ENERGY MANAGEMENT IN GRID CONNECTED PV SYSTEM

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ABSTRACT

Excessive energy use leads to an imbalance between power generated and consumed, which is one of the main problems facing the Indian power grid system. Customers' comfort levels decline as a result of the utility's introduction of power outages and time-of-use billing techniques to control usage. This research proposes a smart control device design for the effective utilisation of stored renewable energy. There are several facets to the suggested system. First, user consumption data is gathered and analysed using the suggested system. The system decides which power source to make accessible based on the data: either grid electricity or renewable power from a battery. Additionally, the system determines how much power needs to be kept in a storage device. Furthermore, in the event of a power outage or breakdown, the system has the ability to determine who should be given priority in order to continue receiving power. We replicated some of the fundamental system functions, such as the ability to change the power source in response to peak hours, user use, and remaining battery life. The outcomes demonstrate a decrease in reliance on grid power and the achievement of service continuity through device priority setting. According to our findings, vital equipment can continue to function even in the event of a power outage, and power dependency on the grid can be decreased to 70–80% during peak hours.

1.INTRODUCTION

The electricity system in India continues to supply power using the original design, despite the fact that it was created to meet simple, localised demands. To account for the existing and projected expansion in India's power supply need, the original approach needs to be reconsidered given the country's size and growth in demand. Utilities use electromechanical relays on the distribution side, which are not a direct, efficient or even effective way to locate line issues. Currently, detecting line faults takes a lot of time and labour. Only "Power Grid Corporation of India Ltd." Company owns and operates approximately 98,367 ckt km of transmission lines, making up a negligible portion of all electricity lines in India that need to be attended to [1]. The enormous burden of detecting line faults calls for a more workable solution, and WSN and renewable energy sources have the ability to reduce costs and offset India's projected future expansion in electrical demand. India's electrical sector has installed a total of 211.766GW of electricity as of January 2013, of which 88.55% came from non-renewable power plants and 11.55% from renewable power plants. Even in this recent past, there hasn't been much forethought in this regard [2]. India is dependent on foreign energy sources due to a lack of investment in renewable energy. Furthermore, as of December 2011, over 300 million Indians—roughly one-third of the country's rural and 6% of its urban populations—did not have access to electricity.

Despite the fact that India has not finished electrifying the entire country, parts that have previously done so are experiencing power outages and must enact power rules in order to comply. The power deficit in 2011–12 was approximately 10.3%, and in 2012, an electrical outage occurred in India that caused three days of darkness for the majority of the northern states [4]. Certain villages or cities may be cut off from the grid for days during events like intense rainstorms, cyclones, and other natural disasters. Up to three or four districts in India may occasionally have a power outage due to issues with generating stations or line faults, isolating these areas. Cities or towns may be cut off from the grid for days in the event of a natural disaster such as a hurricane or prolonged downpour. Power outages can occasionally occur as a result of issues with generating stations or line faults, which will also isolate some areas. One instance of a blackout that impacted the northern states for almost three days happened in India in 2012. Therefore, we can meet the power needs by integrating renewable energy into the grid at the distribution level or in each home.

shortage and can, to some extent, prevent blackouts.

Government organisations are offering subsidies to users who generate power from renewable resources for their own purposes in order to fulfil the rising demand for electricity. In India, government organisations like as ANERT, KELTRON, and others assist citizens in installing power generators at the consumer level. One of the main obstacles, though, is making the most use of the power that is produced. Techniques for energy management are required, as is a system that can dynamically reduce costs and account for India's growing electrical demand in the future. Even in the recent past, India's electrical sector has not shown much foresight; as of January 2013, the country has installed 211.766GW of electricity, of which 88.55% came from non-renewable power plants and 11.55% from renewables. India is dependent on foreign energy sources due to a lack of investment in renewable energy. Furthermore, as of December 2011, over 300 million Indians—roughly one-third of the country's rural and 6% of its urban populations—did not have access to electricity.

Despite the fact that India has not finished electrifying the entire country, parts that have previously done so are experiencing power outages and must enact power rules in order to comply. India experienced a power blackout in 2012 that left most of the northern states without electricity for three days owing to a grid breakdown, while the country's power shortage in 2011–12 was approximately 10.3% [4]. Certain villages or cities may be cut off from the grid for days during events like intense rainstorms, cyclones, and other natural disasters. Up to three or four districts in India may occasionally have a power outage due to issues with generating stations or line faults, isolating these areas. Villages or cities may be cut off from the grid for days in the event of severe rain, cyclones, or other natural disasters. Power outages can occasionally occur as a result of issues with generating stations or line faults, which will also isolate some areas. One instance of a blackout that impacted the northern states for almost three days happened in India in 2012. Thus, incorporating renewable energy into the system at the distribution level or within each home can help to partially prevent blackouts and meet power shortages.

Government organizations are offering subsidies to users who generate power from renewable resources for their own purposes in order to fulfil the rising demand for electricity. In India, government organisations like as ANERT, KELTRON, and others assist citizens in installing power generators at the consumer level. However, one of the main difficulties is making the most use of the power that is produced. Energy management techniques and a system that will dynamically select the power source (renewable energy or AC mains) based on availability are required. The system should also automatically control power usage based on user-set device priorities and/or power availability and consumption.

Our energy resources are primarily derived from coal, oil, and natural gas, with a negligible portion coming from nuclear sources. These are finite resources that, when burned, release pollutants and contribute to global warming. The cost of coal and petrol is rising daily, and these are limited resources that will produce less power and cause pollution if they are of poor quality. Renewable energy sources, such hydropower, solar electricity, and wind power, have limitless supplies and don't emit any pollutants. Despite the wind

With solar plants, the scientific community is still faced with the difficulty of effectively integrating those sporadic resources into the grid at the distribution side. Issues such as fluctuations in voltage, frequency shifts, harmonics, and so on arise when we attempt to incorporate renewable resources at the distribution end.

Energy management and the integration of renewable energy sources into the grid have been the subject of numerous studies. Several of the seminal works in this field are described in this section. A context-based smart gadget for energy management was proposed by Jinsung et al. They suggested a routing protocol as well as an energy-efficient self-clustering sensor network. The author ignored the issue of device prioritisation in favour of concentrating on context-aware energy management systems. They took into account the climatic conditions, the user's presence, etc.

A Smart UPS system for household appliances was suggested by Cavallaro et al. Solar energy is regarded in this system as a backup energy source for battery charging. The suggested control system powers the gadget in accordance with the user-specified priority. Additionally, they suggested a control system that would manage battery charge to avoid

the battery from harm. Imtiaz et al. suggest an intelligent solar energy system that charges the inverter system with solar energy in addition to grid power. According to the system description, in the event that solar power is unavailable, the battery will be charged using grid power. Additionally, in the event that AC power is unavailable, the system will power the devices using battery power. They also suggested a mechanism for managing batteries and tracking maximum power points.

In their work, three charging methods were suggested. To safeguard the battery, the charging current in each of these three modes will vary. A system that assists users in responding to real-time electricity prices was proposed by Tanuja et al. Every appliance's usage will be continuously tracked by the system, which will also analyse user trends. The system notifies customers about the details of their consumption and the most convenient time to use the appliance based on the current price of electricity and use.

Omar et al. carried out the smart grid system's web service implementation. A web service that allows users to view real-time electricity use data has been introduced. Furthermore, the concept of using renewable energy is introduced and energy management is discussed in order to control electricity during peak hours. The protocol known as SOAP is used to integrate web services with systems that provide energy management and automated metre reading. Context-aware prioritisation makes the system smarter and allows for higher-quality services with fewer power supply interruptions. Therefore, our goal is to create a system that will manage energy by dynamically assigning priorities depending on user behaviour, usage patterns, the state of the environment, etc. and utilising locally available renewable resources for each home's unique needs.

In order to meet the need for power, we present a method in this study that aids in making the best use of power from renewable resources. Every home has a photovoltaic system installed, which uses solar energy to create electricity and stores it for later use. After that, it will gather the user's consumption information from the smart metre and do data analysis to examine user behaviour. Based on this information, the system will forecast user activity and keep a battery charge for use during peak hours, which will decrease the amount of grid consumption during peak hours. Additionally, the smart system will prioritise which devices use the saved power and keep a backup power supply in the storage for usage in the event of a power outage. The remainder of the document is arranged as follows: The work's scenario is described in Section II, and the suggested system's design is described in Section III. The hardware and algorithm for testing the system's fundamental capabilities are described in Section IV. The implementation and test results are covered in Section V, and the conclusion and next steps are covered in Section VI.

2.NONCONVENTIONAL ENERGY SOURCES

2.1 INTRODUCTION

The nonconventional energy sources used in the project, such as the wind, hydro, photovoltaic, and battery systems, are briefly covered in this chapter. together with the essential concepts and background knowledge.

2.2 BLOCK DIAGRAM

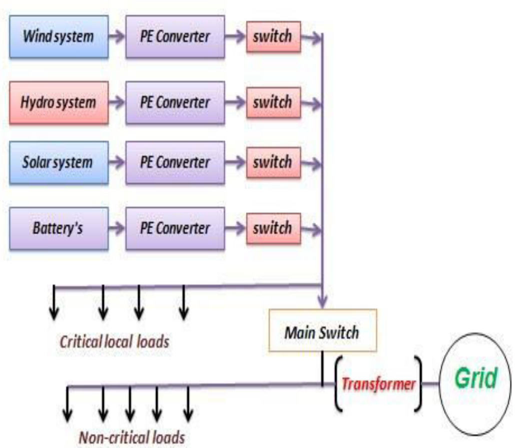

Fig: 1 Block diagram

2.3 SOLAR PHOTOVOLTAICS

2.3.1 Introduction

Becquerel was the first to observe the photovoltaic effect, which converts solar radiation. It is usually understood to mean that when light is shone on a solid or liquid system, an electric voltage appears between two electrodes linked to the system. Solar cells are energy conversion devices that employ the photovoltaic effect to transform sunlight into electrical current. A solar cell, or more broadly a photovoltaic cell, is a single converter cell. A solar array, or solar module, is a group of these cells intended to maximise the output of electric power; this is how the term "photovoltaic arrays" originates. Solar cells can be grouped together in enormous configurations known as arrays.

2.3.2 Basics of Solar Cells

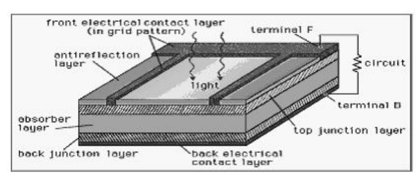

Fig.2.2: Solar cell

Silicon is used to create the vast majority of solar cells, and as silicon forms vary from amorphous (non-crystalline) to polycrystalline to crystalline (single crystal), the technology is becoming more and more efficient and less expensive. In contrast to

2.3.3 Solar Cell Characteristics

The current-to-voltage characteristic, power-to-voltage characteristics of a solar cell are non-linear, which make it difficult to determine the maximum power point.

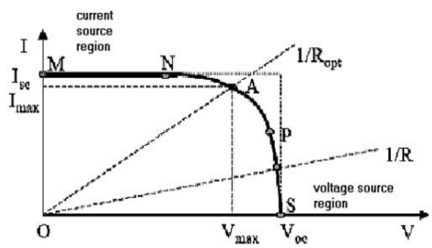

Fig.2.3 charecteristics of solar cell

Because of the non-linear relationship, one must multiply the output current by the voltage in order to find the maximum power point for a solar cell.

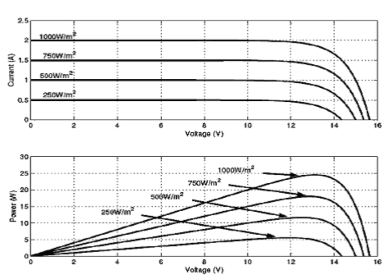

Fig.2.4:I-V and P-V Charecteristics of a solar cell for various Irradiance

The orientation and inclination angles of the solar panel have a significant impact on the irradiance at any given location.

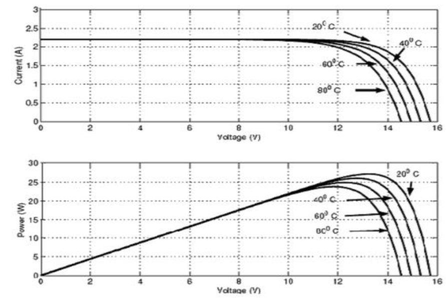

Fig.2.5: I-V and P-V Charecteristics of aSolar Cell with Varying Temperature

The band gap energy of semiconductor materials also varies with temperature.

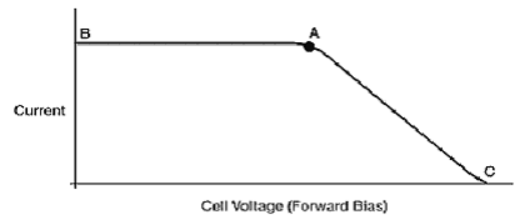

Fig.2.6: Illustration of Maximum Power Point

The cell's short circuit current intersects the Y-axis at point B and the open circuit voltage intersects the X-axis at point C.

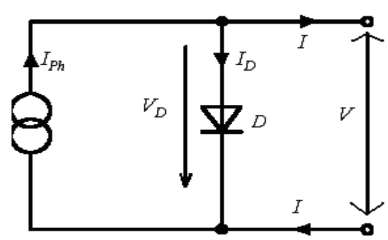

Fig.2.7: Equivalent circuit of a solar cell

The *V-I* equation of the simplified equivalent circuit could be derived from Kirchhoff's current law

$$I = I_{Ph} - I_D = I_{Ph} - I_S \cdot (\exp(\frac{V}{m \cdot V_T}) - 1)$$
…(2.1)

Where

I_{Ph}--- Photo current

I_D--- Diode current

I_S--- Diode reverse saturation current

m --- Diode ideal factor

V_T = (k*T)/q is Thermal voltage (25.7 mV at 25°C)

k = Boltzmann Constant=1.3824*e-23

T = Absolute Temperature

q = charge of an electron=1.60*e-19 couloumbs

V = output voltage of the solar cell

I = output current through the solar cells

The simplified equivalent circuit doesn't give an optimal representation of the electrical process at the solar cell. could be observed, which could be described by a parallel resistor R_P. (Fig. 2.8)

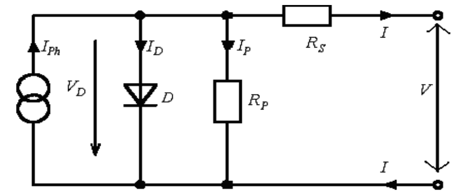

Fig.2.8: Equivalent Circuit for One Diode Model Of A Solar Cell

Derived from Kirchhoff´s first law the equation for the extended I-V curve could be achieved.

$$I = I_{\text{Ph}} - I_D - I_P$$
... (2.2)

$$I_P = V_D R_P = \left\{\frac{(V + \text{IR}_S)}{R_P}\right\}$$
... (2.3)

$$I = I_{\text{Ph}} - \left\{I_S\left(\exp\left(\frac{q(V + \text{IR}_S)}{\text{mkTN}_S}\right) - 1\right)\right\} - \left(\frac{V + \text{IR}_S}{R_P}\right)$$
... (2.4)

Where

$I_{\text{Ph}}$is the photo current

I_D is the Diode current

R_S is the cell’s series resistance, R_P is the shunt resistance

The specifications of the solar module supplied by the manufacturer’s data sheet are as shown in Table.2.1.

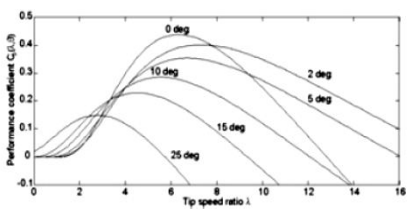

Fig: 2.9 Power coefficient Cp as a function of tip speed ratio l and pitch angle q for a specific blade.

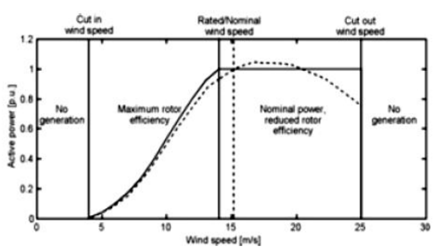

Fig: 2.10 Typical power curve of a constant speed stall (dotted) and a variable speed pitch (solid) controlled wind turbine.

2.4.3. Aerodynamic Power control

The shaft power should be less than the available power from wind to prevent overloading of components.

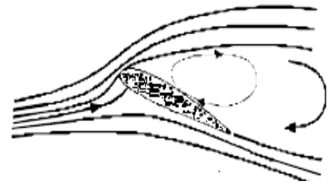

Fig.:2.11flow that is stalled around an above the rated wind speed, with the pitch angle controlling power (and hence torque).

2.4.4. Energy yield

The annual energy yield *E* of a wind turbine depends on its power curve *P(vw)* and the probability density distribution function *u(vw)*of the wind speed at the turbine site:

$$E = \int_0^{\infty} P(v_w) \cdot u(v_w) dv_w \quad \ldots(3)$$

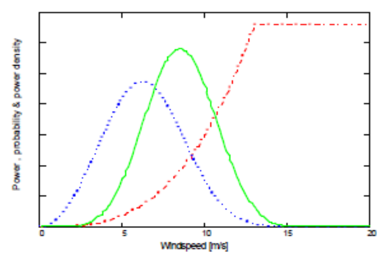

Fig: 2.12 Power P (red, dashed), probability density U (blue, dotted) and power density (green, solid) as a function of wind speed (arbitrary units).

3.BATTERY

3.1 Energy Storage

Since electricity is a highly ordered kind of energy that can be efficiently transformed into other forms, it can be used in more ways than other forms of power. For instance, it can be transformed into heat with 100% efficiency or into mechanical form with almost 100% efficiency.

3.2 BATTERY

The most popular tool for storing energy in a range of applications is the battery, which does so in an electrochemical manner. Electrochemical batteries come in two main varieties:

The battery's state of charge (SOC) can be defined as follows at any given time:

$$SOC \frac{AhCapacityremaining \in thebattery}{RapidAhcapacity}$$

3.3 TYPES OF BATTERY

There are at least six major rechargeable electrochemistries available today. They are as follows:

- Lead-acid (Pb-acid)
- Nickel-cadmium (NiCd)
- Nickel-metal hydride (NiMH)
- Lithium-ion (Li-ion)
- Lithium-polymer (Li-poly)
- Zinc-air

3.3.1 LEAD-ACID

This is the most common type of rechargeable battery used today because of its maturity and high performance-over-cost ratio, even though it has the least energy density by weight and volume.

3.4 EQUIVALENT ELECTRICAL CIRCUIT

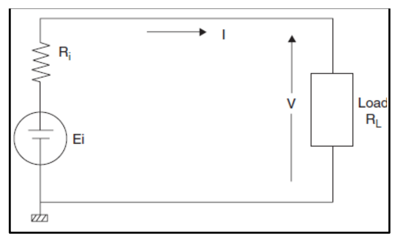

Fig 5.1Equivalent electrical circuit of battery showing internal voltage and resistance

If $V_{dc}>V_{dc_{up}}$, then charging $\rightarrow V_{dc}=V_{dc_{up}}$

If $V_{dc}<V_{dc_{up}}$, then discharging $\rightarrow V_{dc}=V_{dc_{lw}}$

If $V_{dc_{lw}}\leq V_{dc}\leq V_{dc_{up}}$ then no control (rest)

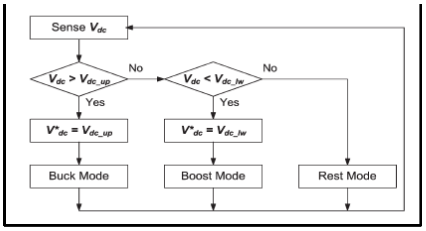

Fig. 5.2. Battery-mode control block (modified hysteresis)

5.SIMULATION RESULTS

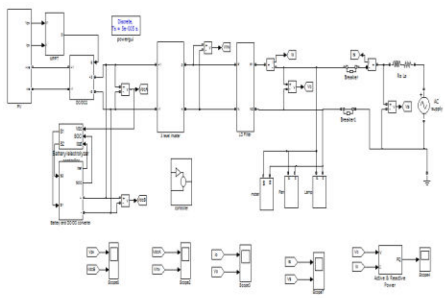

Fig simulink diagram of proposed system

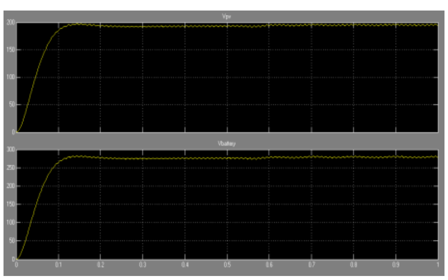

Fig battery voltage & PV voltage

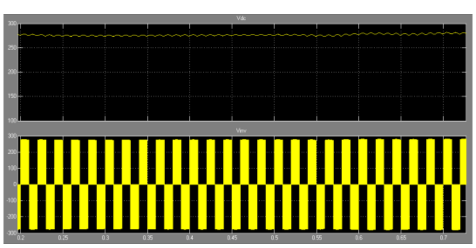

Fig Inverter input voltage & output voltage

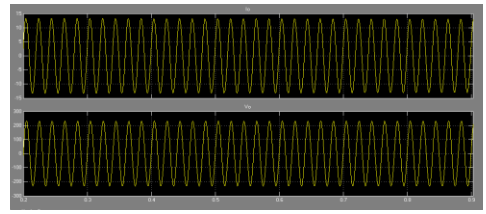

Fig load current & voltage

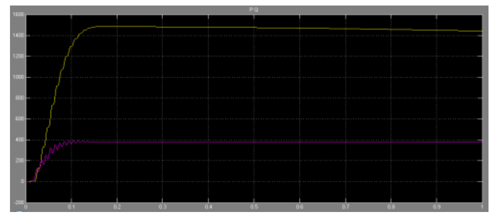

Fig active & reactive power

6.CONCLUSION

In this work, we presented an energy management system that will help to maximise the use of stored renewable power, so minimising reliance on the grid, particularly during peak hours, and resulting in lower consumer electricity bills. Additionally, the system keeps gadgets in operation even in the event of a power outage by giving them top priority, and it constantly adjusts the order of priority based on user activity.

Reducing reliance on the grid for power allows for the addition of more users, thereby completing India's electrification. Our system was put into practice in a test bed, and some of its fundamental functions were also simulated using

Matlab Simulink. The outcomes demonstrate that, by utilising stored renewable power at the appropriate times, reliance on grid power can be decreased to 70–80% during peak hours, bringing down average daily consumption to less than 30% of typical consumption. Future work will involve creating a hybrid system that combines solar and wind energy, allowing a consumer to meet their daily energy needs from many renewable sources. The forecasting method allows us to save the excess power for later use. With this approach, customers will feel more at rest, power outages will be taken into account, and device operations will be rescheduled.

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