An Wireless Sensor Network Based Smart Grid Converter Control Using Hybrid Energy Source

V.Ramya, R.Anandaraj, B.Amalore Naveen Antony

Abstract: A smart grid (SG) has attracted great attention due to recent environmental problems. SG technologies enable users, such as energy system operators and consumers, to reduce energy consumption and the emission of greenhouse gases, by changing energy infrastructure more efficiently. As a part of the SG, home energy management system (HEMS) has become increasingly important, because energy consumption of a residential sector accounts for a significant amount of total energy consumption. This project presents a hardware design of smart grid control converter control strategy that integrates smart home network to be compatible for smart grid integration with hybrid energy system : photovoltaic arrays, wind turbine etc In this network, a Smart Grid Home Gateway can control the electrical appliances based on the programming schedule or data received from control centre Wireless sensor networks (WSNs) are small micro electrical mechanical systems that are deployed to collect and communicate the data from surroundings. WSNs can be used for monitoring and control of smart grid assets.

Index Terms: Smart Grid, Wireless Sensor Network, Converter Control Strategy, Hybrid Energy System.

I INTRODUCTION

The electrical grid is being revolutionarily transformed as Smart grid. Smart Grid is an automated and broadly distributed energy generation, transmission and distribution network. It is characterized by full duplex network with bidirectional flow of electricity and information. It is a close loop system for monitoring and response. Smart Grid is being conceptualized and developed by various organizations around the world such as National Institute of Standards and Technology (NIST), Institute of Electrical and Electronics Engineers (IEEE), European Technology Platform (ETP), International Electrotechnical Commission (IEC),Electric Power Research Institute (EPRI), etc. Diverse set of standards and harmonization between various standards are also being rigorously researched by these organizations. It can be defined in various ways as per its functional, technological or beneficial aspects. As per the definition given by U.S. department of energy, "A smart grid uses digital technology to improve reliability, security, and efficiency (both economic and energy) of the electric system from large generation, through the delivery systems to electricity consumers and a growing number of distributed-generation and storage resources".

Smart Grid is an integration of electrical as well as information and communication technologies to make the power grid more reliable, flexible, efficient and robust. It is an intelligent power grid with assimilation of various alternative and renewable energy resources. Automated monitoring, data acquisition, control and emerging communication technologies are the most prominent features of smart grid deployment. Use of diverse set of communication standards requires analysis and optimization depending upon constraints and requirements. These requirements can be decided onthe basis of area of coverage, type of application, bandwidth requirement, etc. Smart grid hierarchical communication network can be categorized as Home Area Network (HAN), Neighbourhood Area Network (NAN) and Wide Area Network (WAN) as per the applications of communication technologies at various levels of deployment of smart grid.

II RELATED AND PREVIOUS WORKS

A novel high step-up dc/dc converter is presented for renewable energy applications. The suggested structure consists of a coupled inductor and two voltage multiplier cells, in order to obtain high step-up voltage gain. In addition, two capacitors are charged during the switch-off period, using the energy stored in the coupled inductor which increases the voltage transfer gain. The energy stored in the leakage inductance is recycled with the use of a passive clamp circuit. The voltage stress on the main power switch is also reduced in the proposed topology. Therefore, a main power switch with low resistance $R_{DS(ON)}$ can be used to reduce the conduction losses. The operation principle and the steady-state analyses are discussed thoroughly. To verify the performance of the presented converter, a 300-W laboratory prototype circuit is implemented.

The circuit configuration of the proposed converter is shown in Fig. 1. The proposed converter comprises a dc input voltage (V), active power switch (S), coupled inductor, four diodes, and four capacitors. Capacitor $C1$ and diode $D1$ are employed as clamp circuit respectively. The capacitor $C3$ is employed as the capacitor of the extended voltage multiplier cell.The capacitor $C2$ and diode $D2$ are the circuit elements of the voltage multiplier which increase the voltage ofclamping capacitor$C1$. The coupled inductor is modelled as an ideal transformer with a turn ratio N (NP/NS), a magnetizing inductor Lm and leakage inductor Lk.

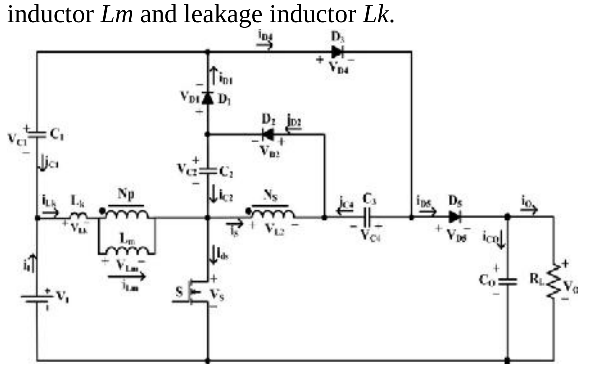

Fig:1.1 High-step-up converter

In order to simplify the circuit analysis of the converter, some assumptions are considered as follows:

1) All Capacitors are sufficiently large; therefore $VC1$,$VC2$, $VC3$,and VO are considered to be constant during one switching period;
2) all components are ideal but the leakage inductance of the coupled inductor is considered.
According to the aforementioned assumptions, the continuous conduction mode (CCM) operation of the proposed converter includes five intervals in one switching period. The operating stages are explained as follows.
1) Stage I [$t0 < t < t1$*]:* In this stage, switch S is turned ON. Also, diodes $D2$ and $D4$ are turned ON and diodes $D1$ and $D3$ are turned OFF. The dc source (VI) magnetizes Lm through S. The secondary-side of the coupled inductor is in parallel with capacitor $C2$ using diode $D2$. As the current of the leakage inductor *Lk Increases* linearly, the secondary side current of the coupled inductor (iS) decreases linearly. The required energy of load (RL) is supplied by the output capacitor CO. This interval ends when the secondary-side current of the coupled inductor becomes zero at $t = t1$.
2) Stage II [$t1 < t < t2$*]:* In this stage, switch S and diode $D3$ are turned ON and diodes $D1$,$D2$, and $D4$ are turned OFF. The dc source VI magnetizes Lm through switch S. So, the current of the leakage inductor *Lk And* magnetizing inductor Lm increase linearly. The capacitor $C3$ is charged by dc source VI , clamp capacitor and the secondary-side of the coupled inductor. Output capacitor CO supplies the demanded energy of the loadRL . This interval ends when switch (S) is turned OFF at $t = t2$.
3) *Stage III [*$t2 < t < t3$]*:* In this stage, switch S is turned OFF. Diodes $D1$ and $D3$ are turned ON and diodes $D2$ and $D4$ are turned OFF. The clampcapacitor $C1$ is charged by the stored energy in capacitor $C2$ and the energies of leakage inductor *Lk And* magnetizing inductor Lm. The currents of the secondary-side of the coupled inductor (iS) and the leakage inductor are increased and decreased, respectively. The capacitor $C3$ is still charged through $D3$. Output capacitor CO supplies the energy to load RL . This interval ends when *iLk is* equal to iLmat$t = t3$.
4) *Stage IV [*$t3 < t < t4$*]:* In this stage, S is turned OFF. Diodes $D1$ and $D4$ are turned ON and diodes$D2$ and $D3$ are turnedOFF. The clamp capacitor $C1$ is charged by the capacitor $C2$ and the energies of leakage inductor *Lk And* magnetizing inductor Lm. The currents of the leakage inductor *Lk And* magnetizing inductor Lm decrease linearly. Also, a part of the energy stored in Lm is transferred to the secondary side of the coupled inductor. The dc source VI , capacitor $C3$ and both sides of the coupled inductor charge output capacitor and provide energy to the load RL . This interval ends when diode $D1$ is turned OFF at $t = t4$.
5) *Stage V [*$t4 < t < t5$*]:* In this stage, S is turned OFF. Diodes $D2$ and $D4$ are turned ON and diodes $D1$ and $D3$ are turned OFF. The currents of the leakage inductor *Lk And* magnetizing inductor Lm decrease linearly. Apart of stored energy in Lm is transferred to the secondary side of the coupled inductor in order to charge the capacitor $C2$ through diode $D2$. In this interval the dc input voltage VI and stored energy in the capacitor $C3$ and inductances of both sides of the coupled inductor charge the output capacitor Co and provide the demand energy of the load RL . This interval ends when switch S is turned ON at $t = t5$.

III PROPOSED SYSTEM

In this project, we presents the control strategy and power management for an integrated three-port converter, which interfaces one solar input port, one bi directional battery port, and an isolated output port. Multimode operations and multi loop designs are vital for such multiport converters. However, control design is difficult for a multiport converter to achieve multifunctional power management because of various cross-coupled control loops. Since there are various modes of operation, it is challenging to define different modes and to further implement autonomous mode transition based on the energy state of the three power ports. A competitive method is used to realize smooth and seamless mode transition. Multiport converter has plenty of interacting control loops due to integrated power trains. It is difficult to design close-loop controls without proper decoupling method.

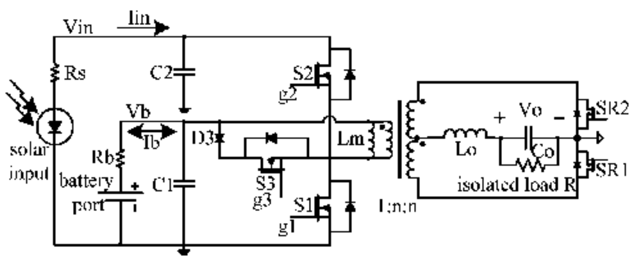

Fig: 3.1Three-port topology and control structure

The three-port topology and control structure. As shown in Figure 3.1, it is a modified version of pulsewidth-modulated (PWM) half-bridge converter that includes three basic circuit stages within a constant-frequency switching cycle to provide two independent control variables, namely, duty-cycles *d*1 and *d*2 that are used to control S1 and S2, respectively. This allows tight control over two of the converter ports, while the third port provides the power balance in the system.The switching sequence ensures a clamping path for the energy of the leakage inductance of the transformer at all times. This energy is further utilized to achieve ZVS for all primary switches for a wide range of source and load conditions.

Having different operational modes is one of the unique features for three-port converters. An orbital satellite's power platform experiences periods of insolation and eclipse during each orbit cycle, with insolation period being longer. Since MPPT can notably boost solar energy extraction of aphotovoltaic (PV) system, the longer isolation period means that MPPT is more often operated to allow a smaller solar array while managing the same amount of load.

Two assumptions are made to simplify the analysis: 1) load power is assumed to be constant and 2) battery overdischarge is ignored because PV arrays and batteries are typically oversized in satellites to provide some safety margins. Four stages in satellite's one-orbit cycle yield two basic operational modes as follows.

In battery-balanced mode (mode 1), the load voltage is tightly regulated, and the solar panel operates under MPPT control to provide maximum power. The battery preserves the power balance for the system by storing unconsumed solar power or providing the deficit during high-load intervals. Therefore, the solar array can be scaled to provide average load power, while the battery provides the deficit during peak power of load, which is attracting to reduce solar array mass. In battery-regulation mode (mode 2), the load is regulated and sinks less power than is available, while the battery charge rate is controlled to prevent overcharging. This mode stops to start mode 1 when the load increases beyond available solar power, i.e., battery parameter falls below either maximum voltage setting or maximum current setting.

The converter has three circuit stages to allow two control inputs that are used to regulate two of the three ports. The output voltage is regulated at any given time, but either input port or battery port can be regulated depending on which is most urgently needed according to available solar power and battery state of charge. The control design for multiport converter is challenging and needs to manage power flow under various operating conditions. Therefore, the control strategy must be "powerful" and "intelligent" enough to realize complicated control tasks, and should have different operational mode transition control. A competitive method was utilizedto realize autonomous mode transitions. Basically, there are no modes from controller point of view, which simplifies the control algorithm and avoids possible system oscillations due to elimination of instant duty-cycle value change. This project also presented a general modelling procedure specially tailored for three-port converters. Since there are many control inputs and state variables for multiport converter, converter model derivation adopts matrix-based averaged state-space method. Moreover, the small-signal models for different operational modes were obtained separately, while the model derived for each mode includes two ports' dynamic characteristics other than one for two-port converters. Then, a decoupling network was adopted to solve the problem ofcontrol-loopinterdependence, so that each port can be treated as an independent subsystem. With proper decoupling, it is then possible to analyze each port's control loop separately.

IV SIMULATION RESULTS

In this section, the simulation results are shown. Where the output schematics are simulated by the MATLAB 2013 Ra and network simulator tool.

Matlab Result

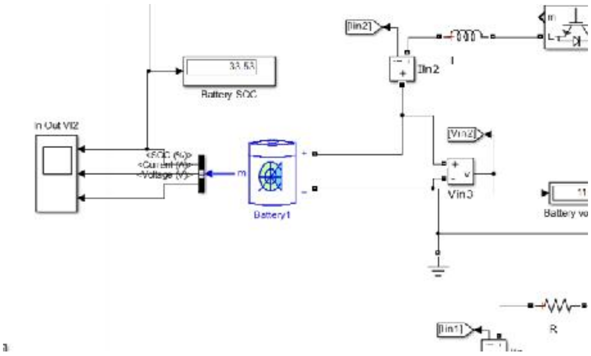

Fig .4.1 BS Energy Storage

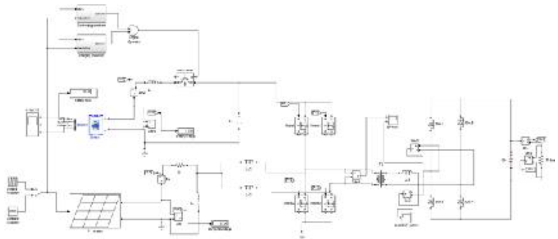

Fig.4.2 Total Topology

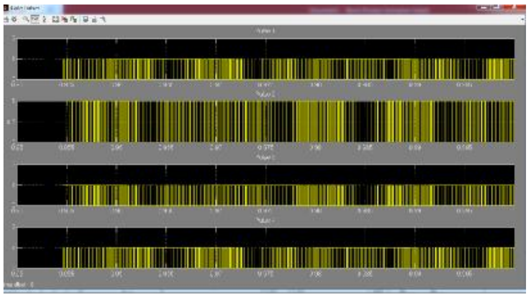

Fig:4.3Pwm waveform

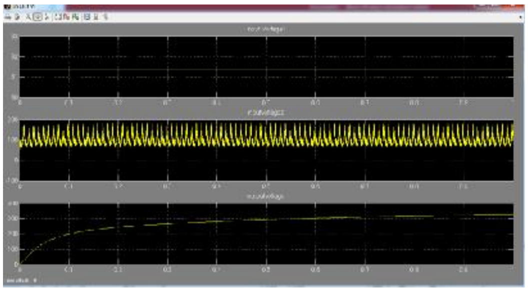

Fig:4.4 Corresponding source and load

Network simulator

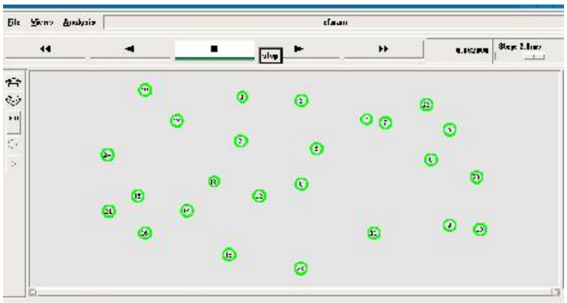

Fig:4.5 Node Creation

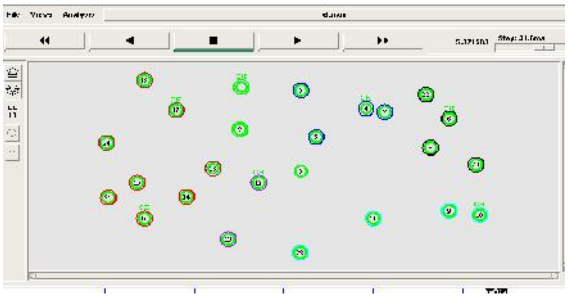

Fig: 4.6 Proposed Topology Communication

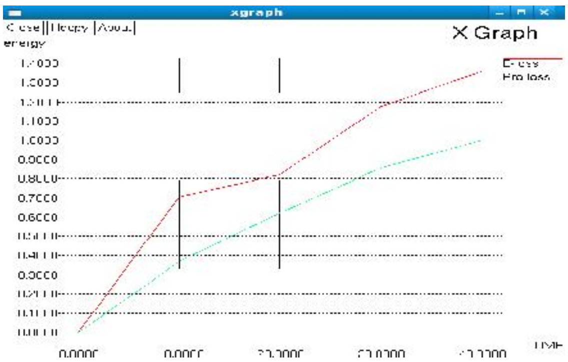

Fig:4.7 Existing and proposed loss comparison

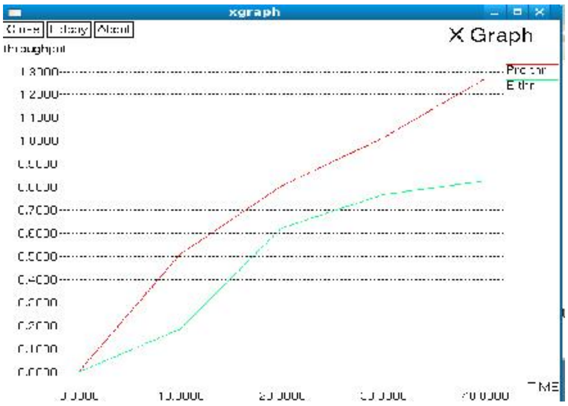

Fig: 4.8 Comparison chart for throughput

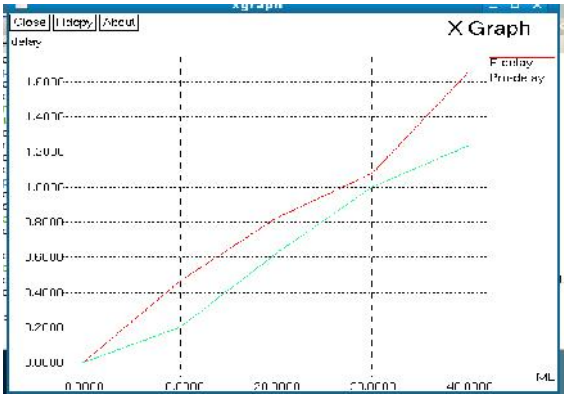

Fig: 4.9 Comparison chart for delay

V CONCLUSION

The present power grid is going through a huge transformation with the deployment of smart grid technology. Smart grid is a complex hierarchical and heterogeneous network. Wireless sensor network is a prominent solution for various applications of smart grid. Wireless sensor networks are distributed collection of sensor nodes situated at various places for measurement and communication of various parameters such as temperature, voltage, current and humidity. These parameters are required for remote monitoring and control of different components of smart grid.WSNs are effective solutions for energy management system in home, industry and business applications. These small sensor nodes are extensively vulnerable to attacks as they are placed in hostile surroundings. Node capture results into complete control of attacker on the WSN node and tampering of hardware as well as software of the node. The energy exhausted sensor nodes can be easily victimized

V.Ramya (ramya6292@gmail.com),
R.Anandaraj (Associate Professor, anandraj.r@egspec.org),
B.Amalore Naveen Antony (Assistant Professor, naveenjosh839@gmail.com)
Department of Electrical and Electronics Engineering, E.G.S Pillay Engineering College,
Nagapattinam,Tamilnadu, India.

References

1. Farooq, H.; Jung, L.T. Choices available for implementing smart grid communication network. InProceedings of the IEEE International Conference on Computer and Information Sciences (ICCOINS),Kuala Lumpur, Malaysia, 3–5 June 2014; pp. 1–5.
2. Feng, Z.; Yuexia, Z. Study on smart grid communications system based on new generation wireless technology. In Proceedings of the IEEE International Conference on Electronics, Communications and Control (ICECC), Ningbo, China, 9–11 September 2011; pp. 1673–1678.
3. Fang, X.; Misra, S.; Xu, G.; Yang, D. Smart grid—The new and improved power grid: A survey. *IEEE Commun. Surv. Tutor.* 2012, *14*, 944–980.
4. Fan, Z.; Kulkarni, P.; Gormus, S.; Efthymiou, C.; Kalogridis, G.; Sooriyabandara, M.; Zhu, Z.;Lambotharan, S.; Chin,W.H. Smart grid communications: Overview of research challenges, solutions, and standardization activities. *IEEE Commun. Surv. Tutor.* 2013, *15*, 21–38.
5. U.S. Department of Energy. Smart Grid System Report. AvailableOnline:http://energy.gov/sites/prod/files/2014/08/f18/SmartGrid-System Report 2014.pdf (accessed on 10 August 2016).
6. Giustina, D.D.; Rinaldi, S. Hybrid Communication Network for the Smart Grid: Validation of a Field Test Experience. *IEEE Trans. Power Deliv.* 2015, *30*, 2492–2500
7. Goel, N.; Agarwal, M. Smart grid networks: A state of the art review. In Proceedings of the IEEE International Conference on Signal Processing and Communication (ICSC), Noida, India, 16–18 March 2015; pp. 122–126.
8. Mulla, A.; Baviskar, S.; Khare, N.; Kazi, F. The Wireless Technologies for Smart Grid Communication: A Review. In Proceedings of the IEEE International Conference on Communication Systems and Network Technologies (CSNT), Gwalior, India, 4–6 April 2015; pp. 442–447.
9. Kuzlu, M.; Pipattanasomporn, M.; Rahman, S. Review of communication technologies for smarthomes/building applications. In Proceedings of the IEEE International Conference on Smart Grid
Technologies—Asia (ISGT ASIA), Bangkok, Thailand, 3–6 November 2015.
10. Chhaya, L.; Sharma, P.; BhagwatiKar, G.; Kumar, A. Design and Implementation of Remote Wireless
Monitoring and Control of Smart Power System Using Personal Area Network. *Indian J. Sci. Technol.* 2016,
9, 1–5.
11. Parvez, I.; Sundararajan, A.; Sarwat, A.I. Frequency band for HAN and NAN communication in Smart Grid. In Proceedings of the IEEE Computational Intelligence Applications in Smart Grid (CIASG)Symposium, Orlando, FL, USA, 9–12 December 2014.
12. Hiew, Y.K.; Arifin, N.M.; Din, N.M. Performance of cognitive smart grid communication in home area network. In Proceedings of the IEEE 2nd International Symposium on Telecommunication Technologies(ISTT), Langkawi, Malaysia, 24–26 November 2014; pp. 417–422.
13. Aalami Far, F.; Hassanein, S.; Takahara, G. Viability of powerline communication for the smart grid. InProceedings of the 26th Biennial Symposium on Communications (QBSC), Kingston, ON, Canada, 28–29May 2012; pp. 19–23