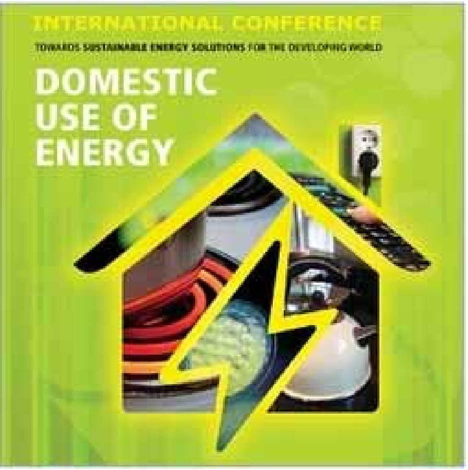


UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

# Automated Hybrid Solar and Mains System for Peak time Power Demand

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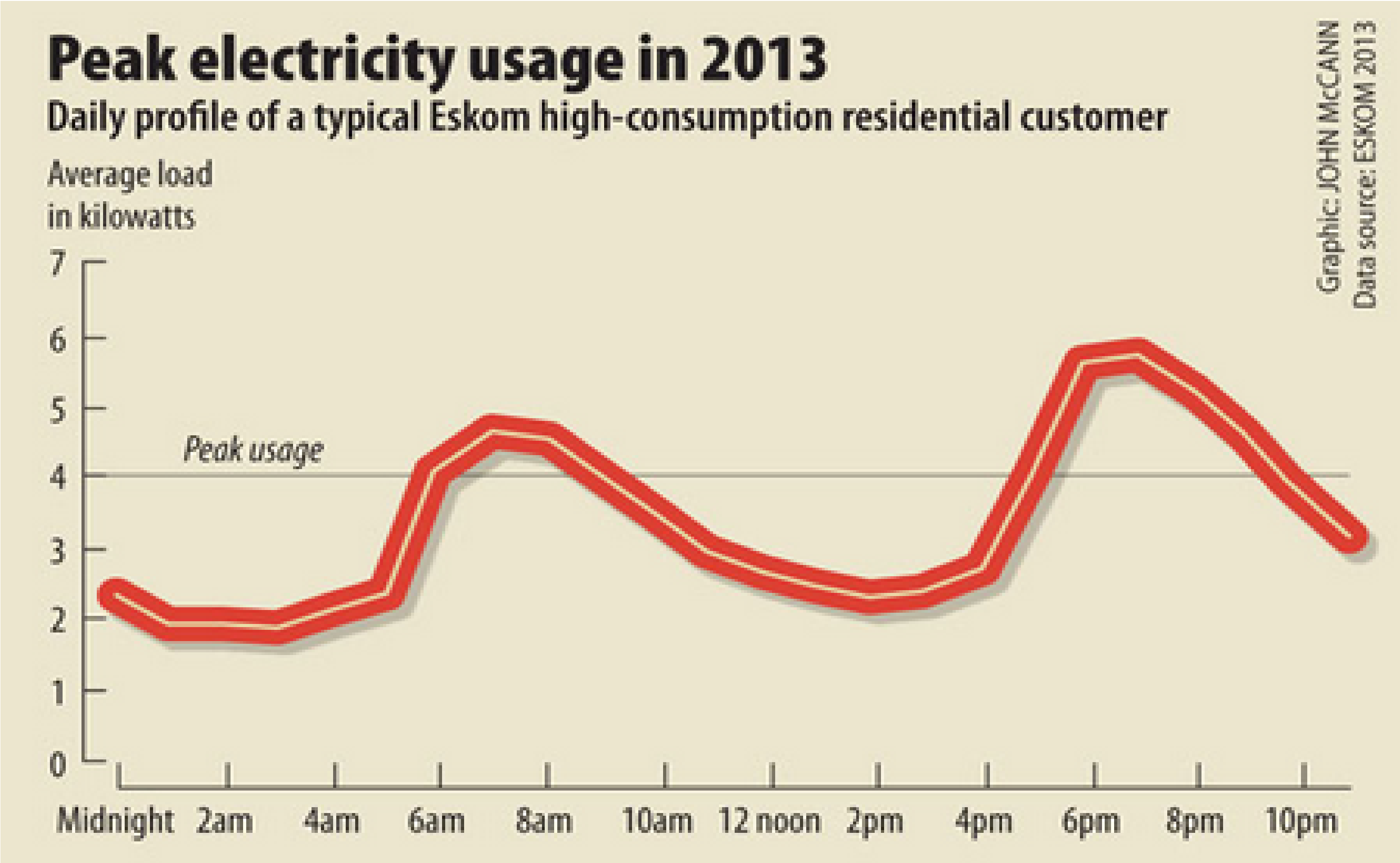
- Sizing of Solar Panel
- Design of Converters
  - Design of maximum Power Point Tracking (MPTT)
  - Design of Boost converter
  - Design of inverter
  - Design of switches for automatic selection of source during peak power demand time
  - Self powered panel cleaning robot
- Discussion
- Conclusions

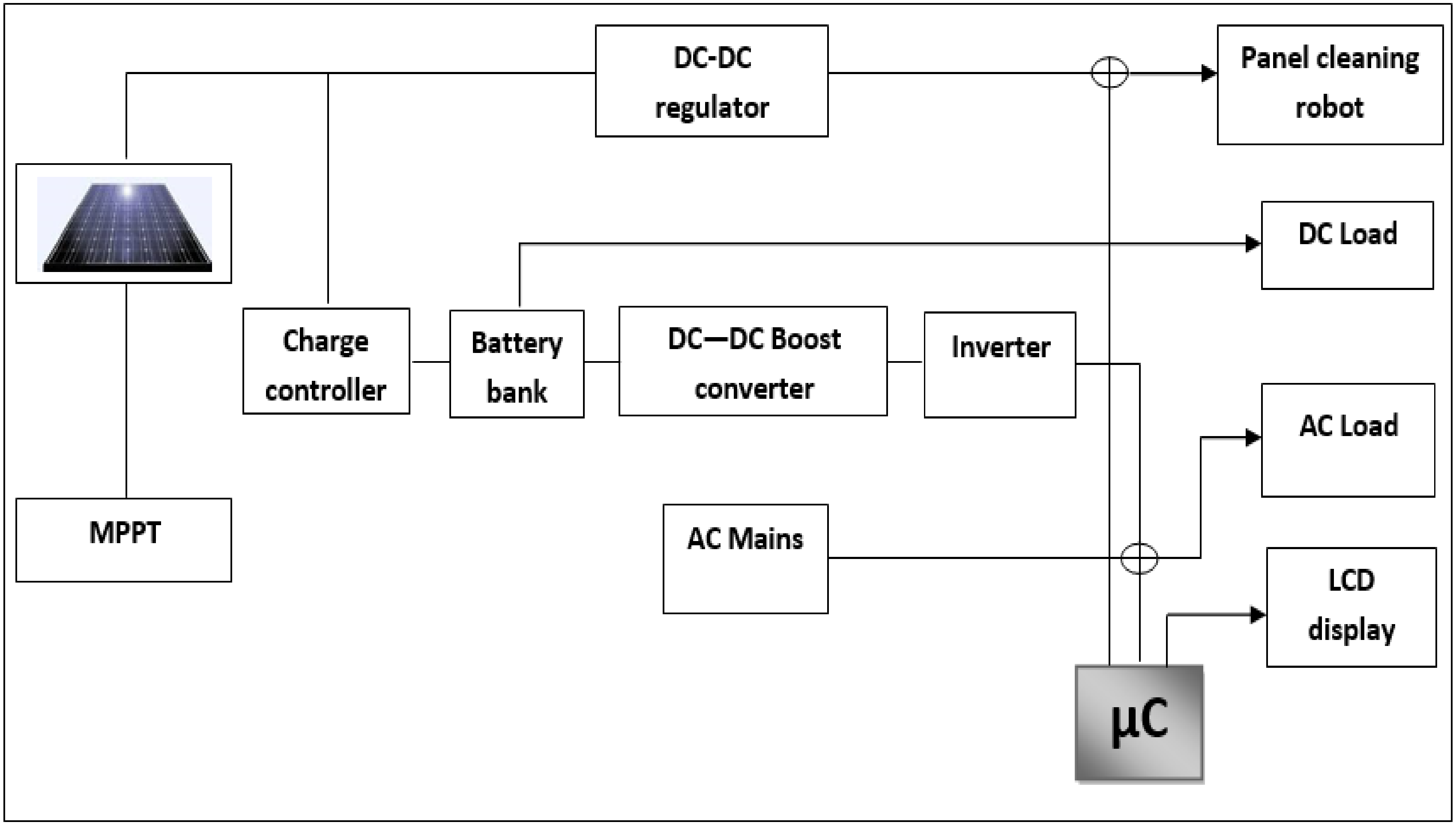
# Introduction

- The purpose of the study is to manage the load shedding by saving power during the peak power demand time.
- The study is focused on the design of hybrid solar and mains system for the purpose of beating the peak power demand
- The power source selection is based on the daily peak power demand in Durban

# Daily peak power demand



# Block diagram of the complete design

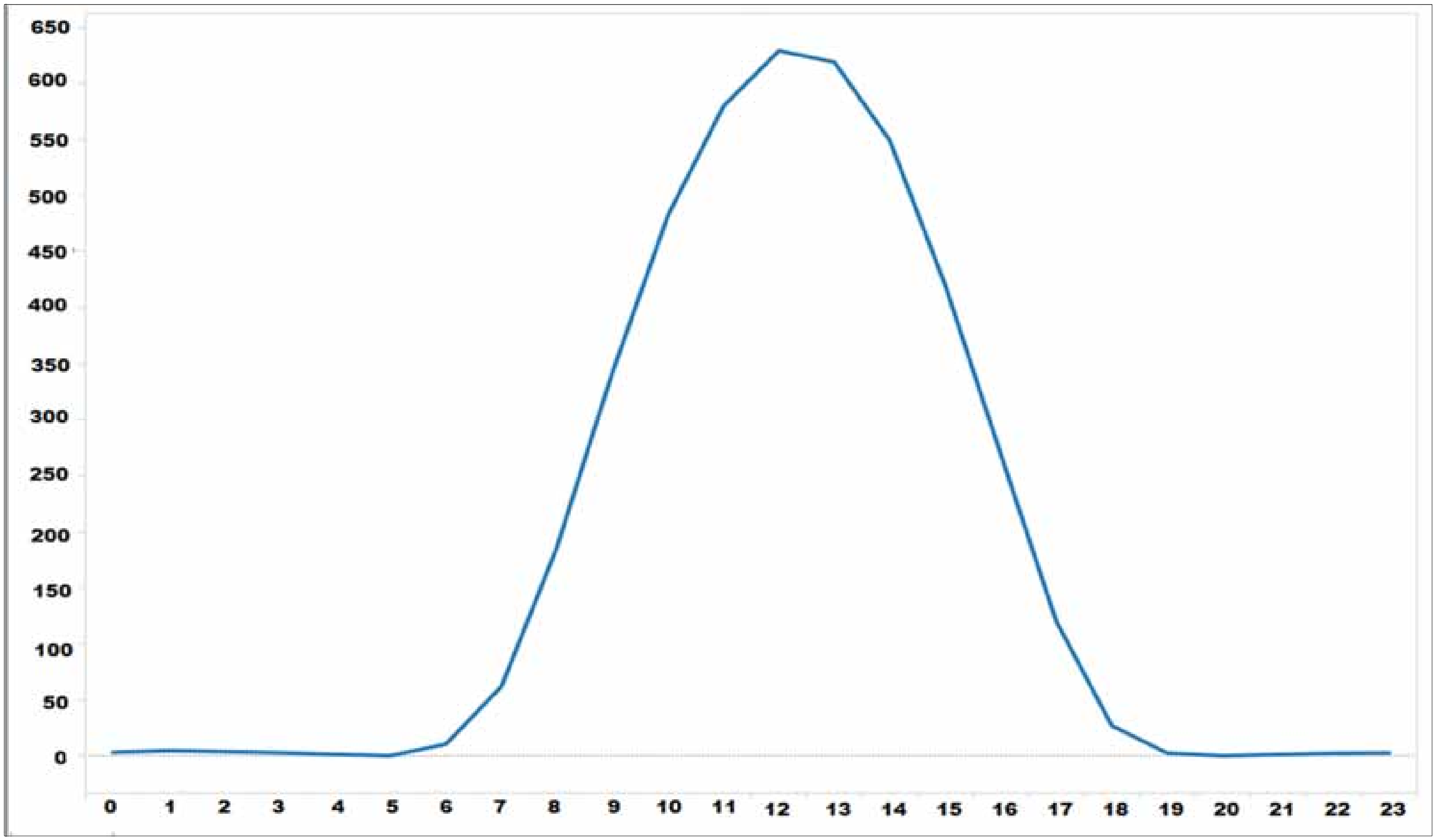


# Sizing of Solar Panel

The current solar sizing is based on Durban irradiance

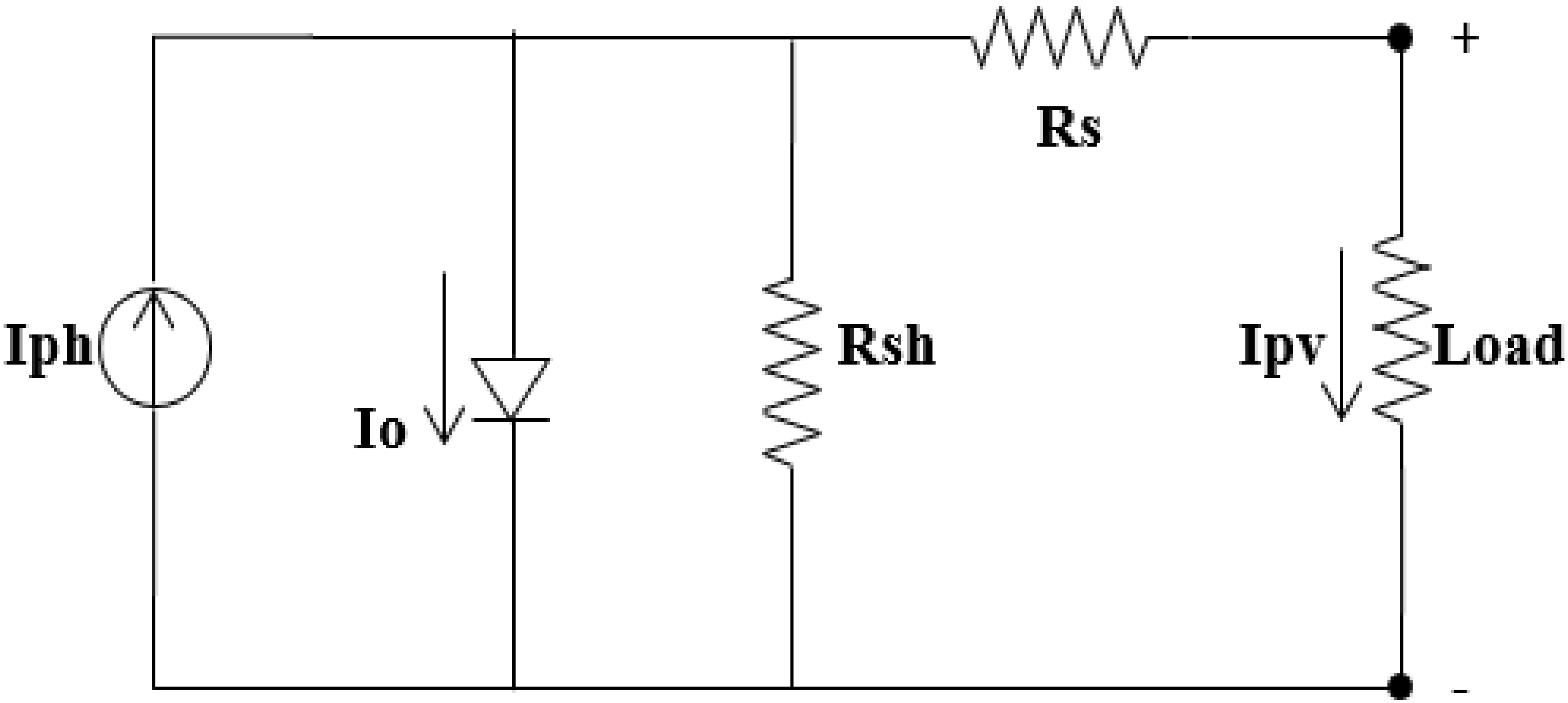
Case study: coffee shop in the Howard College campus
University of KwaZulu-Natal – Durban

# Durban hourly recorded global horizontal irradiance [in w/m2] (Jan 2012-Nov 2014)



# Durban monthly global horizontal irradiance [in w/m$^2$] (Jan 2012- Nov 2014)

# PV cell modelled as a diode circuit



# I-V Characteristic equation of the photovoltaic cell

$$I = I_L - I_o\left[exp\left(\frac{qV}{kT}\right) - 1\right]$$

$$V_0 = \left(\frac{kT}{q}\right) Ln\frac{I_L - I_0}{I_0} \cong \left(\frac{kT}{q}\right) Ln\frac{I_L}{I_0}$$

$$I_0 = I_L exp\left(-\frac{qV_0}{kT}\right)$$

*Where:*

$I_L$ is the cell (light) current

$I_o$ is the reverse saturation (dark) current

*q*=1.6x10-9 Coul

*k*=1.38x10-23 J/K

*T* is the cell temperature, K

Vo the open circuit voltage

# I-V Characteristic equation of the photovoltaic cell

$$P = FIV$$

$$F = \frac{V_0 - \left(\frac{kT}{q}\right) Ln\left(\frac{V_0}{q}\right) Ln\left(\frac{qV_0}{kT} + 0.72\right)}{V_0 + kT/q}$$

P-power output
F - the cell fill factor

*q*=1.6x10-9 Coul

*k*=1.38x10-23 J/K

*T* - the cell temperature, K

Vo - the open circuit

voltage

# Load calculation

Selected:

Power load: 1,000w

Panel power rating: 300w (available on market),

Panel open circuit voltage: 24V,

The surface needed to be covered from the worst irradiance case (132.3w/$m^2$)

$$=1{,}000w/132.3w/m^2 = 7.56m^2$$

Panel size: 1960*982*50mm (available on market),

The surface of the panel = 1960 x 982 = 1.92$m^2$

Number of panels = 7.56$m^2$/1.92$m^2$ = 4 Connected in series-parallel

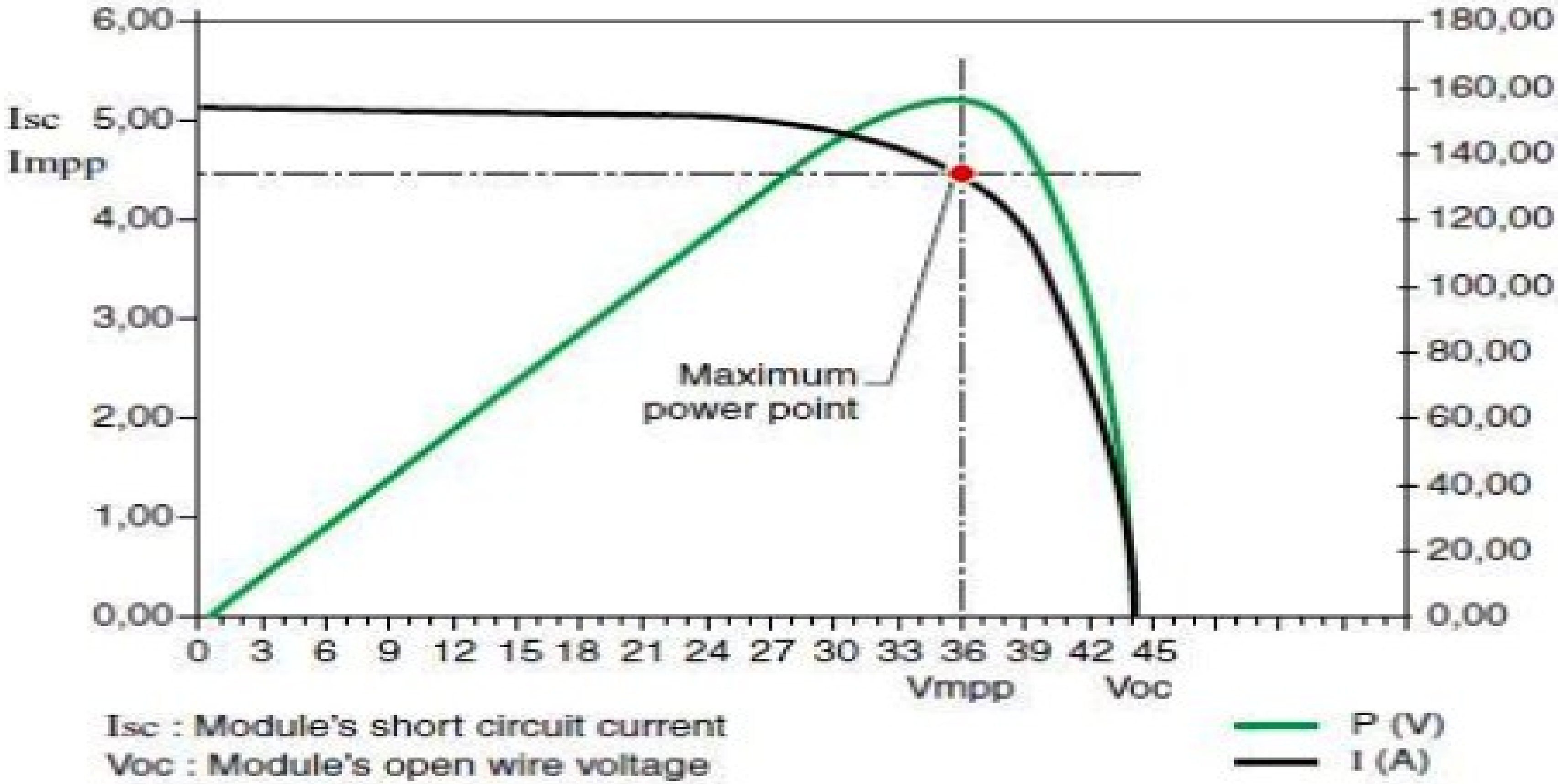
# Maximum Power Point Tracking (MPTT) system

- The efficiency of the solar panels could be increased by tracking maximum power at any time whereby the MPPT system achieved maximum output by varying the operating point on the cell I-V curve
  - There are four common MPPT methods:

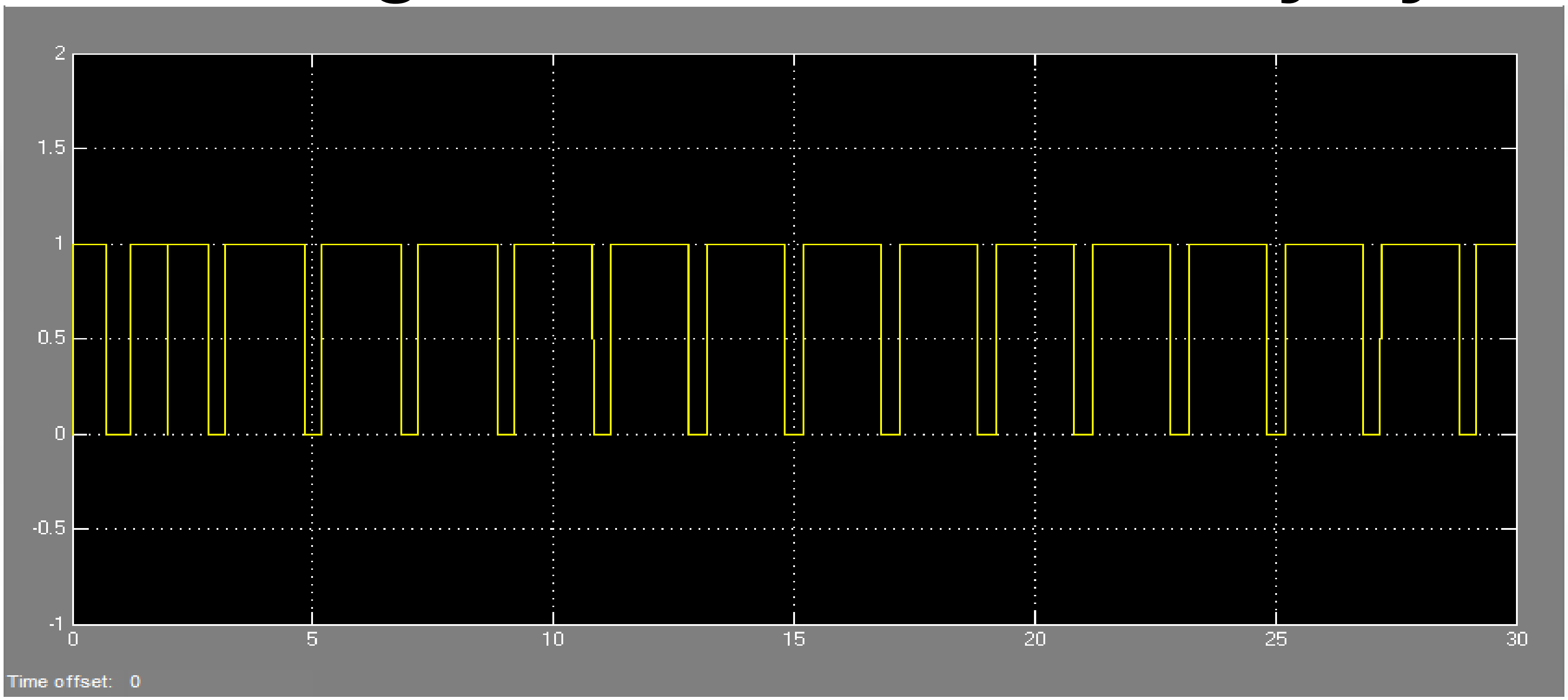
1. Perturb and Observe (P&O) Method
2. Incremental Conductance Method
3. Constant Voltage Method
4. Current Sweep Method

✓The (P&O) has been used

# Solar panel I-V curve

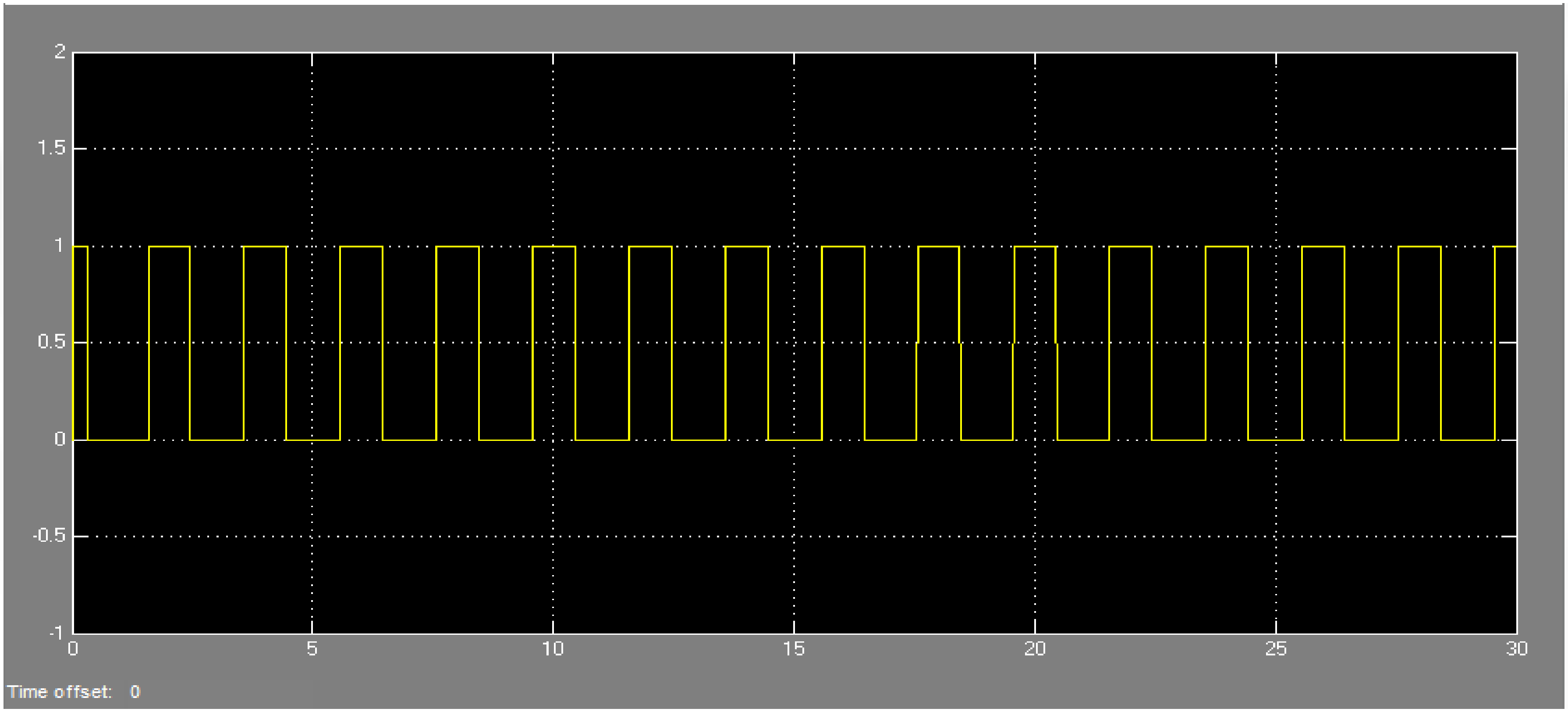


# PWM signal for maximum duty cycle



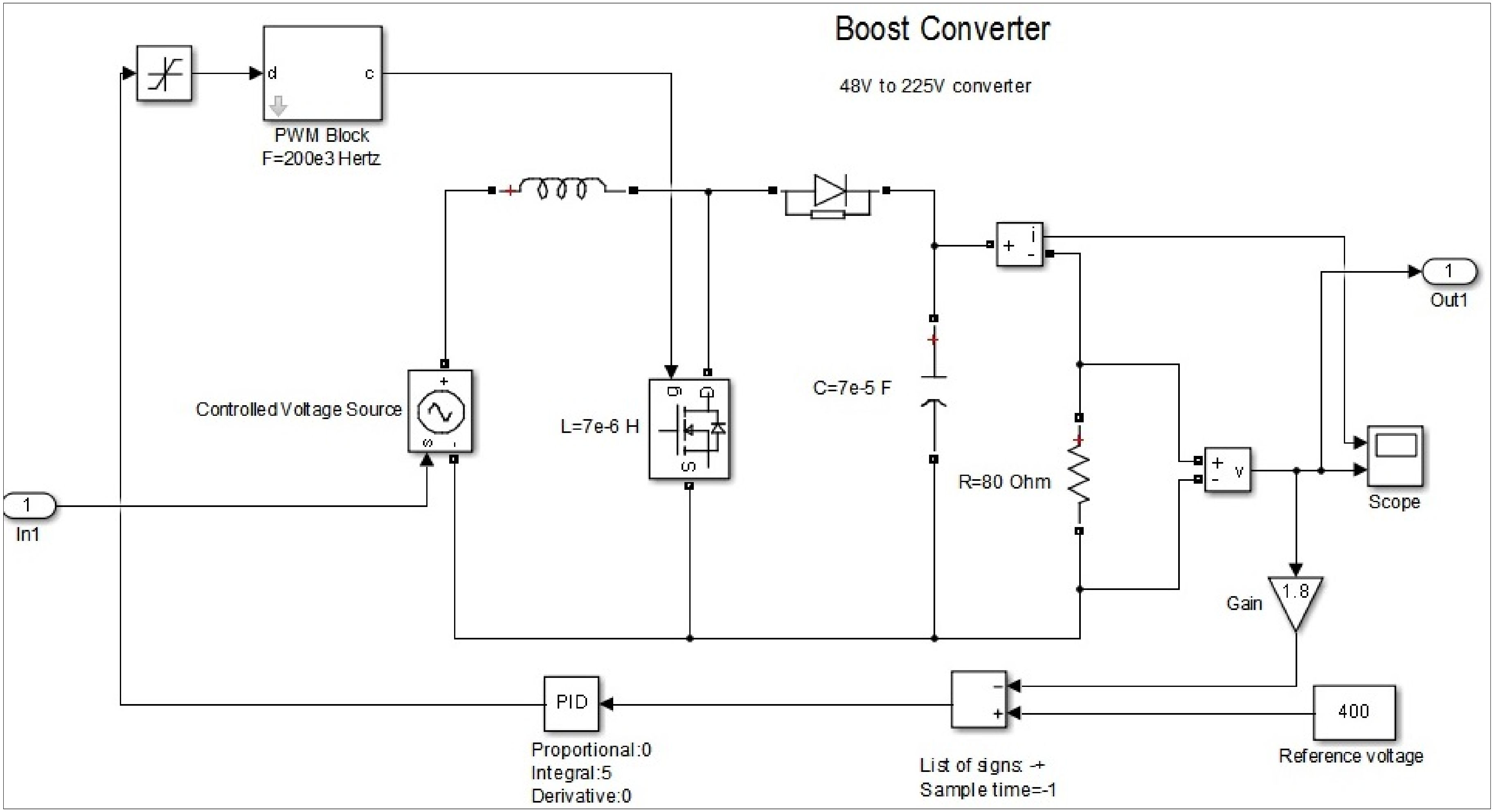

The width of the PWM output increases when current input power is less than previous output power

# PWM signal for minimum duty cycle

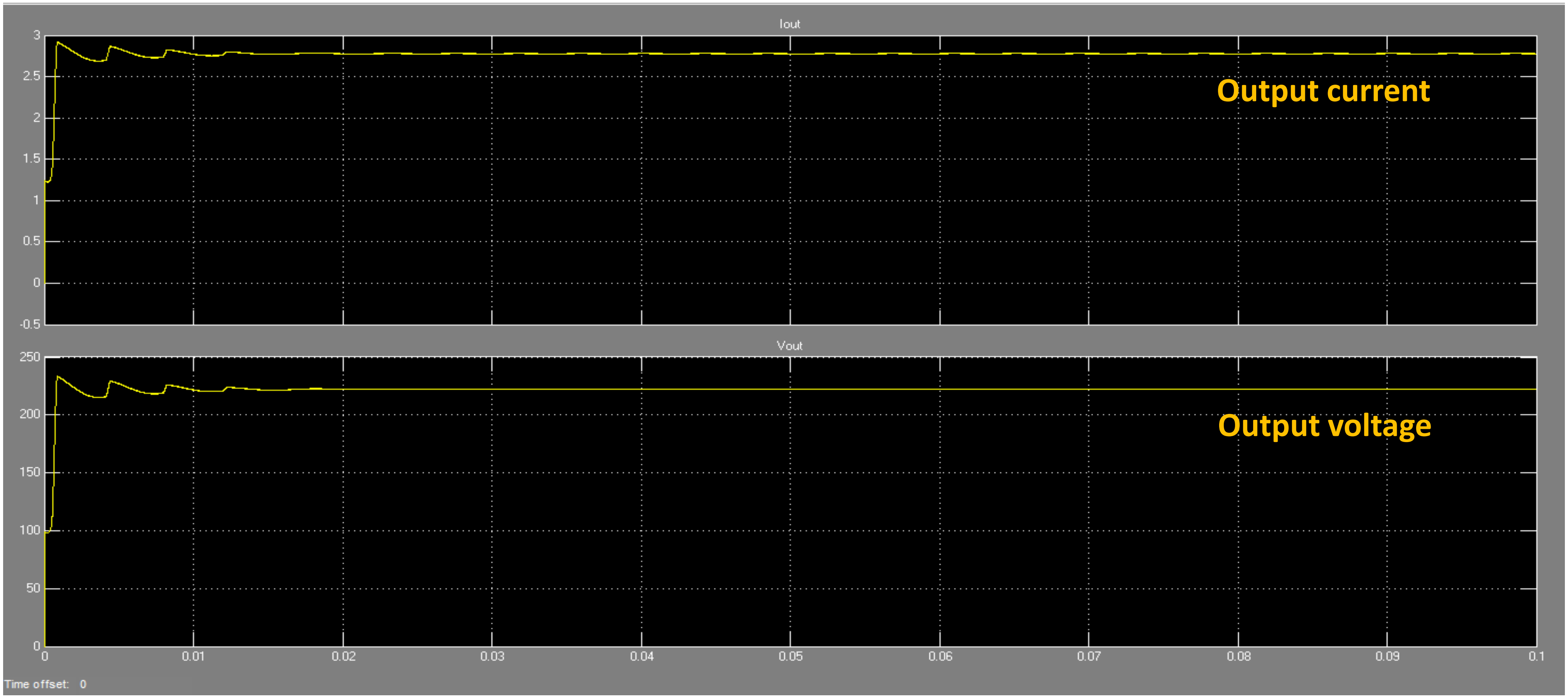



The width of PWM output reduces when the current output power is higher than previous output power

# Simulation model of boost converter

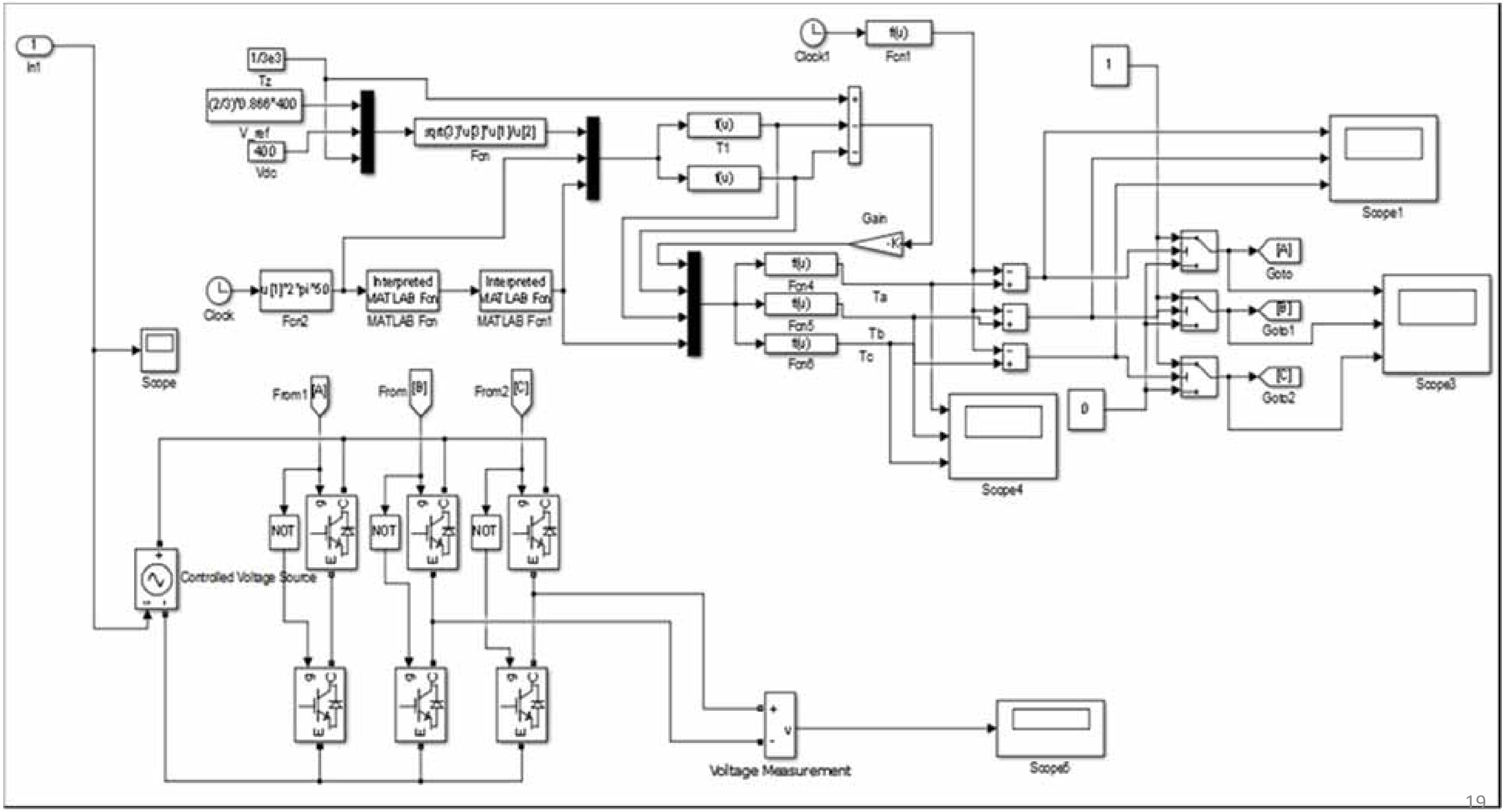


# Boost converter output waveforms

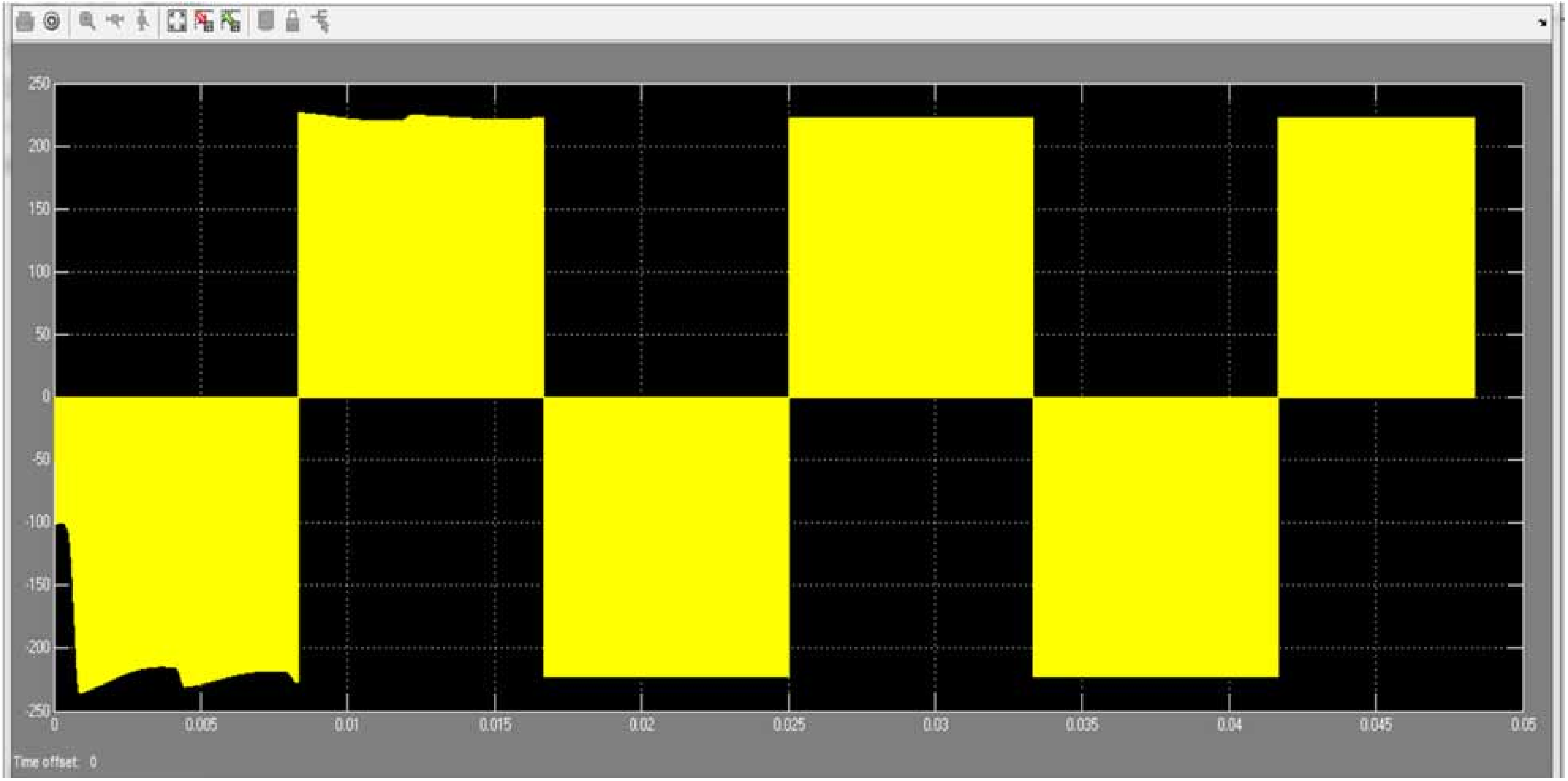



The voltage (220v) and current (2.75A) outputs, stable after 0.01 second delay

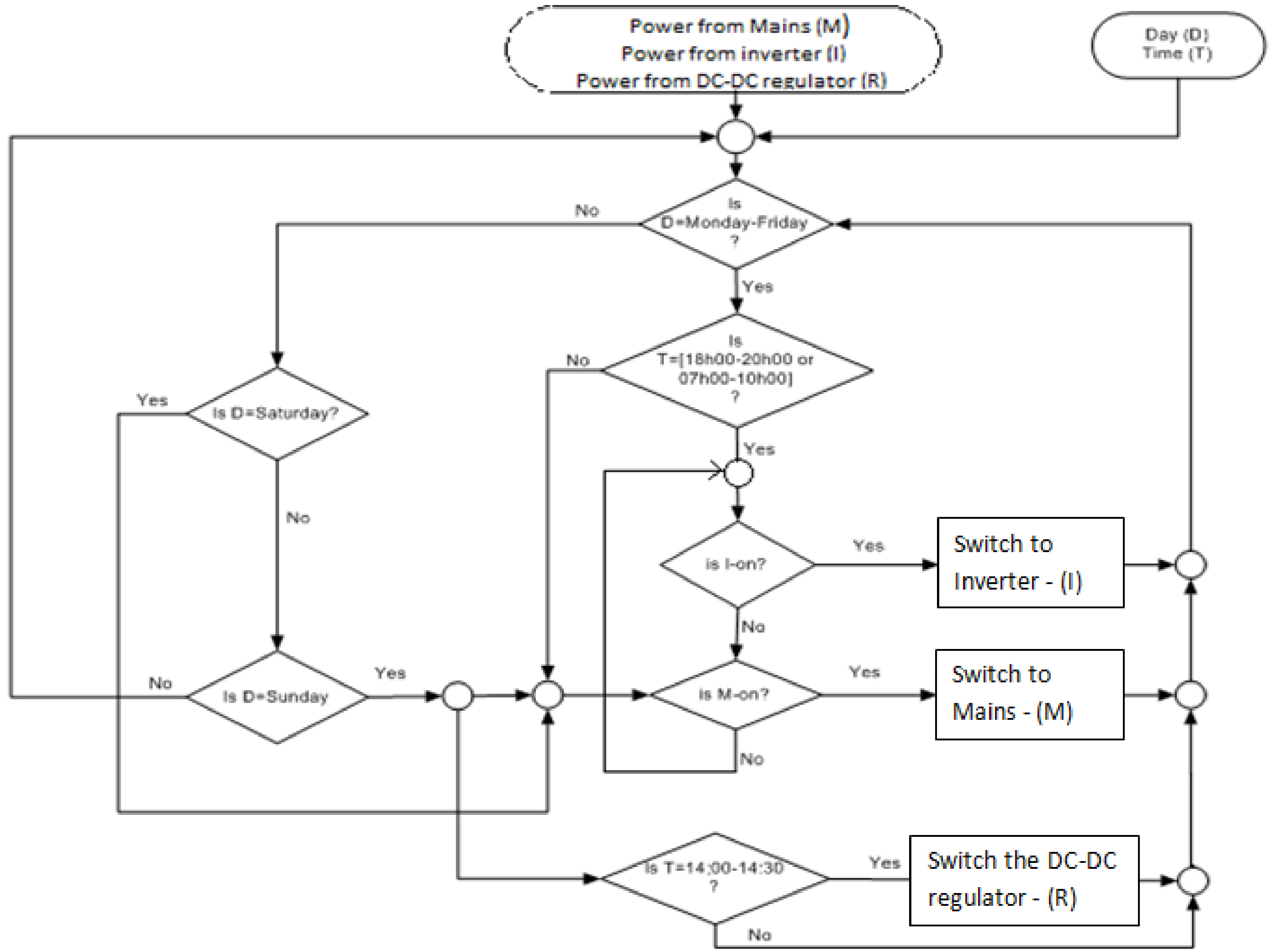
# Simulation model of DC to AC inverter



# Output voltage of inverter



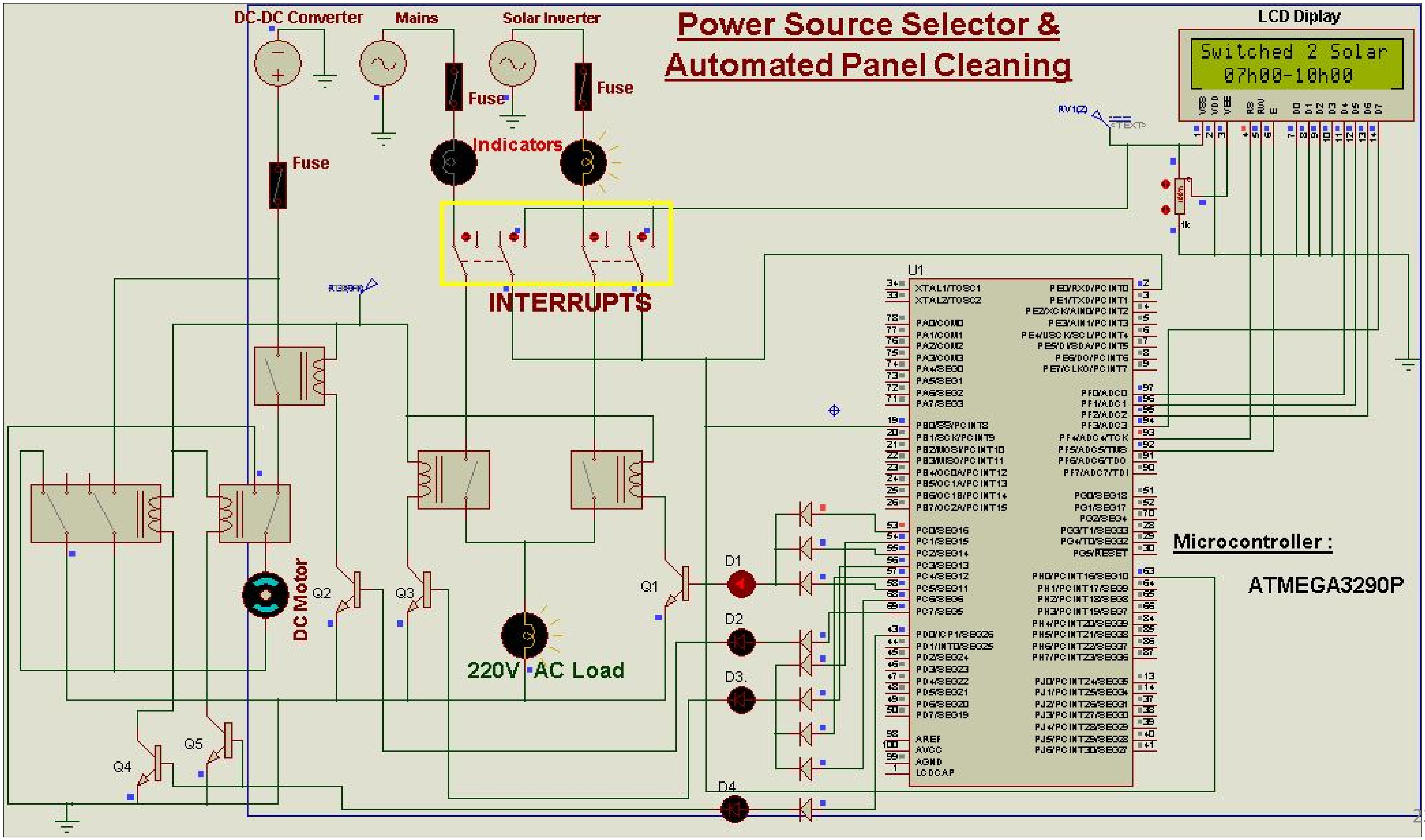
# Flow chart of selection of power source



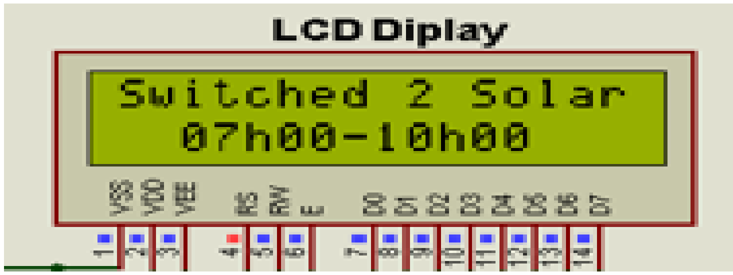
# C++ deburg sample

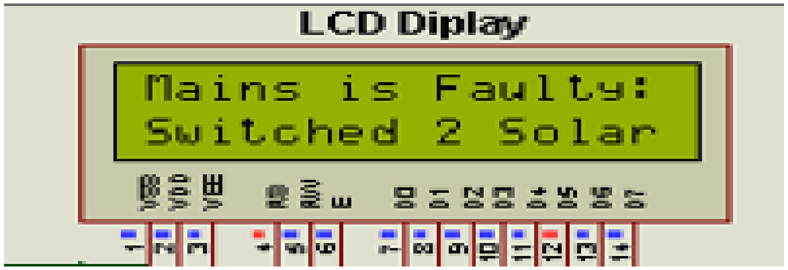
```
If the time is = 5 hour, Mains = 69Volts, Solar = 80Volts RESTART
If the time is = 13 hour, Mains = 120Volts, Solar = 48Volts RESTART
If the time is = 10 hour, Mains = 157Volts, Solar = 221Volts switch to Solar

If the time is = 12 hour, Mains = 181Volts, Solar = 71Volts RESTART
If the time is = 10 hour, Mains = 57Volts, Solar = 150Volts RESTART
If the time is = 12 hour, Mains = 180Volts, Solar = 26Volts RESTART
If the time is = 8 hour, Mains = 52Volts, Solar = 156Volts RESTART
If the time is = 9 hour, Mains = 114Volts, Solar = 31Volts RESTART
If the time is = 12 hour, Mains = 41Volts, Solar = 203Volts RESTART
If the time is = 8 hour, Mains = 71Volts, Solar = 218Volts RESTART
If the time is = 8 hour, Mains = 121Volts, Solar = 82Volts RESTART
If the time is = 7 hour, Mains = 213Volts, Solar = 167Volts RESTART
If the time is = 12 hour, Mains = 44Volts, Solar = 21Volts RESTART
If the time is = 11 hour, Mains = 137Volts, Solar = 149Volts RESTART
If the time is = 10 hour, Mains = 11Volts, Solar = 174Volts RESTART
If the time is = 9 hour, Mains = 5Volts, Solar = 168Volts RESTART
If the time is = 6 hour, Mains = 160Volts, Solar = 25Volts RESTART
If the time is = 5 hour, Mains = 208Volts, Solar = 109Volts RESTART
If the time is = 6 hour, Mains = 191Volts, Solar = 229Volts switch to Solar

If the time is = 11 hour, Mains = 83Volts, Solar = 54Volts RESTART
If the time is = 13 hour, Mains = 112Volts, Solar = 55Volts RESTART
If the time is = 9 hour, Mains = 42Volts, Solar = 89Volts RESTART
If the time is = 6 hour, Mains = 131Volts, Solar = 13Volts RESTART
If the time is = 5 hour, Mains = 68Volts, Solar = 225Volts switch to Solar

If the time is = 6 hour, Mains = 78Volts, Solar = 119Volts RESTART
If the time is = 13 hour, Mains = 187Volts, Solar = 178Volts RESTART
If the time is = 7 hour, Mains = 16Volts, Solar = 79Volts RESTART
If the time is = 13 hour, Mains = 171Volts, Solar = 91Volts RESTART
If the time is = 9 hour, Mains = 123Volts, Solar = 123Volts RESTART
If the time is = 5 hour, Mains = 148Volts, Solar = 138Volts RESTART
If the time is = 5 hour, Mains = 107Volts, Solar = 32Volts RESTART
If the time is = 4 hour, Mains = 102Volts, Solar = 186Volts RESTART
If the time is = 8 hour, Mains = 31Volts, Solar = 110Volts RESTART
If the time is = 9 hour, Mains = 148Volts, Solar = 147Volts RESTART
If the time is = 5 hour, Mains = 51Volts, Solar = 217Volts RESTART
If the time is = 13 hour, Mains = 71Volts, Solar = 52Volts RESTART
If the time is = 13 hour, Mains = 98Volts, Solar = 100Volts RESTART
If the time is = 13 hour, Mains = 160Volts, Solar = 128Volts RESTART
If the time is = 9 hour, Mains = 53Volts, Solar = 42Volts RESTART
If the time is = 13 hour, Mains = 3Volts, Solar = 212Volts RESTART
If the time is = 12 hour, Mains = 52Volts, Solar = 27Volts RESTART
If the time is = 13 hour, Mains = 97Volts, Solar = 28Volts RESTART
If the time is = 12 hour, Mains = 133Volts, Solar = 79Volts RESTART
If the time is = 6 hour, Mains = 31Volts, Solar = 23Volts RESTART
If the time is = 5 hour, Mains = 59Volts, Solar = 128Volts RESTART
If the time is = 8 hour, Mains = 228Volts, Solar = 218Volts switch to Mains
```

# Proteus simulation model

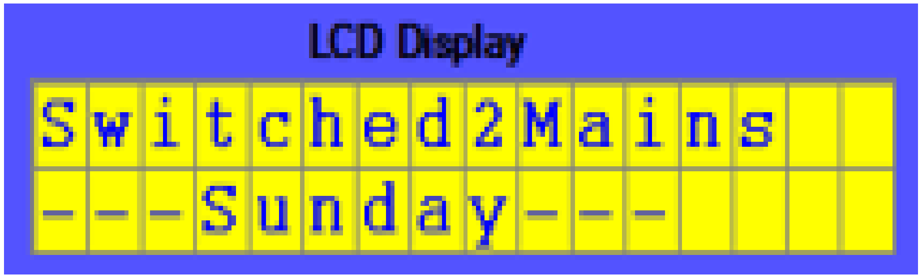


# LCD displays showing source selection

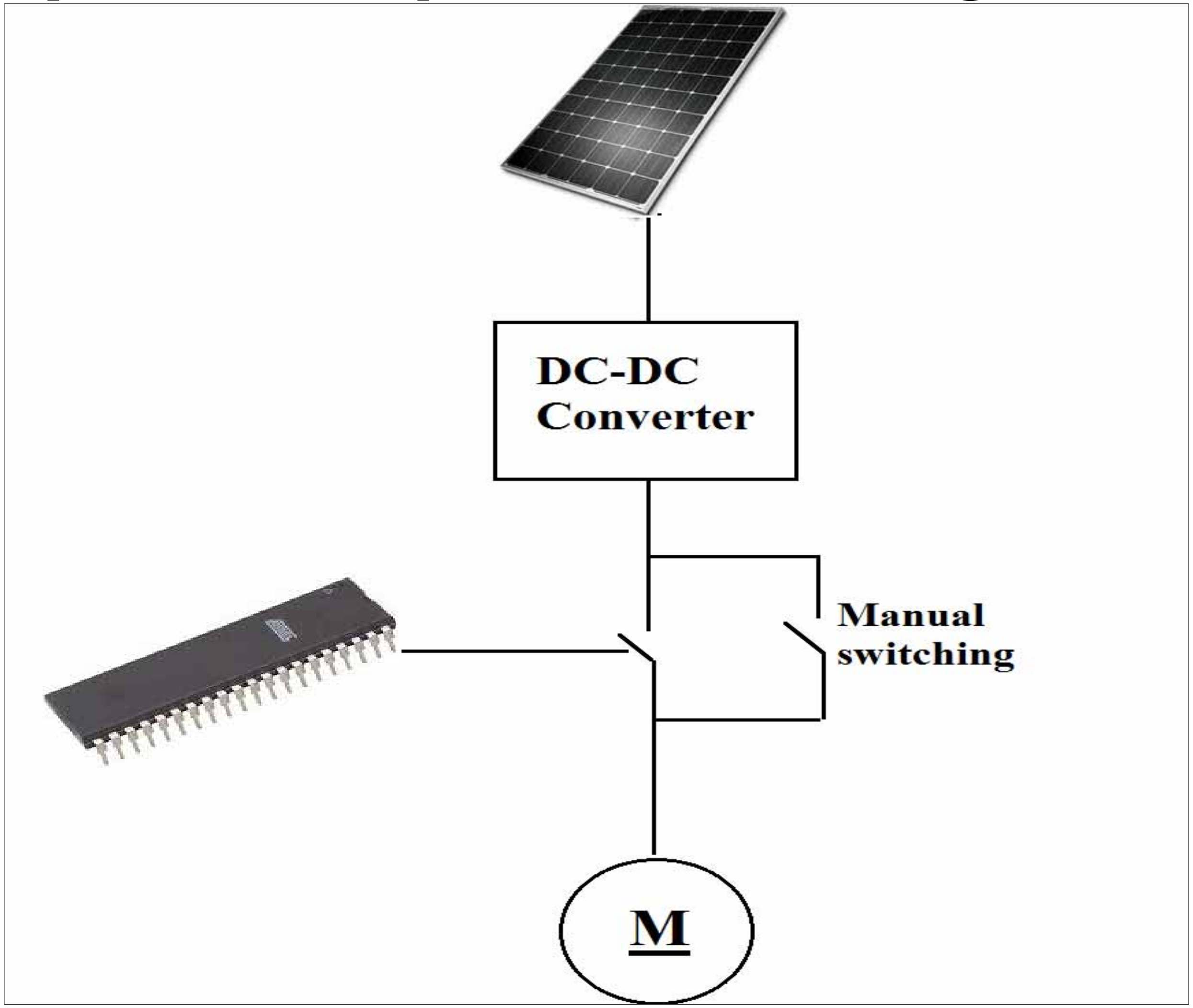


# Panel cleaning schedule in LCD display

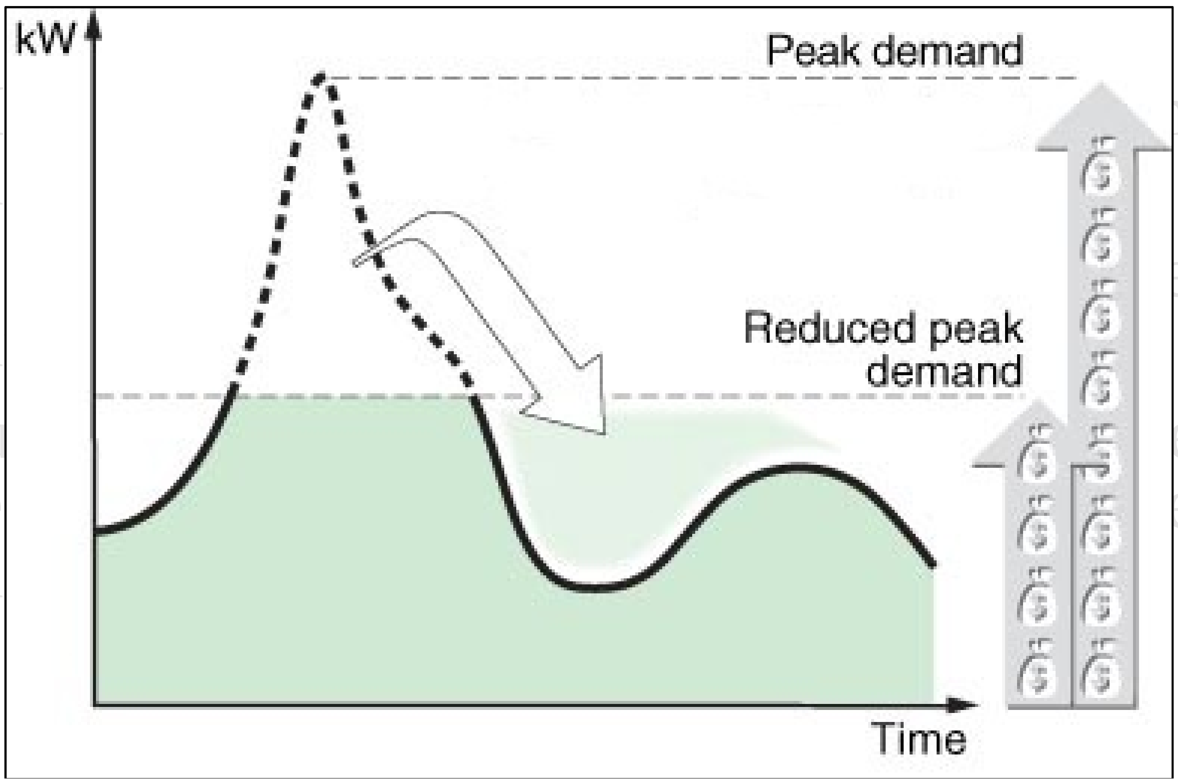



# Solar powered panel cleaning DC motor



# Conclusion

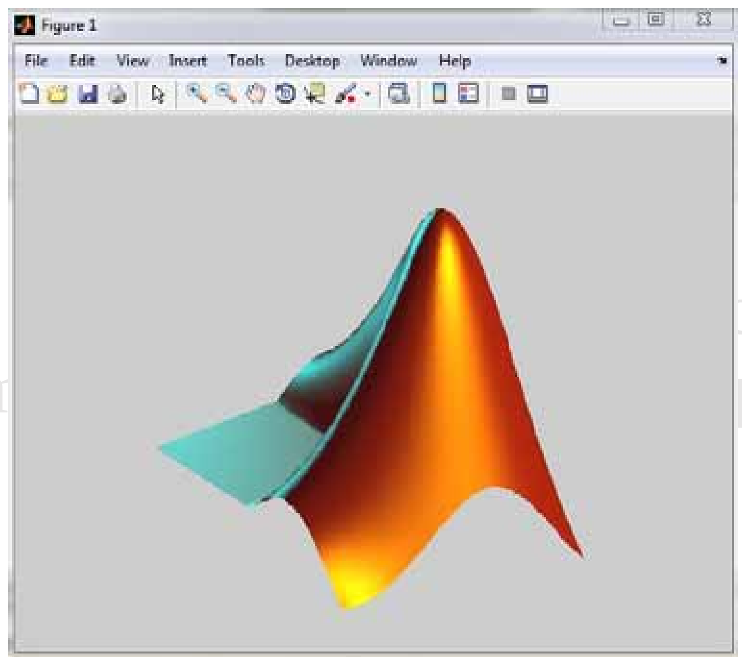
- This paper demonstrated implementation of a hybrid solar/mains system to reduce power demand during peak time




- The M … ns are simula…
- Power … eus simula…
- Althou … em could reduce … eak power deman…

# Conclusion

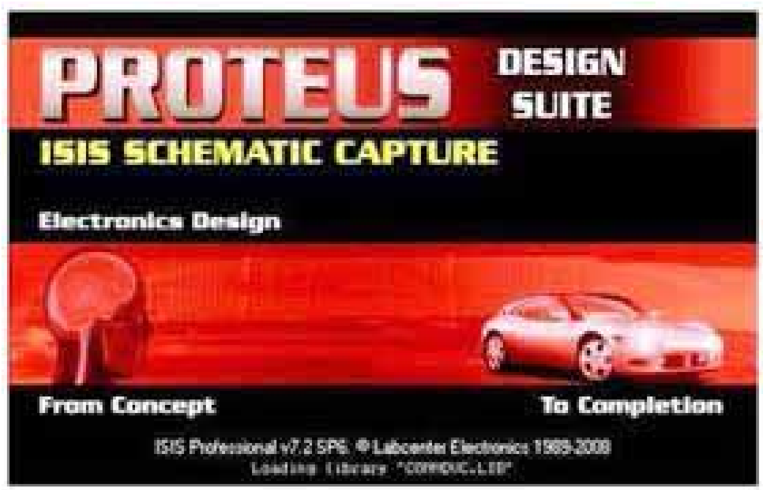
- This paper demonstrated implementation of a hybrid solar/mains system to meet power demand during peak time
- The MPPT, Boost converter and inverter systems are simulated using MatLab




- Power source selection is simulation software
- Although initial costs are could reduce the load on comm power demand.

# Conclusion

- This paper demonstrated implementation of a hybrid solar/mains system to meet power demand during peak time
- The MPPT, Boost converter and inverter systems are simulated using MatLab
- Power source selection is simulated using Proteus simulation software




- Although initial cos tem could reduce the load on eak power demand.

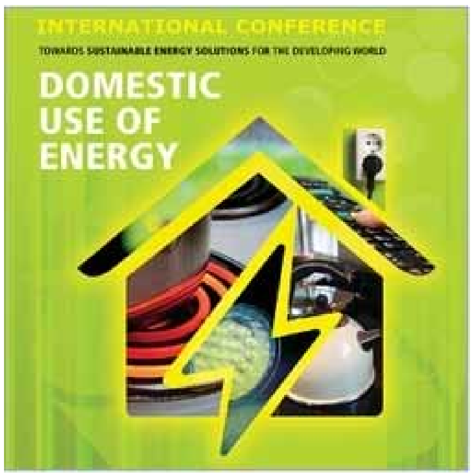
# Conclusion

- This paper d… on of a hybrid solar/mains s… and during peak time
- The MPPT, I… er systems are simulated us…
- Power sourc… ng Proteus simulation sc…

- Although initial costs are high, this hybrid system could reduce the load on commercial grids during peak power demand.

# Acknowledgement


- We acknowledge the support of the UKZN for research and presentation
- We also appreciate the leadership of DUE for the privilege given us to present at this conference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# Thank you!