

## GRID STABILITY ISSUES WITH GRID-CONNECTED SOLAR

### Grid Stability Issues Include

Voltage variations greater than considered acceptable

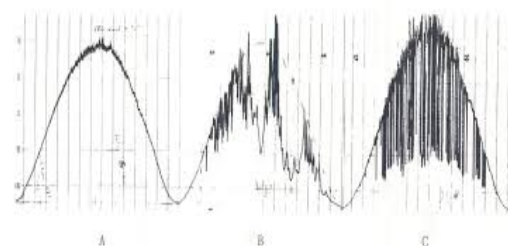
Frequency variations greater than considered acceptable

Causing equipment (including other solar installations) to go off line due to the grid going out of its normal operating range

### Solar is most likely to cause grid stability issues on partly cloudy days

Cloud passage, particularly in the middle of the day, can cause a rapid change from full power in bright sun to 20% of power when panels are shaded by the cloud.

Overcast days are much less of a problem because power levels are much lower and solar energy varies less



clear day

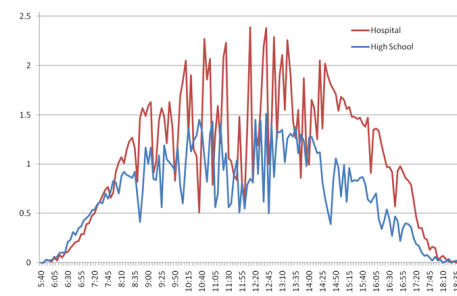
mostly cloudy

partly cloudy

### Solar Variations due to Partly Cloudy Conditions

Least destabilizing arrangement is a great many installations that are 100 kW or less in size distributed over a large geographical area

Most destabilizing arrangement is one large array in a single site



- Sites separated by about 3 km in Niue

### Rough rule of thumb for solar penetration without stability issues

20% of noon time peak load for a single large array in a small geographic area

30%-40% of noon time peak load for multiple medium sized arrays widely distributed geographically

With small arrays (roof-top residential up to 10 kW) and very wide dispersion, even higher total penetrations may not result in stability problems

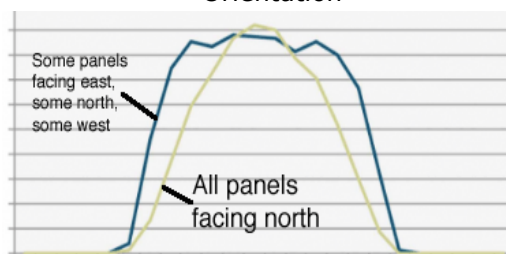
For sites within 10° of the equator, orient some panels toward the east, some toward the equator and some toward the west to reduce stability problems and even out the power delivery over the day

East facing panels peak in the morning

Equator facing panels peak at noon (facing north in the southern utilities and south in the northern utilities)

West facing panels peak in the afternoon

### Southern Hemisphere Panel Orientation



Widely distributed residential rooftop arrays are the least destabilizing

Variety of roof directions

Variety of roof slopes

Small individual size (typically around 3 kW)

Wide geographic dispersion

### Reducing grid stability problems

Add battery storage

Install a fast responding diesel generator comparable in size to the solar. Include controls to offset solar variations

Control the solar so existing diesels can manage to properly follow power changes

DISCUSSION