Abstract

This dissertation investigates the technical feasibility of deploying scalable hybrid DC picogrid systems for rural off-grid areas, by assessing the technical (hardware and software) requirements for implementing a minimal (12V, 100W nominal), laboratory prototype of such a system. The laboratory prototype validates the proposed concept of an ad-hoc localised low-voltage DC grid ("Picogrid") as a resilient and robust solution for off-grid electrification at low power levels. It demonstrates the scalability, fault tolerance and other features which are required for the intended application.

Existing off-grid low voltage DC systems (like the solar home systems) cannot be scaled up in terms of power increase, load expansion or storage extension and this severely limits the usability of the available systems. The "Picogrid" concept put forward here is one of the possible solutions that can be scaled in every dimension (generation, storage and load) by having multiple autonomous sources and storage nodes networked together in an Ad-Hoc manner. Stable operation is achieved by a global grid code defining each node's action based on the state of the bus voltage as opposed to the state of other nodes. A decentralized form of droop control that applies proportional control of voltage and current was implemented on four prototype nodes with each controller's decision based on the state of the picogrid bus voltage.

Individual node and overall system tests were performed on the prototype. Node tests include; open circuit, short circuit, current limit, over voltage, under voltage and effects of suddenly removing a heavy load. Sharp voltage spikes were observed when a load is suddenly disconnected from the grid due to the sudden drop of load current. These spikes were minimized by having controllers tripping the nodes immediately when the bus voltage rises. Apart from recommending future hardware improvements to the power supply circuit, A different control platform that processes faster than the one used for the picogrid was recommended in order to completely eliminate the spikes. The ease of power scaling as well as recovering from faults without requiring any user interaction was illustrated through system tests when all nodes were connected together. This further proves the picogrid to be a feasible technical solution that can be extended to a full commercial application. Furthermore, the tests show that by having more sources or storage nodes, more power can be automatically obtained from the system. The maximum power produced by a picogrid system

is however limited to the hardware composition especially with regards to the node-node connector cables. Thus the cable size used will determine the maximum power of the system for deployment purposes when costs need to be taken into consideration.