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Editorial...

Hardening of Transmission Lines of Power Grid

From the annals of the development of Power System Engineering the world over, distribution network hardening by resorting to UG Cable in the case of distribution and sub-transmission network was implemented to improve reliability of power distribution. The reliability of the network can be enhanced by burying the distribution network underground thereby saving the network from the vagaries of bad weather, adverse effects of storm, hurricane, lightning etc. as overhead distribution and sub-transmission network are more prone to failure and outages due to natural calamities.

The reliability indices could be improved a lot by hardening the distribution and sub-transmission network. In developed economies and urban areas, this policy was implemented to achieve reliability in power distribution.

Change in climate increases the fury of wind due to heavy movement of air from higher temperature zones to lower temperature zones and hence the over head lines are more prone to hurricanes/ storm. Cross Linked Poly Ethylene (XLPE), the insulator used in the manufacture of UG Cables is a highly heat stable insulator characterised by impermeability to water and high puncture resistance.

The utilities preferred to keep the transmission lines in the overhead configuration due to the heavy cost involved in the manufacture of UG Cables. Transmission lines operate at comparatively higher power levels than their distribution counterparts and hence they generate more heat which is difficult to dissipate underground.

For converting overhead transmission lines to underground cables, utilities have to expend 10-12 times the cost of overhead lines and hence stayed away from choosing the UG option. Due to huge outcry of public in any economy due to the prevalent NIMBY (Not-In My Back Yard) syndrome, now the utilities are opting to bury the transmission lines underground given the increased cost involved in the process of hardening transmission lines. Both AC and HVDC transmission lines are routed underground in many developed economies to reduce public conflicts for transmission line routes in towns and aesthetic places/ tourist destinations.

Some power planners do consider the visual effect of the transmission towers and the suspended lines and choose to bury transmission lines underground for projecting better aesthetics of the area through which the power transmission line is drawn supported along transmission line towers.

Thus the planners in many economies internationally view the hardening of transmission lines, by burying them underground, by using copper conductor surrounded by a thick layer of XLPE insulation as a viable option to reduce the public outcry and to improve the visual effect of the area through which the transmission line is laid.

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KSEBEA Code of Ethics

- **Thou shalt maintain thy integrity under all circumstances.**
- **Thou shalt incessantly work for the advancement of the professional knowledge.**
- **Thou shalt not give an incorrect professional opinion**
- **Remember Thou art a member of a team and the achievement of the team is thy own success.**
- **Thou shalt not malign thy co-professionalists.**
- **Thou shalt strive for the advancement and dignity of thy juniors in the profession.**
- **Thou shalt strive for the welfare of the community.**
- **Thou shalt enlighten the community with the correct aspect of Engineering/Technological activities.**
- **Thou shalt endeavour to develop a dignified status in the society.**
- **Thou shalt strive by conduct and character to be a worthy citizen of the Motherland.**

A REVIEW OF ELECTRICITY TARIFF STRUCTURE IN INDIA

Dr E. Mohammed Shereef, Deputy Chief Engineer, KSEBL

Introduction

Indian power sector is one of the most diversified in the world. It has witnessed many transformations with the progressive changes in policy level. The accelerated pace of generation capacity addition during the past years has led to a situation where in the supply potential exceeds the demand. The enhanced policy-focus on climate change, energy security etc., resulted in penetration of more renewable energy and hence the energy mix also is changed. The demand pattern have also undergone changes consequent to urbanization, increased use of space conditioners, adoption of energy efficient initiatives etc. The Electricity Act 2003, the National Electricity Policy 2005 and the Tariff Policy 2006 mainly provide the structure and the principles to be followed for the determination of electricity tariffs. Tariff rationalization envisages cost reflective and non complex tariff structure. But in many states, the tariff is politically determined and complex with various categories. In most of the states, agricultural and domestic consumers are cross-subsidised by commercial and industrial consumers.

Average cost of supply and revenue realisation

The average cost of supply increased from Rs 2.54/ kWh in 2004-05 to Rs 5.43/kWh in 2015-16 with an annual increase rate of 7.19 % (CAGR). During this period, the average revenue increased from Rs 2.09 / kWh to Rs 4.23/ kWh with an annual increase rate of 6.62 % (CAGR). Though both have increasing trend, the rise in revenue is not commensurate with the increase in the cost of supply. The level of recovery measured in terms of sales revenue as a ratio of cost has declined from 99.5% in 2004-05 to 88.4% in 2015-16. As a result, the revenue gap has been widening over the years. The average cost of supply and average revenue from 2004-05 to 2015-16 is presented in Fig.1.

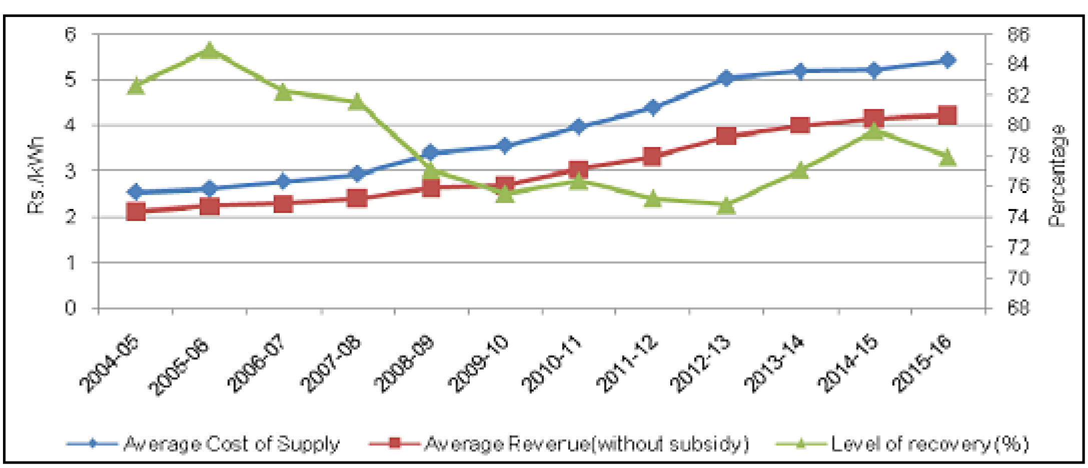

Figure1. Average Cost of Supply and Average Realisation in All India level.

Average Cost of Supply Coverage

The domestic, commercial, agricultural, and industrial consumers account for 80% to 90% of the energy sales. The domestic and agricultural consumers are provided electricity at below cost rates in many states. The Average Cost of Supply (ACoS) coverage calculated for various categories of consumers in the country and Kerala during the year 2015-16 is shown in Figure.2. It can be observed that the ACoS coverage is outside +/- 20% range for most of the categories of consumers. The agricultural and domestic coverage is far below the target range both for Kerala as well as at national average level.

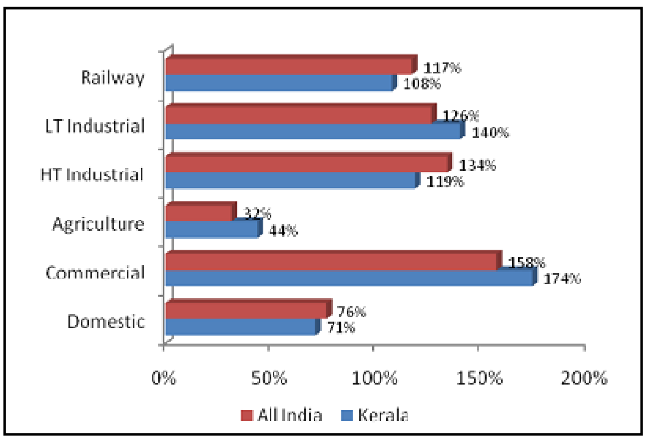

Figure.2 Category wise Average Cost of Supply coverage in 2015-16

The state government does not provide any direct subsidy for subsidised categories. The commercial, agricultural and LT industrial recovery for Kerala is slightly above the national average where as for domestic, HT industrial and railway traction recovery is below the national average. The retail electricity price in India was the lowest in 2016 when compared to the developed countries in the world. The domestic electricity price in India was 6 US cents/kWh where as the average price that in developed countries was around 18 US cents/kWh. During the period 2004 to 2016, the domestic and industrial tariff increased at 2.01% and 1.26% in India which is below the developed countries (2.32% & 2.33%).

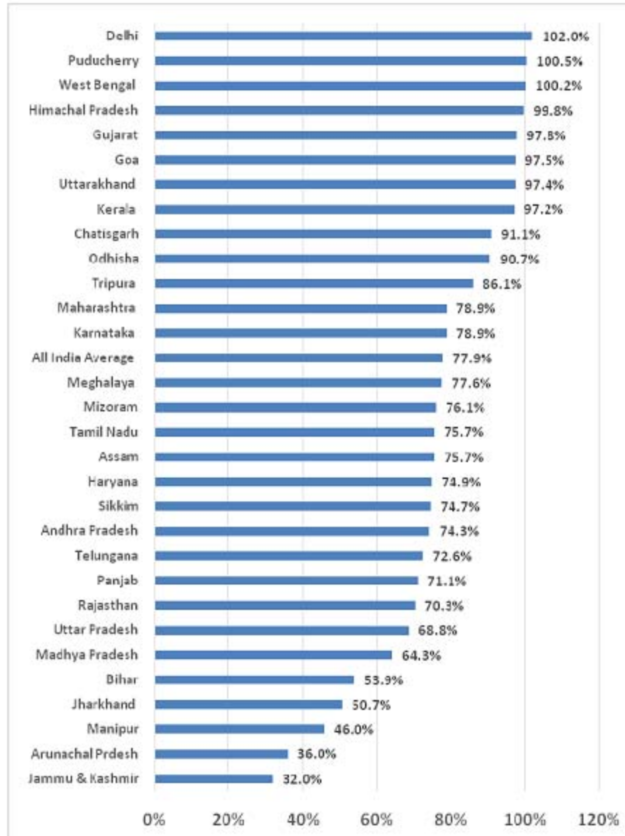

Fig.3 State - wise variation in level of recovery in 2015-16

Electricity Cost

The main components of electricity cost are power purchase cost, generation cost, employee cost, operation & maintenance cost, administration cost, interest etc. Among this, the power purchase cost, generation cost and employee cost together constitute 80% of the total cost. The share of these cost as a percentage of the total cost for the period 2004-05 to 2015-16 for Kerala and at All India level is presented in Table.1

Table.1 Major components of Electricity Cost

Year	*Share of Power purchase in the Cost of Supply (%)*		*Share of Generation cost in the Cost of Supply (%)*		*Share of Employee cost in the Cost of Supply (%)*	
	All India	*Kerala*	*All India*	*Kerala*	*All India*	*Kerala*
2004-05	57.83	41.84	14.70	2.32	8.62	21.42
2005-06	61.54	41.06	13.98	1.37	8.05	22.00
2006-07	61.68	37.53	13.51	2.58	8.26	19.79
2007-08	63.15	41.94	13.26	3.91	8.56	17.17
2008-09	61.68	58.09	13.98	7.06	9.96	20.20
2009-10	61.27	55.07	13.49	5.92	9.38	22.32
2010-11	61.27	55.68	12.11	3.55	8.85	24.28
2011-12	61.40	56.55	12.31	3.64	8.26	23.03
2012-13	62.51	63.06	11.79	4.95	7.80	17.15
2013-14	63.39	61.17	10.83	2.14	7.61	21.34
2014-15	64.09	58.04	11.10	1.80	7.78	23.28
2015-16	61.36	54.81	9.54	0.90	7.53	26.86
CAGR (%)	**0.54**	**2.49**	**-3.85**	**-8.24**	**-1.22**	**2.08**

The power purchase cost is the major component of electricity cost both at national level (around 62%) and for Kerala (around 52%). The employee cost is the second largest component in Kerala (around 22%). The annual increase (CAGR) in power purchase cost is minimal (0.54%) at national level whereas it is negative for generation cost (-3.85%) and employee cost (-1.22%). For Kerala, the annual increase (CAGR) for power purchase cost (2.49%) and employee cost (2.08%), which are higher than the national average. For Kerala the generation cost is decreasing (-8.24%) while power purchase cost is increasing over the years. The reduction in internal generation, increased share of power purchase, renewable penetration etc. are the main reasons for the same.

Conclusion

Though it has been more than a decade since the Electricity Act 2003 and associated policies have been in place, sincere efforts are not seen taken by many of the utilities or the state governments in that direction. This is mainly because, still the electricity tariff is more or less decided based on socio-political considerations rather than economic and efficiency considerations. The country needs a Cost of Supply (CoS) based tariff in all states. The welfare measures may be addressed through social policy instruments of the government. Since the commercial and industrial are the major subsidizing categories, there tariff is above the CoS. If the cross subsidy is reduced, the industrial sector will grow. There is a consensus that sector turn around is possible only if the revenue loss is addressed.

Reference

1. Annual Report 2013-14, Planning Commission, Government of India
2. Report on Performance of State Power Utilities - for various years, Power Finance Corporation Ltd, Government of India
3. Annual Report 2011-12, on the working of State Power Utilities & Electricity Departments, Planning Commission, Government of India.
4. Report on Road Map for Reduction in Cross Subsidy, Forum of Regulators, April, 2015
5. Power System Statistics, KSEB
6. Dr. U. R. Prasad, Analysing Tariffs, PowerLine, December 2017
7. CEA website
8. KSERC website
9. MoP website
10. Energy Prices& Taxes, IEA

Earth Day-April 22

Earth Day is an annual event, celebrated on April 22, on which day events are held worldwide to demonstrate support for environmental protection. It was first celebrated in 1970, and is now coordinated globally by the Earth Day Network,[1] and celebrated in more than 192 countries each year.

When is Earth Day?

Earth Day is observed around the world on April 22, although larger events such as festivals and rallies are often organized for the weekends before or after April 22. Many communities also observe Earth Week or Earth Month, organizing a series of environmental activities throughout the month of April.

Why do we need an Earth Day?

Because it works! Earth Day broadens the base of support for environmental programs, rekindles public commitment and builds community activism around the world through a broad range of events and activities. Earth Day is the largest civic event in the world, celebrated simultaneously around the globe by people of all backgrounds, faiths and nationalities. More than a billion people participate in our campaigns every year.

What can I do for Earth Day?

The possibilities for getting involved are endless! Volunteer. Go to a festival. Install solar panels on your roof. Organize an event in your community. Change a habit. Help launch a community garden. Communicate your priorities to your elected representatives. Do something nice for the Earth, have fun, meet new people, and make a difference. But you needn’t wait for April 22! Earth Day is Every Day. To build a better future, we all must commit to protect our environment year-round.

What is Earth Day Network?

Founded by the organizers of the first Earth Day in 1970, Earth Day Network (EDN) promotes year-round environmental citizenship and action, worldwide. Earth Day Network is a driving force, steering environmental awareness around the world. Through Earth Day Network, activists connect, interact and impact their communities, and create positive change in local, national, and global policies. EDN’s international network reaches over 22,000 organizations in 192 countries, while the domestic program assists over 30,000 educators, coordinating thousands of community development and environmental protection activities throughout the year.

MATURING RENEWABLE ENERGY TECHNOLOGIES AND THE ENVISAGED PARADIGM SHIFT IN ENERGY SECTOR

C. P. George, Deputy Chief Engineer, KSEBL

Introduction

Energy is acknowledged as a key input towards raising the standard of living of citizens of any country. The correlation between per capita consumption of electricity (a proxy for all energy forms) and Human Development Index (HDI) is now a generally accepted fact. Accordingly, energy policies of India have over the years directly aimed to raise per capita consumption of energy (and electricity), even while the main focus of the country's development agenda has been on eradication of poverty. With nearly 304 million Indians without access to electricity, and about 500 million people, still dependent on solid bio-mass for cooking, it may be acknowledged that the country has to go a long way on securing its energy security objectives. While India strives to achieve a better growth rate in its national income, making clean energy available to all of its citizens, ought to be included as a key component of the poverty alleviation programmes.

In relation to its population, India is poorly endowed with conventional energy resources. Its share in the world population is 17% but the shares in the world gas, oil and coal reserves are only 0.6%, 0.4% and 7%, respectively. This has meant heavy dependence on imports even at a rather low level of energy consumption. To manage these severe supply constraints, there are at least two demand-side interventions that can help cut energy usage. They are energy conservation and the energy efficiency. Often conservation and efficiency effects come jointly.

The National Energy Policy (NEP) aims to chart the way forward to meet challenges in the energy domain. We are targeting a reduction of oil import by 10% from 2014-15, by 2022 and a reduction of emissions intensity by 33%-35% by 2030 over 2005. These targets are fixed based on achieving a 175 GW renewable energy capacity by 2022, and the share of non-fossil fuel-based capacity in the electricity mix is aimed at above 40% by 2030. A number of far-reaching developments have taken place in the local and global energy space also have reflected in deciding these targets.

The world is moving away from overwhelming dependence on fossil fuel. Against an 88% total share of fossil fuels globally in the primary energy mix in the year 2005, the same fell to 86% in the year 2015. The share of Renewable Energy (including nuclear and large hydro) has gone up from 12.5% to14% in the period 2005-15.

The above trends, principally owing to climate change concerns, are expected to be maintained over the medium term. The adverse effects of climate change are much more discernible than ever before, with a better understanding of the relationship between energy use and poor environmental outcomes. While the global agenda is of common concern, there is a heightened consciousness of the need to fix poor air quality standards in Indian cities, which is being reflected in tough administrative actions and court mandated orders.

Relevance of Renewable Energy Sources

The sharp decline in the prices of wind and solar technologies in the recent years by about 60% and 52% respectively between 2010 and 2015 (in kWh terms), has led to a change in the relative importance of energy sources. Tropical countries, including India, are richly endowed with the above resources, and can harness them in an innovative manner to meet energy requirements at decentralised locations. In the recent auctions, solar and wind energy prices have achieved bus bar grid parity at the generation end.

All the above developments offer a challenge to the existing energy pathways, and also offer an opportunity to respond by building in sustainability in the new energy infrastructure. There is a raging debate as to whether the latter could be developed in a more decentralised manner. Whether or not the past global practice of large generation plants with capital intensive evacuation/ transmission infrastructures, can now be better done with low cost decentralised solutions, the new energy pathways must be enabled to accept decentralised solutions.

As per the energy modelling exercise undertaken for India Energy Security Scenarios (IESS), 2047, the energy demand of India is likely to go up by 2.7-3.2 times between 2012 and 2040, with the electricity component itself rising 4.5-fold. As such, India has an opportunity to incorporate emerging technologies in the new infrastructure, to be able to exploit these technologies as they mature, and costs falls. The IESS has been used to generate multiple scenarios of the likely energy demand and the above exercise has revealed that in 2040, energy demand could be brought down over the default scenario by 17% by suitable interventions. It has also revealed that even if efforts were stepped up to enhance domestic energy supply, coupled with heroic effort to reduce energy demand, India's overall primary energy import dependence could still rise to 36-55% by 2040 from 31% in 2012.

Policy Aspects

With rising maturity of renewable energy technologies, aided by decline in their costs and upon environment considerations, the Energy policy need to be articulated to boost Renewable Energy capacity. As per the energy policy, a cumulative capacity target of 175 GW has been targeted for the year 2022, and by 2040 a likely capacity of 597-710 GW is expected to be achieved.

Beyond 2022, as the growth is expected to take place autonomously, no target is proposed. The above capacity will translate into 50%-56% and 29%-36% Renewable Energy (excluding large hydro) capacity in installed capacity and generation from all power generation sources by 2040, in place of 14% and 6.5%, respectively in 2015-16. The period 2017-2040 will, therefore, witness a transformation in the electricity sector of India, calling for policy action across the entire value chain of generation, transmission and distribution.

The Renewable Energy policy has to be a subset of the larger electricity sector policy. In the NEP, we are merely considering measures that are required to ensure that the large envisaged Renewable Energy capacity integrates well with the electricity system. The recent sharp reduction in the tariffs for solar and wind power, points towards exposing these technologies with market discipline, and the withdrawal of the role that Government subsidies played so far. On markets, as renewable technologies mature, they ought to support transmission and balancing concerns on their own. It is envisaged that as consumers become agnostic to the source of power, renewable energy will soon blend with conventional power and markets with appropriate regulatory mechanism will determine dispatch rather than policy levels.

Grid Integration of Renewable Electricity and More Efficient Grid Operation

Grid integration means minimizing and/or managing the variability and uncertainty aspects of Renewable Energy. Unlike fossil fuel-based electricity that can be generated steadily, renewable sources like wind and solar cannot be made to generate on demand (or be shut down for later exploitation). The renewable-based generation may actually rise or fall suddenly (e.g. solar), or over seasons more predictably (e.g. wind), causing inconvenience to grid managers. Technically, Renewable Energy is described as an intermittent source of electricity, where intermittency consists of two distinct aspects:

- "Predictability/Uncertainty" refers to the lack of accurate knowledge about future Renewable Energy generation (e.g. sudden drop in solar power).
- "Variability" is the known natural variation in Renewable Energy generation (e.g., wind peaking during monsoon and reduced availability in other seasons), just as exists on the demand side currently (e.g., low demand at mid- night and high demand during late afternoon).

An Expert Group constituted by NITI Aayog has determined that meeting the 175 GW renewable installed capacity target by 2022, would not be as much a financial challenge as a technical one. Internationally — where Renewable Energy accounts for increasingly large shares of power system generation — various changes to grid design, technology and its operation have been implemented that allow successful utilization of renewable electricity. Many of these strategies are inherently useful for improving the overall efficiency of grid operations and reducing overall costs to consumers, whether Renewable Energy accounts for a large (more than 25%) share of the generation mix or not. Some of these changes are one-time changes while others would evolve over time as load shapes and the resource mix continue to change. Of these, upgrading Grid Technology, upgrading Grid operation protocol, expanding "balancing areas" and upgrading grid planning practices are considered as one-time strategy; whereas balancing resource estimation, procurement and dispatch are considered as ongoing strategy.

Strategy

In India, it is expected that in 2022, renewable electricity would comprise more than 15% of electricity generated in the country. The share is expected to be much higher in eight states — TN, Andhra Pradesh, Telangana, Karnataka, Maharashtra, Gujarat, Rajasthan and MP. The challenge imposed by such high Renewable Energy share on the power systems, unless managed, would put-off grid operations, resulting in impact on Renewable Energy absorption by the grid, thus impacting investors. The Centre and States would collaborate to address this problem in close coordination. The following strategy is recommended:

1. ***Upgrade grid technology***: System operators at all levels (i.e. state, regional and national) should have visibility of all the Renewable Energy generation systems in their areas, and grid status in neighbouring balancing areas as well, and also the ability to easily coordinate with them.

i. The capabilities of the transmission companies (i.e. central and state transmission utilities) and Load Dispatch Centres (LDCs) (i.e. POSOCO and State LDCs) will be upgraded by deploying sensors for generating real-time high geographic resolution data on grid conditions.

ii. These data generation sensors will be coupled with sophisticated analytical engines that provide the necessary information for grid operations.

iii. Centralized Renewable Energy forecasting mechanisms will be tightly integrated with system operations.

iv. Advanced decision-making and control systems will be implemented that enable system operators to respond significantly faster to changed grid conditions.

2. ***Upgrade grid operation protocols***: Various aspects of system operations will be updated. The following steps will be taken:

i. Grid Codes: System operators will update their grid codes to ensure that Renewable Energy additions do not affect the grid adversely, and to explicitly acknowledge attributes unique to Renewable Energy generators and consequently, build-in appropriate capabilities so that Renewable Energy generation is not adversely impacted.

ii. Scheduling and Dispatch: Scheduling and dispatch will be upgraded from the current 15-minute basis. System operations technologies and protocols will be updated to enable five-minute scheduling and dispatch of all resources connected to the grid and automated incorporation of Renewable Energy forecasts. This will lower consumer costs and also lower ancillary service requirements.

3. ***Expand Balancing Areas***: Larger balancing areas can help reduce variability by offering more balancing resources/demand, making it easier to manage. However, due to jurisdictional issues, regulation and management is currently being done at state level. A single national-level load dispatch centre that is non-profit, independent, and regulated by CERC would be empowered for managing the entire national grid as one, with appropriate markets and regulatory frameworks in place.

4. ***Promote flexible demand and supply resources***: Power systems, especially those with a high share of Renewable Energy, require access to sufficient flexible resources (e.g., demand response, gas turbines, flexible thermal generation, hydroelectricity etc.) to ensure continued stability of the grid at each moment.

i. The amount of balancing resources needed and how these can be procured and dispatched will be ascertained through regular studies. Grid simulations will be conducted routinely to identify resource pools (both built and un-built).

ii. Procurement mechanisms will be implemented to ensure these resources are connected for use in assuring grid stability.

iii. Finally, mechanisms for fair price discovery and compensation of flexible resource providers (e.g. ancillary services) will be established.

Process

The above strategy will require coordination between multiple agencies at the central level, and similarly a number of actors at the state level. It is expected that the mechanism created by NITI Aayog may address this requirement. Typically, MNRE is in-charge of creating renewable capacity and is a client of the Ministry of Power that owns the grid. Then, at the central level, the CERC works independently to issue regulations, which will enable the grid integration. A key challenge is that most of the action need to happen at the State level, where power is generated and has to be evacuated and consumed. Therefore, the apex agency will need to bring the states and centre together. The following process is contemplated:

- Suitable provisions in the National Electricity Policy and Tariff Policy will enjoin upon the CERC/SERCs to issue regulations to enable the policy related interventions.
- CTU/STU will upgrade the technologies and make necessary investments to handle the intermittency through appropriate technical interventions.
- R&D will be supported for storage solutions at macro- and micro-levels for the discoms and individual consumers to address the challenge of variability.
- Different kinds of reserves (spinning and capacity) will be created and the costs socialized to provide the back-up power to help manage the variability.

Role of Large Hydro Power in Balancing the Variability of Wind & Solar Hydro generators are the best energy sources to ensure **Load Generation Balance** in the Grid by virtue of its inherent capability for quick response and minimum response time. Large hydro-power sources can play a key role in balancing the variability issue in the grid due to its ability to store water in comparison with small hydro power sources. Thus, the need for supporting hydro capacities larger than 25 MW is very important, which are presently not covered under the category of Small Hydro-power (SHP). The availability large hydro power sources ensure better integration of wind and Solar in the Grid without compromising the grid security and the reliability. As the issues of the hydro sector are different from wind/solar technologies, dedicated attention needs to be given to the former.

Despite being endowed with a large potential, this sector has been rather slow in delivering power, and the share of large hydro in the electricity mix has fallen from 12% in 2002 (at the end of the IXth Plan) to 10% in 2014-15. Resettlement & Rehabilitation are not the only reason, though a major one, for poor development of hydro resources. Hydro source of power has a large number of co-benefits including containment of flood, irrigation, fisheries, ground water-charge to name a few. There are adverse consequences, too, which call for quality research at the stage of project development to evaluate the various impacts including social and environmental. As such, a reorientation of the current hydro-power strategy need some course correction and the projects may be implemented transparently with appropriate provision of funds for the implementation of the relevant safeguards.

New Technologies & Development of Enabling Systems

The Smart grid technology which will be rolled-out across the country so as to provide an efficient electricity distribution system, is also devised to support the Renewable Energy. Appropriate technology solutions may be needed to enable RE to drive the electric vehicle agenda. Along with adequate equipment, even institutional and staffing arrangements also may need an upgrade.

Rooftop solar has vast potential across different categories of consumers for power generation. It has also been estimated that this technology is already viable for commercial and industrial consumers. Even in urban areas, rooftop solar has become cost effective especially in higher tariff slabs. However, subsidized tariff for domestic consumers creates a dis-incentive for adoption of roof-top solar and calls for subsidy support from governments.

The large Renewable Energy programme will require land, which is a scarce commodity in many States. It will, therefore, be essential to promote mega solar power plants only on wastelands and non-agricultural tracts. However, in order to achieve a wide Renewable Energy and also to maintain grid stability, generation ought to be brought close to consumption centres, as far as possible. For this, small sized solar plants (up to 50 MWp) need to come up across the country in rural areas especially at the end of the transmission lines. This will reduce the size of plots, which ought to be purchased on commercial basis, and will not be dependent on state intervention in making land available. The co-benefit would be lesser challenge to grid integration.

Over and above **the grid/off-grid** power generation potential, multiple applications of Renewable Energy in domestic, commercial and industrial segments also need to be encouraged. These applications can address energy demand for water heating, air conditioning, cooking, lighting, pumping etc. and supplement energy supply. The deployment of such applications will require innovations in our own country. The Government may encourage the same through appropriate measures, including purchase support. As Heating operations consume nearly 50% of the energy consumed in Industry, solar applications have a large opportunity.

In order to counter the intermittency in supply of renewable energy, there needs to be a push towards integrating the same with **gas-based power plants** and the development of storage technologies. A healthy backup capacity will ease consumer anxiety and help renewable energy find a place in the market. However, looking to the stranded **gas-based/equivalent** capacity, the Government may first endeavour to deploy these capacities. One option could be only to contract future renewable power blended with balancing capacity so as to provide steady supply. This will be in the fitness of things so as to de-risk the DISCOMs from having to arrange back- up/ balancing supply. The above measure can help in salvaging the existing gas-based capacity and also reduce the challenges that come with variable renewable energy. Another related emerging technology is of **Electric Vehicles** that can also double up as a storage device. Suitable application of time-of-the-day tariff mechanisms will be applied to encourage EVs to store-up renewable energy when it is available in excess of demand.

The steep rise in the share of Renewable Energy in the electricity mix will call for a number of measures to adapt the grid. The measures listed above are expected to allow integration of this variable and seasonal electricity sources, by addressing both commercial and technical challenges. Diversified geographical and distributed generation helps in addressing the above challenges in a cost-effective manner.

Financial Issues:

- In the case of technologies that need financial support to compete with conventional power, Performance linked incentives that do not involve upfront payment but encourage generation, may be promoted. Capital subsidy may be phased out and feed-in tariffs ought to drive growth of Renewable Energy.
- In the present environment, RPO (Renewable Purchase Obligation) compliance is the basic requirement for the growth of RE sector. Over

the time, as the cost of these technologies fall, there may be a balanced regional growth of these sources. Once markets drive the renewable energy autonomously, there may be no need to enforce RPOs.

- The level of tariff support, until necessary, will be determined on the basis of marginal cost of power and it has been established that competitively derived prices (both for wind and solar) are ideal for determination of the level of support and also to drive them down.
- Due to inherent qualities of lower cost via economies of scale and ability to meet varying demand for power, grid-based electricity is preferable to the renewable solutions. Therefore, efforts will be made to first electrify villages by extension of grid.
- Renewable Energy Service Companies (RESCOs) can provide capital, technology and maintenance support to the Renewable Energy sector, particularly, in the case of roof top segment.
- The present financing models are placing all the cost of balancing the intermittent renewable supply on the DISCOMs. Tools such as RPO and REC impose a large burden on the latter. The Regulatory Commissions may develop suitable regulations to ensure appropriate financing mechanisms to support them, including building it into the prices of renewable energy, in meeting the difference in the true cost of supply between conventional and renewable supply.
- While renewable generation technologies have become cheaper, the cost of developing local infrastructure and evacuating power continues to be high due to remoteness of sites. The Government and Regulatory Commissions may endeavour to support the non-generation segments of this business through facilitation and engagement with state agencies.
- There is a need to address the technical, commercial and quality of power supply issues. The distribution companies need to be reassured that roof top solutions do not pose a commercial threat to them. The State Governments and Regulatory Commissions may be encouraged to set prices in net-metering solutions in a manner that balances the interests of consumers and discoms.
- The State and Central Governments have a major role in development of Renewable Energy as both local infrastructure and purchase support, can only be provided by Governments.
- Renewable Energy sources have seen concentrated development in resource-rich regions. But the sale of this energy to other parts of India has posed a problem. The grid instability concerns will continue to pose a challenge for concentrated development of Renewable Energy. The RPO is considered as the best solution to address the financing needs of this sector. RPOs can easily ensure growth of Renewable Energy by blending it with conventional power.

Conclusion

India's zeal to step up renewable capacity has to be matched with capability to manage intermittency. The problem is aggravated by differential resource potential across states, which cannot be easily overcome by RPOs. Policy enablement will play a key role in development of balancing supplies. The government's financial support to transmission — inter- and intra-state — will help in catalysing capacity growth as well as grid balancing. In addition, a number of other steps as listed above, will have to be simultaneously taken. Flexible operation of thermal power plants – both coal and gas based – is likely to create a synergy between the conventional and renewable sources, rather than hostility. Even the stranded gas-based capacity may find a market for their power. In addition, a close coordination between generation and transmission will be needed, especially if India has to succeed in raising the share of renewable electricity yet higher by the terminal year of NEP — 2040.

The Internet of Things and Energy Utilities

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Intorduction

The "Internet of things" (IoT) is a blistering topic of discussion both in the industry and outside. It's a concept that has the potential to impact every walks of life. IoT is the concept of connecting any device with an on and off switch to the Internet. This includes everything from cellphones, washing machines, lamps, wearable devices and almost anything else you can think of. This also applies to components of machines, for example a jet engine of an airplane or alternators of hydroelectric stations. In other words the Internet of Things (IoT) is the network of physical devices, vehicles, home appliances and other items embedded with electronics, software, sensors, actuators and connectivity which enables these objects to connect and exchange data. Each thing is uniquely identifiable through its embedded computing system but is able to inter-operate within the existing Internet infrastru-cture. IEEE defines IoT as "A network of items – each embedded with sensors – which are connected to the internet".

The IoT allows objects to be sensed or controlled remotely across existing network infrastructure, creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit in addition to reduced human intervention. IoT augmented with sensors and actuators can be used in smart grids, virtual power plants, smart homes, intelligent transportation and smart cities.

Applications

The applications of IoT are far-reaching. One of the classifications is based on the following broad category; consumer, enterprise (business) and infrastructure management applications.

In consumer applications, a major portion of IoT devices are created for consumer use. Examples of consumer applications include connected car, entertainment, home automation, wearable technology, connected health and appliances such as washing machine, ovens, or refrigerators.

The term "Enterprise IoT," or EIoT, is used to refer to all devices used in business and corporate settings. One of the growing fields of EIoT include media and advertisements.

Another major area, which finds applications of this concept, is infrastructure management. The IoT can be employed in monitoring and controlling operations of railway , wind-farms etc. The application of IoT in construction industry helps in cost saving, time reduction, better quality, paperless workflow and increase in productivity. It can also help in taking faster decisions and save money with real-time data analytic. The IoT intelligent systems enable rapid manufacturing of new products, dynamic response to product demands, and real-time optimization of manufacturing process and supply chain management, by networking machinery, sensors and control systems together. Digital control systems and service information systems to optimize plant safety and security are also within the purview of the IoT. In energy management integration of sensing and actuation systems, connected to the Internet, is likely to optimize energy consumption as a whole.It can find application in environmental monitoring, medical healthcare and transportation sectors.

The Internet of Things and the Energy Utilities

Decreased cost of computing **devices** and **increased computing power and capacity** are **transforming traditional energy** and utilities industries. Companies need to transform their businesses in order to stay competitive and meet new market, regulatory and consumer demands. Best practices are needed to **analyze data, monitor processes, conduct secure operations**, extend the life of assets and **improve productivity and safety**.

In power sector, increasing demand for **renewable energy solutions**, smart grids, distributed energy resources and **distributed energy storage systems**, among other factors, is transforming the energy and utilities sector, from a centralized generation and delivery model to a dynamic one that requires **data analysis and real-time command decisions**. The Internet of Things (IoT) represents a new reality. The knowledge derived from data collected from new Internet-connected devices can be used to develop new services, enhance productivity and efficiency, improve real-time decision-making, solve critical problems, and create new and innovative experiences. However, in the negative side, as more devices connect, companies face increased fragmentation and security challenges.

New IoT technologies and solutions optimize operations through predictive maintenance, remote asset monitoring, **track and trace devices**, emergency alerts and evacuation systems, and energy efficient facilities. For energy utilities, this offer a greater flexibility to accommodate new energy sources, better management of assets and operations, greater reliability, enhanced security, better customer service and of new business models and services.

Advances in computing power, data management and communication bandwidth make the Internet of Things (IoT) a clear and present alternative towards transforming grid resilience and efficiency. Many intelligent electronic devices deployed at substations and distribution networks, coupled with a grid architecture involving applications, sensors and networking can make the existing infrastructure smarter. This new technology helps industries to deal with production challenges and inefficiencies in the grid. The smart-meters are good example of dealing with inefficiencies of the grid.

To realise the full potential of IoT technologies, we need to understand how to create and capture value from information. Employing smarter way in data collection, management control and operation of grid and production will help consumers, distribution agencies and generators in positive ways. The IoT in energy sector is a recent reality and is not a decade away. The Internet of things will help to safeguard the interest of consumers, producers and network operators. •

CODE OF PRACTICE – LEAD IDENTIFICATION (CONTROL WIRING - PROTECTION & METERING CIRCUITS)

A series	C.T secondaries for special protection; A1, A2, A3 etc. (Distance /Differential / REF Protection)	**H** series	LT AC supply; H1, H2, H3 etc.
B series	C.T secondary for Bus bar protection; B1, B2, B3 etc.	**K** series	Controls, closing, tripping; K1, K2, K3 etc.
C series	C.T Secondary for protection circuits; C1, C2, C3 etc. (Back up Protection Over Current & Earth Fault)	**J** series	Main DC incoming; J1 (+ve) J2 (-ve) etc.
D series	C.T secondaries for metering circuits; D1, D2, D3 etc.	**L** series	Alarm indication and annunciation; L1, L2, L3 etc.
E series	Potential Transformer secondaries; E1, E2, E3 etc. (For protection and metering)	**P** series	DC Supply for Bus Bar Protection and LBB protection Circuit.

INTERLEAVED BRIDGELESS CUK CONVERTER FED BLDC MOTOR WITH IMPROVED POWER FACTOR

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***Abstract*—In developing Power Electronic environment, application of low power, low size, high speed drives are achieving more prominence. Though there have been large number of developments in motors and control strategies, the risk and complexity of such drives become bottle-necks in implementation. In this paper, the integration of a bridgeless dc-dc converter and an inverter-fed AC 3 phase motor drive is established giving better input current characteristics and improved power factor. Due to the low power, high speed application of Brush Less (BLDC) motor, the same is selected for the aforesaid drive scheme.**

Index Terms:- Brush Less Direct Current Motor(BLDC),High Frequency Transformer (HFT). Total Harmonic Distortion(THD), Discontinuous Inductor Current Mode(DICM), Zero Crossing Detector (ZCD).

I. INTRODUCTION

Brushless motors rely on semiconductor switches to turn stator windings on and off at the appropriate time. The process is called electronic commutation, borrowing on terminology used for the mechanism in dc motors, called a commutator, that switches current from winding to winding, forcing the rotor to turn.

Speed Control of BLDC Motor is accomplished by the fact that the speed of the motor depends directly up on the emf induced by the windings. Since this emf is directly proportional to the dc link voltage fed to the Voltage source inverter prior to the motor, we are making use of an AC-DC converter. Since there have been many AC-DC converters in the past for the purpose, the main aim is to reduce the distortion in the input side. Primarily the diode bridge rectifier topology for rectification of AC input was thrown away, thereby reducing the conduction losses.

The remaining stress was on achieving a wide range of performance for the converter and the improvement of the power factor on the input side. Also the idea of isolation was also incorporated to improve efficiency and the safety of the converter side

The standard DC-DC converters like Buck, Boost converters have many applications due to their simplicity in operation and reduced number of components, the problems relating to the Switching stress, Operating range etc. made the rise of newer converters like Buck-Boost, CUK, ZETA, etc..Each of them having their own improved operational features, we selected CUK converter due to the advantage like the Continuous operation of input current and the performance depending on the capacitor, rather than the inductors. To allay the use of input side DBR, an interleaved configuration of CUK converter was proposed.

The converter is further improved using the incorporation of two high frequency isolation transformers to get more consistent operation of the whole converter.

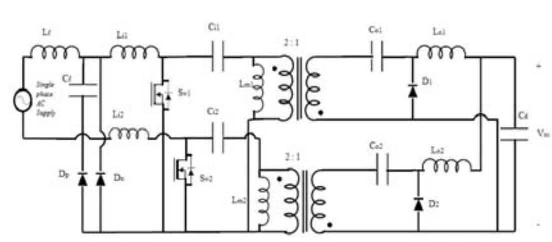

Fig . 1 . Proposed Converter

II. Proposed drive scheme

The converter configuration is fed with a Single phase AC supply.The converter operates in such a way that the upper side CUK converter operates during the positive half cycle of the input and the lower side CUK converter operates during the negative half cycle. The switching and line cycle waveforms are specifically analysed so that the Output side inductor current remains operating in the Discontinuous Inductor Current Mode(DICM).This is to ensure that the converter operates in unity power factor mode as this is the inherent property of the converter.

Coming to the BLDC Motor side, the Speed of the VSI-fed motor depends directly up on the emf induced in it. As the emf is dependent on the input voltage, which is the dc link voltage supplied from the proposed converter. So by varying the output voltage of the same converter, we can control the speed of the motor there by obtaining the speed control of the BLDC motor drive.

In practicality, the detection of Positive and Negative phases of the input for the categorical operation of the two converters is achieved by using a Zero Crossing Detector (ZCD). Also the Rotor position of the BLDC motor is sensed and decoded for the pulse generation of the VSI by the aid of 3 Hall Sensors.

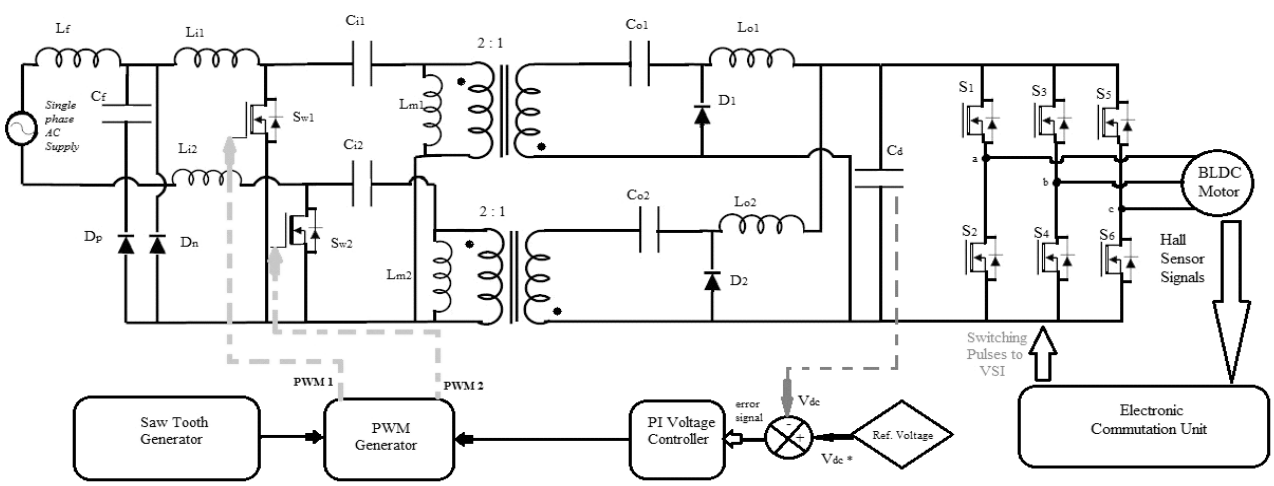

Fig . 1. Complete Topology of Speed Control

III. CIRCUIT ANALYSIS AND DESIGN

A. Operation During Complete Line Cycle of Supply Voltage

Operation During Positive half cycle is explained first

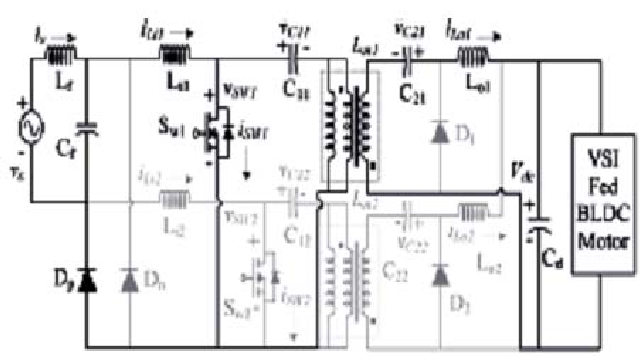

Fig . 3 . Mode (P.a)

Mode (P. a) : In the First mode, Switch Sw1 is turned ON and the inductors Li1, Lo1 and magnetizing inductance Lm1 starts charging. The capacitor Ci1 Charges Lm1 and Co1 delivers DC link voltage.

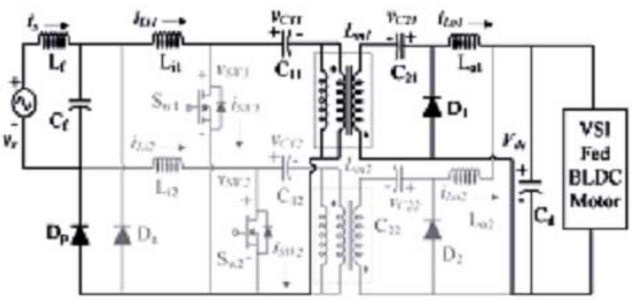

Fig . 4 . Mode (P. b)

Mode (P. b) **:** Now, the switch is being turned OFF. The inductors Li1, Lo1 discharges , thereby charging Ci1 and Co1.The magnetizing inductance Lm1 discharges through Cd.

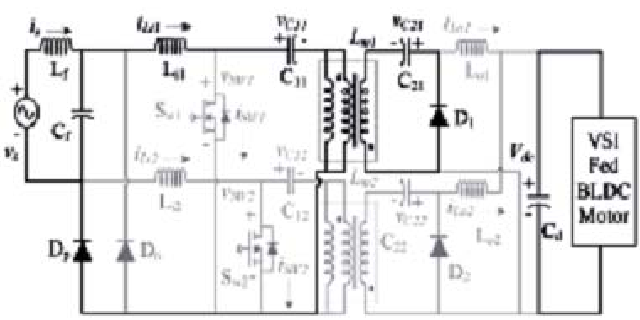

Fig . 5 . Mode (P. c)

Mode (P. c) **:** During this interval , the output side inductor (Lo1) is completely discharged and the input inductor (Li1) and the magnetizing inductance of HFT (Lm1) continue to discharge.

The output side intermediate capacitor (Co1) continues to charge and the dc link capacitor (Cd) supplies the required energy to the BLDC Motor.

The Negative half operation for the converter is realized in a similar fashion. The Operation of the converter is in such a way that the input side energy storage components remains in non conducting mode and the output side components remain non-discharged.

The Negative half cycle operation is illustrated in similar way:

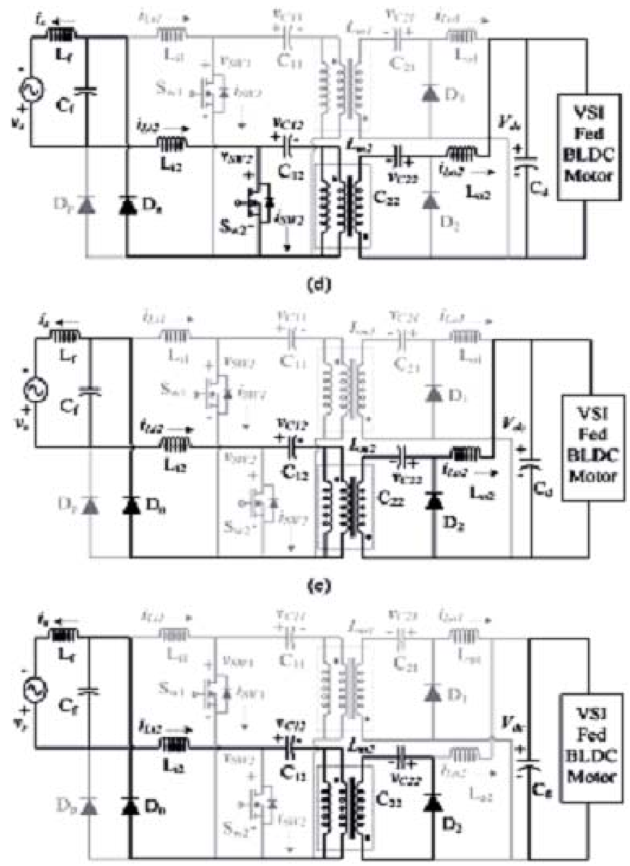

Fig . 6 . Negative half cycle operation of converter Modes (N.a , N.b , N.c)

B. Design

In this type of arrangement of CUK converter, the average AC voltage applied accross the input side will be obtained as :

$$V_{in}(t) = \left|V_m \sin(\omega t)\right| = \left|230\sqrt{2}\sin(340t)\right| ....(1)$$

Under following assumptions:

$V_{min} = 50\,V$

$V_{max} = 130\,V$

$Vs_{min} = 170\,V$

$Vs_{max} = 270\,V$

Since the CUK topology is used, the output voltage is obtained as:

$$V_{DC} = \left[\frac{N_2}{N_1}\right] \frac{D}{(1-D)} V_{in}$$

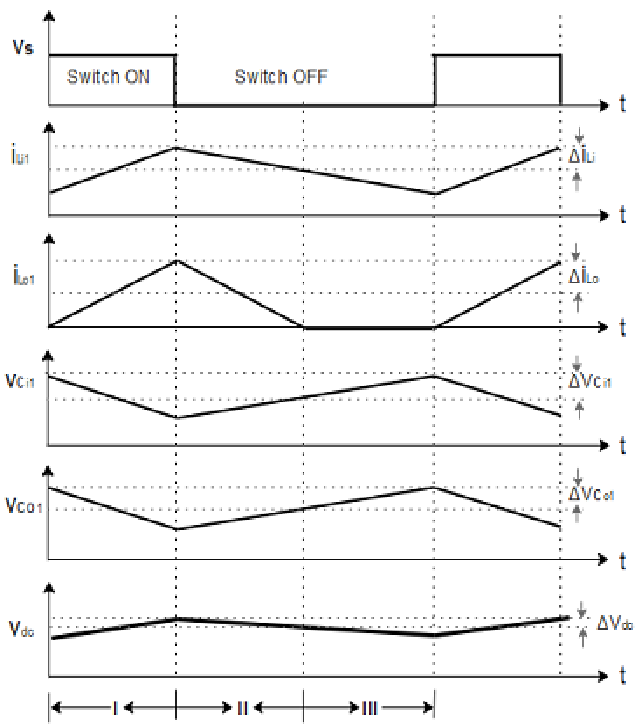

Fig . 7 . Output Waveforms over switching cycle

Let *D(t)* be instantaneous value of duty ratio, then from above equation :

$$D(t) = \frac{V_{DC}}{\left(N_2/N_1\right)V_{in}(t)+V_{DC}} = \frac{V_{DC}}{\left(N_2/N_1\right) * \left|V_{in}\sin(\omega t)\right| + V_{DC}} \quad ...(2)$$

Instantaneous Power,

$$P_i = \left[\frac{P_{max}}{V_{DC\_max}}\right] V_{DC} \quad .... (3)$$

- <u>Inductor Design :</u>

$$L_{i1}=L_{i2}=\frac{V_{in}(t).\,D(t)}{\eta I_{in}(t) f_s} = \frac{1}{\eta . f_s}\left[\frac{V_s^2}{P_i}\right]\left[\frac{V_{DC}}{nI_{in}(t)+V_{DC}}\right] \quad (4)$$

where η is the input current ripple, which is taken as 50 % and n = the turns ratio of the HFT, taken as 1:2.

$$L_{01}=L_{02}=\left[\frac{V_s^2}{P_i}\right]\frac{V_{DC}}{2V_{in}(t) f_s}\left[\frac{V_{DC}}{nV_{in}(t)+V_{DC}}\right] \quad ...(5)$$

Both the Equations are used under the assumption that:

$$P_i = P_{i\_max}$$

$$V_{in} = \sqrt{2}V_{s\_min}$$

The magnetizing inductances,

$$L_{m1} = L_{m2} = \left[\frac{V_s^2}{P_i}\right]\frac{1}{\varsigma . f_s}\left[\frac{V_{DC}}{nV_{in}(t)+V_{DC}}\right] \quad ...(6)$$

Where ς is the permitted ripple current on the output side.

We took it as 50 %.

- <u>Capacitor Design</u>

$$C_{i1} = C_{i2} = \frac{nP_i}{k.\,\sqrt{2}V_s \cdot f_s \cdot (n\sqrt{2}V_s + V_{DC})} \quad ...(7)$$

$$C_{01} = C_{02} = \frac{P_i}{x\,.V_{DC} \cdot f_s\ (n\ \sqrt{2}V_s + V_{DC})} \quad ...(8)$$

$$C_D = \frac{I_{DC}}{2\ \omega\,\Delta\, V_{Dc}} = \left[\frac{P_i}{V_{Dc}}\right]\frac{1}{(2\ \omega.\rho\ .V_{Dc})} \quad ...(9)$$

where:
k =input side ripple voltage (25 %)
x =output side ripple voltage (10 %).

C. Speed Control Scheme

An electronic commutation of the BLDC motor includes the proper switching of the VSI in such a way that a symmetrical dc current is drawn from the dc link capacitor for 120æ% and is placed symmetrically at the centre of the back electro-motive force (EMF) of each phase.

A Hall-effect position sensor is used to sense the rotor position on a span of 60æ%; which is required for the electronic commutation of the BLDC motor

The front end converter is controlled by feeding back the dc voltage. A voltage follower based approach is used for the PFC based CUK converter. The control scheme comprises of a feedback dc voltage, reference voltage generator and PWM generator. The reference voltage is obtained by multiplying the reference speed by motor speed constant (Kv).

$$V_{DC}^{*} = K_V.\omega..........(10)$$

This reference speed is compared with actual speed of the motor and error is used for PWM generation for the front end converter switches. Thus speed control is obtained.

IV. SIMULATION ANALYSIS

Simulation of the proposed converter and the drive scheme was done in MATLAB 2015a taking the input voltage as 220 V and analyzed the motor waveforms and required THD levels. The results shows the test results of the proposed BLDC motor drive operating at rated load with the supply voltage as 220 V and dc link voltage of 130.

The magnitude and frequency of the stator current demonstrate the operation of the BLDC motor at desired Speed. A sinusoidal supply current in phase with the supply voltage is obtained which shows a near unity PF at both values of dc link voltage.

A. Simulation Parameters

Components	Details
Filter Inductor, Lf	3.77mH
Filter Capacitor, Cf	330nF
Input inductors Li1,Li2	5mH
HFT Internal Capacitors C11,C12	220nF
HFT External Capacitors C21, C22	4.4µF
Output Inductor L01, L02	70µH
DC Link Capacitor Cd	2.2mH
Magnetizing Inductance Lm1, Lm2	6mH

Table . 1. Details of Simulation

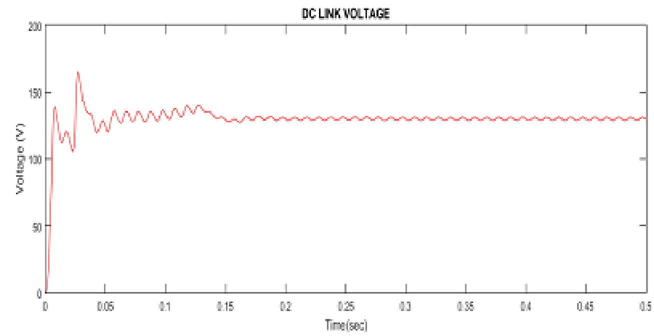

Fig . 8 .DC Output Voltage

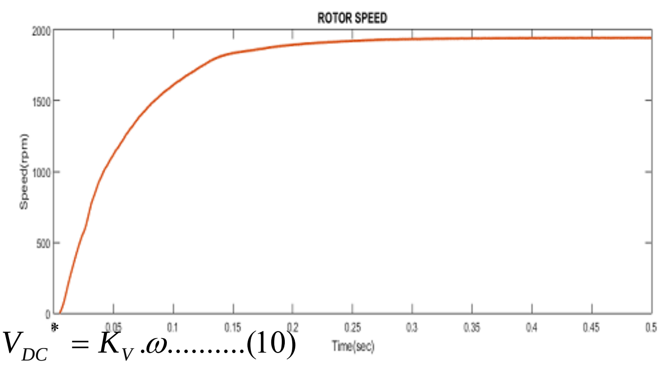

Fig . 9 .Motor Speed

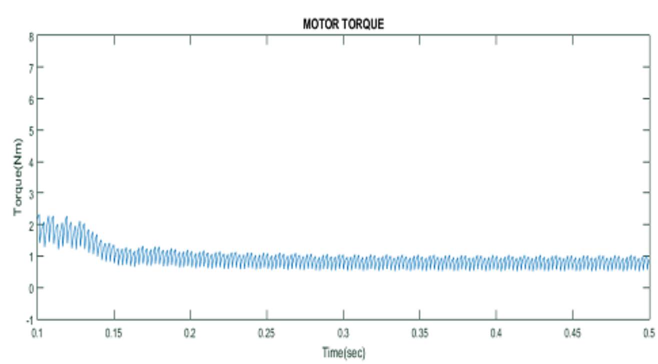

Fig . 10 . Motor Torque

The Power Factor of the converter is improved as being demonstrated in the input Voltage and Current wave-forms:

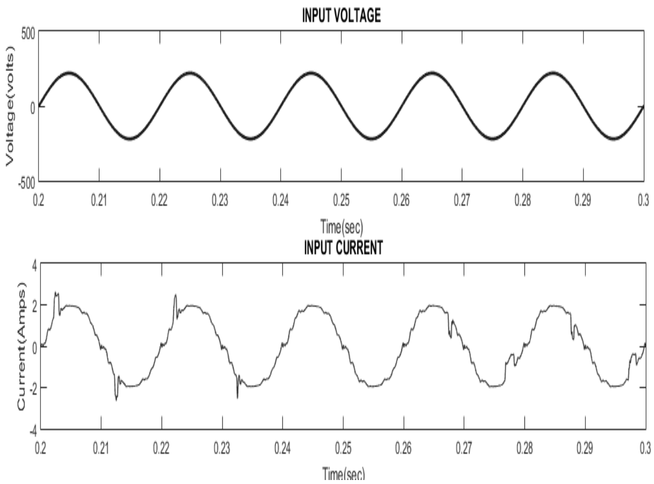

Fig . 11 . Input Voltage and Current

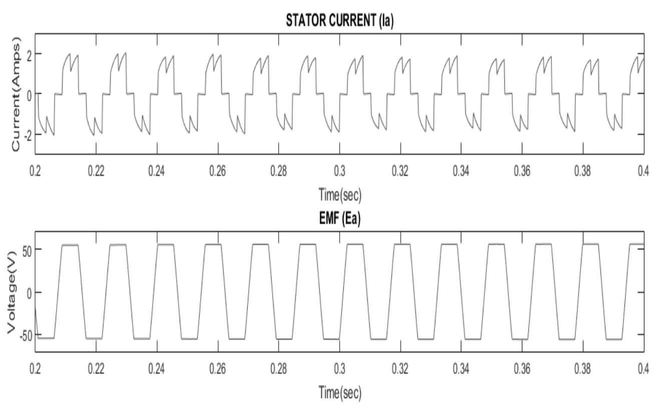

Fig . 12 . Stator Current and emf of BLDC Motor

A. Interfacing of the MatLab model to dsPIC

The Simulated Model of the CUK Converter circuit was modelled and programmed using dsPICF302010.This PIC was selected because of the inherent simplicity of the operation of same owing to its 16-Bit nature and also the availability of 6 PWM pins in a single unit.

VIII. CONCLUSION

The Described converter was designed and simulated using MatLab and tested successfully. From the Simulated analysis of the proposed converter, it was found that the THD of the Supply at consumer side is significantly reduced by the use of bridgeless topology of already existing CUK converter fed BLDC motor. The impeachment of the conventional Diode Bridge Rectifier topology aided much in the reduction of electric losses to a great extent .The speed control of the BLDC motor has been achieved by controlling the dc link voltage of the VSI fed BLDC motor. The MatLab model was converted to digital code using special Libraries and was programmed using dsPICF302010 for further analysis.

IX. REFERENCES

[1] Y. Chen, C. Chiu, Y. Jhang, Z. Tang, and R. Liang, “A driver for the single phase brushless DC fan motor with hybrid winding structure,” *IEEE TRANS. IND. ELECTRON.*, VOL. 60, no. 10, pp. 4369–4375, Oct. 2013.

[2] V. Bist and B. Singh, “PFC Cuk converter fed BLDC motor drive,” *IEEE TRANS. POWER ELECTRON.*, VOL. 30, NO. 2, pp. 871–887, Feb. 2015.

[3] Mohamed Z. Youssef , “ Design and Performance of a Cost-Effective BLDC Drive for Water Pump Application”, IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 62, NO. 5, pp : 3277 -3284, MAY 2015,

[4] Vashist Bist, Bhim Singh, “ A Unity Power Factor Bridgeless Isolated CUK Converter-Fed Brushless DC Motor Drive “, IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 62, NO. 7, pp : 4118 - 4129, JULY 2015.

[5] B. Singh and S. Singh, “Single-phase power factor controller topologies for permanent magnet brushless dc motor drives,” *IET POWER ELECTRON.*, VOL. 3, NO. 2, pp. 147–175, Mar. 2010.

[6] V. Bist and B. Singh, “An adjustable speed PFC bridgeless buck-boost converter fed BLDC motor drive,” *IEEE TRANS. IND. ELECTRON.*, VOL. 61, NO. 6, pp. 2665–2677, Jun. 2014.

[7] B. Singh and V. Bist, “Power quality improvement in PFC bridgeless SEPIC fed BLDC motor drive,” *INT. J. EMERG. ELECT. POWER SYST.*, VOL. 14, NO. 3, pp. 285–296, 2013.

Seven Level Inverter for PV Applications

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***Abstract*—In this work, a seven level inverter with MPPT for PV application is proposed. The proposed MPPT based multilevel inverter generates seven-level ac output voltage when we give the appropriate design of the gate signals. The multilevel inverter is fed from a PV cell through a boost converter.The control is based on MPPT. The total harmonic distortion can be reduced by using a low pass filter. In this topology, the switching losses and voltage stress are reduced . The operation of the inverter and the voltage balancing of input capacitors are discussed. The multilevel inverter is controlled with sinusoidal pulse-width modulation (SPWM).**

***Keywords*—DC–AC inverter, FPGA, Maximum Power Point Tracking (MPPT), Multilevel.**

I. INTRODUCTION

The demand and the quality of electric power are higher due to high-technology development. The major problem faced all over the world is the scarcity of power. Solar energy is freely available in nature and its utilization has been increased in recent years. Because of the advancement in semiconductor technology, the specification of power devices and power conversion technique is promoted. Inverter is the inter medium which transmits power to other electrical equipment such as uninterruptible power supply, servo motor, air-conditioning system, and smart grid composed of renewable energy. Therefore, harmonic pollution of power system become more serious. Several standards and regulations have been formulated to limit harmonics and to improve power factor . Furthermore, in order to meet the industry requirements for high power applications, the voltage stress in the power device should be reduced. Although an insulated gate bipolar transistor (IGBTs) have features of high power rating and subjected to high voltage stress, it cannot be operated at high frequency. The design of IGBT gate driver is complicated and the use of low rating component at high-power application is not possible. The proposed workutilise a photovoltaic cell fed to a boost converter whose control is based on the MPPT. The output of the boost converter is coupled to a multi-level inverter. The voltage rating of the power switch can be reduced by using a seven level inverter topology.The proposed inverter can be used for high-power application. It has an advantage of low dv/dt, low input current distortion, and lower switching frequency. The major feature of the

proposed topology is that the number of power components can be reduced. Sinusoidal pulse-width modulation (SPWM) is used for the control. FPGA is used for the generation of sine pwm.

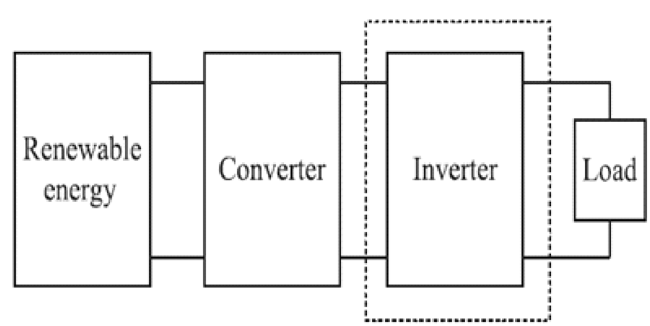


Fig.1 Schematic Block Diagram

II. POWER STAGES

A. Proposed Converter

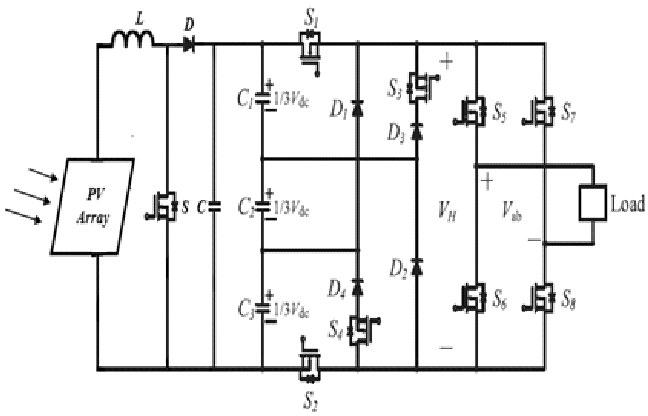


Fig.2 Circuit Diagram

Fig.2 shows the seven level inverter with boost converter. The boost converter step up the input voltage magnitude to the required output voltage . The output of the boost converter is replaced by an equivalent DC source Vdc.

B. Circuit Configuration of Multilevel Inverter

The circuit shows the proposed seven level inverter topology . The input voltage divider circuit which consists of three series capacitors *C*1, *C*2 and *C*3. The divided voltage is transmitted to the H-bridge by four MOSFETs, and four diodes. The proposed multilevel inverter generates a seven-level ac output voltage with the appropriate gate signals.

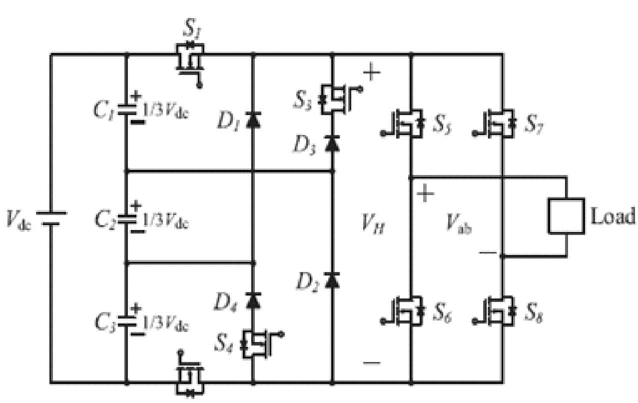


Fig.3 Seven level inverter topology

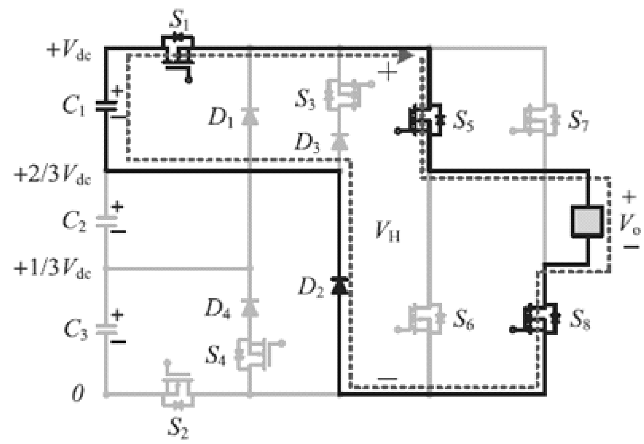


Fig. 4. Switching circuit for an output voltage of 1/3*V*dc.

B. Operating Principle

The required seven output voltage levels (+1/3*V*dc, +2/3*V*dc,*V*dc, 0, -1/3*V*dc, -2/3*V*dc,-*V*dc) are generated as follows:

1) To generate a voltage level *Vo*= 1/3*V*dc, *S*1 is turned on in the positive half cycle. Energy is provided by the capacitor *C*1 and the voltage across H-bridge is 1/3*V*dc. *S*5 and *S*8 are turned on, and the voltage applied to the load terminals is 1/3*V*dc. Fig. 4 shows the current path at this mode.

2) To generate a voltage level *Vo*= 2/3*V*dc, *S*1 and *S*4 are turned on. Energy is provided by capacitor *C*1 and

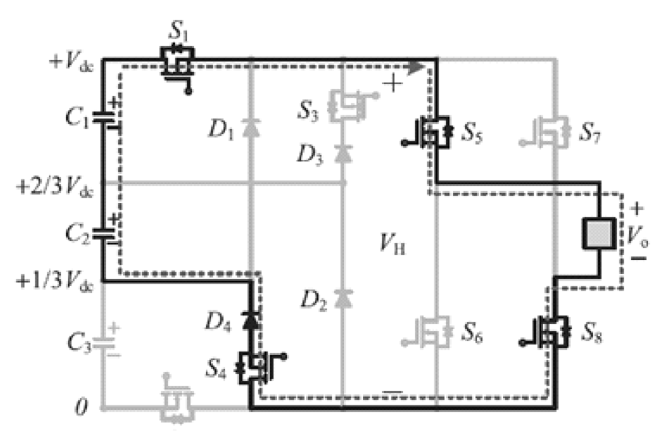


Fig. 5. Switching circuit for an output voltage level of 2/3*V*dc.

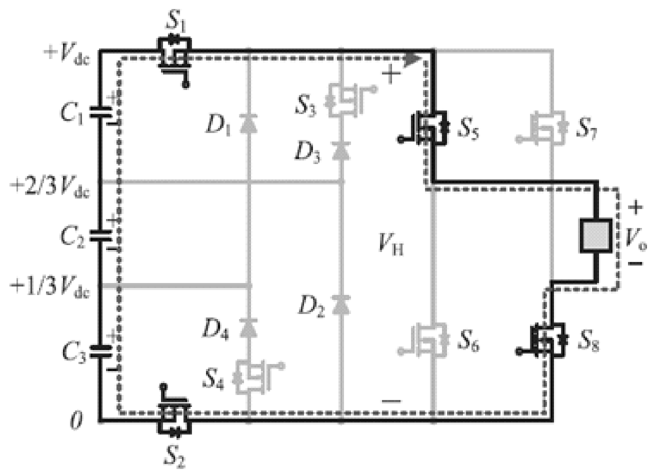


Fig. 6. Switching circuit for an output voltage level of *V*dc.

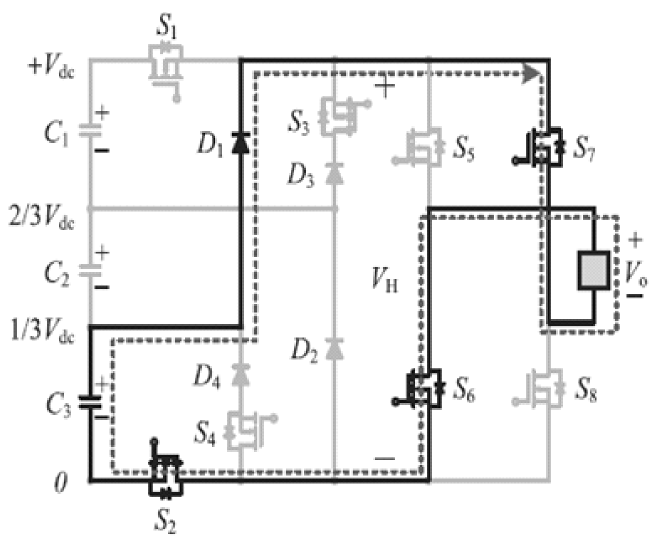


Fig. 7. Switching circuit for an output voltage level.”1/3*V*dc.

*C*2. The voltage across H-bridge is 2/3*V*dc. *S*5 and *S*8 are turned on, and the voltage applied to the load terminals is 2/3*V*dc. Fig.5 shows the current path at this mode.

3) To generate a voltage level *Vo*= *V*dc, *S*1 and *S*2 are turned on. Energy is provided by the capacitor*C*1, *C*2, and *C*3. The voltage across H-bridge is *V*dc. *S*5 and *S*8 are turned on, and the voltage applied to the load terminals is *V*dc. Fig.6. shows the current path in this mode.

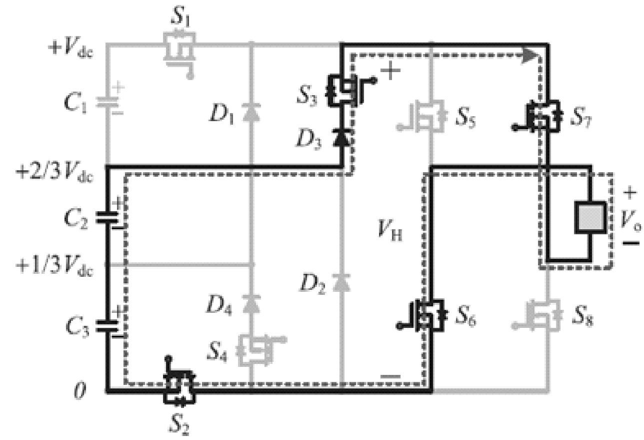


Fig. 8. Switching circuit for an output voltage level of “2/3*V*dc.

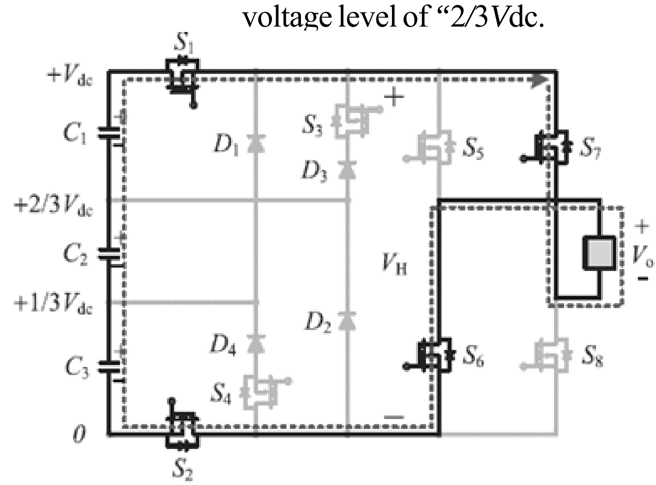


Fig. 9. Switching circuit for an output voltage level of.”*V*dc.

4) To generate a voltage level *Vo* = “1/3*V*dc, *S*2 is turned on at the negative half cycle. Energy is provided by the capacitor *C*3, and the voltage across H-bridge is 1/3*V*dc. *S*6 and *S*7 are turned on, and the voltage applied to the load terminals is “1/3*V*dc. Fig. 7 shows the current path in this mode.

5) To generate a voltage level *Vo*= “2/3*V*dc, *S*2 and *S*3 are turned on. Energy is provided by the capacitor *C*2 and *C*3 and the voltage across H-bridge is 2/3*V*dc. *S*6 and *S*7 are turned on, and the voltage applied to the load terminals is -2/3*V*dc. Fig. 8 shows the current path in this mode.

6) To generate a voltage level *Vo*= “*V*dc, *S*1 and *S*2 are turned on. Energy is provided by the capacitor *C*1, *C*2, and *C*3, the voltage across H-bridge is *V*dc. *S*6 and *S*7 is turned on, the voltage appearing across the load

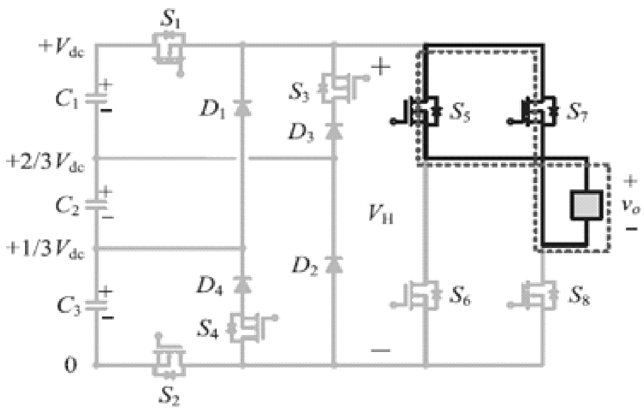


Fig. 10.Switching circuit for an output voltage level of *0*

TABLE ISWITCHING SEQUENCE

	Switching combinations							
Output voltage V_o	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
$1/3V_{dc}$	on	off	off	off	on	off	off	on
$2/3V_{dc}$	on	off	off	on	on	off	off	on
V_{dc}	on	on	off	off	on	off	off	on
$-1/3V_{dc}$	off	on	off	off	off	on	on	off
$-2/3V_{dc}$	off	on	on	off	off	on	on	off
$-V_{dc}$	on	on	off	off	off	on	on	off
0	off	off	off	off	on	off	on	off

TABLE II COMPARISON BETWEEN FOUR DIFFERENT SEVEN-LEVEL INVERTERS

	Proposed	Diode-clamped	Capacitor-clamped	Cascaded multicell
Input sources	1	1	1	3
Input capacitors	3	6	2	3
Clamped capacitors	0	0	5	0
Power switches	8	12	12	12
Diodes	4	10	0	0

terminals is “*V*dc. Fig. 9 shows the current path in this mode.

7) To generate a voltage level *Vo* = 0, *S*5 and *S*7 are turned on. The voltage appearing across the load terminals is zero. Fig. 10 shows the current path at this mode.

C. Comparison of different topologies

Table II represents the number of components required to implement a seven-level inverter using the proposed topology. The three methods that can be considered as the standard multilevel configurations are the diode-clamped inverter, the capacitor-clamped inverter, and the cascaded multi-cell inverter. In this seven level inverter, the number of power devices are reduced.

III. GENERATION OF SPWM

For the control of inverter, triangular carriers are distributed by phase disposition technique. The advantage of phase disposition technique is that its realization is not complicated and its THD is less. These carriers are compared with a reference sine wave*V*sin to get the signal for the switches. The peak-to-peak value of triangular carrier is *V*tri. The frequency of carrier is same as the switching frequency of inverter. The peak value of reference sine wave is *V*sin, and the modulation index *m*A is defined as

$$m_A = \frac{V_{\sin}}{3V_{tri}} \quad \text{———} \quad (1)$$

The peak value of output sine wave and mA can be expressed as

$$V_o = m_A \times V_{dc} \quad \text{———} \quad (2)$$

The method that determines the switching signals givenin Fig. 12 is as follows.

1) *v*sin<0 and *v*sin> *v*tri2 → *S*2 are turned on

2) *v*sin> *v*tri4 → *S*4 is turned on.

3) *v*sin< *v*tri8 → *S*7 is turned on.

4) *v*sin> *v*tri8 → *S*8 is turned on.

5) *v*sin>0 and *v*sin< *v*tri1→*S*1 are turned on.

6) *v*sin< *v*tri3 → *S*3 is turned on.

7) *v*sin> *v*tri6 → *S*5 is turned on.

8) *v*sin< *v*tri6 → *S*6 is turned on.

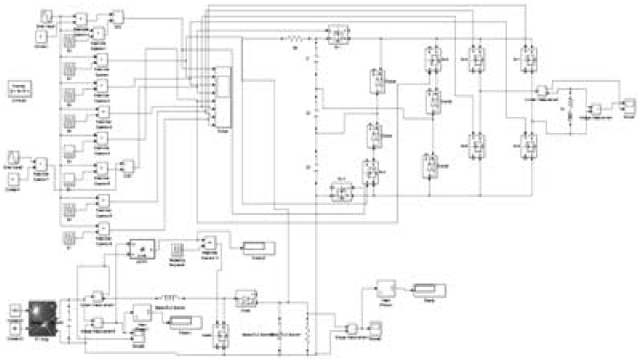


Fig.11. MATLAB model of MPPT based Seven Level Inverter

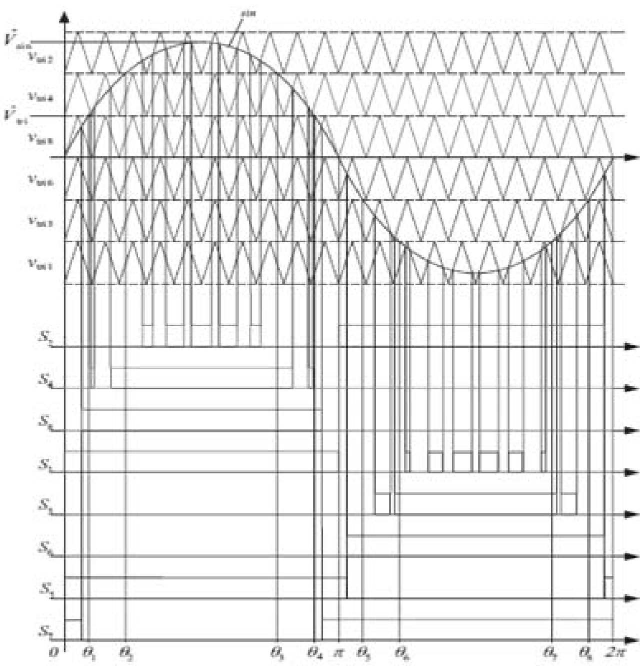


Fig. 12. Reference sine wave, carriers, and control signals for the switches.

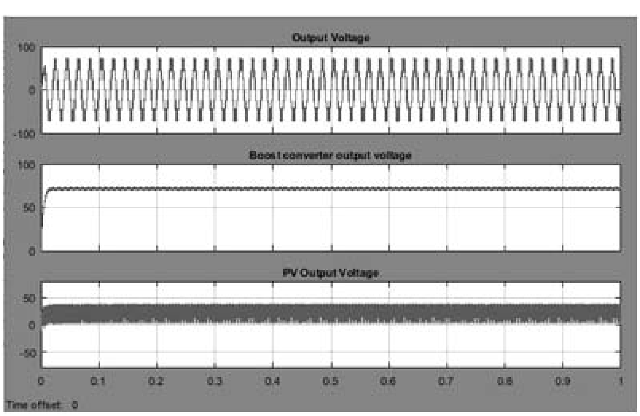
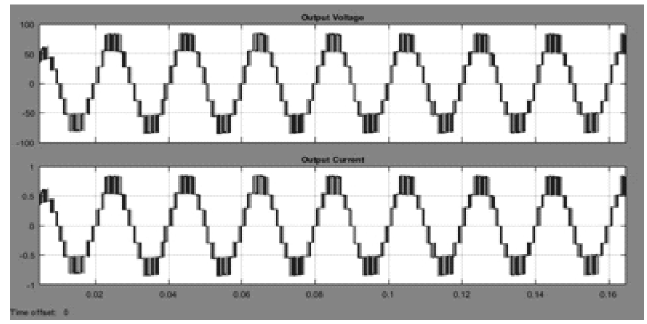


Fig. 13 Output voltage, boost converter output voltage and PV output voltage



F.14. Seven level Inverter output voltage and currentwith Rload.

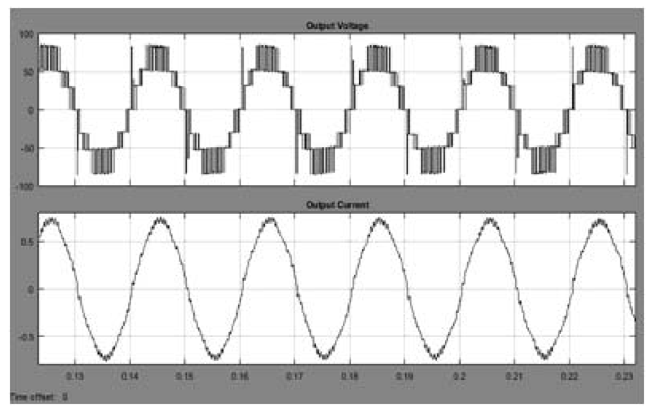


Fig.15. Seven level Inverter output voltage and current with RL load

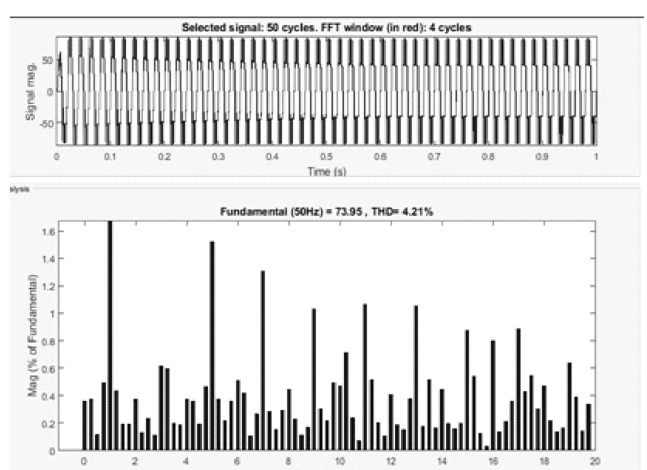


Fig.16. FFT analysis.

IV. RESULTS AND DISCUSSIONS

Fig.11 shows the matlab model of the MPPT based seven-level inverter. The MPPT is obtained at the point 27V and 426W from the matlab model. The output of the boost converter is 84V. Fig. 14 and 15 presents the simulation output voltage and current waveform for R and RL load respectively.The seven voltage levels are +28V, +56V+84V, -28V, -56V, -84V and 0. Fig.16 shows the harmonic spectrum and FFT analysis of the output voltage. The high frequency harmonics is attenuated by using an LC filter. Fig.16 shows the FFT analysis. The THD is 4.1%. Multilevel structure is usually used in inductive loads such as motor. Thus, this paper applies the proposed topology in inductive load. The power loss is less since the number of power components is less. For an RL load the power factor is 0.96. The output power is 426W.

TABLE III PARAMETERS

PV input	29V
Input voltage Vdc	75V
Output Voltage	41Vrms
Rated Output power Po	300W
Switching Frequency	18kHz

V. CONCLUSION

A seven level inverter fed by boost converter with the energy-efficient fast-tracking MPPT circuit is designed and simulation is carried out. The MPPT strategy used is Perturb & Observe method. The output of the boost converter is given as the input to the seven-level inverter. The main idea behind the proposed configuration is to reduce the number of power devices. The reduction of power devices is proved in comparison with other traditional structures. The major advantage of this topology is the reduction in harmonics. The THD of this topology is 4% .

VI. ACKNOWLEDGMENT

We take this opportunity to express our sincere gratitude to those who have been very helpful in the successive completion of this work. We deeply express our sincere thanks to Dr K. P. Indira devi, Principal in charge of Government Engineering College, Thrissur, Dr Nandakumar M., Professor and Head of Department of Electrical and Electronics Engineering, for encouraging and providing the facilities to conduct the project on the topic 'Seven level inverter with MPPT for PV applications'. It is my privilege to express our sincere regards to my project guide Mr. Sanishkumar T G and co-guide Dr A. Amardutt, Department of Electrical Engineering for the guidance, encouragement and whole hearted cooperation throughout the duration of this work. I take the opportunity to thank all our lecturers and lab assistants who have directly or indirectly helped in the progress of this work.

VII. REFERENCES

1. Tsorng-Juu Liang, Shih-Ming Chen and Shih-Wen Tsai "Design and Implementation of a Novel Multilevel DC–AC Inverter." *IEEE Transactions on Industrial Applications*, VOL. 52, NO. 3, 2436–2443 May/June 2016
2. Cheng-Han Hsieh, S. Daher, J. Schmid, and F. L.M. Antunes, "Multilevel inverter topologies for stand-alone PV systems," *IEEE Transactions on Industrial Electronics vol. 55, no. 7,*pp. 2703–2712, Jul. 2008.
3. M. R. Banaei and E. Salary, "New multilevel inverter with reduction of switches and gate driver," in *Proc. IEEE 18th Iran. Conf. Elect. Eng. (IECC), 2010, pp. 784–789.*
4. R. A. Ahmed, S. Mekhilef, and W. P. Hew, "New multilevel inverter topology with minimum number ofswitches," in *Proc. IEEE Region 10 Conf. (TENCON), 2010, pp. 1862–1867.*
5. Cegliaet *al.*, "A new multilevel inverter topology," in *Proc. Devices Circuits Syst.*, 2004, vol. 1, pp. 212–218.
6. N. A. Rahim, K. Chaniago, and J. Selvaraj, "Single-phase seven-level grid-connected inverter for photovoltaic system," *IEEE Trans. Ind.Electron.*, vol. 58, no. 6, pp. 2435–2443, Jun. 2011.
7. S. Daher, J. Schmid, and F. L.M. Antunes, "Multilevel inverter topologies for stand-alone PV systems," *IEEE Trans. Ind. Electron.*, vol. 55, no. 7, pp. 2703–2712, Jul. 2008.

A Novel DC-DC Converter Topology for Industrial Float Cum Boost Battery Charger

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***Abstract*—A two switch isolated zeta converter based topology is proposed for battery charger. This topology helps to reduce the voltage stress across the switch by using two switches and two diodes on primary side of a high frequency transformer(HFT) which improves the system reliability. The proposed converter is made to operate in discontinuous inductor current mode (DICM) which improves the input power factor without any auxiliary circuit. The converter also exhibits good dynamic characteristics to the load and source voltage variations. The proposed converter topology is designed and its performance is analyzed in MATLAB/Simulink environment. The investigation is conducted regarding the input PF, displacement factor, Total Harmonic Distortion(THD) of source current, dynamic load and line regulation.**

Index Terms—Isolated Zeta converter, Discontinuous inductor current mode(DICM), input power factor, Total harmonic distortion (THD), battery charger.

I. INTRODUCTION

A battery charger is a device used to put energy into a rechargeable battery by forcing an electric current through it. They are designed to provide the most reliable supply to the batteries to which they are connected. Battery chargers are mainly used for charging the battery bank which is responsible for the supply of control systems such as breaker closing coil, trip coil, indications, protection relays etc. Mainly, if we are taking the supply from main, (without battery backup) at the time of power failure, the above mentioned equipments will not work. These battery chargers are designed mainly to work in two modes-float and boost mode and hence they are named so. When battery is discharged to a very low value, boost mode operation is preferred. Since charger voltage is high during boost mode, battery current will be high and thus charging speed get increased. In float mode, the charging rate will be less. Even if the battery is fully charged, the charger will have to supply current in order to compensate for self discharge rate of the battery. This is done by operating in float mode. Hence the battery current will be small while operating in this mode.

The battery chargers are of two types viz. SCR based chargers and SMPC based chargers.SCR based chargers make use of fully converters or semi converters for charging the battery bank whereas in SMPC chargers, DC-DC converters are used. SCR based chargers works in lower frequency range and hence the circuit will be bulkier and the volume and size of charger increases. In order to overcome these problems it is better to go for SMPC based chargers which can brings down the size and volume of the charger. The major responsibility of the converter is to regulate the output voltage and current during the battery charging process. From [2] the need for PF correction techniques in the charger to improve its power quality(PQ) indices is understood. In [6], the author have proposed a boost converter to incorporate PFC. But the boost converter have the drawback such as high inrush current and lack of current limiting during overload conditions. A full-bridge buck converter and a half-bridge buck converter have also been reported in the literature [7] and [8]. But buck–boost converters offer better PFC at the input compared with buck converters. Besides that , the half bridge inverter are not well suited for high frequency commutation and hence restrict their use in the charger application.

In [3] , several single-stage isolated PFC topologies that possess a simple power circuit with easy control schemes are compared with two-stage PFC converters. Among them, an isolated zeta converter offers reduced inrush current and excellent overload current protection. But the conventional isolated zeta ac–dc converter suffers from a major drawback of high-voltage stress across the switch, i.e.,

$Vd + nVo$, where Vd is the input voltage, Vo is the output voltage, and n is the turns ratio of a high-frequency transformer (HFT). However, in case of a two-switch zeta converter, the voltage stress of the switches is limited to the input dc voltage Vd .Murthy-Bellur and Kazimierczuk [4] presented the continuous conduction mode (CCM) operation of a two-switch zeta converter, which adds the requirement of input current sensing to incorporate PFC feature.

In order to minimize the switch stress and complexity of the control circuitry by way of eliminating the input current sensor, this paper deals with the analysis, design, and development of the two-switch modified zeta converter operating in the DICM, with high-frequency isolation, regulated output voltage, and improved PQ. For achieving wider operating range, the DICM operation is convenient, which also offers additional advantages, such as reduction in the number of sensors and component size. This, in turn, reduces the complexity of the control circuit and makes the power supply compact.

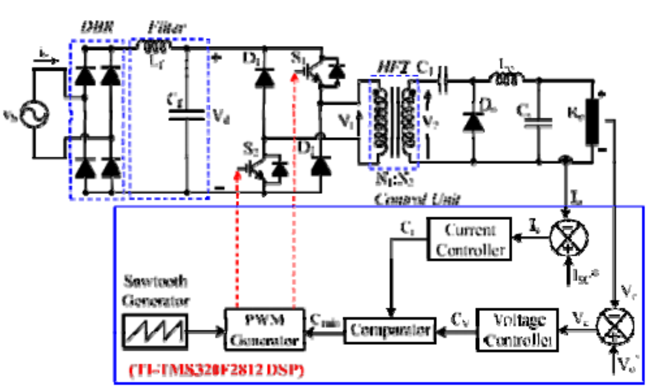

Fig. 1. Proposed modified zeta converter based battery charger circuit.

The performance of the proposed converter is verified by means of modeling the proposed power supply in the MATLAB/Simulink platform. Its performance has been evaluated over a wide range of load and supply voltage. The obtained results assure an excellent performance of the modified Zeta converter based charger with an improved PQ at the supply side.

II PROPOSED MODIFIED ZETA CONVERTER TOPOLOGY FOR BATTERY CHARGER

Fig. 1 shows the configuration of the modified isolated zeta converter for a single-phase battery charger. It comprises of a single phase supply followed by a diode bridge rectifier (DBR), an input LC filter, and a modified zeta converter connected to a resistive load. The HFT provides a galvanic isolation between the input ac source and the output. Two diodes D1 and D2 are connected across switches S1 and S2, respectively. Both the switches are turned ON and OFF simultaneously. The proposed zeta converter can convert a single-phase 230 V ac power supply into 24 V dc output voltage in a single stage power conversion process with an inherent PFC feature. The DICM operation in this zeta converter is defined by the current discontinuity through the magnetizing inductance, Lm. The operating stages of the proposed converter during a complete switching cycle are described as follows.

A. Operating Modes

Three operating modes of the proposed zeta converter within one complete switching period Ts are shown in Fig. 2(a)–(c). In order to analyze the operating principle, all semiconductor devices are considered to be ideal. The supply voltage vs is considered to be constant within each switching cycle as the switching frequency fs (=20 kHz) is much higher than the line frequency, f (=50 Hz).

Mode I: During this interval, both switches, S1 and S2, are turned ON; the power source supplies energy to the transformer magnetizing inductance, Lm. Thus, the currents through the transformer magnetizing and output inductors iLm and iLo increase linearly. On the other hand, diodes D1 and D2 remain OFF. The equivalent circuit for this operating mode is shown in Fig. 2(a). Diode *Do* is reverse biased during this stage. Intermediate capacitor *C*1 discharges through output inductor *Lo*, output capacitor *Co*, and load *Ro*

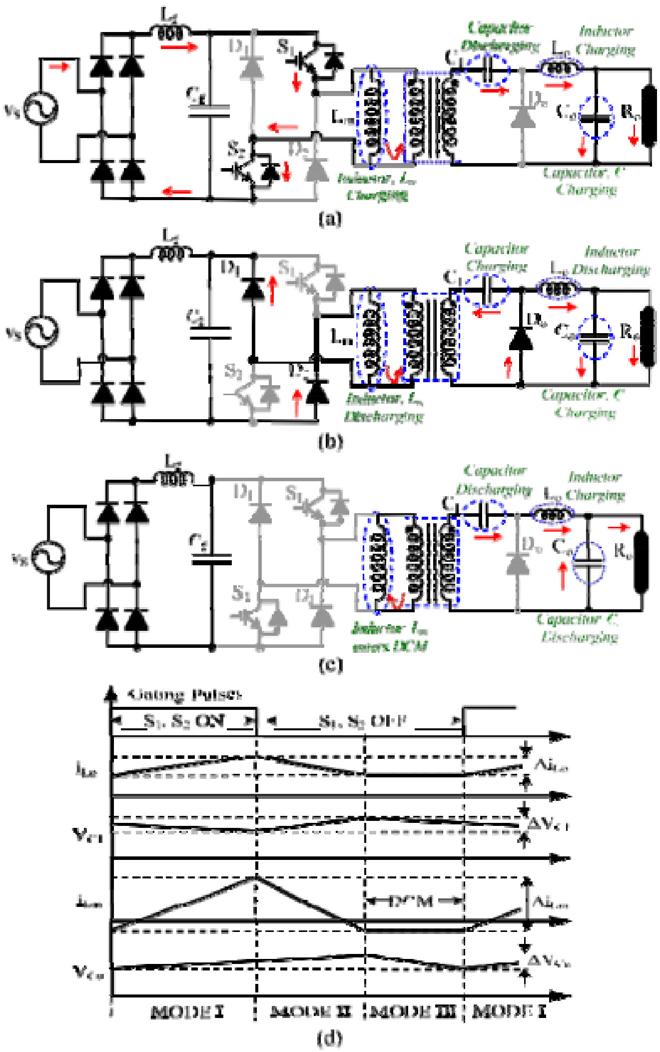

Fig. 2. Operating modes of proposed modified zeta converter based AWPS, (a) Mode I; (b) Mode II; (c) Mode III; (d) Waveforms during one switching period.

Mode II: Fig. 2(b) illustrates the second operating interval during which both switches S1 and S2 are turned OFF and diodes D1 and D2 start conducting. Thus, the energy stored in the magnetizing inductance *Lm* of HFT is transferred to dc link capacitor. Diode *Do* also becomes forward biased. *Lm* and *Lo* transfer the energy stored to the intermediate capacitor *C*1 and output capacitor *Co*, respectively. During this time interval, the current through diode *Do* decreases, until it becomes zero.

Mode III: Referring to Fig. 2(c), the third stage starts when the absolute values of currents in *Lm* and *Lo* (*I*Lm and *ILo*) become equal to each other, thereby reverse biasing the diode *Do* again. Thus, the magnetizing inductor *Lm* enters DICM. The intermediate capacitor *C*1 and the output capacitor *Co* discharge during this period to release their stored energy. This enforces the intermediate capacitor's voltage and output voltage to decrease. This stage continues until both the switches start conducting. The associated waveforms for this converter over one switching period are presented in Fig. 2(d).

A. Control Strategy

The proposed converter is made to operate in DICM to obtain various benefits, such as inherent PFC, simple control, and so on. Both switches S1 and S2 are synchronously operating during each (pulse-width modulation) PWM period. Thus, the same gating signal is used to drive both the power switches. This simplifies the control circuit significantly. The dc output voltage is observed and compared with the reference voltage to generate the voltage error .The generated voltage error signal is then processed by the proportional and integral (PI) controller. Concurrently, a current loop is implemented for restraining the output current within the desired limit. The dc output current is compared with the reference output current limit *I*SC to generate the current error. This *error* is given to a PI current controller to integrate the overload current handling capability in the proposed battery charger. The outputs of both PI controllers are compared and whichever is lower is given to the PWM generator to generate the gating pulses for the switches. The PWM duty cycle is adjusted in accordance with changes required in the output dc voltage and the load current.

I. DESIGN OF PROPOSED TOPOLOGY

The parameters of the proposed converter are designed, such that it operates in DICM to attain inherent PFC at source side. A 600-W prototype of the proposed PFC converter is designed to maintain a constant dc voltage at the output for battery charging application. The average input voltage *Vd* , after rectification of input ac voltage V_S, is given by

$$V_d = \frac{2\sqrt{2}V_s}{\pi} = \frac{2\sqrt{2}*230}{\pi} = 207\,V$$

The voltage gain of the proposed converter can be obtained by applying constant volt-second relationship to the output inductor *Lo*.

$$\frac{V_o}{V_d} = \frac{D}{n(1-D)}$$

where *n* is the HFT turns ratio and *D* is the duty ratio of the proposed zeta converter, which decides the ON and OFF period of both the power switches. The duty ratio *D* is considered as 0.3 to obtain 24 V/ 25 A at the output. Substituting *D* = 0.3, the HFT turns ratio *n* comes out to be 3.

A. Selection of Magnetizing and Output Inductances

The value of magnetizing inductance *Lm* is selected, such that the current remains discontinuous in a single switching cycle when the switching frequency *fs* is chosen to be 20 kHz.

$$L_{m,min} = \frac{n^2 R_o (1-D)^2}{2Df_s} = \frac{3^2 * 0.96 * (1-0.3)^2}{2*0.3*20000} = 407\mu H$$

The value of the output inductor *Lo* must be large enough to maintain continuous current during the entire switching cycle.

$$L_o > \frac{V_o(1-D)}{f_s \Delta i_{Lo}} > \frac{24(1-0.3)}{20000*0.1*25} > 336\mu H$$

B. Selection of Intermediate and Output Capacitances

Considering peak-to-peak ripple voltage across capacitors *C*1 to be V_{C1}, the value of intermediate capacitor *C*1 is given by

$$C_1 = \frac{DV_o}{f_s R_o \Delta V_{c1}} = \frac{0.3*29}{20000*0.96*7.2} = 62.9\,\mu F$$

The expression for calculation of output capacitor *Co* is given by

$$C_o \geq \frac{I_o}{2\omega \Delta V_o} \geq \frac{25}{2*2\pi*50*0.6} \geq 66mF$$

where *ù* = 2*ð f* , where *f* is the line frequency of 50 Hz, and *"Vo* is the ripple voltage across the output capacitor *Co*.

C. Input Filter Design

A low-pass filter is designed to suppress higher order harmonics in input supply current.

$$C_{fmax} = \frac{I_{sm}}{\omega V_{sm}} tan\theta$$

where *I*Sm is the peak input supply current, *V*Sm is the peak input supply voltage, and *è* is the displacement angle between the input supply voltage and the input supply current.

$$\frac{1}{4\pi^2 f_c^2 C_f} = L_f + 0.05\frac{V_s^2}{P\omega}$$

Considering the source impedance (*Ls)* to be 4%–5% of the base impedance, the value of filter inductance L_f is calculated according to above equation

fc is the cutoff frequency, such that *f* < f_C < f_S; thus, it is considered that *fc* = (*fs*/10)

Hence, an input side *LC* filter with inductance *Lf* and capacitance *Cf* as 4 mH and 440 nF, respectively, is selected to eliminate the high-frequency harmonics .

TABLE I SPECIFICATIONS FOR THE PROPOSED CONVERTER

Output Power	600 W
Supply Voltage @ 50 Hz	230 V
Output DC voltage	24 V
Output DC current	25 A
Switching frequency	20 kHz
Intermediate capacitor	70 µ F
Magnetizing inductor	180 µ H
Turns ratio	3 : 1
Output inductor	3 mH
Output capacitor	70 mF
Input filter inductor	4 mH
Input filter capacitor	440 nF

IV. SIMULATED PERFORMANCE OF THE PROPOSED MODIFIED ZETA CONVERTER TOPOLOGY FOR BATTERY CHARGER

The proposed modified zeta converter for battery charger is simulated in the MATLAB/Simulink environment. The performance of the proposed converter is analyzed on the basis of several performance indices. Various PQ indices, such as PF, displacement PF (DPF), distortion factor, and THD, are investigated to illustrate the improved PQ operation of the proposed topology.

A. Performance of the Proposed Battery charger at Rated Load Condition

The performance of the proposed converter at rated load condition is shown in Fig. 3(a) & (b). It can be clearly seen that the input ac mains current is in phase with ac mains voltage resulting in unity PF in Fig 3(c). The output voltage is maintained constant at 24 V. It is apparent that the peak voltage stress of the PFC switch is limited to input voltage and the peak current stress is 25 A, which is sufficiently low for a PFC converter operating in DICM. This low voltage stress results in reducing the cost of the devices as well as increases the reliability of the converter.

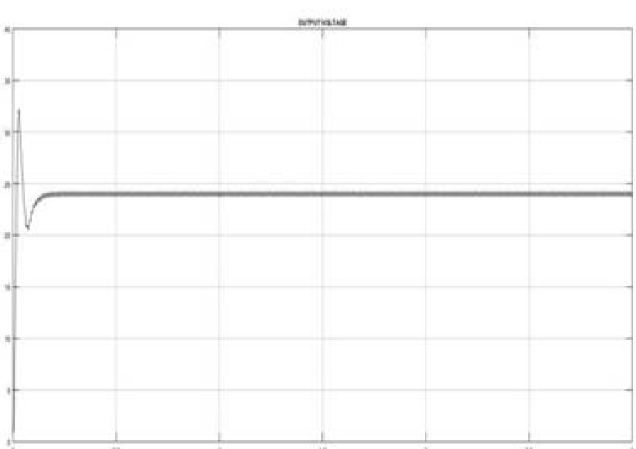

Fig.3 (a) DC output voltage

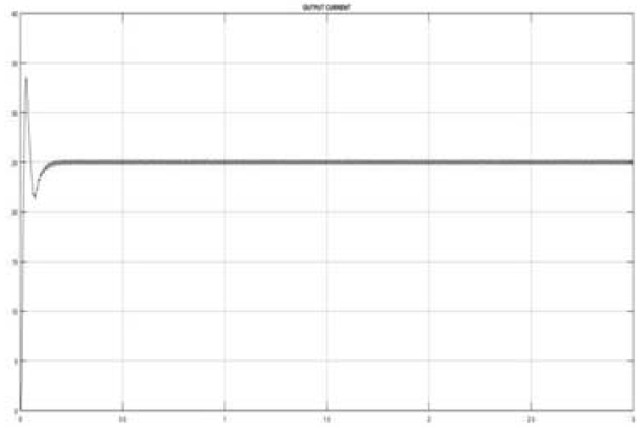

Fig. 3(b) Load current

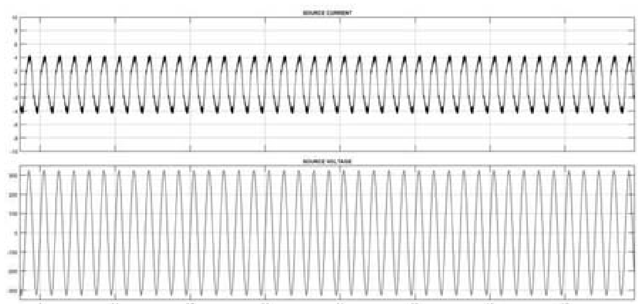

Fig. 3(c) source current and voltage

On conducting the FFT analysis of source current waveform, Total harmonic distortion is obtained as 14% at the rated conditions.

A. Dynamic Performance of the Proposed Battery charger Under Varying Load

The load regulation have been evaluated under a constant input voltage of 230 V(rms). A sudden step change in load is applied by increasing the output current from 12.5 to 25 A as shown in Fig.4(a). Even with this step load change, output voltage is regulated at 24 V as in Fig. 4(b).

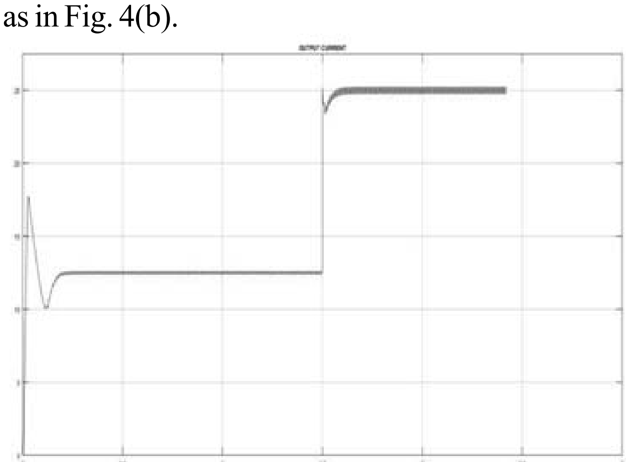

Fig 4(a) Load current variation

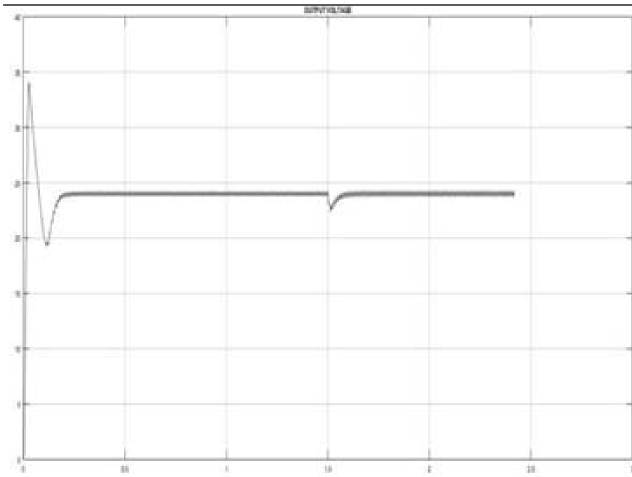

Fig 4(b) Output dc voltage

A. Current Limiting behaviour of the proposed Battery charger

In order to demonstrate the current limiting capability of proposed battery charger , reference current is set to 15 A. Thus at full load condition, the current control loop get activated and so that the load current is regulated to 15 A and obviously the output voltage start decreasing accordingly. This feature enables the charger to operate in current control mode and the same can act as current limiter in voltage control mode. The output current and voltage are illustrated in Fig. 5(a) & (b)

Fig. 5(a) output current

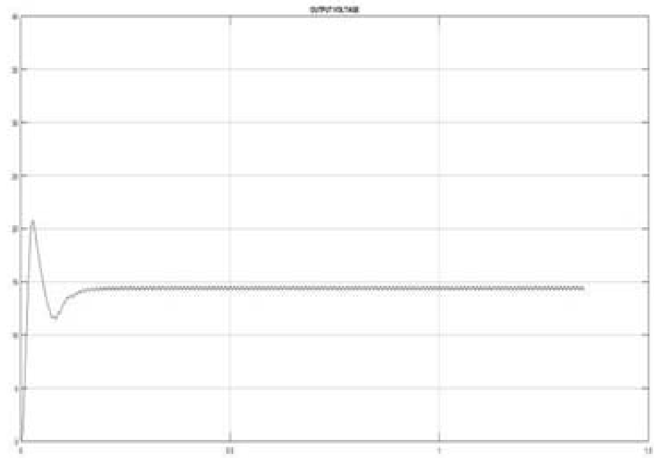

Fig. 5(b) output voltage

A. Dynamic Performance of the Proposed Battery charger Under varying supply voltage

The dynamic line regulation has been evaluated for a constant load current of 25 A .The voltage variations for 200 V and 260 V are shown in Fig.6(a). It is evident that from test results, the output voltage and current are maintained at 24 V and 25 A respectively as in Fig.6(b) & (c). Therefore the converter manages to draw rated power even under varying supply voltages.

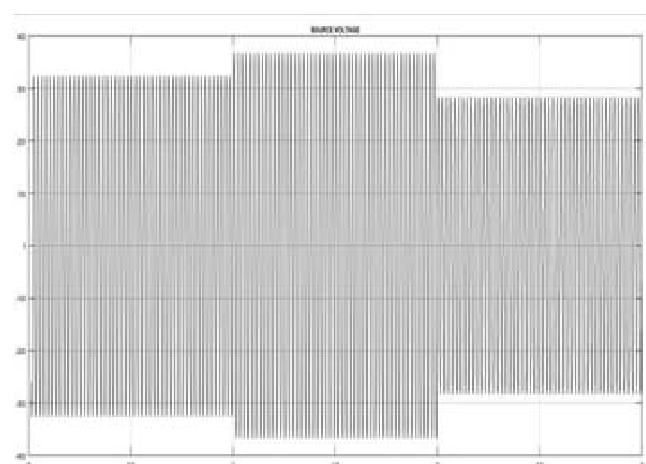

Fig. 6(a) Source voltage variations

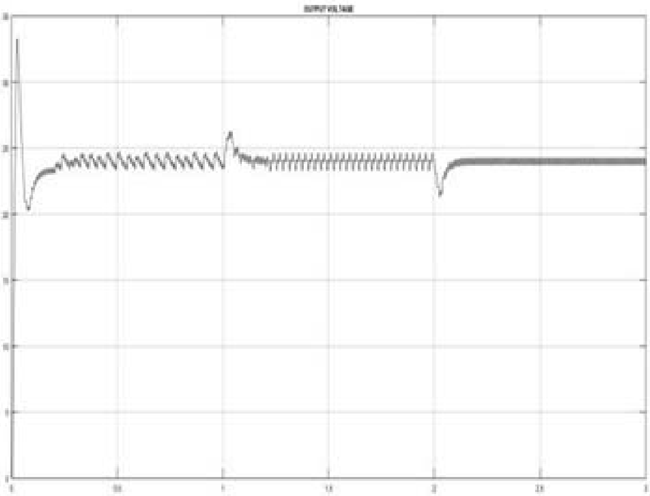

Fig. 6(b) output voltage

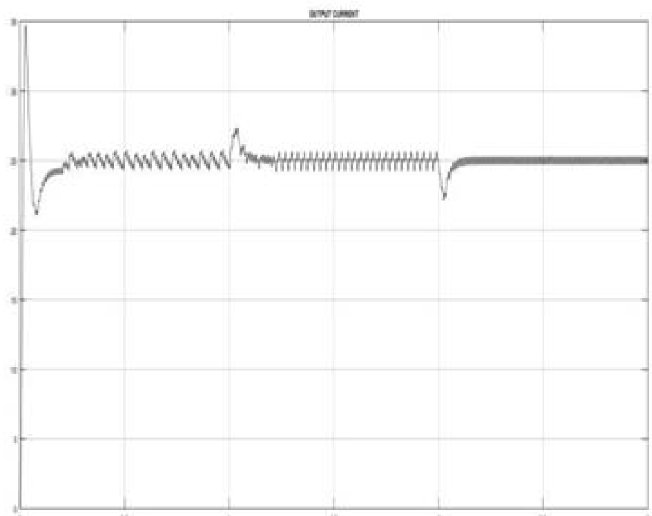

Fig. 6(c) output current

CONCLUSION

A single-stage zeta converter based battery charger has been proposed operating in a wide range of loads and supply voltage conditions. The proposed converter for battery charger has been realized using high frequency isolation, ease of control, and single-stage power conversion. Using a simple closed loop PI controller, the zeta converter-based float cum boost battery charger has been designed to improve the PQ at the utility interface.The simulation results have depicted that the proposed topology and dual loop control scheme offers faster dynamic response and current controlling ability to the battery charger. The current control loop can also be used as a current limiter in the voltage mode battery charging period. It is able to maintain constant output voltage irrespective of load and supply voltage variations. Because of the reduced voltage stress across the devices, it would possess high reliability.

The main advantage of the proposed converter is its simplicity in control, since only one gating signal is used to drive both the switches. The DICM operation of the proposed zeta converter facilitates the inherent PFC feature. Besides these features, it is important to emphasize that the proposed PFC converter achieves significant PQ improvement irrespective of the load and supply voltage variations.

REFERENCES

[1] Swati Narula ,Bhim Singh and Gurumoorthy Bhuvaneswari, "Powerfactor corrected Welding Power supply using modified Zeta converter",IEEE Journal of emerging and selected topics in power electronics Vol.04 ,No.2,June 2016

[2] B. Singh, S. Singh, A. Chandra, and K. Al-Haddad, "Comprehensive study of single-phase AC-DC power factor corrected converters with high- frequency isolation," IEEE Trans. Ind. Informat., vol. 7, no. 4, pp. 540–556, Nov. 2011

[3] B. Singh, B. N. Singh, A. Chandra, K. Al-Haddad, A. Pandey, and D. P. Kothari, "A review of single-phase improved power quality AC-DC converters," *IEEE Trans. Ind. Electron., vol. 50, no. 5, pp. 962–981,*Oct. 2003.

[4] D. Murthy-Bellur and M. K. Kazimierczuk, "Isolated two-transistor Zeta converter with reduced transistor voltage stress," *IEEE Trans. Circuits Syst. I,Reg. Papers, vol. 58, no. 1, pp. 41–45, Jan. 2011*

[5] V. Vlatkovic, D. Borojevic, and F. C. Lee, "Input filter design for power factor correction circuits," *IEEE Trans. Power Electron., vol. 11, no. 1,* pp. 199–205, Jan. 1996

[6] R. Casanueva, F. J. Azcondo, F. J. Díaz, and C. Brañas, "TIG welding machines," *IEEE Ind. Appl. Mag.*, vol. 17, no. 5, pp. 53–58 Sep./Oct. 2011. [7] J. Schupp, W. Fischer, and H. Mecke, "Welding arc control with power electronics," in *Proc. 8th Int. Conf. Power Electron. Variable Speed Drives*, 2000, pp. 443–450.

[8] K. Mahmoodi, M. Jafari, and Z. Malekjamshidi, "Operation of a Fuzzy controlled half-bridge DC-converter as a welding current-source," *Indonesian J. Elect. Eng.*, vol. 10, no. 1, pp. 17–24, Mar. 2012.

ENGINEERS' DAY : September 15

September 15 is celebrated every year in India as Engineers' Day to commemorate the birthday of the legendary Engineer Sir M. Visvesvaraya (1860-1962).

The KSEBEA observes the Engineers' day every year. This day is celebrated throughout the state through all our units.

Er. Mokshagundam Vishveshwariah, (popularly known as **Sir MV**)was a notable Indian engineer, scholar, statesman and the Diwan of Mysore during 1912 to 1918. He was a recipient of the Indian Republic's highest honour, the Bharat Ratna, in 1955. He was knighted as a Commander of the British Indian Empire by King George V for his myriad contributions to the public good. Every year, 15 September is celebrated as Engineers' Day in India in his memory. He is held in high regard as an eminent engineer of India. He was the Chief Designer of the flood protection system for the city of Hyderabad, now capital city of Telangana, as well as the Chief Engineer responsible for the construction of the Krishna Raja Sagara dam in Mysore. He was born in Muddenahalli in Karnataka state.

Earth Hour's logo

Earth Hour

Earth Hour is a worldwide movement for the planet organized by the World Wide Fund for Nature (WWF). The event is held worldwide annually encouraging individuals, communities, households and businesses to turn off their non-essential lights for one hour, from 8:30 to 9:30 p.m. on the last Saturday in March, as a symbol for their commitment to the planet. It was famously started as a lights-off event in Sydney, Australia in 2007. Since then it has grown to engage more than 7000 cities and towns worldwide. Today, Earth Hour engages a massive mainstream community on a broad range of environmental issues. The one-hour event continues to remain the key driver of the now larger movement.

National Energy Conservation Day - 14th of December

National energy conservation day is celebrated every year by the people all over India on 14th of December. The Energy Conservation Act in India was enacted by the Indian Parliament in the year 2001. The Bureau of Energy Efficiency is a statutory body which comes under Government of India and helps in the development of policies and strategies in order to reduce the energy use. The Energy Conservation Act in India aims to employ professional, qualified and energy managers as well as auditors who have expertise in managing the energy, projects, policy analysis, finance or implementing the energy efficiency projects.

Call for papers: Invitation to publish research articles, reviews, supplemental articles, case studies and letters in Hydel journal

http://www.ksebea.in
ISSN 0970-4582

We would like to invite you and/or your colleagues to submit research articles, reviews, supplemental articles, case studies and letters to be considered by peer-review for publication

Aim and Scope of the Journal

Hydel is a technical journal edited and published by Kerala State Electricity Board Engineers' Association (KSEBEA) for the last 63 years, which publishes research articles, reviews, supplemental articles and letters in all areas of electrical engineering. Hydel is a peer-reviewed journal, aims to provide the most complete and reliable source of information on current developments in the field. The emphasis will be on publishing quality articles rapidly.

The scope of journal covers all aspects of electrical engineering which include (but not limited to) Power systems, Electrical Machines, Instrumentation and control, Electric Power Generation, Transmission and Distribution, Power Electronics, Power Quality & Economics, Renewable Energy, Electric Traction, Electromagnetic Compatibility and Electrical Engineering Materials, High Voltage Insulation Technologies, Protection, Power System Analysis, SCADA, Signal Processing and Electrical Measurements.

Submission: Authors are requested to submit their papers electronically to ksebeaalpy@gmail.com in the prescribed format for IEEE Transactions and Journals (April2013) (MS Word).

Audience: *Practising Engineers, Researchers, Students, Faculty Members, and Professionals.*

Energy Efficiency

Efficient energy use is the goal to reduce the amount of energy required to provide products and services. For example, insulating a home allows a building to use less cooling energy to achieve and maintain a comfortable temperature. Installing fluorescent lights, LED lights or natural skylights reduces the amount of energy required to attain the same level of illumination compared with using traditional incandescent light bulbs. Improvements in energy efficiency are generally achieved by adopting a more efficient technology or production process or by application of commonly accepted methods to reduce energy losses. Energy efficiency and renewable energy are said to be the *twin pillars* of sustainable energy policy and are high priorities in the sustainable energy hierarchy. In many countries energy efficiency is also seen to have a national security benefit because it can be used to reduce the level of energy imports from foreign countries and may slow down the rate at which domestic energy resources are depleted.

Amazing Facts

- In the average home, 75% of the electricity used to power electronics is consumed while the products are turned off. The average desktop computer idles at 80 watts, while the average laptop idles at 20 watts.
- Enough sunlight reaches the earth's surface each minute to satisfy the world's energy demands for an entire year.
- Only 10% of the energy used by a traditional light bulb generates actual light. The other 90% of the energy creates heat.
- Google searches account for about 0.013% of the worlds' energy usage. This equals enough electricity to power 200,000 homes continuously. The energy it takes to conduct 100 searches on Google is the equivalent of a light bulb burning for 28 minutes.
- T he first power plant - owned by Thomas Edison - opened in New York City in 1882.
- Thomas Edison invented more than 2,000 new products, including almost everything needed for us to use electricity in our homes: switches, fuses, sockets and meters.
- Benjamin Franklin didn't discover electricity, but he did prove that lightning is a form of electrical energy.
- A bolt of lightning can measure up to three million (3,000,000) volts, and it lasts less than one second!
- The word "electrocute" is a combination of the words electro and execute, meaning you were killed by electricity. So if you don't die, you were not electrocuted, you were shocked.
- Benjamin Harrison, the 23rd president of the US, was the first president to have electricity in the White House but he never touched any light switches because he was too scared of getting electrocuted.
- Huge amounts of renewable energy can be stored over a long period of time by using Pumped Storage Hydropower, where water is pumped up a hill with renewable electricity then sent back down the hill to generate on demand clean electricity at up to 80% efficiency.
- In 1963, Quebec government bought out all the private power companies and nationalized electricity. Today, 96% of Quebec's power is from hydroelectricity, and it has some of the cheapest electricity rates in North America while earning billions in revenue.
- Only 10% of energy in a light bulb is used to create light. Ninety percent of a light bulb's energy creates heat. Compact fluorescent light bulbs (CFLs), on the other hand, use about 80% less electricity than conventional bulbs and last up to 12 times as long.
- About 5,000 years ago, the energy people consumed for their survival averaged about 12,000 kilocalories per person each day. In AD 1400, each person was consuming about twice as much energy (26,000 kilocalories). After the Industrial Revolution, the demand almost tripled to an average of 77,000 kilocalories per person in 1875. By 1975, it had tripled again to 230,000 kilocalories per person
- The world's biggest blackout occurred on August 14, 2004, when a massive power outage occurred across the northeastern U.S. and throughout Ontario, Canada, affecting 50 million people.
- In 2007, wind produced 1.3% of the electricity in the world. The world's largest wind farm is the Horse Hollow Wind Energy Center near Abilene, Texas.

Covering 92 square miles, the center has more than 400 turbines that are 262 feet tall. They produce 735 megawatts of electricity

- Approximately 30% of energy used in buildings is used inefficiently or unnecessarily.
- In the last 50 years, atmospheric CO2 has shot up to levels unprecedented in the previous 400,000 years. The man-made injection of CO2 into the atmosphere is primarily from the burning of fossil fuels.
- The most powerful hydroelectric project in the world is China's Three Gorges Dam. The enormous power plant brings power to millions of Chinese villagers and will generate more than 22,000 megawatts from six generators.
- American hospitals are some of the most energy-intense buildings on the planet.
- China has taken over the U.S. as both the world's largest CO2 emitter and the world's largest energy consumer.
- Thomas Edison built the first power plant, and in 1882 his Pearl Street Power Station sent electricity to 85 buildings. People were initially afraid of electricity and parents would not let their children near the lights.
- English polymath Thomas Young (1773-1829) was the first to use the word "energy" in its current sense, replacing the traditional term *vis viva*, meaning "living force."
- More than 1/5 of the world's primary energy is used for transport, followed by industry, construction, and agriculture. Much is in the form of gasoline, of which nearly 792.5 million gallons is burned every day.
- A "watt" is a unit of power that measures the rate of producing or using energy. The term was named after Scottish engineer James Watt (1736-1819), who developed an improved steam engine. Watt measured his engine's performance in horsepower. One horsepower equaled 746 watts.
- Researchers note that energy is the key "to the advancement of civilization" and that energy is the catalyst that allows human societies to evolve.
- The word "energy" comes from the Greek *energeia*, meaning operation, activity.
- The world's oil reserves will last until 2052 and gas reserves will last until 2065.
- A hurricane releases 50 trillion to 200 trillion watts of heat energy. This is as much energy as a 10-megaton nuclear bomb exploding every 20 minutes.

DEVICE NUMBERS AND THEIR NOMENCLATURE

2	Time Delay Starting or closing relay
3	Checking or interlocking relay
21	Distance relay
25	Check synchronizing relay
27	Undervoltage relay
29	Isolating Contactor
30	Annunicator relay
32	Directional power (Reverse power) relay
37	Under current or Under power relay
40	Field failure (loss of excitation) relay
46	Negative phase sequence relay
47	Phase-sequence Voltage relay
49	Machine or Transformer Thermal relay
50	Instantaneous Overcurrent relay
51	A.C. Time Over current relay
52a	Circuit breaker Auxiliary Switch “Normally open” (‘a’ contact)
52b	Circuit breaker Auxiliary Switch “Normally close” (‘b’ contact)
55	Power Factor relay
56	Field Application relay
59	Over voltage relay
60	Voltage balance relay
61	Current balance relay
62	Time-delay stopping or opening relay

63	Liquid or Gas pressure, Level or Flow relay
64	Ground Protection relay
67	AC Directional over current relay
68	Blocking relay
74	Alarm relay
76	D.C. Over current relay
78	Phase angle measuring or our of step relay
79	AC Auto reclose relay
80	Monitoring loss of DC supply
81	Frequency relay
81U	Under frequency
81O	Over frequency relay
83	Automatic selective control or transfer relay
85	Carrier or pilot wire receive relay
86	Locking out relay (Tripping relay)
87	Differential relay
87G	Generator differential relay
87GT	Overall differential relay
87U	UAT differential relay
87NT	Restricted earth fault relay
95	Trip circuit supervision relay
99	Overflux relay
186A	Auto reclose lockout relay
186B	Auto reclose lockout relay

KERALA POWER SYSTEM (as on 01-04-2017)

Installed Capacity (MW)		Sales Parameters	
Hydro (KSEBL)	2049.80	Consumer Strength	11,994,816
Thermal (KSEBL)	159.96	Per capita consumption	582
Wind (KSEBL)	2.03	AT & C Loss	16.26 %
Solar (KSEBL)	7.611	T & D Loss	13.93 %
SHP (IPP/CPP)	58.16	Maximum Demand	4004 MW (27.04.16)
Thermal (IPP/CPP)	558.51	Energy requirement	250,000 MU (FY17)
Wind (IPP/CPP)	41.25	Distribution Transformers	76,379
Solar (IPP/CPP)	59.52	Street lights	14,12,689

Transmission and Distribution network

Voltage (kV)	Substations	Capacity	Line Length
(kV)	(Nos)	(MVA)	(Ckm)
400	1	1365	--
220	22	7270.9	2801.8
110	156	7456.8	4460.5
66	79	1735.7	2154.5
33	144	19143.4	1902.3
11	76,39	9141.12	59,496
LT	--	--	2,91,38

Interstate Tie Feeders

Cochin - Thrissur – Areekode 400 kV	
Cochin - Thrissur– Palakkad 400 kV	Sabarigiri – Theni – 220 kV
Thirunelveli Pothencode – 400 kV	Edamon – Thirunelveli – 220 kV
Kaniyampetta – Kadakola 220 kV	Parassala – Kuzhithurai – 110kV
Idukki – Udumalpet – 220 kV	Manjeswaram – Konaje – 110 kV

Power Stations in Kerala (31.03.2017)					
No	**Name**	**Type**	**Machines (Units X MW)**	**Plant Capacity (MW)**	**Firm Generation (MU/pa)**
1	Idukki	Hydro	6 x 130	780	2398
2	Sabarigiri	Hydro	4 x 55 + 2x 60	340	1338
3	Idamalayar	Hydro	2 x 37.5	75	380
4	Sholayar	Hydro	3 x 18	54	233
5	Pallivasal	Hydro	3 x 5 + 3 x 7.5	37.5	284
6	Kuttiyadi	Hydro	3 x 25	75	268
7	Kuttiyadi Ext	Hydro	1 x 50	50	75
8	Kuttiyadi Addl Ext	Hydro	2 x 50	100	223
9	Neryamangalam	Hydro	2 x 17.55	52.65	237
10	Neryamangalam Ext	Hydro	1 x 25	25	58.27
11	Lower Periyar	Hydro	3 x 60	180	493
12	Poringalkuthu	Hydro	4 x9	36	170
13	Sengulam	Hydro	4 x 12.8	51.2	182
14	Kakkad	Hydro	2 x25	50	262
15	Panniyar	Hydro	2 x 16.2	32.4	158
Large Hydro Plants				**1938.75**	**6759.27**
1	Kallada	SHP	2 x 7.5	15	65
2	Malankara	SHP	3 x 3.5	10.5	65
3	PLBE	SHP	1 x 16	16	74
4	Peppara	SHP	1 x 3	3	11.50
5	Madupetty	SHP	1 x 2	2	6.40
6	Malampuzha	SHP	1 x 2.5	2.5	5.60
7	Lower Meenmutty	SHP	1 x 0.5 + 2 x 1.5	3.5	7.63

8	Chembukadavu 1	SHP	3 x 0.9	2.75	6.59
9	Chembukadavu 2	SHP	3 x 1.25	3.75	9.03
10	Urumi 1	SHP	3 x 1.25	3.75	9.72
11	Urumi 2	SHP	3 x 0.8	2.4	6.28
12	Kuttyadi Tailrace	SHP	3 x 1.25	3.75	17.01
13	Poozhithode	SHP	3 x 1.6	4.8	10.97
14	Ranni-Perinadu	SHP	2 x 2	4	16.73
15	Peechi	SHP	1 x 1.25	1.25	3.21
16	Vilangad	SHP	3 x 2.5	7.5	22.63
17	Chimmony	SHP	1 x 2.5	2.5	6.70
18	Adyanpara	SHP	2 x 1.5 + 0.5	3.5	9.01
19	Barapole	SHP	3 x 5	15	36.00
20	Vellathuval	SHP	2 x 1.8	3.6	12.17
Small Hydro Plants				**111.05**	**401.18**
1	KDPP	Thermal	3 x 21.32	63.96	363.6
2	BDPP	Thermal	6 x 16	96	672
Thermal Plants				**159.96**	**1035.6**
1	Kanjikode SS	Wind	9 x 0.225	2.025	4
2	Kanjikode	Solar		1.00	1.63
3	Banasurasagar (F)	Solar		0.01	0.014
4	Chaliyoor Colony	Solar		0.096	0.15
5	Porigalkuthu PH	Solar		0.05	0.06
6	Gen Rooftop	Solar		0.70	0.12
7	Palakkad Tribal	Solar		0.065	0.01
8	P.thara dam s	olar		0.44	0.732
9	Barapole Canal	solar	Bank 1 + top	3 4.00	6.554
10	Edayar SS	solar		1.25	2.080

	Renewable Plants			9.636	15.35
	Total KSEBL Plants			2219.396	8211.4
1	Maniyar SHP	3 x 4		12	36
2	Kuthungal SHP	3 x 7		21	79
3	Ullungal SHP	2 x 3.5		7	32.22
4	Iruttukkanam SHP	3 x 1.5		4.5	15.86
5	Karikkayam SHP	3 x 3.5		10.5	43.7
6	Mankulam SHP	2 x 0.055		0.11	0.29
7	Meenvallam SHP	2x 1.5		3	8.37
8	Kallar SHP	1x 0.05		0.05	0.13
	IPP / CPP SHPs			**58.16**	**215.57**
1	MP Steel Cogen	Thermal	3x 2 + 4	10	67.63
2	Philips Carbon Black	Thermal	1 x 10	10	70.08
3	KPCL	Thermal	3 x 7.3	21.93	140
4	BKPL – BSES	Thermal	3 x 40.5 + 35.5	157	1099
5	RGCCPP-NTPC	Thermal	2 x 116.6+126.6	359.58	2158
	Thermal IPP/CPP			**558.51**	**3534.71**
1	Agali	Wind	31 x 0.6	18.6	37.47
2	Ramakkalmedu	Wind	19 x 7.5	14.25	32.46
3	Kanjikode	Wind	4 x 2.1	8.4	16.19
4	Hindalco	Solar		1	1.58
5	CIAL	Solar		20.5273	32.37
6	Solar Park	Solar		36	56.76
7	ANERT	Solar		2	3.15
Renewable IPP/CPP				**100.777**	**179.88**
Total IPP / CPP				**717.447**	**3930.16**
Grand Total				**2936.843**	**12141.56**