Remote Control of Distributed Generation System

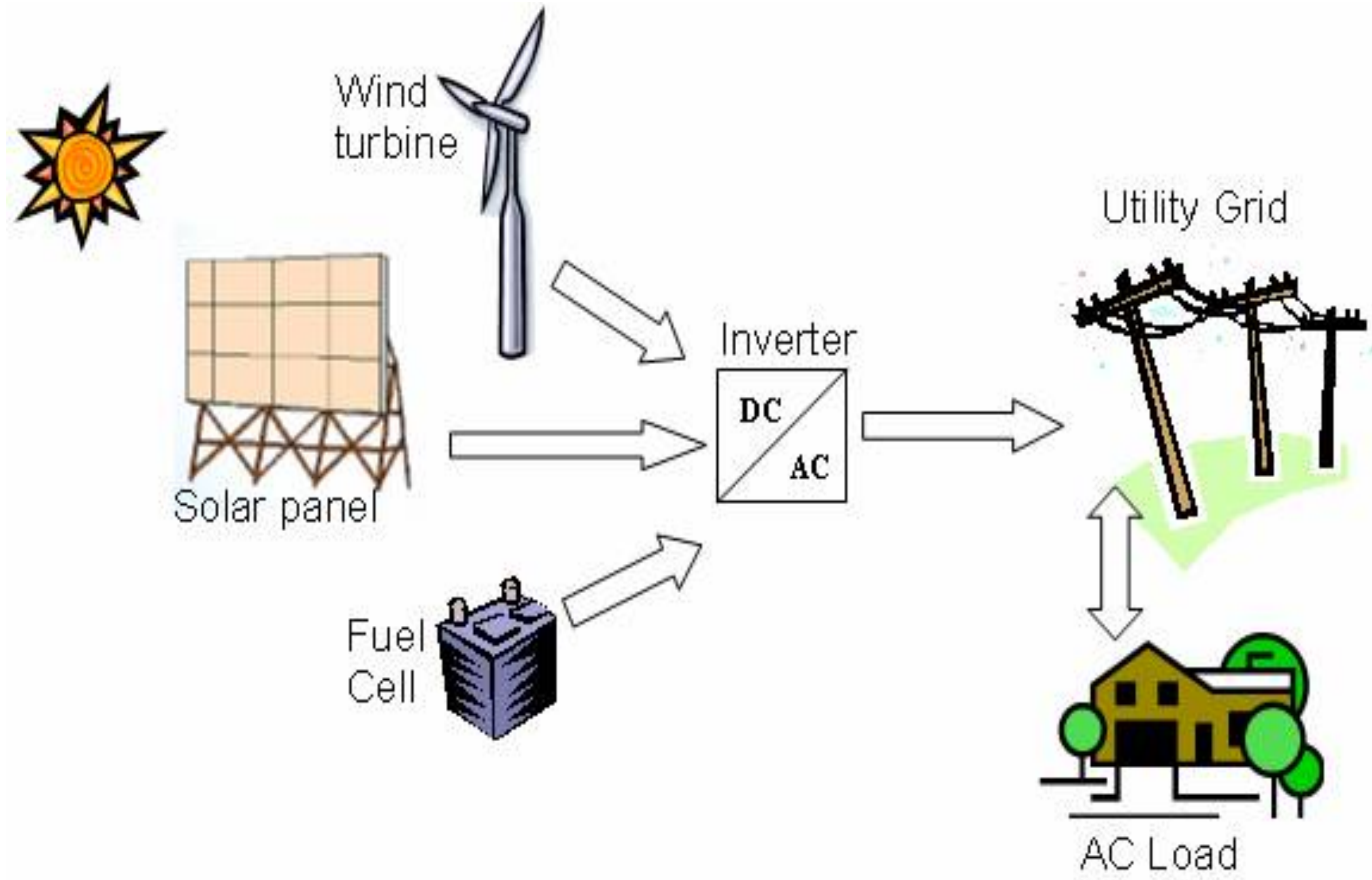
Farhana Shirin Lina
BSC.(Electrical and Electronic)

Memorial University of Newfoundland & Labrador

Outline

- Introduction
- Research Objectives
- Different Control Systems
- System Modeling and Control
- Controller Design and Implementation
- Experimental Test Results
- Conclusions
- Recommendations

Introduction



[http://fec.eng.monash.edu.au/2005/dg/dg.php]

Introduction.........continued

- Distributed generation reduces the amount of energy lost in transmitting electricity because, the electricity is usually generated close to the place where it is used.
- It also reduces the number of power lines that have to be constructed.

Introduction….continued

- In 1993/4 there was just 1.2GW of distributed independent generation in England and Wales. This has grown to over 12GW today
- Renewable energy generation systems range from 1 kW to several hundred MW levels which are normally connected to a main power grid as a distributed generation (DG) system.

Introduction……….continued

- Low cost power conditioning units (PCU) serve as interfaces between the distributed energy source and the grid
- Multistage PCUs offer a higher degree of freedom
- For inverter-based distributed generation systems the inverters are connected to the existing grid; therefore, the voltage cannot be controlled.

Research Objectives

- Developed a remote control of distributed generation system based on grid tie single phase inverter that provides improved control technique while enhancing the realism of the system

- Developed and demonstrate a low cost remote power control method for a small grid connected inverter. It is also required to demonstrate the applications of the developed method for distributed generation.

Different Control System

- PWM control system
- LCL filters
- Microcontroller
- DSP

Different Control System…. continued

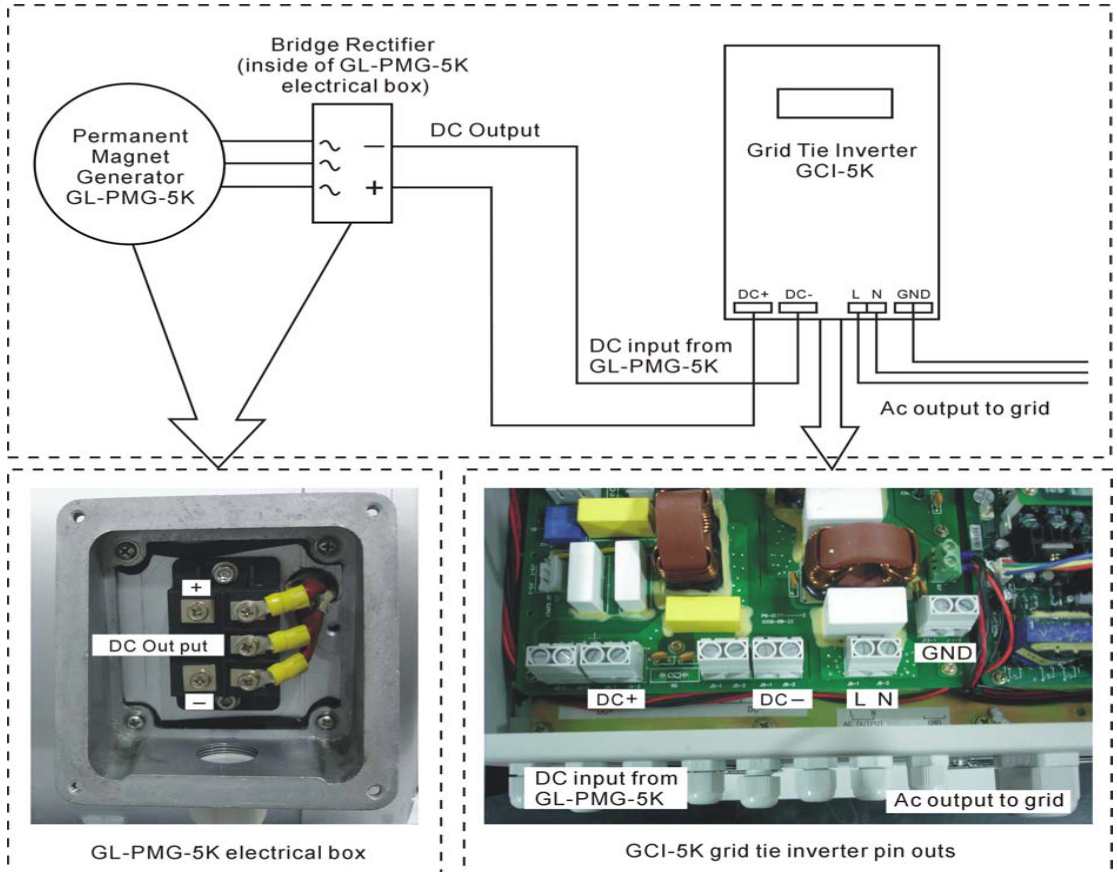


Figure: Wiring diagram of Grid Tie Inverter (GCI-5K) designed and manufactured by GINLONG Technologies

Different Control System…. continued

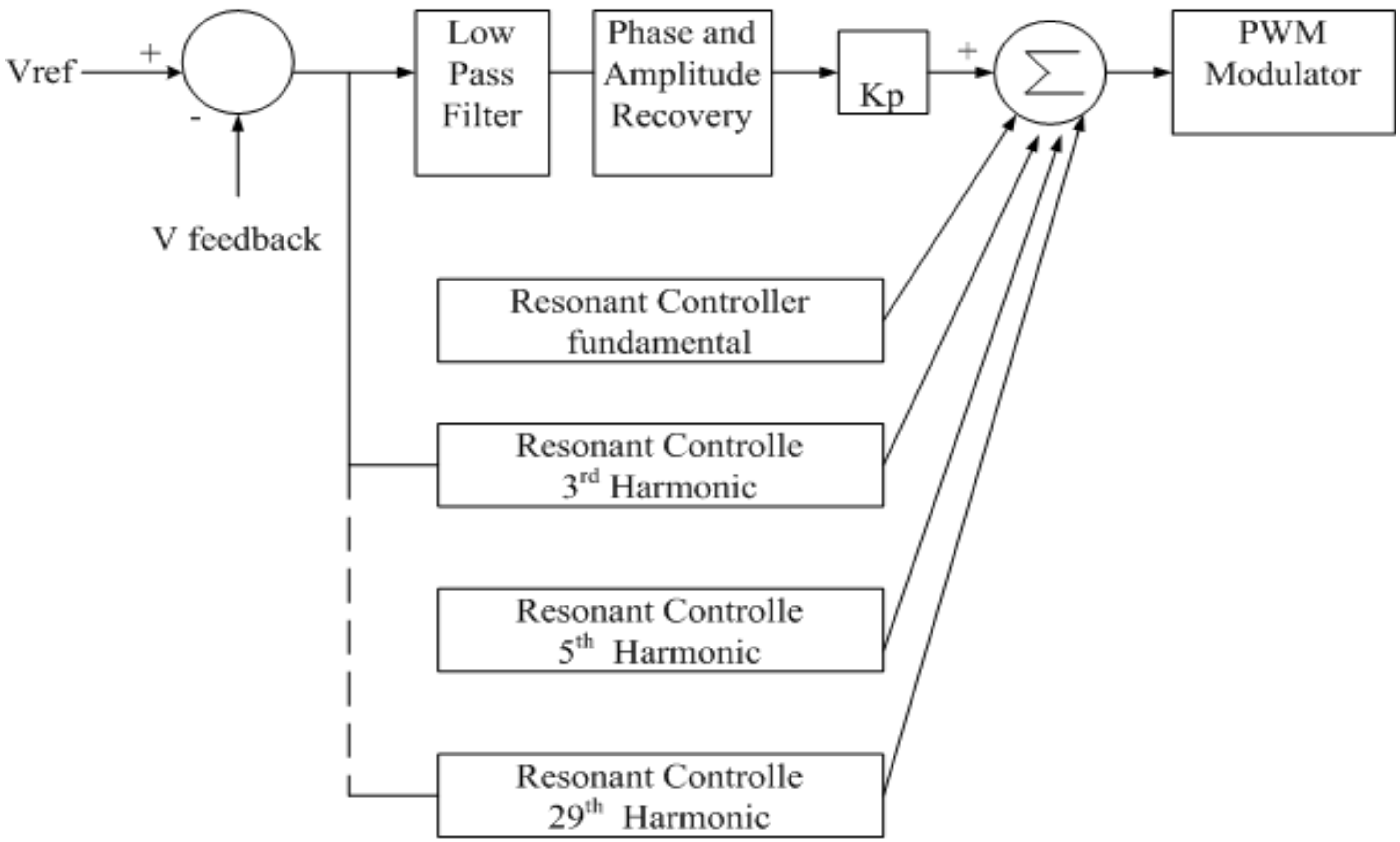


Figure: ADMC 401 DSP-based Harmonic Control

System Modeling and Control

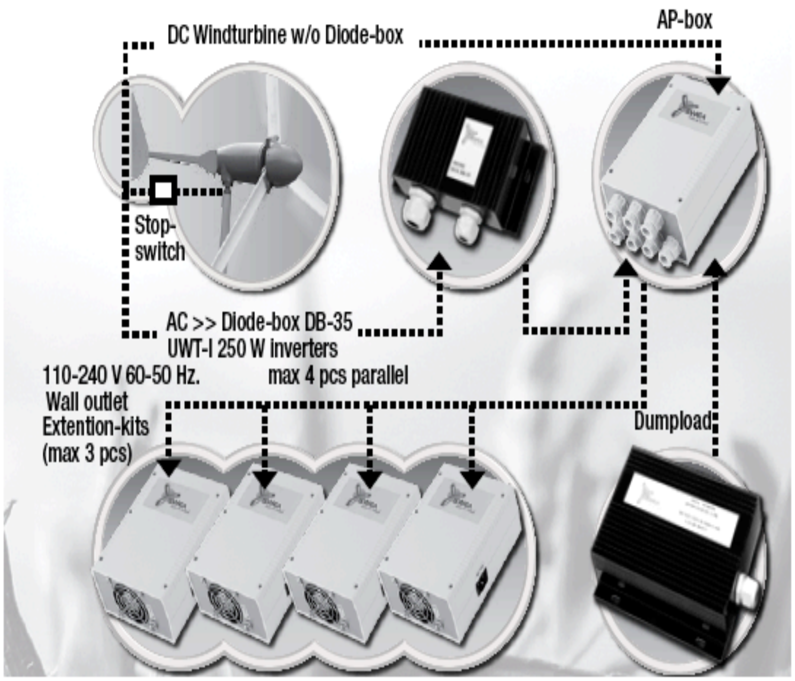


Figure: Grid tie inverter kit (type: UWT-I-250 ST-KIT)

Specifications:

- Wind turbine: 200 to 1000W
- Dumpload:200W
(400 W for 1000 W wind turbine)
- DC in = 24 – 54 V
- Output to the grid= 200W
- Efficiency= 84%

System Modeling and Control.. continued

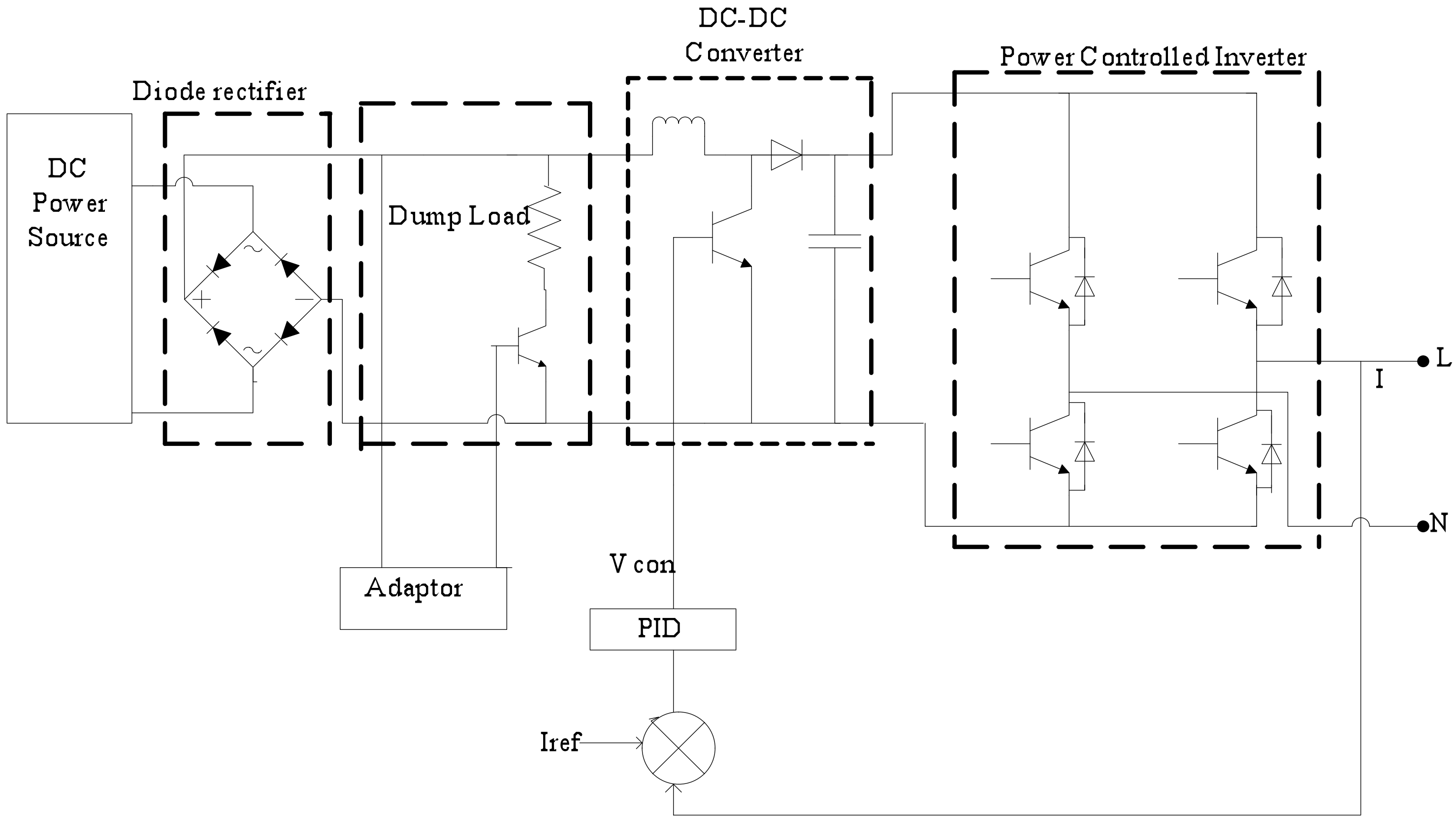


Figure: Grid Connected Inverter Topology and Control

System Modeling and Control…. continued

Figure: Vicor ComPac DC-DC converter

Specifications:

Input voltage: 21~32 V

Output voltage: 48 V, 200W

Output trimming range: 48 V to 52

System Modeling and Control…. continued

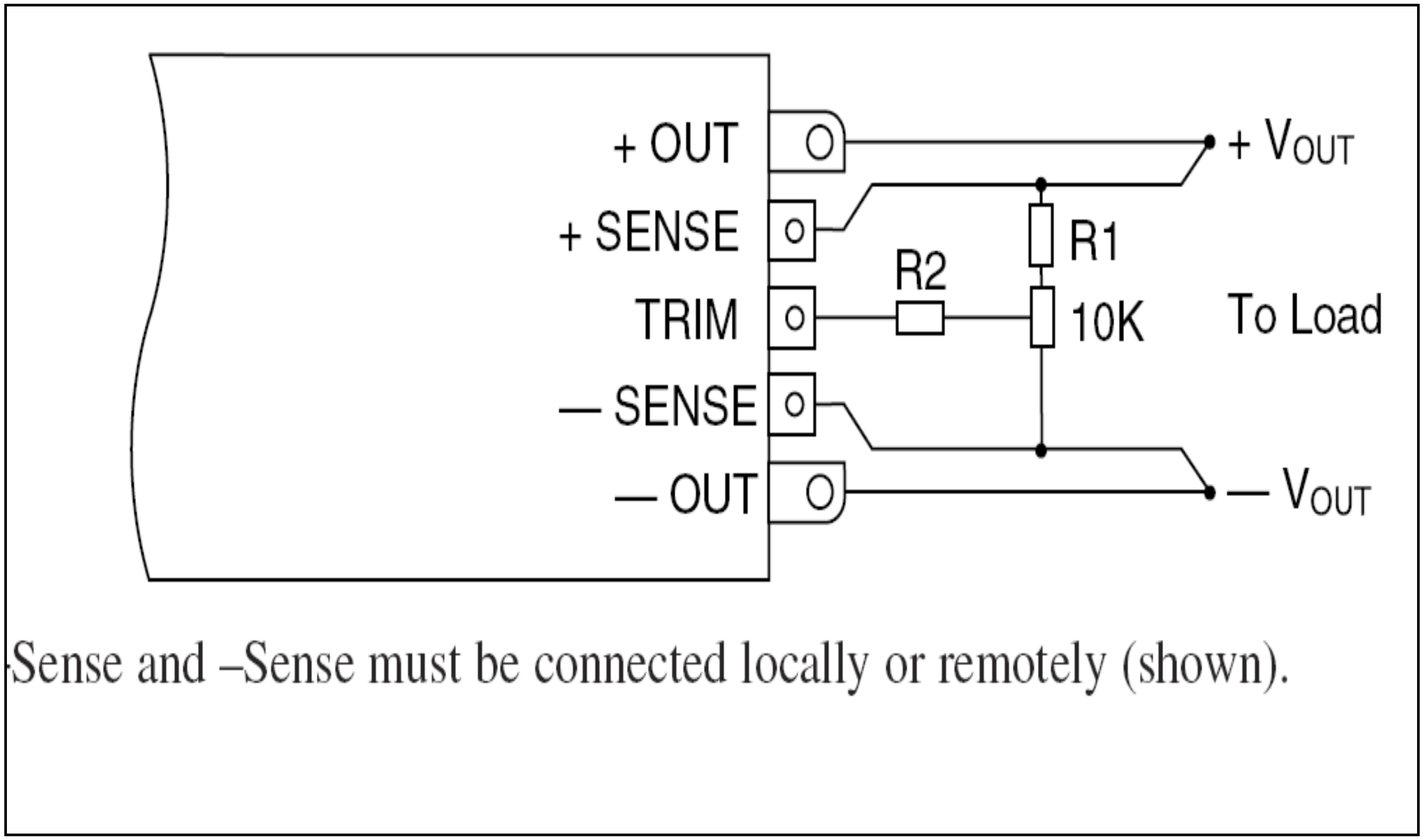


Figure: Output trimming circuit

Resistor values: R1= 90.9 KΩ
R2= 90 KΩ

System Modeling and Control…. continued

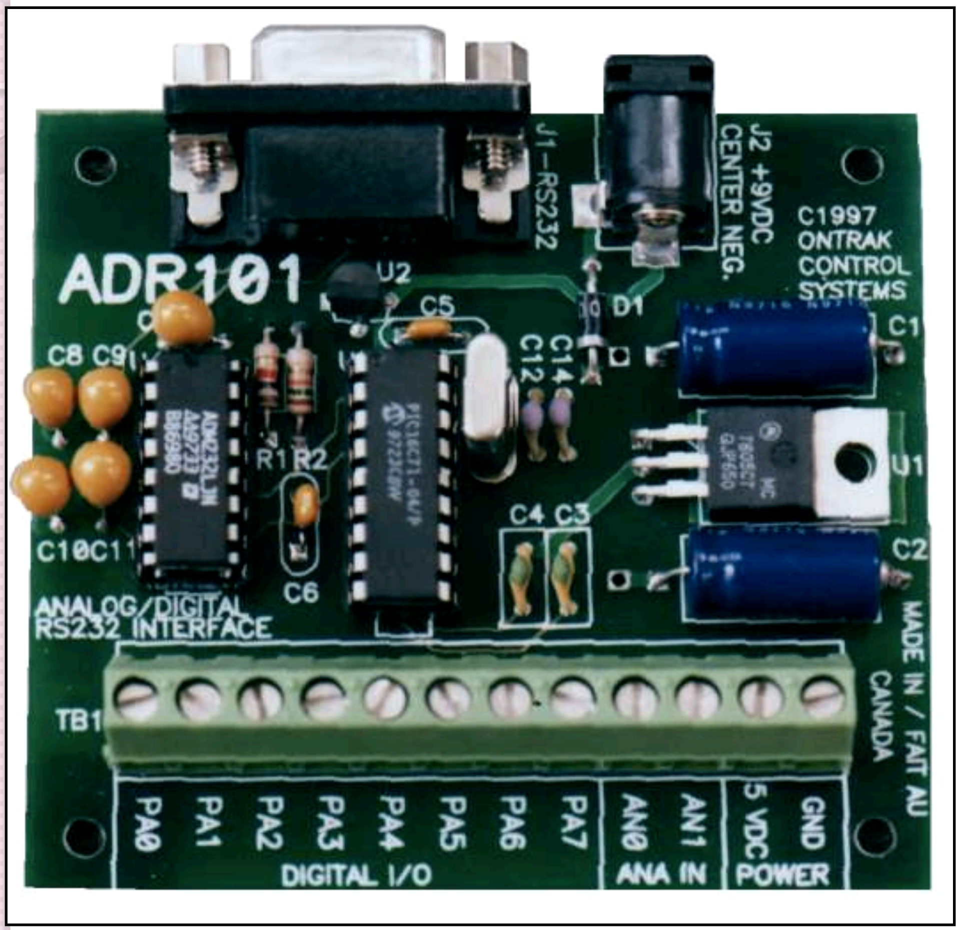


Figure: ADR101 serial data acquisition and control interface

Specification:

- 2, 8 bit analog input (0-5 VDC)
- 8 digital I/O lines individually programmable as input or output
- RS232 interface

- Easy to use with Visual BASIC or TURBO C programs

System Modeling and Control…. continued

Figure: Current transducer (LTS15-NP)

$V_{out} = 2.5 \pm (0.615 \times I_p/I_{pn})$

V_{out}=output voltage

I_P=primary current measuring range

I_{PN}=primary nominal r.m.s current

System Modeling and Control…. continued

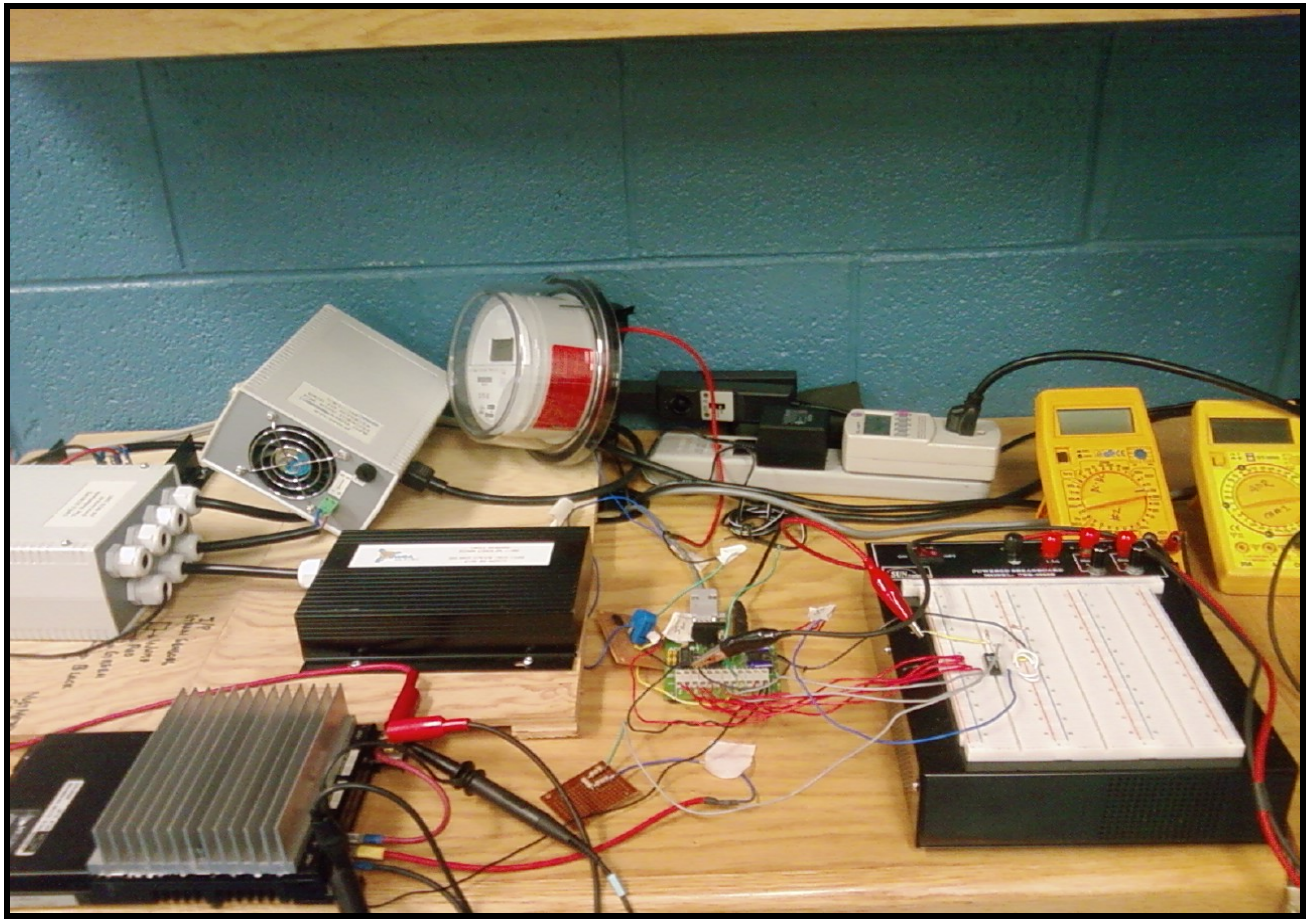


Figure: Photograph of the Remote Control of DG Instrumentation

Controller Design and Implementation

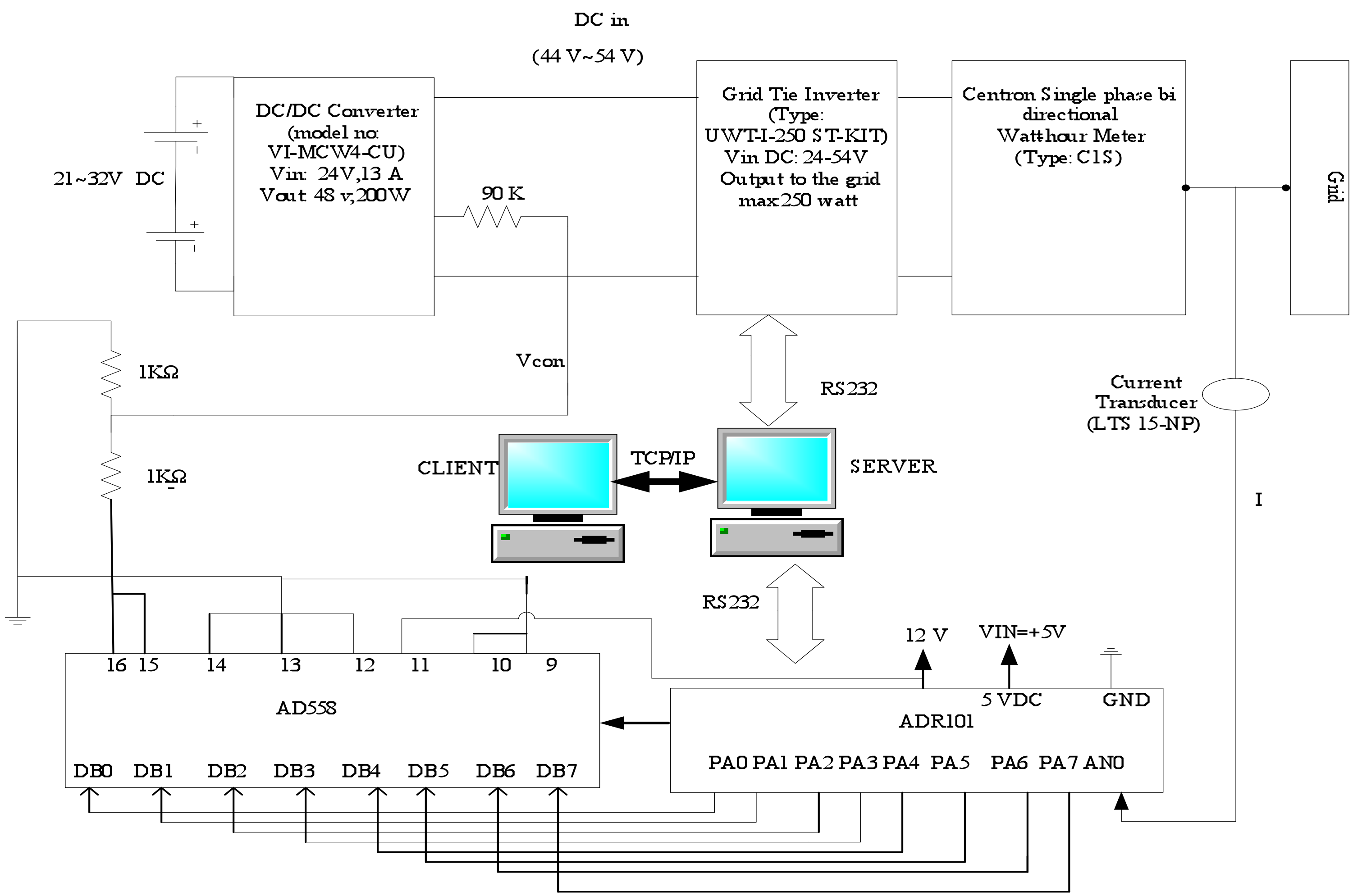


Figure: Circuit Diagram of the Proposed System

Controller Design and Implementation …. continued

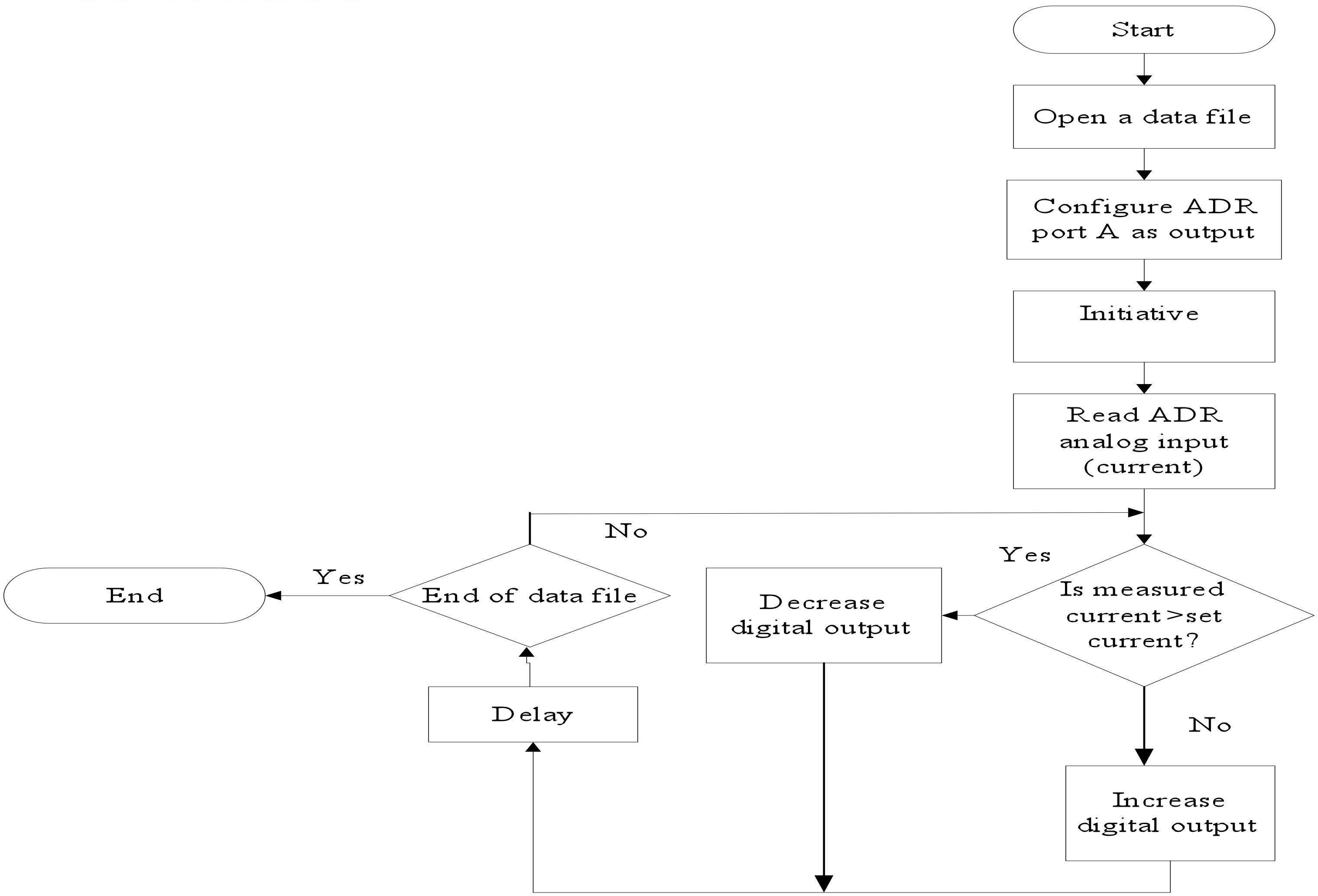


Figure: Flow Chart of the Control Algorithm

Controller Design and Implementation …. continued

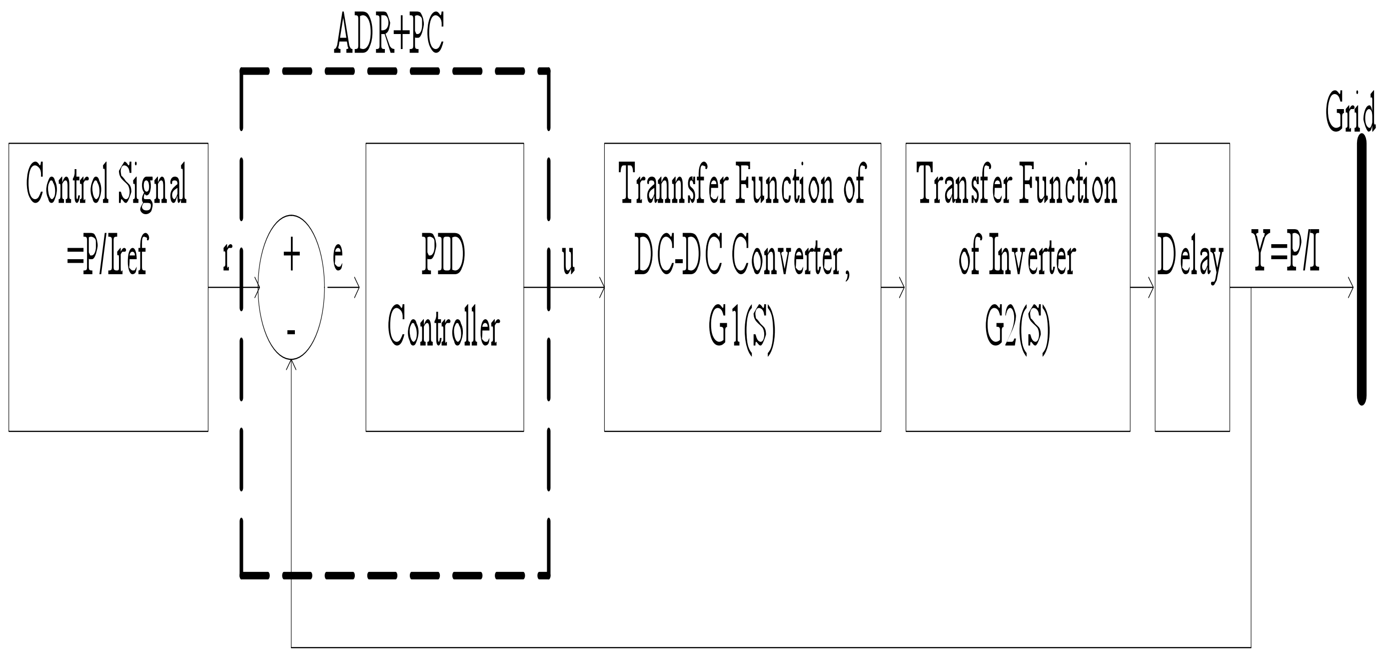


Figure: Close Loop Diagram of the Proposed Control System

Controller Design and Implementation …. continued

DC-DC converter transfer function $G_1(S) = G_{DC}/\tau_1 * S+1$

Here,

G_{DC} = DC gain for *DC-DC converter*

τ_1 = *Time constant* = 50 m.sec

= *0.05 sec*

Hence, $G_1(S) = 0.04/0.05s + 1$

Grid connected inverter transfer function $G_2(S) = G_{AC}/\tau_2 * S+1$

Here,

G_{AC} = gain for Grid connected inverter

τ_2 = time constant =180 m.sec

=*0.18 sec*

Hence, $G_2(S)$ = 0.1/0.18s + 1

Controller Design and Implementation …. continued

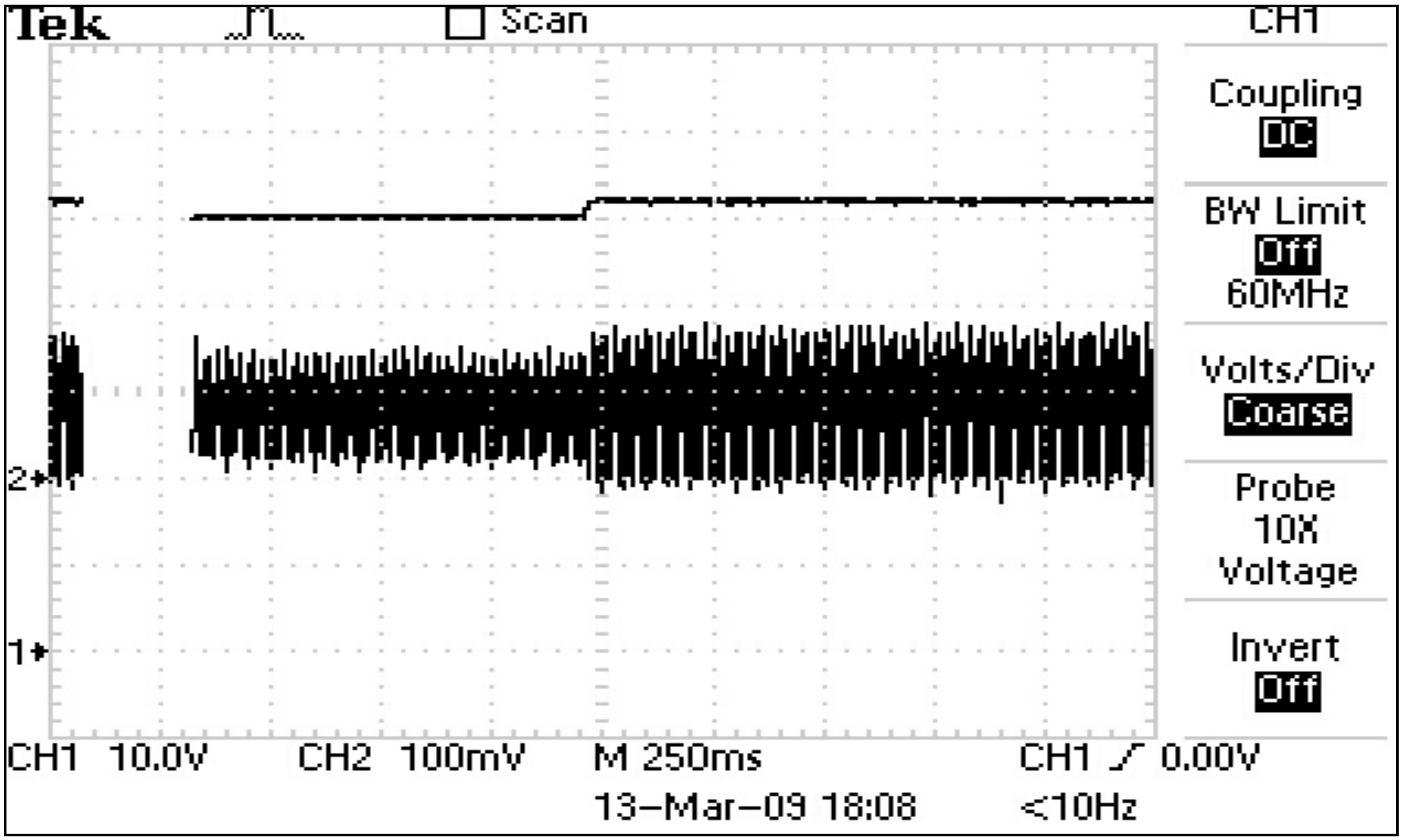


Figure: Step Response of DC-DC Converter and Current Transducer

Controller Design and Implementation …. continued

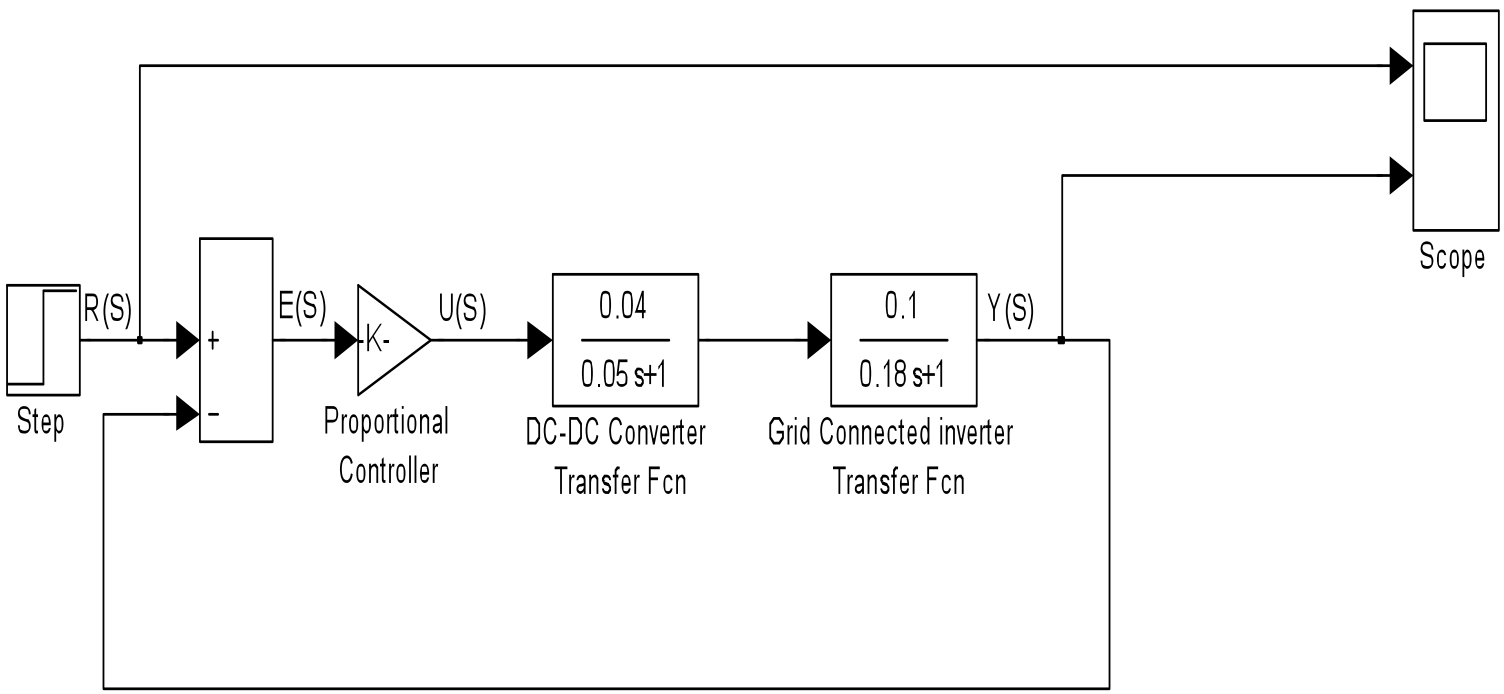


Figure: Matlab Simulink Block Diagram of the Proposed Control System

Experimental Test Results

A. Simulation Results

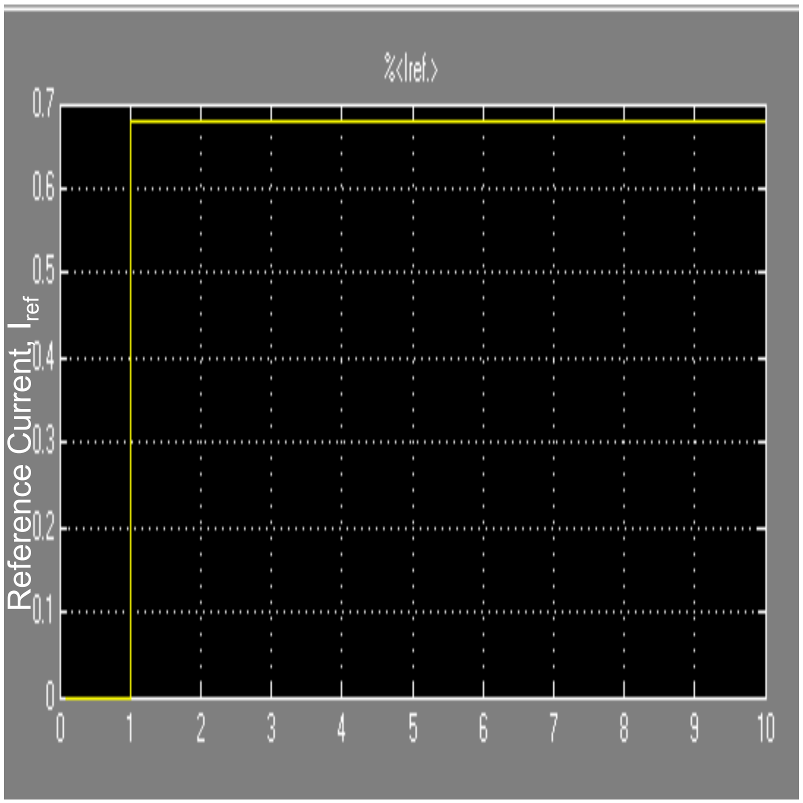


Figure: Reference Current at 0.68 amps

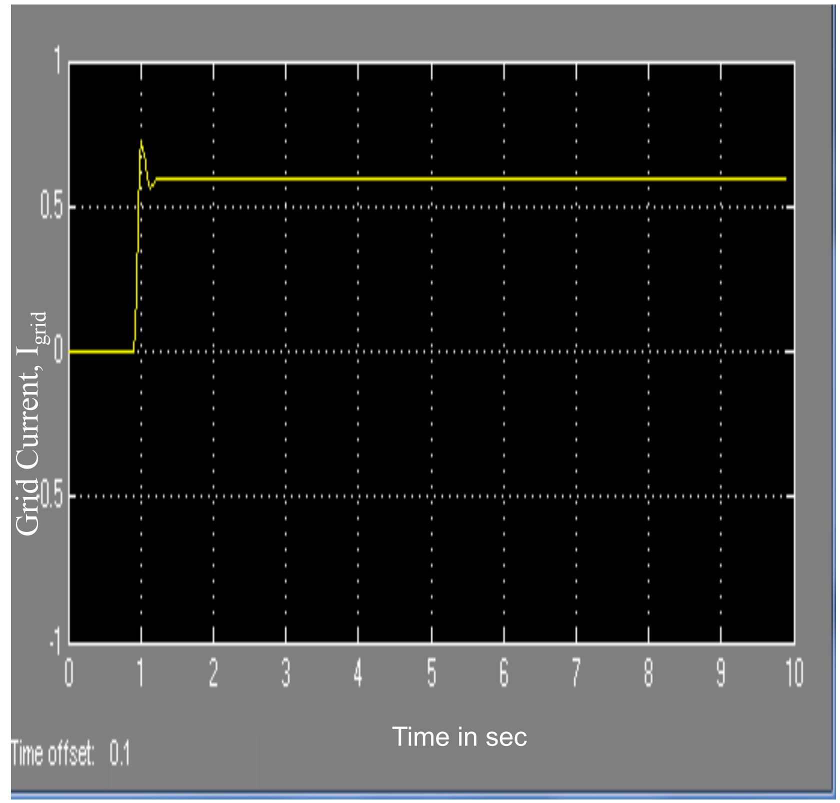


Figure: Output Grid Current of the Proposed System

Experimental Test Results .... continued

A. Simulation Results

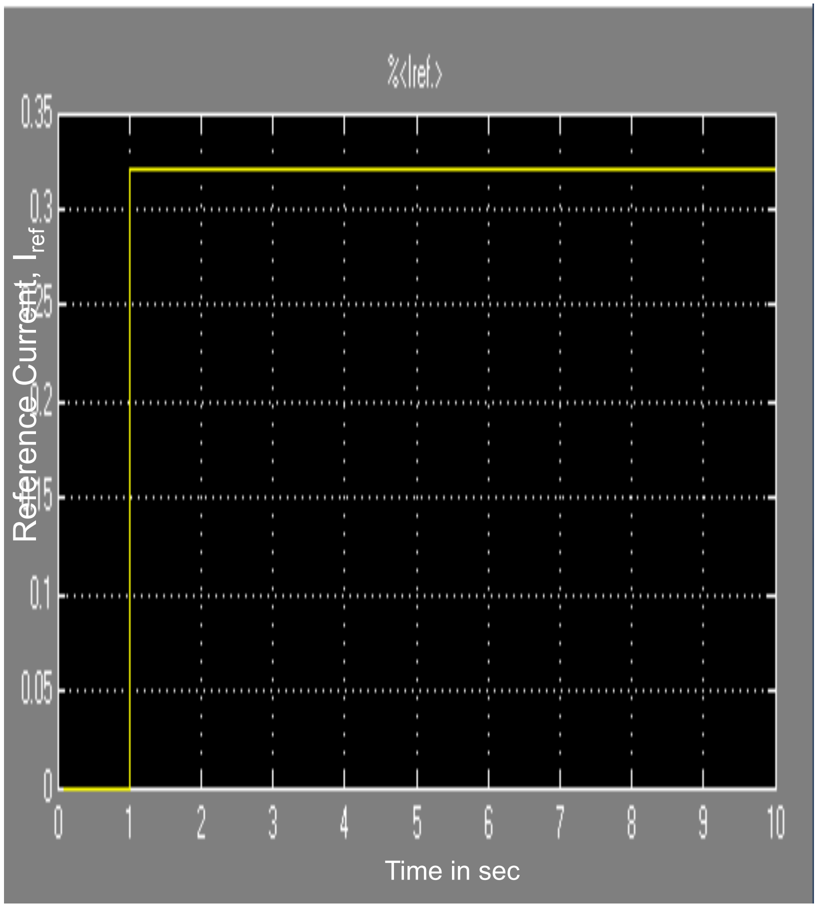


Figure: Reference Current at 0.32amps

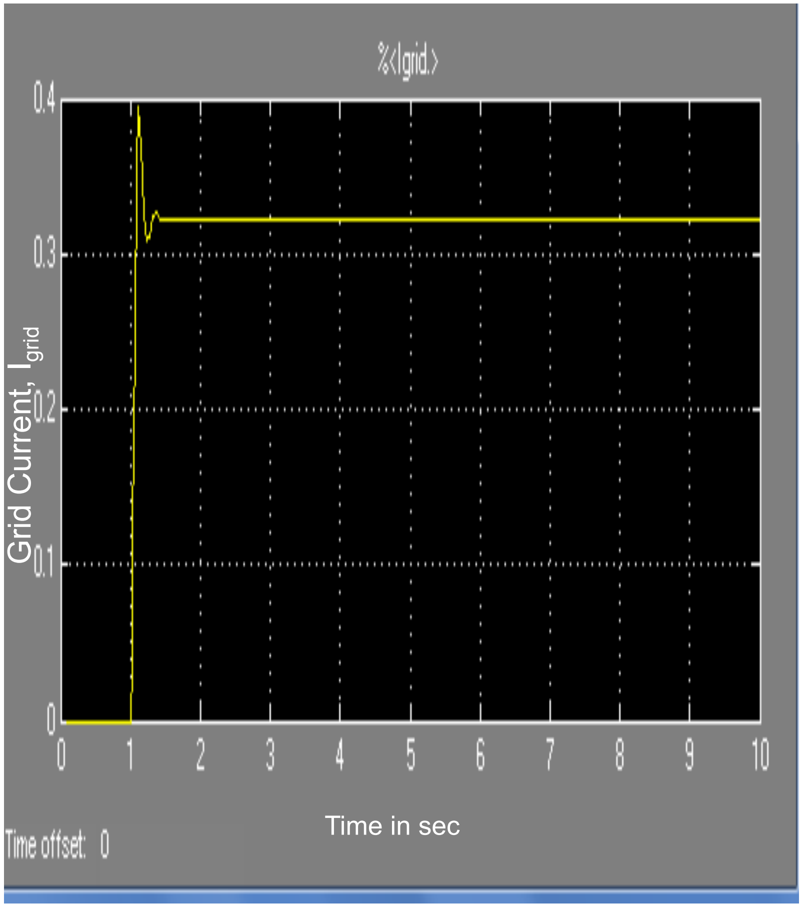


Figure: Output Grid Current

Experimental Test Results .... continued

B. Control System Test Results

Table: Experimental Test Results

Ref. Current (I_{ref})	Control Voltage (V_{con})	Grid Current (I_{Grid})	DC-DC Converter Output (V_{DC-DC})	Supplied Power to the grid (W_{Grid})	Phase Voltage (V_{AC})
0.23	1.961	0.23	47.6	27.6	120
0.32	2.941	0.32	49.5	38.4	120
0.57	3.922	0.57	51.4	68.4	120
0.68	4.902	0.68	53.3	81.6	120

Experimental Test Results .... continued

B. Control System Test Results

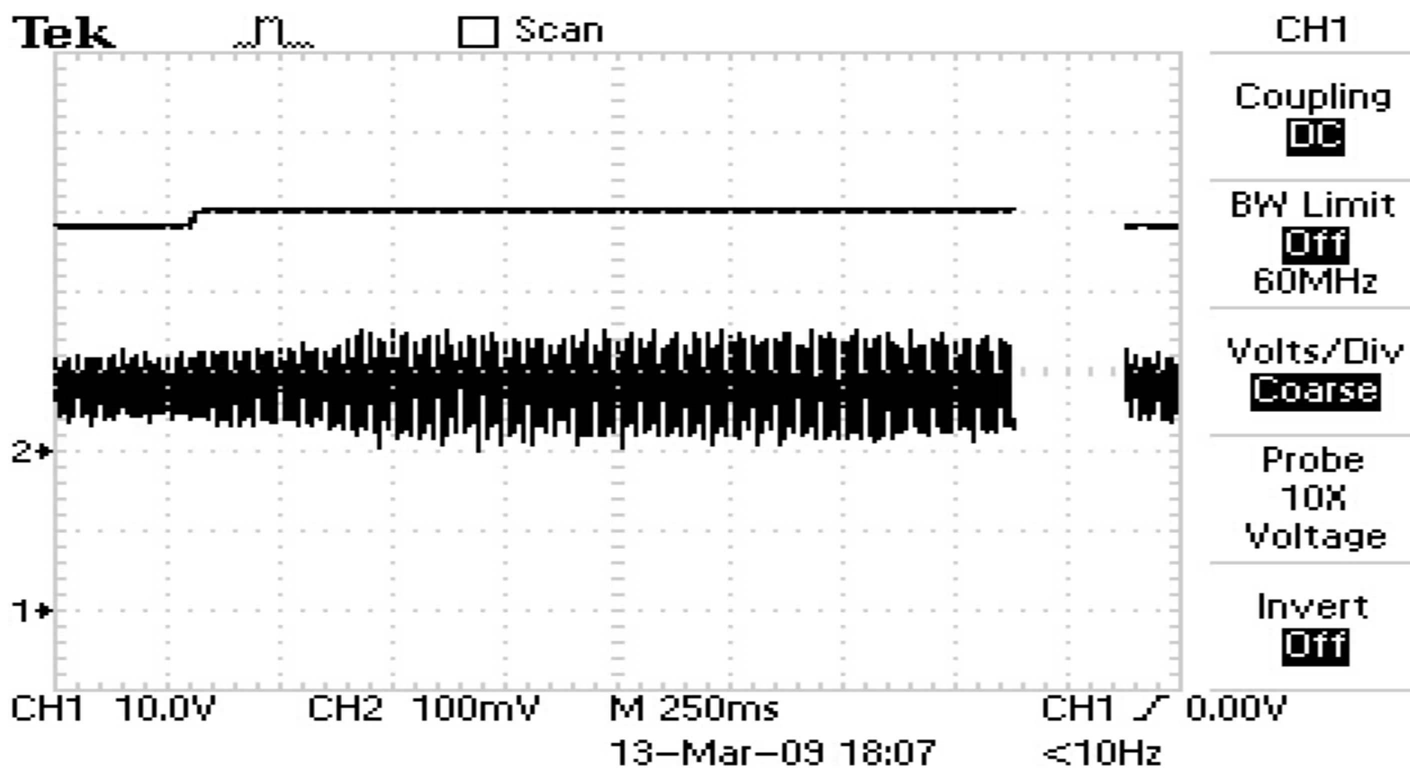


Figure: DC-DC converter and current transducer intermittent output

Experimental Test Results …. continued

B. Control System Test Results

Table : Inverter DC Input and Supplied Power to the Grid

Inverter input DC voltage $=V_{in}$	Power to the grid$=W_{out}$
47.6	27.6
49.5	38.4
51.4	68.4
53.3	81.6

Experimental Test Results .... continued

B. Control System Test Results

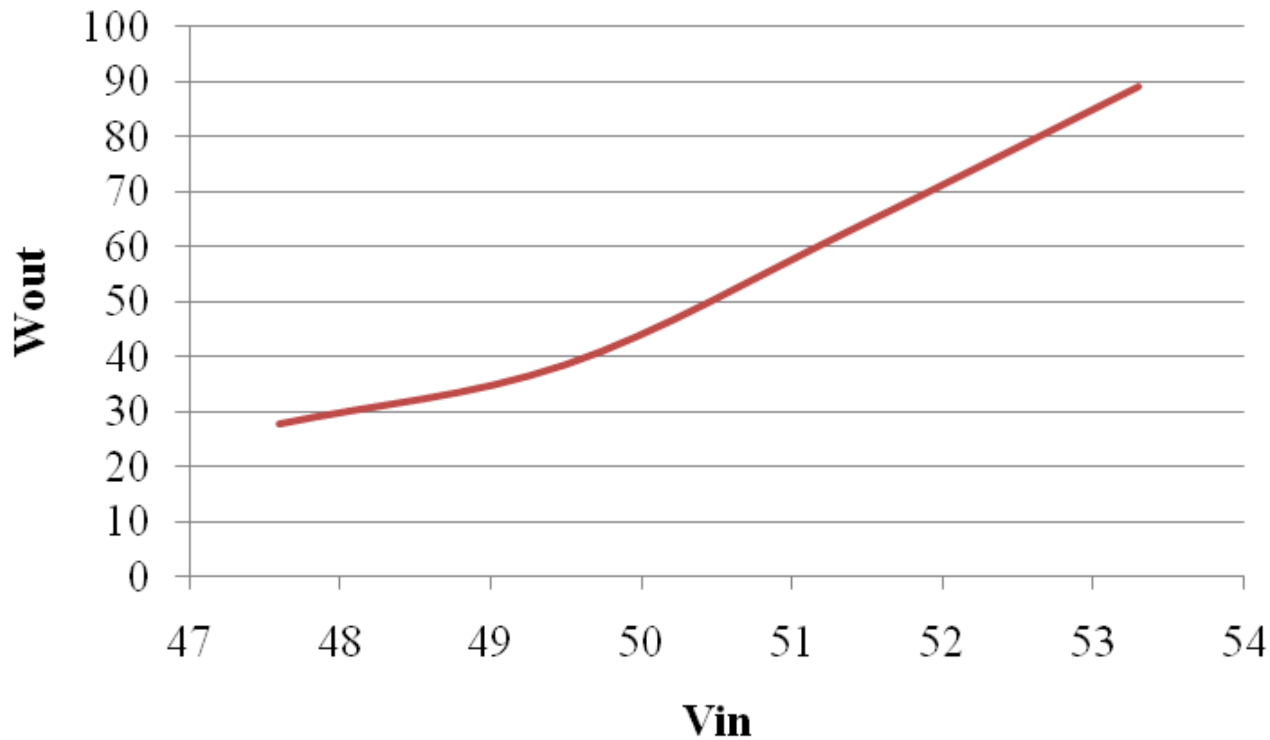


Figure: Power Curve of the Inverter

Conclusions

- The developed remote control system presented a novel remote control technique of a distributed generation system.
- A remote control system which can be used for small grid connected inverter and DG system has been designed, tested and simulated.
- Economically feasible PC based remote system was developed
- The cost of the controller was considered.
- Proportional (P) control had been applied.

Conclusions …. continued

•The Matlab simulations for the model for different reference current were implemented.

•The simulations were performed by applying P control to track a reference current

•The P control was implemented experimentally and compared to the simulation results.

Conclusions …. continued

•The proposed system has presented good performance and capability for remote power control of a small grid connected inverter.

•The illustrated technique is also capable of remotely monitoring the system performance of the grid tie inverter and power control via the Internet from a dispatch center.

•A successful implementation of this system can be used to control remotely located distributed power generation system

Recommendations

- The inverter is used only for wind turbine. Therefore to reflect the real time behavior of the wind turbine, it is very significant to add the dynamics of the wind turbine.

- Wind turbine requirements in a remote control system could make it more realistic which would be another good option to test the proposed remote control system for distributed generation system.

- In order to expand the power supply to the grid for high power applications the development of a control strategy to connect converters in parallel is required.

Recommendations …. continued

- The number of monitored variables can be upgraded to meet specific demands (for example phase current and frequency).
- The control system is needed to be investigated for grid connected inverter input voltage on over and under voltage condition.
- The control system is also needed to be further studied during abnormal frequency situation.
- The control system installation needs further improvement.

Acknowledgements

- This work has been carried out at the Faculty of Engineering & Applied Science at Memorial University of Newfoundland, Canada. It has been funded by Atlantic Innovation Fund Canada and School of Graduate Studies (SGS) of Memorial University. I am obliged to express my gratitude to those organizations providing me financial support during my course program.

- My gratitude goes to my supervisor Dr. M. Tariq Iqbal for his supervision

- I would also like to thank all the fellow members of the Centre for Instrumentation, Control and Automation (INCA), Energy system lab at Memorial University for providing a good working environment.

Publication Lists

Conference Papers

1.**Farhana Shirin**, Tariq Iqbal, "Remote Control of a Small Grid Tie Inverter", *Proceedings, Eighteenth Annual Newfoundland Electrical and Computer Engineering Conference (NECEC), November 6th, 2008,St. John's, Newfoundland.*

2.**Farhana S. Lina**, M. T. Iqbal, "Remote Control of Power Fed to the Grid in a Small Distributed Generation System", *Proceedings Canadian Conference on Electrical and Computer Engineering, May 6th, 2009 St. John's, Newfoundland.*

Dedicated to--Sarah

Thank you