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Finger Typed Electrode

Enhancement of Power

Highlights

High Resistivity Silicon

Development of Alternative

Discovering Thoughts, Inventing Future

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Finger Typed Electrode Based Electro-Optical Demodulator Fabricated on High Resistivity Silicon

By Quazi Delwar Hossain, Gian-Franco Dalla Betta, Lucio Pancheri & David Stoppa

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Abstract - This paper focus on a finger typed electrode based electro-optical photo mixing demodulator. This device is fabricated on high resistivity silicon in custom technology. The main performance indicatorssuch as DC characteristics, DC and AC demodulation contrast and phase-linearity measurement of a test sample are experimentally characterized. Experimental results exhibit a good DC charge separation and good dynamic demodulation capabilities from 100Hz to 30MHz.The average linearity error of finger typed electrode device for square wave 4.09% has been measured. The dependency of the device performance on modulation frequency and voltage is also discussed.

Keywords : electro-optical demodulator, high resistivity silicon, demodulation contrast, photonic device, modulation frequency.

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FINGER TYPED ELECTRODE BASED ELECTRO-OPTICAL DEMODULATOR FABRICATED ON HIGH RESISTIVITY SILICON

Strictly as per the compliance and regulations of :

Finger Typed Electrode Based Electro-Optical Demodulator Fabricated on High Resistivity Silicon

Quazi Delwar Hossain [α], Gian-Franco Dalla Betta [σ], Lucio Pancheri [ρ] & David Stoppa [ω]

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I. Introduction

Recently a lot of effort has been concentrated to develop standard 3D vision imagers due to the drastic increase in demand of 3D imaging system. The 2D-imaging system can evaluate only the intensity projection of a scene, there is no information about the depth of the 3D objects.

Range-imaging sensors acquire three-dimensional (3D) maps from a scene and can be used in a variety of applications such as bio medical appliances, surveillance system; several applications in automobiles, robomechatronics single point measurement etc. 3D image isextracting information from the geometric estimation of third co-ordinate of a scene.

In this work, we present a finger typed field assisted electro-optical demodulator fabricated in custom technology. After reviewing related research work in Section 2, the device architecture with its working principle and ISE-TCAD simulation are introduced in Section 3. In Section 4 the electro-optical characteristics of the device is reported. Finally the paper is concluded in Section 5.

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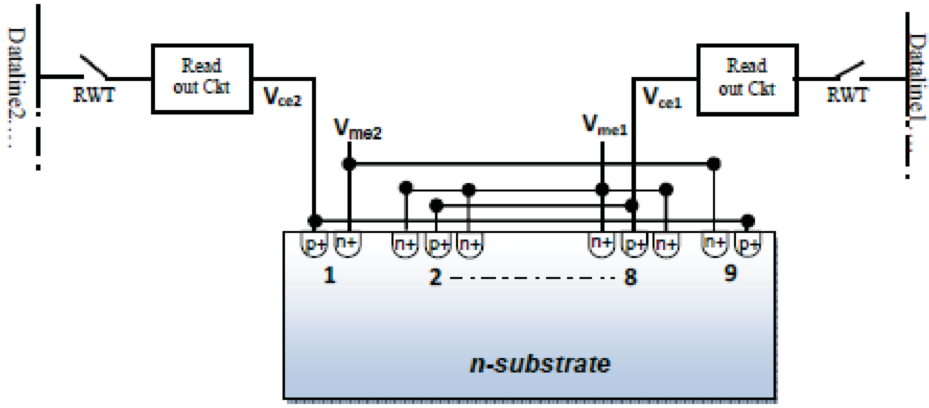
II. Related Work

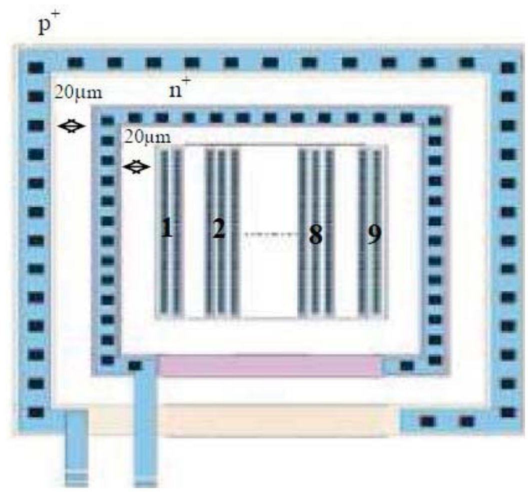
A number of applications that can detect the time or phase information of reflected light for 3D imaging are available in the literature. Depth information can be determined by correlating the incoming modulated light signal from the scene with a reference signal synchronous with the modulation signal of the light source [1]. In time-of-flight optical ranging, the phase information is used to plot the distance map of the observed scene, thus enabling the reconstruction of the shape and position of the observed objects [2]. TOF technique provides the best performance in terms of acquisition speed, reliability, overall cost of the system and is most suited to integrate electronic circuitry with more functionality. Several studies on image capturing techniques using specialized pixels coupled with active illumination have reported to produce images with information even at a low intensity level [3]-[4].TOF based 3D imagers so far reported in different literatures depending on the type of photo detector used in the pixels.

The time or phase information in addition to signal intensity is based on a variety of light-sensitivedevices such as: p-i-n photodiodes, linear or Geiger mode avalanche photodiodes and photomultipliertubes. Several works [5]-[8] reported a standard photodiode coupled with complex readout circuitry using indirect time-of-flight.

The key element of 3D range camera of photo demodulators have been implemented with different types of technologies such as: Charged Couple Device (CCD), Complementary Metal Oxide Semiconductor (CMOS) and CMOS/CCD hybrid approach. The photo generated charge is mixed on two or more photo-gates thus achieving an intrinsic demodulation effect [9]-[12].



(a)



(b)

Figure 1 : (a) Cross sectional view of multiple strip CAPD and (b) Device layout

The advantage is the read-out channel simplicity which results in a small pixel size.The disadvantages are the lower sensitivity due to the presence of the "photo-gate", the lack of immunity to the ambient light and the cost of the non-standardtechnology.A Photonic Mixer Device (PMD) is an interesting solution for dynamic 3D-vision that is reported in [13]. An alternative demodulating detector structure, the Current Assisted Photonic Demodulator (CAPD) has been reported in [14].The function of detection and demodulation in a single device uses a modulated electric field that infiltrates deeper into the substrate to enhance the charge separation and collection mechanism.A linear Current Assisted Photonic Mixing Device fabricated on high resistivity silicon has been described in [15].

III. Device Architecture and Working Principle

A finger-typed electrode based electro-optical demodulator consists of multiple strips. The cross sectional view and the layout of the device is shown in Figure 1 (a) and (b) respectively. The above Figure1(a) shows an active pixel that contains a finger typed photonic mixing demodulator that is integrated with a read out circuit and a row select transistor for each collecting electrode.This device has four electrodes, two of them known as collecting electrodes and connected to V_{ce1} and V_{ce2} and rest of them are known as modulating electrodes and connected toV_{me1} and V_{me2}.These modulated electrodes are connected to the device substrate. This device consists of nine collecting electrodes. Among these electrodes, the seven central regions (from region 2 to region 8 as shown in Figure.01) consist of a p+ type detection junction and two n+ type substrate contacts. The rest of collection regions contain one collecting junction and one substrate contact, like the region 1 and 9 (Figure.1) [16].

All of the substrate contacts and the collection junctions are connected as shown in the device cross sectional diagram. The collecting electrode V_{ce1} and the modulating electrode V_{me1} are connected to the 2, 4, 6 and 8 regions according to the detection junctions and substrate contacts. On the other hand, the collecting electrode V_{ce2} and the modulating electrode V_{me2} are

Global Journal of Researches in Engineering (F) Volume XIII Issue IV Version I Year 2013

connected to the region 1, 3, 5, 7 and 9 accordingly. This device is also enclosed with an n+ bulk-contact, shared along the array and placed at a minimum distance of about 20μm from the pixel boundary. A p+ ring is surrounded by n+ bulk-contact at a distance of about 20μm for better isolation of each device. The distance between the neighboring modulating electrodes is 20 μm and the total area of this device is 0.4mm $\times$ 0.4mm.Firstly, the device simulation software ISE-TCAD is used to investigate the operational behaviour of the device. In this device a potential difference is applied between the modulating electrodes to direct the signal charges towards the two detection regions.

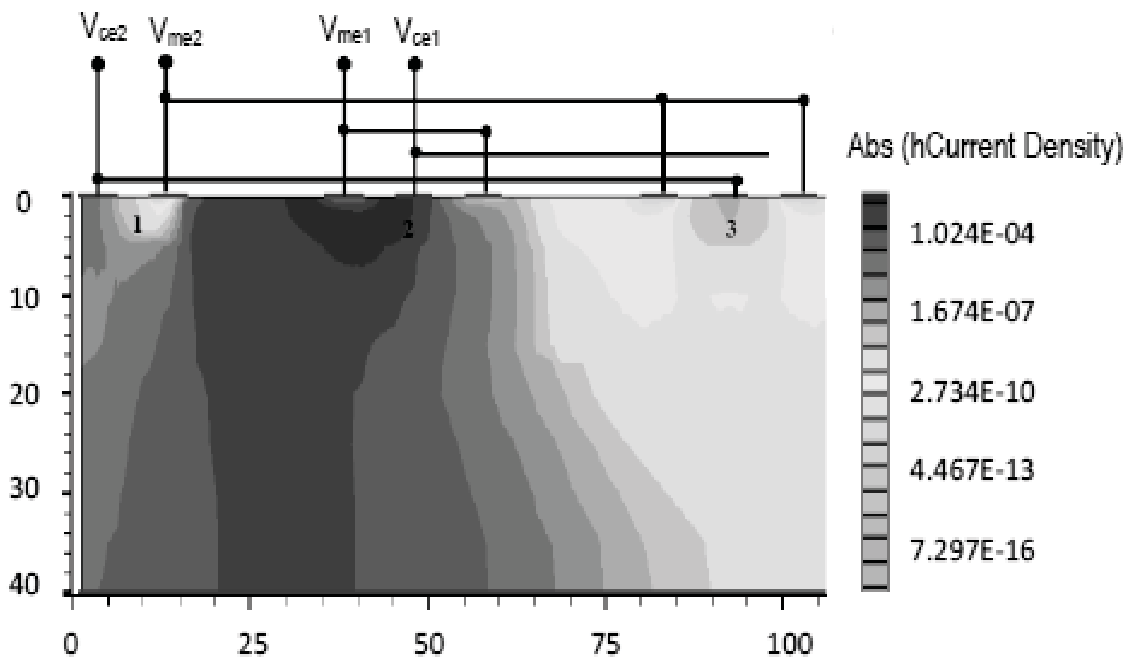


Figure 2 : Simulated hole current density under illumination

When a potential difference $\Delta V = V_{me2} - V_{me1}$ is applied at the modulated electrode V_{me2}. An electric field formed inside the substrate of the device guides the photo-generated charge carriers towards the detection electrode V_{ce2}.

At 780 nm light incident on the device surface the hole current density of this device shown in Figure 2. This simulated photograph shows the region 1and 2 according to the cross sectional view of the device shown in Figure 1(a). Most of the generated holes move toward the collecting electrode V_{ce2}, guided by the electric field with a voltage difference applied between two modulating electrodes i.e. $V_{me2} > V_{me1}$.

IV. Performance Characteristics of the Device

The customize Fabricated structure is characterized electrically and optically. The demodulation contrast of the device and the effect of frequency and modulation voltage on it are assessed. Phase measurements are carried out to evaluate linearity of the device.

a) Dc Characteristics

An experimental characterization was carried out. The DC characterization set up of the test device is shown in above Figure 3.The device is enlightened with a wide spectrum lamp.

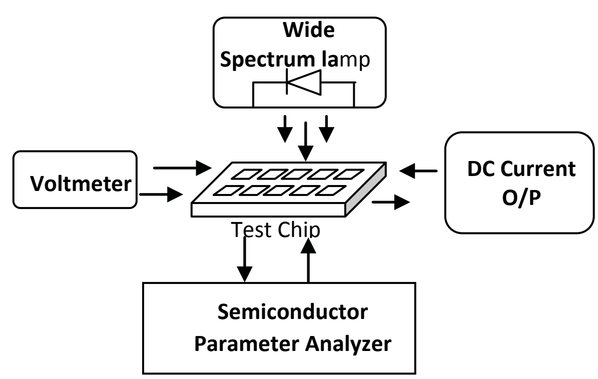


Figure 3 : Experimental setup for DC characterizations

In this measurement the required voltage at different electrodes can be supplied with a voltage source. A semiconductor parameter analyzer is used to read out the detection current from the collecting electrodes. Table: 1 shows the detection current from two collecting electrodes I_{ce1} and I_{ce2} at different modulation voltages.

Table 1 : Detection current at different modulation voltages

V_{me2}(V)	I_{ce1}(μA)	I_{ce2}(μA)
0.000	0.442	20.280
0.200	0.932	19.790
0.400	1.895	18.820
0.600	3.324	17.480
0.800	5.006	15.840
1.000	6.783	14.150
1.200	8.282	12.740
1.400	9.392	11.740
1.600	10.250	10.970
1.800	10.930	10.380

Now we can calculate the demodulation contrast by using the following equation.

$$DCDemodulationContrast(\%) = \left|\frac{I_{ce2} \; - I_{ce1}}{I_{ce2} \; + \; I_{ce1}}\right| \times 100\%$$

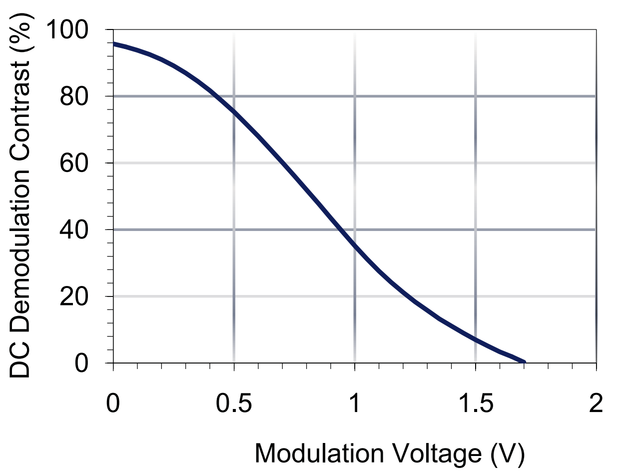


Figure 4 : Demodulation efficiency vs. Modulation Voltage

The device shows a maximum DC demodulation contrast larger than 90%, thus indicating that, this device is potentially enabling a very efficient mixing process.

b) Dynamic Characteristics

In order to measure average current at the collecting electrodes and the dynamic demodulation contrast we have conducted and experiment. The schematic representation of this experiment set up is shown in Figure 5.

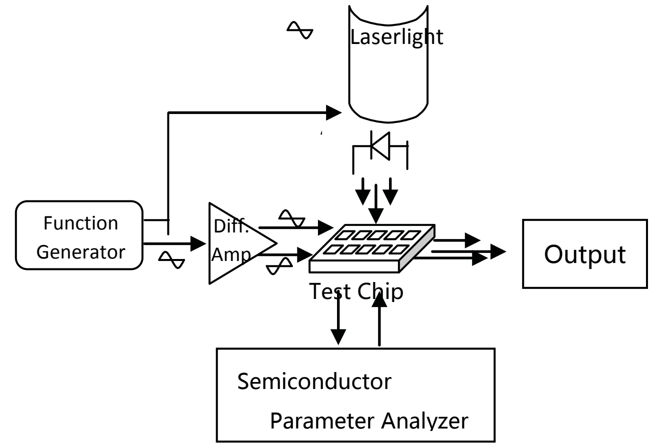


Figure 5 : Experimental setup for Dynamic characterizations

Two sinusoidal waves are generated by using a function generator. One of the two sinusoidal waves is used to modulate a laser emitter and illuminate the device. The other is connected to the input of a differential amplifier. The differential amplifier outputs with 180^0 phase shift are connected to the modulating electrodes V_{me1} and V_{me2} of the device. The electric field formed in the substrate average current through the collecting electrodes V_{ce1} and V_{ce2} is read out with a Semiconductor Parameter Analyzer. For this measurement, the sinusoidal signal for laser emitter and two modulating signals are needed to use with an appropriate synchronization. At different modulation frequencies, the average current is measured under a 650nm red laser with 90% modulation depth used to illuminate the test device.The capability to separate and transfer the charges of a sensor to the corresponding output node can be expressed as a demodulation contrast. For data acquisition a LABVIEW software program was developed for the interface with PC and the experimental set-up.

The dynamic demodulation contrast is the most important performance indicator for this device. The demodulation contrast depends on both the amplitude of the modulation voltages and frequencies.

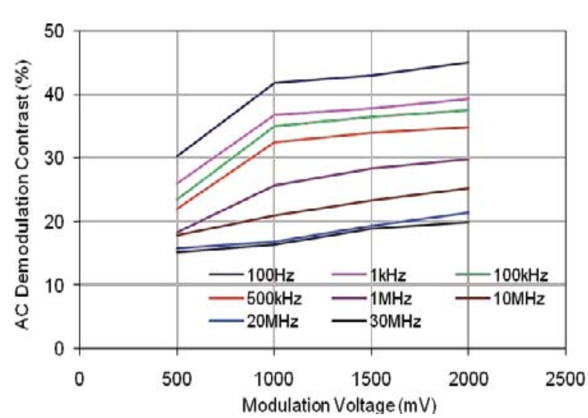


Figure 6 : Demodulation contrast at different modulation voltage

The dynamic demodulation contrast can be defined as:

$$\frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}} \times 100\ \% \quad \ldots\ldots\ldots\ \ldots\ldots (i)$$

Where I_{max} and I_{min} are the photo-generated currents flowing at collecting electrodes V_{ce1} and V_{ce2}. The demodulation contrast for the finger typed device as a function of the modulation voltage amplitude at eight different frequencies from 100Hz to 30MHz is shown in Figure: 6.

By increasing the modulation voltage it should be possible to increase the majority current that cause the drift of the minority carriers, namely holes. When the modulation voltage is applied to the modulating electrodes, the photo generated holes arrive at the collecting electrode of the device. If applying more voltages, the electric field penetrates deeper in the substrate so that more holes reach detection node resulting in a higher demodulation contrast. Due to the larger voltage applying at the modulating electrodes the power consumption is increased. So the amplitude of modulation voltage should be carefully chosen. By increasing of the modulating frequency the decrease of the demodulation contrast can be described with respect to diffusion time. The photo-generated charges in the deeper of the substrate need more time to reach the active region where the demodulating electric field is present and thus reduces the demodulation contrast.

The phase linearity measurements performed between the applied phase and measured phase of the device. In these measurements a variable phase delay ΔV is applied between the laser input to illuminate the device and two modulation electrodes of the device. The value of ΔVcan be recovered acquiring four amplitude measurements with four different phase shifts ϕ_{11}, ϕ_{12}, $\phi_{21}$and ϕ_{22} applied to the modulated laser signal considered as -180°, -90°, 0° and +90° respectively [17]. The phase shift can be calculated with the equation (ii) given below:

$$\Delta\theta = \arctan\frac{I(\varphi_{11}) - I(\varphi_{21})}{I(\varphi_{12}) - I(\varphi_{22})} \quad \ldots.\ \ \ldots.\ \ \ldots.\quad (ii)$$

This measurement is performed using a sinusoidal wave and square wave modulation signals at 20 MHz, and the resulting phase is reported in Figure: 7 for this device. The average linearity error of finger typed electrode device for square wave is 4.09% thus, validating the good linearity of the device.

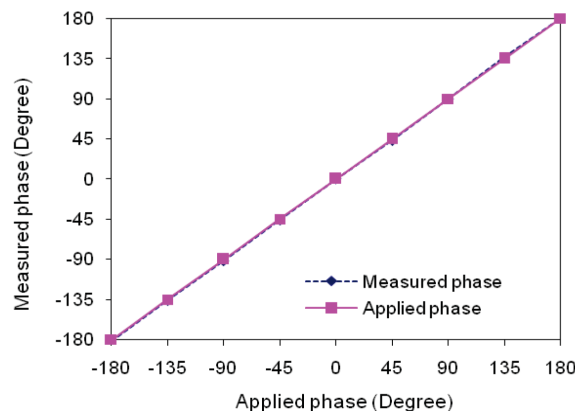


Figure 7 : Phase linearity measurement for Finger typed Device for Square wave

c) Device Capacitance Measurement

Figure: 8 is shown the experimental setup for capacitance measurement of this device. An LCR Meter is used to measure capacitance accurately. The LCR meter serves two main functions- measure the capacitance of the device and supply the required biasing voltage across the junction. This experiment is controlled by using a LABVIEW program via GPIB interface between the Computer and the LCR meter.

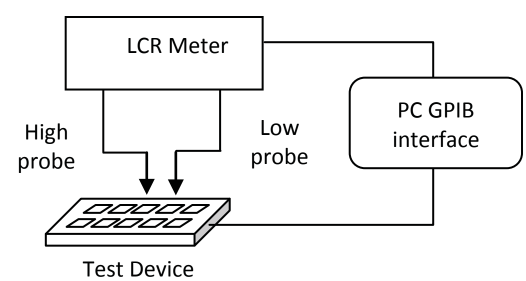


Figure 8 : Set-up for device capacitance measurement

At three different frequencies- 3MHz, 1 MHz and 100 kHz the C-V response of the device is shown in Figure: 9. Due to a larger depletion width the higher reverse bias produces a lower capacitance. At lower frequency, the capacitance is larger than at higher frequency. Because of their finite charging and discharging time the deep-level impurities in the space charge region make the capacitance to be frequency dependent [18, 19].

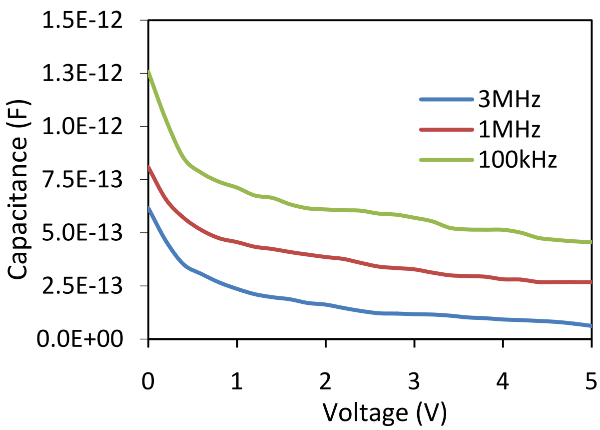


Figure 9 : C-V characteristics of the device

V. Conclusion

This paper has described the characterization of a finger typed electro-optical demodulator fabricated in a custom technology on high resistivity silicon substrates. A 400µm × 400µm structure with finger typed electrodes has been considered and tested in terms of electrical and electro-optical performance. The maximum phase linearity error between the applied phase and the measured phase is 4.09% for square wave. In particular, the DC and dynamic demodulation performance of the multiple strip devices has been investigated. The measured dynamic demodulation contrast is more than 20% at 20 MHz modulation frequency. This customize device corresponds to understand field assisted photo mixing demodulator in term of optimizing the performance to make them in complementary metal-oxide-semiconductor technology.

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Harmonics Reduction of a Single Phase Half Bridge Inverter

By Imran Azim & Habibur Rahman
University of Engineering & Technology RUET, Bangladesh

Abstract - This paper presents an approach to minimize the harmonics contained in the output of a single phase half bridge inverter. With a view to reducing harmonics an LC low pass filter is used which blocks the harmonics and undeniably passes almost sinusoidal output at the output terminal. An illustration of Fourier Transform has been provided in this paper in order to perceive both the fundamental and harmonics component precisely. It has been found from simulation that the Total Harmonic Distortion (THD) before and after the application is 44.999% and 0.0183% respectively. That is why, this LC low pass filter is quite effective to reduce THD of a 1-phase half bridge inverter.

Keywords : single phase half bridge inverter, IGBT, harmonics analysis, FFT, THD, LC low pass filter, MATLAB simulation.

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HARMONICS REDUCTION OF A SINGLE PHASE HALF BRIDGE INVERTER

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I. Introduction

Dc-to-ac converters are known as inverters. The function of an inverter is to change a dc voltage to a symmetric ac output voltage of desired magnitude and frequency [1]. Some typical applications are variable speed ac drives, induction heating, standby power supplies, uninterruptible power supplies(UPS), traction, HVDC and so forth [2].

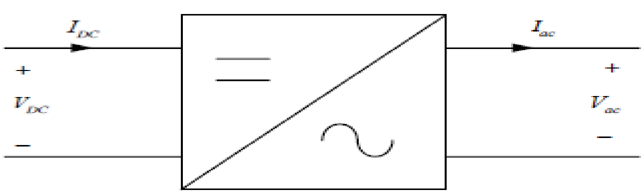

Figure 1 : General Block Diagram of Inverter

Inverters can be broadly classified into two types such as single phase inverters and three phase inverters. The output voltage could be fixed or variable at a fixed or variable frequency. A variable output can be obtained by varying the input dc voltage and maintaining the gain of the inverter constant. The output waveforms of an ideal inverter should be sinusoidal. However, the waveforms of practical inverters are non-sinusoidal and contain certain harmonics which can be seen with ease in frequency domain. Due to the availability of high speed power semiconductor devices, the harmonic contents of output voltage can be minimized or reduced significantly by switching technique. BJTs, MOSFETs or IGBTs can be used as ideal switches to explain the power conversion techniques. But IGBT is more popular as it combines the advantages of BJTs and MOSFETs. An IGBT has high input impedance, like MOSFETs, and low on state conduction losses like BJTs [3-4].

Total Harmonic distortion (THD) is a measure of closeness in shape between a waveform and its fundamental component. For improvement purpose, a LC Low pass filter is appended at the output terminal that provides low harmonic impedance to ground [5].

II. Single Phase Half Bridge Inverter

A half bridge inverter consists of a three wire dc source in which $V_s/2$ voltage is obtained across the load as seen in Figure 2. When Q_1 is turned on and Q_2 is turned off, the instantaneous voltage across the load is $V_s/2$ as observed in Figure 2. On the other contrary, if Q_2 is turned on and Q_1 is turned off then according to figure 2. - $V_s/2$ voltage appears across the load. The logic circuit is designed in a way that Q_1 and Q_2 are not turned on at the same. Otherwise, dc source may be shorted out. So, there must a dead time between the switches [6].

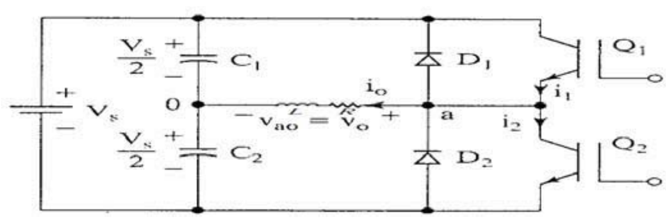

Figure 2 : Circuit Diagram of Single Phase Half Bridge Inverter

Instantaneous inverter output voltage,

$$vo = \sum_{n=1,3...}^{\infty} 2\frac{Vs}{n\pi}\sin nwt \qquad (1)$$

Instantaneous inverter output current,

$$io = \sum_{n=1,3...}^{\infty} 2\frac{Vs}{n\pi\sqrt{R^2+(nwL)^2}}\sin(nwt-\theta n) \qquad (2)$$

III. IGBT

The Insulated Gate Bipolar Transistor (IGBT) is a minority-carrier device with high input impedance and

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large bipolar current-carrying capability. Many designers view IGBT as a device with MOS input characteristics and bipolar output characteristic that is a voltage-controlled bipolar device. To make use of the advantages of both Power MOSFET and BJT, the IGBT has been introduced. It's a functional integration of Power MOSFET and BJT devices in monolithic form. It combines the best attributes of both to achieve optimal device characteristics [6].The IGBT[7, 14] is suitable for many applications in power electronics, especially in Pulse Width Modulated (PWM) servo and three-phase drives requiring high dynamic range control and low noise. It also can be used in Uninterruptible Power Supplies(UPS), Switched-Mode Power Supplies (SMPS), and other power circuits requiring high switch repetition rates. IGBT improves dynamic performance and efficiency and reduced the level of audible noise. It is equally suitable in resonant-mode converter circuits. Optimized IGBT is available for both low conduction loss and low switching loss. Without a hint of doubt an IGBT is the most common device chosen for new power electronics applications. It has highest capabilities up to 1700KVA, 2000V and 800A [8].

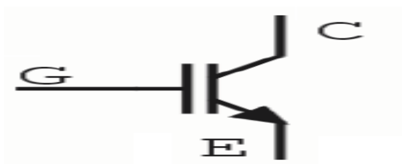

Figure 3 : Circuit Symbol of IGBT

A circuit symbol for the IGBT is shown in Figure 3.

It has three terminals called Collector (C), Gate (G) and Emitter(E).

IV. HARMONICS ANALYSIS

A harmonic is a signal or wave whose frequency is an integral (whole-number) multiple of the frequency of some reference signal or wave. The term can also refer to the ratio of the frequency of such a signal or wave to the frequency of the reference signal or wave. Let f represent the main, or fundamental, frequency of an alternating current signal, electromagnetic field, or sound wave. This frequency, usually expressed in hertz, is the frequency at which most of the energy is contained, or at which the signal is defined to occur. If the signal is displayed on an oscilloscope, the waveform will appear to repeat at a rate corresponding to f Hz.

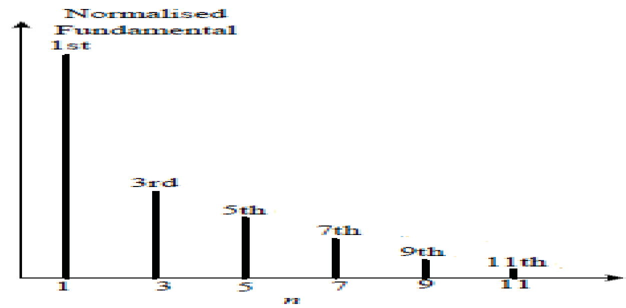

Figure 4 : Harmonic Spectra of an Inverter

As is observed, Harmonic decreases as n increases. It decreases with a factor of (1/n). Even harmonics are absent–Nearest harmonics is the 3rd. If fundamental is 50Hz, then nearest harmonic is 150Hz. Due to the small separation between the fundamental an harmonics, output low-pass filter design can be quite difficult [8].

The effects of harmonics are unpleasant due to the fact that these cause unbalance and excessive neutral currents. Harmonics give rise to interference in nearby communication networks and disturbance to other consumers. In electric motor drives, they cause torque pulsations and cogging [9].

V. FFT ANALYSIS

It is a linear algorithm that can take a time domain signal into the frequency domain and back. Fourier analysis allows a more intuitive look at an unknown signal in frequency domain [10].As is presented in Figure 4. the fundamental component & the harmonic components can be understood without cumbersome.

VI. THD

Total Harmonic Distortion is a measure of distortion of a waveform. It is given by the expression [11]

$$THD = \sqrt{\frac{\mathrm{Im}^2 - \mathrm{Im}_1^{\,2}}{\mathrm{Im}^2{}_1}} \qquad (3)$$

Therefore, it is needless to say that THD can be defined as the ratio of the RMS value of all odd number of non fundamental frequency terms to the RMS value of the fundamental [12].

VII. LC LOW PASS FILTER

The implementation of an LC filter at the inverter ac terminals could trigger a parallel resonance which tends to amplify the harmonic voltages and currents in ac network leading, in some cases, to potential harmonic instabilities owing to the fact that the filter capacitance has a profound impact on the harmonic performance [8,13].

An LC low pass filter is used to bring the harmonics into a lower state [9].

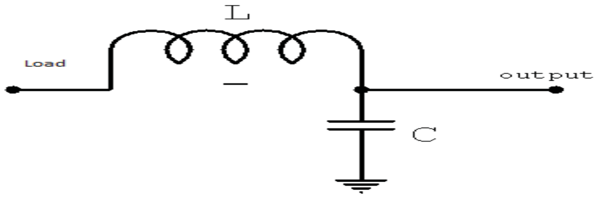

Figure 5 : LC low pass filter

VIII. Simulation and Result

It is assumed that input voltage is 220V. Other necessary parameters are considered deliberately with assuming up to 15th harmonics prevalent at the output so as to [Equation 1 and 2] can be plotted using [10].

According to the illustration, Figure 6. And Figure 7. deal with the inverter output voltage in time domain and frequency domain respectively whereas inverter output current both in time domain and frequency domain have been demonstrated in Figure 8 and Figure 9 respectively.

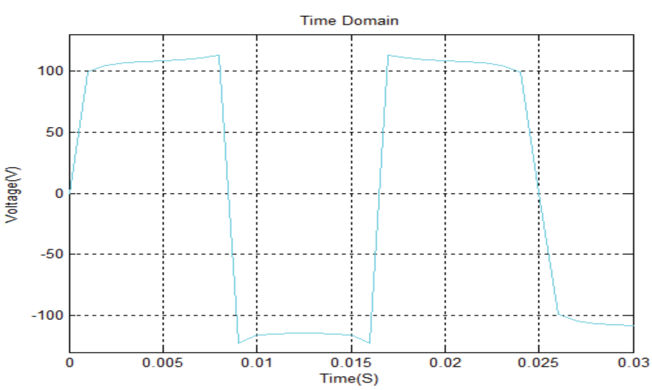

Figure 6 : Time domain Response of Inverter Output Voltage with Harmonics up to 15th

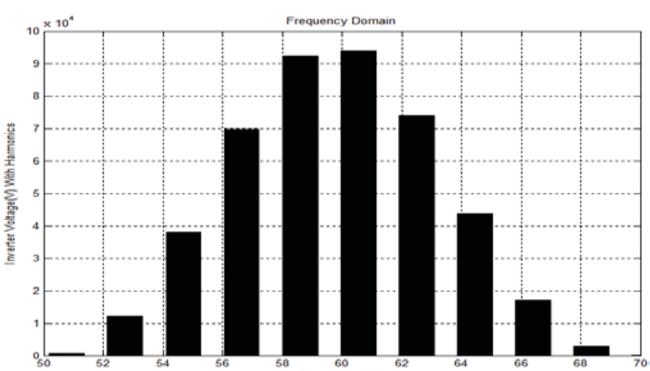

Figure 7 : Frequency domain Response of Inverter Output Voltage with Harmonics up to 15th

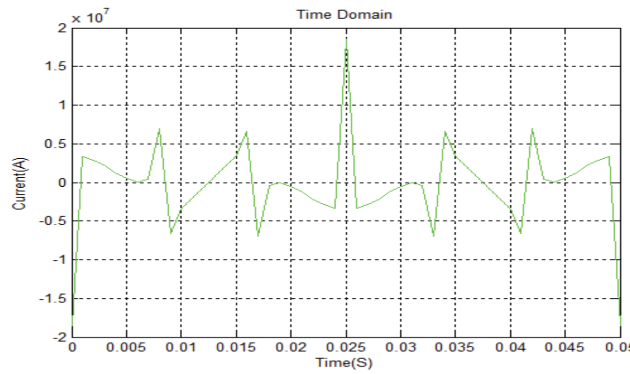

Figure 8 : Time domain Response of Inverter Output Current with Harmonics up to 15th

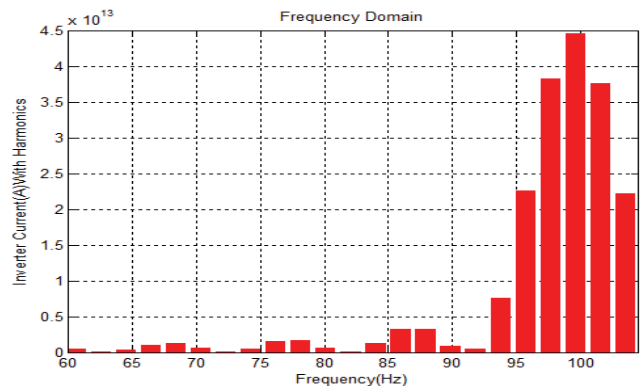

Figure 9 : Frequency domain Response of Inverter Output Current with Harmonics up to 15th

There is no denial that too much harmonics exist at the output even though fundamental frequency is 60Hz. In this case applying [Equation 3] obtained THD is 44.999% which is unquestionably excessive and is needed to be mitigated for better performance. Thence, An LC low pass filter is connected with the load and the output is taken across the capacitance having 10000F value so that it has an effect on the present harmonics.

Finally, the output is plotted using [10] again and nearly a sinusoidal response is observed which has been depicted in Figure 10. Furthermore, from frequency domain response described in Figure 11, it is found that the fundamental component has the highest amplitude.

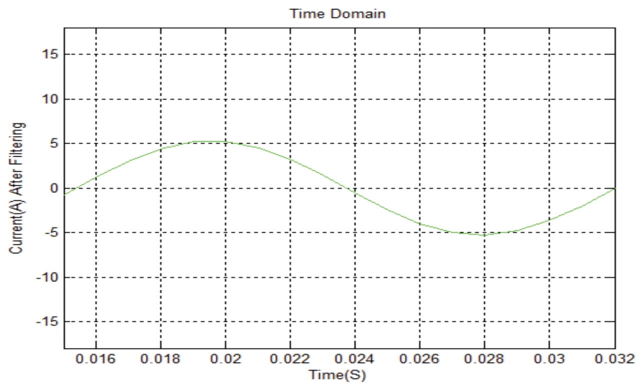

Figure 10 : Time domain Inverter Output Response after appending an LC low pass Filter

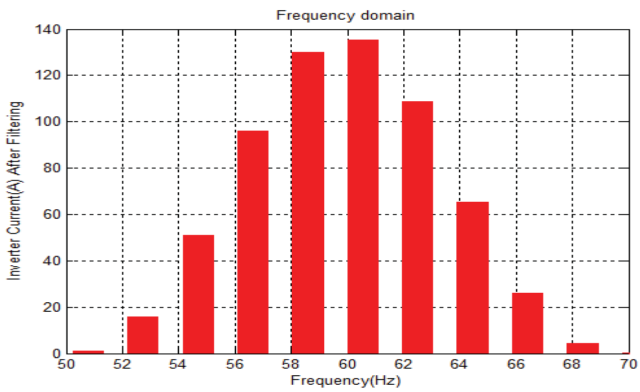

Figure 11 : Frequency domain Inverter Output Response after appending an LC low pass Filter

Here, calculted THD is 0.0183%.

IX. Result and Discussion

At normal condition, when up to 15th harmonics are considered then there exists 44.999% THD. But as soon as an LC low pass filter is implemented it has been dropped to 0.0183%. Therefore, a vast improvement has been noticed.

A single phase half bridge inverter finds an extensive utilization in variable speed ac drives, induction heating, standby power supplies, uninterruptible power supplies(UPS), traction, HVDC, grid connection of renewable energy sources and so on due to simple design and cost effective aspects. However, unlike single phase full bridge inverter the maximum ac voltage is limited half the value of full dc voltage source. Again it may need a center tapped source. Now, if it is intended to get higher ac voltage then a step up transformer can be used.

In coming days, using this concept, the output responses of single phase full bridge inverter can be observed as well as the harmonics occurred at the output can be minimized by applying LC low pass filter. An implementation of 2nd order LC low pass filter would be interesting in this case.

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Development of Alternative Scenario for Ethiopia's Electricity Sector by LEAP Software

By Md. Minarul Islam, Elizabeth Mosqueda & Mir Tanweer Husain
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Abstract - Ethiopia, a country in Africa, is endowed with renewable energy sources such as hydro, solar and wind. These energy sources are economically exploitable and if electrical energy could be prouduced it could be surplus beyond the country's demand. Exporting electrical energy, Ethiopia could earn more money without disturbing environment as it is a global warming issue now-a-days. But due to lack of technology, the rich renewable resources are not utilized properly, and as a result, only 15% of the population of the country have access to electricity. In this paper, based on moderate scenario, an alternative scenario for Ethiopia's electricity sector will be developed to meet its energy demand upto the year 2030. For alternative scenario, the time range from year 2008 to 2030 was considered in LEAP software. In the alternative scenario, hydro and geothermal were judiciously selected as the source of energy. Solar energy was not selected due to its upfront cost which is unbearable by any developing countries. Wind energy was not selected because of seasonal variations in energy production around the year.

Keywords : ethiopia energy scenario, hydro energy, geothermal energy, energy demand, environmental issue, energy export.

GJRE-F Classification : FOR Code : 850303, 090699

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Strictly as per the compliance and regulations of :

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I. Introduction

The production of world electricity in 2008 was 20,261TWh, which was 11% of the solar energy the earth receives in one hour. Sources of electricity were fossil fuels 67%, renewable energy 18%, and nuclear power 13%. Ninety-two percent of renewable energy was hydroelectric followed by wind at 6% and geothermal at 1.8%. Solar photovoltaic was 0.06%, and solar thermal was 0.004%[1]. The share of renewables in electricity generation is around 19%, with 16% of global electricity coming from hydroelectricity and 3% from new renewables. The amount of electrical energy produced in 2008 around the world, from different fuel sources, are shown in figure 1. A global-country comparison can be seen on the table 1.

Approximately, Africa produced 9% of the world Energy. African production is dominated principally by traditional biomass and oil [1]. The average consumption per household is 47 KWh/year per capita. Around the world, 500 KWh/yr is the average minimum level of consumption for a reasonable quality of life.

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In this paper, as an alternative scenario will be proposed for Ethiopia's electricity sector, let us look through the Ethiopia's baseline scenario. Ethiopia's energy supply is covered mostly by waste and biomass (92%). Oil (6.7%) and hydropower (0.9%) are the other two primary energy sources. The installed capacity of electrical power is about 2060 MW (88% hydro, 11% diesel and 1% thermal). This production is equal to 10% of the demand. For this reason, the country is dependent on the imports of petroleum to meet its requirements.

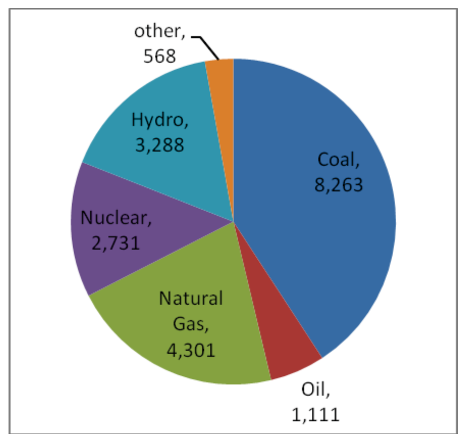

Figure 1 : Source of Electrical energy (TWh/year) around the world (2008) [1]

Table 1 : Electricity production sources global-country basis[1-2]

	World (%)	Africa (%)	Ethiopia(%)
Hydro	16%	27	94
Natural Gas	21	25	3
Coal	41	40	
Oil	5	10	

With only 15% of the population having access to electricity, there is a significant bias between electricity supply of urban and rural population: 80% of urban areas have access to electricity, whilst only 2% of rural areas habitants have access to electricity [3]. As it can be observed in the Figure 2, the average electrification rate in developing countries is 72%. Therefore, there is a gap of more than 57% to achieve the target for developing countries, specially for Ethiopia.

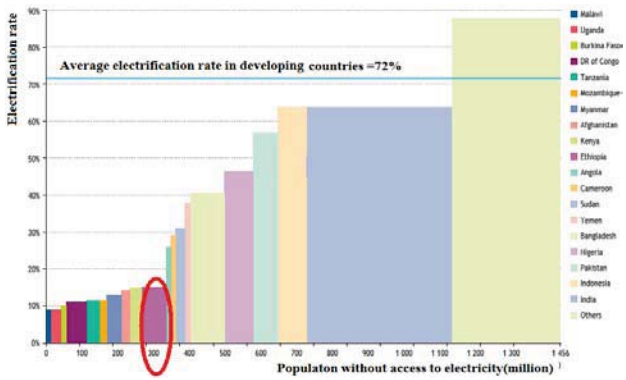

Figure 2 : Electrification rates and population without access to electricity, 2008

According to Ethiopian Electric Power Corporation (EEPCo) electricity generation in 2010 was 3,981.07 GWh. Hydropower generates 88% of the electricity and thus is the country's dominating electricity source. The other sources for EEPCo energy generation are diesel and geothermal as shown in the figure 3.

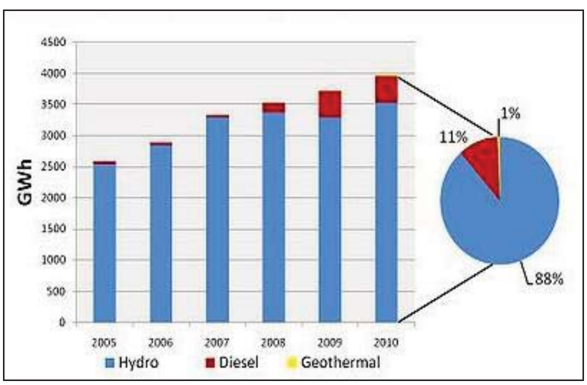

Figure 3 : Development of Energy Generation of EEPCo ICSs and SCS, Period 2005-2010 (in GWh) and share by fuel 2010

Although there are a number of private, municipal and cooperative owned small scale power producers in areas not served by the utility their combined contribution is estimated not to exceed 2% of EEPCo's capacity.

EEPCO runs two systems; the Interconnected System (ICS) and the Self Contained System (SCS). The ICS, which generates more than 98 percent of total EEPCO supply capacity, is supplied mainly from a set of large hydro systems with some thermal back up. The SCS is a much smaller system of decentralized mini-grid and off-grid systems supplied by small hydro plants and diesel generators. The technologies used by the ICS and SCS are shown in the table 2.

Table 2 : EEPCo's ICS and SCS plants[4]

	Hydro power	Geothermal	Diesel-grid Connected	Total Capacity
ICS	plants- 1842 MW	1 plant- 7.3 MW	15 plants- 172.3 MW	2019.3 MW
SCS	3 plants- 6.15 MW	-	31.34 MW	37.49 MW

The ICS is currently becoming bigger because of the interconnection of SCS to ICS. In 2010, a total of 5, 163 towns were connected by EEPCo. The electricity generation increased 53% from 2005 to 2010. This results in a shortage of electricity, because of a slant between the grid extension and the load of power generated. Transmission and distribution losses are around 20%. This event causes that the users willingness to pay increases significantly in isolated systems.

Nevertheless, Ethiopia's target was to supply 20% of the population with electricity by the year 2012. This is due to the 5 year Growth and Transformation Plan, launched in 2010 which aims to quadruple or even quintuple the country's current capacity and to connect 4 million costumers by 2015. The plan includes the installation of the following new plants:

- 8 hydropower plants with 8, 737 MW of total capacity.
- 7 wind plants with 866 MW of total capacity.
- 70 MW geothermal power plant of total capacity.

Keeping this plan in mind, the alternative scenario is developed. If this scenario is implemented, it will meet Ethiopia's energy demand which will improve the economic growth of the country.

II. Ethiopia's Electricity Generation Potential

a) Hydro Potential

The total hydro potential of Ethiopia is 45, 000 MW[6]. Which is the second highest potential in Africa (after Congo). Approximately 30,000 MW hydro power is economically feasible[8-9]. Current production is of only 2.5% of the potential. It is also important to mention that a vast potential is not only given for large hydropower projects, but also for small scale schemes. The potential from micro hydropower schemes is 100 MW, that could be developed on a land area of 200,000 km2. Most promising sites can be found in the western part of the country since suitable constant flows are prevailing, figure 4. Though, the drying seasons has to be taken into account because of the lack of water during this period of the year. Hydropower is the main source of electric power in Ethiopia. The exploitable hydro energy potential is estimated to be about 159TWh/year. Nearly 50% of this resource is in the Abay River Basin and 22% is in the Omo-Gibe River Basin.

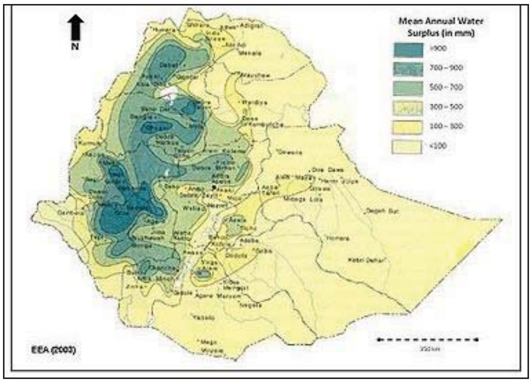

Figure 4 : Mean Annual Water Surplus in Ethiopia

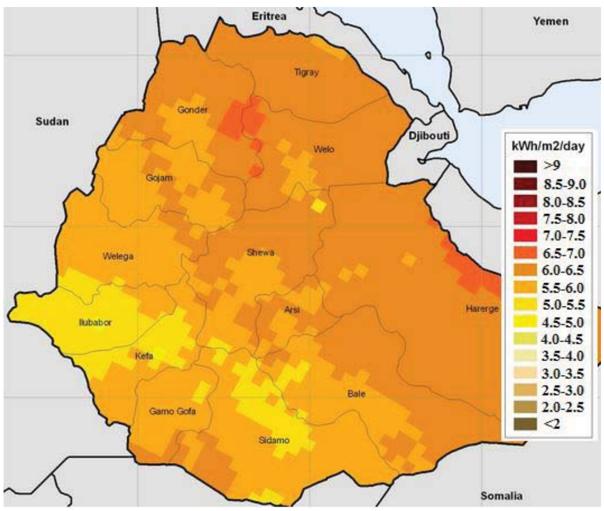

Figure 5 : Solar Irradiation in Ethiopia (in kWh/m2/day)[5]

b) Solar Potential

Ethiopia's solar potential has been shown in figure 5. The solar potential is 5 kwh/m2day[9]. Ethiopia receives a solar irradiation of 5000-7000 Wh/m2 according to region and season. Although the growth rate of the solar PV market has grown (from <5% since the early 1990s to 15 – 20% in the last few years) it is still at an early stage. With an installed capacity of approximately 5MW and an estimated PV market potential of 52 MW, not even 10% is exploited.

c) Biomass

A total of 30 MW of capacity surplus could be fed in the grid by sugar factories. Power production potential of landfill gas is estimated to be 24 MW.

d) Wind

With wind resources with a velocity of 5-6(m/s), Ethiopia's wind potential is estimated to be 10,000 MW[6,9]. EEPCo is planning to develop seven wind sites that are in close proximity to the ICS by 2015. They will have a capacity between 50 and 300 MW. The installed wind power capacity would be approximately of 720 MW. In rainy seasons the hydropower potential is high whereas low winds prevail, vice versa hydropower potential is low in the dry season whereas the wind potential is high as can be seen in the figure 6.

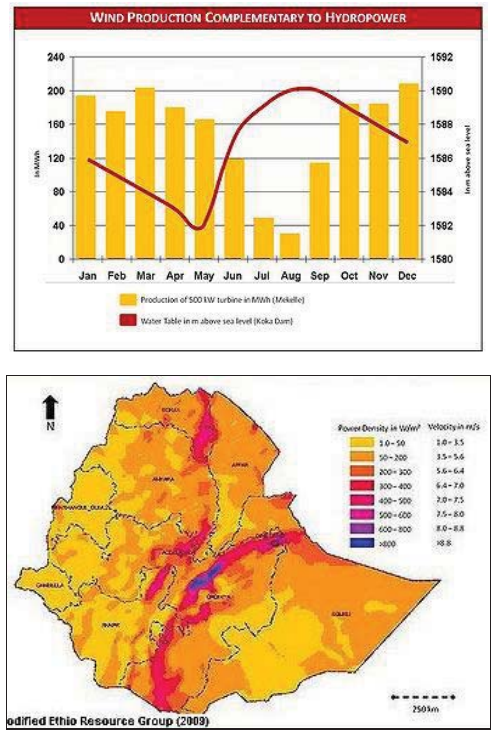

Figure 6 : Annual Mean Wind in Ethiopia and wind production compared to hydropower generation [4]

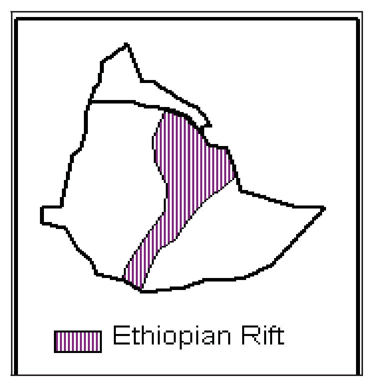

Figure 7 : Geothermal Ethiopia's energy base

e) Geothermal Energy

Ethiopia's geothermal resources are estimated to be 5 GW of which 700 MW are suitable for electric power generation [6-9]. They are primarily located in the Rift Valley, figure 7. Only one 7.3 MW geothermal has been commissioned so far but was shut down in 2002. Based on available scientific information and experiences on the Rift geothermal system both in Kenya and Ethiopia, it is plausible to assume the presence of a huge geothermal energy base in Ethiopia.

III. Technologies Selected for Ethiopia' Alternative Energy Scenario

For the development of Ethiopia's alternative scenario to meet its energy demand, two technologies, as shown in figure 8, were selected as follows:

- Hydropower plants (mycropower plants for the SCS system and hydropower plants for the ICS system)
- Geothermal power plants.

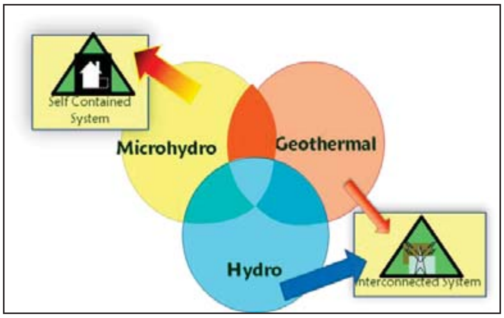

Figure 8 : Approach for alternative scenario

a) Aspects of the Selected Technologies

Hydropower Plants : The hydropower plants were chosen because of the highest potential of the country and the current low production as well as the possibility to develop large or small projects. Hydropower is the most abundant energy source of Ethiopia, it is thought to form the backbone of the country's energy sector development. Additionally, hydro is the cheapest potential amongst PV and wind. For this reason, hydro power can be selected as the best technology suitable.

Geothermal Plants : The development of the alternative scenario involves the introduction of geothermal power plants that are feasible because they are located in the Ethiopian geothermal rift.

Other technologies not considered : Despite of this, we were willing to introduce wind, but the wind availability was not sufficient in some areas to produce electricity, and in the areas where we have potential there were already transmission lines, which means that they would be suitable under ICS.

b) Description of the Elaborated Systems

Self Contained System : We choose to install 36 hydropower plants with an average capacity of 10 MW distributed along the country where no ICS is available, Figure 9. The selected areas have hydro potential. Additionally, the small projects would offer the opportunity to initially start as SCS and then get connected to the grid. We selected to put this power plants near rivers. The gap to be fulfilled for the self contained system is of around .131 GW. The vast amount of the SCS hydro power plants was located near rivers.

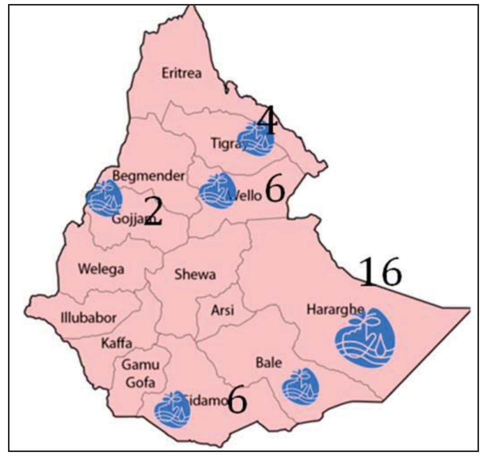

Figure 9 : Proposed SCS plants

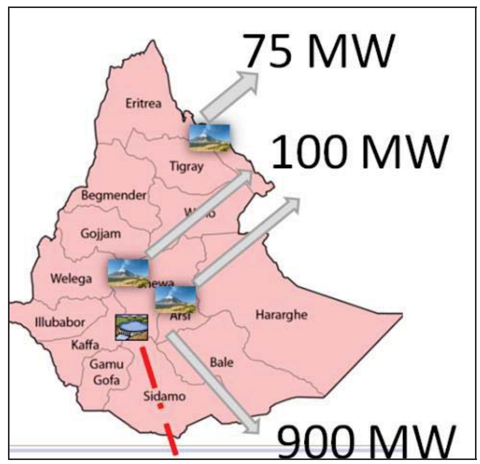

Figure 10 : Proposed ICS plants

Interconnected system : There is a deficit of around 400,000 MWh for the period 2008-2030. To fulfill the deficit we decided to construct 4 new Powerplants (3 Geothermal and 1 Hydro) figure 10. The plants that we decided to construct were:

Geothermal Power Plants : Corbetti Geothermal Power Plant. Corbetti Plant has a capacity of 75 MW. This plant was selected because it is already been considered by EEPCo and is in the Ethiopian rift to generate electricity through geothermal sources. We installed as well two other geothermal plants Tulu Moya & Dofan Geothermal Power Plants with a capacity of 100 MW. For the replacement of business as usual plant Yayu coal (capacity of 100 MW), we decided to install a 100 MW plant which will have very similar characteristics.

Hydro Plant : Additionally we add one big hydropower plant of 900 MW, Figure 10. This plant would be available in the west part of the country, because there is a very big potential for hydropower plant. Gibe IV would be of around 1472 MW. For this reason, our consideration of installing one plant of 900 MW is not by any chance out of analysis. As the new plant will be located near the line that exports electricity to Kenya, we can expect also to export electricity.

IV. Comparison between Moderate and Alternative Scenario

a) Demands in Moderate and Alternative Scenario

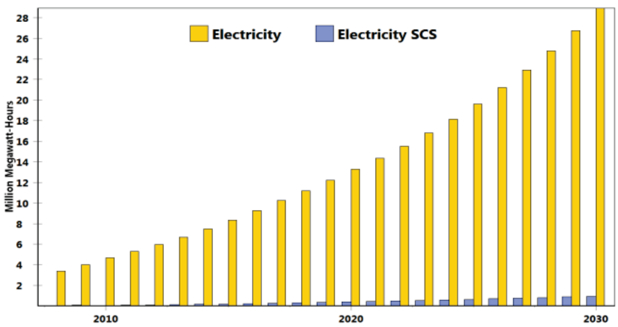

Figure 11 : Scenerio: Ethiopia moderate demand

Ethiopia's moderate scenario, figure 11, describes the electrical energy requirement for next 30 years. From figure 11, it is seen that in 2008, the total demand(ICS and SCS) is 3.46 million which is increasing exponentially and becomes 29.86 million MWh in 2030. We did not change anything in the forcasted demand of electrical energy for Ethiopia in our alternative scenario.

b) Outputs : Alternative Scenario

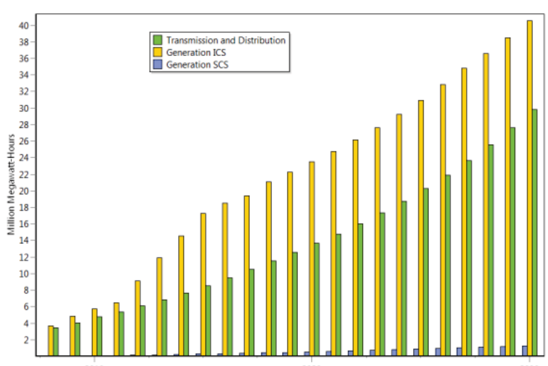

Figure 12 : Transformation:outputs; ethiopia moderate demand

The transformation: outputs result catagory displays the electrical energy produced in ICS, SCS with their losses in transmission and distribution, figure 12. From figure 12, we see that in 2008, total output is 7.21 million MWh (consist of ICS generation of 3.67 million MWh, SCS generation of 0.07 million MWh and losses in both ICS and SCS of 3.46 million MWh). In 2012, the output is 14.70 million MWh (ICS generation 8.54 million MWh, SCS generation 0.07 million MWh, transmission and distribution loss 6.08 million MWH). In 2030, the total output is 69.83 million MWH(ICS generation 39.89 million MWh, SCS generation 0.07 million MWh, transmission and distribution loss 29.86 million MWh). It is seen that the transmission and distribution losses are always very big. In this studies, no attempts were taken to reduce the losses.

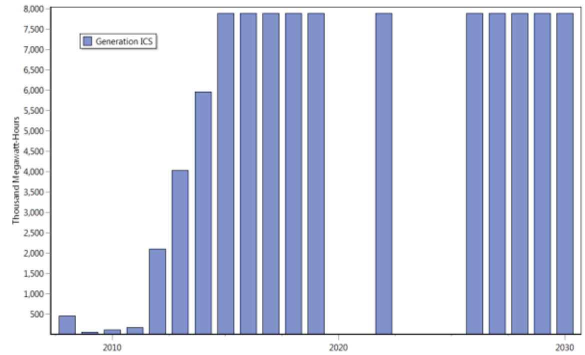

Figure 13 : Unmet requirement, ICS; Ethiopia moderate demand, Fuel: all fuels

c) Unmet Demands in ICS

The unmet requirements in ICS generation will be large from 2012 to 2019 then there will be no unmet requirements in the year of 2020, 2021 and from year of 2023 to 2025. Again, it becomes large from the year 2026 to 2030 as shown in figure 13. We ignored the unmet requirements from the year 2008 to 2011 because the unmet requirements were very small.

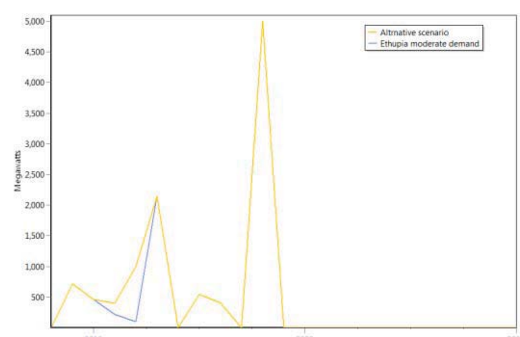

Figure 14 : Capacity added in ICS for alternative scenario, Capacity: all capacities

We attempted to reduce the unmet demands in ICS from the year of 2011. For this reason, we added two power plants named Corbetti GPP and Tulu Moya and Dofan of capacity 75 MW and 100 MW respectively. Both were geothermal power plants. Again, we added another two plants in the year of 2012 where one named as Abaya GPP(geothermal plant) of capacity 100 MW and one named as Gilgel Gibe IV(hydro power plant) of capacity 900MW. Addition of these four plants are shown in figure 14.

d) Capacity Installation in ICS

After addition of 4 power plants in ICS, we see that there are no unmet demands in ICS in the year of 2013 and from 2018 to 2026, figure 15. The limitation of the analysis here is that we installed plants in the year of 2011 and 2012 but its effect goes to unmet requirements in the year of 2013 and from the year of 2018 to 2026.

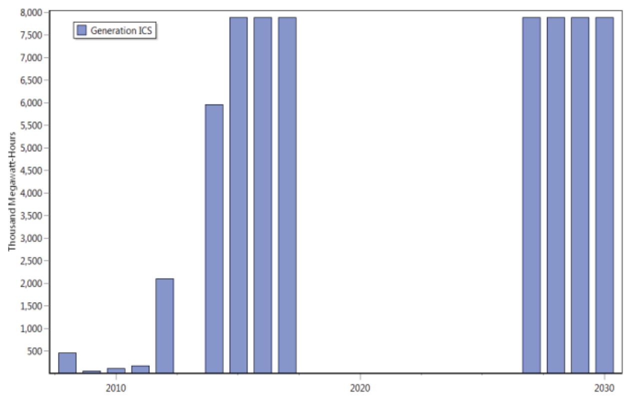

Figure 15 : Unmet demands in the alternative scenario, Fuel: all fuels

We see no change of unmet requirements in the other years. However, our target was not to reduce all the unmet demands in ICS but a little. Also due to increase export energy, we installed that plants in the ICS.

e) Unmet Demand in SCS of Ethiopia Moderate Scenario

The figure 16 shows the unmet damands in the SCS area. We see that the unmet demands in the year of 2008 and 2030 are 0.01 million MWh and 4.21 million MWh respectively where the demands are increasing almost exponentially with the year. Our target in the Ethiopia alternative scenario was to meet all the unmet demands in the SCS area.

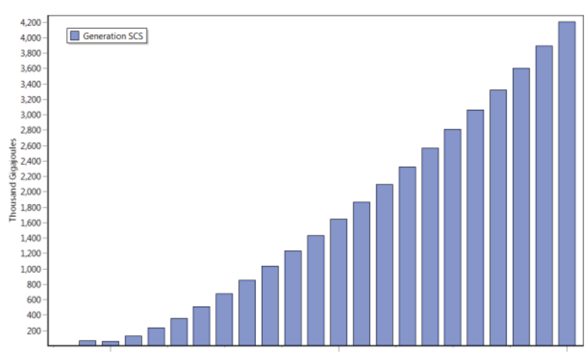

Figure 16 : Unmet demands in Ethiopia moderate scenario, Fuel: all fuels

f) Capacity Installation in SCS

We offered 35 small hydro plants of capacity 5MW and 10MW in different years in the period of year 2008 to 2030. The figure 17 shows the installation of power plants in different years and the table 3 shows the capacity added to the SCS area in our alternative scenario in the respenctive year according to the unmet demands.

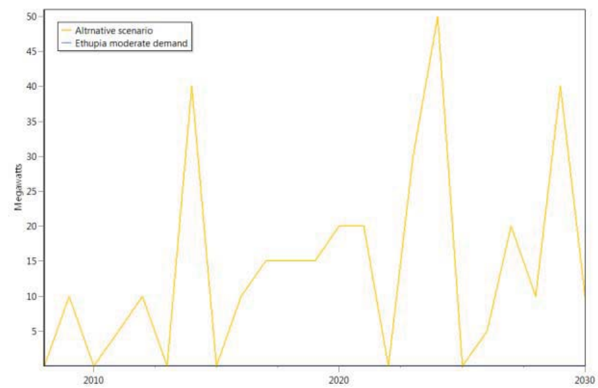

Figure 17 : Installatin of small hydro power plants in SCS area, Capacity: all capacities

Table 3 : Capacity added to SCS area

Year	Alternative scenario(MW)	Ethiopia Moderate demand(MW)
2009	10	0
2011	5	0
2012	10	0
2014	40	0
2016	10	0
2017	15	0
2018	15	0
2019	15	0
2020	20	0
2021	20	0
2023	30	0
2024	50	0
2026	5	0
2027	20	0
2028	10	0
2029	40	0
2030	10	0

g) Unmet Demands in SCS of Ethiopia Alternative Scenario

After installing the small hydro plants in the SCS area we see that the unmet demands will be very small in few years. The figure 18 describes the unmet requirements in the Ethiopia alternative scenario. The table 4 explains the small unmet demands in some years. In our alternative scenario, we left these unmet demands, because these are small and sometimes to meet these small demands, the installation of new power plants will not be economically feasible.

Table 4 : Generation SCS

year	Unmet demands in alternative scenario(Thousands MW)
2008	9.02
2009	0.32
2011	1.87
2013	37.08
2022	8.04
2028	4.76

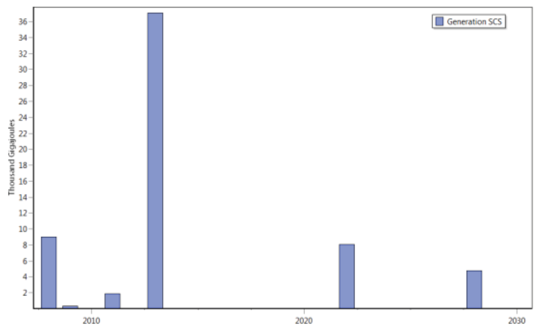

Figure 18 : Unmet demands in alternative scenario in SCS area

h) Capacity and Reserve Margin

The figure 19 describes the comparison between two scenarios for Ethiopia's electrical power capacity from the year 2008 to 2030. As we tried to reduce the unmet demands in the alternative scenario, its capacity is higher than the capacity in the moderate scenario.

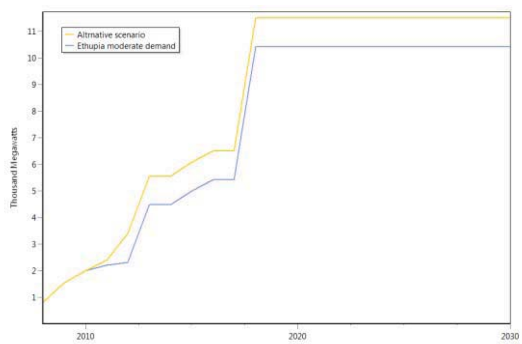

Figure 19 : Capacitis in both scenarios

The figure 20 shows the amount of reserve margin in the ICS area. This variable is generally only relevant for electricity generation modules. This variable is only reported if we have specified capacity data for the module.

Reserve margin is defined as follows:

$$\text{Reserve Margin}(\%) = \frac{100 * (\text{Module Capacity} - \text{Peak Load})}{\text{Peak Load}}$$

Where, Module Capacity = Sum(Capacity * Capacity Value) for all processes in the module.

Assuming that we have specified certain processes that will be added automatically using the Endogenous Capacity, then the actual reserve margin reported here should be greater than or equal to the planning reserve margin. This is because LEAP automatically adds new plants as needed in order to keep the reserve margin on or above the planning reserve margin. On the other hand, if plants are not being added automatically and if we have not exogenously specified sufficient capacity expansion, then it is possible that the actual reserve margin may fall below the planning reserve margin.

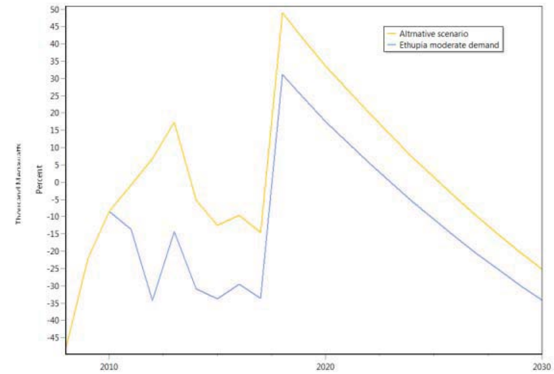

Figure 20 : Actual reserve margin in ICS are for both scenario

From the figure 20, we see that the reserve margin in alternative scenario is always greater than the reserve margin in the moderate scenario.

i) Exports

The results in figure 21 explains the exports from ICS area in both scenario. We see in the bar chart that exports in alternative scenario are greater than moderate scenario one from the year of 2012 to 2017 and 2027 to 2030, also exports are equals in both scenario from the year of 2018 to 2025.

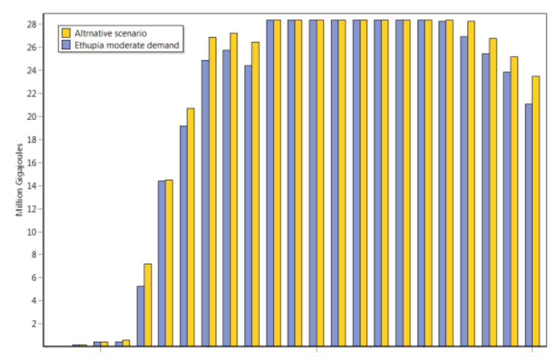

Figure 21 : Export of electricity from ICS in both scenario

j) Module Balance

The module balance in figure 22 explains domestic requirements, exports, inports, outputs and unmet demands. The unmet demands are always smaller than module outputs. We see that the exports are gradually decreasing, because in our scenario we selected domestic demands as priority that is why with the increase of domestic demands exports are decreasing.

But if we select exports as priority then the export would be constant all through the years which is shown in figure 23.

But the problem with export as priority that the unmet demands are always larger than the module outputs which may result in load shadding.

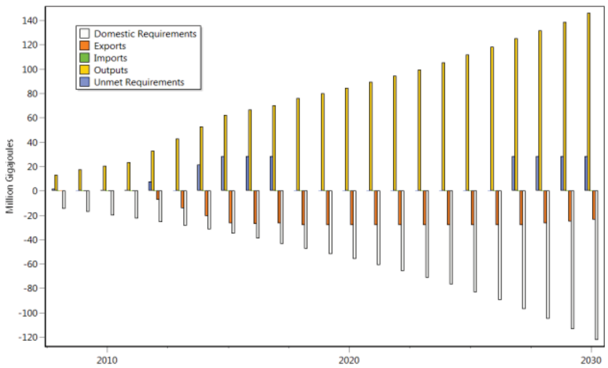

Figure 22 : Module balance with domestic demands prority in alternative scenario

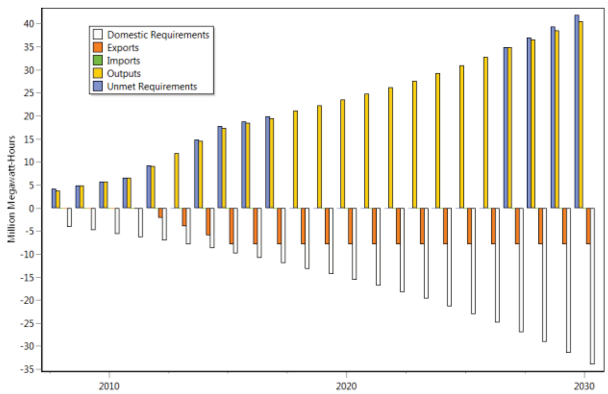

Figure 23 : Module balane with export prority

V. Impact on Import & Export of Secondary Fuel

a) Import

In the BAU scenario, Ethiopia needs to import secondary fuel namely diesel for both ICS and SCS electricity generation. In the proposed alternative scenario, new plants have been considered based on country's own renewable resources. In case of ICS, the proposed power plants' capacity is more than the existing electricity deficit.

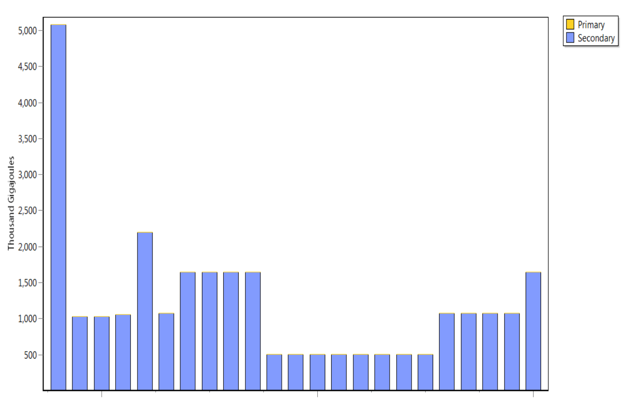

Figure 24 : Import - BAU Scenario

As a result, in some cases LEAP has chosen to use the additional electricity from the new power plants instead of diesel based power plants due to less generation cost. Consequently, there is reduction of diesel import from other countries. Diesel import in BAU scenario, figure 24, is compared to diesel import in alternative scenario, figure 25.

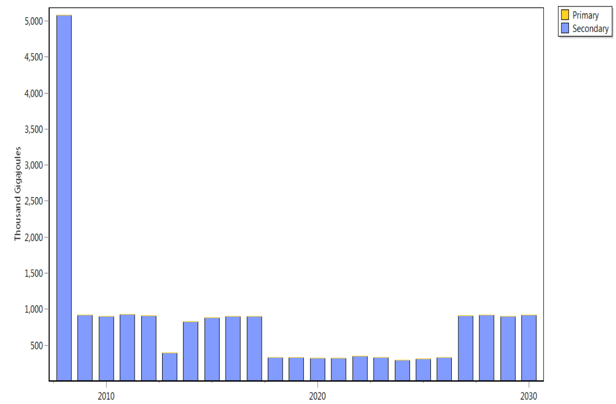

Figure 25 : Import - Alternative Scenario

b) Export

One of the objectives of the alternative scenario was to fulfill the demand of electricity for ICS. Though the focus was not to boost up electricity export, slight increase of export is also observed, comparison of figure 26 and 27.

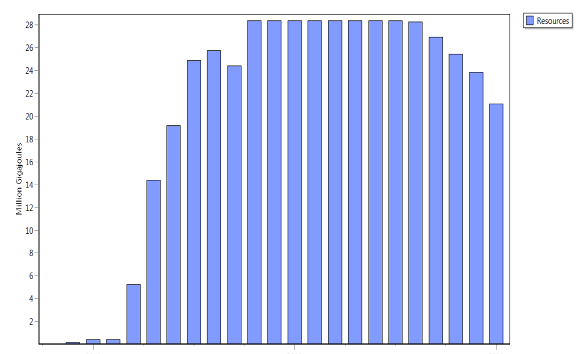

Figure 26 : Export - BAU Scenario

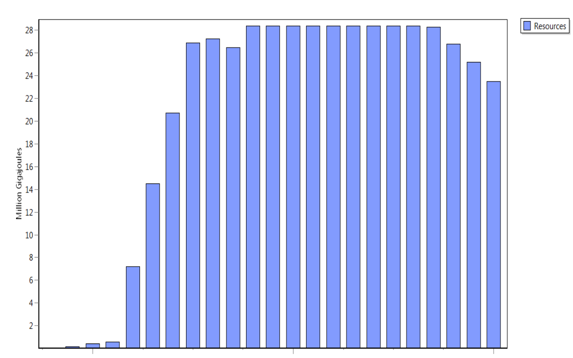

Figure 27 : Export - Alternative Scenario

Because, according to the alternative plan, the additional amount of electricity will be exported to neighbor countries after meeting the domestic demand. Here, this is to be noted that for 'Priority Use of Output' of 'Transformation- Generation ICS- Output Fuel- Electricity' we chose 'Domestic Requirement' instead of 'Export'. So our export quantity didn't remain fixed rather varied.

VI. Synopsis of Energy Balance

From 2008 to 2030, Ethiopia's Energy balance for each year reflects the changes in resources and transformations brought within the scenarios. For example, we can consider the energy balance of Ethiopia in 2012 for both the scenarios (please refer to Appendix – Table 6: Energy Balance for Ethiopia, 2012 - BAU Scenario and Table 7: Energy Balance for Ethiopia, 2012-Alternative scenario)

In the year 2012, there is considerable amount of increase of production from hydro and geothermal sources in the alternative scenario compared to BAU scenario. Subsequently, import of diesel has reduced from 379 thousand barrel of oil equivalent (BOE) to 156 thousand BOE in the proposed scenario. On the other hand, export has increased from 903 thousand BOE to 1235 thousand BOE. For SCS, electricity generation from hydro has increased and from diesel has decreased. Electricity from coal power plant has reduced from 654 thousand BOE to 0. Total transformation in BAU was 1467 thousand BOE and it has changed to 3805 thousand BOE in the alternative scenario. Total demand for electricity is 3767 thousand BOE in both cases as no change was done from the moderate scenario. In the year 2012, there was unmet demand of 40 thousand BOE in case of SCS which has been totally diminished in the alternative scenario.

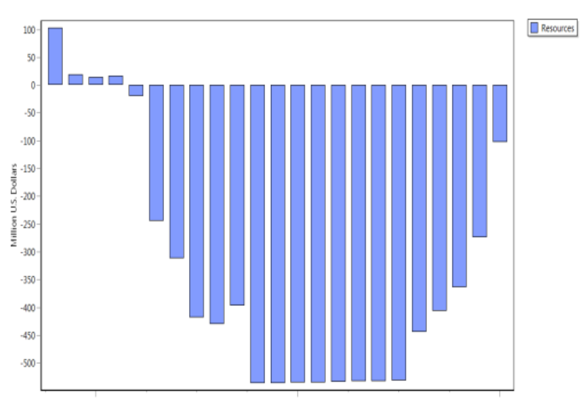

Figure 28 : All costs (domestic / foreign) – BAU

VII. Financial Investigation of the Scenarios

a) Cost & Benefit of the Scenarios

The figures 28 and 29 show the financial comparison between the moderate and alternative scenarios. It is observed that the involved costs are less and the negative costs i.e. benefits are more in the alternative scenario. For example, in the year 2030, the benefit available in the BAU and alternative scenario is around 90 Mill US $ and 430 Mill US $ respectively. It means benefit would be around 5 times more than the BAU scenario.

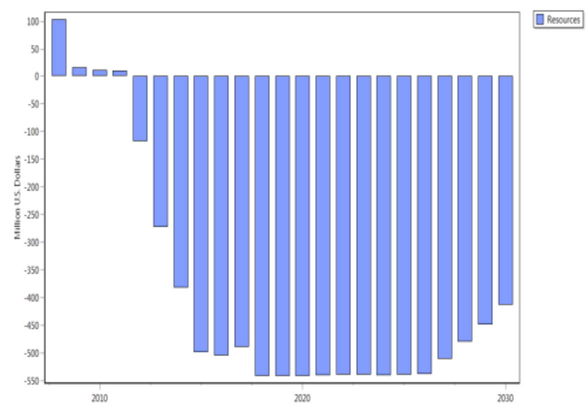

Figure 29 : All costs (domestic / foreign) - Alternative Scenario

b) Financial Investigation of the Alternative Scenario

The cumulative cost and benefit of the proposed alternative scenario from the year 2008 to 2030 compared to Ethiopia's moderate demand in Million US Dollar is given on the table 5.

Table 5 : Alternative scenario

Costs	
Demand	
Domestic	0.0
Commercial	0.0
Street Lighting	0.0
Industrial LV	0.0
Industrial HV	0.0
Rural Electrification	0.0
Transformation	
Transmission and Distribution	0.0
Generation ICS	1,688.5
Generation SCS	-2.6
Resources	
Production	-309.6
Imports	-162.6
Exports	-177.5
Unmet Requirements	0.0
Environmental Externalities	0.0
Net Present Value	1,036.2
GHG Savings (Mill. Tonnes C Eq.)	0.5
Discounted GHG Savings (Mill. Tonnes C Eq.)	0.3
Cost of Saved Carbon (U.S. Dollar/Tonne C Eq.)	3,585.1

It is observed that the cost involved in generation ICS is 1,688.5 Million US $. Small hydro power plants were proposed for SCS generation. In the long run, there would be benefits which is equivalent to 2.6 Million US $. As no change was brought in the demand side, there is no involvement of cost also. It is seen that the collective benefits from production, import & export of resources are 309.6, 162.6 & 177.5 Million US $ respectively. It means though some amount would be spent for import, it will bring benefit equivalent to 162.6 Million US $ in the long run. Overall, after considering the benefits, cumulative cost involved is 1,036.2 Million US $ (discounted at 5% to the base year). To be mentioned here, there is no cost involved in environmental externalities for this green scenario, on the other hand, there will be considerable amount of GHG saving. According to the IPCC's 100 years' integration global warming potential factors, the total cumulative emissions of all greenhouse gases avoided by the alternative scenario are 0.5 Million Tonnes of Carbon equivalent.

VIII. Environmental Aspect of the Scenarios

There was a coal power plant called 'Yayu Coal' in the moderate or business-as-usual scenario. In the alternative scenario, because of the environmental considerations, this plant was replaced by environment friendly geothermal power plant. The impact of this decision has been clearly illustrated in Figure 30 and 31. In the year 2012, when the coal power plant would likely be installed, GHG emission would be around 380 thousand tones CO2 equivalent. On the other hand, there is apparently no emission of global warming potential GHGs in the alternative scenario.

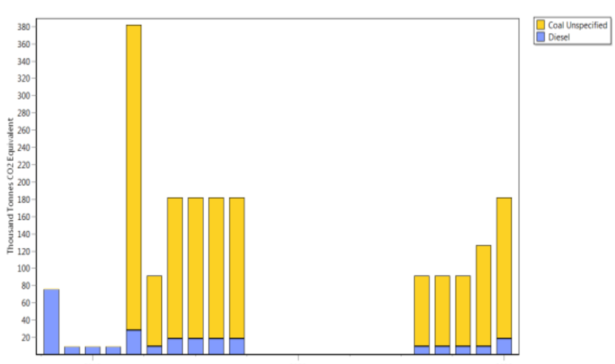

Figure 30 : Global Warming Potential - BAU Scenario

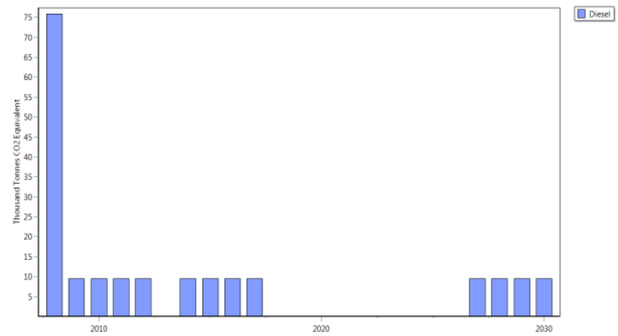

Figure 31 : Global Warming Potential - Alternative Scenario

IX. Conclusion

Ethiopia is endowed with renewable energy resources. The alternative scenario focused on maximum utilization of this resource as a source of clean electricity for the country. There is abundant of sunshine all through the year in the country. But solar energy was not selected due to its high upfront cost. There are some potentials of wind energy also in Ethiopia. Unfortunately, that is limited to some areas only and there are lots of seasonal variations in production around the year. However, the country has many rivers with huge potentials of hydro energy. That's why, in the proposed scenario, hydro and geothermal were judiciously selected as the source of energy. In the business-as-usual scenario, there were some unmet demands of ICS electricity. The alternative scenario has fulfilled the gap and also increased export of electricity to neighboring countries. In case of SCS, there was unmet demand at every year. These gaps have been almost fulfilled in a conservative manner as the additional production would be wasted. Besides, there was one coal based plant in the business-as-usual scenario which has been replaced by geothermal power plant. This change has turned the alternative scenario a cleaner one compared to BAU with diminishing of global warming potential GHG emissions. Thus, our proposed alternative scenario is capable enough to meet the electricity demand of Ethiopia in a more reliable and sustainable way than the business-as-usual scenario.

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Appendix

Table 6 : Energy Balance for Ethiopia, 2012 - BAU Scenario

Scenario: Ethiopia moderate demand (Thousand Barrel of Oil Equivalent)

	Electricity	Diesel	Wind	Hydro	Geothermal	Coal	Electricity	Total
Production	0	0	279	4698	86	654	0	5717
Imports	0	379	0	0	0	0	0	379
Exports	-903	0	0	0	0	0	0	-903
From Stock Change	0	0	0	0	0	0	0	0
Total Primary Supply	-903	379	279	4698	86	654	0	5193
Generation SCS	0	-86	0	-20	0	0	46	-60
Generation ICS	5288	-293	-279	-4678	-86	-654	0	-701
Transmission and Distribution	-684	0	0	0	0	0	-21	-706
Total Transformation	4604	-379	-279	-4698	-86	-654	25	-1467
Statistical Differences	0	0	0	0	0	0	0	0
Domestic	1144	0	0	0	0	0	2	1146
Commercial	900	0	0	0	0	0	2	902
Street Lighting	34	0	0	0	0	0	0	34
Industrial LV	404	0	0	0	0	0	0	404
Industrial HV	388	0	0	0	0	0	0	388
Rural Electrification	832	0	0	0	0	0	61	894
Total Demand	3701	0	0	0	0	0	65	3767
Unmet Requirements	0	0	0	0	0	0	40	40

Table 7 : Energy Balance for Ethiopia, 2012 – Alternative Scenario

Scenario: Alternative scenario (Thousand Barrel of Oil Equivalent)

	Electricity	Diesel	Wind	Hydro	Geothermal	Electricity SCsS	Total
Production	0	0	279	5049	3322	0	8650
Imports	0	156	0	0	0	0	156
Exports	-1235	0	0	0	0	0	-1235
From Stock Change	0	0	0	0	0	0	0
Total Primary Supply	-1235	156	279	5049	3322	0	7572
Generation SCS	0	-58	0	-69	0	87	-41
Generation ICS	5620	-98	-279	-4980	-3322	0	-3059
Transmission and Distribution	-684	0	0	0	0	-21	-706
Total Transformation	4936	-156	-279	-5049	-3322	65	-3805
Statistical Differences	0	0	0	0	0	0	0
Domestic	1144	0	0	0	0	2	1146
Commercial	900	0	0	0	0	2	902
Street Lighting	34	0	0	0	0	0	34
Industrial LV	404	0	0	0	0	0	404
Industrial HV	388	0	0	0	0	0	388
Rural Electrification	832	0	0	0	0	61	894
Total Demand	3701	0	0	0	0	65	3767
Unmet Requirements	0	0	0	0	0	0	0

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3. Submission of Manuscripts,

4. Manuscript’s Category,

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Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
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- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

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- Put figures and tables, appropriately numbered, in order at the end of the report
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Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
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Discussion:

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- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

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- Submit to work done by specific persons (including you) in past tense.
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Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

INDEX

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