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DESIGN, IMPLEMENTATION AND EVALUATION OF A CONTROL SYSTEM TO OPTIMIZE THE PERFORMANCE OF A PERMANENT MAGNET SYNCHRONOUS MOTOR (PMSM) SUPPLIED BY A STAND-ALONE PHOTOVOLTAIC SYSTEM WITHOUT BATTERIES

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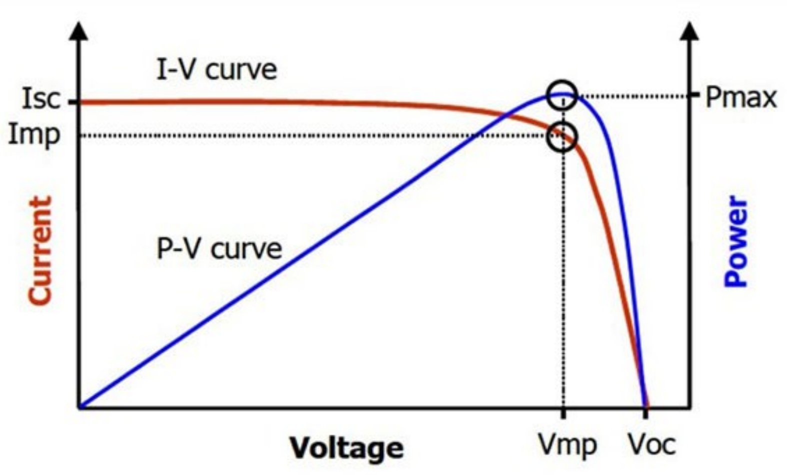
OBJECTIVE:

Harness the maximum energy available in a stand-alone photovoltaic module in order to feed a PMSM motor without any energy accumulation system

Stand-alone photovoltaic Generator

Maximum Power Point Tracking (MPPT)



Permanent Magnet Synchronous Motor

REQUIREMENTS:

1. Maximum Power Point Tracking carried out by a PI controller. PID derivative component must be null to avoid instability in PMSM motor.
2. Response must be quick, soft and damped when sudden power changes occur due to either irradiance changes (CLOUD PASS) or setpoint changes (MOTOR STARTER UP).
3. Rotary speed in PMSM motor should be regulated between stop (V_{oc}) and its maximum value (V_{MP})

HARDWARE AND SOFTWARE

Photovoltaic module

Used as a generator.
Model A-10J of Atersa.
STC Characteristics:

- Peak power ≈ 60 W
- V_{oc} -> 62.1 V
- I_{sc} -> 1.36 A
- V_{MP} -> 48.9V
- I_{MP} -> 1.22 A

Voltage divider

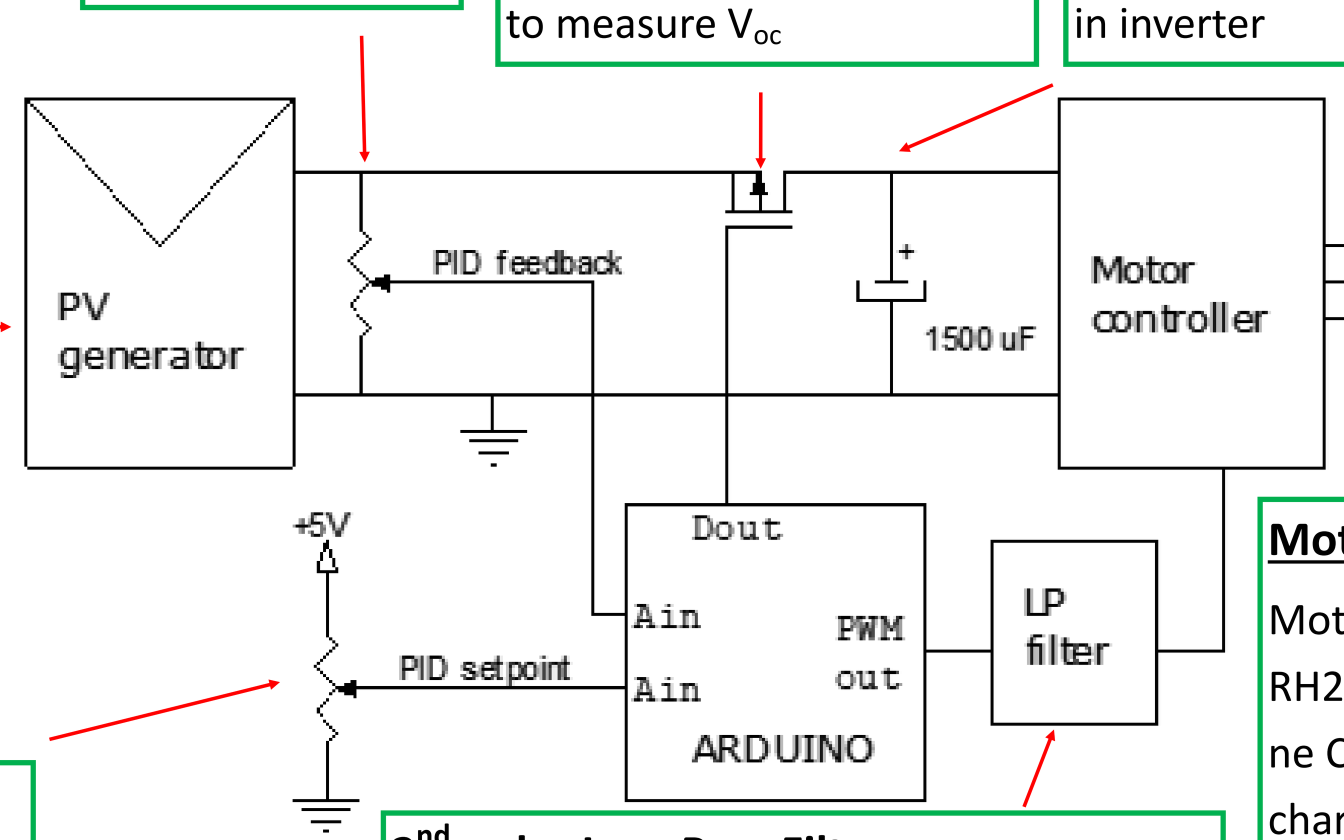
Control input.

MOSFET

Disconnect PV from circuit to measure V_{oc}

Capacitor

Prevent voltage drops under 30 V in inverter



Potentiometer

Set control setpoint and provide regulation to it between V_{oc} and V_{MP}

2nd order Low-Pass Filter

Work as D/A Converter (PWM control output-> Inverter analog control input)

Motor and Inverter

Motor Nine Continent RH205B and Inverter Nine Continent CE6-17A characterized by:

- Power Input > 30 V
- Control Input ϵ [1,4] V

Arduino UNO Platform

Software has been programmed in Arduino environment. Its purposes are:

- Controlling PV generator disconnection from circuit in order to periodically update V_{oc} since it depends on temperature.
- Maximum power point (VMP) estimation as ratio between V_{oc} and V_{MP} is roughly constant for a wide range of temperature:

$$V_{MPP} \cong 0.78 * V_{OC}$$

- Carrying out PI control, which must be reverse:
  - Setpoint at mínimum -> PV generator supplies V_{oc}
  - Setpoint ar máximum -> PV generator Supplies V_{MP}
- Performing **AMIGOf** tuning method, whose main equations:

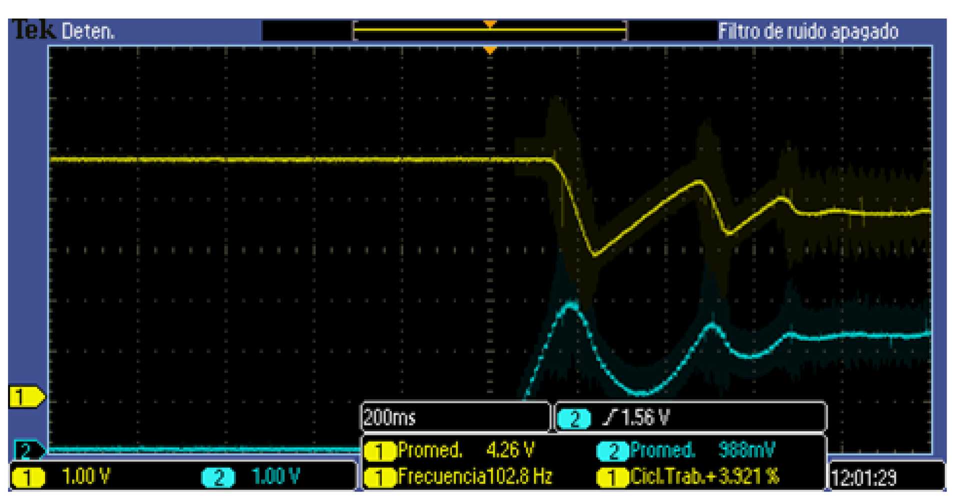
$$K_p = 0{,}16 * K_C$$

$$T_i = \frac{K_p}{K_i} = \frac{T_C}{1 + \frac{4{,}5}{K_C * k_s}}$$

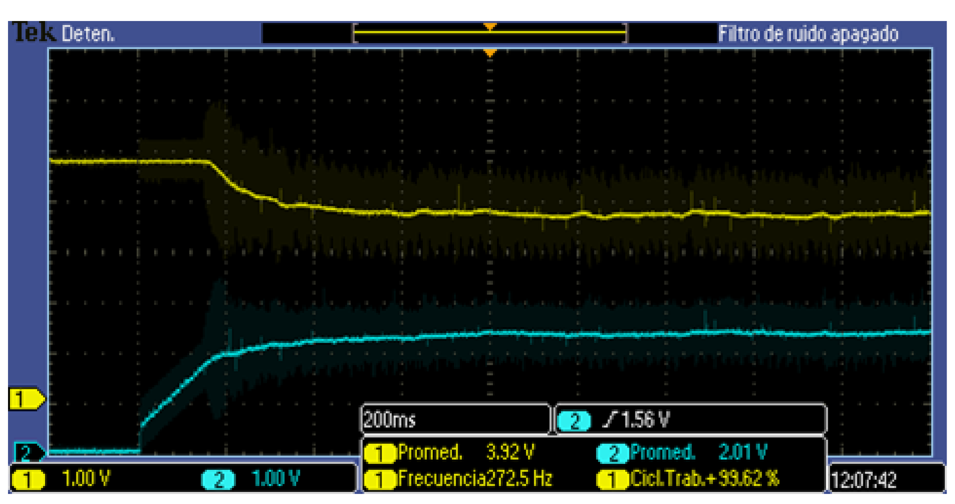
TEST AND RESULTS:

Optimal response requires a fine manual adjustment after applying AMIGOf tuning. Fine tuning has been achieved with START-UP (with a magnetic brake) and CLOUD PASS tests

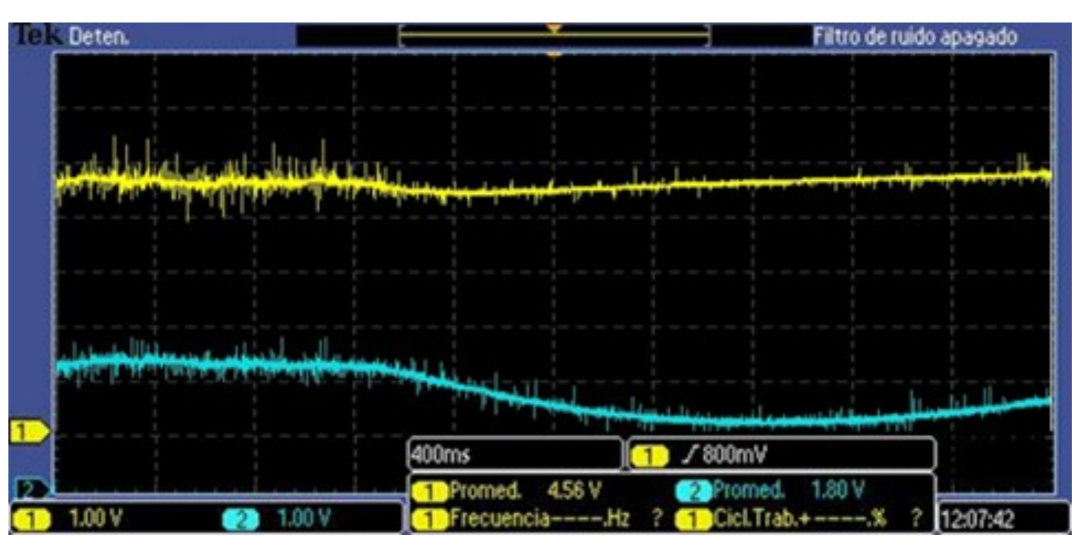
- AMIGOf tuning:
  Kp = 0.112
  Ti = 20.7 ms



- Fine tuning:
  Kp = 0.112
  Ti = 44.8 ms



- Cloud pass test



ADVANTAGES AND APPLICATIONS

1. Independece from batteries -> Main problem in accumulation systems
2. Renewable energy -> environmentally-friendly
3. Optimization of the available energy

These advantages make suitable these applications:

- Light Electric Vehicles (LEVs)
- Photovoltaic Pumping Systems (PVPS)