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"Solar PV based Scalable DC Microgrid Design and Simulation for Rural Electrification"

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***Abstract*— A smart grid refers to a new and innovative system of electrical distribution that has the ability to manage and control information and power generation. It is capable of using different power sources to get the energy needed. The smart grid is also capable to store the produced energy that was not used by the consumer. What makes the smart grid really innovative is the shift that one can notice between the old grid and the new one. A smart grid relies more on a two-way communication system between the power supplier and the power consumer. Here the power supplier will produce energy using different energy sources (solar, wind power) based on the information got from the power consumer. Based on REN21's report (2016), renewable sources contributed 19.2% to humans' international energy consumption and 23.7% to their generation of electricity in 2014 and 2015, annually. This energy consumption is split as 8.9% returning from ancient biomass, 4.2% as energy (modern biomass, energy and solar heat), 3.9% hydroelectricity and 2.2% is electricity from wind, solar, geothermal, and biomass.**

Keywords- Solar PV based Scalable DC Micro grid Design, Power quality issues, MATLAB simulation.

I. INTRODUCTION

By 2035, the population of the world is supposed to increase by almost 1.5 billion which will make the population reach 8.8 billion people. This increase in the population will cause two things. The first one is an increase of the demand on energies. The demand on energies will cause the decrease of fossil fuels resources and the increase of CO2 emissions to reach approximately 39 billion tones by 2035. The second one is creating issues related to power grids which can be resumed to:

- Congestion : The components of the power grids are old and cannot satisfy the demand for a growing population
- Security, protection, transmission losses and losses due to the gap between production and consumption.
- Problems emerge when the power grids are far from where the power is needed.

The energy that is collected from renewable resources is called renewable energy, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable energy provides energy in four areas like: electricity generation, air and water heating/cooling, transportation, and rural (off-grid) energy services.

Based on REN21's report (2016), renewable sources contributed 19.2% to humans' international energy consumption and 23.7% to their generation of electricity in 2014 and 2015, annually. This energy consumption is split as 8.9% returning from ancient biomass, 4.2% as energy (modern biomass, energy and solar heat), and 3.9% hydroelectricity and2.2% is electricity from wind, solar, geothermal, and biomass. Worldwide investments in renewable technologies amounted to quite US $286 billion in 2015, by countries like China and also U.S. in wind, hydro, solar and bio-fuels. Globally, there are 7.7 million jobs related to the renewable energy industries, with solar photovoltaic being the most important renewable employer. As of 2015,

quite half of all new electricity capability globally installed was renewable. Sustainable power source springs from common procedures that are recharged never endingly. In its differed shapes, it gets directly from the sun, or from warmth produced profound among the planet. Encased inside the definition is power and warmth created from sunlight, wind, sea, hydro power, and biomass based energy assets, and bio-powers and substance component got from sustainable assets. Sustainable power source assets are crucial open doors for energy intensity existing over wide and territories, in qualification to energy source options that are engaged in an exceptionally limited scope of states. Prior to the era of coal during 19th century, almost all energy used was renewably produced. Not a wonder, the oldest famous use of renewable energy within the ancient style was biomass to fuel fires, dates from 790,000 years past. Use of biomass for fireplace failed to become commonplace till several many thousands of years later, someday between 200,000 and 400,000 years past. Most likely the second oldest usage of renewable energy is harnessing the wind so as to drive ships over water. This observation may be derived back from 7000 years, to ships on the river in the time of recorded history. The first sources of ancient renewable energy were human labor, animal power, water power, grain crushing windmills, conventional biomass. A graph of energy use within the US until 1900 shows oil and fossil fuel had identical importance in 1900 as wind and solar had in 2010.

A smart grid refers to a new and innovative system of electrical distribution that has the ability to manage and control information and power generation. It is capable of using different power sources to get the energy needed. The smart grid is also capable to store the produced energy that• was not used by the consumer. What makes the smart grid really innovative is the shift that one can notice between the old grid and the new one. A smart grid relies more on a two-way communication system between the power supplier and the power consumer. Here the power supplier will produce energy using different energy sources (solar, wind power) based on the information got from the power consumer.

One can notice the difference compared to the old grid where a hierarchical system was followed, i.e. the power producers continue to produce energy even if the demand was met.

The advantages of the smart grid can be summarized to:

1. **Adaptive**: consumer needs and changing conditions.
2. **Predictive**: when it comes to power outages.
3. **Integrated and Interactive**: communication between producer and consumer.
4. **Optimized**: increase efficiency, reliability and economic performance.
5. **Environment friendly**: large use of RE Secure: less disruptions.

II. FORMULATION PROPOSED WORK

Component of Micro grid

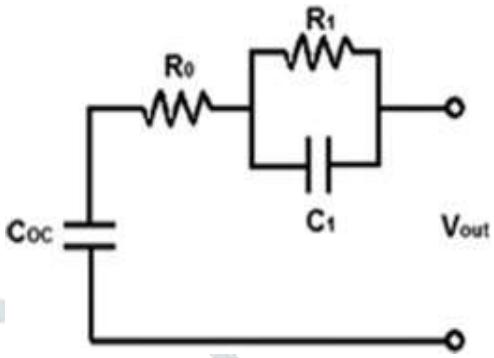
The micro grid, which is considered to be the "building block of smart grid", is combination of many components which are: distributed energy resources (DERs) such as PV and wind turbines, inverters, storage devices such as batteries, and loads (luu).

Battery Mathematical Model

Many parameters such as the nominal voltage and the total capacity are used in order to describe the battery. The most important one is the state of charge (SOC) which corresponds to a value of 0% when the battery in not charged (empty) and to a value of 100% when it is fully charged invertors that transform the DC obtained from solar power to AC ready to be used.

Photo-Voltaic Cell

A PV system or a solar panel is one of the most used sources of renewable energies. It relies on sun rays to generate electricity and is made up of several solar cells made from silicon and protected by layers of glass. PV systems contain

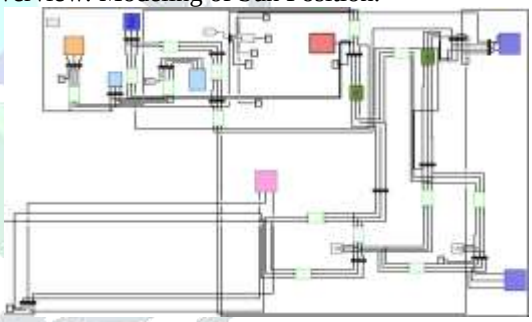


invertors that transform the DC obtained from solar power to AC ready to be used.

III. RESEARCH METHODOLOGY/PLANNING OF WORK

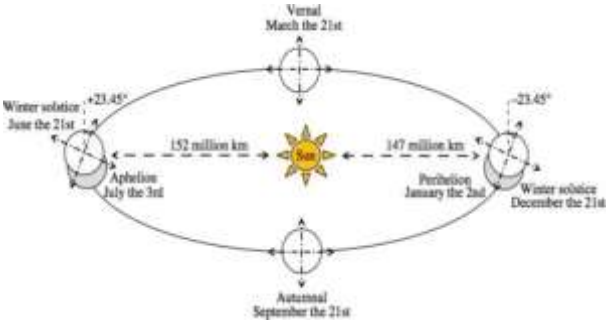
The proposed work is planned to be carried out in the following manner:

Overview: Modeling of Sun Position.

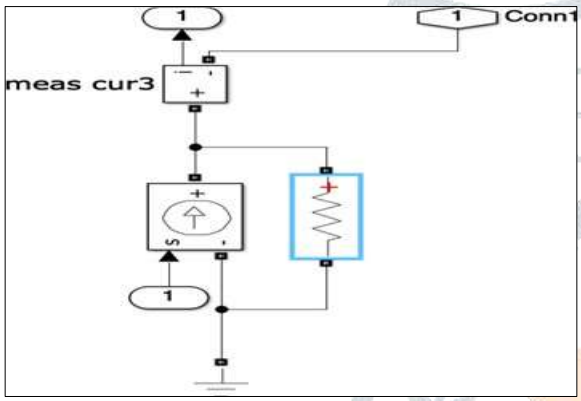


Solar energy is nothing but the share of the Sun's radiant light and that reaches the surface of the Earth and is available there for different application of energy generation. In other words, it consists of converting the energy form emerging from the Sun into more valuable and beneficial applications. For example, this can be achieved by exciting the electrons in photovoltaic cells, photosynthesis which is one of the natural energy supply processes, or by warming objects. This energy is free, unpolluted and available in very large quantities in most places on Earth during the whole year. This energy is more useful during the times fossil fuel costs are high and significant atmosphere degradation caused by the high usage of these fossil fuels is notices. Solar energy that is carried on solar radiations consists of two parts. The first one is extraterrestrial solar radiation which is available above the atmosphere, and the second one is the global solar radiation which is available below the atmosphere. Besides, the values of solar radiations being measured can be exploited to develop solar radiation models describing mathematical relationships between the meteorological variables including sunshine ration, humidity and temperature, and solar radiation. These models are mainly

Solar Panel



Sunlight is needed to get energy from the solar panel, so the two most important parameters that need to be provided are: irradiance and temperature. Module performance is generally rated under standard test conditions (STC): irradiance of 1,000 W/m2, solar spectrum of AM 1.5 and module temperature at 25oC. Once they are given we can obtain the generation profile. It is shown in the plot bellow:



Design and implantation

More than half of the world is still in need of electrification. Most of these areas are far away from the grid and are in a location where it is impossible for the grid to penetrate. Due to this the growth of these areas is substantially affected. This problem can be solved by employing DC (Direct Current) off grid systems according to the needs of these places. The main advantage of employing a DC off grid system is that it can be powered by renewable energy sources directly.

This is a good opportunity to initiate the use of renewable energy technologies in areas where the grid cannot penetrate. As most of the basic appliances like lights, cell phone chargers etc., consume DC it will be easy to incorporate renewable energy technologies like solar PV, wind turbines and fuel cells. The storage batteries used in these kinds of systems also require DC for charging. So the off grid DC micro grid will be suitable for rural areas where grid connection is hard to reach. The DC micro grid and mini grid systems are gaining more and more importance in recent days. Research is being done in this area by developed countries to bring about a change in the electrification of buildings. The DC mini grid is seen as a viable alternative for the existing AC electrification network due to its advantages. DC electrification is not only considered for rural areas but also for urban buildings as well. DC electrification is not a new idea as it was in usage before the arrival of AC as the electrical load was DC back in the old days. The arrival of complex appliances like air conditioning, AC (Alternative Current) motors and long-range power transmission influenced the use of AC electrification. There is a steady increase in the appliances that work on DC and more and more are being invented. Most electronic appliances that we use today such as laptops, computers, TV etc. require DC for their working. These appliances draw AC and convert it to low voltage DC through the adaptors provided for these appliances. This conversion can be avoided if the electrification is DC. Most of the appliances in our daily life consume DC, for example, light bulbs which are in use for a long time. Due to the technological advancements, we now have LED lights, which work by converting AC to DC with a sufficient working voltage. One of the major issues in converting AC to DC is the power loss associated with it. Due to these disadvantages the DC electricity network and mini grid are seen as a viable option to replace AC grid and electrification in developing regions. A micro grid (MG) can be defined as a group of renewable energy sources and energy storage devices controlled by a monitoring system to provide power to the loads for which it is designed the energy source may or may not include the local utility grid. A micro grid can be seen as a smaller version of the traditional power grids. The consortium of Electric Reliability Technology Solutions (CERT) describes the concept of a micro grid as an aggregation of loads and micro sources operating as a single system providing both power and heat. A micro grid consists of power generators, distribution and control systems for voltage regulation just like a conventional grid. However, the main difference between the conventional grid and the micro grid is the close proximity between the power generation and the end users. In recent years micro grids have gained a lot of attention due to the advancements in renewable energy technologies. 2.. The diesel generators can be used as a backup power supply or as a regular power source running parallel to the renewable energy sources (RES). The control system denoted is used as a means to regulate the power from various sources to the load.

- A solar PV module can be described as an arrangement of solar cells in series and parallel enclosed in protective casing. The solar cells are stacked in series and parallel to generate a notable amount of power. A solar cell is a device, which converts sunlight into electrical energy. It can be described as a silicon (or other material) PN junction diode. A single solar cell generates a voltage of 0.5 to 0.8V depending on the technology with which it is made of. Matlab/Simulink is a platform where any component can be modeled using its respective mathematical expressions. The first method is by modeling the component using mathematical equations of the chosen component. In this case the mathematical expression of a solar cell.
The solar cell is represented by its output current in its mathematical equation.

- The next method is to use the library block of Simpower systems, where a PV array can be modeled by grouping PV modules according to the required power output.

- The third method is to make use of the solar cell block from simelectronics library. The difference between this method and the first is that in this method the solar cell block already contains the mathematical expression.

IV. FACILITIES REQUIRED FOR PROPOSED WORK

- Photo-Voltaic Cell
- Rectifier
- Inverter
- Converter
- Storage
- Battery
- DC Controller

V. CONCLUSION

DC Micro grid is preferred if more components are directly DC compatible. For that particular system, it is possible to reduce the dump load size and also improved efficiency by removing all types of converters. Examples of DC compatible components are LED lights, TV, laptop, mobile charger etc. DC micro grids are cheaper in cost. AC Micro grid is preferred when Micro grid directly connected to the grid here no dump load is required. Micro grids are expensive due to inverters. The main advantage with AC Micro grids is expandable and efficient.

This master thesis helps to encourage further study of individuals in the renewable energy system. The worldwide prospect is to reduce fossil energy supply. It is one of the important issues in present days. By using renewable energy sources; if the energy produced locally it would result in a build of the Micro grid in the region as well as reduced transmission losses i.e. energy produced and used locally. Local pollution can also be lowered and in a wider perspective, since the electric power-grid is connected throughout many countries with a common trade system, it can also help to reduce the pollution globally. It is also the prospect for this thesis to spread knowledge to individuals how the system parts work and how to choose a proper wind turbine generator the best way possible.

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