Frequency Shift Power Dependant Load

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1 Introduction

This document is aimed at people with an off-grid AC coupled micro grid that use Frequency Shifting Power Control for power generation regulating. The objective is to design and build a controller that will optimise the use of excess renewable power that is currently not being used due to batteries being full or not able to accept as much power. Our controller will detect an increase in the grid frequency and activate a load, being able to assign 0% to 100% power if the load is a restive load. In the future a model for using other types of loads, like pumping water, will be developed. In this document the controller will be designed for a grid formed by SMA Sunny Island inverter and Fronius Primo grid-tie PV inverters. Other inverters might operate at different frequency range or use another methodology other than Frequency Shift Power Control to regulate generation, check with your inverter manufacturer.

Glossary

PV Photovoltaic

FSPC Frequency Shift Power Control

PAC Phase angle control

GTI Grid Tie Inverter

BBI Battery based inverter

2 Theory

2.1 Frequency Shifting Power Control

In this type of grid, our inverter is the brain of the system and will regulate where power comes and goes to. On the DC side we have the batteries and optionally a DC charger. To these batteries we have connected our battery based inverter (from now on BBI) which will generate our AC grid. On the AC side we have our loads and also the grid-tie inverter for our renewable energy (for simplicity we are going to assume we have solar energy and this is a PV inverter) all in parallel. So once batteries are full and there is less consumption than available PV energy, how do we inform our PV inverter to start reducing its output power?

The answer to this is Frequency Shifting Power Control. The PV inverters will ineject directly to our grid, all power that is needed at the moment will be consumed directly and any excess is going to be used by the BBI to charge the batteries. One the batteries are fully charged or can't accept all the excess power in the grid, the BBI will slowly start to increase the AC frequency to indicate to the PV inverters that they should reduce their output power. For SMA inverters power reduction will start at 51Hz and will be reduced linearly to 0% at 52Hz. This can be seen by the blue line in figure 1.

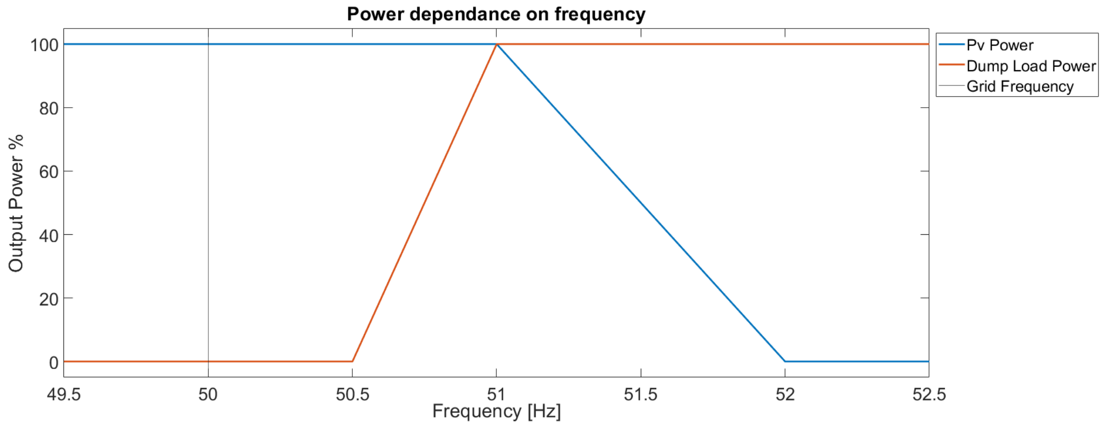

Figure 1: Change in power generation and load consumption based on grid frequency

So in order to maximise PV generation we want to turn on a load that will consume this excess energy so generation is maximised. This energy can be used to heat water or heat a room. So this same increase in frequency should indicate to our controller that it should star to turn on our load. Be aware that after 51Hz the PV output starts to be reduced, so our load should start to turn on before and this way PV output will only be reduced once our load is on at 100% and we still have excess generation. Another factor to take into consideration is that if we just turn our load fully on all of a sudden, this change in consumption will make our frequency drop, in effect making our load turn off again. For this reason we approach this problem using a triac to be able to perform phase angle control (from now on PAC) and be able to turn on our resistive load at any power between 0% and 100%. This way as frequency starts to go up and our load slowly turns on, it will reach equilibrium and only use the available extra power. The output power of our controller for the dump load can also be observed in figure 1 as the red line. For loads that have to be on or off, a different approach will be needed.

Be aware that these mentioned values are for *SMA* inverters, inverters from other brands such as *Victron* use different ranges and you should check in the user manual or with the manufacturer for proper configuration. Also the grid we are operating is a 50Hz grid, but this could be different depending on what country you are in.

2.2 Phase Angle Control

Phase angle control is a PWM approximation for AC current. It is achieved by a Triac, which job is to allow current to go through it when it receives an activation signal to its gate. Triac will stay in the on state till the current going through it reaches a minimum threshold value. So selecting the delay for the firing of the triac will allow us to choose how much time the triac is going to be in a conductive state and therefore regulate the power. As an example, for a 50Hz grid, a half wave is 10ms long. So if we have a delay of 5ms from the zero crossing point (when voltage is 0) we would effectively only use half of the sine wave and power would be 50% of that it would be in regular conditions. If the trigger signal is given to triac at the zero crossing point then output power will be 100%. This can be observed in figures 2 and 3 where with the blue line we can observe the signal our microcontroller gets to indicate the zero crossing point and in yellow we have our controller output for the load.

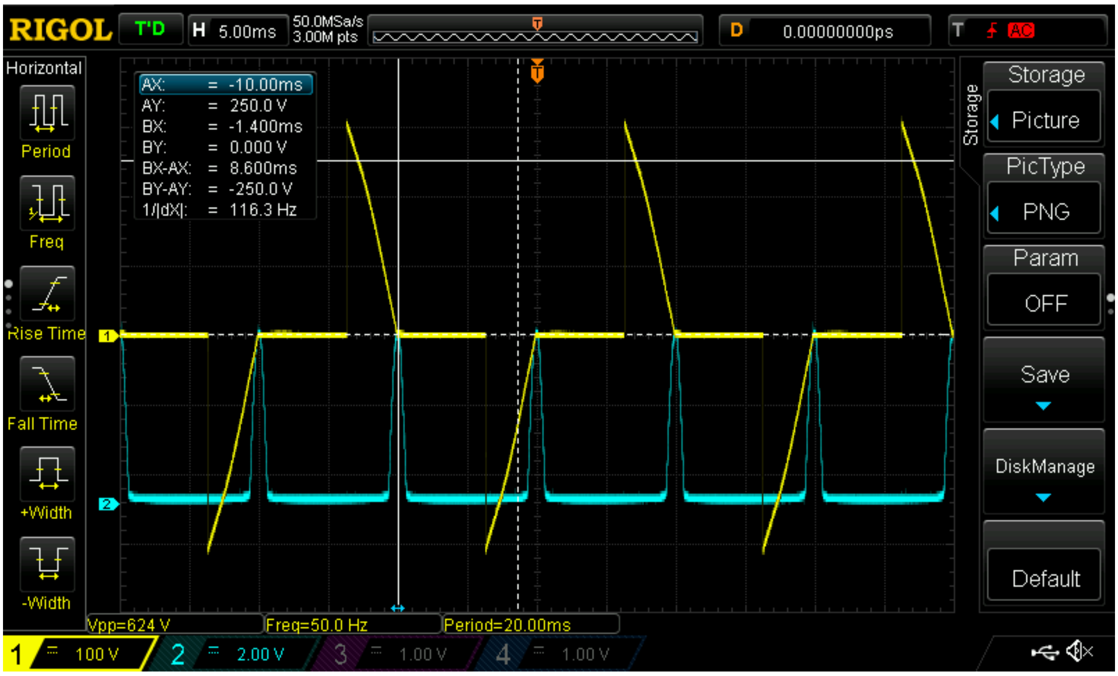

Figure 2: Oscilloscope image corresponding for approximately 40% output power

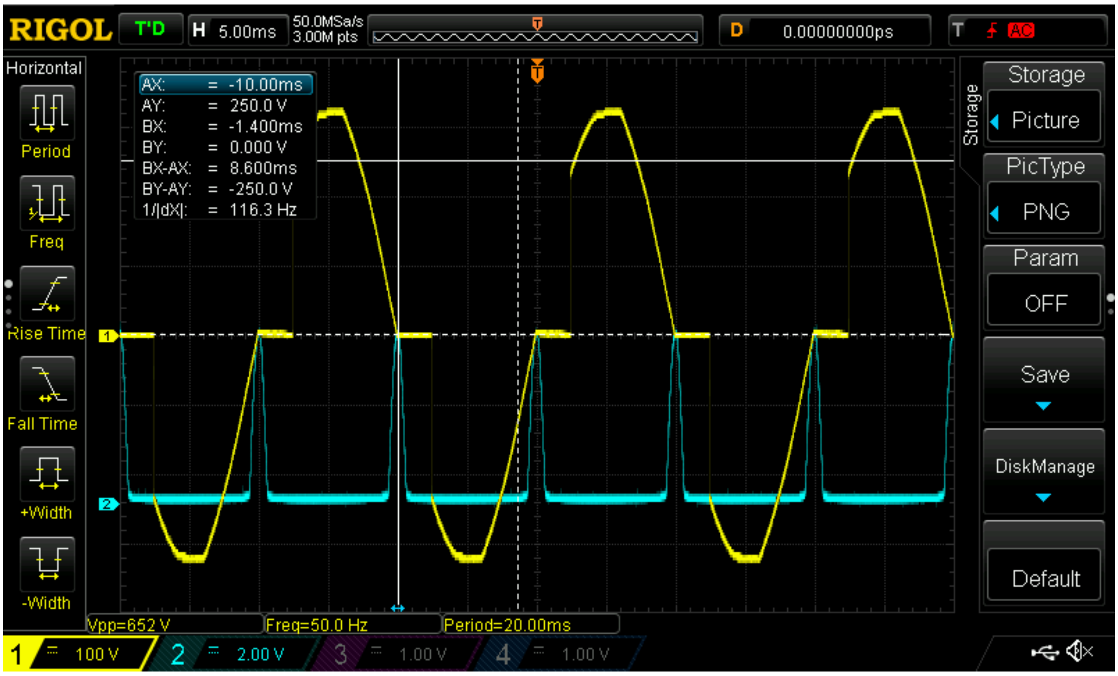

Figure 3: Oscilloscope image corresponding for approximately 70% output power

2.3 The controller

Our controller will be based on a arduino nano microcontroller. This will be the brain of the controller, will measure the grid frequency and output the trigger signal for the triac.

For the project we are going to need the following components

- 1 Arduino Nano
- 1 BTA 16-600b Triac
- 1 330 Ω resistor
- 2 1kΩ resistor
- 1 10kΩ resistor
- 1 mb10f full bridge rectifier or 4 1n4007 diodes
- 1 PC817 optocoupler
- 1 MOC 3020 optocoupler for triac
- 2 3 pole block terminal
- 1 3 pin fan header
- 12V power supply
- PCB