An innovative approach of Rural Electrification via DC Micro grids in Pakistan

Shahid Zulfiqar, Usman Munawar, Muhammad Bilal Javed

Abstract— The chronic and aggressively growing issues regarding global warming, environmental pollution and inversely decreasing fossil fuels. Renewable energy resources like solar energy and wind energy are best alternative resources earth possesses from its existence. This idea could specifically be implied to target rural and deserted areas where there is very limited or no electricity even in today's world. There are a lot of unprivileged areas of Pakistan that are being deprived off the transmission lines just to enlighten their homes because of the soar economic condition of their country that could not afford to provide them this basic necessity. A solution is being devised to design DC micro grid that could provide them at least enough energy to enlighten their homes which runs through solar panel. It has been improvised by keeping track of the sun's movement using Arduino board, a motor and some LDRs to attain maximum efficiency as compared to fixed mounted solar panel and urgent power supplier. By this way they could simply run their different DC loads directly without any conversion. This idea though specifically targets rural and deserted areas could bring a revolutionary change for small communities, businesses, and smart buildings because one way or the other the world has to come to renewable energy resources.

Index Terms— Smart grids, DC Micro grid, Arduino Board, LDRs, DC Loads, Energy Crisis in Pakistan, Rural Electrification.

1 INTRODUCTION

Developing countries which are in need of dire energy due to their growing economies and industries generally and Pakistan which is facing the chronic situation of energy shortfall from nearly a decade specifically, need self-sufficient, reliable and independent alternate source of energy that could provide a sigh of relief to the increasing demand of energy. But if this alternative provides a solution to the threats and dangers of environmental pollution and the emission of carbon dioxide from its industries which causes floods and hence a gigantic amount destruction almost every year like this year a few months ago and also saves a huge amount of foreign reserves in purchasing fossil fuel to produce electricity which again cause emission of carbon resulting air pollution, then this alternative would simply be regarded as best way to coup with the problems, our country faces.

Having acknowledged the issues regarding environment pollution, scarce amount fossil fuels which would not be meeting energy requirements of the world by the mid of this century, heavy cost of fossil fuels, loss of valuable foreign exchange reserves in purchasing fuel, AC based infrastructure for transmission of electricity, costs of transmission lines to the rural and sparsely populated areas need some viable solution their problems. These rural and far flung areas of south Punjab, internal Sindh, FATA, Gilgit Baltistan, Azad Kashmir and mostly undeveloped areas of Baluchistan are not even connected to the national grid system and they are not even enjoying the luxury of having electricity at their homes. Those people living in rural areas without electricity need some micro-managed system that could provide them energy to enlighten their homes. So, the key objective of this paper is to

1) Target the problems of these rural areas specifically among others and devising a mechanism to provide them independent, viable, cheap, off the national grid (zero transmission costs) energy solution to enlighten their homes by using solar panel at micro level to meet their basic needs of energy.
2) The research goal is to generate DC from solar panel and to consume that DC in the same fashion for our low voltage appliances by using the idea of DC microgrid. This would not only save 3 way conversion that is from direct current to AC and again to DC for that devices which operate at DC but it would be helpful saving significant amount of energy as well.
3) The research includes study the behavior of DC microgrid in Pakistan environment & proposed results.
4) This research paper share the outcomes of development of hardware model of DC microgrid.

The project includes the development the software such that a microcontroller is programmed in such a way that it takes input according to voltage variations and set the panel to the direction towards sun to get maximum voltages all the time.

2 LITERATURE REVIEW

2.1 2.1 BACKGRUOND

Our electrical grid was designed in a way to move centrally stationed alternating current, through HV of power conduction lines and LV distribution feeders to industries, trades & households that uses the power in AC motors, luminous lights and other Alternating current appliances. Though, all kind of DC appliances require structure's AC power converted into Direct current that is a low efficient process of using power in

- *Shahid Zulfiqar is currently Research officer in Al-Khawarizmi Institute of Computer Science, University of Engineering & Technology Lahore, Pakistan, PH-00923006804657. E-mail: shahid10EL39@ieee.org*
- *Usman Mumawar is currently senior research officer at Al-Khawarizmi Institute of Computer Science, University of Engineering & Technology Lahore, E-mail: usman.munawar.pk@ieee.org*
- *Muhammad Bilal Javed is an entrepreneur at Plan 9 incubation Pakistan.*

DC. These AC-DC conversions from centrally powered station (DC-AC-DC) result in significant energy sufferers [1]. Probable results to this problem is if we use Direct current microgrid inside building. This approach might help us eliminates completely or minimizes these low efficient rectifiers losses. In this DC micro-grid system, AC gets converted to DC when it enters the DC grid by using rectifier that have high-efficiency, which at that time supplies electricity to DC appliances. But this option which we will discuss in this paper might be applicable to those rural areas where people are disconnected to the utility grid. This method decreases AC to DC conversion losses to about from 32% to 10 percent [2]. Solar Panel installation on rooftops and distribute this DC generation from other sources could be supplied directly to DC equipment. This proposed solution can be implemented to eradicate power shortage in distant rural villages of Pakistan.

A. What actually a DC Microgrid definition?

DC micro grids could implemented in a specific section or can cover several parts of multiple buildings. That is specifically an area upon which the DC microgrid is being served while considering the deployment because an significant strategy of Direct current network at specific potential has important factor in it.

B. DC microgrid potential

The big question which arises here is that how the grid would appear if its design is improved by solar PV involvements, resulting take full advantage of productivity of all of our electrical devices? What peripheral advantages would be attained by additional speed up of these two (DC microgrid and solar photovoltaic cells) firm growing components of the electrical Power Equation? [5].So DC-powered electric appliances which today actually represent 50 percent of the electronic load in many houses. Fifty years after the advent of semiconductors in electronic devices and consumer products have become ubiquitous. Internet connectivity and computing is now involved in many devices, luminous lights are being replaced by leds and moveable electronic are appliances continuing to flourish.

Figure 2-2 A DC Microgrid for an Individual Home Courtesy: Solar Energy Industries Association (SEIA) Social Media Section [9].

It is renowned fact that the environment issues are becoming more and more aggressive by each passing day endangering even the survival of human beings in those areas which are highly affected by global warming causing floods, resulting calamity and devastation. Secondly, it is also very well known that fossil fuel reserves that our earth possess are reducing at a rapid rate and will be extinct almost by the mid of this century, already causing man to strive for alternating fuels and find out ways to keep growing economically, innovatively at a pace as today to meet the energy demands of all humankind which is also growing rapidly. The following picture will help understand the idea. This dc grid removes the complex problems of present grid system & saves cost of high T&D cost.

The similar idea could be extended for small rural communities.

Figure 2-3 A DC Microgrid for a Small Community.

C. Improvisation of Solar Panel Targeting Rural Areas.

Development of DC microgrid platform for optimized renewable energy sources and battery, with sparsely populated rural and deserted areas of Pakistan targeted specifically and furthermore, common spllications in houses like using IT, cooking food and lighten up the house. Design of DC microgrid for rural areas of Pakistan presents a practical model of solar panel.

D. Solar Potential in Pakistan

Solar Potential in Pakistan is huge. We have areas where max 9KWh/m3/day to average 5KWh/m3/day. Sun hours are average 8-11 hours. Our main focus is to harness this power.

3 FUNCTIONAL REQUIREMENTS

As demonstrated in this document, the numbering for sections upper case Arabic numerals, then upper case Arabic numerals, separated by periods. Initial paragraphs after the section title are not indented. Only the initial, introductory paragraph has a drop cap.

A- DC Microgrid

ID	Details
FR-01-001	Renewable Energy Resource: This project intends to use renewable energy resource for power generation.
FR-01-002	DC Generation: project intends to generate DC from solar panel instead of AC.
FR-01-003	Consumption: This project involves consumption of DC for different appliances.
FR-01-004	No Conversion: Generated DC would directly be consumed without conventional three-way DC-AC-DC conversion.

B- Solar Tracking

ID	Details
FR-02-001	Tracking: This project aims to follow the sun to achieve maximum efficiency.
FR-02-002	Single-axis: Project specifically designed to track sun's daily movement to attain efficiency as compared to fixed pain.
FR-02-003	Dual-axis: This project's secondary priority is to track sun's seasonal movement which is optional as mentioned in project proposal.
FR-02-004	LDR's: This project uses light dependent resistors which are to be used to track the sun's movement.

C- Running of DC Appliances

ID	Details
FR-03-001	DC Loads: This project aims to control different DC devices through microcontroller.
FR-03-002	Different DC devices: Project also intends to operate different DC devices having different operational DC voltages.

4 PROJECT DESIGN

Method that has been adopted to accomplish tasks comprises of different sections that includes project hardware, mechanical structure, project software and mechanism that includes integration of various sections.

1) Mechanical structure
2) Software
3) DC microgrid mechanism
4) Motor drive circuitry

System integration includes hardware, software and DC microgrid sections in an organized fashion to make it whole single integrated piece.

Design Description

Below are the different modules comprising of the product to be developed. It is notable here that documenting is only the about noticeable features and techniques to learn them easly in a simple way.

4.1 Module 1

Description: Mechanical structure section, which comprises of the formation of base of the project.

Details: This module is the core and first element of the project and is of mechanical type, it includes the formation of mechanical base at which the major weight of the project lies including solar panel and both the motors. This module also includes very important but delicate and challenging part which is the most appropriate position of both the motors and their fixation so that they could both be able to move the panel in both directions to track the sun all day.

4.2 Module 2

Description: Motor drive circuitry

Details: This module is also an important part of the project and is of electronic type. It includes the formation of electronic circuitry of motor drive theory which includes the power supply from battery and their handling and movement from microcontroller.

4.3 Module 3

Description: Relay circuit Board

Details: This module takes much importance too in a way that relay boards in the project are used to help with polarities of motors. Because of the relay boards motors are made to move in both the directions to track the exact position of sun.

4.4 Module 4

Description: DC microgrid phenomenon

Details: This module includes the generation DC from solar panel and its storage in the battery. Consumption of DC in the same fashion is an important part of this module. Fascinating idea of this part is that different DC devices are to be operated from the same source controlled by the microcontroller.

4.5 Module 5

Description: AC discharging

Details: This module contains the DC to AC inverter that converts direct current to alternating current so that rate of battery discharging by an AC load could be measured and could be compared with battery's discharging by a DC load.

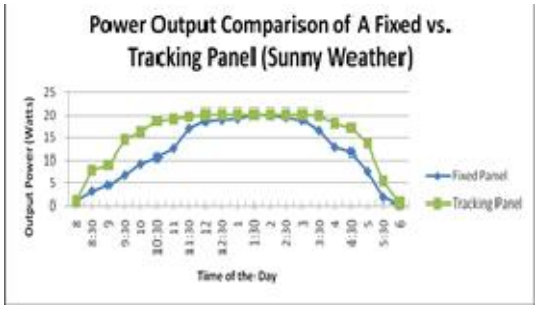
Figure 5-2 System Integration in the same order provided by the author.

5 FUNCTION TESTING

Once the system was integrated and all the errors were removed until individual module testing provided correct results, the system was tested as a whole for the above mentioned functional requirements. The results are provided in the table below:

5.1.1 Testing Requirements for Solar Tracking

Requirement Tested	CYC-LE 1	CYCL-E 2	FINAL STATUS	DETAILS
FR-02-001	Ok	Ok	Ok	The respective relays turned on turning the motors.
FR-02-002	Ok	Ok	Ok	Both left and right LDR□s detected the difference in light intensity and rotated the panel accordingly along x-axis.
FR-02-003	Failed	Ok	Ok	Weight of the panel provided more resistance to the motor than anticipated. Hence motor drew maximum current for rotation along y-axis.
FR-02-004	Ok	Ok	Ok	LDR's given a supply of 5V and output signal fed to the microcontroller which indicated correct voltage levels on LCD according to the light intensity on each of the sensors.



5.1.2 Testing Requirements for DC Microgrid

Requirement Tested	CYC-LE 1	CYCL-E 2	FINAL STATUS	Details
FR-03-001	Ok	Ok	Ok	Different DC devices were powered on and off through control signal from the microcontroller via relay switches. Also, their status was displayed constantly on the LCD.
FR-03-002	Failed	Ok	Ok	In addition to the existing fixed operational voltage devices, an additional DC power source was delivered which provided DC voltage in a fixed range.

6 RESULTS

The project was intended to optimize the output power of a solar panel using dual-axis solar tracking and at the same time to increase the backup time of the system by using DC to charge the battery and then dissipate the power through DC loads. Thorough testing of the system led us to the results which will be discussed in detail in this section.

6.1 Comparison of Fixed Panel with Solar Tracking Panel

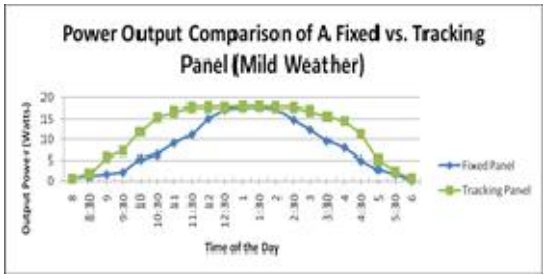


Figure 6-1 Power Output Comparison between a Fixed Panel and a Tracking Panel for a Mild Sunny Day.

The graph shows a clear difference in power output of the panel throughout the day after using the solar tracking technique. It was establish that the secure panel providing an average 42% of 20W, or 8.47W. On the other hand, the traced PV panel attained 60% productivity or 12W over same designated test time 9.5 hours. About 18% increase in average output power was obtained by simply keeping the PV panel facing the sun throughout a mild sunny day.

Figure 6-2 Power Output Comparison between a Fixed Panel and a Tracking Panel for a Bright Sunny Day.

It was observed that during bright sunny days, the solar panel was able to attain a maximum power output of 20W which was not achieved during any other days. An average output power of 11.9W was produced by the fixed pane whereas an average power of 15.4W was produced by the tracking panel thus showing an average 17% increase in power output during a bright sunny day.

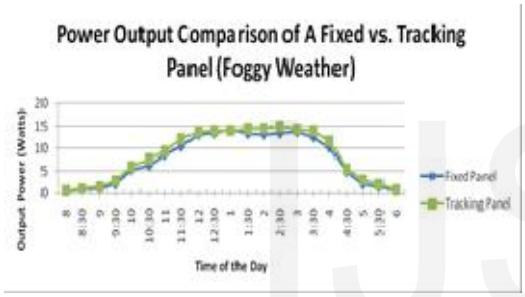


Figure 6-3 Power Output Comparison between a Fixed Panel and a Tracking Panel for a Foggy Day.

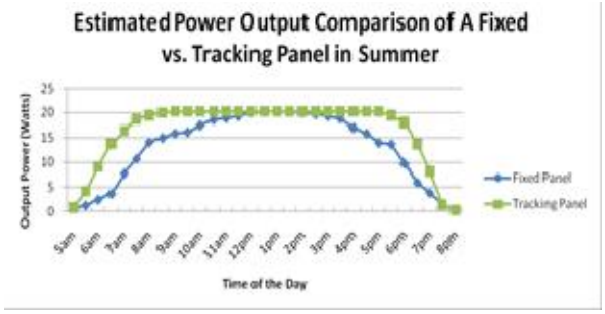


Figure 6-4 Estimated Power Output Comparison between a Fixed Panel and a Tracking Panel in summer.

Based on above readings, we were also able to predict the behavior and the power output increase that would be produced by the tracking panel during summer. This optimization of the solar panel through the dual-axis solar tracker is expected to increase the average power output up to 82% during summer.

6.2 Comparison of an AC Charged/Discharged System with a DC Microgrid

Another important objective of our project was to highlight the power consuming capacity of a system which is charged using AC power supply and dissipates energy on devices also running on AC supply, against a DC microgrid. The developed graph is show below. DC Loads runs smooth while the voltage drops quickly for AC loads.

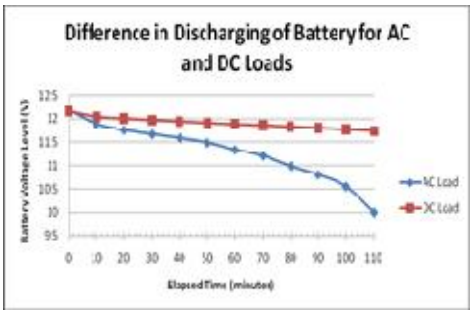


Figure 6-5 Comparison of Battery's Decreasing Voltage Levels for AC and DC Loads.

7 CONCLUSIONS & FUTURE WORK

The greater issues like global warming, environmental pollution and exponential decay and decrease in fossil fuels while the energy demand curve growing rapidly, very long electricity transmission lines, its infrastructure and cost, its impact on economy and considerable amount of electrical losses coerced humanity to think about alternative resources that could meet present and future energy demands. Renewable energy resources like solar energy and wind energy are best alternative resources earth possesses from its existence.

This idea has specifically been investigated to target rural and deserted areas where there is very limited or no electricity even in today's world. It has been improvised by following the sun's movement to attain maximum efficiency as compared to fixed mounted solar panel and urgent power supplier. By this way they could simply run their different DC devices directly without any conventional conversions. This idea though specifically targets rural and deserted areas could bring a revolutionary change for small communities, businesses, and smart buildings because one way or the other the world has to bow to renewable energy resources. Generally, existing method generates DC from solar, converted to AC to transfer it national grid and then converted back to DC for our home appliances. The design of DC microgrid provides the solution to generate DC and consume in the same fashion for Dc appliances, resulting saving huge amount of transmission infrastructure, averting significant amount of electricity conversion losses by giving a positive impact to the economy and to lives of rural and deserted areas.

Some of the ideas for future development are mentioned below:

7.1 Smart buildings

The idea of DC microgrid could be extended to make individual houses, commercial buildings like university campuses, banks, schools and hospitals independent, off the grid and self-sufficient. The following picture illustrates the net zero building model

(buildings that produce as much energy as they consume).

Figure 7-1 Net Zero Energy Building Model

7.1 Solar tree

Another innovative idea is of solar tree. A tree that has solar panels and would be deployed in public parks and other public places which would provide cool shadow to its passers-by in summer, would provide free energy to fire up their mobiles laptops and other portable DC appliances. This tree would also provide free WIFI to connect to the world and cool water to drink in summer and hot water in winter. A solar tree that powers your smartphone, gives you free Wi-Fi, cold water - and a place to rest in the shade. This concept could soon be real in public parks.

Figure 7-2 A Solar Tree

8 REFERENCES

[1] "DC Microgrids: Benefits and Barriers" by Paul Savage, Robert R. Nordhaus, and Sean P. Jamieson1. May 2011.

[2] "Solar Tracking System": More Efficient use of Solar Panels" by J. Rizk and Y. Chaiko. Nov 5, 2008.

[3] M. Serhan and L. El-Chaar, "Two Axes Sun Tracking System: Comparison with a fixed System", International Conference on Renewable Energies and Power Quality (ICREPQ'10), March 2010.

[4] Emerge Alliance organisation (n.d) Retrieved August 23, 2014 from http://www.emergealliance.org

[5] Report of International Energy Agency at (per capital consumption and energy use by appliance), available at http://www.iea.org/papers/2005/AIXGapplianceenergyeff_TG.pdf (last visited April 15, 2010); 2007 Energy. Information Administration Estimate, available at http://www.eia.doe.gov/emeu/rec/contents.html (last visited April 15, 2010)

[6] Energy Independence and Security (Act of 2007) Retrieved September 23, 2014 from http://www.wikipedia.org/energy-independence-security.

[7] There followed seven "Points of Varying Agreement", and a survey of who was doing what with microgrids at that time; survey available at http://www.electricdistribution.ctc.com/pdfs/Microgrid_Vision_Workshop_Presentation.pdf (last visited March 15, 2010).

[8] See (public) Executive Summary of 1.0 version the standard, available at http://www.emergealliance.org (last visited March 22, 2010).

[9] Solar Energy Idustries Association (n.d) Retrieved September 7, 2014 from http://www.seia.org/

[10] Asmarashid Ponniran, Ammar Hashim, and Handy Ali Munir, "A Design of Single Axis Sun Tracking System", the 5th International Power Engineering and Optimization Conference (PEOCO2011), June 2011.

[11] David Cooke, "Single vs. Dual Axis Solar Tracking", Alternate Energy e Magazine, April 2011

[12] Tiberiu TUDORACHE, Constantin Daniel OANCEA and Liviu KREINDLER, "Performance Evaluation of A Solar Tracking PV Panel", U.P.B. Sci. Bull., Series C, Vol.74, Iss. 1, 2012

[13] Comparison of Efficiencies of Single-Axis Tracking System and Dual-Axis Tracking System with Fixed Mount. International Journal of Engineering Science and Innovative Technology (IJESIT) Volume 2, Issue 2, March 2013.

[14] Nader Barsoum, "Fabrication of Dual-Axis Solar Tracking Controller Project", Intelligent Control and Automation 2011, 2, 57-68.

[15] The Guardian (2014, September 28) Solar-energy-sunflower-ibm-airlight electricity, Retrieved October 11, 2014 from http://www.theguardian.com/environment.

[16] Antel (n.d) Retrieved November 19, 2014 from http://antel.hk/product2.asp?CID1=39&CID2=261

[17] Data Sheet Catalog (n.d) Retrieved October 9, 2014 from http://www.datasheetcatalog.com

[18] Future Technology (n.d) Retrieved November 17, 2014 from http://www.futurlec.com/ Capacitors.

[19] Engineers Garage (n.d) Retrieved December 3, 2014 from http://www.engineersgarage.com /electronic-components/16x2-lcd-module-datasheet

[20] Man Tech Zone (n.d) Retrieved November 15, 2014 from http://www.mantech.co.za/datasheets/ products/A000047.pdf

[21] G. Foley, Rural electrification in the developing world Energy Policy, 20 (2) (1992), pp. 145–152

[22] Chaurey, A. and T. C. Kandpal "Assessment and evaluation of PV based decentralized rural electrification: An overview." Renewable and Sustainable Energy Reviews 14(8): 2266-2278.