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"Hydroelectric Energy for 20 Isolated Rural Villages in Ludewa District"
A Study of LV Lines and New Extensions in a Remote Area of Tanzania

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A Mamma Paola e Papà Enrico,
per il sostegno continuo che mi avete sempre dato
e per il bene che vi voglio!
Grazie

ABSTRACT

Tanzania is a newly developing country which in contrast with many other African countries is fortunately blessed with social peace, a necessary premise for a sustainable development.
Tanzania is considered one of the poorest countries in the world. This is more visible particularly in rural areas where a majority of the people don’t have access to electricity or clean drinkable water.
Access to electricity and drinkable water will have many positive effects: not only will it lead to the economic growth of the country but it can also accelerate the development of rural areas.
The project “Hydroelectric Energy for 20 Isolated Rural Villages in Ludewa District”, introduced by the Non-Governmental Organisation ACRA, was established and continues to evolve in one of the poorest rural areas in Tanzania.
The goal of the project is to guarantee a sustainable access to electrical energy for 20 villages in the Ludewa District, Njombe Region. The plant responsible for energy production is a small hydroelectric power plant with a power of 1.7 MW and is able to give electricity to more than 53,000 people.
The internship has been carried out within this project, aiming to study the power line, particularly the low-voltage line, both theoretically and practically.
The activities involved were:

- Field study of low and high voltage poles using GPS;
- Mapping of the power line using QGIS, checking the correct position of the poles and carrying out possible changes to the line where particular problems were detected;
- Comparison with existing maps;
- Checking the correct extension of cables and that the changes made would be implemented;
- Proposal for new extensions of the line creating the possibility to reach new connections, besides taking the account of the necessary materials and their cost;
- The calculation of potential differences for the existing power line and the new extensions in order to find out if more transformers were needed, calculate the number of milling machines that can be installed and their distances;

- In general, following the guidelines provided by the Site Manager, monitoring of the construction site works, checking the incoming materials and solving practical problems.

The period of stay included the end of the dry season and part of the rainy season, that is from the beginning of October 2016 until the end of February 2017.
The decision of taking part in a sustainable project in a country that is socially and culturally so different from Italy and Europe comes from the desire to put theoretical knowledge acquired during university studies into practice and using the basics learnt at the university in order to collaborate in a project of international cooperation with an NGO that aims to reduce poverty through sustainable, innovative and inclusive solutions.
The five months passed in Tanzania have been both about work and growth in human relations.

ABSTRACT

La Tanzania è un paese in via di sviluppo giovane che rispetto ad altri del continente africano gode fortunatamente di pace sociale, premessa necessaria per uno sviluppo sostenibile. La Tanzania è uno dei Paesi più poveri al mondo. La povertà si riversa soprattutto nelle zone rurali e di periferia dove nella maggioranza dei casi non si ha accesso all'elettricità e all'acqua potabile. Garantire l'accesso all'energia elettrica e all'acqua potabile è uno dei punti di partenza per promuovere lo sviluppo sostenibile di un paese.

Il progetto "Hydroelectric Energy for 20 Isolated Rural Villages in Ludewa District", introdotto ed elaborato dall'Organizzazione Non Governativa ACRA, sorge e si sviluppa in una di queste aree rurali della Tanzania.

Lo scopo dell'intervento è quello di garantire un accesso sostenibile all'elettricità per 20 villaggi nel distretto di Ludewa, nella regione di Njombe. L'impianto responsabile della produzione di energia richiesta è un piccolo impianto idroelettrico capace di produrre una potenza 1,7 MW e in grado di fornire energia a più di 53.000 persone.

Il tirocinio è stato eseguito all'interno di questo progetto con l'intento principale di seguire le linee elettriche, in particolare le linee di bassa tensione.

Le attività hanno riguardato:

- Rilevamento tramite l'utilizzo del GPS della linea di bassa e di alta tensione;
- Tramite QGIS rielaborazione dei dati raccolti con il GPS e disegno della linea elettrica, controllando la corretta posizione dei pali ed eseguendo dove si evidenziavano particolari problemi possibili modifiche della linea;
- Confronto con il primo disegno delle linee di bassa tensione;
- Controllo della corretta stesura del cavo e che le modifiche apportate nei disegni venissero effettivamente eseguite;
- Proposta di nuove estensioni della linea, con la possibilità di raggiungere nuove connessioni e calcolo dei materiali necessari per eseguirle;
- Valutazione delle cadute di tensione per la linea esistente e per le nuove estensioni, in modo da comprendere se fosse necessaria l'aggiunta di nuovi trasformatori e a che distanza massima fosse possibile installare particolari macchine, che richiedessero

potenze maggiori e funzionanti con sistema trifase;

- In generale affiancamento al Site Manager, monitorando i lavori di cantiere, controllando l’arrivo dei materiali e risoluzione di problemi di natura pratica.

Il periodo del tirocinio ha coperto la fine della stagione secca e l’inizio di quella delle piogge, da inizio ottobre 2016 a fine febbraio 2017.

La scelta di prendere parte ad un progetto in un paese così diverso dal punto di vista socio-culturale dall’Italia e dall’Europa deriva principalmente dal fatto di voler mettere in pratica le conoscenze teoriche acquisite durante il percorso personale di studi, sfruttando le nozioni apprese all’università per collaborare ad un progetto di cooperazione internazionale con lo scopo da parte della ONG di rimuovere la povertà attraverso soluzioni sostenibili, innovative e partecipate.

I cinque mesi trascorsi in Tanzania sono stati motivo di crescita sia lavorativa che umano e relazionale.

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CHAPTER I
Tanzania Country

Tanzania is a newly developing country which in contrast with many other African countries is fortunately blessed with social peace, a necessary premise for a sustainable development. Thanks to President Nyerere indeed, economic and social policies have been implemented so as to avoid tribal wars, from which almost all African countries suffer.

Tanzania is considered one of the poorest countries in the world.

In order to gain a better understanding the activities completed during this internship, it would be necessary to describe where the Non-Governmental organization ACRA decided to implement the developmental project called “Hydroelectric Energy for 20 Isolated Rural Villages in Ludewa District”.

Figure 1 *Tanzanian Flag (https://en.wikipedia.org/wiki/Flag_of_Tanzania)*

1 General Context

Tanzanian or Tanganyika, officially the United Republic of Tanzania is a country in Eastern Africa within the African Great Lakes region. Parts of the country are in Southern Africa. At 947,303 km^2, Tanzania is the 13th largest country in Africa and the 31st largest in the world. It borders Kenya and Uganda to the north; Rwanda, Burundi, and the Democratic Republic of the Congo to the west; and Zambia, Malawi, and Mozambique to the south. Tanzania is located on the eastern coast of Africa and has an Indian Ocean coastline approximately 800 kilometres long. It also incorporates several offshore islands, including Unguja (Zanzibar), Pemba, and Mafia. The country is the site of Africa's highest and lowest points: Mount Kilimanjaro, at 5.895 metres above sea level, and the floor of Lake Tanganyika, at 352 metres below sea level, respectively.

Tanzania is mountainous and densely forested in the northeast, where Mount Kilimanjaro is located. Three of Africa’s Great Lakes are partly within Tanzania. To the north and west lie Lake Victoria, Africa's largest lake, and Lake Tanganyika, the continent's deepest lake. To the southwest lies Lake Nyasa. Central Tanzania is a large plateau, with plains and arable land. The eastern shore is hot and humid, with the Zanzibar Archipelago just offshore.

Figure 2 *Tanzania Country (http://www.worldaudit.org/countries/tanzania.htm)*

Tanzania's population of almost 51.82 million (2014) is diverse, composed of several ethnic, linguistic and religious groups. Tanzania is a presidential constitutional republic, and since 1996, its official capital city has been Dodoma, where the President's Office, the National Assembly, and some government ministries are located. Dar es Salaam, the former capital, retains most government offices and is the country's largest city, principal port, and leading commercial centre.

European colonialism began in mainland Tanzania during the late 19th century when Germany formed German East Africa, which gave way to British rule following World War I. The mainland was governed as Tanganyika, with the Zanzibar Archipelago remaining a separate colonial jurisdiction. Following their respective independence in 1961 and 1963, the two entities merged in April 1964 to form the United Republic of Tanzania.

Over 100 different languages are spoken in Tanzania, making it the most linguistically diverse country in East Africa. Among the languages spoken in Tanzania are all four of Africa's language families: Bantu, Cushitic, Nilotic, and Khoisan. Swahili and English are official languages of Tanzania. A highly multilingual country, Swahili is used in parliamentary debate, in the lower courts, and as a medium of instruction in primary school; and English is used in foreign trade, in diplomacy, in higher courts, and as a medium of instruction in secondary and higher education. President Nyerere encouraged the use of Swahili; as a means of unifying the country's many ethnic groups. Approximately 10% of Tanzanians speak Swahili as a first language, and up to 90% speak it as a second language. Most Tanzanians thus speak both Swahili and a local language; many educated Tanzanians are trilingual; also speaking English.

Tanzania is divided into thirty-one regions, twenty-six on the mainland and five in Zanzibar (three on Unguja, two on Pemba). In 2012, the thirty-one former regions were divided into 169 district, also known as local government authorities. Of the 169 districts, 34 are urban units, which are further classified as three city councils (Arusha, Mbeya, and Mwanza), nineteen municipal councils, and twelve town councils.

The urban units have an autonomous city, municipal, or town council and are subdivided into wards and mtaa. The non-urban units have an autonomous district council but are subdivided into village councils or township authorities (first level) and then into kitongoji.

The city of Dar es Salaam is unique because it has a city council whose areal jurisdiction overlaps three municipal councils. The mayor of the city council is elected by that council. The twenty-member city council is composed of eleven people elected by the municipal councils, seven members of the National Assembly and "Nominated members of parliament under 'Special Seats' for women". Each municipal council also has a mayor.

The economic reforms were associated with the institutional reforms. It has tried to make the public sector more efficient, through the transfer of the power from the central Government to the local authority. That reform did not have the expected effects, because many employees didn’t have the knowledge or a strong motivation.

Moreover, new laws have been issued and the supervision has been increased to obstruct the corruption within the public sector. Nevertheless, the problem is still widespread and Tanzania

is still one of the most corrupt countries in the world. This causes a bad quality of services for the people.
Others reforms have made changes in the judiciary, legislative system, educational and health sectors.

Figure 3 *Tanzania Country (https://it.wikipedia.org/wiki/Tanzania).*

1.1 Population

The proximity with the Democratic Republic of the Congo, Ruanda and Burundi, very critical zone and with brutal conflicts, contributed to the arrival of many refugees in Tanzania and that increased the demographic growth.
According to a 2014 census, the total population was 51.82 million. The under 15 age group represented 44.1% of the population. The number of the inhabitants of recent years is just an estimate, because it is very difficult to count the population precisely, as it is increasing every day, especially in the rural villages that are difficult to reach.
The population distribution in Tanzania is extremely uneven. Most people live near the northern border or the eastern coast, with much of the remainder of the country being sparsely populated. Density varies from 12 per km^2 in the Katavi Region to 3,133 per km^2 in the Dar es Salaam Region.

Approximately 70% of the population is rural, although this percentage has been declining since at least 1967. Dar es Salaam (population 4,364,541) is the largest city and commercial capital. Dodoma (population 424,347), located in the centre of Tanzania, is the capital of the country and hosts the National Assembly.

Table 1 *Summary of Key Indicators for Tanzania, Tanzania Mainland and Tanzania Zanzibar, 2012 Census*

Indicator	Tanzania		Tanzania Mainland		Tanzania Zanzibar	
	Number	Percentage	Number	Percentage	Number	Percentage
Population Size, Growth and Distribution						
Total Population	**44,928,923**	**100.0**	**43,625,354**	**100.0**	**1,303,569**	**100.0**
Male	21,869,990	48.7	21,239,313	48.7	630,677	48.4
Female	23,058,933	51.3	22,386,041	51.3	672,892	51.6
Rural	31,623,919	70.4	30,924,116	70.9	699,803	53.7
Urban	13,305,004	29.6	12,701,238	29.1	603,766	46.3
Average Annual Intercensal Growth Rate (2002 – 2012)	-	**2.7**	-	**2.7**	-	**2.8**
Age and Sex Profile						
Children (0–4 years)	**7,273,832**	**16.2**	**7,069,895**	**16.2**	**203,937**	**15.6**
Male	3,637,982	16.6	3,535,673	16.6	102,309	16.2
Female	3,635,850	15.8	3,534,222	15.8	101,628	15.1
Young Population (0–14 years)	**19,725,456**	**43.9**	**19,171,107**	**43.9**	**554,349**	**42.5**
Male	9,864,400	45.1	9,586,897	45.1	277,503	44.0
Female	9,861,056	42.8	9,584,210	42.8	276,846	41.1
Young Population (0–17 years)	**22,504,526**	**50.1**	**21,866,258**	**50.1**	**638,268**	**49.0**
Male	11,240,635	51.4	10,922,412	51.4	318,223	50.5
Female	11,263,891	48.8	10,943,846	48.9	320,045	47.6
Elderly Population (60+ years)	**2,507,568**	**5.6**	**2,449,257**	**5.6**	**58,311**	**4.5**
Male	1,200,210	5.5	1,170,323	5.5	29,887	4.7
Female	1,307,358	5.7	1,278,934	5.7	28,424	4.2
Elderly Population (65+ years)	**1,736,851**	**3.9**	**1,700,125**	**3.9**	**36,726**	**2.8**
Male	819,987	3.7	801,509	3.8	18,478	2.9
Female	916,864	4.0	898,616	4.0	18,248	2.7

The population consists of about 125 ethnic groups. The Sukuma, Nyamwezi, Chagga, and Haya people have more than 1 million members each. Approximately 99% of Tanzanians are of African descent, with small numbers of Arab, European, and Asian descent. The majority of Tanzanians, including the Sukuma and the Nyamwezi, are Bantu. The Nilotic people include the nomadic Maasai and Luo, both of which are found in greater numbers in neighbouring Kenya.

The population also includes people of Arab, and Indian origin, and small European and Chinese communities. Thousands of Arabs and Indians were massacred during the Zanzibar Revolution of 1964. As of 1994, the Asian community numbered 50,000 on the mainland and 4,000 on Zanzibar. An estimated 70,000 Arabs and 10,000 Europeans lived in Tanzania.

Some albinos in Tanzania have been the victims of violence in recent years. Attacks are often to hack off the limbs of albinos in the perverse superstitious belief that possessing the bones of albinos will bring wealth. The country has banned witch doctors to try to prevent the practice, but it has nevertheless continued and albinos remain targets.

1.2 Economy

Nowadays, Tanzania is still one of the more politically and economically stable countries of the African continent.

From 2009 until 2013, Tanzania's per capita GDP (based on constant local currency) grew an average of 3.5% per year, higher than any other member of the East African Community (EAC) and exceeded by only nine countries in Sub-Saharan Africa: the Democratic Republic of Congo, Ethiopia, Ghana, Lesotho, Liberia, Mozambique, Sierra Leone, Zambia, and Zimbabwe.

Tanzania's largest trading partners in 2012 for its 5.5 billion US dollars in exports were South Africa, Switzerland, and China. Its imports totalled 11.7 billion US dollars, with Switzerland, China, and the United Arab Emirates being the biggest partners.

Tanzania weathered the Great Recession, which began in late 2008 or early 2009, relatively well. Strong gold prices, bolstering the country's mining industry, and Tanzania's poor integration into global markets helped to insulate the country from the downturn. Since the recession ended, the Tanzanian economy has expanded rapidly thanks to strong tourism, telecommunications, and banking sectors.

According to the United Nations Development Programme, however, recent growth in the national economy has benefited only the "very few", leaving out the majority of the population.

Tanzania's 2013 Global Hunger Index was worse than any other country in the EAC except Burundi. The proportion of persons who were undernourished in 2010-12 was also worse than any other EAC country except Burundi.

The level of poverty in Tanzania is very high. Tanzania has made little progress towards reducing extreme hunger and malnutrition. The 2010 Global Hunger Index ranks the situation as “alarming”. Children in rural areas suffer substantially higher rates of malnutrition and chronic hunger, although urban-rural disparities have narrowed as regards both stunting and underweight. Low rural sector productivity arises mainly from inadequate infrastructure investment; limited access to farm inputs, extension services and credit; limited technology as well as trade and marketing support; and heavy dependence on rain-fed agriculture and natural resources.

Approximately 68 percent of Tanzania's citizens live below the poverty line of $1.25 a day and 16 percent of children under 5 are malnourished. The most prominent challenges Tanzania faces in poverty reduction are unsustainable harvesting of its natural resources, unchecked cultivation, climate change and water-source encroachment, according to the United Nations Development Programme (UNDP).

There are very few resources for Tanzanians in terms of credit services, infrastructure or availability of improved agricultural technologies, which further exacerbates hunger and poverty in the country according to the UNDP. Tanzania ranks 159 out of 187 countries in poverty according to the United Nation's Human Development Index (2014).

The Tanzanian economy is heavily based on agriculture, which accounts for 24.5% of gross domestic product, provides 85% of exports, and accounts for half of the employed workforce. The agricultural sector grew 4.3% in 2012, less than half of the Millennium Development Goal target of 10.8%. 16.4% of the land is arable, with 2.4% of the land planted with permanent crops.

Maize was the largest food crop on the Tanzania mainland in 2013 (5.17 million tonnes), followed by cassava (1.94 million tonnes), sweet potatoes (1.88 million tonnes), beans (1.64 million tonnes), bananas (1.31 million tonnes), rice (1.31 million tonnes), and millet (1.04 million tonnes). Sugar was the largest cash crop on the mainland in 2013 (296,679 tonnes), followed by cotton (241,198 tonnes), cashew nuts (126,000 tonnes), tobacco (86,877 tonnes), coffee (48,000 tonnes), sisal (37,368 tonnes), and tea (32,422 tonnes). Beef was the largest meat product on the mainland in 2013 (299,581 tonnes), followed by lamb/mutton (115,652 tonnes), chicken (87,408 tonnes), and pork (50,814 tonnes).

According to the 2002 National Irrigation Master Plan, 29,4 million hectares in Tanzania are suitable for irrigation farming; however, only 310,745 hectares were actually being irrigated in June 2011.

1.3 Climate

Climate varies greatly within Tanzania. In the highlands, temperatures range between 10 and 30 °C during cold and hot seasons respectively. The rest of the country has temperatures rarely falling lower than 20 °C. The hottest period extends between November and February (25-31 °C) while the coldest period occurs between May and August (15–20 °C). Annual temperature is 20 °C.

Tanzania has two major rainfall regimes: one is uni-modal (October–April) and the other is bi-modal (October–December and March–May). The former is experienced in southern, central, and western parts of the country, and the latter is found in the north from Lake Victoria extending east to the coast. The bi-modal regime is caused by the seasonal migration of the Intertropical Convergence Zone.

In these last two years the rain season is not following the standard regimes as is established by the nature. This year the rains has begun just in February in the highlands in Njombe and in Dar es Salaam started in March. This is probably due to the effect of climate change on Africa, as it is occurring all over the world.

1.4 Healthcare

Healthcare in Tanzania is available depending on one's income and accessibility. People in urban areas have better access to private and public medical facilities. Insurance has only been introduced in recent years whereas pension schemes have been around longer but the limitations of either are vast and not attending to the needs of the majority of Tanzanians.

As of 2012, life expectancy at birth was 61 years.

The under-five mortality rate in 2012 was 54 per 1,000 live births. The maternal mortality rate in 2013 was estimated at 410 per 100,000 live births. Prematurity and malaria were tied in 2010 as the leading cause of death in children under 5 years old. The other leading causes of death for these children were, in decreasing order, malaria, diarrhoea, HIV, and measles.

Malaria in Tanzania causes death and disease and has a "huge economic impact". There were approximately 11.5 million cases of clinical malaria in 2008.

According to the Tanzania Demographic and Health Survey 2010, 15% of Tanzanian women have undergone female genital mutilation (FGM) and 72% of Tanzanian men have been circumcised. FGM is most common in the Manyara, Dodoma, Arusha, and Singida regions and non-existent in Zanzibar. The prevalence of male circumcision was above 90% in the eastern (Dar es Salaam, Pwani, and Morogoro regions), northern (Kilimanjaro, Tanga, Arusha, and Manyara regions), and central zones (Dodoma and Singida regions) and below 50% only in the southern highlands zone (Mbeya, Iringa, and Rukwa regions).

The national health service is provided in three different levels:

- Hospitals;
- Health centres;
- Dispensaries.

For the national standard, each dispensary should give its service not to more than 10,000 people, the health centres not to more than 50,000 and hospitals not to more than 100,000 people. The service is guaranteed from both public and private institutions. In the majority of the cases the last ones belong to the church or it does not belong to governmental organisations. The public centres and particularly the dispensaries are quite common in the country (more than in other Africans countries) and they offer a free service, although the service is often of poor quality. Sure enough, the buildings are frequently inadequate, the medicine, the instrument for work and the employees are not enough and they are not really professional.

1.5 Energy Situation

Most electricity in Tanzania is generated using gas; hydropower is also a significant source of power. Tanzania has a capacity of 1,521 MW with only 60% of this power available, most of the time, as it highly depends on hydroelectric plants (38% of installed capacities). Only 24% of urban areas have access to electricity, while 7% of rural areas have it. 65% of Tanzania's population lives in these rural areas. Though the country's supply of electricity nearly doubled between 2005 and 2011, only about 20% of Tanzanians are on the electrical grid. The electrical supply varies, particularly when droughts disrupt hydropower electric generation; rolling blackouts are implemented as necessary. Nearly a quarter of electricity generated is lost because of poor transmission infrastructure. The unreliability of the electrical supply has hindered the development of Tanzanian industry.

A further study reveals that the lack of access to energy services increases rural poverty as a result of the more often limited production opportunity. As a result, all across the country consumption of energy by the households is mainly characterized by huge usage of traditional energy biomass for example charcoal and firewood which accounts for approximately 90% of the total primary energy consumption in the country with electricity only representing 1,5% and petroleum products at 8%. The country relies heavily on imported fossil fuels for its electricity, which increases the burden on the country and rural community as the prices of imported fuels are quite unstable and have been hindering efforts to improve rural energy access. Consequently, the country experiences regular power cuts and of course high electricity losses. The Tanzania Electric Supply Company (TANESCO), is a state-owned parastatal that was established under the Ministry of Energy and Minerals in 1964, its main responsibility being to generate, transmit, distribute and sell electricity to Tanzania Mainland and to sell bulk power to the Zanzibar Electricity Corporation that in turn sells it to the public in island i.e. Unguja and Pemba.

Despite having abundant renewable energy potential, Tanzania's per capita electricity consumption is amongst the lowest in the world; 81.66 kWh per capita compared to 432 kWh in Sub Saharan Africa; and 2,176 kWh as world average (World Bank, 2003 - 2007). The extension of the grid to rural users is often not economically viable and, in some cases, not technically possible; thus meaning that 80% of Tanzania's population has inadequate access to energy. Energy consumed in rural Tanzania accounts for 85% of the total national consumption, and it is mainly generated by biomass burning (particularly fuel-wood). Low access to affordable, commercial modern energy has negative effects on economic growth, agricultural mechanization, industrialization as well as conservation of the environment (URT 2003).
On rural, off-grid areas, where distribution costs are prohibitive, expansion of the availability of affordable renewable energies is considered a priority (MKUKUTA II, 2010).
The National Energy Policy (Ministry of Energy and Minerals) supports a rural electrification that takes the economic and political structure of the country into consideration so that the energy sector can effectively contribute to the growth of the national economy and to improve the standard of living in a way as to manage natural resources in a sustainable way. The current framework fosters also private sector participation in modern energy service activities, indeed REA is supporting rural electrification initiatives through concession and incentives for project developers and end users. Rural Energy Agency (REA) is an autonomous body under

the Ministry of Energy and Minerals of the United Republic of Tanzania.

2 Specific Context of the Project

The development project "Hydroelectric Energy for 20 Isolated Rural Villages in Ludewa District" was carried out in Njombe Region, mainly mountainous on the borders with Malawi. The population is devoted mostly to agriculture and the commercial activities connected to farming. The prevalence of HIV is more comparing to other regions.

2.1 Njombe Region

Njombe Region is one of the thirty-one administrative regions of Tanzania.
Njombe Region was established on 1st March 2012 by the Government Gazette. The region is located in Southern Highlands Zone which comprises of Ruvuma, Iringa, Mbeya, Katavi, Rukwa Regions and part of Morogoro Region. It borders Iringa Region in the North, Morogoro Region in the East and Ruvuma region in the South. It also borders Republic of Malawi via Lake Nyasa and part of Mbeya Region in the North-West and West. It lies between latitude 08° 40' and 10° 32' South of the Equator and between longitude 33° 47' and 35° 45' East of Greenwich. This spatial location of the region offers unique advantages to investors in two main ways:

- as a logistical hub with connections to all directions of Tanzania and beyond borders with reasonably developed transport infrastructural facilities by road, railway, water and air. Very few regions in Tanzania have that advantage;
- a combination of conducive weather and soil types suited for tropical and temperate crops and livestock.

The Region is divided into four districts namely Njombe, Wanging'ombe, Makete and Ludewa. Also there are six Local Government Authorities namely Njombe and Makambako Town Councils, Njombe, Makete, Wanging'ombe and Ludewa District Councils. There are a total of 18 Divisions, 96 Wards, 384 Villages and 35 Mitaa as indicated in Table 2.

Table 2 *Distribution of Administrative Units by Councils (Regional Commissioners' Office, 2013)*

No:	Council	Division	Ward	Village	Mitaa
1	Njombe DC	1	11	44	0
2	Njombe TC	2	13	44	26
3	Makambako TC	1	8	21	9
4	Wanging'ombe DC	3	17	101	0
5	Ludewa DC	5	25	77	0
6	Makete DC	6	22	97	0
	TOTAL	**18**	**96**	**384**	**35**

The Region has the total surface area of 24,994 km^2 out of which 21,172 km^2 is covered by land (84.7%) and 3.822 km^2 is covered by water (15.3%).

Ludewa district is unique as it endowed with a vast coast line along Lake Nyasa with ports to link to Ruvuma and Mbeya regions with Tanzania, and to neighbouring Malawi. There is a huge opportunity for investment in both tourism facilities and passenger/cargo transport vessels.

The regional climate is influenced by a number of factors which have led to the formation of three climatic zones namely, the Highlands Zone, the Midlands Zone and the Lowlands zones. The Highlands Zone lies at an altitude of 1,600 – 3,000 meters above sea level. This area includes Imalinyi in Wanging'ombe district, Lupembe in Njombe district, Mlangali, Liganga and part of Mawengi Division in Ludewa and Makete districts. Temperature is normally below 20 °C with rainfall ranging from 1,000 to 1,600 mm per annum, falling in a single season from November through May. The dry and cold season occurs after the rain season, and it lasts from June to September. The Midlands Zone lies between 700 – 1,700 meters above sea level. This area includes Ludewa and Njombe Town and Northern parts (Lupembe and Makambako) with rainfall ranges between 1,100 and 1,300 mm and temperatures are mild to cold falling to below 10 °C during June-July. The lowland zone lies between 600 – 1,400 metres above sea level. Temperature is between 15 °C and 25 °C with rainfall ranging from 600 to 1,000 mm, with occasional mild droughts in 4 out of 5 years. The variation in climatic conditions in terms of temperature and rainfall patterns offers investors opportunities to diversify their agricultural (e.g. horticulture) and livestock products (e.g. milk and wool) to take advantage of low seasonal supplies in other parts of Tanzania, East and Southern Africa and the world market in general.

2.2 Population

According to 2012 Population and Housing Census, the Region had 702,097 people, 329,359 being males and 372,738 females with average annual growth rate of 0.8%. Population distribution by sex is indicated in the following table.

Table 3 *Population by Sex and Average and Household Size, (National Bureau of Statistics, 2013)*

S/No.	District/Council	Total	Male	Female	Average Household Size
1	Njombe TC	130,223	61,112	69,111	4.1
2	Wanging'ombe DC	161,816	75,427	86,389	4.0
3	Makete DC	97,266	45,300	51,966	3.7
4	Njombe DC	85,747	40,047	45,700	4.2
5	Ludewa DC	133,218	63,442	69,776	4.4
6	Makambako TC	93,827	44,031	49,796	4.2
	TOTAL	**702,097**	**329,359**	**372,738**	**4.1**

Investors should expect to get a highly literate young and middle-age population given that Njombe region was among the pioneers in establishing Community Secondary Schools long before the approach was adopted as national policy. The people of Njombe region are also reputed for their hard work and self-driven aptitude as well as honesty in business and workplace as employees.

The region is boasting of a sizeable number of upcoming business women and men who have invested and continue to reinvest their surpluses in the region and beyond, especially in the transport sector (buses and heavy cargo trucks), hotels/restaurants and retail business in locally and imported finished goods and other services such as education and health provision. Some have invested in timber and cereal processing. A new investor should therefore expect to find a healthy environment for competitive business and government machinery well experienced in assisting the private sector to thrive.

2.3 Economic activities and Agriculture

The region has three agro-ecological zones, namely; Highlands, Middle and Lowland. Some parts of the lowlands are within the great rift valley, offering the region a unique combination of agro-ecological combinations from very cold to very warm temperatures, high to low humidity conditions and from temperate type of vegetation to tropical and savannah type of forest cover. Most of the cereals are produced in low lands and midland, while cash crops such as pyrethrum, tea and coffee are produced from the midlands and highlands. There is also potential for cashew production in some low lying areas such as Masasi Division in Ludewa

The diversity of agro-ecological conditions offers investors in the agricultural sector a wide margin for coping with emerging challenges of climate change. Among the newly introduced commodities, which had low economic value a decade ago, include water melons (lowlands), avocados, apples, pineapples and flowers (middle and highland areas).

Agriculture has continued to dominate the livelihood and economic activities of the people in the region, whereby about 90 percent of the population earn their living from the sector. So far weather conditions continue to be the major determinant of agricultural performance in the region as a proportionally small area is irrigated, mostly for rice, horticultural crops (mostly onions and tomatoes) and tea production.

Figure 4 *Tea Plant Ludewa District*

The region is among the major maize producers in the country, competing with Mbeya, Ruvuma, Iringa, Rukwa, Morogoro, Kigoma and Katavi regions. The region's total land is estimated to be 2,117,200 hectares out of which 1,090,000 hectares is an arable land, but only 513,594 Ha (47.1%) of the arable land is under cultivation. The latter includes an annual average of 415,396 hectares of food crops and about 98,198 hectares under cash crops. Thus, the region has a large untapped land resource that requires development in terms of crop production either by peasant or commercial farmers. The largest proportion of the region's cultivated area is owned by peasants who cultivate an average area of 0.8 hectares per household. The Region is also the major producer of round potatoes and wheat.

The region is covered by 496,627 Hectares of forest which is about 27.14% of the regional land area. This includes natural forests of 109,948 Hectares and tree plantations of 196,128 Hectares. Plantations comprise Eucalyptus, Pines, Black wattle and Cypress. The total area covered by forest plantation in 2013 was about 386,679 Hectares.

Table 4 *Major Food and Cash Crops Production for the Years 2011/12 and 2012/13, (Regional Commissioners' Office, 2013)*

Crops	2011/2012		2012/2013	
	Area cultivated	Production	Area Cultivated	Production Estimates
	Ha	Tonnes	Ha	Tonnes
Food Crops				
Maize	227,432	561,027	244,377	598,838
Beans	35,520	34,227	47,707	49,085
Round potatoes	43,609	434,798	51,465	529,315
Sweet potatoes	5,069	13,005	5,215	13,197
Cassava	15,342	60,937	16,084	64,038
Wheat	12,257	15,757	14,926	19,517
Cow Pea	11,838	14,214	13,605	15,983
Green Pea	7,615	9,119	8,157	10,799
Finger millet	739	954	898	1,041
Paddy	1,135	2,132	1,371	2,443
Millet	339	369	599	653
Ground nuts	6,624	8,569	7,256	9,235
Pigeon Peas	250	349	250	350
Vegetables	4,391	34,024	3,485.8	28,953.12
Total	**372,160**	**1,189,481**	**415,396**	**1,343,447**
Cash Crops				
Sun flowers	64,209	79,438	80,176	98,701
Pyrethrum	3,514	183	4,725	3,282
Coffee	749	147	2,741	308
Tea	7,290	19,593	7,809	26,968
Cashew nut	421	49	900	90
Fruits	434	1,801	1,212	5,761
Barley	361	364	623	623
Flowers	0	0	12	287
Total	**76,981**	**101,575**	**98,198**	**136,020**

2.4 Healthcare

Following the establishment of Njombe Region and according to the health sector policy the Regional authority is required to construct and operate a Regional Referral Hospital with modern buildings, equipment and specialized medical staff. Currently the region has 10 hospitals of which 3 are owned by the Government, 5 by religious institutions and 2 by private sector. Again the region has 22 health centres of which 12 are owned by the Government and 10 by religious institutions while there are 190 dispensaries of which 158 are owned by the Government, 26 by religious institutions and 6 by private sector.

The dispensaries are the first level in the national health system. They are very widespread in the territory. The reason is that one of the purposes of President Nyerere's politics was to provide a dispensary, a school and drinkable water to the majority of the villages.

A huge problem is the low number of the employees. Government dispensaries usually work together with a rural medical assistant (intermediate figure between the doctor and the nurse) and two or three nurses.

Each public dispensary receives monthly medicines from the district. The drugs are supplied free to the patient, but often are not enough.

Another problem is the lack of analysis laboratory in the dispensaries especially in the public ones. This problem limits the correctness of the diagnosis.

Also in private hospitals, where the presence of a good technical laboratory is guaranteed, unfortunately the correctness of the analysis is not often present. In fact, sometimes the technicians of the laboratory are not able to calibrate the machines or they simply forget to do it. Otherwise, if the machines work properly and are calibrated, a blood test is kept at a temperature that is too high, under the sun and it can compromise the results of the analysis.

2.5 Energy

Firewood and charcoal are the major sources of energy for cooking in the region where they stand at 95% of the total energy required for cooking and other domestic energy uses in Rural and urban areas. Other sources of energy include electricity (Hydro and thermal electric power), solar energy and fossil fuels (Kerosene, diesel and petrol). Electricity is produced and supplied by Tanzania Electricity Supply Company (TANESCO), Tanganyika Wattle Company Ltd, Roman Catholic Missions (Uwemba, Mavanga, Lugarawa, Matembwe) Lutheran Mission (Bulongwa), Rural Energy Agency (REA), Lupande, Mawengi and Madunda Hydro Power Project (LUMAMA), CEFA Ikonda and some individuals. This electricity can not only support large scale production activities in extraction, manufacturing and processing industries but also home supplies especially in urban and to some extent in rural areas. There are potential areas for investing in energy (hydro power, coal, solar and wind). Firewood is the major source of energy in electricity generation at Tanganyika Wattle Company Ltd. Fossil fuel such as kerosene is used for lighting mostly in rural areas. Solar energy is used by a minority in the region.

2.6 Context Project Area

Ludewa District is one of the four districts of the Njombe Region and it is located approximately 150 km south of Njombe Town. The district contains portions of the Livingstone Mountains, and borders Malawi on Lake Nyasa. It is approximately 8,397 km^2 of which 6,325 km^2 is land area and 2,072 km^2 is water area.

The Ludewa District it is divided into 5 Divisions, 25 wards and 76 villages, with a total population of 128,155 people (2002 statistics) and according to the 2012 projection, the estimated population is to be 144.622 people (about 66,622 males and 78,000 females). Ludewa district is a rural area with a huge number of natural resources that could offer great development potentials: agriculture, forests, water.

Much of Ludewa district's population earn a living by engaging in small scale agriculture on the mountainsides, fishing on Lake Nyasa, working on tea plantations, and in mines for coal, gold and iron ore. Concerning the Agriculture, the District has a total of 465,030 ha of arable land, of which about 11% is under crop production such as maize, paddy, wheat, bananas, ground nuts and sunflower. Cash crops include coffee, pyrethrum and sunflower.

Ludewa district is very isolated, as it is surrounded by the Livingstone mountains on one side and Lake Malawi on the other side. Moreover, the roads of the districts are in bad conditions, for example many roads are narrow and big trucks cannot travel on them. The villages of the Ludewa district are not reached by the national grid and agriculture, the main income-source for people of the district, is still traditional, for instance, there are no systems of anti-erosion cultivation and there are no plants for the transformation of products.

Thus the district is generally affected by a very low economic growth and high poverty levels, with the common consequences of such circumstances: above all, very high emigration rate of young people towards Dar es Salaam and Iringa. At present only 4% of the population have access to electricity produced by the old hydroelectric plant, built by the Diocese of Njombe in order to supply the Lugarawa hospital.

The rural villages of Lugarawa and the District of Ludewa are far from bigger urban centres and out of any connection with the national network. Therefore, a very high percentage of the consumed energy is produced by engine generators: generators have a high cost that creates an obstacle toward local development.

CHAPTER II

ACRA Project

The project "Hydroelectric Energy for 20 Isolated Rural Villages in Ludewa District", introduced by the Non-Governmental Organisation ACRA, was established and continues to evolve in one of the poorest rural areas in Tanzania.

Figure 5 *Ludewa District, ACRA, "Hydroelectric Energy for 20 Isolated Rural Villages in Ludewa District Tanzania" Feasibility Study*

The goal of the project is to guarantee a sustainable access to electrical energy for 20 villages in the Ludewa District, Njombe Region. The project has begun in 2014 and should be finish in year 2018.

The rural electric grid envisioned by the project will link 20 villages, parted in 86 sub-villages, for a total of 53,380 beneficiaries who will be granted access to hydroelectric power produced by the plant. In particular, there will be access to hydroelectric energy for:

- 10,508 families;
- 32 primary and secondary schools having about 16,000 students;

- 19 dispensaries/health centres;
- 511 small shops/bars;
- 118 milling machines;
- 38 mechanical and carpentry laboratories;
- the Lugarawa hospital with 200 beds which currently has irregular access to electricity from the small and old hydropower plant.

Table 5 *Beneficiaries of the project, ACRA, "Hydroelectric Energy for 20 Isolated Rural Villages in Ludewa District Tanzania" Feasibility Study*

s/n	Villages	Nb of sub-villages	Sub-villages	Population - Beneficiaries	Households
1	Mlangali	3	Ulayas, Madindu (already covered by Mawengi), N'galike, Mlangali ndani	2.341	580
2	Ligumbiro	5	Makimba, Uduti, Viganga, Ligumbilo, Masaula	2.235	461
3	Lufumbu	4	Mdete (already covered by Mawengi), Itiwili, Maganga, Maduku, Itoki, Ihonjogoro	2.460	550
4	Madope	3	Njiapanda (Lusitu), Kidiwike, Mlingano, Mbugani (already covered))	1.924	288
5	Luvuyo	4	Uhuji, Maraganga, Mjimwema, Mkinino	1.970	425
6	Mangalanyene	4	Batini, Lingomelo, Ligelango, Mdandamo	1.907	312
7	Manga	4	Mangajuu, Ulialia, Ilala, Lubindi	2.234	521
8	Madilu	5	Madila mjini, Manzese, Temeke, Matunda, Lifungula	3.547	574
9	Ilawa	3	Ilala, Mjimwema, Njomlole	1.017	217
10	Mfarasi	3	Mdetele, Mhigiti, Viganga, Mpocho	1.300	242
11	Lugarawa	7	Luafyo chini, Luafyo juu, Lupefu, Luholomela, Mhawike, Msanyo, Ukindo	8.026	1.740
12	Mdilidili	4	Matika, Lushoto, Lusapo, Mavula	2.631	643
13	Shaurimoyo	5	Myombo, Songambele, Njimwema, Amkatwende, Mwendapole	2.862	612
14	Mkongobaki	5	Luwande, Maraganga, Mwangaza, Mpechi, Ushirikiano	2.046	425
15	Amani	5	Luhaha, Masilu, Maluluma, Ulembwe, Dodoma-Chimbo	3.924	688
16	Maholong'wa	5	Maboga, Makasi, Kihenyena, Ndilima, Maholong'wa	2.850	538
17	Madindo	5	Mlanje, Madindo, Lushoto, Mlulu, Kibito	3.250	518
18	Ludende	5	Ludende A, Ludende B, Mseke, Mpumbwi, Masita	3.535	580
19	Lipangala	4	Kidingili, Lupepo, Mhumbi, Mnoge	2.376	407
20	Ugela	3	Ushirikiano, Mlangali Ndani, Kijina	945	187
20	**Total**	**86**		**53.380**	**10.508**

1 Summery Project

The area of intervention is one of the most populated in the district; this is a consequence of the soil fertility and the presence of the hospital in Lugarawa, the biggest village of the project, which is one of the most well-equipped and most effective in the district. The electricity provided by this project will reach one third of the inhabitants of the district, 20 villages out of the existing 76. Considering also another ongoing project carried out by ACRA and NDO (Diocese of Njombe) that supplies energy to 7 villages in the Mawengi ward, with the Lugarawa plant there will be a wide area self-sufficient for its energy needs, connected to the national grid for the selling of the excess of the energy produced.

The Madope catchment basin, that will provide the necessary water quantity for the future hydroelectric plant, has an extension of 16.4 km^2. It is a small basin at a high elevation (2,000-2,500 m.a.s.l), drained by the homonymous stream. The stream exits the basin at its southern edge, along a very inclined course excavated in the rocky oriental wall of the Lugarawa valley, upstream of the village.

A few years ago, a barrage has been built at the outlet of the Madope basin, which, using an intake and a concrete canal, diverts part of the flow toward the contiguous eastern basin to supply more water to the old small hydroelectric power plant, located a little upstream of the village of Lugarawa. The water is canalised around the small hill that closes the Madope basin toward SE, then it is released along a vertical rocky wall and forms a waterfall about 100 m high. From the point of the impact on, the water flows freely downstream on a slightly modified natural path. A small dam, upstream the power plant, supplies the head for the energy production.

The deviation of part of the Madope stream constituted an artificial waterfall of 460 metres, which will be conveyed in the penstock of the new plant and will supply the small hydroelectric plant, located inside the nearby valley of Lugarawa.

Figure 6 *Penstock way, B. PETRUCCI, Geological Mission Final Report, August 2010*

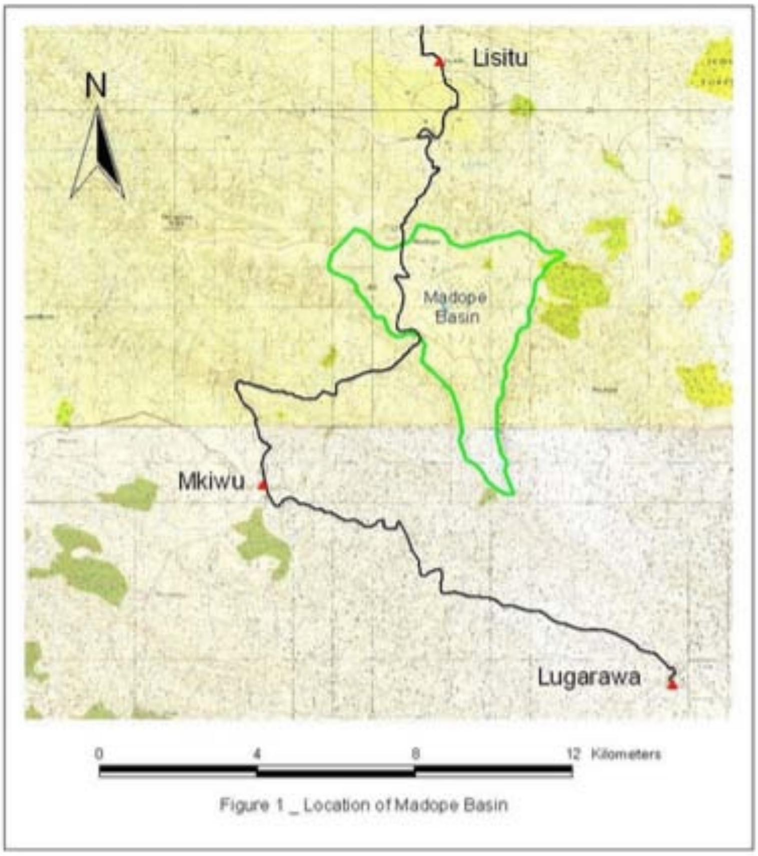


Figure 7 *Location of Madope Basin, B. PETRUCCI, Geological Mission Final Report, August 2010*

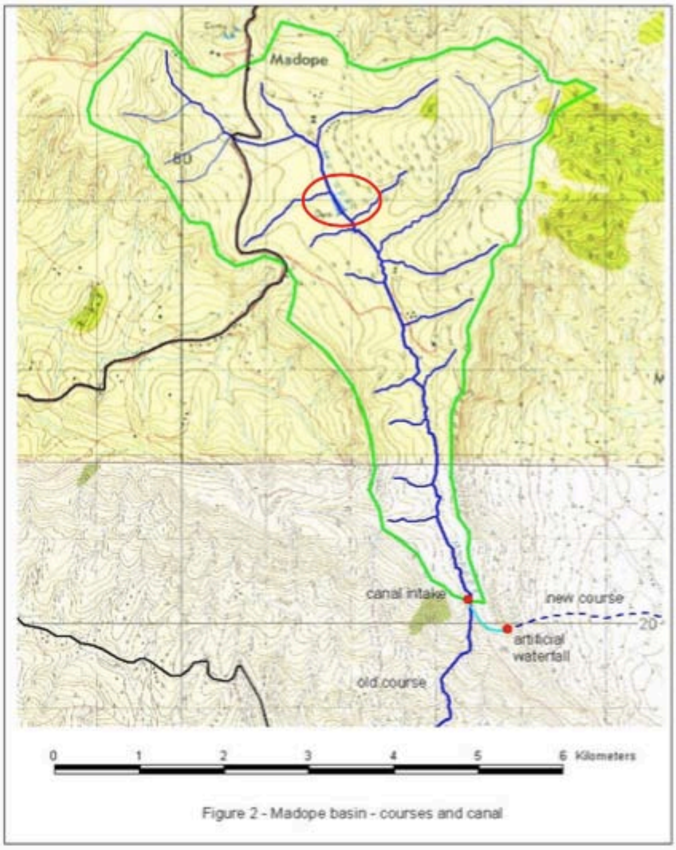


Figure 8 *Madope Basin – courses and canal, B. PETRUCCI, Geological Mission Final Report, August 2010*

From the future power plant three medium voltage electrical transmission lines (33 kV) will depart, reaching 20 villages. The first line, going towards north, will reach the national electric line in the Luponde area, to sell the electricity surplus to TANESCO.

The second line links, towards north the villages of Madope and the Madilu ward. A third line will reach Lugarawa and then, passing Shaurimoyo village, will end at the villages of the Ngongobaki ward. Finally, one line will reach the village of Mlangali and terminate at the Ligumbiro village. In total, the medium voltage line of 33 kV will be 156 km long.

2 Current energy supply

Currently, the only relevant infrastructure in the area for the supply of electric power is a mini hydroelectric power plant built in 1979 to supply the Lugarawa Hospital. The plant consists of a Ossberger turbine, producing up to 165 kW, with a maximum flow of 2.55 m^3/s and a 9 m penstock fall. At the moment, the turbine is damaged in one of its parts, and this reduces its productive capacity to around 80 kW. During dry season the water supply of the Lugarawa torrent sharply decreases and energy production is extremely insufficient to cover the demand. The 380 private users can use energy only for a few hours a day, in the evening time, as priority during daytime is given to the hospital. Even in this way during the dry season, the power supply of the hospital is insufficient, as a diesel power generator is needed in order to keep some devices running.

To overcome water shortage, in 1997 the Nyasa Water Basin Authority authorized the deviation of the Madope torrent stream in Lugarawa. During dry season, after these modifications have been made, the water supply is never greater than 200 l/s; so the electricity shortage has not been resolved yet.

However, the deviation of part of the Madope stream constituted an artificial waterfall of 460 metres, which will be conveyed in the penstock of the new plant.

Summarizing, 424 out of 10,508 families are benefitting from the old mini-hydroelectric power plant whilst 544 own a solar panel. The remaining 9,540 families use kerosene lamps to light their house. The 43 schools are not supplied with electricity and cannot hold evening classes. The 19 dispensaries do not enjoy sufficient power supply and cannot preserve medicines which need low temperatures for their integrity.

The 118 milling machines are activated by diesel engines, and so are the 12 welding and mechanical machines. The 12 carpentries employ exclusively manual tools and no mechanical tool. Most small shops and bars use kerosene lamps. Main shops are provided with diesel generators. In total, the area of intervention comprises of 161 small-size power generators, which give light to small shops and make a few machines work inside the workshops.

Current electricity consumers are only 8.88 % of the whole population in the area. Their consumption is very low because the production of the mini-hydropower in Lugarawa and that of the solar panels altogether is very small.

3 Demand forecasts

All consumers who currently use kerosene for illumination and diesel for running workshop machines wish to be provided with electricity, because the latter is much more profitable and comes at a lower cost than diesel or kerosene. From the survey held in the project area it was understood that each family consumes approximately 1 litre kerosene/week for their petrol lamps. The monthly expenditure in kerosene is about 4 euro; that is higher than the electricity costs afforded monthly by the families in the nearby area of Mawengi. The arrival of electricity then would reduce the need for candles and kerosene lamps with their inherent fire safety risks and improve indoor air quality.

According to the outcomes of the Mawengi project, carried out also by ACRA during recent years, costs for maize grinding with electrical mills are halved compared to the costs of using diesel powered mills. Thanks to the introduction of electricity families pay 30% less for grinding their maize, while mill owners' earnings remain the same. In such conditions, there should be no problem concerning the population's ability to pay for the electricity service. Furthermore, electricity will be distributed to the users through pre-paid meters. Surplus energy will be sold to TANESCO.

In terms of domestic consumption, an annual increase of 3% is predicted to be caused by both demographic (1.4%), growth immigration (0.3%) and consumptions (1.3%). The number of schools is supposed to remain equal, however the energy demand is predicted to increase due to the extension of classrooms, use of modern material and computers, and holding courses in the evening time. Annual consumption increase will be around 3%.

A similar increase in consumption can be projected for small shops, bars and dispensaries/health centres and carpentry laboratories.

4 Energy option analysis

Several possible alternatives have been preliminarily considered to supply electrical energy to several villages in the Ludewa district.

The alternatives taken into consideration to achieve the project goals, i.e. to supply electricity to people living in rural areas under affordable costs, are:

1. to build a distribution grid in remote areas and to connect it to the national grid;
2. to build a distribution grid and to supply electricity to it by a hydropower plants in a standalone way;
3. to build a distribution grid and to supply electricity to it by a hydropower plants connected to the national grid.

Theoretically also the option to produce energy using many gen sets has been considered, but it was preliminarily rejected for the following reasons:

- cost of fuel, at present and in future (which will probably increase);
- cost of the transportation of fuel to remote areas;
- environmental impact of both fuel use and fuel transport;
- no economic fall down of fuel costs on the local economy.

Moreover, the PV technology was taken into consideration for its environmental attractiveness but it didn't pass the preliminary check because of:

- The high cost of every MWh;
- The need for accumulators, which are have a short technical life and significant managing problems;
- unattractiveness for private investors, as they aren't suitable for supplying the great amount of energy needed by industrial activities, even small, such as mills, sawmills, forgeries and so on.

The choice among the three options mentioned above has been made on the basis of benchmarks, considering technical, economic, ecologic and social aspects.

a) Technical benchmark: reliability of the energy supply;

b) Economic benchmark: cost per kWh for families in rural areas;

c) Ecologic benchmark: CO_2 emission (produced or avoided) ;

d) Social benefit for the local communities: possible investments in social services (health, school, electric grid extension and so on).

The social benefits of a power supply project for rural areas are many and similar in the case of any of the three options. What the different between the three options is the money available for social investments, mainly in the health field and for a future extension of the grid to others remote villages.

The participation of the Lugarawa hospital in the project is a great chance to address social investments in the health field in a very direct and efficient way in favour of local people.

After a careful investigation, option 3 was the best choice, because it presented the best performance for all the indicators: Technical, Economic, Ecologic, and Social.

Option 3 exploits the chance to sell the electricity produced by hydropower schemes to the national grid, thanks to the law which states the "purchase obligation" of such an energy production and a suitable tariff.
On the other side, a direct connection line is needed between the Madope SHP (stand alone hydropower plant) and the TANESCO line, for technical and safety reason. The connection with the TANESCO grid also provides the chance to supply the rural grid taking electricity from the national grid, if the SHPs are out of service, increasing the reliability of the energy supply.

5 Meteorological data and flow rate

The climate of the region is characterized by two seasons: the rain season, generally from December to April, and the dry season, generally from June to October, while May and November are transition months. Rainfall data measured at 16 rain gauging stations located near the catchment area are available. Many stations are located near Njombe town; their distance from the basin centre varies from 5 km to 60 km. The mean monthly rainfall is the average value from all the available data, and is reported (in mm) in the following table.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	*Year*
233	216	171	174	38	4	3	2	5	14	70	212	*1.142*

The Madope river has no gauging station, so no recorded data are available to characterize the river flow regime. However, the diverted water was monitored in the most critical situation, that is at the end of the dry season, by direct measuring of the water surface level in the existing culvert.
During the monitoring, the water surface level was never less than 40 cm, which means a flow rate never less than 182 l/s in the dry season, while in the rain season the flow rate is on average 251 l/s. The minimum value is quite similar to the observed one: 200 l/s.
After a further investigation of the flow regime using the data related to the rainfall, quoted in the above table, and the value of soil permeability (10%) suggested by the geologist, it was possible to obtain the following discharge data for the river in l/s.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1327	1230	974	990	354	139	132	**126**	145	202	399	1207

Actually, the minimum flow rate (126 l/s in August) is quite different from the measured minimum flow. Considering that 10% of permeability is a very conservative assumption, it is suggested to increase the value of permeability considered up to 15%. The results obtained with a 15% rate of infiltration are listed below.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1253	1161	920	935	410	195	189	**183**	202	259	376	1140

This values are also closer to the observations which report a discharge no lower than 182 l/s. At the end, the available discharge that can be diverted into the plant is:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1216	1.125	883	899	374	159	152	146	165	222	340	1104

The maximum flow rate of the scheme is stated as 500 l/s, which is available for 5 months, while the minimum technical flow is 10% of the maximum one, as the turbine will be a two-jet Pelton. Taking flow limits into consideration, we can calculate the flow (in l/s) exploited each months by the hydroelectric plant.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
500	500	500	500	374	159	152	146	165	222	340	500	338

6 Feasibility analysis results

The results of the feasibility analysis show very clearly that the hydroelectric exploitation of the Madope site is the only real and concrete chance to supply electric energy to many small villages in the Ludewa district area under affordable prices. This unique chance happens thanks to two favourable situations:

a) the existing waterfall of 460 m of head allows to build a significant hydroelectric scheme in a simple and cheap way;

b) the opportunity to sell a part of the plant energy to the TANESCO grid takes away any energy production limit due to energy consumptions, mostly in the first years of the project, and it guarantees a significant budget to develop the rural grid and the connections to the most disadvantaged areas of the district.

The indicators are very good also from economic, social, and environmental aspects:

- Economic: the excellent performance of the hydroelectric scheme and the low implementation costs, thanks to the favourable morphology of the site, ensure a relevant income, suitable to finance the maintenance of the project, which is the most important factor in its durability in the future. Moreover, the project profitability can self-finance the rural grid extension, following the increasing needs due to natural population growth and increasing energy consumption.
- Social: the hydroelectric scheme of Ludewa looks like the only chance to boost the economic development of remote villages in the Ludewa district, supplying power at affordable prices.
- Environmental: the hydroelectric scheme exploits the already existing intake structures at Madope and the old Lugarawa hydro plant, completely rehabilitated and updated, so that the environmental impacts are minimized as much as possible. Considering the significant amount of avoided CO_2 emissions and the ecological flow caused by the intake structure, the total environmental impact of the project seems very positive.

7 Technical Description

A total production capacity of 9,000 MWh/y, of which 8,400 MWh is from the new plant and 600 MWh from the old mini-hydroelectric power plant (repaired and updated), is predicted. It has been estimated that through electricity distribution a leakage of 10% will occur, corresponding to 8,100 MWh/y.

The construction of the new small-hydropower of Lugarawa can fulfil the energy needs of the 20 villages involved for a medium-long period and also to cope with unexpected consequences of major increases in consumption. The surplus of energy produced will be sold to TANESCO and connected to the grid in favour of other users. Without the selling of the surplus to TANESCO, the project would not be sustainable.

7.1 Hydroelectric works

At present there is a diversion weir around 1.5 m high and 25 m wide (across the river); the intake is also equipped with a flushing gate (leading to the river) and it conveys water through a culvert concrete tunnel, around 540 m long and with a diameter of 50 cm, with a bed slope of 0,35%. The culvert joins an open flow canal with concrete walls, some 200 m long, with a steep slope.

As to the conditions of the civil structures, the weir wall is made of concrete and it is in good condition. Some upgrading is needed to improve their reliability and usefulness: basically the works to be done are:

- raising of the right abutment wall in order to prevent floods from damaging the supply canal;
- demolition of the first 20 m of the culvert to obtain a canal, with flushing and interception gates;
- replacement of poor locally made gates and frames;
- installation of a protecting screen at the inlet of the culvert;
- some restoration work of the worn out parts and of small damages.

Also the terminal (downstream) part of the culvert has been demolished to leave place to a storage forebay tank with an accumulation capacity of at least 5,000 m^3, very useful to cover the peaks of the electricity request. In order to increase the maximum flow to 500 l/s, the existing culvert must be substituted by a new one, made of a PVC pipe with the diameter of 500 mm. The crest level of the spillway, which determines the plant head, will have an elevation equal to that of the culvert axis in the final downstream section and a length of 10 m, which allows to discharge the maximum flow of 500 l/s with a 10 cm rise in water level. The penstock, will be a steel pipe, covering all its length (1,226m) and running above ground level with a steep slope down to the powerhouse.

The external part of the penstock will lean against saddles and will be clamped at the vertices by concrete blocks located on rock. The pipe diameter will be around 500 mm.

7.2 Penstock

At the end of penstock, a small building will lodge the generation equipment, the electric panels and all the devices necessary to manage the plant in an efficient and safe way. The building's foundations will be made out of reinforced concrete, whereas the parts above ground level will be built according to traditional local techniques. Within the powerhouse or very close to it there will be the cabin for connection with the national grid, with one room dedicated exclusively to TANESCO, one for consumers and one (containing the metering equipment) accessible for both. From the powerhouse a short tailrace of 100 m will depart, simply dug in the ground, to take the turbine water back into the river.

7.3 Capacity and expected energy production

According to the available flow rate and the plant features listed above, considering the plant efficiency range between 82% (in minimum flow condition) and 84.1% (in maximum flow condition) and assuming a plant availability (very cautious, only for economical evaluation) of 85%, the annual expected energy production are:

Table 6 *Annual expected energy production, N. FROSIO,* "Hydroelectric project for rural electrification in Ludewa district" Feasibility study*, Technical Report, May 2013*

Months	Qnat	Q disp	Q hp	DE [m]	P [kW]	E [kWh]
Jan	1,25	1,22	0,50	407,37	1.680	1.062.594
Feb	1,16	1,13	0,50	407,37	1.680	959.763
Mar	0,92	0,88	0,50	407,37	1.680	1.062.594
Apr	0,94	0,90	0,50	407,37	1.680	1.028.317
May	0,41	0,37	0,37	412,05	1.273	805.316
Jun	0,20	0,16	0,16	416,93	534	326.776
Jul	0,19	0,15	0,15	417,01	512	323.877
Aug	0,18	0,15	0,15	417,09	490	310.101
Sep	0,20	0,17	0,17	416,84	556	340.139
Oct	0,26	0,22	0,22	415,90	753	476.168
Nov	0,38	0,34	0,34	413,09	1.158	708.784
Dec	1,14	1,10	0,50	407,37	1.680	1.062.594
						8.467.025

7.4 Transmission and distribution system

A three-phase transmission line of 33 kV (156 km long) is recommended to meet the country standard (TANESCO std). The design of the line remains as overhead line, aluminium conductor, steel reinforced, bare conductor (ACSR 100 mm), three conductor system with earth. The local made treated wood poles of 12 and 10 meters tall are the standard sizes. A distribution line 162 km long has to be installed in a proper distribution system to overcome low voltage and to meet distribution standards. The recommended conductor size is 50 mm aluminium PCVC insulated conductors (AAC-PVC) for the main distribution lines and 25 mm (AAC-PVC) for service lines. Step-down transformers of three types are involved to step down from 33,000 V back to 400 V.

CHAPTER III

Activities

1 Project Introduction

Tanzania is a newly developing country which in contrast with many other African countries is fortunately blessed with social peace, a necessary premise for a sustainable development. Thanks to President Nyerere indeed, economic and social policies have been implemented so as to avoid tribal wars, from which almost all African countries suffer.

Tanzania is considered one of the poorest countries in the world. This is more visible particularly in rural areas where a majority of the people don't have access to electricity or clean drinkable water.

Access to electricity and drinkable water will have many positive effects: not only will it lead to the economic growth of the country but it can also accelerate the development of rural areas. Access to clean water and electricity can largely contribute to the improvement of health conditions. For instance, the availability of electricity gives people the possibility to store food in refrigerators and gives hospitals the possibility to store medicines and blood samples. Providing electricity to remote rural clinics makes the use of important medical devices possible, and the guaranteed continuous supply of electricity could largely reduce the number of deaths due to the lack of oxygen for patients which is often caused by interruptions in the electric supply or malfunctioning of medical devices. In fact, many hospitals in need of electricity for operating medical devices are currently using generators in order to produce energy, many of which, unfortunately, can't guarantee a continuous supply.

Thanks to electricity the productivity of activities like farming, food production, clothes manufacturing and many others would increase, significantly reducing the amount of physical work each person has to do during a day. Access to electricity would also allow the use of many electrical devices such as televisions, radios, computers, etc. which could facilitate the communication between rural areas and bigger villages and towns, allowing people to keep in touch and improve their knowledge, which is a great improvement for people who usually have no idea about anything that happens outside of their village as they are so isolated.

The availability of electricity would help guarantee the existence of a continuous and efficient telephone network as important telephone companies could use electricity to feed their various repeaters. Doing this with no electricity is a serious challenge, especially during the rainy season as the roads become less accessible and it would be extremely difficult to carry oil up the mountains to feed the repeaters. Having a continuous and efficient telephone network would help locals stay in touch with the rest of the world and give them access to various media outlets. Continuing activities like education after daylight hours would be possible using electricity. The existence of electricity also reduces the need for candles and kerosene lamps which have an inherent fire safety hazard and aiding them would improve indoor air quality. Access to electricity would also accelerate the development of residential zones and simplify many commercial activities.

The project "Hydroelectric Energy for 20 Isolated Rural Villages in Ludewa District", introduced by the Non-governmental organisation ACRA, was established and continues to evolve in one of the poorest rural areas in Tanzania.
The goal of the project is to guarantee a sustainable access to electrical energy for 20 villages in the Ludewa District, Njombe Region and try to achieve the points mentioned above. The plant responsible for energy production is a small hydroelectric power plant with a power of 1.7 MW and is able to give electricity to more than 53,000 people

Figure 9 *Sign of the project*

The internship has been carried out within this project, aiming to study the power line, particularly the low-voltage line, both theoretically and practically.
The activities involved were:

- Field study of low and high voltage poles using GPS;
- Mapping of the power line using QGIS, checking the correct position of the poles and carrying out possible changes to the line where particular problems were detected;
- Comparison with existing maps;
- Checking the correct extension of cables and that the changes made would be implemented;
- Proposal for new extensions of the line creating the possibility to reach new connections, besides taking the account of the necessary materials and their cost;
- The calculation of potential differences for the existing power line and the new extensions in order to find out if more transformers were needed, calculate the number of milling machines that can be installed and their distances.
- In general, following the guidelines provided by the Site Manager, monitoring of the construction site works, checking the incoming materials and solving practical problems.

The period of stay included the end of the dry season and part of the rainy season, that is from the beginning of October 2016 until the end of February 2017.
The decision of taking part in a sustainable project in a country that is socially and culturally so different from Italy and Europe comes from the desire to put theoretical knowledge acquired during university studies into practice and using the basics learnt at the university in order to collaborate in a project of international cooperation with an NGO that aims to reduce poverty through sustainable, innovative and inclusive solutions.
The five months passed in Tanzania have been both about work and growth in human relations.

A part of the internship was about the visit and supervision of the construction site which is divided in:

- Intake: Which is equipped with a flushing gate, leading to the river, and it carries water through a culvert concrete tunnel, around 540 m long and with a diameter of 50 cm, with a bed slope of 0.35%. The culvert joins an open flow canal with concrete walls, around 200 m long, with a steep slope.

Figure 10 *Intake during the month of October*

- Pond: a storage forebay tank with an accumulation capacity of at least 5,000 m3, very useful for times of peak electricity demand.

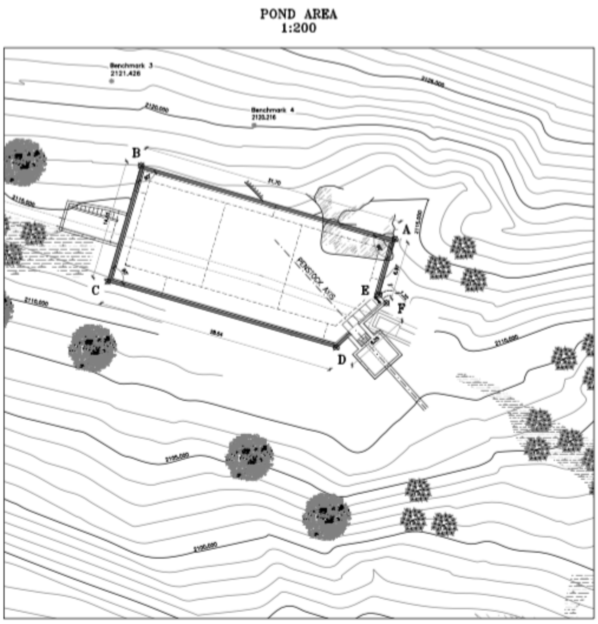


Figure 11 *Pond Area – drawn by Eng. Nino Frosio*

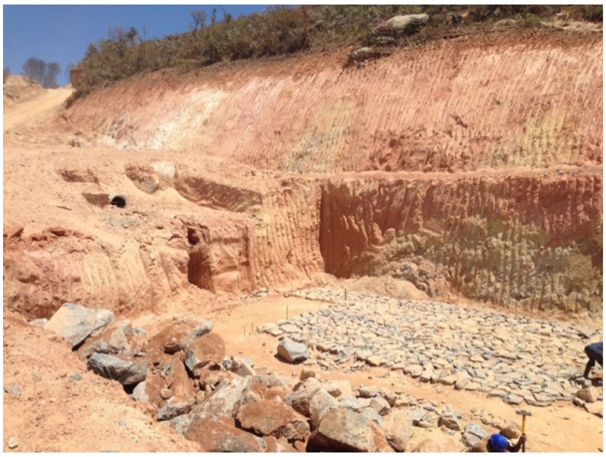


Figure 12 *Pond during the month of October*

Figure 13 *Pond during the month of December*

Figure 14 *Pond during the month of February*

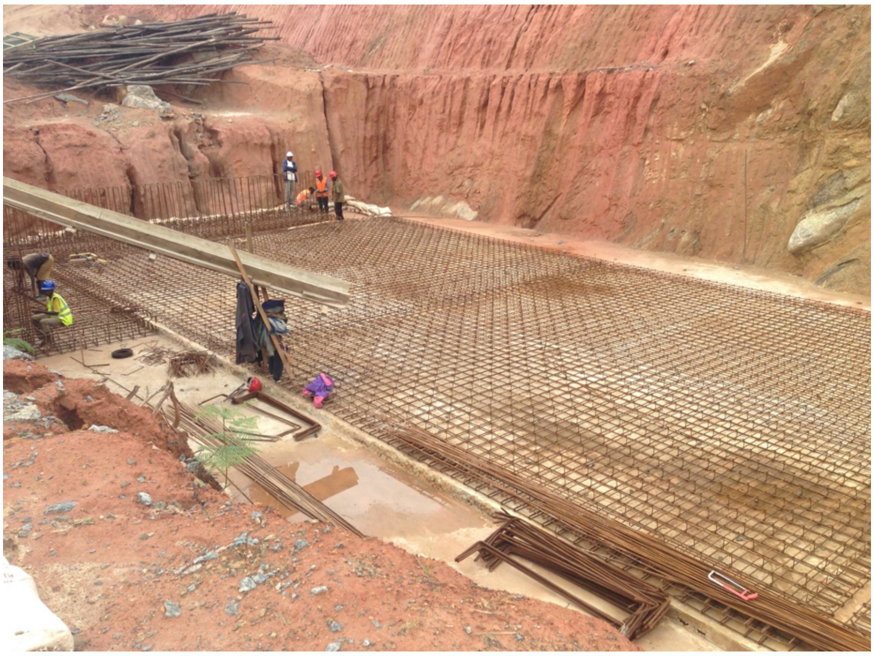


Figure 15 *Pond during the month of February*

- Penstock: The penstock, will be a steel pipe, with the length of 1,226 m, and running above ground level with a steep slope down to the powerhouse. The external part of the penstock will lean against saddles and will be clamped at the vertices by concrete blocks located on rocks.   The pipe diameter will be around 500 mm.

Figure 16 *Start of the Penstock*

Figure 17 *Pipes of the penstock*

- Powerhouse: At the end of penstock, a small building will lodge the generation equipment, the electric panels and all the devices necessary to manage the plant in an efficient and safe way. The building's foundations will be made out of reinforced concrete, whereas the parts above ground level will be built according to traditional local techniques. Within the powerhouse or very close to it there will be a cabin for the connection with the national grid, with one room dedicated exclusively to TANESCO, one for the users and one (containing the metering equipment) accessible for both. A short tailrace of 100 m will depart from the powerhouse, simply dug in the ground, to take the turbine water back into the river.

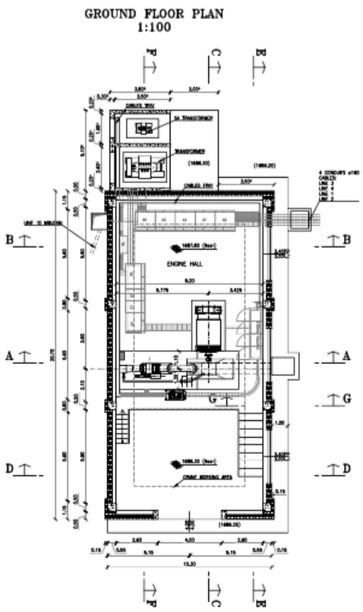
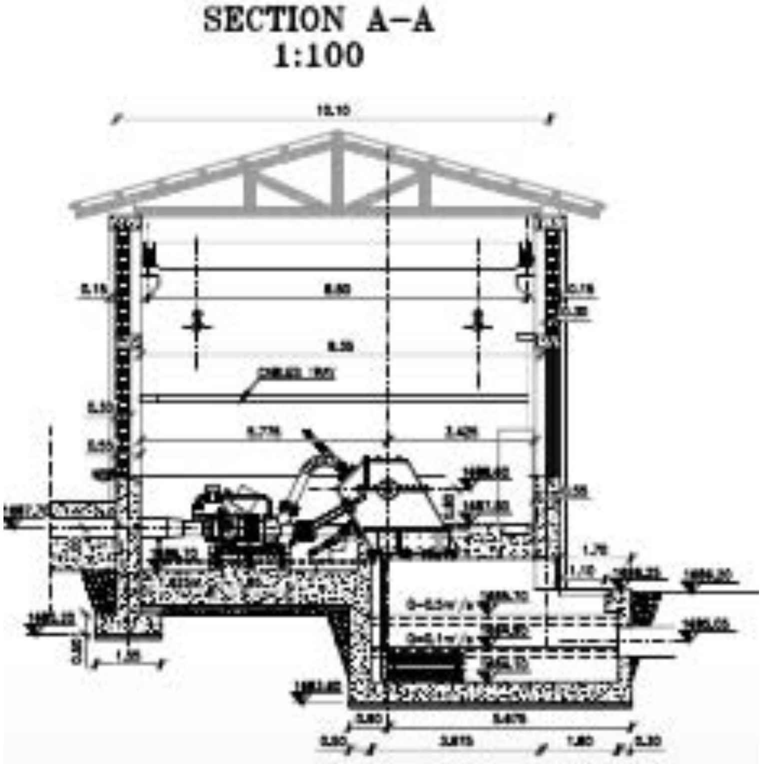


Figure 18 *Ground floor plant of the Powerhouse – drawn by Eng. Nino Frosio*



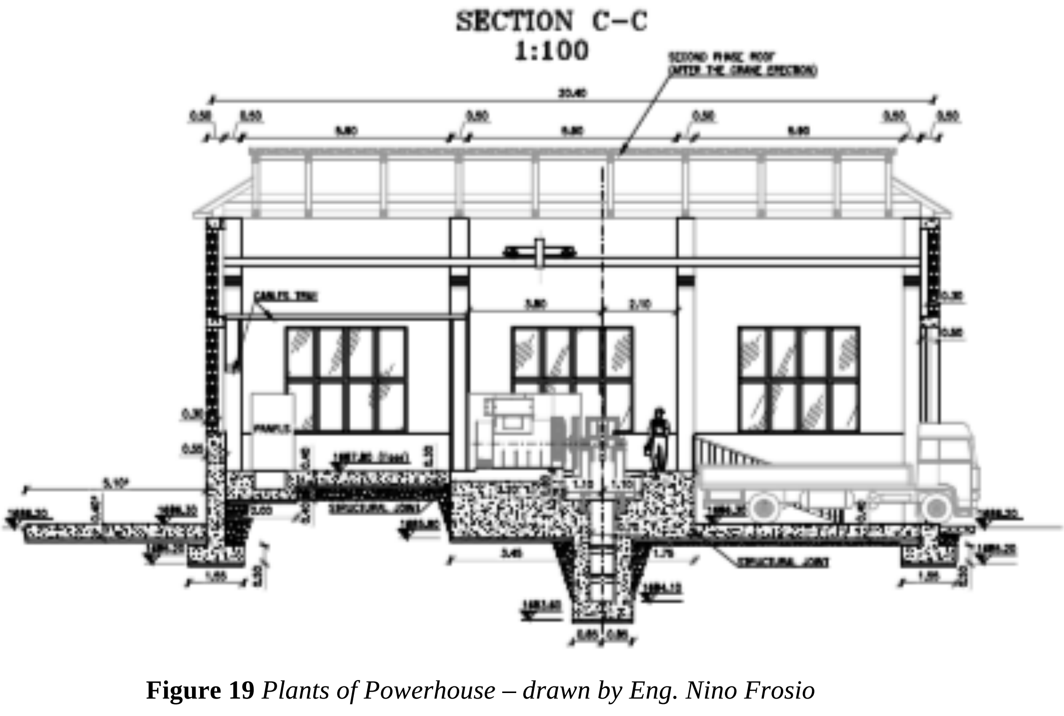


Figure 19 *Plants of Powerhouse – drawn by Eng. Nino Frosio*

Figure 20 *Powerhouse during the month of October*

Figure 21 *Powerhouse during the month of December*

Figure 22 *Powerhouse during the month of February*

Figure 23 *Turbine's lodge during the month of February*

- **Power line:** A three-phase transmission line of 33 kV (156 km long) is recommended to meet the country standard (TANESCO). The design of the line remains as overhead line, aluminium conductor, steel reinforced, bare conductor (ACSR 100 mm), three conductor system with earth. The locally-made treated wood poles of 12 and 10 meters tall are the standard sizes for medium and low voltage lines. A distribution line 162 km long has to be installed in a proper distribution system to overcome low voltage and to meet the distribution standards. The recommended conductor size is 50 mm aluminium PCVC insulated conductors (AAC-PVC) for the main distribution lines and 25 mm (AAC-PVC) for the service lines. Step-down transformers of three types are involved to step down from 33,000 V back to 400 V.

Figure 24 *Power line during the month of December*

Figure 25 *Power line during the month of February*

2 Low and high voltage poles study

During the internship every one of the 20 villages of the project has been visited, with particular attention on how the poles of the electrical line were installed, highlighting possible issues which are shown below.

Simultaneously, each LV and MV pole of the power line was marked by means of GPS and later office work was done during which the GPS data were loaded on QGIS and the low power line of each village was drawn.

QGIS (previously known as Quantum GIS) is a cross-platform free and open source desktop geographic information system (GIS) application that provides data viewing, editing, and analysis. Just as other software GIS systems, QGIS allows users to create maps with many layers using different map projections. Maps can be assembled in different formats and for different uses. QGIS allows maps to be composed of raster or vector layers. Typical for this kind of software, the vector data is stored as either point, line, or polygon feature. Different kinds of raster images are supported, and the software can dereference images.

All the following maps have been drawn by QGIS:

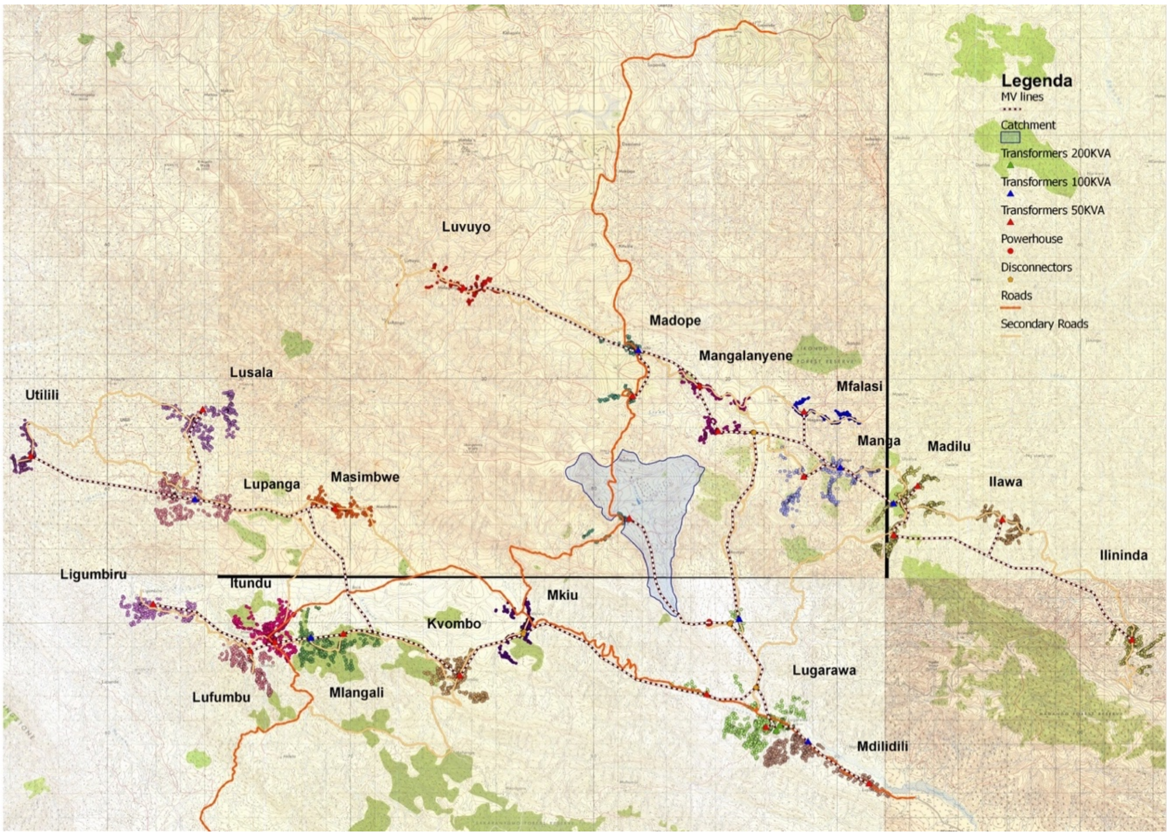


Figure 26 *Map of the 20 Villages of the project*

Working with the computer it was possible to have a more global view of the power line and it was easy to underline the places were specific problems could occur.

In fact, often it was necessary to go to various villages personally to verify the correctness of the line. Sometimes on the drawing sketched on QGIS the lack of some poles was observed, but going to site different problems could be detected, like:

- Effective lack of the pole;
- Excessive distance between one pole and the next;
- Presence of a dip and impossibility to install an additional pole;
- Crossings roads;
- Obligation caused by the Tanzanian law to install the poles 30 meters far from the centre of the road;
- Presence of buildings or other structures.

To cope with these issues, some solutions have been researched that have often caused changes to the line. For instance, in some parts it was necessary to shift the poles to others positions or

it was necessary to add a new pole, so that the maximum distance between two LV poles of 10 meters tall was at most 50 meters and that a larger area could be covered.
Another change of the line was thought for the villages of Mlangali and Ligumbiru. For these the possibility to save one transformer was proposed. Effectively, the line of these two villages was designed for two transformers, because the two villages are composed of two different parts and therefore difficult to connect using only one low voltage electrical line supplied with just one transformer.
For Mlangali this idea proved to be impractical since there were a large number of inhabitants and a large area to be covered, therefore the presence of both transformers was necessary.
For Ligumbiru instead, since it is a small village, the possibility of transferring one of the transformers between the two main centres of the village and taking advantage of the presence of the high voltage poles between these two parts to build a part of the underline was proposed, in this way the other transformer would be saved.

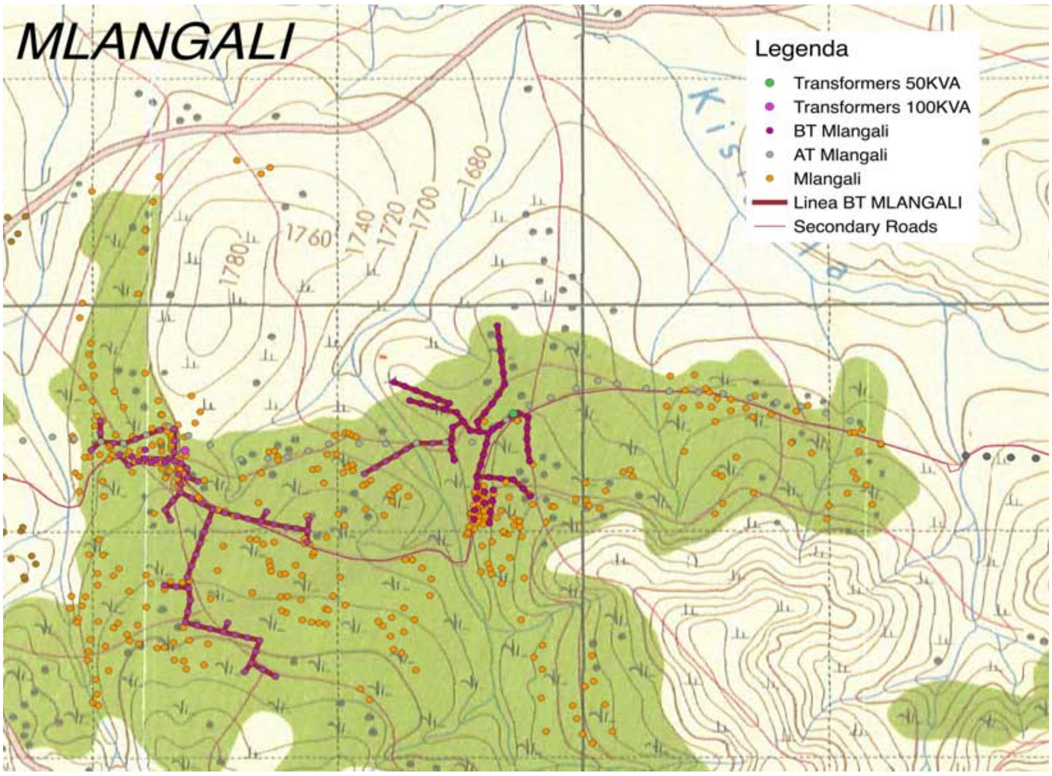


Figure 27 *Mlangali Village power line*

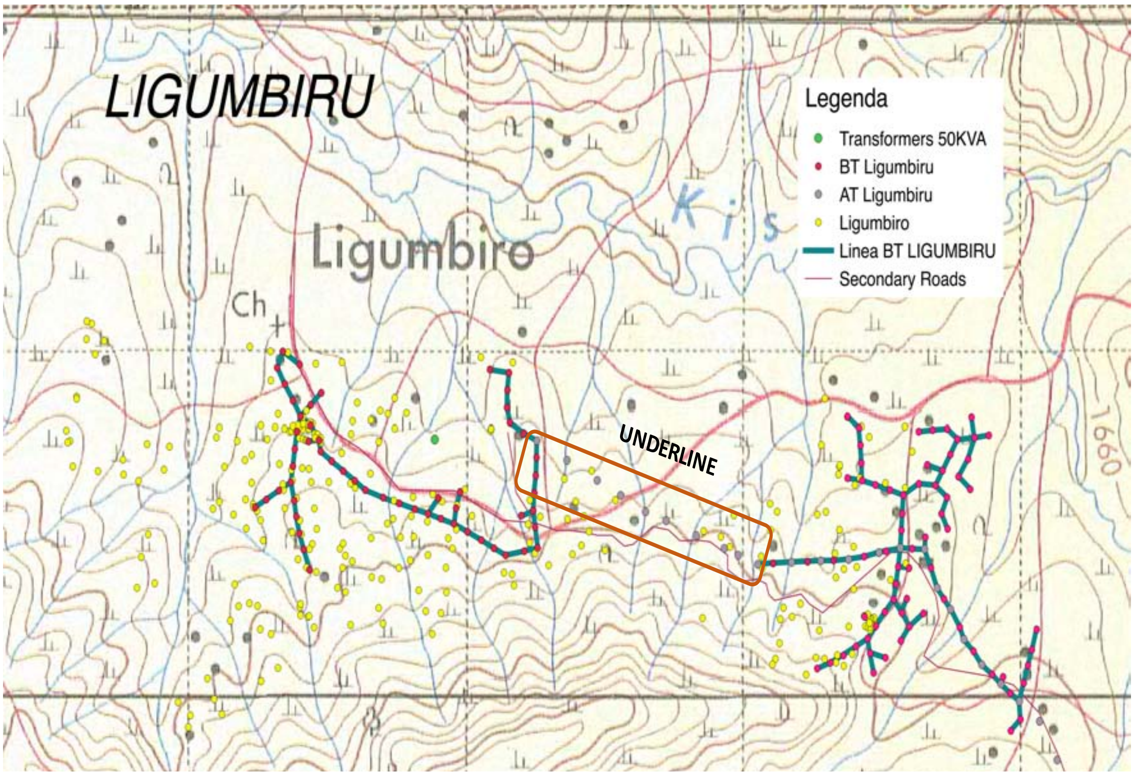


Figure 28 *Ligumbiru Village power line*

Once the drawing of the LV line was complete and the paper check of the LV line was finished, the supervision of the correct stringing line along the LV and MV line and of the installation of sand isolator on the MV poles started.

During this step it was fundamental to report to the authorized personnel for the fastening of the cable where the changes have been done on the line and to verify that these modifications would be applied.

In addition, a comparison with the existing maps was done. It was verified that the declared poles from the contractors are those actually revealed by the GPS.

The following are the maps of some villages:

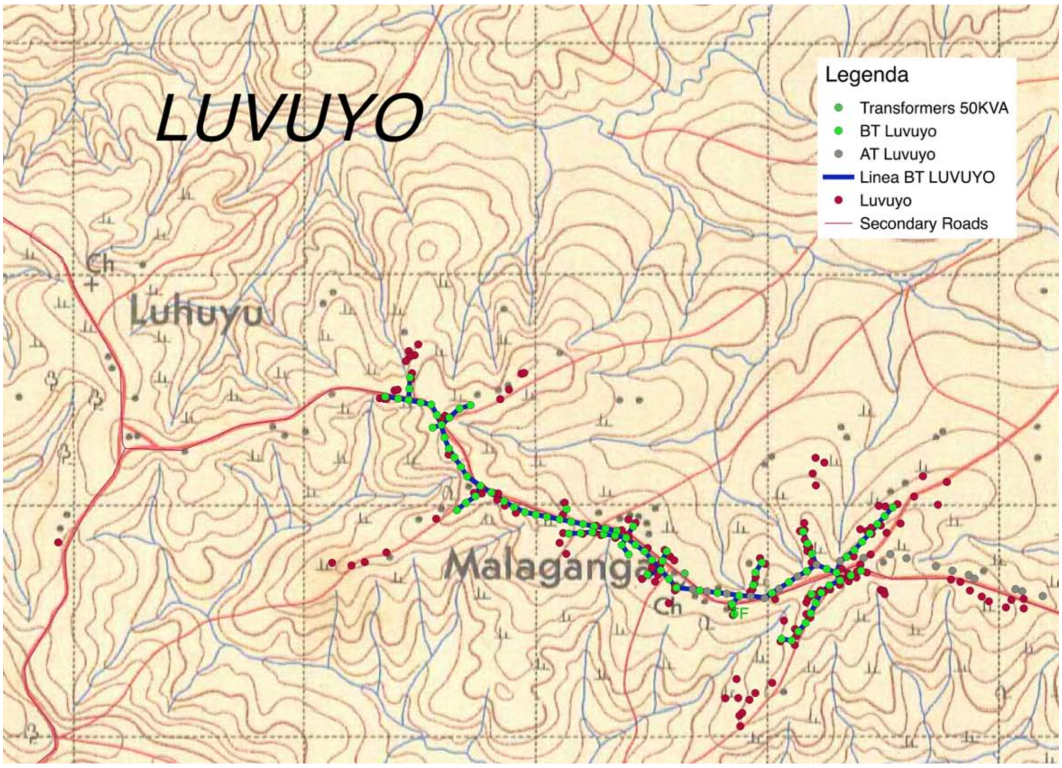


Figure 29 *Luvuyo Village power line*

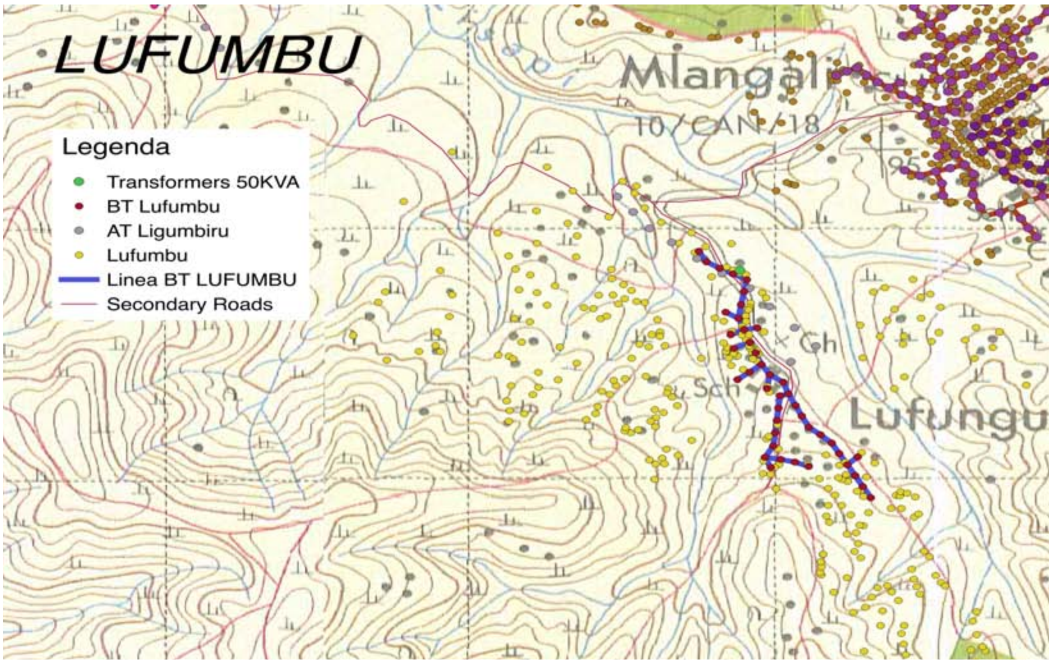


Figure 30 *Lufumbu Village power line*

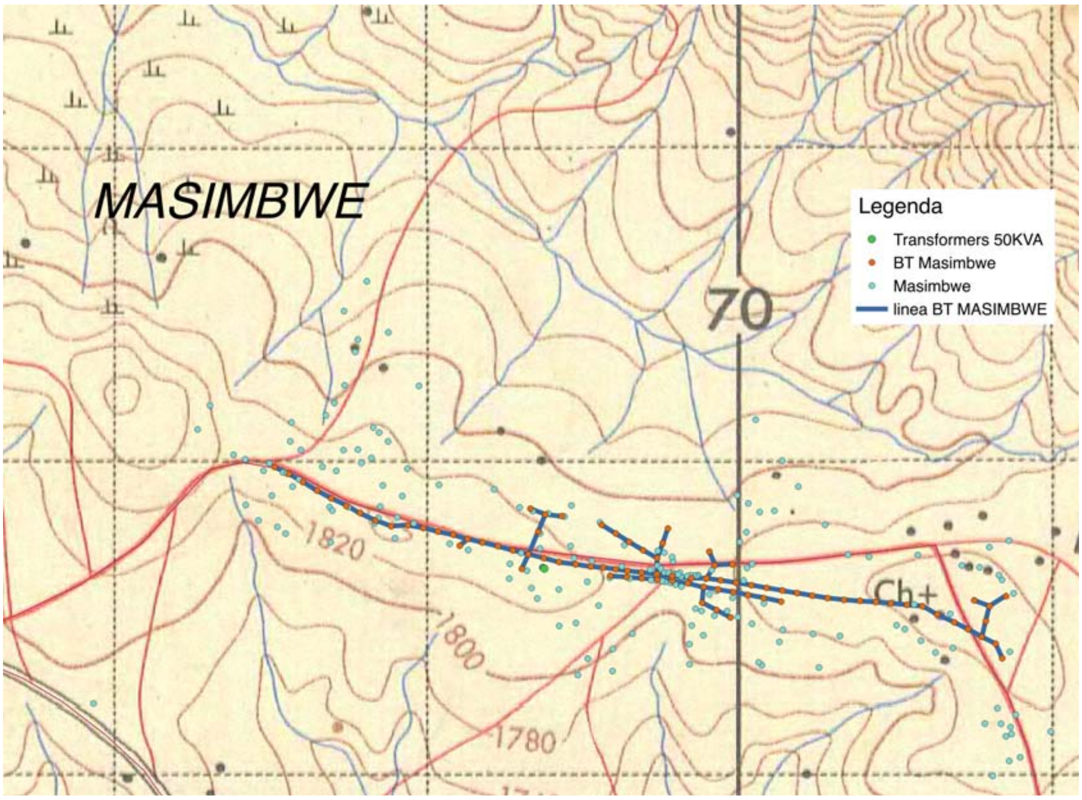


Figure 31 *Masimbwe Village power line*

3 New extensions of the electrical line

In recent months, the project has received some new financing from REA, thus probably guarantying an extension of the line. Rural Energy Agency (REA) is an autonomous body under the Ministry of Energy and Minerals of the United Republic of Tanzania. Its main role is to promote and facilitate improved access to modern energy services in rural areas of Mainland Tanzania. REA became operational in October 2007.

In addition to the control of the line under construction some possible new extensions were thought of and proposed, which will be possibly extending the line in places of more importance, where for instance there is a large density of population and in places where there are major service buildings for the society of the village.

During this first analysis of the new extensions it was necessary to make some decisions regarding the people and in that particular case it was chosen which consumers will be reached by the power line in the future and who instead will be destined to remain disconnected from the line still for many years. Because the most important buildings were already reached by the

current power line it was not a concrete choice as all the houses and families have almost the same life standard and the same needs of electricity and in this first preliminary analysis the selection of consumers was done on a random basis.
Sometimes we face decisions that interest not just ourselves but many people and in this case all the society of the villages. We are responsible for the future life of these inhabitants, without knowing who they are, who they will become, or how many problems they will have.
Working for this first study using a computer, it was easier to decide which houses will be reached by the new line and which will remain isolated. It's already known that each of these families would like to be connected to the line, so there is not only one parameter to consider or maybe there is no real criterion, but often there are no others alternatives and we have to decide about many lives without really realizing it.

It is possible to divide the consumers of the new connections in three different categories:

- Low cost consumers (close to the electrical line);
- Medium cost consumers;
- High cost consumers (very far from the electrical line).

It is important to think about which kind of consumers are better to be connected to the power line and for that choice there are two alternatives:

1. connect more people, but of the "low and medium cost consumers", i.e. the consumers that are closer to the already existing electrical line;
2. connect less people but the consumers in farther areas, i.e. the "high cost consumers".

Some pictures of the new extension thought for some villages are shown below:

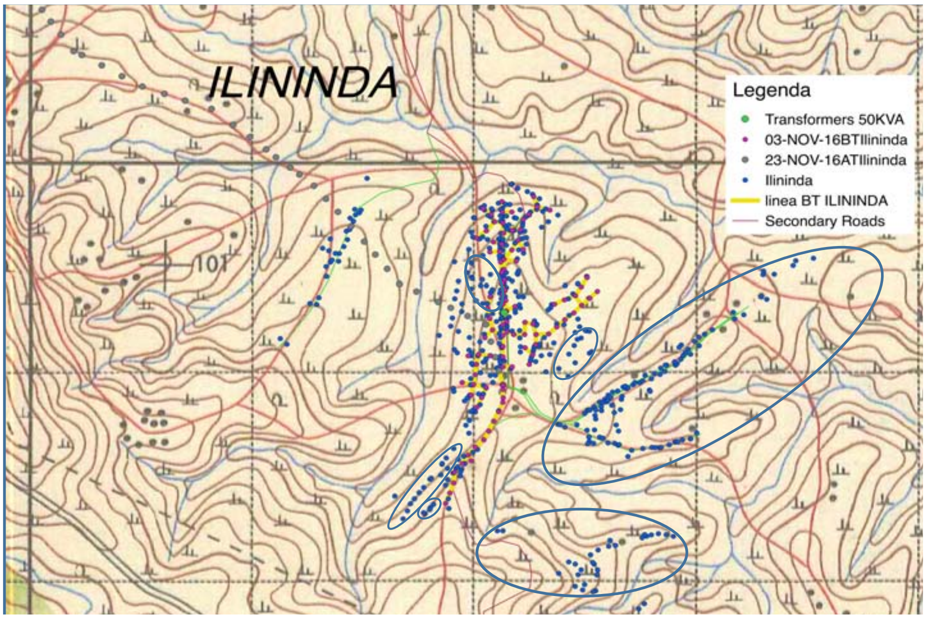


Figure 32 *Ilininda Village with the new extensions of the power line (shown inside blue circle)*

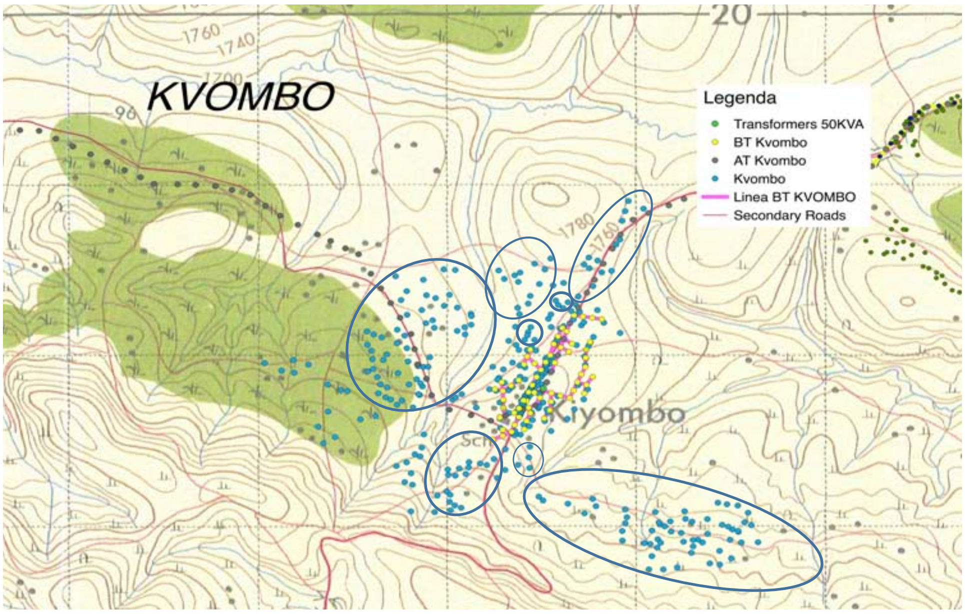


Figure 33 *Kvombo Village with the new extensions of the power line (shown inside blue circle)*

For the choice of the new extensions, both of the last two alternatives have been taken into account. The first one in easier to implement, because in most of the cases it will be necessary to add just one or few poles with some hundred meters of cable to connect the new houses, but it's also true that in the future, if one of these consumers wants to be connect to the line, they just have to ask for the addition of one pole with 50 meter of cable from the village and it will not be a large cost for the society. The second alternative is more expensive than the first.

Sometimes it is necessary to add many poles and many meters of electrical cable to reach the new consumers, but in this way we are creating the possibility to have a power line also where currently there are no houses and so that would be a motivation for the growth of new buildings and commercial activities in those areas.
For this alternative sometimes the possibility to extend the medium voltage line and to put a new transformer was thought of, in order to reach also the farther areas. This could be an advantage for the people of the villages, because in the future they will not have the possibility to extend the medium voltage line and to add new transformers because it would be too expensive and therefore it would be less complicated for them to follow the first alternative.
For a preliminary analysis not just one of these alternatives but a combination of both was taken into consideration.

In a first investigation, the evaluation of the new connections was carried out considering only the maps of the villages and choosing areas with a higher density of buildings. After that just for some villages an inspection of the newly planned extensions was done, but not for all the 20 villages. It was not possible to do a precise research because the available time was short and the weather conditions didn't allow that. In fact, the last months of the internship were conducted during the rainy season and it was complicated and dangerous to reach the villages. Therefore, it was decided to visit just the villages close to Lugarawa, the biggest village with the largest number of inhabitants for a second time, as it is also the location of the main office of the project.
Through inspection and by asking information through phone conversations with the heads of the villages, it was verified that the most important buildings like the hospital, dispensaries, schools, municipalities, churches and others were already fitted with LV poles.
In the extensions of the line, new buildings, which have been built in the last two years or are still under the construction, have to be taken into consideration. These new buildings are essentially modern houses comparing to what the standard of a rural village in Tanzania currently is. This would, in addition to lights for illumination, allow the use of many household electrical appliances like refrigerators, washing machines, electric iron, television, and any other appliances that these people are able to buy in the future, due to their financial status, in contrast to the less wealthy villagers of the older housing system.

Below you can find the maps of some of the villages containing houses that will get the extension of the line.

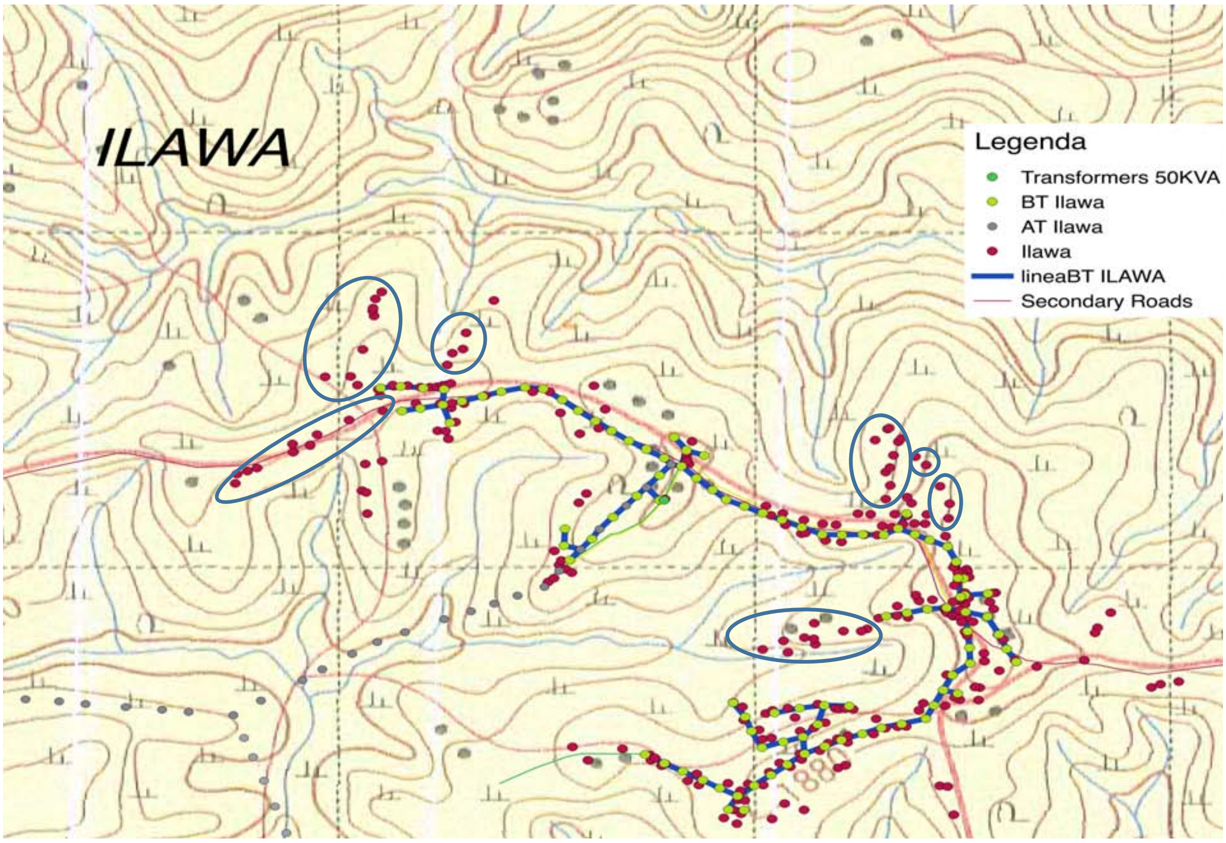


Figure 34 *Ilawa Village with the new extensions of the power line (shown inside blue circle)*

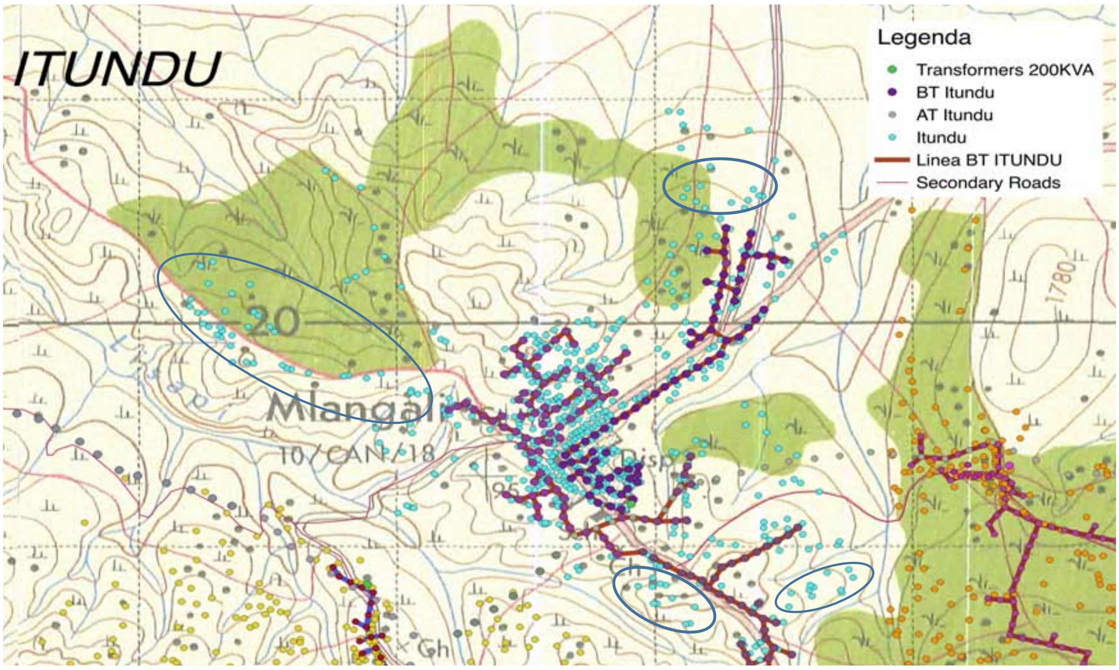


Figure 35 *Itundu Village with the new extensions of the power line (shown inside blue circle)*

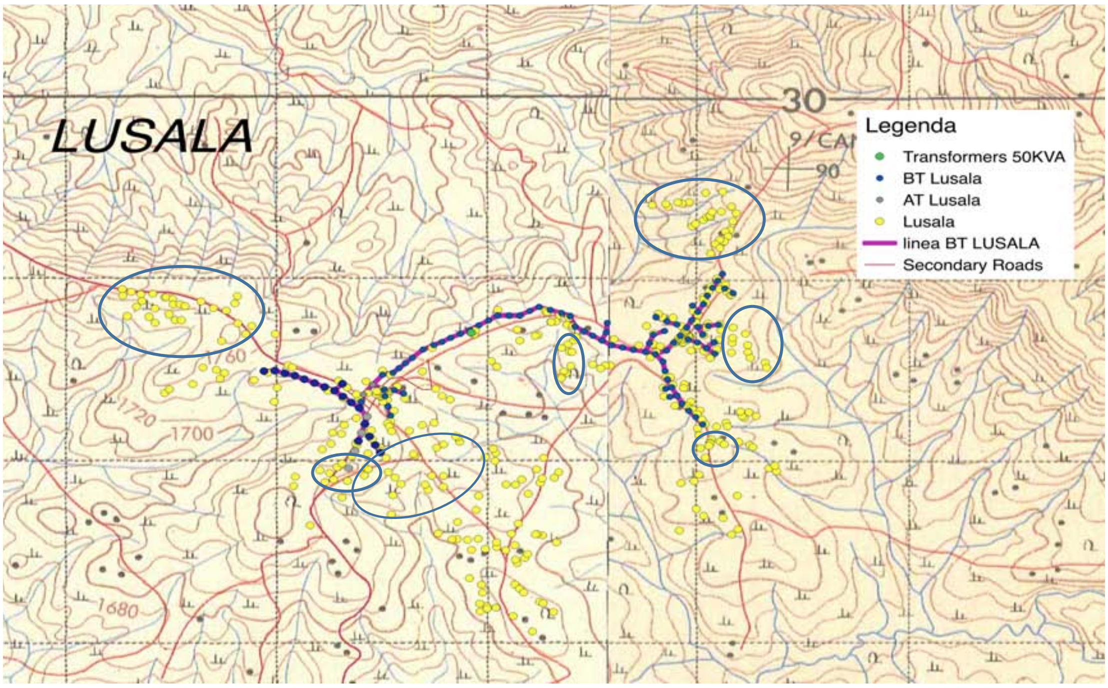


Figure 36 *Lusala Village with the new extensions of the power line (shown inside blue circle)*

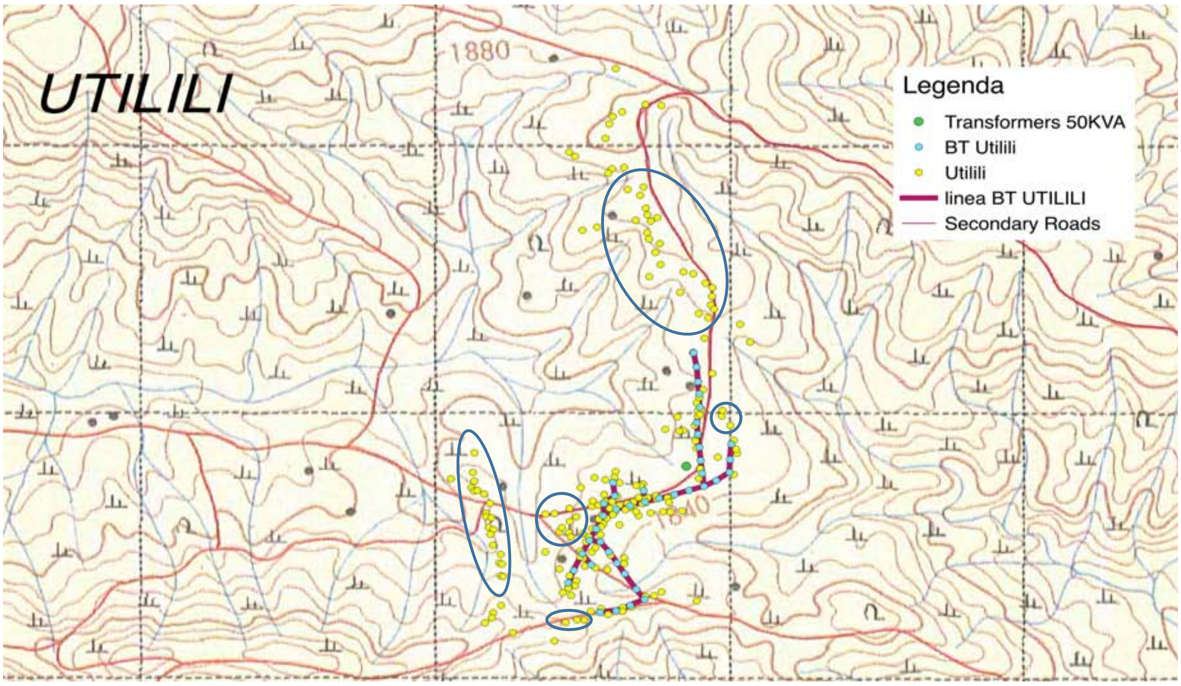


Figure 37 *Utilili Village with the new extensions of the power line (shown inside blue circle)*

After that the necessary amount of materials needed for the new extensions was estimate and also a preliminary estimate of the costs of these materials was done.

Having estimated the costs of the materials and the work done for the extensions of the power line, it was possible to compare these costs for all the 20 villages with the amount financial aid received from REA.

The evaluation done for Mfalasi village is shown below.

Just as in the case of all other villages, the number of low-voltage and medium-voltage poles available inside the village was counted, and then the number of houses already within reach or outside the reach of the power line of the actual electric plant was calculated. After that, the number of houses that could access electricity with the new extension was estimated using the maps of their villages. For Mfalasi, 28 buildings out of 30 could be reached by the extension, but not every village will have such good results.

In fact, in Table 8 below it is possible to see that after the new extension of the power line, still 1,286 buildings will not be reached by the line, because they are too far from the main line or are too difficult to reach because of natural obstacles. For these houses it would be necessary to find some alternatives in order to supply them with electricity and therefore it a preliminary study was carried out to install some photovoltaic plants for these houses, which will be explained in the next section.

For the new connections for each village the costs of all materials and of the works that have to be done was estimated.

The costs of the new connections consist of:

- Extra cable cost per meter [Euro/m];
- Cable cost (dressing):
    - Tension/Suspension clamp (3 for each pole);
    - LV Tension Bolt (2 for each pole);
    - Parallel groove clamp (2 for each connection);
    - Stay set (1 for each 4 poles);
- Extra LV and MV poles cost;
- Work cost;
- Meters cost;
- Installation cost of meters;
- Transformer cost.

In Table 9, the complete cost of the new extension of the line has been shown.

This was just a preliminary cost analysis, in fact currently a coordinator in Dar es Salaam is in charge of giving a detailed estimate of the real cost, using the list of all the necessary materials for the new line; so that a better comparison with the financial aid received from REA can be made.

Table 7 *Mfalasi Village (Number of poles and cost of new extensions)*

MFALASI

POLES	
BT	AT
70	1

Reached houses	Not reached	Total houses
117	30	147

NEW CONNECTIONS		
poles	cables [m]	new connections
16	800	23
3	150	5
19	**950**	**28**

COST		
N°connections	28	
Extra cable	950	m
Extra poles	19	
Pole cost	239000	Tsh
Total poles cost	4541000	Tsh
Total poles cost	1970	€
€/m cable	3,77	€/m
Total cable cost	3582	€
Cost extra cable	2450500	Tsh (dressing)
Cost extra cable	1063	€ (dressing)
Works cost	2500	€/km
Total Works cost	2375	€
TOTAL COST	**8990**	€

Table 8 *Materials need for the extensions*

Villages	POLES LV	POLES MV	CONNECTIONS Reached	CONNECTIONS lenght connec. [m]	NEW CONNECTIONS poles LV	NEW CONNECTIONS cable [m]	NEW CONNECTIONS new connection s	NEW CONNECTIONS cable single houses	houses not reached by the actual line	houses not reached by new extension	total houses
Luvuyo	88	10	101	4764	30	1510	31		44	13	145
Madope1	49	7	249	5710	18	990	22		26	38	309
Madope2	65	2							16		
Madope3									18		
Mangalanyene1	88	5	192	7591	48	2400	68		43	16	276
Mangalanyene2	58	19							41		
Mfalasi	70	1	117	3484	19	950	28		30	2	147
Manga	136	22	256	7641	64	3200	122		159	37	415
Madilu1	99	16	456	9393	119	5950	208		162	27	691
Madilu2	83	4							73		
Ilawa	99	6	181	5014	30	1500	48		69	21	250
Ilininda	99	3	241	4817	86	4300	163		200	37	441
Mkiu	103	14	208	5733	18	900	26		57	31	265
Kvombo	66	8	117	3342	124	5700	173		214	41	331
Mlangali	130	9	156	6465	81	4050	112		223	111	379
Itundu	194	8	458	9972	52	2600	72		144	72	602
Lufumbu	43	1	77	2099	67	3350	110		204	94	281
Ligumbiru	124	23	133	7976	21	1040	31		126	95	259
Masimbwe	76	10	89	4281	29	1450	36		92	56	181
Lupanga	97	3	183	4992	34	1700	61		271	210	454
Lusala	96	6	160	5097	80	4000	112		219	107	379
Utilili	41	1	107	1508	36	1800	59		88	29	195
Lugarawa	209	28	626	11702	0	2227	0		165	165	791
Mdilidili	80	7	347	4459	16	800	28		112	84	459
TOTAL	**2193**	**213**	**4454**	**116040**	**976**	**50417**	**1510**	**73990**	**2796**	**1286**	**7250**

Table 9 *New extensions cost*

NEW CONNECTIONS COST [€]	METER COST NEW CONNECTIONS Single-phase 30 $ = 28.04	Three-phase 84 $ = 78.51	Installation 50000 Tsh = 21 €	Transformer Cost [€]	Extra MV poles cost [€]	Cable MV cost [€]	Total cost new connections [€]
14143	729,04	392,55	651				
9042	476,68	392,55	462				
		392,55					
		392,55					
22689	1766,52	392,55	1428	4316,6	1520		
		392,55					
8990	644,92	392,55	588				
30523	3280,68	392,55	2562				
56591	5692,12	392,55	4368	4316,6	1520		
		392,55					
14228	1205,72	392,55	1008				
41008	4430,32	392,55	3423	4316,6	1520		
8513	588,84	392,55	546				
55454	4710,72	392,55	3633	4316,6	1520		
38263	3000,28	392,55	2352				
24565	1878,68	392,55	1512				
31800	2944,2	392,55	2310				
9874	729,04	392,55	651				
13664	869,24	392,55	756				
16182	1570,24	392,55	1281				
37803	3000,28	392,55	2352				
17086	1514,16	392,55	1239				
13963	0	392,55	0				
7609	644,92	392,55	588				
545980	**39676,6**	**9421,2**	**31710**	**17266,4**	**6080**	**1600**	**651734,2**

Observing the number of new possible connections, particular attention was paid to the fact that new connections should not be more than 2 kilometres far from the existing transformers. In cases where the distance was more, it was necessary to think of the possibility of adding a new transformer. Only for four of the villages of the project are new transformers expected to be ordered. To understand if there is such a necessity, the potential differences for some of the villages were calculated in order to obtain the maximum possible distance from the transformer and the connectible loads. To calculate the potential differences, first a single phase load was simulated. After that a three phase load and then the potential difference for the case of more than one load fed from the same transformer, was calculated.

During the study of the new extensions it was possible to divide the consumers in three main categories:

- Consumers already connected to the line;
- Consumers that will be reached by the extension of the line;
- Consumers that will not be reached by the line neither now, nor after the extension.

For the last group, an alternative for the supply of electricity might be provided, given it has about the same cost of installation as the new connections.

4 Alternative new connections

There will be many houses that will not be reached by the new extensions of the line and therefore will not have electricity. For these buildings it is convenient to think about some alternative that would have around the same price as the new extensions.
In fact, sometimes it is not efficient to connect just one or some houses to the power line by the new extensions, especially if they are isolated. In that case it is better to search other alternatives so that to permit everyone to have access to electricity.
In order to give each building an independent access to electricity, for the remaining houses (about 1,300) which will not be connected to the power line, the possibility to install rooftop photovoltaic modules was considered.
This plant will be integrated with an energy storage system, in order to provide energy for each house also during the hours of darkness, since almost 6.30 p.m., when the sun usually sets, until midnight. During the day, when the sun is shining, the PV module will supply the necessary energy to the users allowing the use of almost the power of 1 kW, assuming that each house should have around three led lights, potentially a television and a radio.

For a PV plant of this size the main elements for the installation are:

- 4x PV modules of 250 W;
- 1x MTTP 1,000 W;
- 2x batteries AGM 12V, 200Ah.

There are also other necessary materials, like the cable, the objects needed for the installation of the modules on the roofs and a 12V/6V transformer for radio and mobile phones.
For these materials, an estimate was not calculated as their costs are much lower than the cost of the modules, MTTP and the batteries. In fact, the real costs of these materials multiplied by the number of houses not connected to the power line (around 1,300) was asked from Dar es Salaam.

In this way all the buildings of the 20 villages in Ludewa District would be able to have electricity during the next few years and this choice could avoid the growth of social inequality between the people of the villages. In fact, sometimes some choices and interventions have been done for giving electricity to some people instead to others, without real justification.

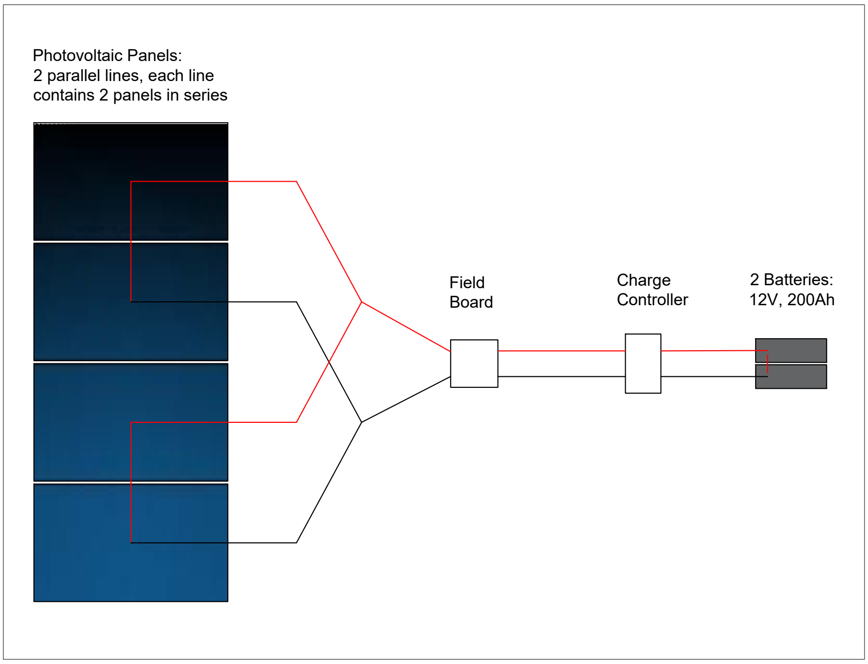


Figure 38 *PV project plant*

Table 10 *Cost of materials*

QUOTATION FOR SUPPLY OF SOLAR EQUIPMENTS								
					Currency TZS			
No.	ITEM	DESCRIPTION	QTY	UNIT	UNIT PRICE	SUB-TOTAL	VAT	TOTAL AMOUNT
1	Solar Panel	Crystalline,250Wp/24V	5200	pcs	700,000.00	3,640,000,000.00	N/A	3,640,000,000.00
2	Solar Battery,Maintanace free	AGM 200Ah/12V	2600	pcs	850,000.00	2,210,000,000.00	N/A	2,210,000,000.00
3	Solar Charge controller	MPPT 80A/150V Max	1300	pcs	1,950,000.00	2,535,000,000.00	N/A	2,535,000,000.00
			GRAND TOTAL			8,385,000,000.00	N/A	8,385,000,000.00

As it can been see from the quotation, the cost of the necessary materials for the installation of 1300 photovoltaic plants, is excessively high.

The cost is so high for two main reasons:

- The required and predicted materials for the photovoltaic plants are not easily available in Tanzania and so they must be brought from abroad;
- Recently import regulations have changed so that 20% will be added to the final cost.

The costs are in Shillings and as exchange rate, it is possible to assume that approximately one Euro is 2,000 Shillings.

The fact that the plant has been oversized must also be considered, because each family will need at most 200 Watt. However, even if the plant alone had an inferior size, the final cost would have been nevertheless very high.

Instead, to guarantee to each family a minimum power of 50 Watt, enough power for using some lights and charging mobile phone, it should be possible to propose the photovoltaic plant again using a photovoltaic panel of 50 Watt with a battery of 100 Ah for each household. The estimated cost is around 250 Euro, which, multiplied by the number of households in which the photovoltaic plant must be installed would be:

$$Final\ cost = 250Euro * 1300 = 325.000\ Euro$$

This cost is surely more affordable than the first photovoltaic plant that was thought at the beginning.

The medium consumption of the families is so low because the household in rural areas follow the solar cycle, following the day-night succession, using electricity for illumination just during dark hours. Moreover, charging mobile phones will require less power compared to European mobile phones, because phones used in rural areas are not modern phones and for these it would be enough to charge once a week.

If any of the money received by ACRA from REA remains, with that it could be possible to think about the possibility to install mini photovoltaic plants of 50 W for these houses that will not be reached by the electrical line.

The cost for each beneficiary of the hydroelectric plant under construction is 141,79 Euro, considering that for each photovoltaic plant there will be a cost of around 300 Euro, during next months it should be appropriate to find other new valid alternative solutions for all those households that will not be reached by the power line, that would be competitive from an economic point of view with the cost of the beneficiaries of the hydroelectric plant.

In this way, guaranteeing electricity access for everyone, it is possible to avoid the growth of social inequality within the villages.

5 Potential difference evaluation

To understand how many milling machine could be installed in a single village and to understand how far the power line could be extended, the potential differences for some of the villages were calculated. This would also help estimate the maximum possible distance from the transformer and the maximum number of connectible loads. In order to calculate the potential differences, first a single phase load, then a three phase load and then the case of more than one load fed from the same transformer, were simulated.

Some particular loads have been chosen for the study, such as:

- minimum loads (0,2; 0,3; 0,5 and 1,0 kW)
- high loads (15 kW), like mills, machines of carpentries, etc.

General power line data:

U_n = 400 V

f = 500 Hz

S_{T1} = 100 kVA (transformer 1)

S_{T2} = 150 kVA (transformer 2)

S_{T3} = 200 kVA (transformer 3)

$U_{\%} \leq 3\%$ (lights)

$U_{\%} \leq 10\%$ (motors)

Cable data:

S_1 = 25 mm^2 (cross section)

d_1 = 6,5 mm (external diameter)

$r1_{20°C}$ = 1,200 Ω/km

I_{1max} = 107 A

S_2 = 50 mm^2 (cross section)

d_2 = 8,6 mm (external diameter)

$r2_{20°C}$ = 0,641 Ω/km

D_{12} = D_{23} 0,75 m (distance between the three conductor cables)

D_{31} = 1,50 m

I_{2max} = 165 A

To find the inductance of the cable the following equation can be used:

$$\mathrm{Le} = 0{,}05 + 0{,}46 * \log_{10}\left(\frac{2 * \mathrm{D}}{\mathrm{d}}\right)$$

Where D is:

$$\mathrm{D} = \sqrt[3]{\mathrm{D}_{12} * \mathrm{D}_{23} * \mathrm{D}_{13}} = 0{,}945\ \mathrm{m}$$

For the two cables we can find:

$$\mathrm{L}_{1e} = 1{,}183\ [\frac{\mathrm{mH}}{\mathrm{km}}]$$

$$\mathrm{L}_{1e} = 1{,}127\ [\frac{\mathrm{mH}}{\mathrm{km}}]$$

So we can find the reactance of the line:

$$\mathrm{x}_1 = 2\pi \mathrm{f} \mathrm{L}_1 = 0{,}372\ \Omega/\mathrm{km}$$

$$\mathrm{x}_2 = 2\pi \mathrm{f} \mathrm{L}_2 = 0{,}354\ \Omega/\mathrm{km}$$

In the manual for the cable we can only find that the resistance per kilometre at 20°C. Thus it will be necessary to calculate the resistance per kilometre at the working temperature of the cable, using:

$$\mathrm{r}_{\vartheta} = \mathrm{r}_{20°\mathrm{C}} * [1 + \alpha * (\vartheta - 20)]\ [\frac{\Omega}{\mathrm{km}}]$$

Where θ is the working temperature of the cable in centigrade, with which the resistance must be calculated. Since we are on the equator we can assume the working temperature of the cable to be around 70°C.

α is the temperature coefficient of resistance and for aluminium cables it is:

$$\alpha = 4{,}03 * 10^{-3}\ [°C^{-1}].$$

The resistance per kilometre will increase by 2 ÷ 3 % for the following reasons:

- Increased effective length of the cable comparing to the topographic length of the line;
- Additional losses;
- The skin effect phenomenon
- Hysteresis and parasitic losses;

So we can compute r as below:

$$r = 1{,}03 * r_{\vartheta}$$

Considering all of the facts above, we can calculate the resistance per kilometre at 70°C to be:

$$r1_{70°C} = 1{,}485\ \Omega/km$$

$$r2_{70°C} = 0{,}792\ \Omega/km$$

Small loads' data:

P1 = 0,2 kW

Q1 = 0,0968 kVar

cosφ = 0,9

P2 = 0,3 kW

Q2 = 0,145 kVar

cosφ = 0,9

P3 = 0,5 kW

Q3 = 0,242 kVar

cosφ = 0,9

P4 = 1,0 kW

Q4 = 0,484 kVar

cosφ = 0,9

Maximum load data:

P = 15 kW

Q = 7,26 kVar

cosφ = 0,9

Now the active and reactive currents of the minimum loads of 0.3 kW and 1 kW and the maximum load of 15 kW can be calculated as below:

$$I_{0,3a} = \frac{P}{U_n}\ [A] = 0{,}749\ A$$

$$I_{0,3r} = \frac{Q}{U_n}\ [A] = 0{,}362\ A$$

$$I_{1a} = \frac{P}{U_n}\ [A] = 2{,}49\ A$$

$$I_{1r} = \frac{Q}{U_n}\ [A] = 1{,}209\ A$$

$$I_{15a} = \frac{P}{\sqrt{3}U_n}\ [A] = 21{,}65\ A$$

$$I_{15r} = \frac{Q}{\sqrt{3}U_n}\ [A] = 10{,}48\ A$$

We have chosen to consider only the minimum load of 0.3 kW for now, as it will be the power used most by the consumers. Some will use slightly higher power, but the majority will use less, as electricity will be used mainly for lighting and sometimes charging mobile phones.

Now we will calculate the potential differences in different cases, considering the maximum potential difference permissible to be 3% for lights and 10% for motors.

For simplicity we assume that there is one single load attached to the end of the line and that the electrical current comes from a transformer that converts medium voltage to low voltage (33000V to 400 V).

Figure 39 *Transformer connected to one load*

So we assume the maximum potential difference to be:

$$\varepsilon = \frac{\varepsilon_{\%}}{100} * 400 = \frac{3}{100} * 400 = 12 \text{ V for lights}$$

$$\varepsilon = \frac{\varepsilon_{\%}}{100} \frac{400}{\sqrt{3}} = \frac{10}{100} \frac{400}{\sqrt{3}} = 23 \text{ V for motors}$$

For both the above cases we can write the following formula:

$$\varepsilon = (r_{70°C} * I_a + x * I_r) * l \text{ [V]}$$

Where l is the exact distance between the load and the transformer. Knowing the maximum permissible potential difference, for both the cables (with a cross-section area of 25 and 50 mm^2) with the loads of 1 kW and 15 kW we can write:

$$l = \frac{\varepsilon}{(r_{70°C} * I_a + x * I_r)} \text{ [km]}$$

$$l1_{25} = 2{,}89 \text{ km};\ 1 \text{ kW load with the cable with the cross secition area of } 25\ mm^2$$

$$l1_{50} = 5 \text{ km};\ 1 \text{ kW load with the cable with the cross secition area of } 50\ mm^2$$

$$l15_{50} = 1{,}102 \text{ km}; 15 \text{ kW motor with the cable with the cross secition area of } 50\ mm^2$$

For the motor with a 15 kW power, the calculations have been done only when the cable has a cross-section area of 50 mm^2, as this is the cable that will be used for main branches of the line, and for heavier loads, like that of a motor.

For all the 20 villages we can assume these maximum lengths of the line, where it is possible to connect the last mono-phase or three-phase load, when there is only one load, without considering the existence of other loads.

Other calculations have been done to consider also the other loads that can exist for the three villages seen below, using Excel.

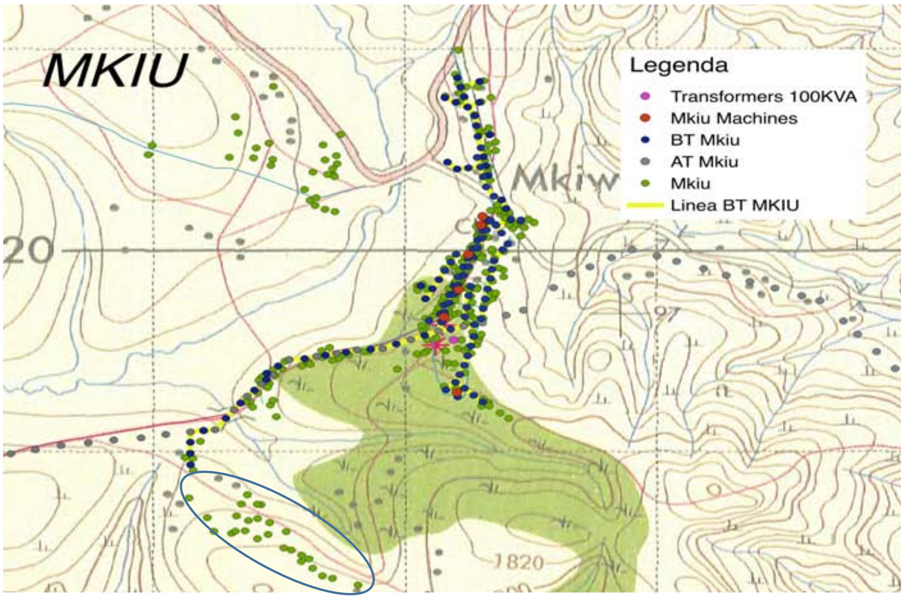


Figure 40 *Mkiu village with its milling machines (shown as red dots) and the new extension of the line (shown inside blue circle)*

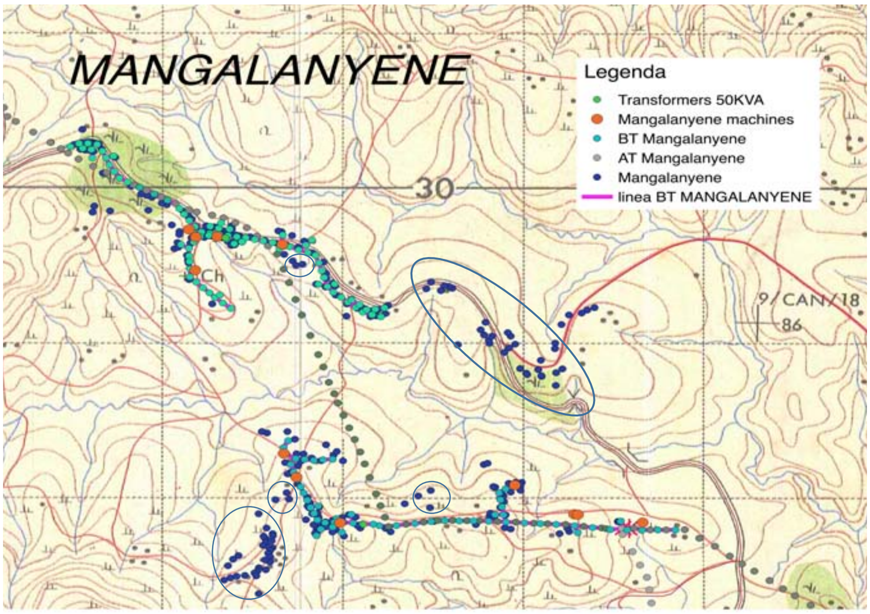


Figure 41 *Mangalanyene Village with its milling machines (shown as orange dots) and the new extension of the line (shown inside blue circle)*

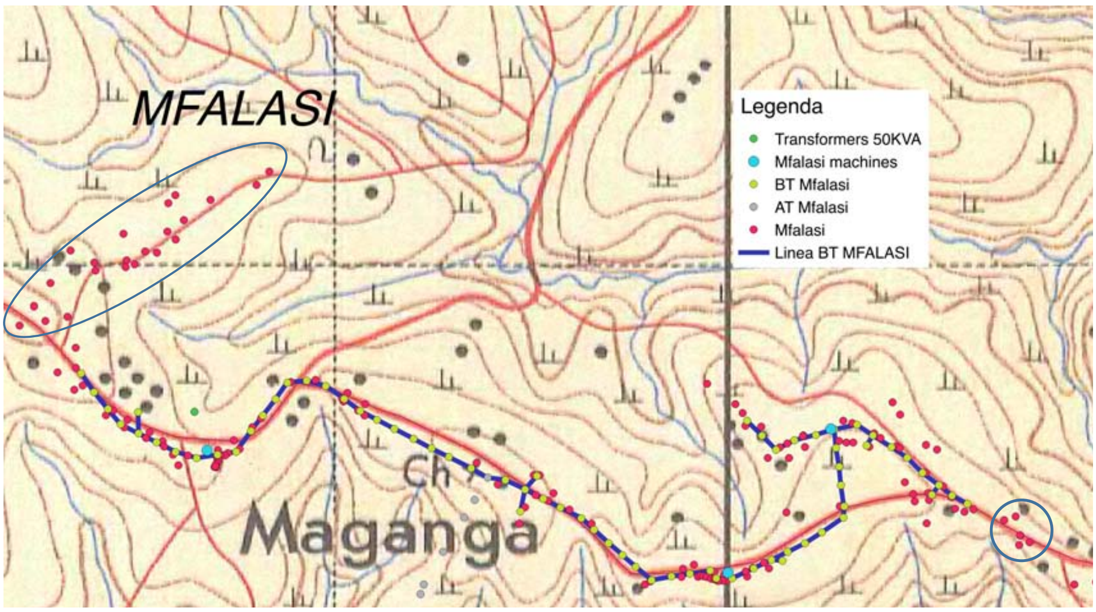


Figure 42 *Mfalasi Village with its milling machines (shown as turquoise dots) and the new extension of the line (shown inside blue circle)*

The potential differences for each of the villages has been calculated in the worst-case situation for the power line. For example, for situations where we had:

- Loads very far from the transformer;
- An elevated number of power loads 0,2 kW; 0,3 kW; 0,5 kW and 1kW
- More than two motors attached to the line.

For Mkiu Village, we verified that all the 6 milling machines are in the 1.102 km distance allowed, but for Mfalasi village, we realized that one in three machines was located in a distance farther than what was allowed, even if only by 100 meters. Below we will analyse the fact that we are inside an acceptable limit for the potential differences.

Mangalanyene village is made of two smaller villages. The one located closer to the top of the map is very similar to Mkiu regarding the positions of the milling machines. In Mkiu there are 5 milling machines distributed in a distance of 550 meters. In Mangalanyene we have a similar situation but there are 4 machines instead of 5, so studying Mkiu shall suffice. The other smaller village of Mangalanyene which is located closer to the bottom of the map, we have one machine that is very much outside the distance allowed, thus for now, if another transformer is not added, it cannot be used. The other milling machines are distributed along the power line within a distance which is close to what has been allowed (around 900-1000m), so it's important to specifically study this case.

For the analysis of small loads, it's enough to study Mkiu village, as it is the most populated village comparing to the others.

Also, for the analysis of new extensions, it will be enough to study Mkiu village, where the extensions of the power line extend through 2100 meters, reaching 60 new connections, like the case of the other two villages.

On these simulations, we have done a few approximations regarding the power line, the cross-section of the cable and the powers of the loads.

It will be somehow correct to model the three-phase distribution lines with an equivalent mono-phasic circuit characterized by lumped longitudinal elements, i.e. the resistance, the reactance ($R = rl$ [Ω] and $X = xl$ [Ω] where r and x are in Ω/km, and l is the length of the line) and the potential differences between the phases.

In the following analysis, we assume that all the electric values are purely sinusoidal and have a constant frequency of 50 Hz.

The cross-section area of the cable is not really constant. In fact, three different kinds of cable with different diameters have been used for different parts of the line, all of which are made of the same PVC aluminium core:

- 2x25 mm^2 for 4403 consumers, each consumer will be reached by the power line from the nearest pole using this type of cable for a maximum distance of 50 meters.
- 4x25 mm^2 for LV overhead power lines. This type of cable is used for parts of the line which extend from the main branch, and reach low-duty households.
- 4x50 mm^2 for LV overhead power lines. This type of cable has a larger cross-section area and will be used for main parts of the line, in particular where loads requiring higher power are attached.

Below technical specifications of the three types of cable discussed above are shown as on the product manual:

EMTA CONDUCTOR & CABLE

LOT 2a - Item 3a & LOT 2b - Item 3b : Aerial Bundled Cable (ABC) - PVC Insulated Aluminium core, 2x25 sqmm for 4403 users
LOT 2b - Item 1b : Aerial Bundled Conductors (ABC) -PVC Insulated Aluminium core, 4x50 sqmm for LV overhead power lines
LOT 2b - Item 2b : Aerial Bundled Conductors (ABC) - PVC Insulated Aluminium core, 4x25 sqmm for LV overhead power lines

ISO 9001:2000 SGS UKAS QUALITY MANAGEMENT 005

NFA_2X

CODE NAME			2x25 mm² RM	4x25 mm² RM	4x50 mm² RM
STANDARD			TS HD 626 S1 / 4F	TS HD 626 S1 / 4F	TS HD 626 S1 / 4F
Nominal Cross Sectional Area	Phase Conductors	mm²	25	25	50
	Public Lighting conductor		-	-	-
	Neutral Messenger		-	-	-
Number & Diameter of Cores	Phase Conductors	No./ mm	7 / 5.6 mm - 6.5 mm (max	7 / 5.6 mm - 6.5 mm (max)	19 / 7.7 mm - 8.6 mm(max)
	Public Lighting conductor		-	-	-
	Neutral Messenger		-	-	-
Minumum Breaking Strength For Cores	Phase Conductors /min	Mpa	4,17	4,17	8,45
	Public Lighting conductor / min		-	-	-
	Neutral Messenger		-	-	-
Calculated Resistance at 20°C	Phase Conductors	Ohm/km	1,200	1,200	0,641
	Public Lighting conductor		-	-	-
	Neutral Messenger		-	-	-
HDPE Insulation & Thickness	Phase Conductors	mm	1,3	1,3	1,5
	Public Lighting conductor		-	-	-
	Neutral Messenger		-	-	-
Current Carrying Capacity		A	107	107	165
Diameter of Bundle Assembled Cores		mm	18	22	28
Marking			Printed on the phase core insulation: manufacturer, year of manufacturing, insulation material. etc.		
Core Identification			constructions twisted into a bundle include: - phase (main) insulated cores(M) - one, two, or three additional reduced insulated cores for lighting (R)		
Length of Per Reel		m	1.000	1.000	1.000
Drum Dimensions		mmxmmxmm	1000x500x660(760)	1200x600x680(780)	1400x600x680(780)

EMTA KABLO SANAYI VE TİCARET A.Ş.
İstasyon Mahallesi İbişağa Caddesi No:4 34940 Tuzla – İstanbul
Tel:(+90) 216 446 66 06 / Fax:(+90) 216 446 43 93
sales@emtaconductor.com - www.emtaconductor.com

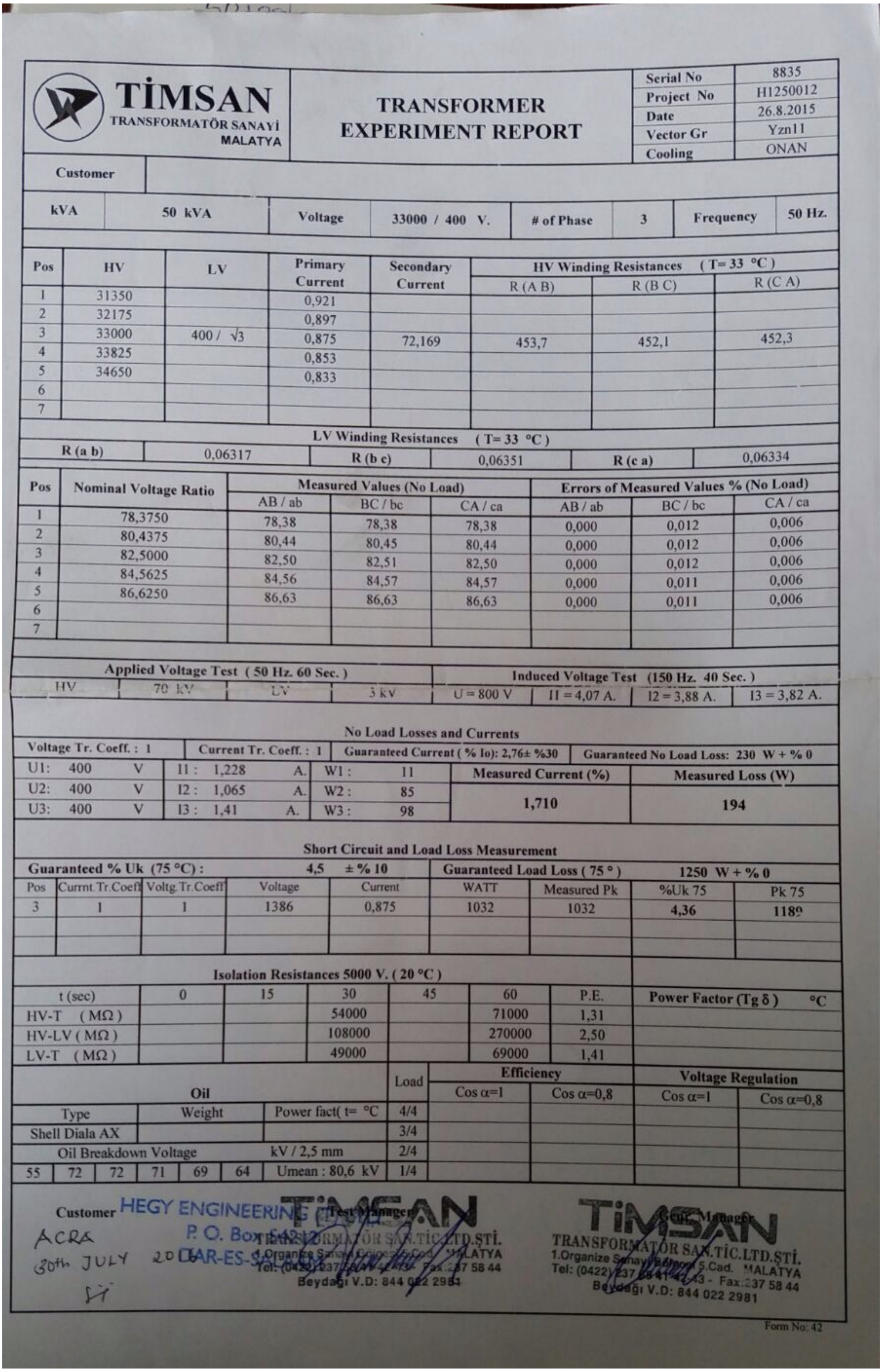
Figure 43 *Technical specifications of the three types of cable*

To simplify the calculation about the potential difference we have assumed that the power line is made of a cable with a constant cross-section area and the calculations have been done considering just the cross-section areas of 25 mm^2 and 50 mm^2. For a first estimate we can take this simplification as correct. The case with the cable with a cross section of 25 mm^2 is the situation with more risk, whereas the cross-section of 50 mm^2 is the best case for the transfer of power along the line. Making the calculation with both kinds of cables it is possible to obtain an intermediate result between the two alternatives.

Another approximation has been done about the power absorbed from the loads. We assumed that the largest loads absorb a power of 15 kW. These kinds of loads could be like motors, hacksaws and others. The smaller loads instead were all assumed to be of equal power, that is 0,3 kW or even less, but in the following years it is possible to reach the value of 1 kW.
Some houses, beyond the use of lights for the illumination, will also have a television and a radio and only a very small percentage, close to 5%, use other electrical appliances like refrigerators, irons, computers and wash machines. In most cases, local people will use electricity just to illuminate the inside of their buildings, usually 10 square meters large and for charging their mobile phones, therefore for a total of a few hundred Watts.
During the following years, thanks to the growth of new commercial activities and to the development of the villages, the power asked by the consumers could increase up to a value around 1 kW.
The villages will have transformers of three different sizes:

- 50 kVA;
- 100 kVA;
- 200 kVA.

Below technical specifications of the 50 kVA transformer have been shown as appears on the product manual.



TİMSAN TRANSFORMATÖR SANAYİ MALATYA

TRANSFORMER EXPERIMENT REPORT

Serial No	8835
Project No	H1250012
Date	26.8.2015
Vector Gr	Yzn11
Cooling	ONAN

Customer							
kVA	50 kVA	Voltage	33000 / 400 V.	# of Phase	3	Frequency	50 Hz.

Pos	HV	LV	Primary Current	Secondary Current	HV Winding Resistances (T= 33 °C) R (A B)	R (B C)	R (C A)
1	31350		0,921				
2	32175		0,897				
3	33000	400 / √3	0,875	72,169	453,7	452,1	452,3
4	33825		0,853				
5	34650		0,833				
6							
7							

LV Winding Resistances (T= 33 °C)

R (a b)	0,06317	R (b c)	0,06351	R (c a)	0,06334

Pos	Nominal Voltage Ratio	Measured Values (No Load) AB / ab	BC / bc	CA / ca	Errors of Measured Values % (No Load) AB / ab	BC / bc	CA / ca
1	78,3750	78,38	78,38	78,38	0,000	0,012	0,006
2	80,4375	80,44	80,45	80,44	0,000	0,012	0,006
3	82,5000	82,50	82,51	82,50	0,000	0,012	0,006
4	84,5625	84,56	84,57	84,57	0,000	0,011	0,006
5	86,6250	86,63	86,63	86,63	0,000	0,011	0,006
6							
7							

Applied Voltage Test (50 Hz. 60 Sec.)				Induced Voltage Test (150 Hz. 40 Sec.)			
HV	70 kV	LV	3 kV	U = 800 V	I1 = 4,07 A.	I2 = 3,88 A.	I3 = 3,82 A.

No Load Losses and Currents

Voltage Tr. Coeff. : 1 | Current Tr. Coeff. : 1 | Guaranteed Current (% Io): 2,76± %30 | Guaranteed No Load Loss: 230 W + % 0

U1:	400	V	I1 :	1,228	A.	W1 :	11	Measured Current (%)	Measured Loss (W)
U2:	400	V	I2 :	1,065	A.	W2 :	85	1,710	194
U3:	400	V	I3 :	1,41	A.	W3 :	98		

Short Circuit and Load Loss Measurement

Guaranteed % Uk (75 °C) : 4,5 ± % 10 | Guaranteed Load Loss (75 °) 1250 W + % 0

Pos	Currnt.Tr.Coeff	Voltg.Tr.Coeff	Voltage	Current	WATT	Measured Pk	%Uk 75	Pk 75
3	1	1	1386	0,875	1032	1032	4,36	1189

Isolation Resistances 5000 V. (20 °C)

t (sec)	0	15	30	45	60	P.E.
HV-T (MΩ)			54000		71000	1,31
HV-LV (MΩ)			108000		270000	2,50
LV-T (MΩ)			49000		69000	1,41

Power Factor (Tg δ) °C

Oil

Type	Weight	Power fact(t= °C
Shell Diala AX		

Oil Breakdown Voltage kV / 2,5 mm

55	72	72	71	69	64	Umean : 80,6 kV

Load	Efficiency Cos α=1	Cos α=0,8	Voltage Regulation Cos α=1	Cos α=0,8
4/4				
3/4				
2/4				
1/4				

Customer HEGY ENGINEERING P. O. Box 542 DAR-ES-SALAAM

ACRA 30th JULY 2016

Test Manager — TİMSAN TRANSFORMATÖR SAN.TİC.LTD.ŞTİ. 1.Organize Sanayi Bölgesi 5.Cad. MALATYA Tel: (0422) 237 ... Fax: 237 58 44 Beydağı V.D: 844 022 2981

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Form No: 42

Figure 44 *Technical specifications of the 50 kVA transformer*

In the calculation of the potential difference the size of the transformer was not considered and it was assumed that the transformer is able to reach the power demand of the loads. The number of loads was assumed to be appropriate for that size of transformer. Probably the number of loads will be larger but this problem will be solved given the fact that in the villages the milling machines will be used only for a few hours a day and not all of them will be used at the same time.

In a power line, fed from just one extreme, in order to calculate the potential difference at the end of the line, on the last load, it is important to consider all the loads distributed along the line with the respective active and reactive electrical current absorbed by them. The calculations go as shown below:
The potential difference is calculated with the following formula:

$$\varepsilon = (r_{70°C} * M_a + x * M_r)\ [V]$$

Where M_a e M_r are respectively the active and reactive moment of the electrical currents absorbed by the loads along the power line and will be calculate as shown below:

$$M_a = (l_1 I_{a1}) + [(l_1 + l_2) * I_{a2}] + [(l_1 + l_2 + l_3) * I_{a3}] + \cdots [A * km]$$

$$M_r = (l_1 I_{r1}) + [(l_1 + l_2) * I_{r2}] + [(l_1 + l_2 + l_3) * I_{r3}] + \cdots [A * km]$$

The percentage of potential difference will be calculated as below:

$$\varepsilon_{\%} = \frac{\varepsilon * 100}{U_n}\ mono - phase\ load$$

$$\varepsilon_{\%} = \frac{\sqrt{3} * \varepsilon * 100}{U_n}\ three - phase\ load$$

For Mkiu village, we have considered a part of the line on the left side of the transformer, which is 1,300 meters long, for our calculations. Along this line there are a total of 40 loads of 0.3 kW. The simulations have mostly been done using loads of 300 Watt, because the households need electricity only for illumination and phone charging, almost 50 Watt and 300 Watt corresponds to the power required by a group of loads.

Table 11 *Potential difference evaluation of 0,3 kW loads (Mkiu Village)*

LOADS	Distance from transformer [km]	P load [kW]	Q load [kVar]	Ma [A*km]	Mr [A*km]
1	0,02	0,3	0,145	0,015	0,007
2	0,04	0,3	0,145	0,030	0,015
3	0,06	0,3	0,145	0,045	0,022
4	0,08	0,3	0,145	0,060	0,029
5	0,10	0,3	0,145	0,075	0,036
6	0,12	0,3	0,145	0,090	0,044
7	0,14	0,3	0,145	0,105	0,051
8	0,16	0,3	0,145	0,120	0,058
9	0,18	0,3	0,145	0,135	0,065
10	0,20	0,3	0,145	0,150	0,073
11	0,22	0,3	0,145	0,165	0,080
12	0,24	0,3	0,145	0,180	0,087
13	0,26	0,3	0,145	0,195	0,094
14	0,28	0,3	0,145	0,210	0,102
15	0,30	0,3	0,145	0,225	0,109
16	0,32	0,3	0,145	0,240	0,116
17	0,34	0,3	0,145	0,255	0,123
18	0,36	0,3	0,145	0,270	0,131
19	0,38	0,3	0,145	0,285	0,138
20	0,40	0,3	0,145	0,300	0,145
21	0,42	0,3	0,145	0,315	0,152
22	0,44	0,3	0,145	0,330	0,160
23	0,46	0,3	0,145	0,345	0,167
24	0,48	0,3	0,145	0,360	0,174
25	0,50	0,3	0,145	0,375	0,181
26	0,52	0,3	0,145	0,390	0,189
27	0,54	0,3	0,145	0,405	0,196

28	0,56	0,3	0,145	0,420	0,203
29	0,58	0,3	0,145	0,435	0,210
30	0,60	0,3	0,145	0,450	0,218
31	0,62	0,3	0,145	0,465	0,225
32	0,64	0,3	0,145	0,480	0,232
33	0,66	0,3	0,145	0,495	0,239
34	0,68	0,3	0,145	0,510	0,247
35	0,70	0,3	0,145	0,525	0,254
36	0,72	0,3	0,145	0,540	0,261
37	0,90	0,3	0,145	0,675	0,326
38	1,00	0,3	0,145	0,750	0,363
39	1,30	0,3	0,145	0,975	0,471
40	1,32	0,3	0,145	0,990	0,479
TOTAL				13,380	6,467

The obtained results are the following, where E1 and E2 correspond to the percentage potential differences related to cables with a cross-section of 25 and 50 mm^2.

Ma [A*km]	13,38
Mr [A*km]	6,47
E1 [V]	22,28
E1%	5,57
E2 [V]	12,89
E2%	3,22

It is possible to observe that the results for the cable with a smaller cross section do not follow the limits of the potential difference of 3 %, while with the cable of 50 mm^2 we are very close to the admissible limit. The limit is crossed for two main reasons:

- some of the loads will get an assumed power of 0,3 kW, others a bit more and the majority will get less than 0,3 kW;
- the loads will not work at the same time.

Since the effective value of the percentage potential difference will be a value between E1 and E2, we can assume that the obtained results are coherent with the admissible potential different of 3 %.

In the following calculations five three-phase loads have been connected to the power line. Looking at the map of Mkiu it is possible to see that the concentration of millings machines is higher closer to the top of the map of the power line and it was verified through QGIS that the machines were located at a distance of 100, 200, 400 and 550 meters from transformer.

Table 12 *Potential difference evaluation of 5 milling machines (Mkiu Village)*

LOADS	Distance from transformer [km]	P load [kW]	Q load [kVar]	Ma [A*km]	Mr [A*km]
1	0,10	15	7,26	2,17	1,05
2	0,20	15	7,26	4,33	2,10
3	0,40	15	7,26	8,66	4,19
4	0,50	15	7,26	10,83	5,24
5	0,55	15	7,26	11,91	5,76
TOTAL				37,89	18,34

Ma [A*km]	37,89
Mr [A*km]	18,34
E2 [V]	36,50
E2%	15,81

For connecting the transformer to the machines a cable with a constant cross-section area of 50 mm^2 will be used, therefore just the percentage potential difference E2 concerning the cable with a larger cross-section area has been calculated. As you can see, E2 crosses the allowed limit of 10 % for the motors, that means that the five milling machine will work just a few hours a day and not simultaneously. Smaller loads are not taken into consideration during this simulation, because during the day, when the milling machines are working, thanks to the illumination of the sun, it will not be necessary to use the electrical lights.

We tried to remove the last load located 550 meters from the transformer for analysing if there will be any improvement in the percentage potential difference along the line.

Table 13 *Potential difference evaluation of 4 milling machines (Mkiu Village)*

LOADS	Distance from transformer [km]	P load [kW]	Q load [kVar]	Ma [A*km]	Mr [A*km]
1	0,1	15	7,26	2,17	1,05
2	0,2	15	7,26	4,33	2,10
3	0,4	15	7,26	8,66	4,19
4	0,5	15	7,26	10,83	5,24
TOTAL				25,98	12,57

Ma [A*km]	25,98
Mr [A*km]	12,57
E2 [V]	25,03
E2%	10,84

In this case the potential difference decreased five percent comparing to the previous simulation and we reached a value very close to the admissible limit of 10 %. It is possible to conclude that for Mkiu village it is possible to let four motors, located with different distances from the transformer, work simultaneously at certain times of the day, but in any case they should be within the maximum admissible distance of 1,102 meters.

If we suppose that during the day around 10 commercial activities or offices decide to use electricity for illumination and phone charging or for using television/radio, it is possible to observe that the potential difference on the milling machine farthest from the transformer will not change much comparing to the case without small loads.

Table 14 *Potential difference evaluation of 4 milling machines and 0,3 kW loads (Mkiu Village)*

LOADS	Distance from transformer [km]	P load [kW]	Q load [kVar]	Ma [A*km]	Mr [A*km]
1	0,10	15	7,260	2,17	1,05
2	0,20	15	7,260	4,33	2,10
3	0,21	0,3	0,145	0,16	0,08
4	0,22	0,3	0,145	0,17	0,08

5	0,23	0,3	0,145	0,17	0,08
6	0,24	0,3	0,145	0,18	0,09
7	0,25	0,3	0,145	0,19	0,09
8	0,30	0,3	0,145	0,23	0,11
9	0,32	0,3	0,145	0,24	0,12
10	0,36	0,3	0,145	0,27	0,13
11	0,40	15	7,260	8,66	4,19
12	0,50	15	7,260	10,83	5,24
TOTAL				27,58	13,35

Ma [A*km]	27,58
Mr [A*km]	13,35
E2 [V]	26,57
E2%	11,50

Regarding the potential difference related to the new extension of the power line, it was assumed that the power line reaches loads that absorb a power of 200 W, that is the necessary power for lights illumination and for phone charging. Actually, in most of the houses there is only one light, as the houses consist of just one main room, 10 square meters large where the family lives, and they have only one mobile phone.

The new extensions of Mkiu Village reach the distance of 2,100 meters far from the transformer. Supposing that we have only loads of 200 W and 60 of them, we will slightly cross the admissible potential difference limit. The value of 200 W is low; some houses could use more electricity but others may use less. Although this is an underestimated value, for this stage of the simulation it was enough to understand if the existing transformer, at least for the first period of the work on the extensions, will be able to guarantee the use of lamps for around 60 buildings.

Observing the obtained results, it is possible to conclude that we are a bit out of the potential difference limits, therefore to guarantee a higher power supply for the buildings it would be necessary the add of another transformer in the village.

Table 15 *Potential difference evaluation of new extensions*

LOADS	Distance from transformer [km]	P load [kW]	Q load [kVar]	Ma [A*km]	Mr [A*km]
1	0,02	0,2	0,097	0,010	0,005
2	0,04	0,2	0,097	0,020	0,010
3	0,06	0,2	0,097	0,030	0,015
4	0,08	0,2	0,097	0,040	0,019
5	0,10	0,2	0,097	0,050	0,024
6	0,12	0,2	0,097	0,060	0,029
7	0,14	0,2	0,097	0,070	0,034
8	0,16	0,2	0,097	0,080	0,039
9	0,18	0,2	0,097	0,090	0,044
10	0,20	0,2	0,097	0,100	0,048
11	0,22	0,2	0,097	0,110	0,053
12	0,24	0,2	0,097	0,120	0,058
13	0,26	0,2	0,097	0,130	0,063
14	0,28	0,2	0,097	0,140	0,068
15	0,30	0,2	0,097	0,150	0,073
16	0,32	0,2	0,097	0,160	0,077
17	0,34	0,2	0,097	0,170	0,082
18	0,36	0,2	0,097	0,180	0,087
19	0,38	0,2	0,097	0,190	0,092
20	0,40	0,2	0,097	0,200	0,097
21	0,42	0,2	0,097	0,210	0,102
22	0,44	0,2	0,097	0,220	0,107
23	0,46	0,2	0,097	0,230	0,111
24	0,48	0,2	0,097	0,240	0,116
25	0,50	0,2	0,097	0,250	0,121
26	0,52	0,2	0,097	0,260	0,126
27	0,54	0,2	0,097	0,270	0,131
28	0,56	0,2	0,097	0,280	0,136
29	0,58	0,2	0,097	0,290	0,140
30	0,60	0,2	0,097	0,300	0,145
31	0,62	0,2	0,097	0,310	0,150
32	0,64	0,2	0,097	0,320	0,155
33	0,66	0,2	0,097	0,330	0,160
34	0,68	0,2	0,097	0,340	0,165

35	0,70	0,2	0,097	0,350	0,169
36	0,72	0,2	0,097	0,360	0,174
37	0,74	0,2	0,097	0,370	0,179
38	0,76	0,2	0,097	0,380	0,184
39	0,78	0,2	0,097	0,390	0,189
40	0,80	0,2	0,097	0,400	0,194
41	0,82	0,2	0,097	0,410	0,199
42	0,84	0,2	0,097	0,420	0,203
43	0,86	0,2	0,097	0,430	0,208
44	0,88	0,2	0,097	0,440	0,213
45	0,90	0,2	0,097	0,450	0,218
46	0,92	0,2	0,097	0,460	0,223
47	0,94	0,2	0,097	0,470	0,228
48	0,96	0,2	0,097	0,480	0,232
49	0,98	0,2	0,097	0,490	0,237
50	1,00	0,2	0,097	0,500	0,242
51	1,03	0,2	0,097	0,515	0,249
52	1,06	0,2	0,097	0,530	0,257
53	1,09	0,2	0,097	0,545	0,264
54	1,12	0,2	0,097	0,560	0,271
55	1,15	0,2	0,097	0,575	0,278
56	1,70	0,2	0,097	0,850	0,412
57	1,75	0,2	0,097	0,875	0,424
58	1,80	0,2	0,097	0,900	0,436
59	1,90	0,2	0,097	0,950	0,460
60	2,00	0,2	0,097	1,000	0,484
61	2,10	0,2	0,097	1,050	0,508
TOTAL				21,100	10,218

Ma [A*km]	21,10
Mr [A*km]	10,22
E1 [V]	35,13
E1%	8,78
E2 [V]	20,33
E2%	5,08

In Mfalasi, there are 3 milling machines in total. For the two machines situated at the same side of the transformer, a verification of the potential difference has been done, because the farther of the two machines is located at a distance very close to the allowed maximum distance limit (1,102 km) that guarantees a maximum potential difference of 10%.

As we have already assumed, the potential difference crosses the 10% limit so the two machines must not be used simultaneously. The farther machine, if it is used alone, being at a distance farther than 1,102 meters from the transformer (although slightly), will be very close to the limit of 10%, therefore it will be possible to use it when the other machine is not working.

Table 16 *Potential difference evaluation of 2 milling machines (Mfalasi Village)*

LOADS	Distance from transformer [km]	P load [kW]	Q load [kVar]	Ma [A*km]	Mr [A*km]
1	0,7	15	7,26	15,16	7,34
2	1,2	15	7,27	25,98	12,58
TOTALE				41,14	19,91

Ma [A*km]	41,14
Mr [A*km]	19,91
E2 [V]	39,63
E2%	17,16

If just the first machine, the machine 700 meters far from the transformer, works, it is possible to use also some mono-phase loads. 13 mono phase loads were considered, because the village of Mfalasi doesn't have a large population and because its power line is made of just one main branch of the line, only the cable with 50 mm^2 cross section area is used. It is thus possible to verify that when the machine is working also some mono-phase loads could be used and the potential difference value will not change much. This village has many possibilities to get larger, increasing the commercial activities and the number of milling machines.

Table 17 *Potential difference evaluation of 1 milling machine and 0,2 kW loads (Mfalasi Village)*

LOADS	Distance from transformer [km]	P load [kW]	Q load [kVar]	Ma [A*km]	Mr [A*km]
1	0,05	0,2	0,097	0,03	0,01
2	0,10	0,2	0,097	0,05	0,02

3	0,15	0,2	0,097	0,08	0,04
4	0,20	0,2	0,097	0,10	0,05
5	0,25	0,2	0,097	0,13	0,06
6	0,30	0,2	0,097	0,15	0,07
7	0,35	0,2	0,097	0,18	0,08
8	0,40	0,2	0,097	0,20	0,10
9	0,45	0,2	0,097	0,23	0,11
10	0,50	0,2	0,097	0,25	0,12
11	0,55	0,2	0,097	0,28	0,13
12	0,60	0,2	0,097	0,30	0,15
13	0,65	0,2	0,097	0,33	0,16
14	0,70	15	7,260	15,16	7,34
TOTAL				17,43	8,44

Ma [A*km]	17,43
Mr [A*km]	8,44
E2 [V]	16,79
E2%	7,27

For Mangalanyene village only the case of the kitongoji, which is the small village close to the bottom of the map, will be studied. The reason for this choice is that this village is characterized by the worst and most important cases. On the left side of the transformer there are some mono-phase loads and three three-phase loads, located respectively at a distance of 270, 700 and 900 meters from the transformer.

Calculating the potential difference, it is possible to verify that during the day these three machines, crossing the allowed limit of 10 % can not work simultaneously.

Table 18 *Potential difference evaluation 3 milling machines (Mangalanyene Village)*

LOADS	Distance from transformer [km]	P load [kW]	Q load [kVar]	Ma [A*km]	Mr [A*km]
1	0,27	15	7,26	5,85	2,83
2	0,70	15	7,26	15,16	7,34
3	0,90	15	7,26	19,49	9,43
TOTAL				40,49	19,60

Ma [A*km]	40,50
Mr [A*km]	19,60
E2 [V]	39,01
E2%	16,89

Looking at the two following tables, it is possible to understand, that just in case one of the two farther machines is not working, then the admissible limit of 10% is not cross.

Table 19 *Potential difference evaluation of 2 milling machines (Mangalanyene Village)*

LOADS	Distance from transformer [km]	P load [kW]	Q load [kVar]	Ma [A*km]	Mr [A*km]
1	0,27	15	7,26		
2	0,7	15	7,26	15,16	7,34
3	0,9	15	7,26	19,49	9,43
TOTAL				34,65	16,77

Ma [A*km]	34,65
Mr [A*km]	16,77
E2 [V]	33,37
E2%	14,45

LOADS	Distance from transformer [km]	P load [kW]	Q load [kVar]	Ma [A*km]	Mr [A*km]
1	0,27	15	7,26	5,85	2,83
2	0,7	15	7,26		
3	0,9	15	7,26	19,49	9,43
TOTAL				25,34	12,26

Ma [A*km]	25,34
Mr [A*km]	12,26
E2 [V]	24,41
E2%	10,57

The Last case for Mangalanyene village is interesting to study. In this case, there are two milling machines at the same side of the transformer, both located at a distance of around 1 km. As it is possible to see in the results of the simulation, when both of these machines are working, we cross the admissible limit of 10%. So we can say that these two machines are not allowed to run simultaneously, just one can work in precisely times of the day.

Table 20 *Potential difference evaluation of 2 milling machines (Mangalanyene Village)*

LOADS	Distance from transformer [km]	P load [kW]	Q load [kVar]	Ma [A*km]	Mr [A*km]
1	1,03	15,00	7,26	22,30	10,79
2	1,04	15,00	7,26	22,52	10,90
TOTAL				44,82	21,69

Ma [A*km]	44,82
Mr [A*km]	21,69
E2 [V]	43,18
E2%	18,70

Through the calculation done and the considerations made it is possible to conclude that for analysed Mkiu and Mfalasi villages, the present number of transformers is enough to supply energy to all the milling machines, except one in Mfalasi village, because it is located too far from the transformer. Moreover, it is possible to feed electricity to more than one machine simultaneously, and at the same time even to some small mono-phase loads, so that during the day the shops and commercial activities are able to use electricity for illumination, television or radio and phone charging. When the majority of the mono-phase loads are working, as during the evening hours, after the sun set, the transformer is able to guarantee a power around 0,3 kW to each load at the same time. In Mangalanyene indeed, there should be the necessary to add a transformer to supply energy to all the milling machine, but for the small loads there are no particularly problems.

For now, we can consider that as a positive result, because every building can get the electricity for at least illumination and phone charging. Obviously in the future, when it is necessary to increase the power supply for the consumers and they will require on average a power of 1 kW per household, it will be necessary to add a number of transformers for each village so that the potential difference will remain inside the allowed limit.

For the new extensions of the line it will be essential to analyse each village to understand if the adding of new transformers is effectively needed and where the new transformers should be located. Until this moment, just four transformers have been planned to be added, but that was planned before the start of these calculations on the potential differences. Looking at the obtained results now, it seems necessary to add more than four transformers, but this has to be decided based on the analysis of each single village.

During the following months it will be necessary to visit every village and mark the real place of the milling machines using GPS. Thus we can verify, as these three villages, that the machines are within the allowed distance limit that can be allowed to have a potential difference lower than 10%. Moreover, for the new extension it is interesting to calculate the potential difference, in order to understand if the new buildings reached by the power line could be fed by the same transformer or if there will be the need for a new one.

It will be necessary to add some general rules for the villages for clarify the idea of when each machine can work, and which of the machines can run simultaneously.

Regarding the mono-phase consumers the problem will not be noteworthy, because every one of them will required energy only for some lamps and phone charging. In the future it could be that with the development of the villages, the families need more electricity and it will be necessary to review and evaluate the number of transformers of the project and their respective sizes.

A policy must be made that considers the consumers in three different categories, depending on their distance from the transformer, for instance:

- consumers within the distance of 1 kilometre from transformer are free to connect loads to the power line at each time of the day;
- consumers within the distance of 1 to 1,3 kilometre from transformer are allowed to use the loads just in some hours of the day and must use only loads with a low power;
- consumers located at a distance more than 1,3 kilometres from transformer are not allowed to use special loads, like three-phase loads.

6 Social Part

Beyond the technical part of the project, there is a huge and very important social section.

It includes two different sectors, the environmental and the social part through the villages.

The first one regards the reforestation of the project area and the requalification of waters.

The second one takes care of the relationship with the village inhabitants and the structure of the trade of electricity.
The social tasks are very diverse and complicated and to understand a bit of its roles, an interview was carried out with a member of the local staff that handles this special sector.
It was possible to understand the control structure of electricity trade for this project and how it will sell.
Contracts have been made between the supply service and the beneficiaries and electricity will be distributed to consumers through pre-paid meters. Each owner of a single meter will go monthly or whenever he needs to the energy company and buy the amount of electricity that he will use. Every village will possess its own office where people can go to pay for energy.
They will not pay for the power of the domestic plant but for the energy that they will effectively consume. Then, if someone has a plant of 1,5 kW but he uses the energy just for one light, he will pay only for that light. Now, it is still too soon to say how much each family will spend on electricity, because it depends on many factors, but it is possible to estimate that a family that will use just some lights will spend monthly almost 5,000 Tsh (less than 2.5 Euro) and for the families who have also television and radio, the cost of electricity will increase to about 15,000 Tsh (less 7.5 Euro) per month.
At this time the consumers are not still divided into classes, but it will be possible to do that at the end of the project. Consumers will be divided into three classes like for LUMAMA, the old energy project carried out by ACRA in Mawengi:

- domestic users;
- commercial users;
- industrial users.

The price for the three different kinds of users will be different and it will increase from the domestic users to the industrials.
The policy that will be used, will follow the policy of the Tanzanian institution, TANESCO and EWURA.
The Energy and Water Utilities Regulatory Authority (EWURA) is an autonomous multi-sectorial regulatory authority established by the EWURA Act Cap 414 of the laws of Tanzania. It is responsible for technical and economic regulation of the electricity, petroleum, natural gas and water sectors in Tanzania pursuant to Cap 414 and sector legislation.

EWURA mission is “To Regulate the Energy and Water Services in a Transparent, Effective and Efficient Manner that Promotes Investments and Enhances the Socio Economic Welfare of the Tanzanian Society.”

The functions of EWURA include among others, licensing, tariff review, monitoring performance and standards regarding quality, safety, health and environment. EWURA is also responsible for promoting effective competition and economic efficiency, protecting the interests of consumers and promoting the availability of regulated services to all consumers including low income, rural and disadvantaged consumers in the regulated sectors.

In carrying out its functions, EWURA shall strive to enhance the welfare of Tanzania society by:

- promoting effective competition and economic efficiency;
- protecting the interests of consumers;
- protecting the financial viability of efficient suppliers;
- promoting the availability of regulated services to all consumers including low income, rural and disadvantaged consumers;
- taking into account the need to protect and preserve the environment;
- Enhancing public knowledge, awareness and understanding of the regulated sectors.

If you ask the people what they think about the project they will answer you in a positive way. At the beginning it was difficult to imagine that the project could really become true, but now it is easy to see that the site and the electrical lines work. The project was just on a paper before and now it is becoming real and the inhabitants of the villages believe in that and they are really enthusiastic.

With the arrival of electricity many things will change, there will be the possibility to increase the number of milling machines and therefore the number of the new commercial activities will rise.

There will be an economic growth and also for the only hospital of the district in Lugarawa it will be a huge innovation. In fact, at this time the hospital is supplied with the old hydropower plant but the energy is not enough to guarantee the use of many machines and particularly of more than one refrigerator, a very important appliance for keeping medicine, blood tests and others analysis.

The employees were asked about the biggest difficulty that they have found for the social part about the project.

A relevant issue, that was not so easily to solve, was the signing of contracts to get permission, from the inhabitants of the villages, for the passage of the medium voltage line. It was difficult because many people are owners of some plot of land and they have been requested by ACRA to grant a part of their land or to cut some trees in order to allow the building of the medium voltage line.

For some people it was a big problem, because often the trees or the plot of land was the only one income for the future for this family and they will not have their money back because this project will be done for the population of the 20 villages.

Another important thing is the end of the project. When all the site works have finished and the plant starts, the work that at this moment is being carried out by ACRA, will be continued by a new company named Juwalu, in Swahili “jumuiya za watumiaji umeme wa Lugarawa” and it means “Lugarawa Electricity Users Association”. It is an association that comprises all the beneficiaries of the project from the 20 villages. It is among the shareholders of the company that in the future will manage and run the project.

Juwalu will collaborate with to others entities: E&E (Professional College of Njombe) and the Hospital.

During these months Juwalu has got the training from ACRA, it will have the resource for planning the project, it has for instance commercial trees that can be sold to have a new income for buying new poles, cables and other components that will be necessary for the maintenance of the plant.

In Juwalu there is a “Board of Trustees" made of 3 members. From that point on, the framework of the Juwalu’s structure follows a pyramid structure, which is possible to observe in the drawing below.

The “Board of Juwalu” is composed of 6 members and from here the structure is shared in 6 zone committees. Each of them is situated inside more than one village and each committee consist of 5 members, for a total of 30 members who will be named GA “General Assembly” and they will discuss all the issues that will come to light when ACRA will not be in Lugarawa anymore.

Every village of the committee zone will have its transformer and each transformer will have 5 members who will decide for it and solve its set of problems.

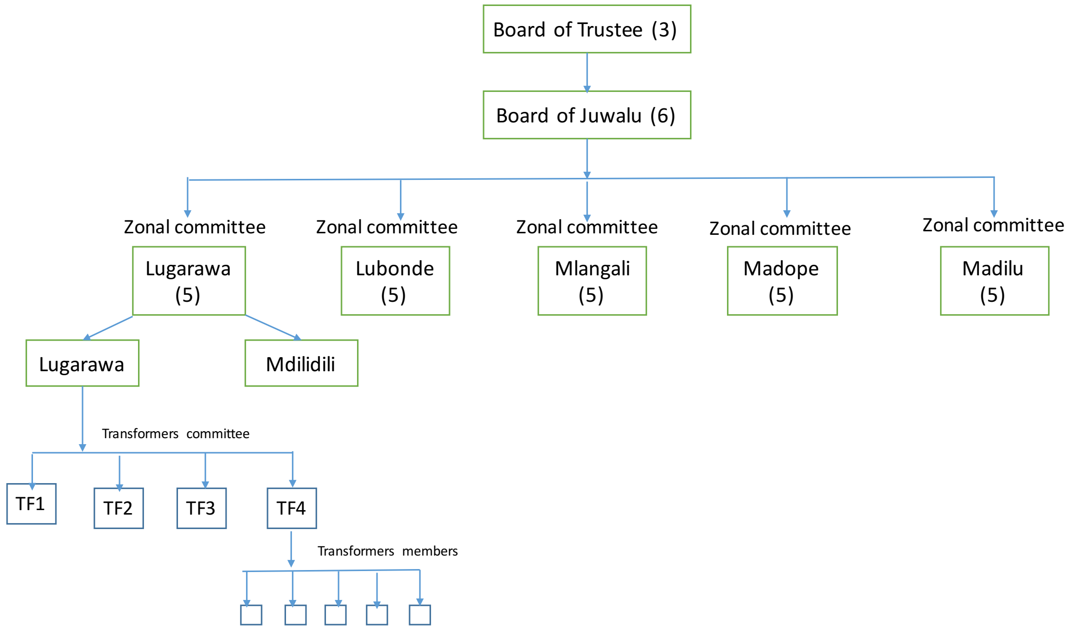

Figure 45 *Structure of Juwalu*

One of the most important problems of these rural projects is the continuing of the same project. In fact, it often happens that when the existing NGO (Not Governmental Organisation) leaves the rural area the project will survive for some months or years and after that will collapse and it is difficult for it to be revived. Therefore, it is very important to teach and train the new company that will take care of the project. These are the most important things that allow having a good management of the project and its durability.

7 Conclusion

Tanzania is a young developing country, that in front of others African countries enjoys fortunately of social peace, necessary premise for a sustainable development.
Tanzania is one of the poorest countries in the world. There is more poverty especially in the rural areas where the majority of people do not have access to the electricity and drinkable water.
The access to electricity and drinkable water could have many positive effects and not only can lead to the growth of a country's economic but also can support the development of rural areas.

Access to clean water and electricity can largely contribute to the improvement of health conditions.

Thanks to this Hydroelectric project, the NGO ACRA will contribute significantly to the development of a rural area in the Ludewa district that includes 20 villages for a total of 53,380 beneficiaries. The project will also give the possibility of economic and cultural development to other areas near the 20 villages. In fact, the presence of the new power line will increase commercial activities, the communication between these villages and other districts or regions and will allow the expansion of the power line itself, so that other consumers will be reached by the line and in the future other energy projects will be able to be integrated with the power line of this project, so that also the other nearby districts could benefit from this important project.

The activities involved during this internship, mainly about the LV power line, lead to the following conclusions:

- The field study of poles of the power line using GPS and then mapping of the power line using QGIS, allowed a more global view of the line and provided a means for understanding where particular problems were.
  Thanks to this study, it is possible to have a better supervision on the works in progress on the power line. At present the stringing of the cable on the poles is being done and with the maps provided, the engineer in charge of the electrical part of the project has access to information about the exact path of the power line, any changes made to the line and their precise locations. He will also be able to make a decision about the location of the transformer in Ligumbiru Village, using the considerations in chapter 3 about the potential difference as an example.

- Thanks to the proposal for new extensions of the line, creating the possibility to reach new connections, it is possible to have an idea about the best places to add a power line extension, the amount of additional material needed, and an indication for their relative costs. A visit to the field would be necessary next months in order to understand if the assumed new connections are practically achievable and if there are some additional households that would like to be reached by the line in the future. In fact, many new buildings, which have been built in the last two years or are still under construction, have to be taken into consideration, because they have not been marked by GPS during last year.

- Some alternatives to the new connections were proposed, because due to different problems, not all the households of the 20 villages will be reached by the power line. For these buildings, the installation of a photovoltaic plant was considered. After a first cost estimation it was clear that the cost of this kind of energy plant is too high and it is not easily feasible and therefore another alternative should be taken into consideration.

- Through the calculation of potential differences for the existing power line and the new extensions it was possible to see if there is the need for more transformers and how many loads could work simultaneously. After the simulation of different loads, it is possible to conclude that:
  - milling machines must be located within a distance of 1,102 meters from the transformer. Currently, most of them are situated within this distance limit;
  - ideally, for each village there is a maximum of four simultaneously working milling machines situated on the same side of the transformer and not too far from it;
  - if some milling machines are working, the assumed small mono-phase loads should have a power around 0,3 kW;
  - during evening hours all the small mono-phase loads can work simultaneously with an average power of 0,3 kW, indeed there will be loads that require more power, some as much as 1 kW, but they will be the minority. The simulations have mostly been done using loads of 300 Watt, because the households need electricity only for illumination and phone charging, almost 50 Watt and 300 Watt corresponds to the power required by a group of loads;
  - some of the new extensions will need new transformers, it is important to study each village case by case, calculating the potential difference;
  - a policy must be made that considers the consumers in three different categories, depending on their distance from the transformer.

This master’s thesis could be taken as a guide for new extensions of the power line of the project. The further steps that can be taken for new extensions could be:

- Marking the location of all the milling machines in all the 20 villages using GPS;

- Study and simulation of the potential difference of each of the 20 villages, like the study done for Mkiu, Mfalasi and Mangalanyene, in order to understand if it will be the necessary to add new transformers for the current households connected to the power line and for the new extensions and if the milling machines are within the maximum distance limit;

- Visiting each village and checking if there are particular or important buildings that need to be reached by the new extension of the power line.

The project should end during year 2018, and although new extensions are made, since the extensions of the power line only need the addition of a few new poles, some meters of cable and a few new transformers, not much time is needed in order to add them. As the engineer that is responsible of the power line has three work teams that are able to work very well and fast, and also the fact that by the month of May rain season will have finished, the site works could be facilitated.

It is possible to estimate that during next year both the current project and the new extension will end.

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