and thus more effective capital investment management. Table 1 summarises the above information.

Table 1: Comparison of Houses Connected to DC- and AC-Coupled Networks

Time (Years)	DC-Coupled		AC-Coupled	
	Decentralised Storage	Centralised Storage	Decentralised Storage	Centralised Storage
0	0	0	0	0
5	507	403	421	322
10	1028	831	854	669
15	1521	1233	1304	1017
20	1982	1627	1756	1365
25	2410	2011	2179	1728

By avoiding many power conversion stages, DC networks supplied by DC power sources such as PV systems are the most cost-effective paths to rural electrification. Efficiencies could be improved further if DC-inherent appliances are used with the DC networks, further eliminating power conversion losses. Results also show that, based on costs, consumers would prefer to join DC minigrids as opposed to AC minigrids due to lower connection fees, ease of grid expansion, and overall better performances.