

**FEASIBILITY STUDY ON SOLAR PV INTEGRATION IN TO
THE GRID CONNECTED CELLULER MOBILE
TELEPHONY BASE STATION SITES.**

Kasun Chaturanga Wijesinghe

(108895J)



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Degree of Master of Science In Electical Installations.

Department of Electrical Engineering

University of Moratuwa
Sri Lanka

2010/2011

**FEASIBILITY STUDY ON SOLAR PV INTEGRATION IN TO
THE CELLULER MOBILE TELEPHONY BASE STATION
SITES.**

Kasun Chaturanga Wijesinghe

(108895J)



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Thesis/Dissertation submitted in partial fulfillment of the requirements for the degree Master
of Science in Electrical Installations.

Department of Electrical Engineering

University of Moratuwa

Sri Lanka

March 2015

Declaration, copyright statement and the statement of the supervisor.

“I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis/dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature:

Date:



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

The above candidate has carried out research for the Masters/MPhil/PhD thesis/
Dissertation under my supervision.

Signature of the supervisor:

Date

Abstract

Price of electricity is increasing worldwide with depleting of non renewable sources in global context even true in local. In here it is proposed to integrate Solar PV in scalable on to the telecom Radio Base Stations (RBSes) on to the cabin rooftops, as a shelter to the Outdoor RBS models, and to the tower structures in a context of local telecom operators, to reduce the utility power consumption. The techno economical feasibility of Solar PV integration methodologies in to On-Grid telecom RBSes, basically in to the DC bus by rectifier systems comprising of inbuilt DC to DC converting Solar PV charger controllers or in to the A/C bus through grid tie inverter system facilitate with “Net metering” are discussed and proved its success under sites having domestic tariff rates, one of applicable tariff in to service industry apart from the rates under General Purpose 1 tariff structure. Also benchmark the tariff rates which makes 3 years of payback in each design are discussed with other possible options to inherit future green energy trends.



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

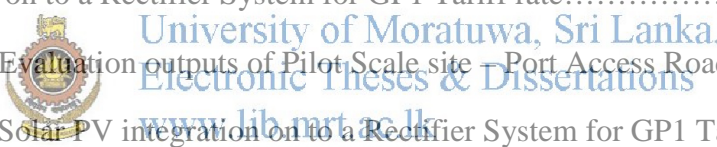
Acknowledgement

I need to convey my sincere gratitude to for Dr W.D. Asanka S Rodrigo, Senior Lecturer from Electrical Engineering Department in University of Moratuwa, Sri Lanka for directing motivating and providing the knowledge base throughout the time not confined only to this course. Also I would like to convey my sincere gratitude to all the lectures from Electrical Engineering Department in University of Moratuwa about making us as best electrical engineers to the world with best up to date knowledge. Also I would like to convey my sincere gratitude to Thusitha Dissanayake former MSc in Electrical Installations from University of Moratuwa, proving me the resource and knowledge about designing Solar PV systems and to approach industrial reference. Further I would like to convey my sincere gratitude to Mr Srijith De Silva, Owner of Power Management Technologies from Sri Lanka about providing the materials , sharing his experience to implement the trial system in Dialog Axiata PLC, and the Management of Dialog, keeping me as an interface to the industrial communications. Finally I would like to convey my sincere gratitude to my parents and family members helping me in numerous ways to help achieving my targets all the time.



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Table of Contents	Page
Abstract	1
Acknowledgement.....	2
List of Figures	4
List of Tables.....	6
Chapter 1: Introduction.....	8
1.1: Background.....	8
1.2: Motivation.....	9
1.3: Objectives.....	9
Chapter 2: Problem Statement.....	10
2.1: Problem identification.....	10
Chapter 3: Proposed Solution.....	11
3.1: Alternative energy systems for telecommunication	
Radio Base Stations.....	11
3.2: Design Parameters for Solar PV power plant.....	15
3.3: Solar PV integration methodologies in to On-Grid	
telecom RBSes.....	18
Chapter 4: Research Design.....	21
4.1: Methodology.....	21
4.2: Site categorization according to the regional	
deployments.....	22
4.3: Site categorization according to the Power Loading.....	22
4.4: Site categorization according to the applicable tariffs.....	23
4.5: Hybrid power system simulation tools for Solar PV	
integration and pay back evaluation	25
4.6: Modeling using Software.....	27
4.7: Assumptions made during simulation for Option 1.....	28
4.8: Assumptions made during simulation for Option 2.....	37

4.9:	Shading Calculations.....	45
4.10:	Payback Analysis for Option 1.....	48
4.11:	Payback Analysis for Option 2.....	51
4.12:	Net Present Value (NPV) & Internal Rate of Return (IRR) Analysis.....	54
4.13:	Sensitivity analysis of finding NPV and IRR for varying electricity tariff rates, and reduced life span in practical environmental conditions..	73
4.14:	Methodology for implementation, both Solar PV integration on to the DC bus & for Net Metering.....	80
4.15:	Benchmark the tariff rates which paybacks within acceptable time under different tariff structures.....	81
4.16:	Implementation of Pilot Scale site for Solar PV integration on to a Rectifier System for GP1 Tariff rate.....	86
4.17:	Evaluation outputs of Pilot Scale site – Port Access Road did Solar PV integration on to a Rectifier System for GP1 Tariff rate... 	90
Chapter 5:	Conclusion.....	93
5.1:	Comparison between Solar PV integration in to On-Grid Base Station, directly on to the DC bus Vs net metering system.....	93
5.2:	Advancements of Solar PV integration in to Telecom RBSes.....	97

List of figures

Number	Page
Figure 1.1.1.1: Schematic diagram of a wind-solar-diesel hybrid energy system	8
Figure 3.1.1: Sri Lankan Annual average daily total solar resources for fixed flat plate collector tilted at latitude developed (Source: National Renewable Energy Laboratory)....	12

Figure 3.1.2: Sri Lanka wind map developed (Source: National Renewable Energy Laboratory)	14
Figure 3.3.1.1: Solar PV integration in to Hybrid Controller.....	19
Figure 3.3.2.1: Solar PV integrated grid tie inverter system applicable for “Net metering”.....	19
Figure 4.6.1: HOMER preliminary information.....	27
Figure 4.7.1.1: System configuration and Solar PV data for panel size of 1kW	30
Figure 4.7.1.2: Solar resource data from NASA entered in to Homer.....	30
Figure 4.7.1.3: Daily load profile of site load of 2kW.....	31
Figure 4.7.1.4: Applicable tariff rate imposed by the utility GP1 (27 Rs/kWh).....	32
Figure 4.7.1.5: Annual output summary simulated through HOMER software of 1kW Solar PV Integration in to Rectifier System.....	32
Figure 4.7.2.1: System configuration and Solar PV data for panel size of 2kW.....	33
Figure 4.7.2.2: Annual output summary simulated through HOMER software of 2kW Solar PV Integration in to Rectifier System.....	34
Figure 4.7.3.1: System configuration and Solar PV data for panel size of 3kW.....	35
Figure 4.7.3.2: Annual output summary simulated through HOMER software of 3kW Solar PV Integration in to Rectifier System.....	36
Figure 4.8.1.1: System configuration and Solar PV data for panel size of 1kW.....	38
Figure 4.8.1.2: Solar resource data from NASA entered in to Homer.....	38
Figure 4.8.1.3: Daily load profile of site load of 2kW.....	39
Figure 4.8.1.4: Applicable tariff rate imposed by the utility GP1 (27 Rs/kWh).....	39
Figure 4.8.1.5: Annual output summary simulated through HOMER software of 1kW Solar PV integration in to Grid tie inverter system.....	40
Figure 4.8.2.1: System configuration and Solar PV data for panel size of 2kW.....	41
Figure 4.8.2.2: Annual output summary simulated through HOMER software of 2kW Solar PV	

integration to Grid tie inverter system for Net Metering.....	42
Figure 4.8.3.1: System configuration and Solar PV data for panel size of 3kW.....	43
Figure 4.8.3.2: Annual output summary simulated through HOMER software of 3kW Solar PV integration to Grid tie inverter system for Net Metering.....	44
Figure 4.9.1.1: Solar Altitude angle.....	45
Figure 4.9.1.2: Solar Azimuth angle.....	46
Figure 4.9.2.1: Sun's projection on to the tower.....	46
Figure 4.9.2.2: The Sun position angles of an each hour for every day from the month of January to December for the Latitude 6.54.....	47
Figure 4.14.1: Flow chart for both Solar PV integration on to the DC bus & for Net Metering.....	81
Figure 4.16.1: First On Grid Solar PV integrated site directly on to the DC bus of rectifier (To the Hybrid controller) on 14/10/2013.....	89
Figure 4.17.1: Current drawn from the Solar PV DC/DC charger controller module & the rectifier to the load at 3.02 p.m on 14/10/2013.....	91
Figure 4.17.3: Current output of Solar PV DC/DC charger controller during range of light intensities during between at 9 a.m. to 6 p.m. on 14/10/2013.....	92
Figure 5.2.1: Configuration of Pure Solar Power System.....	98
Figure 5.2.2: Configuration of Solar Utility (with Gen Set) for DC and DC/AC System.....	98
Figure 5.2.3: Configuration of Solar Power & Wind Power System with Horizontal and/or Vertical axis Wind Generators.....	99
Figure 5.2.4: Configuration of Hybrid Solar, Wind, Utility(Gen Set), Fuel Cells Integrated Power System.....	99

List of Tables

Number	Page
Table 4.2.1 - Site categorization according to the regional deployments.....	22
Table 4.3.1 - Site categorization according to the Power Loading.....	23
Table 4.4.1 – Applicable Tariff rates to the Telecom service sector.....	23

Table 4.4.2 - Site categorization according to the applicable tariff categories.....	24
Table 4.4.3 - Sites under Special - Site Owner imposed tariff rates.....	24
Table 4.7.1 - Monthly Averaged Radiation Incident On An Equator-Pointed Tilted Surface (kWh/m ² /day) with Latitude 6.54 and Longitude 79.50 derived from Surface meteorology and Solar Energy database by NASA.....	29
Table 4.9.2.1 - Summarized output of shading lengths due to tower.....	48
Table 4.10.1.1 - Simple Paybacks of Solar PV integrations on to Rectifier System for different tariff categories.....	50
Table 4.10.1.2 - Summarized simple payback times for Solar PV systems integrated on to the DC bus.....	51
Table 4.11.1.1 - Simple paybacks of Solar PV integration in to Grid tie inverters for Net Metering with different tariff categories.....	53
Table 4.11.1.2 - Summarized simple payback times for Solar PV systems integrated in to Grid tie inverter for Net Metering.....	54
Table 4.12.6.1- Summarized NPVs and IRRs according to the D1 and GP1 tariff rates for Solar PV systems integrated on to the DC bus.....	63
Table 4.12.12.1 - Summarized NPVs and IRRs according to the D1 and GP1 tariff rates for Solar PV systems integrated in to Grid tie inverter for Net Metering.....	72
Table 4.13.6.1 - Summarized NPVs and IRRs according to the varying electricity tariff rates for the real life span of 10 years for both Solar PV integration into DC bus and Solar PV integrated in to Grid tie inverter for Net Metering.....	80
Table 4.15.1.1- Expected tariff rates which makes 3 years of payback for Solar PV integrations on to Rectifier Systems with different capacities of array sizing.....	83
Table 4.15.2.1- Expected tariff rates which makes 3 years of payback for Solar PV integration in to Grid tie inverter for Net Metering with different capacities of arrays.....	85
Table 4.15.2.2 - Benchmarked tariff rates payback in 3 years for each Solar PV system integrated on to the DC bus vs. Grid tie inverter for Net Metering.....	86
Table 4.17.1- Actual savings from the billing proof of Port Access Road RBS.....	90
Table 5.1.1 - Summarized simple payback times for each Solar PV system capacity integrated on to the DC bus vs. Grid tie inverter for Net Metering.....	94
Table 5.1.2 - Summarized NPVs and IRRs according to the D1 and GP1 tariff rates for each Solar PV system capacity integrated on to the DC bus vs. Grid tie inverter for Net Metering.....	94
Table 5.1.3 – Comparison of Grid Connect Solar system for Net metering against DC Solar System for Rectifier DC Bus.	96