Modelling Different PV-Based Minigrids Architectures

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Introduction:

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

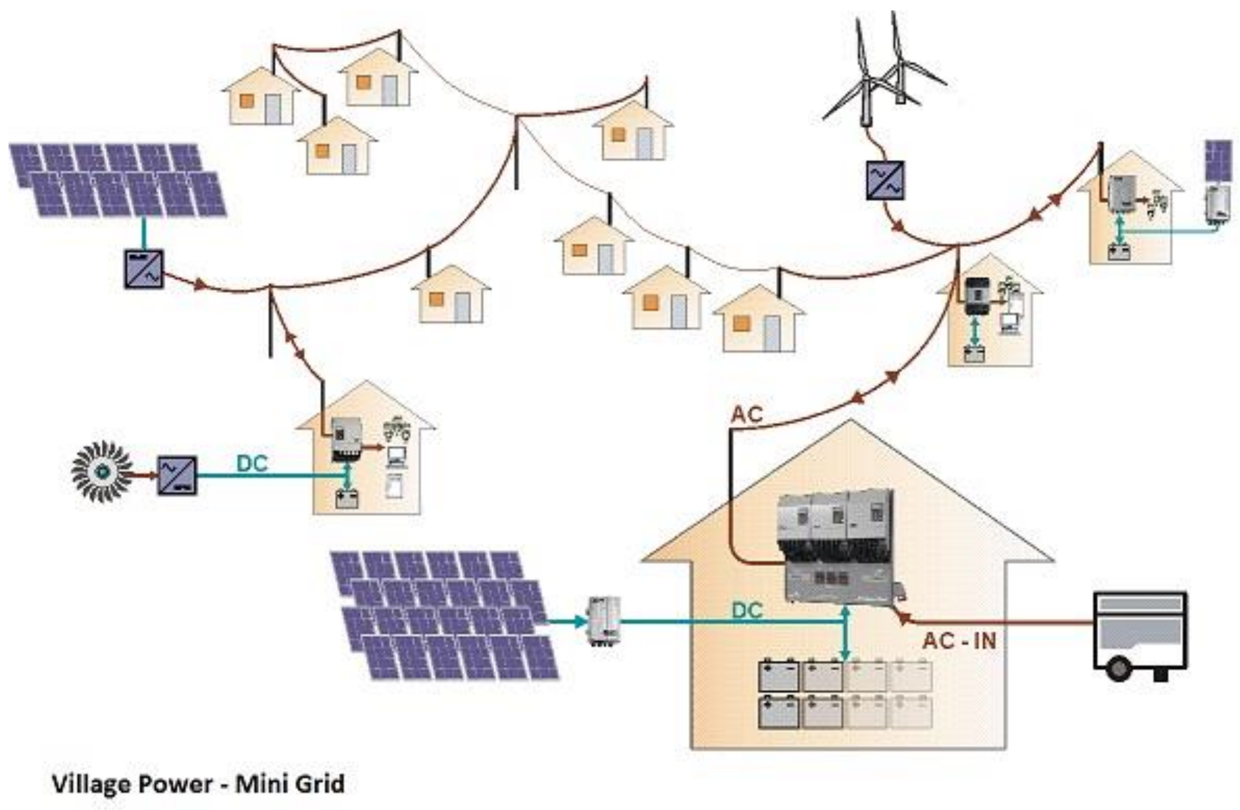

Fig. 1: A PV-Based Hybrid Minigrid

Inverters used to interface communal grids with utility grids can be classified according to modes of operation as PQ or V-f, and modelled as [1-3]

$$P(f) = P_0 - (f_{set} - f)k_f$$

$$Q(V) = Q_0 - (V_{set} - V)k_v$$

Methodology:

Different communal grid architectures, revolving about energy storage, are modelled and simulated in MATLAB/Simulink to determine the most cost-effective option for a given transmission and distribution network.

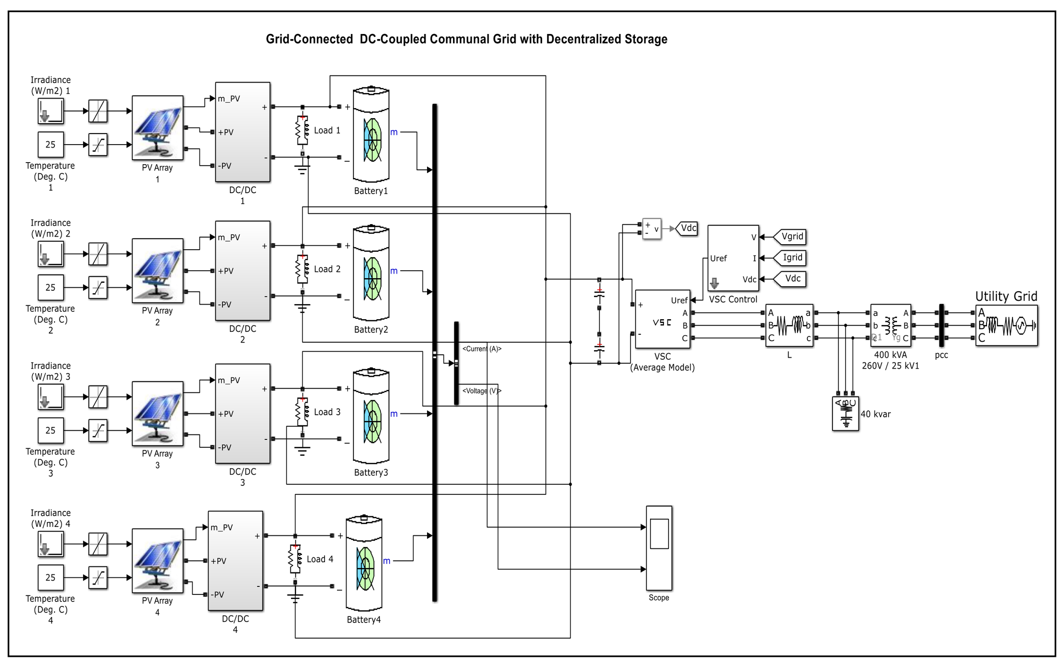

Fig. 2: Simulink Model of a DC-Coupled Minigrid

Simulated data from the Simulink models are fed into an agent based model (ABM) developed in NetLogo, to simulate effects of control architectures on temporal diffusion of PV-based communal grids in a rural developing community

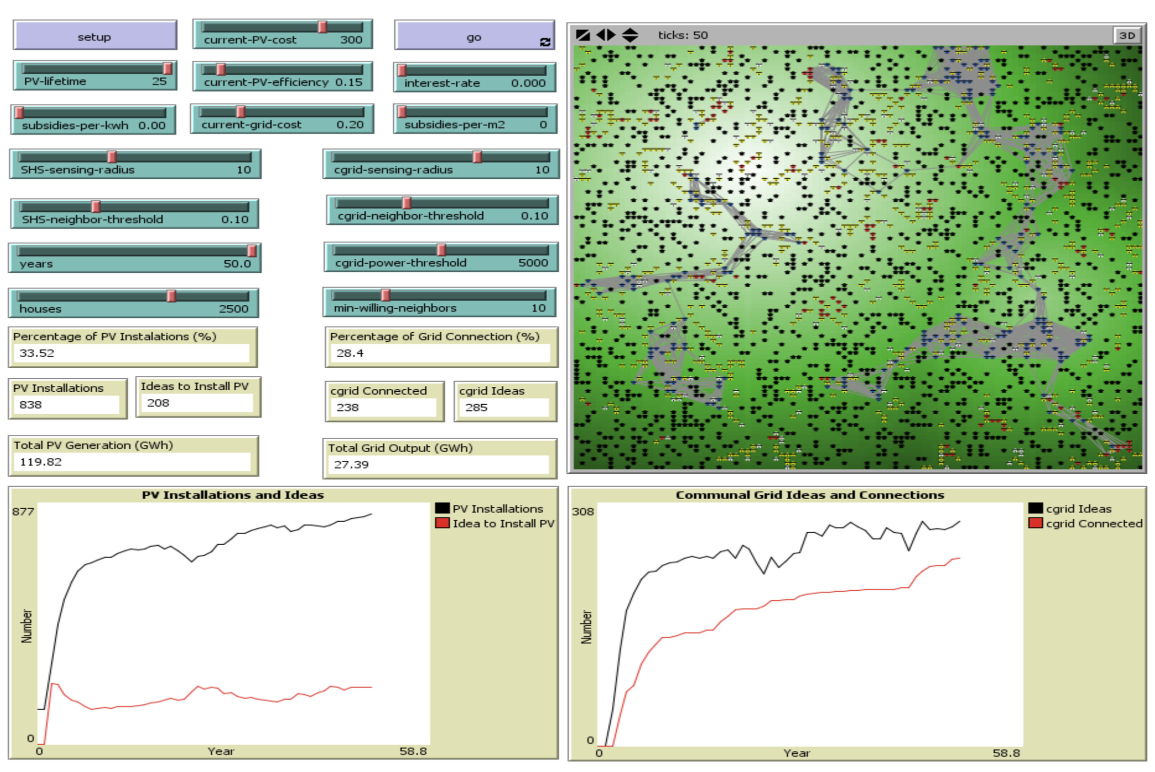

Fig. 3: NetLogo Graphical User Interface

Results and Discussion:

After 25 years, 2,103 households would have joined communal grids with decentralised storage systems, representing 21.5% of all households. This is higher than the 1,571 households that would have joined networks with centralised storage systems, representing 16% of all households.

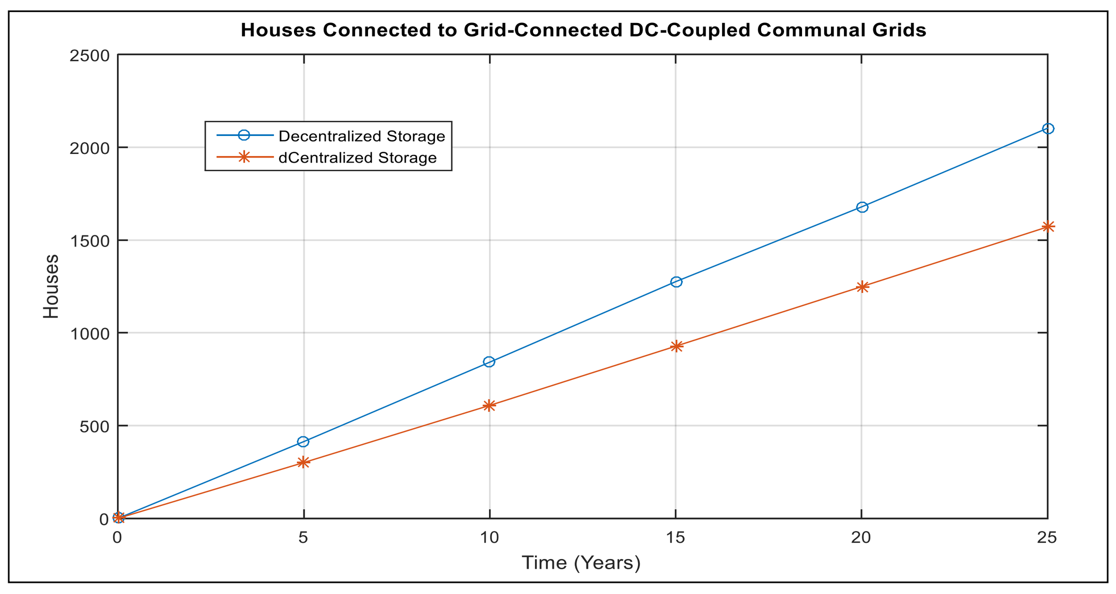

Fig. 4: Houses Connected to DC-Coupled Networks

After 25 years, 1,887 households would have joined communal grids with decentralised storage systems, representing 19.2% of all households. This is higher than the 1,286 households that would have joined networks with centralised storage systems, representing 13.1% of all households

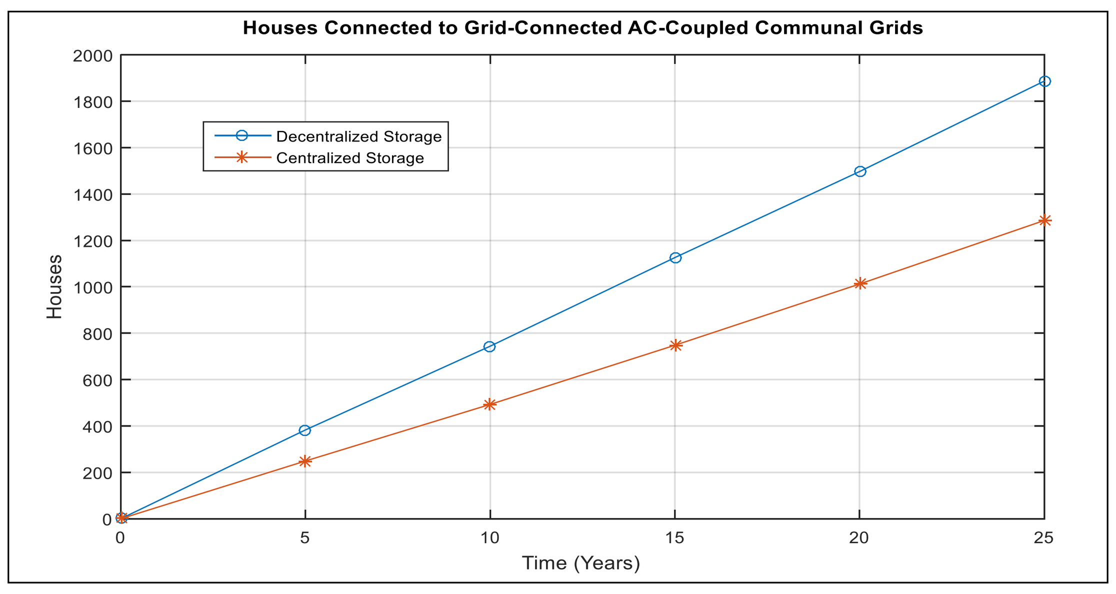

Fig. 5: Houses Connected to AC-Coupled Networks

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	414	301	383	249
10	842	609	744	493
15	1276	928	1126	748
20	1679	1249	1497	1012
25	2103	1571	1887	1286

In conclusion, for cost-effective communal grids, DC-coupled networks with decentralised storage systems are recommended as the most-cost effective architectures for rural communal grids. Where a communal grid must be AC-coupled communal grids, systems with decentralised storage and multi-master operation modes are recommended for cost-effectiveness

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