Vol 3, Issue 1, 2016, ISSN 2001-2837- Pages 1-47

International Journal of Technoscience and Development (IJTD)

Vol 3, Issue 1, 2016, ISSN 2001-2837

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Vol 3, Issue 1, 2016, ISSN 2001-2837- Pages 1-47

Monitoring Water Quality on Lake Victoria Using MODIS Imagery

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ABSTRACT
Lake Victoria is one of the key ecosystems in East Africa. With a size of 68,800 km^2, it is the largest lake in Africa. It supports the livelihoods of more than 20 million people directly and indirectly as a source of portable water and fish, for recreation, industrial use etc. This renders the monitoring of its water quality of paramount interest. Traditionally water quality testing is carried out by in-situ measurements or taking of water samples for further testing in the laboratory. This approach has been seen to be costly, cumbersome, it is irregularly carried out and does not give a synoptic perspective of the water quality variation on Lake Victoria, especially given its size. This has motivated the need to explore the use of MODIS satellite imagery in monitoring water quality on the lake. This paper explores the use of archived MODIS satellite imagery to study Lake Surface Temperature (LST) and Chlorophyl_a (Chl_a) variation from 2003 – 2010. The results show that from the time series dataset, in general the northern region of the lake exhibits annual seasonal LST variation which can be characterized as bimodal. These seasonal peaks coincide with the occurrence of the region's rain season, which information could potentially be useful in modeling experiments. The Ocean Color (OC v5) algorithm was used to extract Chl_a from the dataset. The daily Chl_a extracts were averaged over a year and mapped. These annual images were then reclassified according to Carlton's Index for Chl_a. The results show that on average, closer to the shores the lake is largely hypertrophic whereas the lake is largely eutrophic. The lake also exhibited traces of Mesotrophic behaviour in some of the years. This has potential implications about the identification of breeding/fishing zones. These results show that the use of satellite imagery in monitoring water quality, its challenges notwithstanding, can be operationalized for the effective management of Lake Victoria.

Keywords: Chlorophyll_a, Lake Surface Temperature, Lake Victoria, MODIS, Water quality

1.0 INTRODUCTION

Lakes are a vital component of the Earth's fresh water resources, and are crucial for the survival of terrestrial life (MacCallum and Merchant, 2012; MacCallum et al, 2011). In the heartland of Africa is the main source of the River Nile – Lake Victoria, the largest fresh water lake in Africa, spanning 68,800 km^2 and supporting a rich diversity of flora, fauna and the economic livelihood of over 20 million people directly and indirectly (Cavalli et al, 2009). At 1134m above sea level, it has a maximum depth of 84m and an average depth of 40m. Its maximum length (North to South) is 337km and maximum width (East to West) 250km. Lake Victoria is a trans-boundary lake surrounded by Uganda, Kenya and Tanzania. Through the river Nile, Lake Victoria continues to sustain the livelihoods of South Sudan, Sudan and Egypt. Like many inland lakes, Lake Victoria is faced with a challenge of growing human population around it and consequently increased water demand, increasing industry, agriculture and urbanization and ultimately increased eutrophication (Stefouli and Charou, 2012; Cavalli et al, 2009). The importance of Lake Victoria vis a vis its challenges faced make it imperative to have a robust research and monitoring program to assess baseline conditions and provide necessary information to the various stakeholders involved in the management of the lake (Stefouli and Charou, 2012).

In the assessment of water quality of any aquatic system, a number of parameters are considered important. Some of these parameters include Chlorophyll_a (Chl_a) that exists in all algae groups and is also an indicator of bio production of inland water bodies (Thiemann and Kaufmann, 2000; Odermatt et al, 2010); turbidity which is caused by soil erosion and leads to a concentration of suspended particulate material (SPIM) and Dissolved Organic Matter (DOM) in freshwater that absorbs light and affects water transparency. Lake Surface Temperature (LST) is important because it gives an indication of a lake's biological and chemical activity (MacCallum and Merchant, 2012; Stefouli and Charou, 2012). Knowledge of LST can for instance give an indication of the breeding grounds or potential occurrence of different lacustrine species since they have preferred temperature ranges within which they survive. Beyond these preferred ranges their survival is compromised and may diminish their population counts. In similar measure, the rate of chemical reactions is directly proportional with temperature increase, which in turn affects biological activity. Knowledge of LST can also be used in the identification of upwelling zones, and hence enables better monitoring of lake productivity (Chavula et al, 2012). LST is also an important indicator of the lake state and a driver of regional weather and climate near large lakes (Austin and Colman, 2007). LST hence enables the modeling of the hydrological cycle and other metrological phenomena e.g. heat flux, energy balance and evaporation (Oesch et al, 2003; Schwab et al, 1992). This paper focuses on Lake Surface Temperature (LST) and Chlorophyll_a (Chl_a) as key parameters used to asses water quality on Lake Victoria.

As already mentioned, Chl_a is contained in all species of phytoplankton and can be regarded as the total amount of phytoplankton biomass (Thiemann and Kaufmann, 2000). Chl_a enables the monitoring of the mass generation of phytoplankton and is used as an indicator of eutrophication (Koponen et al., 2001). Eutrophication is the phenomenon of aquatic ecosystem enrichment due to increased nutrient loading (NOWPAP, 2007). Eutrophication degrades the water quality by accelerating organic matter growth and decomposition as well as decreasing light availability in coastal water beds. This consequently leads to increased costs of treating water for human and animal consumption, and more importantly could potentially expose users to harmful algal blooms.

Conventionally, water quality testing is carried out at sampling points on the lake. Whereas LST can be measured in-situ, to determine Chl_a, a sample has to be taken to the laboratory for further testing. Invariably this is expensive, cumbersome, time consuming and not representative of the condition of the entire lake (Stefouli and Charou, 2012; Cavalli et al, 2009). Given the size of Lake Victoria, effectively monitoring water quality is especially difficult due to the extensive travel and hence only a few points can be sampled. This consequently implies that with conventional determination of water quality it is not possible to establish spatial variation of LST and Chl_a patterns and properties (Stefouli and Charou, 2012). It is challenges such as these that have prompted the consideration of satellite remote sensing technology as a means of monitoring water quality (Chavula et al, 2012), and increasingly research is being carried out to assess its potential (e.g. Plattner et al., 2006; Becker and Daw, 2005). This is motivated by the fact that imagery derived from satellites orbiting the earth enables one to access synoptic and regular data of lakes hence potentially enabling the effective monitoring of water quality (Stefouli and Charou, 2012). This paper presents the results of exploring MODIS-derived LST and Chl_a as an alternative to conventional means of determining water quality variation on Lake Victoria.

2.0 BIO-OPTICAL MODELLING USING MODIS IMAGERY

MODIS (Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra and Aqua satellites. Terra's orbit around the Earth is timed so that it passes from North to South across the equator in the morning, while Aqua passes South to North over the equator in the afternoon. In combination, Terra and Aqua satellites are able to view the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands at moderate resolution (250 -1000m). In the process, the satellites collect data about land and ocean surface temperature, primary productivity, land surface cover, clouds, aerosols, water vapor, temperature profiles, and fires. Bio-optical modeling provides a means by which geophysical parameters (e.g. LST and Chl_a in this case) can be extracted from satellite imagery using an algorithm (Morel and Maritorena, 2001).

2.1 Extracting LST from MODIS Imagery

The LST algorithm makes use of MODIS bands 31 and 32 at 11µm and 12µm. The algorithm for computing LST from observed brightness temperatures is shown in equations 1 - 5 (Bryan, 2006):

For dBT<= 0.5

$$LST = a00 + a01*BT11 + a02*dBT*bLST + a03*dBT*\left(\frac{1}{Cos(ø)-1}\right) \quad (1)$$

For dBT>= 0.9

$$LST = a10 + a11*BT11 + a12*dBT*bLST + a13*dBT*\left(\frac{1}{Cos(n)-1}\right) \quad (2)$$

For 0.5 <dBt< 0.9

$$LST(lo) = a00 + a01*BT11 + a02*dBT*bLST+ a03*dBT*\left(\frac{1}{Cos(n)-1}\right) \quad (3)$$

$$LST(hi) = a10 + a11*BT11 + a12*dBT*bLST + a13*dBT*\left(\frac{1}{Cos(n)-1}\right) \quad (4)$$

$$LST = LST(lo) + \frac{dBT-0.5}{(0.9-0.5)\cdot(LST(hi)-LST(lo))} \quad (5)$$

Where:

BT11 = Brightness temperature at 11 µm, in deg-C (i.e. band 31)
BT12 = Brightness temperature at 12 µm, in deg-C (i.e. band 32)
dBT = BT11 - BT12
LST (lo)= Low LST when dBT>= 0.5
LST (hi) = High LST when dBT>= 0.9
bLST = Baseline LST
Cos(ø) = Cosine of sensor zenith angle

The coefficients a00, a01, a02, and a03 and a10, a11, a12, and a13 are based on match-ups between the satellite retrievals of brightness temperature and field measurements of sea surface temperature.

2.2 Extracting Chl_a from MODIS Imagery

The extraction of Chl_a from the imagery is effected by using the Ocean Colour algorithm version 5 (OC3v5) (O'reily et al. 2000). The algorithm form describes the polynomial best fit that relates the log-transformed geophysical (in this case Chl_a) variable to a log-transformed ratio of remote-sensing reflectances (of the MODIS imagery):

$$Log_{10}(Chl_a)=0.241-2.477r+1.530r^2+0.106r^3-1.108r^4 \quad (6)$$

where

$r = Log_{10} \{(R_{rs} 443>R_{rs}490)/R_{rs}555\}$

R_{rs} – electromagnetic wavelengths used for Chl_a extraction

The input radiances are in the form of either remote sensing reflectance or normalized water leaving radiance.

3.0 METHODOLOGY

MODIS data was used to monitor LST and Chl_a on Lake Victoria for the years 2003 - 2010. SeaDAS version 6.2 software was used to visualize, process and analyze MODIS Level-2 (L2) data. The MODIS L2 images were corrected for both geometric and atmospheric errors during the image pre-processing stage. LST was extracted using the National Aeronautics Space Administration (NASA's) SST algorithm (SST4). The mapped daily LST for Lake Victoria was averaged for each year. The daily LST were also used to extract two areas (Entebbe and Jinja on the northern shores of Lake Victoria) whose LST over the years was analyzed as well as their respective time series trends. On the other hand, Chl_a was extracted using the Ocean Colour (OC v5 algorithm) applied to all the daily images. In order to better assess the data, the annual Chl_a was averaged and reclassified according to Carlson's index. Carlson's index is one of the common indices used to categorize trophic levels (Trophic State Index) in fresh waters. The Carlson's index for lakes (Carlson, 1977) yields continuous values scaled between 0 and 100, based either on secchi disk transparency, Chl_a concentration or total phosphorus content (Thiemann and Kaufmann, 2000). The index enables the comparison of the trophic state of lakes where only one parameter is measured and is a good measure for the nutrient supply and change detection in eutrophic waters (Thiemann and Kaufmann, 2000).The Carlson index for Chl_a uses the algal biomass as an objective classifier of a lake's trophic status (Carlson, 1977). Table 1 shows the trophic categorization used in this paper based on Chl_a concentration.

Table 1: Trophic classification

Trophic category	Chlorophyll-a (mgm^{-3})
Oligotrophic	≤2.6
Mesotrophic	2.6 - 20
Eutrophic	20 - 56
Hypertrophic	56+

4.0 RESULTS AND DISCUSSION

4.1 Lake Surface Temperature

Figure 1 depicts the mapped annual averaged LST for Lake Victoria. The main apparent advantage of using MODIS is the synoptic view of the spatial distribution of LST in the lake. By observing the temperature scale, the lake has an average temperature of about 24°C. Whereas this archived Satellite data is available and can be revisited time and again, unfortunately the same cannot be said about the corresponding in-situ data.

Figure 2 shows the annual LST variation for Entebbe and Jinja (Extracted from the Northern shores of Lake Victoria), while Figure 3 depicts the time series LST observation for the period 2003 – 2010. From Figure 2, it is evident that the annual LST variation in Lake Victoria, as represented by Entebbe and Jinja, exhibits an annual seasonal pattern best described as bimodal. The first LST peak is between March - May the second between September – November. Generally the earlier LST peaks are higher than the second peaks. The lower annual temperatures are generally observed between June – July and December - February. These temperature patterns coincide with the rainfall season in the Northern part of Lake Victoria and may explain the influence of rainfall on the LST (Burgis and Symoens,1987). High LST during the rainy season may be explained by the fact that in the rainy season there is less evaporation from the water surface and consequently less heat loss through radiation. The link between high LST and rainfall could prove vital especially in hydrological modeling and presents an opportunity for further research. From Figure 3, the results show a minimal increasing trend in the temperature, however the data available was not sufficient to make any generalizations about this trend.

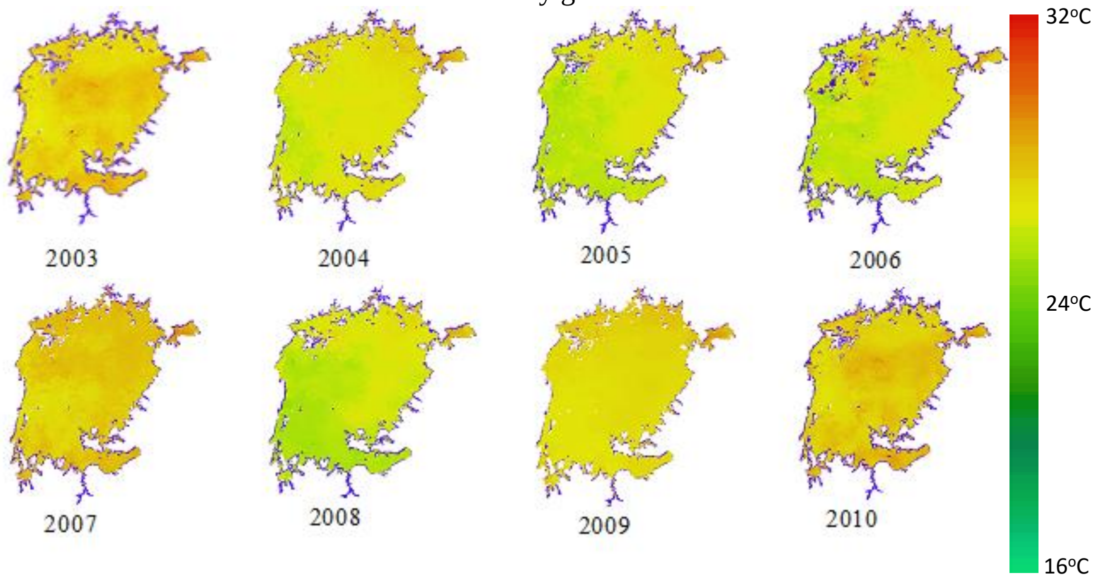

Figure 1: Annual Averaged LST maps for the period 2003 – 2010

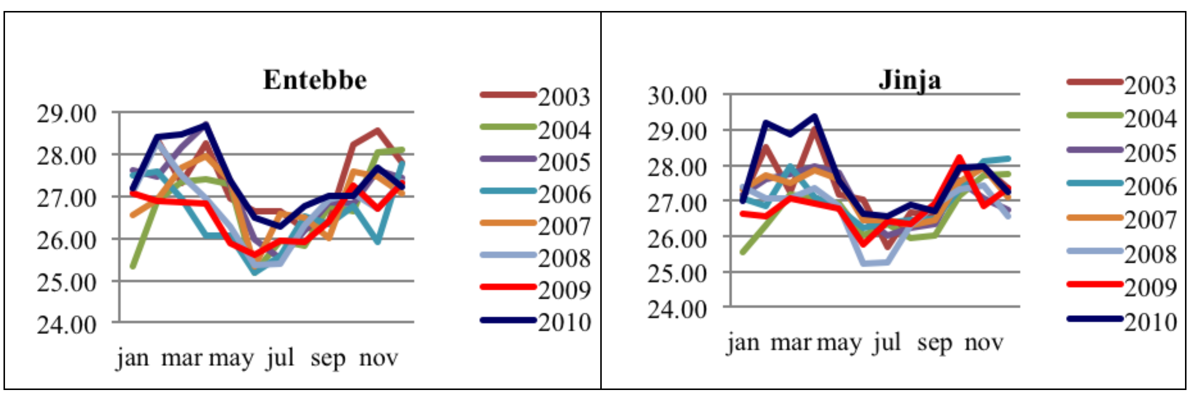

Figure 2: Variations of LSWT at Entebbe and Jinja

The next step in this research will be to collate these temperature results with other water quality parameter variations to model lake productivity, potential fishing zones etc. It is also recommended that Lake Victoria specific algorithms be derived to give more accurate results of LST. This will require collecting in-situ data simultaneous to MODIS overpasses. Being able to extract LST daily will go a long way in improving the management of Lake Victoria water resources.

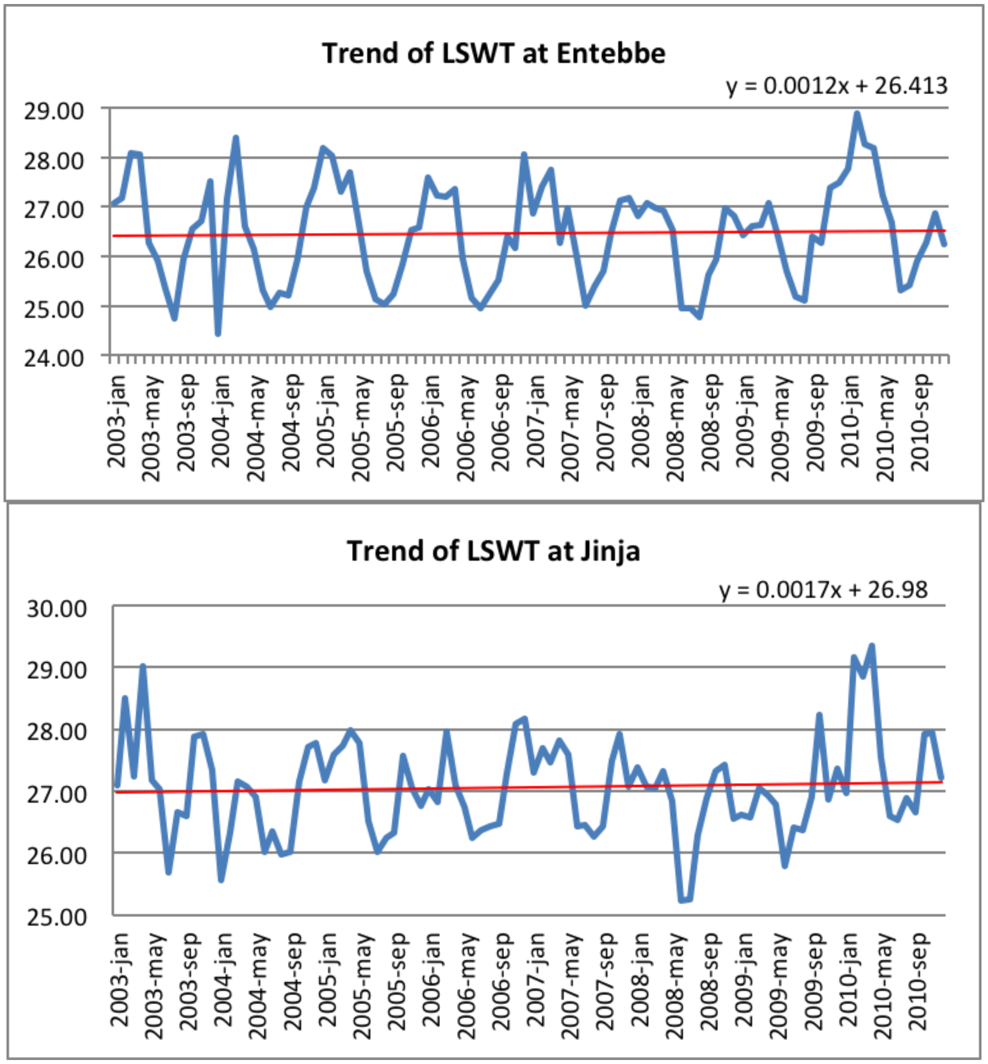

Figure 3: Trend of LST at Entebbe and Jinja

4.2 Chl_a

From Figure 4, it is obvious that one of the advantages of employing satellite imagery is the ability to derive a synoptic view of the Chl_a distribution on Lake Victoria. To be able to extract this perspective from in-situ measurements would call for heavy investment that may be beyond the means of the organizations interested in this sort of data. The other advantage of the MODIS imagery is that it has a daily temporal resolution implying that the daily synoptic perspective of Chl_a on Lake Victoria can be accessed and can go a long way in better managing the water resources.

Figure 4 depicts the annual averaged Chl_a distribution and variation over the entire lake for the period 2003 to 2010. From the scale bar, it is evident that Chl_a concentration is higher at the shores than the middle of the lake. This is because the shores are more susceptible to nutrient enrichment as compared to the rest of the lake due to surface run off and waste disposal from the various human activities taking place. However, nutrient enrichment due to surface runoff is dependent on the topography of the catchment area (Wetzel, 2001).

The annual Chl_a distributions in Figure 4 were then reclassified according to Carlton's Index and are depicted in Figure 5. Both Figure 4 and 5 show that on average the areas closer to the shores are hypertrophic while Lake Victoria is largely a eutrophic lake. Generally, the results demonstrate that the hypertrophic and eutrophic regions have been consistent throughout the study period. The figures also indicate that there are instances when the lake depicts mesotrophic characteristics (as evidenced by the yellowish color scale i.e. Chl_a varying between 2.6 – 20 mg m^{-3}). The 2009 and 2010 images also have a portion in black (in the NE part of the lake) which means that no Chl_a data for that portion was obtained, in this case due to cloud cover. These observations are attributed to the high nutrient enrichment at the shores that decrease towards the middle of the lake. The major contributors of nutrient enrichment along the shore regions are: surface run off; constant mixing of the lake especially in shallower regions and waste disposal from the various human activities that take place in the lake's catchment area (Cavalli et al, 2009). These provide favorable conditions for increased development of algae resulting in high Chl_a concentrations. Left unmitigated, there is a potential that this will lead to the development of harmful algal blooms (cynobacteria) which produce toxins that are poisonous to both humans and the fish (Tusseau-Vuillemin, 2001) as well as the birds and animals that drink from the lake.

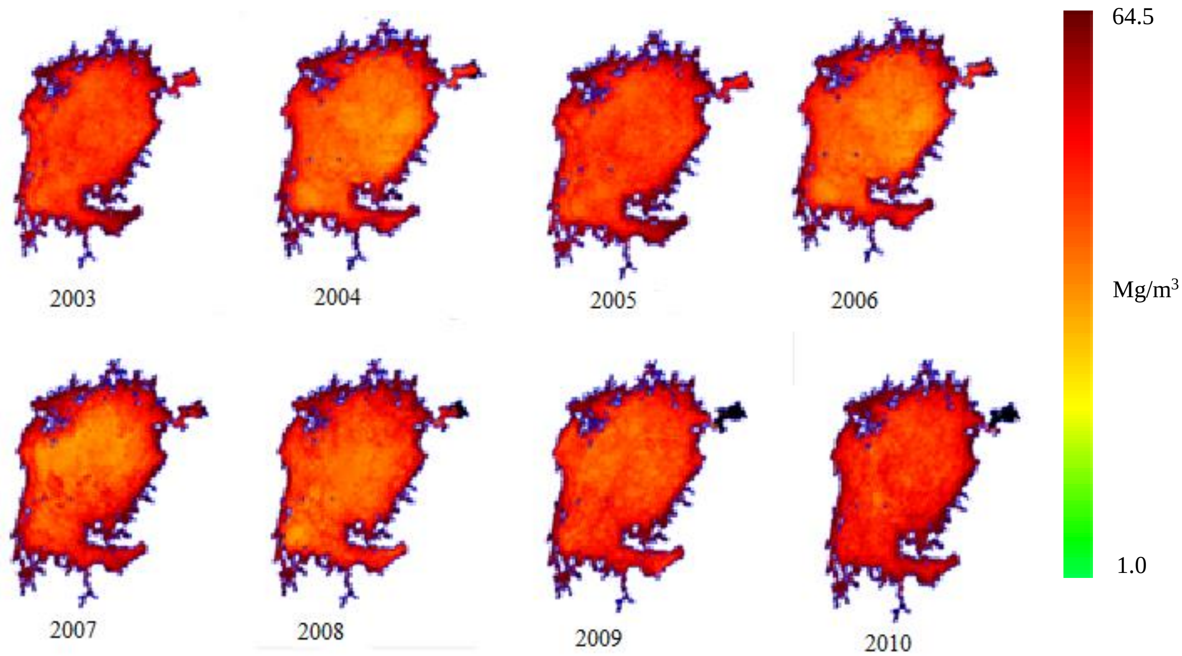

Figure 4: Annually Averaged Chl_a images

One of the main benefits of being able to map out the trophic zones as seen in Figure 5 is that the maps can be used to predict potential breeding/fishing zones for different fish species. For instance, the Nile Perch is known to prefer conditions where the Chl_a concentrations are relatively lower and have high transparency. Therefore mesotrophic zones could be potential breeding areas for such fish. On the other hand, Tilapia is known to prefer shallow waters with higher chlorophyll concentrations since they mainly feed on the phytoplankton that are mostly in the shore region due to the high nutrients. By regularly mapping out the trophic zones, these fishing zones can be identified hence potentially increasing on the revenue from fish. This information, however, would have to be considered together with other water quality parameters such as LST, Secchi depth etc.

Ideally the authors should have made comparisons between the modeled Chl_a from MODIS and in-situ measurements. Unfortunately the data available (e.g from the National Water and Sewerage Corporation) is not in a format that can be used in this research. The next phase in this research will be to carry out validation of the MODIS derived Chl_a with in-situ measurements coinciding with the satellite overpass.

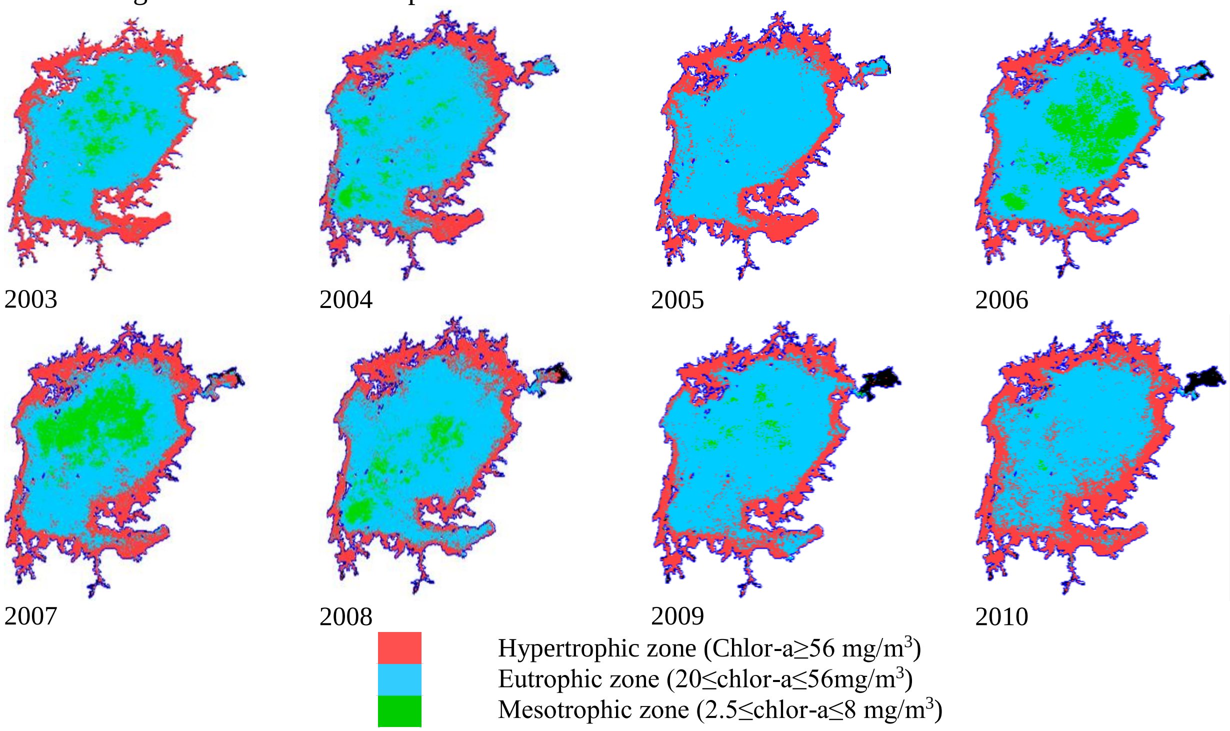

Figure 5: Annual averaged Chl_a distribution according to Carlson's Index Trophic Zones

5.0 CONCLUSIONS

From this study, it is evident that remote sensing provides a novel and efficient way of monitoring Chl_a and LST on Lake Victoria. Once validated and operationalized, it will go a long way in the management and monitoring of this very important ecosystem. Some of the potential beneficiaries will be the National Water and Sewerage Corporation, the Fisheries Sector, the National Environmental Management Authority etc. The aim is not to replace in-situ measurement of water quality on Lake Victoria, but to provide a fast, efficient and reliable means of monitoring its water quality. It is however important to observe that a number of potential challenges to the adoption of Satellite Imagery in monitoring and managing Lake Victoria are anticipated such as: cloud cover, poor access to imagery, poor internet band width to regularly acquire the imagery, shortage of expertise to process the data and the need to be able to present these results in a way that is relevant to the user community.

6.0 ACKNOWLEDGEMENTS

The authors would like to acknowledge the Europe-Africa Marine EO Network (EAMNet) through whose auspices the satellite imagery was obtained. The authors would also want to acknowledge the technical support of the National Water and Sewerage Corporation of Uganda as well as the National Fisheries Resources Research Institute for their technical support. The authors are also grateful for the reviewer process that has gone a long way in improving the publication. Special thanks is made to Prof. Gerhard Bax for his valuable critique of the original manuscript.

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Vol 3, Issue 1, 2016, ISSN 2001-2837- Pages 1-47

Simulation for control strategies of hybrid wind/ hydrogen systems for smart grid applications in Kampala and Tororo-Uganda

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ABSTRACT

The production of electrolytic hydrogen using electricity generated from a non-polluting source is one of the strategies to promote access to sustainable energy in Africa. One of such system is the wind energy conversion system (WECs). This paper presents results of a system consisting of a wind turbine of 200 kW, an Electrolyzer, and a 3.5kW peak electric load connected to an electric grid required to produce 4-5kg of hydrogen per day. The electric grid is taken as large enough to serve as a back-up supply. Mathematical equations are derived for the interconnecting components of the system and programmed in MATLAB to simulate the operation and control strategies of the system. The model has been tested using wind speeds for Kampala City and Tororo Town in Uganda. This results show that it's feasible to produce 4-5 kg of hydrogen from a non-polluting source. The smart grid monitors the hydrogen flow within storage and optimizes the flow of power from the wind generator and the electric grid to meet the hydrogen and load demand for the day. The paper demonstrates that such an integrated system has the potential to support remote investments in the production of electrolytic hydrogen from a non-polluting source for stationary and transportation activities.

Keywords: control strategies; hybrid wind/hydrogen system; Matlab simulation, smart grid.

1. Introduction

In order to secure the energy supplies in countries which are fully dependent and also net importers of fossil fuels, renewable energy sources are identified as alternatives in the reduction of greenhouse gas (GHG) emissions (Zhou & Francois 2009)**.** These GHGs are brought about by emissions from mostly utility generation plants and millions of transport vehicles, this then requires to limit greenhouse gas emissions using renewable energy (Carton & Olabi 2015). For the latter, Hydrogen gas (H_2) is regarded as a promising energy carrier from renewable energy sources (Korpås & Greiner 2008). Thus, emission free renewable energy sources such as wind energy (WE), can be used to provide the required H_2 as an alternative to the fossil fuels. Since WE is intermittent in nature due to the variability in wind speed, hydrogen cannot be produced as required on demand. Hence energy storage facilities –in this case the electric grid, can be integrated with the wind turbine to store excess of electricity generated when the hydrogen demand has been met for use in no wind or/ low cut in speed; in addition to supplying the electric load. The connection of intermittent renewable energy to the electricity networks calls for new methods of managing and operating them (Carr et al. 2012). This requires robust strategies for operating the Electrolyzer to prevent too frequent start-ups and shut-downs and, at the same time, having the Electrolyzer connected directly to the grid. In addition, this then requires implementation of efficient control strategies to regulate the flow of electricity from the wind turbine to the grid at wind power peaks when the hydrogen demand has been met and from the grid to the Electrolyzer at low wind speeds to produce hydrogen.

Many control strategy studies have been made on the production of electrolytic hydrogen. In (Korpås & Greiner 2008), (Elbaset 2011) and (Greiner et al. 2007) the results indicate clear benefits of using the grid as a backup for production of hydrogen at times of low wind speeds. (Beccali et al. 2013), provides suggestions in planning, development and sizing of wind hydrogen power systems in considerations of local and regional resources, demands constraints and opportunities for such a system. This paper considers the idea of producing hydrogen for each hour to achieve the daily hydrogen load. But since wind has stochastic tendencies that can affect both power quality and planning of power systems, then energy storage systems are required in controlling wind power output and providing the required ancillary services to the power systems(Diaz-Gonzalez et al. 2012)Control strategies are required for a scenario where a wind hydrogen system is connected onto a grid and where excess wind energy is sent to the electric load and grid. The smart grid applications of such a system involving supervisory control strategies that combine all the equipment models are investigated.

1.1 Nomenclature

$P_{wind}(t)$	Power generated by wind turbine	Vci	cut in speed of the turbine
$P_{ely}(t)$	Electrolyser power	Vco	cut-out speed of the turbine
$P_{grid}(t)$	Grid power	Vr	Rated speed
P_r	Rated power of the turbine	$\dot{m}_{h,load}$	H_2 load
Eff_{AD}	Efficiency of AC/DC converter	$\dot{m}_{h,ely}$	the flow rate of H_2 from electrolyser
C_p	efficiency of the wind turbine	$m_h(t)$	mass of stored H_2
ρ	Air density	$\dot{m}_{h,def}(t)$	amount of H_2 not supplied
SPC_c	specific power consumption	$\dot{m}_{h,fill}(t)$	the flow rate of H_2 to the storage

	of the compressor		
SPC_e	specific power consumption of the Electrolyzer	$M_{H2,max}$	Daily hydrogen storage capacity
d_{H2}	average hourly H_2 demand	A	Swept area

1.2 Methodology

This paper considers the idea of producing hydrogen for each hour to achieve the daily hydrogen load of 4-5kg. This required to set up control models for the hybrid wind hydrogen system. The researchers were able to identify major inputs and outputs of the hybrid system, identifying the various control strategies required to achieve the flow of energy from the various components. This means that the electrolyser and compressor are selected depending on the capacity to produce the required daily hydrogen load. The set up system is then simulated using Matlab software, first using hypothetical inputs of wind speeds and electrical loads and then validated using input data for the two towns in Uganda that include Kampala and Tororo to find out if it meets the required objectives. The input data for the validation area was got from RETScreen software for the wind speeds and then expounded using Weibull probability density function to obtain the 24 values using as this function is used in energy assessments since it conforms well to the observed long-term distribution of mean wind speeds for a range of sites.

2. System layout and interconnection

The system configuration is shown in Figure 1. Electrical current will flow from the wind turbine generators to the electrolyser, the load and grid at wind power peaks and from the grid to the electrolyser and the load at low wind speeds. The wind energy that is produced in excess of the electrolyser and load demand is sent to the grid. At low wind speeds or low cut in speeds the energy will flow from the grid to the electrolyser and load. The dimensioning of the grid connected system is based on a constant average hourly H_2 demand. The rationale for this is that transport and stationary activities run with fairly constant running patterns every day year around (Greiner et al. 2007)

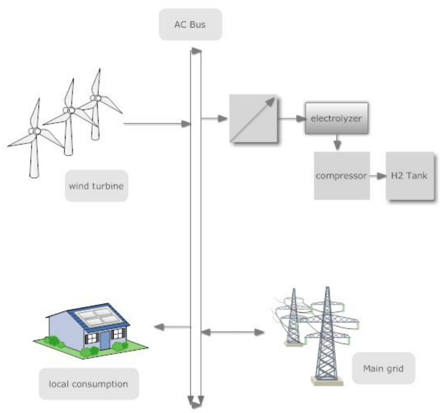

Figure 1: Layout of the system

3. System component models and specifications

3.1 The Wind Turbine model

In the wind turbine model, the average hourly wind speeds are evaluated and converted to wind turbine power. When the speed is between the cut in and rated speed of the wind turbine, the power generated by the wind turbine is given by (Nelson et al. 2006) as in equation 1. A Utility grade turbine with a size of 200kW is considered with a cut-in speed of 3.8 m/s and the cut-out speed of 25 m/s. The wind turbine will not generate useful power if the wind speed is below the cut-in speed. Mathematically, the power generated by the wind turbine is given as in equation 1.

$$P_{wind}(t) = \frac{1}{2}\rho A (Vt)^3 C_P Eff_{AD},$$
$$P_{wind}(t) = V < Vci,$$
$$P_{wind}(t) = \frac{1}{2}\rho A (Vt)^3 C_P Eff_{AD}, \quad Vci < V < Vr \quad ,$$
$$P_{wind}(t) = P_r, \quad Vr < V < Vco \quad ,$$
$$P_{wind}(t) = P_r, \quad V > Vco, \qquad (1)$$

Where P_r is the rated power, V_{ci}, V_{co} and V_r are the cut in, cut-out and rated speed of the wind turbine. Therefore the following parameters are constants; Cp = 0.59, A = 490.87 m^2, Eff_{AD}= 0.98 and ρ = 1.225 kg/m^2

3.2 The Electrolyser, Compressor and Hydrogen Storage According to (Green et al. 2011) adding hydrogen electrolyser to energy system changes the capacity mix in generation by adding the viable capacity of these stations. The model used for the electrolyser and compressor is the combined electrolyser/compressor (Korpås & Greiner 2008). The relation between the Electrolyzer power and the mass flow rate of hydrogen,$\dot{m}_{h,ely}$ (kg/h) is given by equation (2);

$$P_{ely}(t) = SPC_e \dot{m}_{h,ely}(t) \qquad (2)$$

Where SPC_e (kWh/kg) is the specific power consumption of the Electrolyzer, taking into account rectifier losses, power required for water splitting, H_2 compression and auxiliary power (Korpås & Greiner 2008). The electrolyzer operation is limited by the restriction in equation (3).

$$P_{ely}^{min} \leq P_{ely}(t) \leq P_{ely}^{max}(t)\, or\, P_{ely}(t) = 0 \quad (3)$$

Where P_{ely}^{max} is the Electrolyzer capacity or rated capacity and P_{ely}^{min} is the power consumption at minimum H_2 production. The restriction in equation. (3) States that the Electrolyser is either be operated at $P_{ely}(t) \geq P_{ely}^{min}$ or switched off. Recently, depending on electrolyser manufacturer, these units have a minimum operating point ranging from 10% to 50% of nominal power (Elbaset 2011)

The H_2 storage balance is as in equation (4).

$$m_h(t) = m_h(t-1) + (\dot{m}_{h,ely}(t) - \dot{m}_{h,fill}(t))\Delta t (4)$$

Where m_h (kg) is the mass of stored H_2 and $\dot{m}_{h,fill}$ (kg/h) is the flow rate of H_2 to the storage. The amount of H_2 that can be stored and extracted is limited by the minimum and maximum allowable storage levels as in equation (5):

$$m_{ely}^{min} \leq m_h(t) \leq m_h^{max}(t) \qquad (5)$$

If there is not enough stored H_2 to cover the storage at time step t, there will be a deficit of H_2 represented by equation (6):

$$\dot{m}_{h,def}(t) = \dot{m}_{h,load}(t) - \dot{m}_{h,fill}(t) \quad (6)$$

Where $\dot{m}_{h,load}$ is the H_2 load and $\dot{m}_{h,def}$ is the amount of H_2 not supplied at that particular hour. In this assessment the minimum amount of hydrogen per day is 4 kg and the maximum required hydrogen per day is 5 kg. Therefore, SPC_{ely} (kWh/kg) is taken as a summation of the individual power consumptions of the electrolyser and compressor. The minimum electrolyser power is found by equation (8).

$$P_{ely,min} = SPC_e x d_{H2} (7)$$

Where $P_{ely,\ min}$ (kW) is the minimum electrolyser power, SPCe (kWh/kg) is the specific power consumption of the electrolyser and dH_2 (kg/h) is the average hourly H_2 demand. The same approach for the electrolyser is used when dimensioning the compressor as in equation (9) (Greiner et al. 2007).

$$P_{C,min} = SPC_C x d_{H2} \quad (8)$$

Where $P_{c,min}$ (kW) is the minimum electrolyser power, SPCC (kWh/kg) is the specific power consumption of the electrolyser and dH_2 (kg/h) is the average hourly H_2 demand.

The maximum daily Hydrogen demand is 5.0 kg/day. Considering a 24 hour day at the site this makes an hourly demand of hydrogen of 0.208 kg/hr.

According to (Levene et al. 2006), 39.40 kwh/kg is required to produce 1 kg of H_2 at 25 ^{O}C. Therefore efficiencies of electrolysis systems can be calculated dividing the energy per kg used in the system into 39.40 kwh/kg of H_2.Thus the energy required for the electrolyser is calculated as 8.20 kW. For the compressors the specific power consumption is 2.2 kwh/kg of H_2. Thus the energy required for each of the compressor is 0.46 kW. The power converter is dimensioned to deliver the maximum amount of power required by the actual electrolyser and compressor when in 100% operation as in equation (9) (Greiner et al. 2007)

$$P_{PC,min} = \frac{P_{ELY} + P_C}{\eta_{PC}} \quad (9)$$

This implies that the maximum amount of power required can be (8.20+ 0.46) = 8.66kW, and the minimum is taken as 30% of the maximum power, or 0.2598kW, this is for the both the required maximum and minimum required mass of hydrogen per day.

3.3 The hydrogen tank

Since the amount of hydrogen being produced per hour is known, the net hydrogen generation is found by subtracting the hydrogen load from the hydrogen produced (Geer et al. 2005). The net hydrogen produced is the change in the hydrogen storage. Here storage is assumed to be lossless. The system is to be operating in constant power mode. This makes the hydrogen produced to always be equal to the hydrogen load and therefore the net hydrogen production is always zero.

4. The control strategy for the system

The operational control strategies are based on the routes of energy flow per hour within the system, the objectives of the control strategy are to;

1. Maximize the utilization of available wind energy;
2. Minimising the amount of H_2 not produced to meet the daily limit and;

3. Overcome the inconvenience of the continuous start/stop of the electrolyser by ensuring the operation of the electrolyser at its nominal power or minimum required power over long periods of time by maintaining power supply from the grid to meet the nominal requirement of the electrolyser, while maintaining the constant power to the load demand.

Objective 1 is handled by adjusting the electrolyser power in periods of high wind power output so that excess power can be sent to the load and the grid. The daily energy that reaches the load and the grid varies according to the wind speed and limited by restriction in equation (10)

$$P_{ely}^{min} \leq P_{ely}(t) \leq P_{ely}^{max}(t) \quad or\ P_{ely}(t) = 0 \quad (10)$$

Objective 2 is handled by adjusting H_2 production supply security limit m_h^{lim}, for the stored H_2 in order to maximise the amount of H_2 produced up to the required limit. However, in practice the power export may be limited by voltage quality or voltage stability (Linh 2009). Thus it varies with the power flow situation. However, the modelling framework is not limited to constant power export limit (Korpås & Greiner 2008). According *to* (Korpås 2004), it is shown howP_{ely}^{req} and P_{wg}^{lim} are determined where steady state voltage rise is the limiting factor for the quantity of wind power that can be transferred to the main grid.
The hydrogen storage capacity is minimized by the maximum hydrogen production during the day and is set by equation (11);

$$M_{H2,max} = 24\frac{P_{ely,max}}{SPC_{ely}} \quad (11)$$

It should be noted that the system operates for 24 hours in a day however it should be designed to work for 20 hours where 4 hours are used for maintenance.

Objective 3 is handled by adjusting operation of the electrolyser as follows;
1. If the excess power is greater than the power required for the load, the rest of the power is directed to the electrical grid;
2. If the hydrogen supply security is reached, all the power from the wind turbine is directed to the load and any remaining to the electric grid;
3. If the electrolyser is not covered by the wind turbine production, the power needed to cover the electrolyser demand and the load is supplied by the grid as P_{grid}.

A MATLAB program was developed to simulate the wind energy-hydrogen and grid system and to test the proposed control strategy to find out if it meets the required objectives. This program has been tested using hypothetical inputs of wind speeds and electrical loads and then validated using two towns in Uganda that include Kampala (0.3 ^{0}N , 32.6 E, elevation 1,140m) and Tororo (0.7 ^{0}N , 34.2 E, elevation 1,171m). The assessment in the hypothetical area included balancing of the energy for over 12 months in a year and the power utilisation of the integrated system components given. Simulated input wind speed data for the hypothetical area is shown in Figure 3 for the 24 hours for selected months of the year.

In order to validate the model, two selected areas in Uganda were identified these include Kampala city and Tororo Town. The reason for this selection was that both areas are grid connected and have a well-developed transport system, and in the future there are hopes that hydrogen vehicles will be used in such areas. These wind speeds were got using RETScreen software version 4.1, the average data for wind speeds for each month and other parameters for Kampala and Tororo were obtained as seen in Table 1

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Wind speed distribution for Kampala City and Tororo Town are calculated in RETScreen as a Weibull probability density function. The 24 values representing each hour of the day of the month are calculated. This distribution is used in wind energy assessments, as it conforms well to the observed long-term distribution of mean wind speeds for a range of sites. The Weibull probability density function expresses the probability p (x) to have a wind speed x during the year.

Figure 2 shows a flow chart of the control strategy:

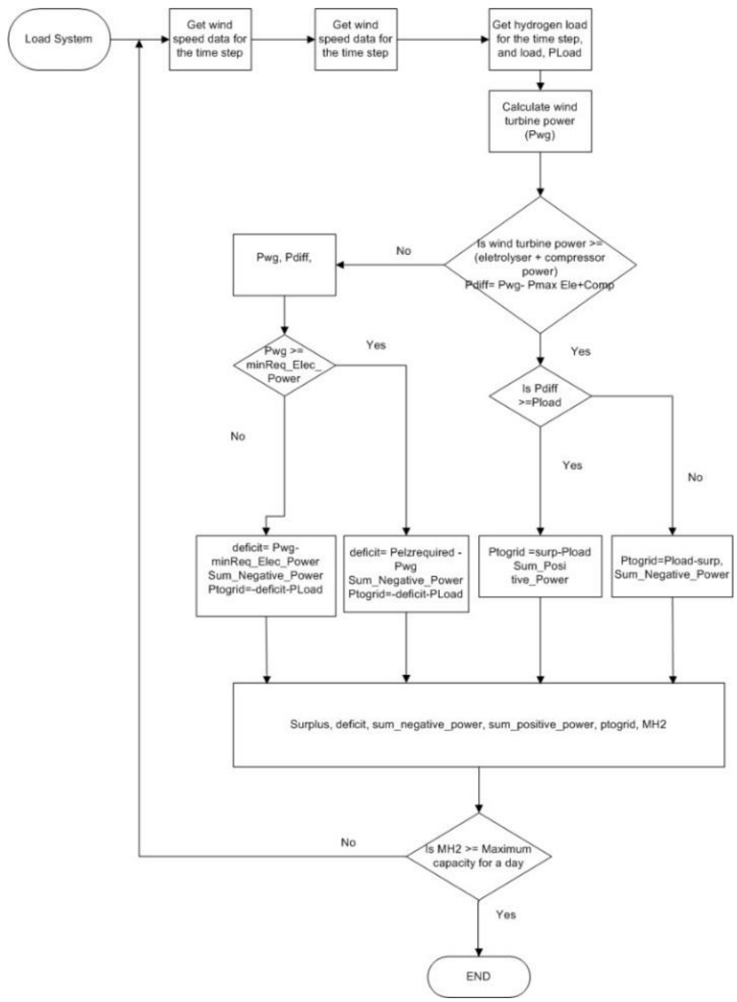

Figure 2: Summary of the operational control strategies

Table 1: wind speeds for Kampala and Tororo as seen in Retscreen.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Kampala	3.8	4.0	4.1	4.1	4.0	4.0	3.9	3.7	4.0	3.9	3.7	3.5
Tororo	3.2	3.3	3.1	3.1	3.3	3.4	3.4	3.4	3.3	3.1	3.1	3.0

Source: *NASA (Retscreen version 4.1)*

5. Simulation results and discussion

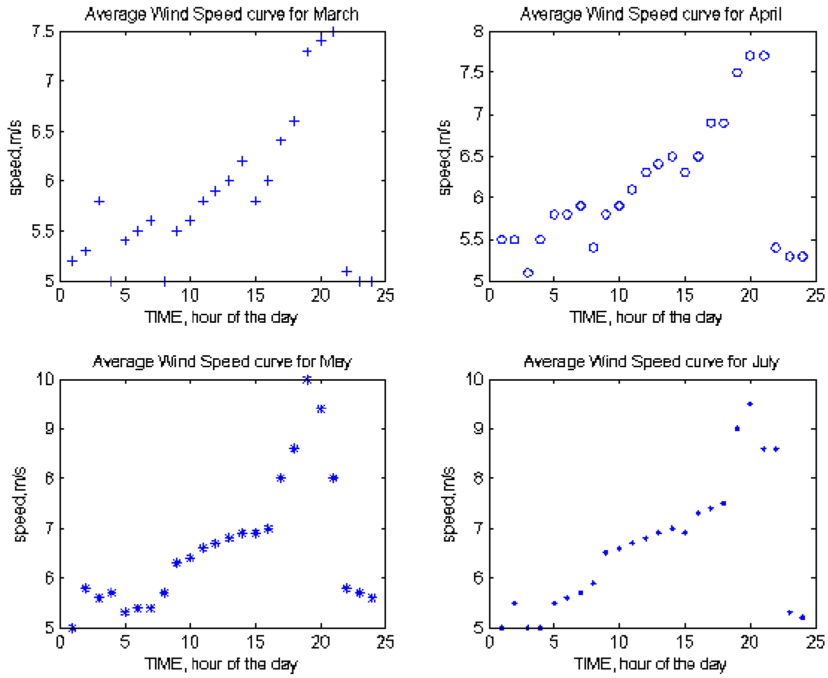

Figure 3: Hypothetical hourly wind speeds for March, April, May, July and August

The characteristics of the wind generator are that the generated power does not exceed the designed turbine power which is 200kW as can be seen in May. Table 2 shows the annual energy produced by the wind-driven generators, energy demand, electrolyser energy, amount of hydrogen production, and surplus and deficit energy for the hypothetical site and for Kampala city and Tororo Town. Negative sign means deficiency and positive is surplus.

For the hypothetical site, the total energy produced by wind generators on an average day of a month is equal 1068.59kWh. The amount of energy supplied to the electrolyser on an average day of a month is 204.81 kWh, and the average load energy required is 52.25 kWh. Therefore the average daily hydrogen load as can be seen with the various months of the year is between 4 and 5 kg. This brings a total hydrogen load of 4.92 kg, which is between 4 and 5kg as required by constraints of the study.

The wind power generated for the site is given in Figure 4.

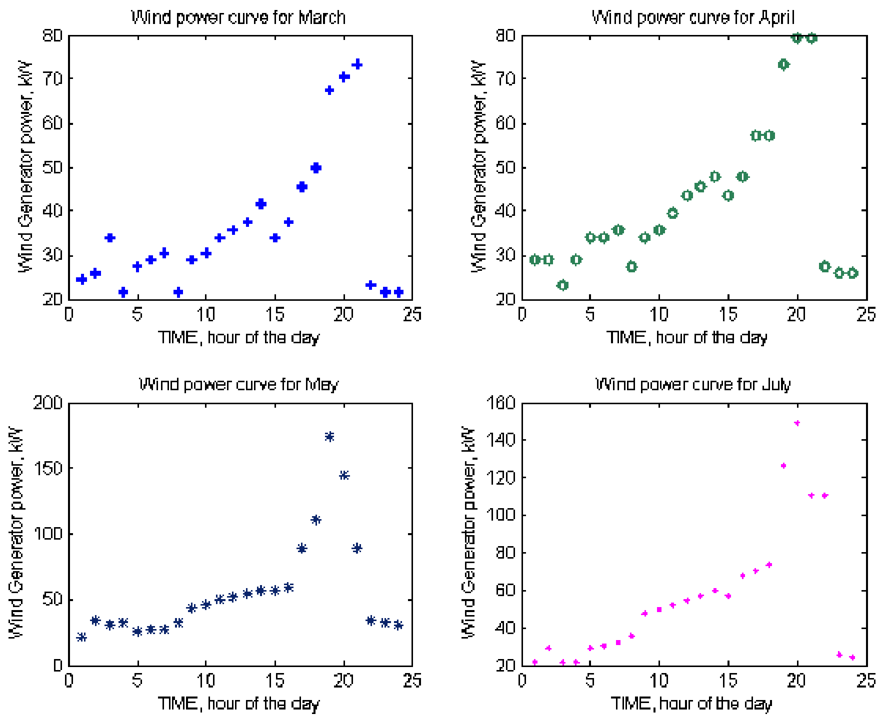

Figure 4: The wind power curve from the hypothetical wind speeds for March, April, May, July and August

The average monthly energy surplus to the electrical grid is equal to 814.27kwh and the average energy taken from the grid is equal to 2.39 kWh. This shows that the system is sustainable since the deficit is almost 0% thus production of electrolytic hydrogen with a non-polluting source is possible. Here the energy surplus is 40% and the deficit energy is 0%. This implies that energy can be sold to the grid at a time when there is surplus energy –a typical smart grid scenario.

The Figure 5 shows the wind power generated, electric load demand, and electrolysis plant load and grid power on hourly basis. There is surplus in March, July, and part of August which shows that the system is self-reliant. This indicates that electrolytic hydrogen can be got using a clean source of energy.

Table 2 shows the results for the simulation of the model using Kampala city and Tororo town data, indicating the wind energy produced, the electrolyzer energy use, the load energy use and hydrogen produced. The same figure like that in figure 5 can be generated out of that information from the Weibull distribution.

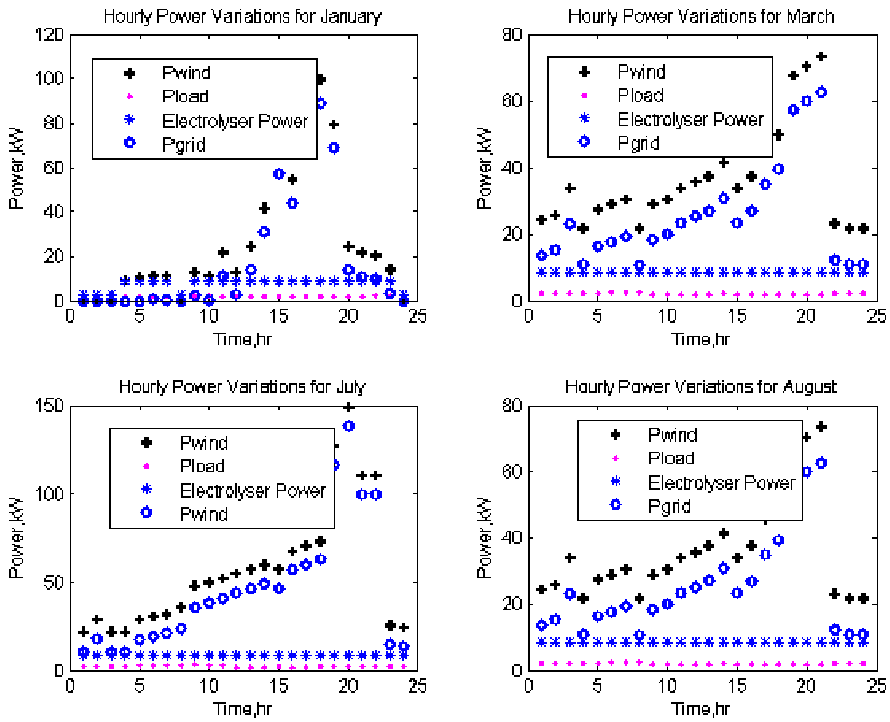

Figure 5: Hourly variations in power for January, March, July and August based on hypothetical data.

Table 2: The Energy flow for each average day of the month in a typical year for a hypothetical site

Annual Power parameters/ site	Wind Energy, kWh	Electrolyzer energy demand, kWh	Load Energy, kWh	Hydrogen Production, kg	Energy to /from Grid	
					Surplus, kWh	Deficit, kWh,
Hypothetical	12823.178	2457.708	627.030	59.031	9771.297	-28.697
Kampala	9279.73	2491.20	627.03	59.89	8126.00	-1957.25
Tororo	7702.68	2491.20	627.03	59.89	6683.29	-2094.68

6.0 Conclusion

The supervisory control strategy for a wind hydrogen system connected to an electric grid showed feasibility. The system model has been validated using wind speeds for Kampala City and Tororo Town in Uganda as in Table 1 and Kampala with surplus energy sent to the grid than Tororo is best place to have such a model operational as in Table 2. Technically, therefore, a good wind resource is a critical factor to the success of a commercial wind energy project.

The smart grid application of the model is feasible in many aspects; the model monitors and manages in real time the amount of hydrogen in storage and then coordinates with the wind generator and the electric grid to act accordingly to meet the hydrogen demand of the day. At the same time, the model can monitor the needs of the electric loads to supply power in real time at the time of use, these loads must not exceed the power exported to the grid.

The results obtained herein, confirmed that with such dimensioned components, it's possible to produce 4-5kg of hydrogen in an area with wind speeds above 4m/s measured at a height of 10 m from a non-polluting source and also that such an integrated system has the potential to support remote investments in the production of electrolytic hydrogen.

Acknowledgement

The authors would like to acknowledge the guidance of Associate Prof. Adel A. Elbaset of the Faculty of Engineering, Minia University in Minia Egypt, the Department of Energy Technology, KTH in Stockholm and the Department of Mechanical Engineering, Makerere University for the support rendered in completing this paper.

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Barriers to Implementation of Uganda's National Industrial Policy: a case study of the Iron and Steel Sector

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ABSTRACT

This research is a descriptive study of the state of implementing Uganda's National Industrial Policy (NIP) with emphasis on the Iron and Steel sector. The major aim was to assess the process and the associated challenges, to devise means for better NIP implementation.

The research involved interpretation of both qualitative and quantitative data collected from the policy makers, implementers, industries in the Iron and Steel sector, experts and associations.

The research found that the National Industrial Policy was well formulated and able to guide Uganda's industrialisation. Major challenges to NIP implementation included lack of a coherent implementation strategy and commitment to put in place infrastructure/structures to implement the NIP for example, a National Council to oversee implementation of the policy. This was evidenced by dissatisfaction by the key stakeholders in the iron and steel sector with way the policy was being implemented.

The study recommended that the government should put in place a Statutory Council to oversee the entire implementation of the NIP if it is to make the much needed impact not only in the iron and steel sector but the whole industrial sector. This way, the government would be fully commit to creating an environment that supports implementation of the policy especially providing resources, legal support and the other supportive policies.

Key words*:* *Uganda, National Industrial Policy, Implementation, Challenges, Iron and Steel*

1.0 INTRODUCTION

The importance of industrialisation as an engine of economic growth and development cannot be overstated (Wade, 2003). Industrial development is expected by African governments and policy makers to lead the transformation of low-productivity and low-growth economies into those that are dynamic and competitive.

Historical facts reveal that all developed countries of the world broke the vicious circle of underdevelopment by industrialisation and virtually all of today's industrialized nations actively supported and protected their industries through specific policies and institutions (Chang, 2002, 2005; Marti & Ssenkubuge, 2009).

Indeed, no country has made economic progress without positive stimulus from intelligent governments (Lin & Chang, 2009). Through industrialisation, developing nations aspire to achieve higher economic growth, and to eventually attain developed nation status. This explains why Industrialisation has been an integral part of African development strategies throughout the post-Independence era (Lall &Wangwe, 1998; Bolaky, 2011).

1.1 Industrial Policies

For industrialisation to be realised and its effectiveness to be felt, there is need for intervention from the state to coordinate the nation’s economic activities. A policy is the tool used as guidance for decision making by the state in the industrial interventions.
As noted by Evenett (2003), the term ‘industrial policy’ means different things to different people. Industrial policy can mean any policy that affects a subset of industries differentially from the remaining group of industries (Hart, 2001), or mean a (large) set of innovation and education, trade, sectorial and competition polices employed by governments to induce structural change and industrialisation (Cimoli, Dosi, & Stiglitz, 2009).

In this paper, “Industrial Policy” has been defined as a set of rules, regulations, principles, policies and procedures laid down by the government for regulating, developing, and controlling industrial undertakings in the country.

1.2 Performance of Industrial Policies

There are good grounds for believing that industrial policy can play an important role in promoting development and there certainly are examples where industrial policy has played this role (like in the Asian Tigers). However, for every such example there are cases where industrial policy has been a failure and may even have impeded development like the case of Ghana in the 1960s and all over Latin America from the 1940s (Robinson, 2009). The difference between success and failure cases rests in the politics of policy for each given case.

With all the importance of industrialisation and industrial policies, it remains doubtful whether the approach of industrial policy-making in developing countries has indeed been successful in transforming their economies (Lall &Wangwe, 1998; Goh, 2005). To date several studies have been conducted to analyse the failure of Africa to industrialize and also to address the question of how policies might be reshaped to boost industrial development and accelerate structural transformation in Africa (A Jakaiye & Page, 2012).

1.3 Focus of this Paper

This paper focuses on Uganda’s adopted strategies/policies for industrialisation and the degree to which their implementation has been effected citing the major challenges this process has faced.

This study was undertaken in the iron and steel sector mainly companies manufacturing construction iron and steel products mainly used for construction and the relevant government bureaucracies responsible for implementation of Uganda's National Industrial Policy. The iron and steel subsector was chosen because it is the basis for industrialization in that it provides inputs, tools and equipment for other subsectors. Therefore, developing the iron and steel subsector sets the stage for industrial take-off.

Two documents which were crucial for this study are the National Industrial Policy (NIP) of 2008 and the National Industrial Sector Strategic Plan (NISSP) of 2011. The NISSP is the guideline for implementing the NIP.

1.4 Methodology

Approach

The research was a survey type to collect information about policy making and implementation regarding the Uganda's manufacturing sector. Qualitative and descriptive data was collected and analysed.

The researchers aimed to develop a profound understanding of how policy implementation is done so as to ably formulate an explanation for the challenges impeding the NIP implementation. Contact with the respondents was based on structured interviews. In addition, literature review was carried out on recent articles and related Government policies in order to validate observations and interpretations.

Study Population

In each of the studied organizations, a department head was interviewed to get the relevant data and information. The sample and the respondents are shown in Table 1, below: There were multiple respondents from some organizations. The steel companies and some organizations did not want to be named.

Table 1: Organizations sampled and respondents

Entity	No.	No. of Respondents
Ministry of Trade, Industry and Cooperatives, Ministry of Finance, Planning and Economic Development	2	3
Government Agencies including National Planning Authority	5	10
Independent Industry-Associations (Uganda Manufacturers Association and Uganda Small Scale Industries Association)	2	2
Iron and Steel Companies	6	9
Total	**15**	**24**

2.0 CONTEXT OF UGANDA'S INDUSTRIAL POLICY

2.1 Industrial Policy Evolution

Industry has always been of great influence to Uganda's economic growth. It was the major force behind the country's robust economic growth in Uganda's first decade of independence by providing up to 17% of formal sector employment and earning close to 20% of the total export earnings (ADB, 1994).

Since the 1950s with the establishment of Uganda Development Corporation (UDC), Uganda's industrialisation has been dominated by state intervention through Import Substitution Industries (ISI). Through UDC, the government set up large industrial enterprises which thrived until in the

1970s when industry together with the entire economy went into a downward spiral due to deportation of the Asians and general maladministration. By 1979 when the Amin regime was overthrown, most of the industries including those in the iron and steel sector had failed completely.

In the 1980s, the Uganda government started a series of Structural Adjustment Programs (SAPs) to revitalize the economy recovered from the aftermath of 1970s. SAPs operated within a liberalized policy framework with no specific industrial policy prescriptions and did not subscribe to strategic thinking about industrialization and in the 1990s efforts to come up with an industrial policy began (Okuku, 2008).

2.2 Current Industrial Policy

Uganda's current industrial strategy operates within a liberalized policy framework comprised in the National Industrial Policy (NIP) passed in 2008. It is a broad generic industrial policy i.e. it contains policy-actions that target the entire industrial in form of human resource development, Public-Private-Partnership enhancement, etc. though at the same time there is some degree of priority given to the knowledge, agriculture, engineering, and raw material based industries.

The NIP acknowledges a need for formulation of supporting policies if it is to be effectively implemented. These include: - industry financing, labour management, small and medium enterprises mobilisation, subsector policies and standards regulation policies among others.

The implementation of the NIP is guided by the National Industrial Sector Strategic Plan (NISSP). Ministry of Trade, Industry and Cooperatives leads the implementation in collaboration with Uganda National Bureau of Standards; Uganda Industrial Research Institute; Management Training and Advisory Centre; and The Uganda Cleaner Production Centre. The Ministry was also to regularly interact with the private sector, the academia and relevant industrial organizations, and NGOs for the policy to be well implemented.

2.3 The Iron and Steel Sector

The surveyed companies ranked; C4, C3, C5 and C2 in order of the most competitive for the companies dealing in construction iron and steel products. The companies serve the entire region of East Africa (including Uganda, Kenya, Rwanda, Burundi, Tanzania, DRC, and South Sudan). In this research, competitiveness was defined as the degree to which companies rank a given competitor as a threat to winning the new emerging market and/or winning away their already existing market share. The operational characteristics of the surveyed companies are shown in Table 2 while the SWOT analysis is given in Table 3

Table 2: Operation Characteristics of the Surveyed Companies

Plant	Raw Material Range	Production Facilities	Installed Capacity (MTpa)	Actual production (MTpa)	Product Range
C1	• Metallic scrap • Machine-shop tools • Steel sections	• Foundry • Pattern Shop • Machine Shop	1,800	1,320	• Castings • Machine parts (20tons – 0.5g) • Any fabrication
C2	• Metallic scrap	• Furnace	1,800	1,200	• Steel bars

		• Rolling Mill			• Steel sections
C3	• Wire rods • Coils (HRC) • Billets	• Rolling Mill • Machine Shop			• Steel bars • Roofing sheets • Steel tanks • Wire products
C4	• Iron Ore • Metallic scrap • Plastic scrap and Castings	• Ore smelting plant • Rolling Mill • Foundry • Galvanizing Plant • Plastics plant	360,000	270,000	• Steel bars • Steel sections • PVC Products • Roofing sheets • Wire products
C5	• Iron ore • Metallic scrap	• Ore smelting plant • Induction Furnace • Rolling Mill	50,000	30,000	• Steel bars

Interventions by government cited by companies in relation to NIP implementation included:

(i) The ban on exportation of iron ore and/or scrap metal;
(ii) Building of Industrial Parks. This is providing more and better facilitated working space;
(iii) Sponsorship of Science Subjects. This is increasing the level of expertise required in the industry;
(iv) Stable and Secure Industrial Environment. This reduces riskiness of operating in Uganda and thereby increasing the financial credit-rating of Uganda and Foreign Direct Investment; and
(v) The efforts to increase power supply. The sector has high expectations in the Karuma and Isimba hydro-power dams whose construction is expected to be completed in 2018 and add about 850 MW to the national grid.

Some specific government involvements in the sector were regarded as negative. These included:

(i) Tax increase. Especially increasing tax on power has increased operating costs and hence affects the competitiveness of the companies.
(ii) Favouritism. Some companies insisted that the government is biased when making major decisions usually favouring the lead investors in the sector.

3.0 FINDINGS AND DISCUSSION

3.1 Policy Making

Uganda's policy making process followed a bottom-up approach (see Figure 1) and was managed by the Office of the Prime Minister where the decision to finance and implement the policies is also made

Table 3: SWOT analysis of the Ugandan Iron and Steel sector.

Strengths: ➢ Abundant resources of iron ore which of high purity (over 68%) ➢ Modern new plants and modernized old plants well regionally dispersed. ➢ Government supportive policies like the ban on exportation of sponge iron ➢ Uganda's strategic location and access to several markets in Rwanda, DRC, Burundi, Kenya, Tanzania and the [illegible]	**Weaknesses:** ➢ High cost and inconsistency of energy/power ➢ Higher duties and taxes ➢ Dependence on imports for steel manufacturing equipment and technology ➢ Slow statutory clearances for development of mines ➢ Lack of highly skilled human resource
Opportunities: ➢ Rapid urbanization ➢ Increasing demand for consumer durables ➢ Untapped and/or increasing rural demand ➢ Production high strength and technology-intensive products	**Threats:** ➢ Slow growth in infrastructure development ➢ Cheap semi-processed steel imports ➢ Ever decreasing supply of scrap metal ➢ Limited and unfavourable financing for the industry ➢ No steel sub-sector policy

Operating in a liberal economy, the iron and steel sector in Uganda currently has no industry-specific policy. Some specific strategic moves have been made in an effort to regulate the industry like the banning of iron-ore exportation, investment incentives especially to foreign investors, provision of land for expansion through the industrial parks initiative, etc. All these interventions however, occur as separate and uncoordinated interventions in the industry no wonder the challenges faced by the industry which include: poor quality and counterfeit products, lack of technical skills, high transport costs, limited financing, etc. still persist.

3.2 Nature of the Industrialisation Strategy

Though the NIP itself intended to focus on four key priority industries where it is assumed that Uganda has competitive advantage, the NISSP objectives cut across the entire industrial sector and aim to see upgrade or transformation in the entire industry-structure. Uganda's Industrial Policy, is therefore, a generic intervention. Though the NIP appears to be specific, deep analysis of the NIP document reveals that it does not give clear policy statements that are to achieve the policy goals/targets in these specific industries. It goes further to give generic policy actions applicable to the entire manufacturing sector (GoU: MTTI, 2008.).

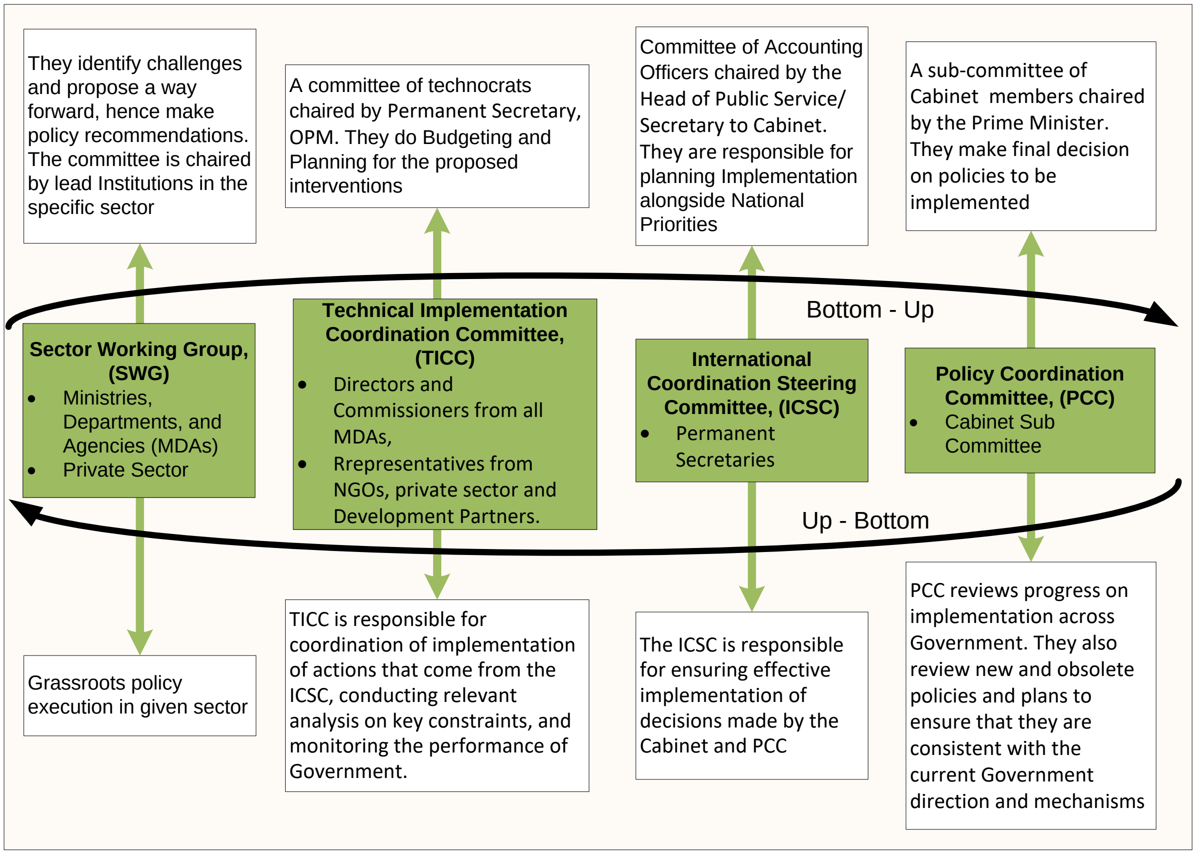

Figure 6: Interpretation of Uganda's Policy Management Framework

It can be said therefore, that, Uganda's NIP is of a functional type, a generic guide for the industry to achieve an envisioned ideal-structure after implementation. The vision of the policy is to build the industrial sector into a modern, competitive and dynamic sector fully integrated into the domestic, regional and global economies.

3.3 Implementation Progress and Impact of the NIP

Some progress has been made in implementation of the NIP but not enough to achieve the targets, which are: (Ainebyona, 2014), (World Bank, 2014).

- 25% -contribution of manufacturing to total GDP (11% in 2014)
- 30% -contribution of manufacturing to total exports (less than 10% in 2014)
- 30% -Value added in Industry (% of GDP) 922%, 2014
- 4.0 score -Competitiveness Index (3.44 in 2014)

There is, however, little progress with regard to NIP implementation for the iron and steel sector. The major problems still persist, in fact one of the surveyed companies is threatened with receivership because of consistent lack of raw materials especially coal which is imported and very expensive to buy and transport from South Africa.. Linkage to iron ore has not started.

The call for an iron and steel sector policy is a clear indication that for the NIP to impact the different industry sectors, subsector policies must be enacted and implemented.

With the current state of affairs, the NIP has had no tangible impact at least in the iron and steel sector, the case study of this research. There is also no evidence that implementing agencies are ready and equipped to kick-start the policy implementation no wonder the insignificant progress. This is further evidenced in the discovered implementation challenges which clearly indicate that the implementation of the NIP has barely commenced.

3.4 Challenges to NIP Implementation

a) Unfocussed Industrialisation Strategy

The nature of Uganda's industrialisation strategy clearly indicates that the NISSP is not tailored to realise the NIP objectives in the targeted industries of the NIP. A review of both the NIP and NISSP reveals the lack of coherency between the policy statements. Table 4 shows both the NIP and NISSP priorities.

Table 4: Comparison of the NIP and NISSP Objectives

NIP Priority Areas of Intervention	NISSP Priority Areas of Intervention
1. **Natural and domestic resource- based industries:** petroleum, cement, and fertilizer industries. (Promoting competitive industries that use local raw materials.) 2. **Agro-processing;** food processing, leather and leather products, textiles and garments, sugar, dairy products, and value addition in niche exports. 3. **Knowledge-based industries:** ICT, call centres, and pharmaceuticals that exploit knowledge in science, technology and innovation. 4. **Engineering for capital goods:** agricultural implements, construction materials, and fabrication/Jua-Kali operations.	1. Institutional Development; 2. Public-Private-Partnership Enhancement; 3. Infrastructure Development; 4. Deepening and Widening the Industrial Base and Making It Internationally Competitive, Safe and Sustainable; 5. Science, Technology and Innovation; 6. Financial Industrial Sector Transformation; and, 7. Skills and Human Resource Development.
Source: NIP, 2008	*Source: NISSP, 2010*

This is a clear indication that government's strategy/approach to industrialise Uganda may/is not well conceived by the industry. The companies cannot align their objectives to the national industrialisation strategy which is not clear and specific.
The cited challenges further indicate that the industry operates as though there is no industrial policy in place.

b) Poor NIP Implementation Infrastructures

Both the industry and the government lack the necessary capacity to adhere to the current industrialisation strategy. The companies lack the financial, technological, and human resource competence to facilitate the changes and/or upgrades recommended by the policy whereas the implementing agencies and/or government also lack capacity to perform the interventions called for in the NISSP.

The findings in line with this challenge include:

i) There is no designated body to oversee implementation of the NIP. The Industrial Council supposed to oversee implementation is not in place to fate.
ii) The limited financial empowerment and poor management of the already existing inconsistent finances by the agencies.
iii) Limited Human Resource Capability in terms of numbers and skills levels;
iv) Lack of structures for clear interaction between the industry and agencies/government to support NIP implementation. This has led to:
    - Poor strategic linkages to coordinate R&D and M&E activities between agencies/government and the industry.
    - Poor information flow and knowledge sharing between agencies/government and the industry.
    - Coordination failures in government and her agencies whereby the NIP activities are not followed up to be financed and effected according to plan.
v) Infrastructure inadequacy in terms of transport, energy, work places, etc. to support the industrial structure being advocated for;
vi) The weak legal framework that cannot enforce the NIP. Policies and laws to support the NIP are non-existent;
vii) The poor market conditions characterising the industry discourage investment at times and have also led to rent-seeking tendencies in the industry.

c) Lack of Government Commitment to Implementing the NIP/NISSP

While Uganda lacks the structures to implement the NIP, there is no commitment by government to upgrade/improve these structures probably because of the competing national priorities with a small resource envelope.

All the challenges revealed have connection to factors only the government can solve. These include:
i) The limited and inconsistent financing to the implementing agencies;
ii) The weak legal and policy framework to support the NIP implementation process.

4.0 CONCLUSION AND RECOMMENDATIONS

Uganda like most other developing countries has the NIP focussed on an ideal industrial structure associated with modernization; the structure is not only capital and skill-intensive but characteristic of a higher-income country than the country's current state. It does not take advantage of the country's competences in comparison to the global/external factors to develop dynamic industrial structures that compete well both locally and globally. This has long been found out as a challenge to developing countries' industrial policy making (Robinson, 2009; Lin & Chang 2009; Harrison & Rodriguez, 2010).

Despite the commitment to making and passing the NIP, there is little support to effect implementation yet studies show that for economic progress, positive stimulus from intelligent governments is paramount. Literature also asserts that it is the infrastructural, institutional, human resource, financial and STI capacity of a country that support the industrial transformation (Harrison & Rodriguez, 2010).

It is also known that industrial policy has been successful when those with political power who have implemented the policy have either themselves directly wished for industrialisation to succeed, or been forced to act in this way by the incentives generated by political institutions (Kosacoff& Ramos, 1999; Robinson, 2009)

The government should therefore be quick to address the policy implementation bottlenecks to avoid a collapse of the already promising industry and also guide Uganda to an industry lead economic transformation and/or development (Succar, 1987; Kosacoff & Ramos, 1999; Siggel & Ssemogerere, 2004; Lin & Chang, 2009; Harrison & Rodriguez, 2010).

The following policy interventions are recommended for implementation so as to enable the development of the iron and steel sector which will in turn spur rapid industrial transformation and economic growth:

i) Formulation and implementation of an iron and steel sector policy with an implementing agency such as a steel authority
ii) Strengthening financial institutions such as development banks so that they can extend sufficient amounts of funding since steel projects are capital intensive
iii) Reforming the tax regime so that steel manufacturers have advantage over importers of finished products.
iv) Enabling investment in mining and processing of iron ore to supply inputs to existing steel plants
v) Reviewing the energy policy and tariffs for steel projects which are large energy consumers
vi) Supporting higher education institutions to run programs in metallurgy and metal working to supply highly skilled human resources for the steel sub sector.

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Vol 3, Issue 1, 2016, ISSN 2001-2837- Pages 1-47

Human Bodies and the Forces of Nature: Technoscience Perspectives on Hydropower Dams, Safety, Human Security, Emotions and Embodied Knowledges

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ABSTRACT

Hydropower has commonly been promoted as an environmentally friendly and renewable energy resource. Despite this, the major negative social and ecological impacts on the environment and its local inhabitants have been well established for a long time, as well as the high risks for large-scale disasters caused by hydropower dam failures. Drawing on a qualitative study that focuses on the Lule River in Sweden, this article analyses the cultural politics of emotions with regard to dams, reservoirs, safety and human security.

Annually between one and two major dam failures occur around the world, with major consequences for human and non-human lives, the environment and the economy, and the issue has been addressed in policy making and within the work of power companies since the 1970's. However, more people die due to accidents on dams and reservoirs than due to dam failures. In Sweden, the number of hydropower regulation related deaths within the demographically small municipality of Jokkmokk, where a major part of Sweden's hydropower is being produced, is on average 0,02 per cent per year, or 1-2 persons, which would correspond to 180-360 deaths in the Swedish capital Stockholm. Yet, there are no calls for inquiries, investigations and measurements to ensure public safety around dams in Sweden. Linking these two aspects on hydropower dams and safety through the concept of human security we identify a void of understanding and valuing the importance of humans' – operators - lived experiences and invested emotions in the work to avoid dam failures, accidents on the reservoirs and loss of lives. We address the fact that the operators live and are related to the inhabitants of the regulated Lule River and what role this may play in enhanced human security.

We argue that technical reports and studies on dam safety are written in a way that invokes false emotions of control, safety and security for inhabitants as well as political decision makers. New technologies for camera surveillance and monitoring provide opportunities to assemble data on a dam and the water flowing through it (seepage), with the purpose to enhance safety. However, we suggest that these systems actually may produce false emotions of safety and security, reinforcing a paradigm of perceived control of nature's forces and thereby may contribute to decreased safety and human security.

Keywords: *embodiment, dam safety, human security, public safety around dams, remote control*

1. INTRODUCTION

By the end of April, a mere five years earlier, Ola Viekas life had been left in tatters. Before that, he had been so incredibly happy. As an only child he had taken over the reindeer herding from his father. He had fallen in love with the only daughter of Nilas Latte more than ten years ago. They had gotten married the year after, and had a child the next. Their second child was only two months old when the terrible accident happened on that spring day. Nilas had his summer residence east of the outflow of the Vuojat River. Ola had finished moving the reindeer to the mountains. They had decided to go by snow mobile from Ritsem to the cabin of their in-laws. The distance being around ten kilometres over the great Suorva reservoir, Nilas had been driving ahead with fuel wood and provisions. Ola had a sledge behind his snowmobile, with the mother-in-law, his young wife and their two small children. Suddenly the ice broke under the sledge, pulling the snow mobile into the hole as well. He panicked, yelling straight out. He saw how his wife and mother-in-law took a child each and fought their way to the edge of the hole. They threw the children up onto the ice, but when he crawled towards them he too fell into the freezing cold water. He tried to find the children in the snow slush without succeeding. Using his two knives he finally managed to make his way up on to solid ice. Turning around he no longer could see his two small children, his beloved wife, nor his mother-in-law. People who had witnessed the accident came to his help, taking him to the warmth of the nearest cabin in Ritsem (Svonni, 2005). [Translated from Swedish by Öhman]

The above quote originates from the novel *Trespassing Borders/Limits* [in Swedish: "Överskrida Gränser"] by Lars Wilhelm Svonni, born in 1946, author and member of the Sámi parliament in Sweden. The quote from the 2005 novel describes a fatal accident on the by the Swedish state power company hydropower regulated Lule river, at the Suorva reservoir, and the background of the formation of a fictional Sámi terrorist group performing a revenge on the Swedish state for putting them and their family at constant risk. As the story progresses, the terrorist group blows up the Suorva Dam, holding the water of the Suorva reservoir, the largest artificial reservoir in the North of Europe. The result of this fictional terrorist attack is that all villages below the dam are destroyed. Boden, a city with around 30,000 inhabitants, is completely destroyed. Despite the efforts of the group to save human lives by alerting the power company well in advance by first blowing up a couple of smaller dams to indicate a sudden increase of water, some 10,000 people die as the person in charge of the hydropower control station mistakes the sudden rising water levels for an instrumentation error (Svonni, 2005).

In Svonni's novel, the low intense and small-scale disaster – everyday fatal accidents that fail to create headlines in national media, or a state of emergency, as they are primarily experienced by small numbers of people, mainly people in the north, Sámi persons, Indigenous people, and local inhabitants –very concretely meets the high intense, large-scale disaster striking a large number of people. Apart from the unlikelihood of a Sámi terrorist group causing such disaster, both fictional events are fully realistic. In reality it is more likely that the Suorva dam fails due to mismanagement, material exhaustion, sink holes, extreme high water flows, age or the combination of these factors, as described in the dramatic novel on the same theme with the title Fallwater by Mikael Niemi (2012). In practice both the low intense and the high intense disasters are unintentional but yet caused by humans, pretending to control the forces of nature for the production of electricity.

However, so far, in Sweden as well as internationally, focus has largely been placed on so-called big disasters, i.e. the dam failures – which are commonly discussed under the concept of "dam safety" – whereas the smaller scale fatal accidents – commonly referred to as "public safety around dams and regulated water ways" – are much less prioritized. Work regarding "dam safety" started on an international level in the 1970's, after a disaster in the US. Today there is a massive body of literature based on experiences in regard to dam failures, causes and consequences, regulations and work to prevent further failures (cf Jansen 1980, Bradlow et al 2002, Bamane and Valunjkar 2014, Cloete et al. 2016). At the same time, however, there are far more people who die in public safety accidents than due to dam failures (Pritchard/Bennett 2014). In Sweden, there is currently little focus and much less investments in dealing with the issue of Public safety around dams. The work that was initiated by the state owned power company Vattenfall in 2007 and the sector organization Svensk Energi in 2008, places the major part of responsibility on individuals to avoid putting themselves in danger, i.e. to stay away from the water courses, whereas the responsibility of the dam owner is limited to warn the public to stay away from dangerous areas (Norstedt 2013; Vattenfall 2007; Svensk Energi 2008; Idenfors *et al*. 2012; Palo 2013). The watercourses and regulated rivers and lakes being used as routes and spaces for daily livelihood of local inhabitants, including for reindeer herding as an economic and cultural practice of the indigenous Sámi within the actual Sámi territory is not recognized in this view.

In Sweden, since the start of the construction of large-scale hydroelectric dams, only one person has died as a consequence of a dam failure (Sverige 2012, 75). Meanwhile, according to the local rescue services in the Jokkmokk municipality, one single area in Sweden with five thousand inhabitants, one to two persons die on the regulated river every year in fatal accidents like the one described in the quote (Lundström 2010; Nilsson 2013). As a comparison, if the same percentage of people died due to hydropower regulations in the capital municipality Stockholm, with 900 000 inhabitants (Stockholm Stad 2015), that number would amount to between 180 to 360 persons every year. It goes without saying that it would be considered a major hazard that would need to be addressed in policies and actions. In an overview report regarding drowning accidents over the last ten years, 2006-2015, the Swedish Life Saving Society (Svenska Livräddningssällskapet 2015), an NGO with focus on safety and security with regards to water, states that the northernmost counties have the highest number of deaths by drowning, in relation to the number of inhabitants. The cause for this is in the folder claimed to be the cold water in the north as a major factor. Still no alerts are made, no big headlines have ever been seen in media, and no policy changes seem to be in view. People, who do not live in these risky areas, know very little about the conditions under which their everyday portion of electricity is produced.

How can this situation be explained? First of all an important explanation is that the rules and jurisdiction for Swedish hydropower was set both before Sweden had become a democracy, as well as during the time when Sámi territories were under strict colonial tutelage where the indigenous Sámi were not allowed to speak for themselves (Össbo and Lantto 2011, Öhman 2007). As a comparison, US licenses for hydropower plants are limited to between 30 to 50 years. Thereby public safety issues may be addressed in view of a renewal of the license, which strengthens the incentive to reduce the number of accidents. Canada has a similar situation (BB, FERC 1992, CDA 2011). In Sweden, around 90 % of the existing hydropower plants are run by permissions granted under the 1918 Water Act, an act created to take the heat out of lively debates on water courses, before democracy was installed in Sweden and which is undeveloped with regards to both social and environmental protection (Jakobsson 2002, Öhman 2007, Össbo and Lantto 2011). In 2012 a state inquiry committee with the mandate to review the Environmental Code relating to the legislation of water activity was set up. In 2014 the inquiry presented a legislative proposal that all permits issued under ancient law was to undergo a new trial, which is currently under debate within the Swedish government and to be decided by the Swedish parliament (Alskog 2016, Sverige 2014).

Secondly, Swedish hydropower electricity is produced and sold under the device of being clean and environmentally friendly. Media searches and literature studies focusing on the period from the early 1990's up to 2015 done within the research projects shows that despite numerous debates on the issue of the severely negative environmental impacts of hydropower, the fatal consequences of hydropower production for local inhabitants are seldom or next to never discussed in media, although they have been pointed out by Sámi journalists and in articles in Sámi media from at least the 1950's (Utsi 1958, Spiik 1961).

There is yet another aspect to attend to, which brings the dam failures and public safety issues closely together. This is the aspect of the human bodies in the design of dams and reservoirs, in the daily management of them, within a technological paradigm and discourse, where human emotions, affections and lived experience are disregarded.

So far very little work has been made in Sweden when it comes to understanding the human bodies, commonly named the "human factor" in discussions about dam failures (Cf Norstedt *et al*. 2008). So far there is far too little work done to understand the complex aspects of human interactions with water, climate, dams and nature's forces (cf Baecher 2016). Our studies indicate that both dam operators and local inhabitants invest emotionally and practically in upholding safety to avoid dam failures. We have found that this work is built on the human relationships with the river, dams, reservoirs as well as the human social relationships. Living in the area seems to be of major importance for the understanding.

We depart from the concept of *human security* which focuses on the protection of people and individuals. As proposed by Hoogensen and Stuvøy (2006) we integrate insights from gender perspectives and thereby recognize security relationships and the multitude of actors working for the enhancement of security through a variety of different actions. Based on the findings within three trans- and supradisciplinary research projects in this article we argue that the human bodies and emotions, in their social, historical and cultural contexts of dams, safety and human security need to be analysed to a wider extent than that what is currently the case today within the civil engineering sector in general, and in the dams and hydropower sector in particular. Security concerns the maintenance and protection of that which we as humans most value, both material and immaterial, and the actors and their work to promote security is much more complex than what is today acknowledged, we argue that in regard to the political decision making sphere – legislation and control of dams by national and local authorities – there is a need for bringing in the human bodies, or more specifically the *embodiment* of *lived experience* (Merleau-Ponty 1998) as well as studying the cultural politics of emotions (Ahmed 2004) to enhance the understanding of the complex issues at stake in regard to dams, safety and the relation to human security.

2. THEORY, METHODOLOGY AND EMPIRICAL BASIS

The empirical study is qualitative and based on interviews, participatory observations and literature studies. The studies have been carried out as part of three research projects, the focus period stretching from June 2008 until December 2015. Interviews and conversations with actors within the hydropower sector; power companies as well as authorities with responsibility for rescue services and supervision of *dam safety*, as well as with persons in local communities along the Lule River in Sápmi-Sweden. Participatory observations have been made on site in combination with a reading of technical reports and documents dealing with dams and safety issues, including reports of incidents and failures, and reports of deaths on the reservoirs. Sensitive empirical data from observations and interviews have been anonymised. Furthermore we build on our own combined personal embodied experiences, three decades as students, scholars, lecturers and professionals within the science and technology sector, as well as the history of technology with a specific focus on water resources, dams and hydropower constructions. The article approaches hydropower, dams, safety and human security building with *feminist technoscience* perspectives reflecting on possible ways of understanding these issues and contributing to a change. Feminist technoscience as a research field goes beyond gender relations and sex, women and men. The focus is on epistemological and ontological issues, on human bodies and their relations with each other and with non-humans. Technologies and constructed artifacts are commonly considered as being materialised knowledge and understanding. The design of technologies, science and artifacts is seen as processes of knowledge production, where emotions and subjective embodied understandings of the world is at the fore (Latour and Woolgar 1979; Haraway 1988; Harding, 1987; Lykke and Braidotti 1996; Barad 1999; Suchman 2002, Rydhagen 2002, Elovaara 2004).

3. EMOTIONS AND EMBODIED EXPERIENCES OF HYDROPOWER

The reference to Svonni's novel serves two main purposes. First of all, within our research, we have encountered several stories similar to the one described in the novel quote (Lundström 2010; FF; GG). By referring to Svonni's novel, the horrendous events are well pictured, while avoiding exposing the tragedies that have actually happened. It is an ethical approach we opt for. Furthermore, Svonni also provides an opportunity to show the emotions of rage and the desire to be heard. The Sámi terrorist group in the novel we read as a fictional revenge on the Swedish state and what is perceived as an aggressive colonization of Sámi territory through hydropower exploitations. It is a call for action, to make a change, to remember and also to stop the deaths on the hydropower reservoirs. While the frustration and rage against the colonial and racist hydropower exploitations illustrated in the novel is for real it is unlikely that such a terrorist incident would ever be orchestrated by Sámi persons. Instead, actual experiences indicate the opposite - the presence of Sámi and other local inhabitants living around the dams and reservoirs is an important contribution to an enhanced human security (Öhman *et al*. 2010). This was the case of the Suorva dam incident – which was a near failure – in October 1983 after an extra strong spring flood. Thanks to a Sámi man, John Tomma, who had his summer residence below the dam wall, the waters seeping through were discovered at an early stage and reported to the power company Vattenfall (Nutti 2010).

The second purpose of referring to the novel is to point towards the emotional investment in these techno-scientific systems. Sara Ahmed (2004) discusses the major impacts of emotions on politics: … *emotions work to differentiate between others precisely by identifying those that can be loved, those that can be grieved, that is, by constituting some others as the legitimate objects of emotion. This differentiation is crucial in politics as it works to secure a distinction between legitimate and illegitimate lives* (Ahmed 2007, 193). What are the culture politics of emotions in regard to dams, reservoirs, safety and human security?

Most technical reports, state inquiries or rescue plans may at a first glance seem to be stripped of the existence of both emotions and human bodies, for instance reports in Sweden such as the ones from Länsstyrelsen Norrbotten 2014, Riksrevisionen 2007, Sverige 2012. But, when one is instead looking out for the lived experience, emotions in these texts, the emotions displayed in such reports and plans can be summed up as working as a type of appeasement. The way the reports are written exclude the human individuals' experiences of disaster, pain, death, and instead work as reassuring, that nothing bad has ever happened and nothing bad will ever happen. Capricious – but still totally normal – acts by nature, with extreme temperature shifts, freeze-ups, rainfalls, snowfalls, winds, flows, small tornados in combination with the demands of production of electricity from far away, in places where the understanding of the local conditions are not the same, seem to be unaccounted for. The feeling of control is instead what is conveyed through these reports. This style of writing can be interpreted in a way that may be best expressed through a sentence such as "you [the reader] are safe, we have things under control, nothing bad will happen to you", but it is a false promise of control.

4. DETACHMENT → EMBODIMENT

Within engineering sciences, i.e. within training and education of engineers, as well as with regards to the design and construction of large technical systems in general, and with regards to large-scale hydropower, important aspects of the human body is to a large extent disregarded. While the design and construction of technical systems are indeed directed at making sure that human lives are not put at danger, important aspects of the human body of the designer and the operator are to a large extent neglected. This approach comes to life for instance in the representations of hydropower on power companies websites, as well as in the actual technical designs of remote control and surveillance systems. At the forefront is the technology; the technological artefacts – the dam constructions, the power plants, the turbines, the surveillance cameras and measurement techniques (Cf. Öhman 2016a). The humans involved are all too seldom in focus. To fully understand the background of this detachment from the human body it suffices to take a look at the scientific development since the 18th century. The detachment from the human body is indeed not a new invention; it is built on a tradition of philosophy of science – rationalism – developed since the 18th century in Europe, strongly influenced by Descartes mind-body dualism. A rationalistic approach is the belief that the human mind works independently of the human body, or that there is a truth out there, that can be captured by the human intellect. While it seems as this body-mind dualism has prevailed to a large extent within engineering sciences, it was actually challenged already in 1748 by Julien Offray de la Mettrie in his work *L'homme Machine – Man a Machine*:

The human body is a machine which winds up its own springs: it is the living image of perpetual motion. [---] Without proper food, the soul languishes, raves, and dies with faintness. It is like a taper, which revives in the moment it is going to be extinguished. Give but good nourishment to the body, pour into its tubes vigorous juices and strong liquors; then the soul, generous as these, arms itself with courage; and a soldier, whom water would have made run away, becoming undaunted, meets death with alacrity amidst the rattle of drums. (La Mettrie, 1750, p.11)

The rejection of the mind-body dualism has been revived in the 20th century, and brought to life within the concept of embodiment. Embodiment is the process in which our body experiences the surrounding world and this experience becomes a subjective knowledge. For instance Merleau-Ponty formulates it as it is through the body that we have access to the world, actions and perceptions are intertwined. Thereby the process of embodiment is formed by habits and learning (Merleau-Ponty 1998). We integrate our own lived experiences, through our own bodies, to our knowledge and thereafter into our actions. Engineering and scientific practices are indeed dependent on the embodiment of experiences (Harding 1987, Haraway 1988; Barad 1999,).

5. SAFETY VERSUS DEATH AND DESTRUCTION

Language is closely linked to our bodies, it is through language that we appropriate knowledge and understanding and it is through language that we communicate our understanding (cf. Fanon, 1952). Thereby looking closer at the language and concepts, used by actors within the large-scale hydropower sector provides an idea what it is all about. For instance, the use of the terminology of "dam *safety*" – brings about an idea of feeling safe and secure. The concept of dam *safety* focuses on engineers and operators making the rivers safe, and thereby the idea that the rivers and bodies of waters – nature – can be controlled by human beings. A next step in this logic is that when the waters are no longer controlled, this is a failure, or accident. Dams that break down, inundation, flooding, and other forms of disasters are not normal, they are abnormal. The paradox here is that failures are indeed normality. On a global level, there are 1-2 major dam failures per year, and several smaller dams overtop, break or end up needing water to be released to avoid dam failure – and thereby inundation occurs (BB; ICOLD undated; Öhman 2016a). Furthermore, engineers designing dams and dam management techniques are often fully aware of the disasters that may occur if their design is erroneous. Operators managing the dams are in many cases also as conscious about the importance of their work (BB).

Death and destruction are thus a constant part of the experiences when it comes to large-scale

Figure 1: Inside one of the hydropower stations on the Lule River. Photo:M-B Öhmans

hydropower reservoirs and power plants. At any construction of a hydropower plant and reservoir, people have died at accidents. At many construction sites there are memorial stones or boards over the ones who have died during the construction of this or that power plant or reservoir (DD). Furthermore, as in most large scale industrial ventures, the everyday operation of the hydropower plant and reservoirs, death and destruction is a part of the picture as both incidents and actual fatal accidents occur on an everyday basis. Operators or machinists working inside of the power plants work below the surface of water. If a system fails, or someone makes a mistake, their lives are at risk. They are also at risk for other types of accidents. For instance, if a fire breaks out, the escape route through long tunnels or climbing long vertical ladders are on average both very long and dangerous (DD). Such accidents and incidents happen around the world all the time and reports from them are today immediately circulated around within the hydropower sector companies (BB).

Moreover, as the initial quote of the paper makes visible, the daily operation of the dams may cause death for the people living around the dams. Depending on the climate where the reservoir is placed, the dangers are different. In the cold northern hemisphere, the ice covered rivers and lakes function as roads for the inhabitants during the winters. However, because of the regulations, the ice becomes both fragile and treacherous. In summer the large bodies of water becomes dangerous to cross in small boats as the wind can speed up suddenly. In the fall the mountain weather is very hard to predict with sudden storms occurring (GG, Öhman 2010).

In short, death and destruction, as part of the lived – embodied – experience of the hydropower engineers and operators form a constant part of the picture. The problem is how this is dealt with, and by whom it is dealt with. A question to discuss is what this embodied experience does to the engineers, operators and machinists involved in hydropower and reservoirs? How does it produce knowledge and relate to actions taken to prevent failures? How are the emotions related to incidents and accidents dealt with on different levels – individual, organizational and political levels? Interviews and discussions within our study all indicate that to a large extent this lived experience and emotions are neglected, on a formal level although dealt with through verbal knowledge sharing between the operators.

Incidents and accidents that happen are left to the individuals to be dealt with on their own. For instance, at one accidental submerging of a hydropower plant where several operators were at risk of dying, the aftermath seems to have been dealt with mainly by the operators on their own (EE). When asking questions about - whether there is access to psychological support for dealing with such traumas, the informants answered that this help is available, but one has to ask for it, and that this is something that no one seems to be inclined to do:" I think there is someone we can talk to, I don't know who it is. But one takes care of one's own feelings by talking to colleagues" (EE). With regards to people dying or being injured on the reservoirs, this is left completely outside of the concept of "dam safety", and thereby not dealt with at all within the power company. Still the operators will have to live the rest of their lives with the trauma of possibly causing someone's death. To analyse how this comes about, the *hegemonic notion of control* is of interest.

6. EMOTIONS AND THE HEGEMONIC NOTION OF CONTROL

Using the concept "safety" brings in a false understanding that it is possible to control the forces of nature, to make oneself and others safe. This idea of control is part of a hegemonic notion of control over nature and detachment from certain emotions. It is about control over nature's forces, as well as the control over oneself, over one's own feelings. Based on our professional experiences, participatory observations, interviews and studies of technical reports from dam failures and incidents, we suggest that within the current engineering training in general, as well as within the specific instructions to dam operators, the actual human bodies are considered at the same time to be both uninteresting and easily replaceable.

With modern remote control technologies, control over the river can more or less be performed from anywhere, and sometimes it is argued that it is better done from far away (FF; HH). We see that what comes to the fore in reading technical reports and instructions, as well as when taking closer look at the remote control settings of the rivers we have studied, human bodies are frequently considered to be very easy to replace with machines and "new technology" – i.e. the installment of remote control devices as well as remote supervision through cameras and other means of surveillance (Cf Norstedt *et al* 2008).One important reality of this remote control technology is that power production is increased and decreased according to the demand of electricity, which impacts directly on the water levels. As the Lule River is used both for power production for the power company Vattenfall as wellas for stabilizing the Swedish national grid, water levels of the reservoirs may rapidly increase and decrease, as requested from Stockholm where the national grid balance is kept and the main control room for power production within the power company is located. On smaller reservoirs the levels may change within a few hours, on the larger it is a matter of several hours, but the difference is of importance for the local inhabitants' safety. The control of the reservoirs, the release of the water, is made from one specific control station which is located by the Lule River, but still far from – up to 240 kilometres at the most – the dams and reservoirs. The water regulation creates dangers for the local inhabitants, including reindeer herders. In winter time the regulations, in combination with temperature, cause dangerous holes in the ice, or causes existing holes to open up more and cause fatal accidents as described in the Svonni novel quote (FF, GG, Öhman 2008-2015). At other locations, where there are dry beds due to regulation, water may be released onto persons who are in the dry beds for any reasons. As there is no warning signals before water is released in the Lule River, such incidents occur. At one occasion water was released as a reindeer herder was passing with his reindeer (Öhman 2008-2015). Similar accidents with fatal outcomes have happened on amongst other the Ume River (ICOLD/Norstedt 2012).

We have also found that the interpretation of the information collected through these technological devices seems to be a complex issue which may not be given enough consideration. For instance, in 2012 cameras were installed at the control station for the Lule River to supervise the dams. The cameras were installed to be used to see if break-ins or damage are made to the since long unmanned dams and power plants (HH, Öhman 2008- 2015, 2012). However, at the control station, the operators found another usage to be of higher priority, namely as a back-up control of water levels, in case of a report from a station that the water level is not what it is supposed to be. Furthermore, the camera at one specific dam at one occasion showed in real time teenage boys climbing on a dam wall, putting themselves at high risk. This could be seen by the operator, who had no possibility to do anything but to watch them, and then decide if he should call out an emergency. It was a stressful moment for the operator, who saw this dangerous situation, but whose work was not to supervise the dams for such situations. (Öhman 2008-2015, 2012).

[Figure 2. Reindeer migration on the Lule river, Stora Lulevatten, Stuor Julevu. Photo: Fia Kaddik]

We have thus found a void of discussion and analysis with regards to who is supposed to interpret the information channelled, and what the responses to the information provided is supposed to be at any given moment. Furthermore, our findings suggest that at the same time, the human being, the operator, is supposed to always be functioning, and not being touched by emotions or affections in a way that may cause errors. He or she is not supposed to be thinking about facing death, or possibly causing death and destruction to themselves and others by failing in the daily operations of the plant and reservoir. Or at least, that these emotions are not considered important to the everyday control of the river, it is not dealt with the control station other than in informal discussions between the operators (FF; Öhman 2008-2015; Öhman *et al*.

2010).

Yet, during nights and weekends the operators are commonly alone, and there is no one else to discuss with at moments of stress. There is no specific guidance from the power company dealing with these issues of life and death and the emotions of the operators, despite the fact that they are in charge of a major force, the water that may kill other humans if the dams and power plants are mismanaged. One other important aspect which calls for further attention is that the emotional work and relationships by the operators on their own may be the reason for there not having been any major dam failure disaster yet, and that accidents and deaths and the reservoirs are not even more frequent than what is currently the case. Our studies indicate that the operators, who in this study live by the regulated river themselves and thus have friends and family in the river valley, do their best to ensure the safety and wellbeing for other humans (FF; Öhman 2008-2015). We suggest that it is important to take this physical closeness to the river, to take this lived and shared experience taken into account. It is possible that the number of deaths on the reservoirs could be higher if the operators were not part of this local context themselves. It is also possible that the number of incidents leading to failure would have been higher, and that the fact that no major dam failure has happened yet, despite numerous severe incidents (amongst other the Suorva 1983 leakage for instance), can be attributed to the operators relationships with the river valley and all its inhabitants.

7. COUNTING BODIES – WHOSE BODY COUNTS?

Yet another aspect of importance is the counting of human bodies, along with the determination of which human bodies actually count as being important. This relates back to the discussion of emotions, and how the distinction is made between what lives are legitimate to care about (Ahmed 2004). For instance, the prospect of human lives lost in case of a major accident can be discussed in relation to the actual number of human lives lost around large dams on an every year basis. Who are these bodies, what emotions are they carriers of, and which bodies do count, whose emotions count as important and serve as a basis for change in policies, to perform actions in order to enhance human security? A closer look on hydropower in Sweden, in Sámi territory, may provide a better understanding. Are local inhabitants in the north, and Sámi, human bodies counted as important? Is it about the number, only 1-2 per year, dying? Would policies look different if the same percentage of accidents happened in Stockholm?

Today there is no legal definition of the concept of “dam safety” within Swedish jurisdiction (Sverige 2012, 73). The proposal by the national authority, Svenska Kraftnät, in charge of counseling power companies, and other authorities promoting the work with this issue defines it as: “prevention of dam failure, erroneous operation of the power plants and other events that may result in uncontrolled and fast flow of dammed waters, as well as the “preparedness for dam failure” (SVK 2010). The national inquiry of 2012 on dam safety suggests the same definition (Sverige 2012, 73). While the accident in the initial quote from Svonni’s novel is indeed related to the running of a dam – the ice becoming fragile and treacherous because of changing water levels – with the purpose to produce electricity, the issue of “public safety around dams” are still not part of Swedish jurisdiction. Furthermore it is completely left out of the picture in the dominant discourse within Swedish production of electricity. Accidents that happen on the reservoir are not categorized specifically as dam safety problems. It was left outside of the mandate of the Swedish national inquiry on dam safety in 2012 (Sverige 2012, 59). In guidelines for public safety around dams created by the State power company Vattenfall (2007), and by the association for companies in the hydropower sector, Svensk Energi (2008), as well as in conversations with representatives of power companies (BB) the major responsibility for staying safe is placed on the individuals themselves, to keep away from dangerous sites. This view turns an accident as the one in the Svonni quote into as drowning accidents, thus excluded from the statistics of deaths caused by hydropower regulations and the ones being injured or killed are depicted as not supposed to be there in the first place, or else it is their own fault that they are killed or injured.

There is so far no statistics available in Sweden that indicates whether a drowning is related to a regulated river or not. It is thereby very difficult to find out to if the death was in some way caused by hydropower regulation, or not (Idenfors 2013; Nilsson 2013). Our understanding is that these deaths and the grief which ultimately is caused by the production of electricity are generally not really considered a problem that needs to be dealt with. Yet, the reason for the ice to break under the sledge in Svonni's novel, is as most local people, most of them Sámi, around the Suorva dam are painfully aware of, the continuous regulation of the water levels, for the production of electricity – electricity that will for the most part be used far away, providing great economic benefits for other people living in another part of the country, far away from the dangers (GG). This calls for an analysis of the colonial Swedish state, and its relationships with the Sámi, and the colonised or conquered territory of Sápmi (cf Öhman 2007; Össbo and Lantto 2011). Sweden relies heavily on hydropower for the production electricity within the country. The number of dams (the majority being hydropower dams) in Sweden amounts to around 10,000. Out of these 78 are of the highest so called "consequence class 1A" – within the Swedish classification system – meaning that a dam failure would with high probability lead to the loss of human lives, at least 20 lives, and severe damage on societal infrastructure, loss of environmental values and economic values (SVK 2010, Sverige 2012). Out of these 78 class 1A dams, 51 are located within Sápmi, the land of the indigenous Sámi, and also reindeer grazing and migration lands.

As the large scale hydropower exploitation set off in Sweden in the 20th century, Sámi reindeer herding communities were severely affected as was Sámi who were not reindeer herders. For both groups, the fishery was severely disturbed and the everyday life close to the waterscapes became more dangerous and unpredictable because of the water regulations. Reindeer herding communities lost grazing land, as well as land and waterways for the annual migration of the mountain reindeer. Interviews with the affected communities point at several injustices that have taken place (FF; Öhman 2008-2015), despite Sweden boasting an international reputation as one of the top representatives in terms of democracy and human rights. To this day, land rights are being debated and for instance the Swedish government has avoided ratifying the ILO convention 169 that gives indigenous people extensive land rights.

As the hydropower exploitation is extensive within Sápmi – there are numerous Sámi, reindeer herders as well as Sámi and others who are not reindeer herders but who live in the area – many Sámi and other local inhabitants are affected on a daily basis. In interviews, carried out between 2004 and 2015, testimony is provided about how dangerous the life has become for the local inhabitants around the dams, with fatal accidents occurring every now and then that can be directly linked to the regulation of waters, as well as incidents that has not cost human lives, but this only because of sheer luck (GG; Öhman 2006; 2008-2015). For instance one fatal accident occurred in May 2008, when two Sámi men – 50 and 37 years old – on a snow mobile went into a hole in the ice created by the waters coming out from a hydropower station just outside of their own residence by the Suorva dam (Öhman 2008-2015, 2008).

While the hole in the ice is there the whole time during winter time, the extent of it is hard to judge for anyone. As more water is released, the size of the hole may change rapidly. Furthermore the unpredictable changes of temperature in May, which is due to the climate this time of the year in this region, form an important factor in the changes of ice stability, something that is hard for the local inhabitants to predict and handle. In any case, the crossing over the ice is not something they can avoid, this is their home and working area. When they move between neighbours and friends, the ice has to be crossed. The state power company provides support for a supervised ice road, but only up to May 1st , or when the ice is strong enough. After that, the local inhabitants – residents – are left on their own to assess the risks. Also, for reindeer herding, this is the time of the year when reindeer herders have to move over the ice with their herds. This causes constant stress and anxiety, along with the grief over the lost family members and friends in earlier accidents (GG, Öhman 2006, 2008-2015).

Another important feature is the cold temperatures in this region. A person who falls into the water of an ice-covered reservoir does not necessarily have to drown to die. Once in the water, depending on the physical condition of the person and the surrounding temperature, it takes approximately between 5-15 minutes before the person is numb from cold and it becomes impossible to move or do anything to help oneself. And, even if the person manages to get out of the water within that time limit, it suffices to get wet, without getting adequate help, being taken into the warmth; the person is likely to die because of the cold. Therefore, an important feature is the possibility or difficulty of getting assistance in time. Assisting someone who has fallen into the water on such a big reservoir as Suorva is difficult, and the best and fastest help provided by helicopter assistance. However, when someone falls into the cold waters of the Suorva reservoir, the nearest rescue helicopter (ambulance helicopter) is located in Gällivare – 155 kilometers flying distance (Lundström 2010; GG).

8. DISCUSSION

Through emotions, the past persists on the surface of bodies. Emotions show us how histories stay alive, even when they are not consciously remembered; how histories of colonialism, slavery, and violence shape lives and worlds in the present. The time of emotion is not always about the past, and how it sticks. Emotions also open up futures, in the ways they involve different orientations to others.(Ahmed 2004, 202)

Within the dominant hydropower discourse in Sweden there is a strong focus on the technology, the artifacts, to find technologies to prevent and manage accidents and incidents, while the human bodies, the people who work on ensuring that dams are safe, are willfully being neglected. Furthermore, in Sweden the issue of public safety around dams is constantly cut out, and in practice neglected in terms of investment of time and means. The safety of humans, the human security is not in focus. In this paper, we bring forward the concept of human security, as a point of departure, while discussing the politics of emotion in regard to hydropower. In this way we can focus on what hydropower and dams do to human and their feelings of security, as well as the actual fatal accidents. Recent developments in regard to licenses for hydropower in Sweden may open up for a change, and in view of this possibility for change we argue for a broader take on the issues, to go beyond the common way of describing and dealing with safety and security in regard to dams.

We argue that the human bodies, the lived – embodied – experience, emotions and affections, with regards to human security as a whole collectively constitutes an understanding of what makes dams safe and less safe, as well as with regards to the public safety around dams. We suggest that these aspects need to be connected and addressed with major investment in terms of time and funds, and that this is a responsibility to assume by the Swedish state, power companies and authorities at all levels. We thus argue for a broadening of the discourse of dam safety, to deal with the emotions of the human bodies involved with the design and management of the dams, living by and below the dams and reservoirs, within their societal and historical contexts, and to analyse the colonial context under which hydropower exploitation was made, in view of reducing the risks of fatal accidents and both large-scale and small-scale disasters. One particular such lived – embodied – experience which should be further analysed is the everyday experience of death and destruction; the experiences of death caused by hydropower, facing death, being at risk of dying, being the operator of a dam that causes fatal accidents for local inhabitants, as well as possibly being the cause of the death of other people including the destruction of societal and environmental values on a grand level. We argue that both fiction as well as first person narratives may serve this purpose and that the training of engineers, operators and all others in this sector should open up to broader understandings of these perspectives. The relationships between the Swedish state, power production and the indigenous Sámi need to be discussed, taking into account the aforementioned colonial context. The objective then is, as in any scientific investigation of techniques related to the management of large dams, to widen the perspectives on dam safety/public safety, ultimately to prevent accidents and that when such accidents do happen, manage them in ways that reduce the negative consequences for those struck by the disaster.

ACKNOWLEDGEMENTS

We wish to thank all contributors to this article. The first version of this article was submitted and presented as a conference paper and is also published as conference proceedings: Öhman and Thunqvist, 2012, Human Bodies and the Forces of Nature: Regulated Rivers, Safety and Embodied Knowledge, *ICOLD, International symposium*, Kyoto, June 2012. Thanks to ICOLD blind peer reviewers as well as participants at ICOLD Kyoto for comments, in particular Tony Bennett, Maria Bartsch, Urban Norstedt, Lars Hammar and Joakim Evertson. The article has been further developed thereafter and therefore a change in the title has been made. Thanks to the IJTD peer reviewers and also to associate professor Birgitta Rydhagen for useful comments on an earlier version. Thanks to Åsa Össbo for comments on one of the very last versions, to the editor Lydia Mazzi Kayondo-Ndandiko, Johan Sandberg McGuinne for proof-reading the article, and to Fia Kaddik for the photo of reindeer migration on Stora Lulevatten, Lule River. The research was funded by the research projects *Situated perspectives on hydropower exploitation in Sápmi: Swedish technological expansion in the 20th century and its impacts on indigenous peoples* (Swedish Research Council, VR, 2009-2010); *DAMMED: Security, Risk and Resilience around the Dams in Sub Arctica* (Swedish Research Council, VR, 2010-12) and *Rivers, resistance, resilience: sustainable futures in Sápmi and other indigenous peoples' territories* (FORMAS, 2012-15) All research projects were led by Dr. May-Britt Öhman, who is also the main author of this article.

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