Visvesvaraya Technological University

Belgaum, Karnataka-590 018

A Project Report on

BOOST CONVERTER FOR WIND-SOLAR HYBRID SYSTEM

Project Report submitted in partial fulfillment of the requirement for the award of the degree of

Bachelor of Engineering
In
Electrical & Electronics Engineering

Submitted by

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Certificate

Certified that the project work entitled **"BOOST CONVERTER FOR WIND-SOLAR HYBRID SYSTEM"** carried out by Mr. JEEVAN M V, USN: 1CR18EE404; Mr. VENKATA PRASAD P, USN: 1CR17EE082 are bonafied students of CMR Institute of Technology, Bengaluru, in partial fulfillment for the award of Bachelor of Engineering in Electrical & Electronics Engineering of the Visvesvaraya Technological University, Belgaum, during the year 2020-2021. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the Report deposited in the departmental library.

The project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said Degree.

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DECLARATION

We, [Mr. JEEVAN M V **(1CR18EE404),** Mr. VENKAT PRASAD P **(1CR7EE082)],** hereby declare that the report entitled **"BOOST CONVERTER FOR WIND-SOLAR HYBRID SYSTEM"** has been carried out by us under the guidance of **MR. KASHIF AHMED,** Assistant professor, Department of Electrical & Electronics Engineering, CMR Institute of Technology, Bengaluru, in partial fulfillment of the requirement for the degree of **BACHELOR OF ENGINEERING in ELECTRICAL & ELECTRONICS ENGINEERING**, of Visveswaraya Technological University, Belgaum during the academic year 2020-21.The work done in this report is original and it has not been submitted for any other degree in any university.

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Abstract

This paper proposes an integrated, four-port, DC-DC converter for power management of a hybrid wind and solar energy system when it works in the standalone mode. Compared with existing four-port DC-DC converters, the proposed converter has the advantage of using a simple topology to interface sources of different voltage/current characteristics. The proposed converter is constructed for power management of a hybrid energy system which consists of a photovoltaic (PV) panel, a wind turbine generator (WTG), a rechargeable battery bank, and a load. The Simulation and experimental results show that the proposed converter is not only capable of controlling the charge and discharge of the battery according to the state of the charge (SOC), but also maintaining the DC link voltage to be constant.

Acknowledgement

The satisfaction and euphoria that accompany the successful completion of any task would be incomplete without the mention of people, who are responsible for the completion of the project and who made it possible, because success is outcome of hard work and perseverance, but steadfast of all is encouraging guidance. So, with gratitude we acknowledge all those whose guidance and encouragement served us to motivate towards the success of the project work.

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We are thankful to all the faculties and laboratory staffs of **Electrical and Electronics Engineering Department, CMR Institute of Technology, Bengaluru** for helping us in all possible manners during the entire period.

Finally, we acknowledge the people who mean a lot to us, our parents, for their inspiration, unconditional love, support, and faith for carrying out this work to the finishing line. We want to give special thanks to all our friends who went through hard times together, cheered us on, helped us a lot, and celebrated each accomplishment.

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CHAPTER 1

INTRODUCTION

Renewable energy such as wind and solar energy attracted much attention because of its clean and alternative characteristics. According to the International Energy Agency, solar power was the fastest-growing source of global energy in 2017. However, due to the intermittence of the renewable energy, an energy storage device such as a battery or more than two different renewable energy sources are commonly used. An integrated wind, solar, and energy storage system has a better generation profile than standalone wind or solar system. In such a hybrid system, a power converter with a bidirectional port is desired to integrate energy sources to the electric grid. There are two ways to integrate these distributed energy sources, one is to an individual converter for each source, i.e., one converter for each energy source; the other way is to use an integrated multiple port converter which shares some components. The later solution is preferable due to its relative lower cost and higher efficiency compared to the traditional solution.

1.1 Battery:

A battery is a device consisting of one or more electrochemical cells with external connections for powering electrical devices such as flashlights, mobile phones, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode. The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal. When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy. Historically the term "battery" specifically referred to a device composed of multiple cells, however the usage has evolved to include devices composed of a single cell. Primary (single-use or "disposable") batteries are used once and discarded, as the electrode materials are irreversibly changed during discharge; a common example is the alkaline battery used for flashlights and a multitude of portable electronic devices. Secondary (rechargeable) batteries can be discharged and recharged multiple times using an applied electric current; the original composition of the electrodes can be restored by reverse current. Examples include the lead-acid batteries used in vehicles and lithium-ion batteries used for portable electronics such as laptops and mobile phones.

Batteries come in many shapes and sizes, from miniature cells used to power hearing aids and wristwatches to small, thin cells used in smartphones, to large lead acid batteries or lithium-ion batteries in vehicles, and at the largest extreme, huge battery banks the size of rooms that provide standby or emergency power for telephone exchanges and computer data centers. Batteries have much lower specific energy (energy per unit mass) than common fuels such as gasoline. In automobiles, this is somewhat offset by the higher efficiency of electric motors in converting electrical energy to mechanical work, compared to combustion engines.

1.2 DC-DC converter:

A DC-to-DC converter is an electronic circuit or electromechanical device that converts a source of direct current (DC) from one voltage level to another. It is a type of electric power converter. Power levels range from very low (small batteries) to very high (high-voltage power transmission).

DC-to-DC converters are used in portable electronic devices such as cellular phones and laptop computers, which are supplied with power from batteries primarily. Such electronic devices often contain several sub-circuits, each with its own voltage level requirement different from that supplied by the battery or an external supply (sometimes higher or lower than the supply voltage). Additionally, the battery voltage declines as its stored energy is drained. Switched DC to DC converters offer a method to increase voltage from a partially lowered battery voltage thereby saving space instead of using multiple batteries to accomplish the same thing. Most DC-to-DC converter circuits also regulate the output voltage. Some exceptions include high-efficiency LED power sources, which are a kind of DC to DC converter that regulates the current through the LEDs, and simple charge pumps which double or triple the output voltage. DC-to-DC converters which are designed to maximize the energy harvest for photovoltaic systems and for wind turbines are called power optimizers. Transformers used for voltage conversion at mains frequencies of 50–60 Hz must be large and heavy for powers exceeding a few watts. This makes them expensive, and they are subject to energy losses in their windings and due to eddy currents in their cores.

DC-to-DC techniques that use transformers or inductors work at much higher frequencies, requiring only much smaller, lighter, and cheaper wound components. Consequently, these techniques are used even where a mains transformer could be used; for example, for domestic electronic appliances it is preferable to rectify mains voltage to DC, use switch-mode techniques to convert it to high-frequency AC at the desired voltage, then, usually, rectify to DC. The entire complex circuit is cheaper and more efficient than a simple mains transformer circuit of the same output. DC-to-DC converters are widely used for DC micro grid applications, in the context of different voltage levels.

1.3 Hybrid Energy System:

Hybrid energy systems are still an emerging technology. It is expected that technology will continue to evolve in the future, so that it will have wider applicability and lower costs. There will be more standardized designs, and it will be easier to select a system suited to particular applications. There will be increased communication between components. This will facilitate control, monitoring, and diagnosis. Finally, there will be increased use of power electronic converters. Power electronic devices are already used in many hybrid systems, and as costs go down and reliability improves, they are expected to be used more and more.

Hybrid energy systems represent a very promising sustainable solution for power generation in stand-alone applications. Research and development carried out in these emerging technologies will certainly result in reducing the cost of the systems, despite the complex procedure involved in the design and optimization of these systems. Optimum resource allocation, based on load demand and renewable resource forecasting, also promises to significantly reduce the total operating cost of the system. In addition to mere cost minimization criteria alone, it is increasingly important to consider other relevant factors such as minimization of emissions, or maximization of systems reliability. The optimization of the configuration, design and operation of hybrid energy systems is supported by advanced models that describe the systems realistically.

Further research into the development of generic mathematical models will facilitate the development and application of reliable and easily accessible multi-objective optimization tools, such as software programs. The development of a generic, validated and complete methodology for the synthesis and the design of hybrid energy systems – incorporating appropriate planning and standardized models to take into account the characteristics of the location, the suitable hybrid energy system, and all the potential operational and performance scenarios for its application – would significantly improve the implementation of these technologies. The application of modern control techniques (such as a centralized system controller) would further improve the operational performance and energy management of these modular hybrid energy systems, allowing the utilization of the renewable resource to be optimized.

1.4 Solar Energy:

Solar energy is radiant light and heat from the Sun that is harnessed using a range of ever-evolving technologies such as solar heating, photo voltaic, solar thermal energy, solar architecture, molten salt power plants and artificial photosynthesis. It is an essential source of renewable energy, and its technologies are broadly characterized as either passive solar or active solar depending on how they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaic systems, concentrated solar power, and solar water heating to harness the energy.

Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air. The large magnitude of solar energy available makes it a highly appealing source of electricity. The United Nations Development Programme in its 2000 World Energy Assessment found that the annual potential of solar energy was 1,575–49,837 ex joules (EJ). This is several times larger than the total world energy consumption, which was 559.8 EJ in 2012. In 2011, the International Energy Agency said that "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible, and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating global warming, and keep fossil fuel prices lower than otherwise. These advantages are global. Hence the additional costs of the incentives for early deployment should be considered learning investments; they must be wisely spent and need to be widely shared".

1.5 Wind Energy:

Wind power or wind energy is the use of wind to provide mechanical power through wind turbines to turn electric generators for electrical power. Wind power is a popular sustainable, renewable source of power that has a much smaller impact on the environment compared to burning fossil fuels. Wind farms consist of many individual wind turbines, which are connected to the electric power transmission network. Onshore wind is an inexpensive source of electric power, competitive with or in many places cheaper than coal or gas plants. Onshore wind farms have a greater visual impact on the landscape than other power stations, as they need to be spread over more land and need to be built away from dense population. Offshore wind is steadier and stronger than on land and offshore farms have less visual impact, but construction and maintenance costs are significantly higher.

Small onshore wind farms can feed some energy into the grid or provide power to isolated off-grid locations. The wind is an intermittent energy source, which cannot be dispatched on demand.

Locally, it gives variable power, which is consistent from year to year but varies greatly over shorter time scales. Therefore, it must be used together with other power sources to give a reliable supply. Power-management techniques such as having dispatch able power sources (often gas-fired power plant or hydroelectric power), excess capacity, geographically distributed turbines, exporting and importing power to neighboring areas, grid storage, reducing demand when wind production is low, and curtailing occasional excess wind power, are used to overcome these problems. As the proportion of wind power in a region increases the grid may need to be upgraded. Weather forecasting permits the electric-power network to be readied for the predictable variations in production that occur.

Wind farm is a group of wind turbines in the same location used for the production of electric power. A large wind farm may consist of several hundred individual wind turbines distributed over an extended area. Wind turbines use around 0.3 hectares of land per MW, but the land between the turbines may be used for agricultural or other purposes. For example, Gansu Wind Farm, the largest wind farm in the world, has several thousand turbines. A wind farm may also be located offshore. Almost all large wind turbines have the same design — a horizontal axis wind turbine having an upwind rotor with 3 blades, attached to a nacelle on top of a tall tubular tower. In a wind farm, individual turbines are interconnected with a medium voltage (often 34.5 kV) power collection system and communications network. In general, a distance of 7D (7 times the rotor diameter of the wind turbine) is set between each turbine in a fully developed wind farm. At a substation, this medium-voltage electric current is increased in voltage with a transformer for connection to the high voltage electric power transmission system.

CHAPTER 2

LITERATURE SURVEY

2.1 Title: integrated wind, solar, and energy storage: designing plants with a better generation profile and lower overall cost

Author: Chris Ziesler; Peter Johnson; Stephanie Van Kempen

Year: 2018

Description:

Colo cating wind and solar generation with battery energy storage is a concept garnering much attention lately. An integrated wind, solar, and energy storage (IWSES) plant has a far better generation profile than standalone wind or solar plants. It results in better use of the transmission evacuation system, which, in turn, provides a lower overall plant cost compared to standalone wind and solar plants of the same generating capacity. IWSES plants are particularly suitable for regions that have set high targets for wind and solar generation but have limited land available for project development.

2.2 Title: A Family of Three-Port Half-Bridge Converters for a Stand-Alone Renewable Power System

Author: Hongfei Wu; Runruo Chen; Junjun Zhang; Yan Xing; Haibing Hu; Hongjuan Ge

Year: 2011

Description:

A systematic method to generate three-port half-bridge converters (TPHBCs) interfacing a renewable source, a storage battery, and a load is proposed for a stand-alone renewable power system application. Allowing dc bias current in the transformer, the primary circuit of a half-bridge converter can function as a synchronous rectification buck converter, by which a power flow path can be configured between the renewable source and the battery, which is connected in parallel with one of the dividing capacitor. To make the voltage on any two of the three ports independently regulated, a postregulation and a synchronous regulation with various implementations are proposed. As a result, a family of TPHBCs with merits of simple topologies and control, reduced number of devices, and single-stage power conversion between any two of the three ports is presented. A TPHBC with a synchronous regulation is given as an example to verify the proposed approach and experimental results are also given to validate the TPHBC operation. The topology generation idea is further extended and some novel TPCs are derived for different applications.

2.3 Title: Power Electronics: Roles in Renewable Energy Generation - Challenges and Opportunities

Author: Muljadi, Eduard

Year: 2017

Description:

Power electronics (PE) is an application oriented and interdisciplinary area. It uses power semiconductor devices to perform switching action in order to achieve a desired conversion strategy. The PE plays crucial role of conversion and control electrical power. Therefore, PE based power converters are also widely used in renewable energy systems. This paper deals only with the wind and solar-PV systems as they are the most promising renewable energy sources for generation of electricity. Therefore, sustainable growth of wind and solar-PV powered electricity generation is expected in the years to come. The aim of this paper is to illustrate and highlight the role of PE in the research and development of renewable energy systems. To illustrate and highlight the role of PE in research and development of renewable energy systems using wind and Solar-PV, two cases of each type are presented in this paper.

2.4 Title: Dual-Transformer-Based Asymmetrical Triple-Port Active Bridge (DT-ATAB) Isolated DC–DC Converter

Author: Venkat Nag Someswar Rao Jakka; Anshuman Shukla; Georgios D. Demetriades

Year: 2017

Description:

In this paper, a dual-transformer-based asymmetrical triple-port active bridge converter (DT-ATAB) is proposed to interface two different dc-sources and a load. DT-ATAB consists of three active power electronic converters and two high-frequency transformers. All switches of these converters can be turned on with zero-voltage switching to reduce the switching losses. The bidirectional power flow operation is possible between the ports. The DT-ATAB also reduces the circulating powers between the ports for well-matched transformer turns ratios as compared to those in the other existing triple-port active bridge converters (TAB). Furthermore, the magnetic short-circuit conditions arising in the three-winding transformer of the TAB are mitigated in DT-ATAB. The principle of operation, steady-state analysis, various modes of operation (three-port and two-port modes), and a closed loop controller of DT-ATAB are presented. The theoretical analysis of this paper is verified using both simulation and experimental studies. The illustrated results show that DT-ATAB can be used as a promising multiport converter to interface the multiple sources and load to achieve wide-ranging outputs with the minimal losses.

2.5 Title: An isolated three-port bidirectional DC-DC converter for photovoltaic systems with energy storage

Author: Jianwu Zeng; Wei Qiao; Liyan Qu

Year: 2013

Description:

This paper proposes a new isolated, three-port, bidirectional, DC-DC converter for simultaneous power management of multiple energy sources. The proposed converter has the advantage of using the least number of switches and soft switching of the main switch, which is realized by using a LCL-resonant circuit. The converter is capable of interfacing sources of different voltage-current characteristics with an isolated load. In this paper, one photovoltaic (PV) panel, one rechargeable battery, and an isolated load are interfaced by the proposed converter. Simulation and experimental results show that the proposed converter is capable of maximum power point tracking control for the PV panel when there is solar radiation and controlling the charge and discharge of the battery when there is surplus energy and power deficiency with respect to the load, respectively.

2.6 Title: Family of multiport bidirectional DC-DC converters

Author: H. Tao, A. Kotsopoulos

Year: 2006

Description:

Multiport DC-DC converters are of potential interest in applications such as generation systems utilising multiple sustainable energy sources. A family of multiport bidirectional DC-DC converters derived from a general topology is presented. The topology shows a combination of DC-link and magnetic coupling. This structure makes use of both methods to interconnect multiple sources without the penalty of extra conversion or additional switches. The resulting converters have the advantage of being simple in topology and have a minimum number of power devices. The proposed general topology and basic cells show several possibilities to construct a multiport converter for particular applications and provide a solution to integrate diverse sources owing to their flexibility in structure. The system features a minimal number of conversion steps, low cost and compact packaging. In addition, the control and power management of the converter by a single digital processor is possible. The centralised control eliminates complicated communication structures that would be necessary in the conventional structure based on separate conversion stages. A control strategy based on classical control theory is proposed, showing a multiple PID-loop structure. The general topology and a set of three-port embodiments are detailed.

2.7 Title: Full-Bridge Three-Port Converters With Wide Input Voltage Range for Renewable Power Systems

Author: Hongfei Wu; Kai Sun; Runruo Chen; Haibing Hu; Yan Xing

Year: 2012

Description:

A systematic method for deriving three-port converters (TPCs) from the full-bridge converter (FBC) is proposed in this paper. The proposed method splits the two switching legs of the FBC into two switching cells with different sources and allows a dc bias current in the transformer. By using this systematic method, a novel full-bridge TPC (FB-TPC) is developed for renewable power system applications which features simple topologies and control, a reduced number of devices, and single-stage power conversion between any two of the three ports. The proposed FB-TPC consists of two bidirectional ports and an isolated output port. The primary circuit of the converter functions as a buck-boost converter and provides a power flow path between the ports on the primary side. The FB-TPC can adapt to a wide source voltage range, and tight control over two of the three ports can be achieved while the third port provides the power balance in the system. Furthermore, the energy stored in the leakage inductance of the transformer is utilized to achieve zero-voltage switching for all the primary-side switches. The FB-TPC is analyzed in detail with operational principles, design considerations, and a pulse width modulation scheme (PWM), which aims to decrease the dc bias of the transformer. Experimental results verify the feasibility and effectiveness of the developed FB-TPC. The topology generation concept is further extended, and some novel TPCs, dual-input, and multiport converters are presented.

2.8 Title: A Novel Soft-Switching Multiport Bidirectional DC–DC Converter for Hybrid Energy Storage System

Author: Zhihui Ding; Chen Yang; Zhao Zhang; Cheng Wang; Shaojun Xie

Year: 2014

Description:

A novel multiport isolated bidirectional dc-dc converter for hybrid battery and super capacitor applications is presented, which can achieve zero voltage switching for all switches in the whole load range. The bidirectional power flow between any two of the ports is free, and the circulating power is low for the well matching of the transformer voltages of all time regardless of the voltage variations of the battery and super capacitor. Moreover, the current ripples are greatly decreased by interleaved control, which is good for battery and super capacitor. The converter topology and the operation principle are introduced. Detailed analysis on soft-switching of all switches is given. On the basis of theoretical analysis, the principle and method for parameter designing are provided. A hybrid energy management strategy combining bus voltage control and energy management of the energy storage devices is proposed and the control scheme is presented. Moreover, detailed parameter design of a prototype converter is given for a 380-V dc-bus microgrid lab system. Effectiveness of the control strategy, correctness of the analysis on soft-switching, and the parameter design methods are verified by the simulation and experimental results.

2.9 Title: Decoupling-Controlled Triport Composited DC/DC Converter for Multiple Energy Interface

Author: Wuhua Li; Chi Xu; Haoze Luo; Yihua Hu; Xiangning He; Changliang Xia

Year: 2015

Description:

In this paper, a decoupled controlled tri port dc/dc converter is derived by combining two bidirectional single-phase buck-boost converters and one isolated full-bridge converter for multiple input source applications. The power density is improved, and the circuit structure is simplified because the power devices are completely shared in the primary side. Furthermore, the pulsewidth modulation plus phase-shift control strategy is introduced to provide two control freedoms and achieve the decoupled voltage regulation within a certain operating range. The duty cycle of the bidirectional buck-boost converters is adopted to balance the voltage between the two primary input terminals, while their phase angle is applied to regulate the accurate secondary voltage. Furthermore, zero-voltage-switching soft-switching operation is provided for all of the primary power switches due to the inherent phase-shift control scheme. Moreover, the two filter inductors in the bidirectional buck-boost converters and the isolated transformer in the full-bridge topology are integrated and replaced by the winding-cross-coupled inductors to reduce the component numbers and simplify the magnetic structure. Finally, a 1-kW prototype is built to verify all theoretical considerations, and it is shown that the proposed topology is particularly advantageous in the distributed power generation system with multiple energy sources.

2.10 Title: Analysis and design of a multi-port converter using a magnetic coupling inductor technique

Author: Kenichi Itoh; Masanori Ishigaki; Naoki Yanagizawa; Shuji Tomura; Takaji Umeno

Year: 2015

Description:

A novel multiport dc-dc converter with a coupling magnetic inductor is analyzed and designed. The proposed circuit integrates two multiphase converters and one isolated dc-dc converter. These converters can be controlled independently in one circuit by adjusting the duty ratio and phase angle difference. There are four dc ports in the circuit, and the dc power can be delivered multidirectionally among the four dc ports. In this paper, a 1.5-kW prototype of the multiport converter was constructed and successfully operated under full power. The experimental results confirm the theoretical analysis, and the conversion efficiency is above 90% over a wide range of output power. In addition, an example of a multifunctional power conversion system using the multiport converter is demonstrated.

CHAPTER 3

EXISTING SYSTEM

In existing system, a multi-input multi-output (MIMO) system and usually has coupling variable, the existing three-port converter with an extra branch which increases the topology complexity. In this paper, a four-port DC-DC converter is derived from an existing three-port converter without adding any extra power electronic devices

Three Port Converter Topology Conventional power electronic converters usually consist of an energy source, load and corresponding control mechanism, which cause processing of electric power between source and load. This type of classical converters is known as two port DC-DC converter due to the fact that it has one input and one output port, which are connected to source and load respectively.

multiple energy sources in addition with energy storage system. This type of converter system with multiple energy sources can be formed in two ways, one is multiple power processing stages where the sources are interfaced with intermediate DC bus through two port converters and controlled independently. The second type of structure is a single power electronic converter with multiple interfacing ports. Thus, the number of power stages gets reduced and causes several advantages, like high power density, high efficiency, simplicity in control, compact structure and lower cost

multiport converter with battery as its source of energy and a resistive load. So, in case of microgrid application this single converter can be used to connect storage devices to the system. This topology is made of buck/boost switching cells as shown in Fig.2, where each leg consists of two switches. The key feature of this topology is its modular structure. Power and voltage rating for each port may be different for different energy sources as the same topology can be extended to other type of source application also. It is modular in nature with simple control. When more than one of such converters are into operation and one of them is taken out or one more being added, the control of existing modules in operation does not affected

three port DC-DC converter system is introduced in which two battery bank are connected to two input ports to integrate with micro grid system. As, all switching cells are directly connected in parallel, standard switch modules can be applicable. This three port topology is formed by two buck/boost switching cells connected in parallel. Each cell composed of two switches

Among these three ports, two input ports are connected to two storage buck/boost switching units. The third port is used to link the load through a DC bus. In this work, IGBT modules are used to ensure bidirectional power flow in the system

Two loop voltage/current control This control scheme comprises of outer voltage control loop in series with inner current control loop as shown in Fig.4. The outer loop compares the actual DC bus voltage with bus voltage reference and generates inductor current reference for inner current control loop. The deviations in DC bus voltage due to power transfer is taken care of by the slower voltage control loop, whereas faster current control loop (CCL) corrects for the current errors quickly. The design of the CCL involves design of the current loop to meet the required bandwidth, phase margin, gain margin. The inductor currents are able to change more quickly than the output

3.1 EXISTING SYSTEM CIRCUIT

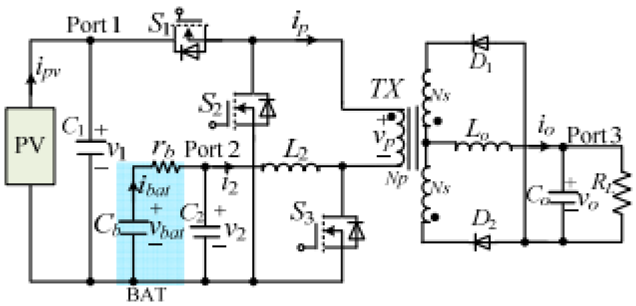


Fig. 1: Existing circuit diagram

3.2 Description of existing topology

The topology of the proposed TPC. One input port consisting of a capacitor C1 and two switches S1 and S2 is connected with a photovoltaic (PV) panel; the other input port consisting of a switch S3, an inductor L2, and a capacitor C2 is connected with a battery. These two input ports are connected to the primary side of the high-frequency transformer whose turn ratio is defined as n = Np / Ns, where Np and Ns represent the numbers of turns of the primary and secondary windings, respectively. The output port consisting of two rectifier diodes D1 and D2, an inductor Lo and a capacitor Co is connected to the load. The power flow of Port 2 is bidirectional such that the battery can work in both charging and discharging modes. As shown in, the battery is modeled as a capacitor Cb connected in series with its internal resistance rb. The capacitance of Cb is sufficiently large such that vbat is taken as a constant value during the modeling stage a small-signal model of a TPC for power management of a PV-battery system. Based on the model, an IVC and an OVC have been designed to regulate the voltage of the PV panel and the output voltage of the TPC, respectively. Experiments have been carried out to validate the two controllers. Results have shown that the voltage of the PV panel and the output voltage of the TPC could be well controlled by the two controllers independently.

CHAPTER 4

PROPOSED SYSTEM

The Proposed System Four Port Dc- Dc Converter Is Implemented for High Voltage The function of this four-port DC-DC converter is to regulate voltage from low level to high level required by a DC-AC inverter while achieving the following three objectives:

1) MPPT: doing maximum power point tracking (MPPT) for both WTG and PV when the renewable energy is available;

2) Battery management: protect the battery from over charge or discharge), the charge (or discharge) current (or voltage) is controlled within certain range;

3) Bus voltage control: regulate the DC bus voltage to a constant value, e.g., 180 V in this paper.

It should be noted that the proposed converter is capable of working in the different operation modes regardless of the availability of wind or solar energy, and charge or discharge of the battery. Since the operation principle in the discharge mode is similar with the charge mode, in this paper, only the analysis in the charge mode is provided.

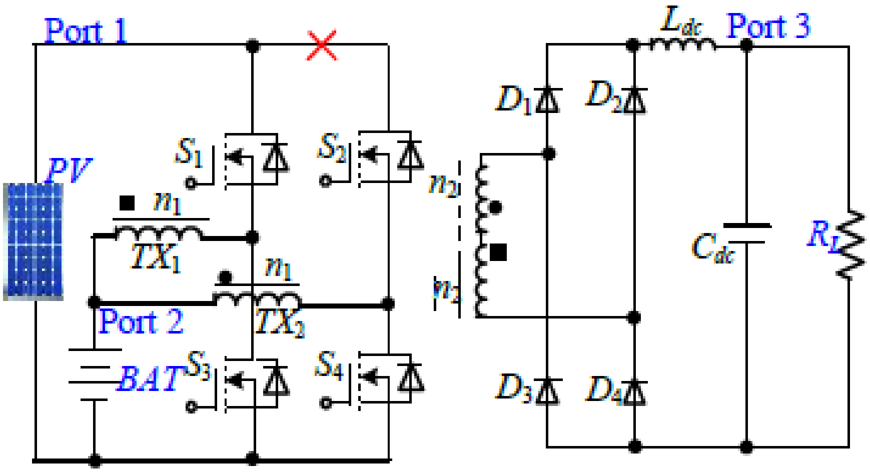


Fig. 2: Four port converter

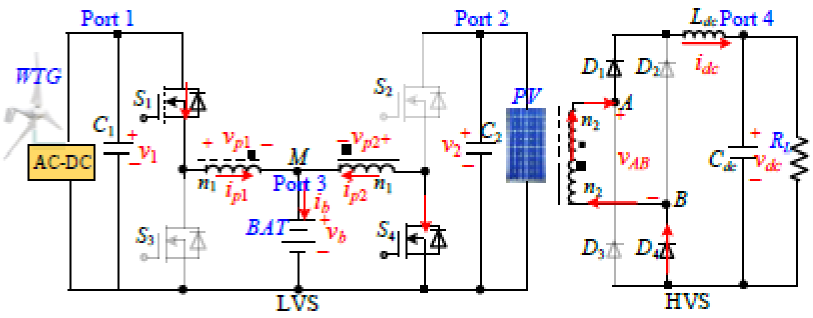


Fig. 3: Switching pulse Mode 1

(b)

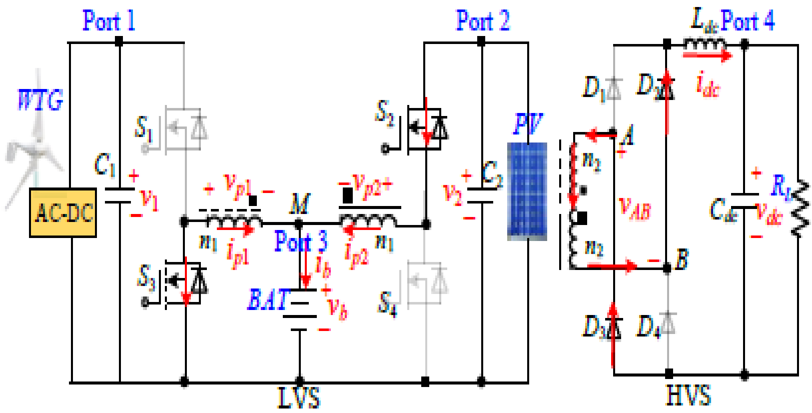


Fig. 4: 2 port diagram

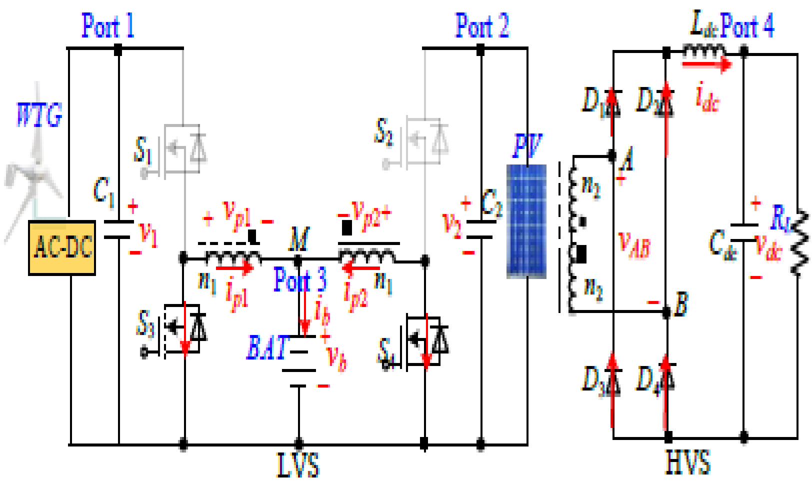


Fig. 5: Port 4

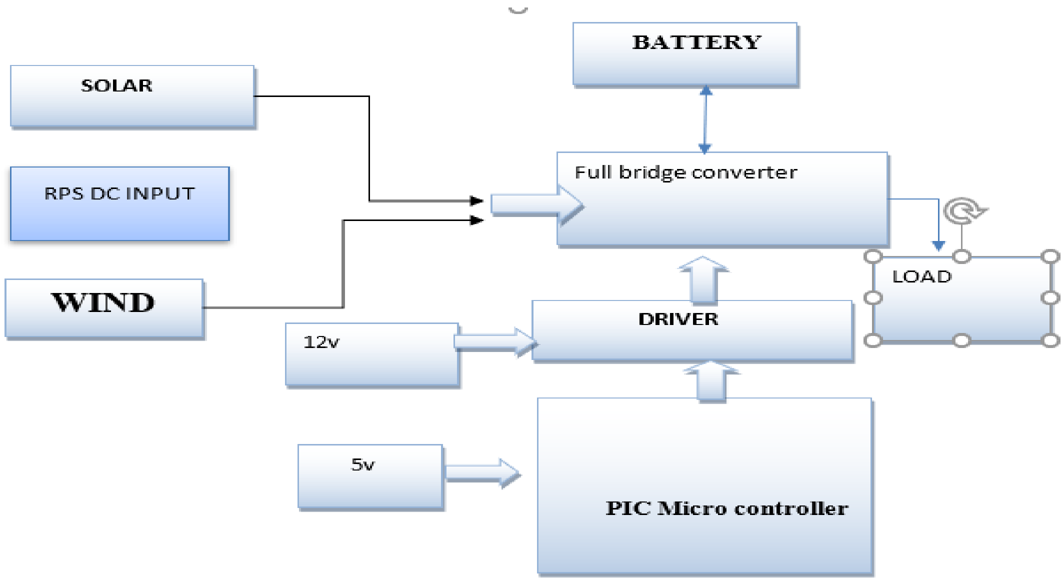


Fig. 6: Hardware block diagram

CHAPTER 5

SOFTWARE REQUIREMENTS

- **MATLAB Version R2017a**

MATLAB

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation.

Typical uses include:

- Math and computation
- Algorithm development
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics.
- Application development, including Graphical User Interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN

5.1 INTRODUCTION

MATLAB (**mat**rix **lab**oratory) is a numerical computing environment and fourth-generation programming language. Developed by Math Works, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and Fortran.

Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the Mu PAD symbolic engine, allowing access to symbolic computing capabilities. An additional package, Simulink, adds graphical multi-domain simulation and Model-Based Design for dynamic and embedded systems.

In 2004, MATLAB had around one million users across industry and academia. MATLAB users come from various backgrounds of engineering, science, and economics. MATLAB is widely used in academic and research institutions as well as industrial enterprises.

5.2 SIMULATION RESULTS

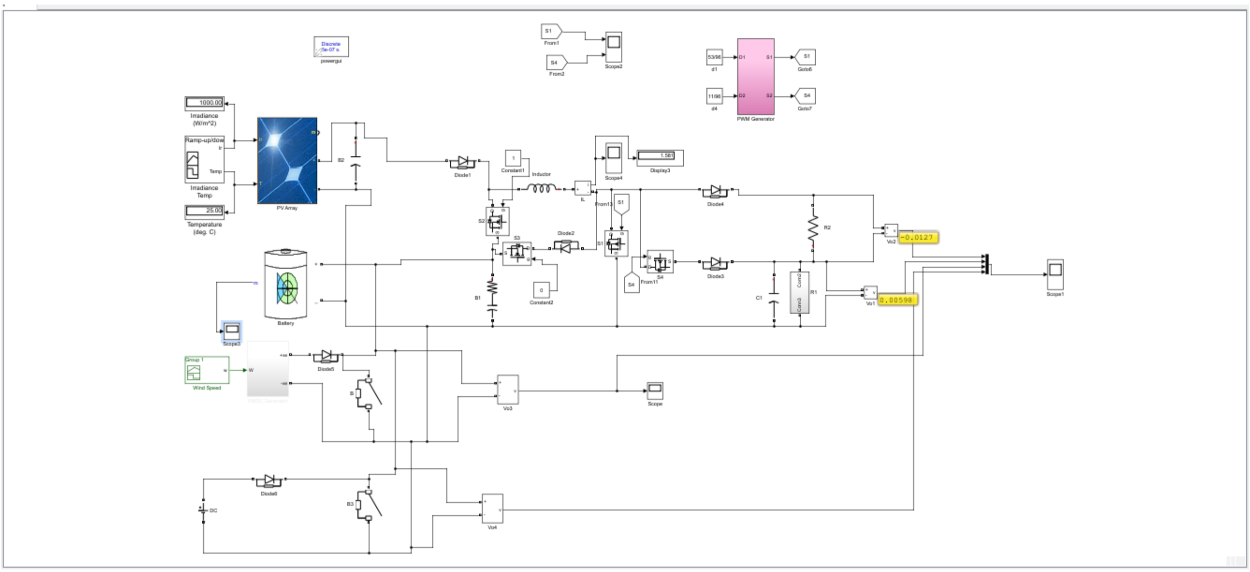


Fig. 7: Simulation results

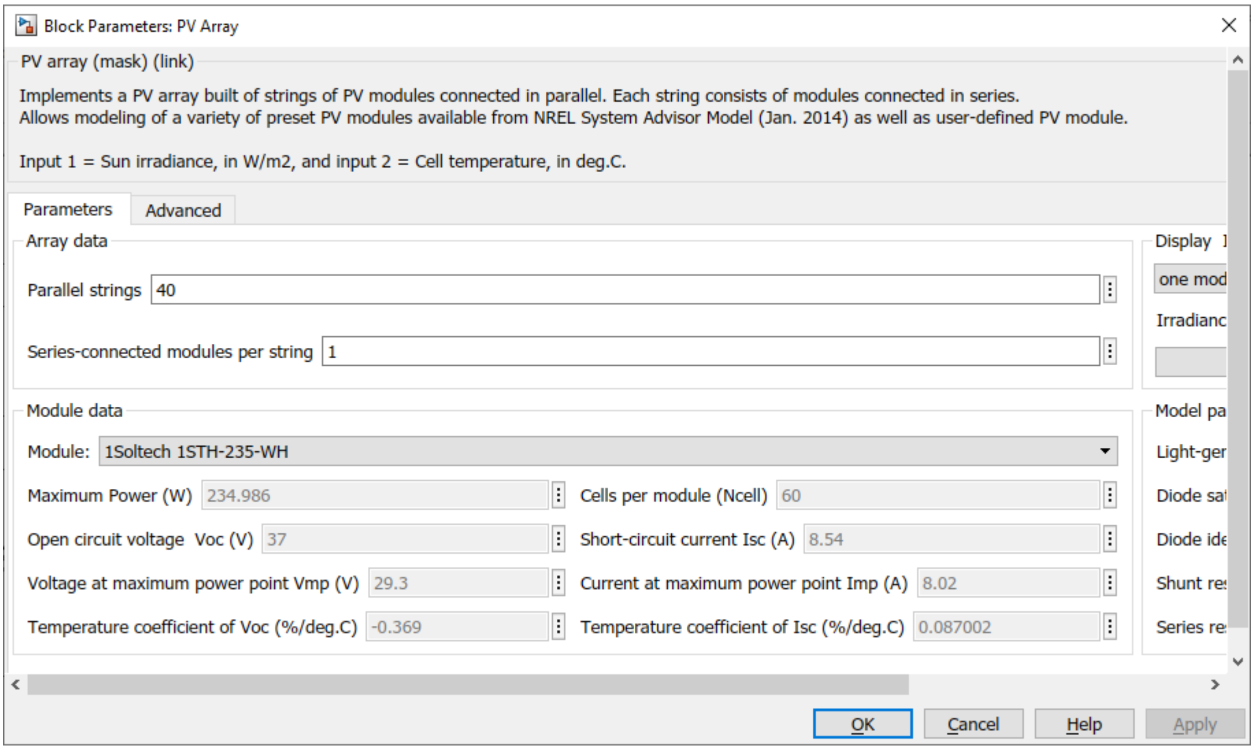


Fig. 8: Solar parameter

Fig. 9: Output voltage

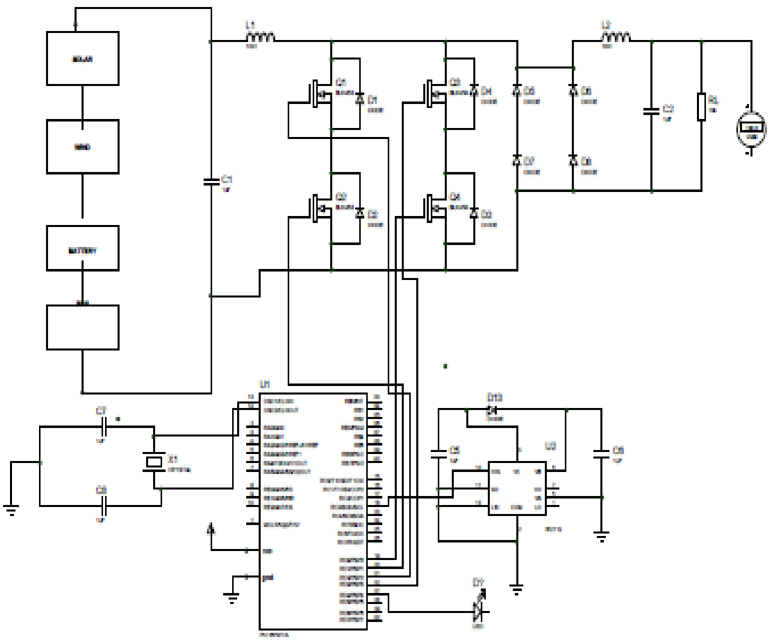


Fig. 10: Hardware circuit diagram

Table 1. Components

Hardware components	QUANTITY
PIC MICROCRO CONTROLLER	1
MOSFET	4
SOLAR	1
WIND SYSTEM	1
POWER SUPPLY	1
BATTERY	24 V ,4.5 amps
Driver board	1

CHAPTER 6

HARDWARE DESCRIPTION

6.1 GENERAL

Main goal of the active power filter (series or parallel) is to eliminate the voltage harmonics and current harmonics. In this case, the reference voltage is always known (the fundamental of the distortion voltage or current) and it is installed in a PIC16F72 as 40points (point by point of known reference voltage and of known fundamental value) the time difference between two consecutive points is $\Delta t = 250$ μs. Then, it is possible to generate the reference synchronized with the main voltage and thus we can use the controller algorithm. A laboratory prototype of the single-phase series active power filter, of F was built and tested with the same power circuit parameters specified in Table 1. The complete control circuit was implemented and the controller used is PIC16F72 microcontroller The simple control circuit of consists of five parts: (1) Power supply and zero crossing detectors. (2) Potential transformer and signal conditioning circuit added with a small DC negative voltage to neutralize the small drift (positive DC bias) Microcontroller circuit (with digital module; inverter) is used at the output of the opt coupler as a driver to turn on/off the MOSFETs with high speed. (4) The inverter bridge.

Experimental main voltage and source current before and after filtration of the proposed series active power filter respectively. The shape of the source current after filtering becomes approximately sinusoidal Note: by adjusting the variable potentiometer of the current sensor, we can use the same controller for different type of capacitive loads, or we can use this controller for different type and values of non-linear loads. The reference current is 1A peak the fundamental of the load current.

6.2 PIC MICROCONTROLLER

This document contains device specific information for the operation of the PIC16F72 device. Additional information may be found in the pic micro Mid-Range MCU Reference Manual (DS33023), which may be downloaded from the Microchip website. The Reference Manual should be considered a complementary document to this data sheet, and is highly recommended reading for a better understanding of the device architecture and operation of the peripheral modules. The PIC16F72 belongs to the Mid-Range family of the pic micro devices.

Fig. 110: PIC16F72

This powerful (200 nanosecond instruction execution) yet easy-to-program (only 35 single word instructions) CMOS FLASH-based 8-bit microcontroller packs Microchip's powerful PIC® architecture into a 28-pin package and is upwards compatible with the PIC16C5X, PIC12CXXX and PIC16C7X devices. The PIC16F72 features 5 channels of 8-bit Analog-to-Digital (A/D) converter with 2 additional timers, capture/compare/PWM function and the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface (SPI™) or the 2-wire Inter-Integrated Circuit (I²C™) bus. All of these features make it ideal for more advanced level A/D applications in automotive, industrial, appliances and consumer applications.

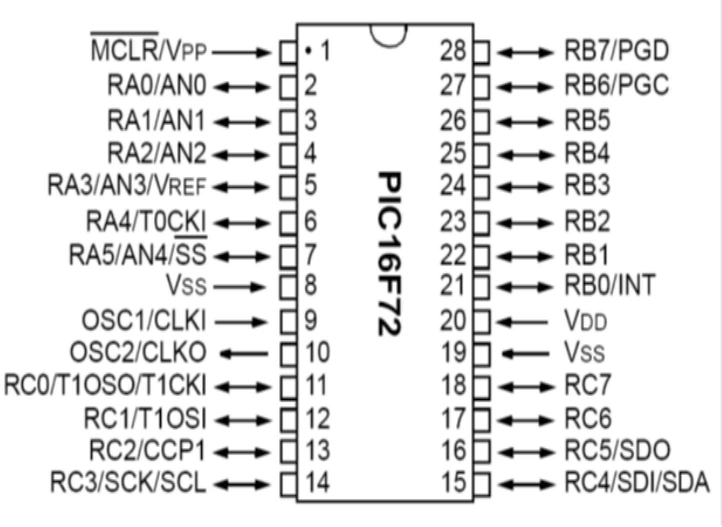


Fig. 12: Pin Diagram

APPLICATION OF MICROCONTROLLER

- **Building control**
  - Access control
  - Temperature sensing
  - lighting
  - If re detection

- **Industrial control**
  - Process control
- **Instrumentation**
  - Industrial instrumentation
- **Metering**
  - Handheld metering systems
- **Motor speed control**
  - AC motor control
  - DC motors
  - Steppers
- **Automotive**
  - LIN slave nodes
  - Body and convenience electronics

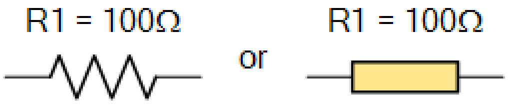
6.3 RESISTORS

Resistors, (R) are the most fundamental and commonly used of all the electronic components, to the point where they are almost taken for granted. There are many different types of Resistors available for the electronics constructor to choose from, from very small surface mount chip resistors up to large wire wound power resistors.

Fig. 13: Resistor

The principal job of a resistor within an electrical or electronic circuit is to "resist" (hence the name Resistor), regulate or to set the flow of electrons (current) through them by using the type of conductive material from which they are composed. Resistors can also be connected together in various series and parallel combinations to form resistor networks which can act as voltage droppers, voltage dividers or current limiters within a circuit.

Standard Resistor Symbols



Resistors are what are called "Passive Devices ", that is they contain no source of power or amplification but only attenuate or reduce the voltage or current signal passing through them. This attenuation results in electrical energy being lost in the form of heat as the resistor resists the flow of electrons through it.

Then a potential difference is required between the two terminals of a resistor for current to flow. This potential difference balances out the energy lost. When used in DC circuits the potential difference, also known as a resistor's voltage drop, is measured across the terminals as the circuit current flows through the resistor.

Resistor are linear devices that produce a voltage drop across themselves when an electrical current flows through them because they obey Ohm's Law, and different values of resistance produces different values of current or voltage. This can be very useful in electronic circuits by controlling or reducing either the current flow or voltage produced across them we can produce a voltage-to-current and current-to-voltage converter.

This relationship written out as a mathematical equation:

$$V = I \times R$$

This is known as Ohm's Law for German physicist **Georg Shimon ohm**.

A resistor quite simply resists voltage! In order as not to overload a component a resistor that is valued at the proper resistance is placed in the circuit to reduce voltage to a particular section of a circuit! A dimmer switch functions in this way! By sliding a dimmer in one direction or another you provide less or more voltage to a light(s) circuit to increase or decrease the brightness of the lights in a room.

6.4 POWER SUPPLY CIRCUIT

Power supply is a reference to a source of electrical power. A device or system that supplies electrical or other types of energy to an output load or group of loads is called a power supply unit or PSU. The term is most commonly applied to electrical energy supplies, less often to mechanical ones, and rarely to others.

Power supplies for electronic devices can be broadly divided into linear and switching power supplies. The linear supply is a relatively simple design that becomes increasingly bulky and heavy for high current devices; voltage regulation in a linear supply can result in low efficiency. A switched-mode supply of the same rating as a linear supply will be smaller, is usually more efficient, but will be more complex.

6.5 Bridge Rectifier

A bridge rectifier can be made using four individual diodes, but it is also available in special packages containing the four diodes required. It is called a full-wave rectifier because it uses the entire AC wave (both positive and negative sections). 1.4V is used up in the bridge rectifier because each diode uses 0.7V when conducting and there are always two diodes conducting, as shown in the diagram below. Bridge rectifiers are rated by the maximum current they can pass and the maximum reverse voltage they can withstand (this must be at least three times the supply RMS voltage so the rectifier can withstand the peak voltages). Please see the DIODES page for more details, including pictures of ridge rectifiers.

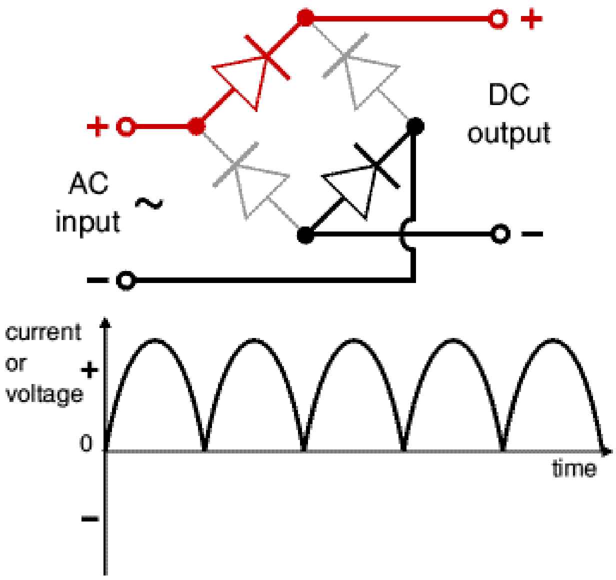


Fig. 14: Bridge rectifier

Alternate pairs of diodes conduct, changing over the connections so the alternating directions of AC are converted to the one direction of DC.

Output: full-wave varying DC: (using the entire AC wave):

Smoothing:

Smoothing is performed by a large value electrolytic capacitor connected across the DC supply to act as a reservoir, supplying current to the output when the varying DC voltage from the rectifier is falling. The diagram shows the unsmoothed varying DC (dotted line) and the smoothed DC (solid line). The capacitor charges quickly near the peak of the varying DC, and then discharges as it supplies current to the output.

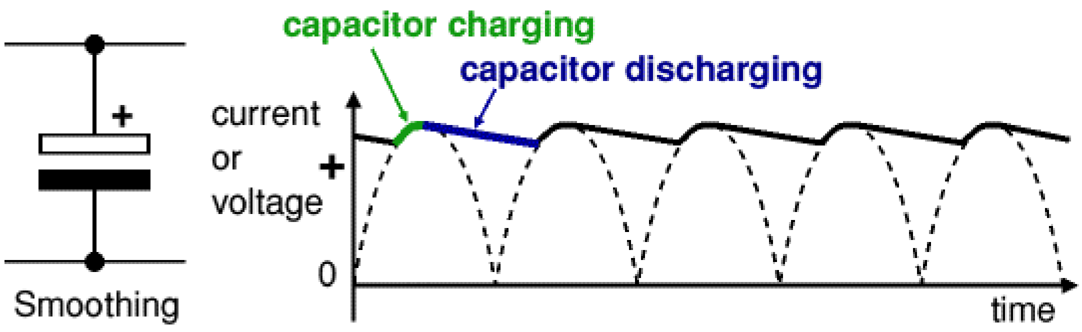


Fig. 15: Smoothing

Note that smoothing significantly increases the average DC voltage to almost the peak value (1.4 × RMS value). For example, 6V RMS AC is rectified to full wave DC of about 4.6V RMS (1.4V is lost in the bridge rectifier), with smoothing this increases to almost the peak value giving 1.4 × 4.6 = 6.4V smooth DC.

Smoothing is not perfect due to the capacitor voltage falling a little as it discharges, giving a small ripple voltage. For many circuits a ripple which is 10% of the supply voltage is satisfactory and the equation below gives the required value for the smoothing capacitor. A larger capacitor will give fewer ripples. The capacitor value must be doubled when smoothing half-wave DC.

Smoothing Capacitor for 10% ripple, C=5*10/vs.*f

C = smoothing capacitance in farads (F)

Io = output current from the supply in amps (A)

Vs = supply voltage in volts (V), this is the peak value of the unsmoothed DC

f = frequency of the AC supply in hertz (Hz), 50Hz in the UK.

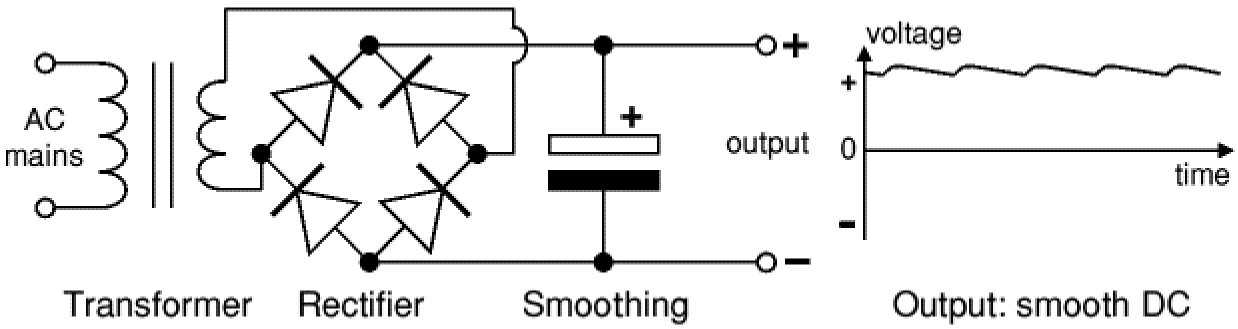


Fig. 16: Power supply circuit

The smooth DC output has a small ripple. It is suitable for most electronic circuits.

Regulator:

Voltage regulator ICs are available with fixed (typically 5, 12 and 15V) or variable output voltages. They are also rated by the maximum current they can pass. Negative voltage regulators are available, mainly for use in dual supplies. Most regulators include some automatic protection from excessive current ('overload protection') and overheating ('thermal protection').

The LM78XX series of three terminal regulators is available with several fixed output voltages making them useful in a wide range of applications. One of these is local on card regulation, eliminating the distribution problems associated with single point regulation. The voltages available allow these regulators to be used in logic systems, instrumentation, HiFi, and other solid state electronic equipment. Although designed primarily as fixed voltage regulators these devices can be used with external components to obtain adjustable voltages and current.

Many of the fixed voltage regulator ICs has 3 leads and look like power transistors, such as the 7805 +5V 1A regulator shown on the right. They include a hole for attaching a heat sink if necessary.

1. Positive regulator
    1. input pin
    2. ground pin
    3. output pin

It regulates the positive voltage

2. Negative regulator
    1. ground pin
    2. input pin
    3. output pin

It regulates the negative voltage

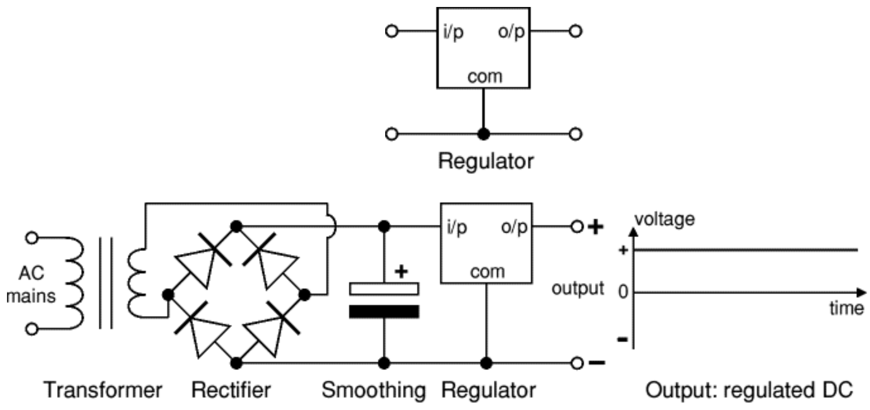


Fig. 17: Power supply circuit with regulator

The regulated DC output is very smooth with no ripple. It is suitable for all electronic circuits.

6.6 RECTIFIER

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The process is known as rectification. Physically, rectifiers take a number of forms, including vacuum tube diodes, mercury-arc valves, copper and selenium oxide rectifiers, semiconductor diodes, silicon-controlled rectifiers and other silicon-based semiconductor switches. Historically, even synchronous electromechanical switches and motors have been used. Early radio receivers, called crystal radios, used a "cat's whisker" of fine wire pressing on a crystal of galena (lead sulfide) to serve as a point-contact rectifier or "crystal detector". Rectifiers have many uses, but are often found serving as components of DC power supplies and high-voltage direct current power transmission systems. Rectification may serve in roles other than to generate direct current for use as a source of power. As noted, detectors of radio signals serve as rectifiers. In gas heating systems flame rectification is used to detect presence of a flame. Because of the alternating nature of the input AC sine wave, the process of rectification alone produces a DC current that, though unidirectional, consists of pulses of current. Many applications of rectifiers, such as power supplies for radio, television and computer equipment, require a steady constant DC current (as would be produced by a battery). In these applications the output of the rectifier is smoothed by an electronic filter (usually a capacitor) to produce a steady current. More complex circuitry that performs the opposite function, converting DC to AC, is called an inverter.

6.7 RESISTOR

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses. High-power resistors that can dissipate many watts of electrical power as heat may be used as part of motor controls, in power distribution systems, or as test loads for generators. Fixed resistors have resistances that only change slightly with temperature, time or operating voltage. Variable resistors can be used to adjust circuit elements (such as a volume control or a lamp dimmer), or as sensing devices for heat, light, humidity, force, or chemical activity. Resistors are common elements of electrical networks and electronic circuits and are ubiquitous in electronic equipment. Practical resistors as discrete components can be composed of various compounds and forms. Resistors are also implemented within integrated circuits. The electrical function of a resistor is specified by its resistance: common commercial resistors are manufactured over a range of more than nine orders of magnitude. The nominal value of the resistance falls within the manufacturing tolerance, indicated on the component.

Features

- Automatically insert able
- High quality performance
- Non-Flame type available
- Cost effective and commonly used
- Too low or too high values can be supplied on case to case basis

Performance Specification

Temperature Coefficient	: ≤10Ω : ±350PPM/°C
	11Ω to 99kΩ : 0 to -450PPM/°C
	100kΩ to 1MΩ : 0 to -700PPM/°C
	1.1MΩ to 10MΩ : 0 to -1500PPM/°C
Short Time Overload	: ±(1% +0.05Ω)Max. with no evidence of

mechanical damage

Insulation Resistance : Min. 1,000MΩ Dielectric

Withstanding Voltage : No evidence of flashover, mechanical damage, arcing or insulation breakdown.

Terminal Strength : No evidence of mechanical damage.

Resistance to Soldering Heat : ±(1% +0.05Ω)Max. with no evidence of mechanical damage.

Solderability : Min. 95% coverage

Resistance to Solvent : No deterioration of protective coating and markings Temperature

Cycling : ±(1% +0.05Ω) Max. with no evidence of mechanical damage

Load Life in Humidity : Normal Type : <100kΩ : ±(3% +0.05Ω)Max.

≥100kΩ : ±(5% +0.05Ω)Max.

Non-Flame Type : <100kΩ : ±(5 +0.05Ω)Max.

≥100kΩ : ±(10% +0.05Ω)Max.

Load Life : Normal Type : <56kΩ : ±(2% +0.05Ω)Max.

≥56kΩ : ±(3% +0.05Ω)Max.

Non-Flame Type : <100kΩ : ±(5% +0.05Ω)Max. ≥100kΩ : ±(10% +0.05Ω)Max

Like that we uses the 1Kohm,100ohm, 4.7kohm,10kohm resistors.

6.8 CAPACITOR

A **capacitor** is a passive two-terminal electrical component that stores potential energy in an electric field. The effect of a capacitor is known as capacitance. While some capacitance exists between any two electrical conductors in proximity in a circuit, a capacitor is a component designed to add capacitance to a circuit. The capacitor was originally known as a **condenser**

Fig. 18: Condenser

Features

- Wide CV value range for general purpose
- Safely vent construction products, GPR series are guaranteed 2,000 hours at 85°C

6.9 MOSFET

MOSFET stands for **metal-oxide semiconductor field-effect transistor**. It is a special type of field-effect transistor (FET). Unlike BJT which is 'current controlled', the MOSFET is a voltage controlled device. The MOSFET has **"gate", "Drain"** and **"Source"** terminals instead of a "base", "collector", and "emitter" terminals in a bipolar transistor. By applying voltage at the gate, it generates an electrical field to control the current flow through the channel between drain and source, and there is no current flow from the gate into the MOSFET.

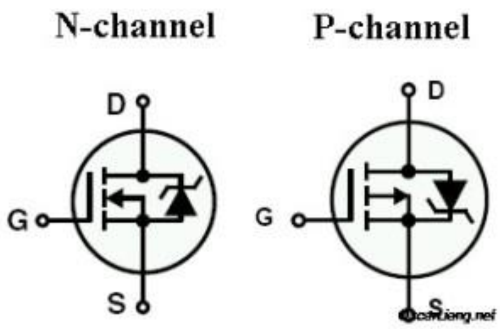


Fig. 19: MOSFET

A MOSFET may be thought of as a variable resistor, where the Gate-Source voltage difference can control the Drain-Source Resistance. When there is no applying voltage between the Gate-Source , the Drain-Source resistance is very high, which is almost like a open circuit, so no current may flow through the Drain-Source. When Gate-Source potential difference is applied, the Drain-Source resistance is reduced, and there will be current flowing through Drain-Source, which is now a closed circuit.

In a nutshell, a FET is controlled by the Gate-Source voltage applied (which regulates the electrical field across a channel), like pinching or opening a straw and stopping or allowing current flowing. Because of this property, FETs are great for large current flow, and the MOSFET is commonly used as a switch.

Okay, let me summarize the differences between BJT and MOSFET.

- Unlike bipolar transistors, MOSFET is voltage controlled. While BJT is current controlled, the base resistor needs to be carefully calculated according to the amount of current being switched. Not so with a MOSFET. Just apply enough voltage to the gate and the switch operates.
- Because they are voltage controlled, MOSFET have a very high input impedance, so just about anything can drive them.
- MOSFET has high input impedence.

To use a MOSFET as a switch, you have to have its gate voltage (Vgs) higher than the source. If you connect the gate to the source (Vgs=0) it is turned off.

For example we have a IRFZ44N which is a "standard" MOSFET and only turns on when Vgs=10V – 20V. But usually we try not to push it too hard so 10V-15V is common for Vgs for this type of MOSFET.

However if you want to drive this from an Arduino which is running at 5V, you will need a "logic-level" MOSFET that can be turned on at 5V (Vgs = 5V). For example, the ST STP55NF06L You should also have a resistor in series with the Arduino output to limit the current, since the gate is highly capacitive and can draw a big instantaneous current when you try to turn it on. Around 220 ohms is a good value.

MOSFET is a voltage controlled field effect transistor that differs from a JFET. The Gate electrode is electrically insulated from the main semiconductor by a thin layer of insulating material (glass, seriously!). This insulated metal gate is like a plate of a capacitor which has an extremely high input resistance (as high as almost infinite!). Because of the isolation of the Gate there is no current flow into the MOSFET from Gate.

When voltage is applied at the gate, it changes the width of the Drain-Source channel along which charge carriers flow (electron or hole). The wider the channel, the better the device conducts.

The MOSFET are used differently compared to the conventional junction FET.

- The infinite high input impedance makes MOSFETs useful for power amplifiers. The devices are also well suited to high-speed switching applications. Some integrated circuits contain tiny MOSFETs and are used in computers.

- Because the oxide layer is so thin, the MOSFET can be damaged by built up electrostatic charges. In weak-signal radio-frequency work, MOSFET devices do not generally perform as well as other types of FET.

If you need to switch high current and or high voltage loads with a micro controller you'll need to use some type of transistor. I'm going to be covering how to use a MOSFET since it's a better option for high power loads. This guide will be just a brief introduction that will discuss how to drive a MOSFET in a simple manner with the ultimate goal of making it act like an ideal switch. I'm not going to get into any of the topics such as Triode region, Saturation, Threshold Voltage, etc… Refer to the N or P channel basic wiring schematics and remember the three pins: Gate, Drain, and Source. When I mention something like Gate-Source potential difference, I'm talking about the difference in voltage between the two pins.

6.10 SOLAR PANEL

Fig. 20: Solar Panel

A solar panel is a set of solar photovoltaic modules electrically connected and mounted on a supporting structure. A photovoltaic module is a packaged, connected assembly of solar cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. Each module is rated by its DC output power under standard test conditions (STC), and typically ranges from 100 to 320 watts. The efficiency of a module determines the area of a module given the same rated output - an 8% efficient 230 watt module will have twice the area of a 16% efficient 230 watt module. A single solar module can produce only a limited amount of power; most installations contain multiple modules. A photovoltaic system typically includes a panel or an array of solar modules, an inverter, and sometimes a battery and/or solar tracker and interconnection wiring.

6.10 BATTERY CHARGER

The rechargeable backup battery provides power to Finger Tec terminals when the primary source of power is unavailable. With the right backup battery, your system won't have to be interrupted during a power failure. 12V1.5Ah Backup Battery Access Control System: The external Rechargeable Backup Batteries are almost always used in an access control system. The backup battery prevents intruders from disabling the access control by turning off power to the building, and continues locking the doors secured by the system. Time & Attendance System: For Time and Attendance System that records clocking-in and out data for employees, power failure might cause discrepancies in the payroll system. Thus, external rechargeable backup batteries are often used in Time & Attendance terminals as a backup power

A battery charger is a device used to put energy into a cell or (rechargeable) battery by forcing an electric current through it. Lead-acid battery chargers typically have two tasks to accomplish. The first is to restore capacity, often as quickly as practical. The second is to maintain capacity by compensating for self discharge. In both instances optimum operation requires accurate sensing of battery voltage. When a typical lead-acid cell is charged, lead sulphate is converted to lead on the battery's negative plate and lead dioxide on the positive plate. Over-charge reactions begin when the majority of lead sulphate has been converted, typically resulting in the generation of hydrogen and oxygen gas. At moderate charge rates, most of the hydrogen and oxygen will recombine in sealed batteries. In unsealed batteries however, dehydration will occur.

Size This is pretty straight forward, how big are the batteries? Lead acid batteries don't get much smaller than C-cell batteries. Coin cells don't get much larger than a quarter. There are also standard sizes, such as AA and 9V which may be desirable. Weight and power density This is a performance issue: higher quality (and more expensive) batteries will have a higher power density. If weight is an important part of your project, you will want to go with a lighter, high-density battery. Often this is expressed in Watts-hours per Kilogram. Price Price is pretty much proportional to power-density (you pay more for higher density) and proportional to power capacity (you pay more for more capacity). The more power you want in a smaller, lighter package the more you will have to pay. Voltage The voltage of a battery cell is determined by the chemistry used inside. For example, all Alkaline cells are 1.5V, all lead-acid's are 2V, and lithiums are 3V. Batteries can be made of multiple cells, so for example, you'll rarely see a 2V lead-acid battery. Usually they are connected together inside to make a 6V, 12V or 24V battery. Likewise, most electronics use multiple alkalines to generate the voltage they need to run. Don't forget that voltage is a 'nominal' measurement, a "1.5V" AA battery actually starts out at 1.6V and then quickly drops down to 1.5 and then slowly drifts down to 1.0V at which point the battery is considered 'dead'. Re-usability Some batteries are rechargable, usually they can be recharged 100's of times.

6.11 Power Capacity and Power Capability

Power capacity is how much energy is stored in the battery. This power is often expressed in Watt-hours (the symbol Wh). A Watt-hour is the voltage (V) that the battery provides multiplied by how much current (Amps) the battery can provide for some amount of time (generally in hours). Voltage * Amps * hours = Wh. Since voltage is pretty much fixed for a battery type due to its internal chemistry (alkaline, lithium, lead acid, etc), often only the Amps*hour measurement is printed on the side, expressed in Ah or mAh (1000mAh = 1Ah). To get Wh, multiply the Ah by the nominal voltage. For example, lets say we have a 3V nominal battery with 1Amp-hour capacity, therefore it has 3 Wh of capacity. 1 Ah means that in theory we can draw 1 Amp of current for one hour, or 0.1A for 10 hours, or 0.01A (also known as 10 mA) for 100 hours. However, the amount of current we can really draw (the power capability) from a battery is often limited. For example, a coin cell that is rated for 1 Ah can't actually provide 1 Amp of current for an hour, in fact it cant even provide 0.1 Amp without overextending itself. Its like saying a human has the capability to travel up to 30 miles: of course running 30 miles is a lot different than walking! Likewise, a 1Ah coin cell has no problem providing a 1mA for 1000 hours but if you try to draw 100mA from it, it'll last a lot less than 10 hours.

6.12 OPERATING INSTRUCTIONS

Once the connection instructions have been followed, plug-in AC power cord, the “POWER” Red (LED) will be on, the charger will begin charging automatically and the “CHARGING” Yellow (LED) will be on during charging. When the battery is fully charged the “CHARGING” Yellow (LED) will be off and the “FULL/FLOAT” Green (LED) will be on. Float Mode allows the charger to effectively be left connected to your batteries, over the course of a season, without overcharging your batteries and maintains your battery's full charge.

Specifications

9.1 Input voltage: 120Vac 50/60Hz 0.4A Max. 9.2 Charging starting conditions: Battery not less than 5.5V 9.3 Rating output: 12Vdc 1.5A 9.4 Battery type: Lead-acid battery 9.5 Maximum charging voltage: 14.4V 9.6 Maintenance charging voltage: 13.2V~14.0V 9.7 Operating Environmental: -10~40℃, 90% RH Maximum 9.8 Weight: 0.62Lbs (0.28kg) approx. 9.9 Dimensions: L4.65" x W1.18" x H2.83" (L118 x W30 x H72mm)

6.13 REVERSE BATTERY / OUTPUT PROTECT CONDITION. The charger has reverse battery and output short circuit protection. If a reverse battery charger condition exists ("FAULT" Red L.E.D.) solid, while output leads are connected backwards), simply unplug charger from AC power and properly remake the connections as described in this manual.

Fig. 21: Battery

6.14 WIND

Wind is simply air in motion. It is caused by the uneven heating of the Earth's surface by radiant energy from the sun. Since the Earth's surface is made of very different types of land and water, it absorbs the sun's energy at different rates. Water usually does not heat or cool as quickly as land because of its physical properties. An ideal situation for the formation of local wind is an area where land and water meet. During the day, the air above the land heats up more quickly than the air above water. The warm air over the land expands, becomes less dense and rises. The heavier, denser, cool air over the water flows in to take its place, creating wind. In the same way, the atmospheric winds that circle the Earth are created because the land near the Equator is heated more by the sun than land near the North and South Poles. Today, people use wind energy to make electricity. Wind is called a renewable energy source because the wind will blow as long as the sun shines.

6.15 FERRITE CORE INDUCTOR

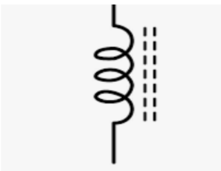


Fig. 22: Inductor

In electronics, a ferrite core is a type of magnetic core made of ferrite on which the windings of electric transformers and other wound components such as inductors are formed. It is used for its properties of high magnetic permeability coupled with low electrical conductivity (which helps prevent eddy currents). Because of their comparatively low losses at high frequencies, they are extensively used in the cores of RF transformer inductors in applications such as switched-mode power supplies, and ferrite loopstick antennas for AM radio receivers.

APPLICATIONS:

There are two broad applications for ferrite cores which differ in size and frequency of operation: signal transformers, which are of small size and higher frequencies, and power transformers, which are of large size and lower frequencies. Cores can also be classified by shape, such as toroidal cores, shell cores or cylindrical cores. The ferrite cores used for power transformers work in the low frequency range (1 to 200 kHz usually[2]) and are fairly large in size, can be toroidal, shell, or shaped like the letters ‘C’, ‘D’, or ‘E’. They are useful in all kinds of electronic switching devices – especially power supplies from 1 Watt to 1000 Watts maximum, since more powerful applications are usually out of range of ferritic single core and require grain oriented lamination cores. The ferrite cores used for signals have a range of applications from 1 kHz to many MHz, perhaps as much as 300 MHz, and have found their main application in electronics, such as in AM radios and RFID tags.

CHAPTER 7

CONCLUSIONS

A new integrated four-port DC-DC converter was proposed for hybrid energy system applications. The proposed converter is derived from a phase-shifting DC-DC converter and was used for interfacing a hybrid system with different energy sources, e.g., a PV panel, a WTG, and a battery. A small-signal model was first derived from the differential equations at different operation stages. Based on the model, multiple controllers were developed to regulate the DC-link voltage, battery voltage and current. Simulation and experimental results have shown that the converter is not only capable of MPPT for the PV panel and WTG when solar and wind power is available, but also can control the charge/discharge of the battery to maintain the DC-link voltage at a constant value.

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