Rural Electrification Practicalities of Using Single Wire Earth Return for Low Cost Grid Extension: The Case of Ntenjeru, Uganda

Geofrey Bakkabulindi, Izael P. Da Silva, Eriabu Lugujjo, Lennart Söder and Mikael Amelin

Abstract— The fact that the vast majority of Uganda's rural areas remain un-electrified makes it imperative that low cost distribution technologies be implemented in order to provide affordable electricity to rural households. Such low cost technologies include the Shield Wire System (SWS), Single Wire Earth Return (SWER) and appropriate engineering techniques. The SWER technology is presented in this paper as well as the implications of its proposed implementation for electrification of the village of Ntenjeru in Uganda. While SWER can reduce the costs of electrification by more than a third compared to conventional high tension transmission lines, there are stringent grounding and safety issues as well as load capacity constraints involved. Furthermore, with the earth used as a current return path, soil resistivity analysis is important in these systems. Since soil resistivity can vary sharply over varying terrain and in different weather conditions, robust SWER systems have to be carefully designed. An analysis of the financial and electrical load implications of this technology in Uganda's local conditions will be presented and its viability as a sustainable method for electric energy distribution in the chosen case study area.

Keywords—Power distribution, rural electrification, soil resistivity, SWER

I. Introduction

THE Government of Uganda in its 2002 Rural Electrification Strategy aimed to increase rural electrification from the then 1% to 10% in the period 2002 – 2012. Currently biomass accounts for over 90% of the country's energy requirements mainly used in its traditional forms i.e. firewood and crop residues [1].

Uganda's current rate of grid-connection is about 5% of the total population [1] which is among the lowest in the world. Efforts to extend the grid to rural areas have been hampered by the high costs of high tension three-phase lines.

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Furthermore, the conventional standards used were initially designed for densely populated urban areas and are thus unsuitable for the low and sparsely distributed rural loads of Uganda.

The Rural Electrification Agency (REA) through its Energy for Rural Transformation (ERT) program currently provides incentives for rural electrification projects in the form of grants and subsidies. The power company featured in this study was to benefit from this scheme by providing a viable business plan for rural electrification in Ntenjeru.

Single Wire Earth Return (SWER) and the Shield Wire System (SWS) technology provide lower cost alternatives to the conventional methods of electrification. SWS makes use of the lightning protection shield wires mounted on the national grid backbone to provide electricity at medium voltage to areas in the corridors of the transmission network affordably.

SWER is suited to the distribution of power to low and sparsely distributed loads. Unlike conventional three-phase lines, SWER is a single-phase distribution technology which uses only one conductor and the earth as the return path. As a result, its costs of implementation are about two thirds those of three-phase lines. SWER is presented in this paper together with the analysis of its proposed implementation in the rural area of Ntenjeru in Uganda.

II. Background of SWER

SWER originated in New Zealand in 1925 and soon gained prominence as the preferred method for rural electrification in New Zealand and Australia. To date, the two countries have about 200,000 km of SWER lines [3]. The early work was carried out by Loyd Mandeno who published the paper "*Rural Power Supply, Especially in Back Country Areas"* in 1947. This paper laid the groundwork for SWER implementation. He also held the patents for the technology in New Zealand and Australia [4]. Other countries that have installed SWER lines since then include Brazil, South Africa and Namibia.

SWER is suitable for small rural loads such as lighting, heating, household appliances, welding, pumping water, etc. It can be used to run induction motors of not more than 10 kW. Anything above that would require three-phase supply which could be achieved from SWER using single- to three-phase converters. However, since these converters are quite expensive, this would defeat the purpose of SWER as a low cost alternative.

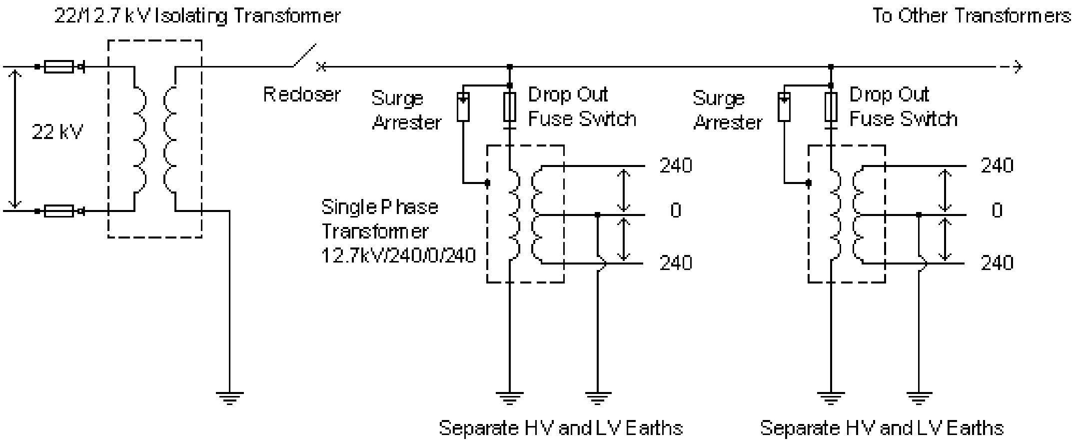

Fig. 1: Typical SWER system layout [8]

III. Benefits of SWER

In addition to low initial capital costs, the use of one conductor eliminates conductor clashing thus reducing fire hazards usually associated with conventional systems. Furthermore, longer span lengths and therefore fewer and lighter poles can be used. This accounts for a marked cost reduction. However, long span lengths require that the conductors be strung with a tension over 18% which can cause vibration damage [4]. This is mitigated in modern systems by using suspension insulators or spiral vibration dampers [4].

The design simplicity of SWER ensures shorter implementation time as well as low maintenance costs after installation. The system is also less likely to be affected by lightning strikes and will have a smaller impact on the environment compared to high tension three-phase lines. It requires a lot fewer insulators as well as switching and protection devices which improves its reliability over three-phase lines of similar length.

IV. Technical Aspects of SWER

A. Principle of Operation

In the Australian SWER system configuration, an isolating transformer is used for MV reticulation using 19.1 kV Single Wire Earth Return [5]. Whereas connection of SWER directly to the phases of three-phase systems is possible as used in the Brazilian SWER system configuration [5], isolation transformers provide earth fault protection on the three phase lines. Otherwise the return current in SWER would flow back to the main three-phase transformer resulting in high voltages supplied to equipment [6], [7]. These transformers are usually in the range 16 to 25 kVA although they are manufactured up to 400 kVA with 33 kV primary and 19 kV secondary [7].

The isolating transformer provides the most technically complex and expensive component of the system. Because of the transformer's high costs and its addition of system losses, SWER is not economically viable for grid extensions less than 6 km. However, for loads less than 5 kVA, the concept of

Micro SWER developed in South Africa can be used to make short extensions without use of the isolating transformer; mainly to supply power to remote mobile repeater sites [4].

SWER usually provides spur extensions from three-phase systems. A conductor is connected from one phase of the medium voltage (MV) three-phase system (33 or 11 kV) to the isolation substation/transformer supplying the load. Consumers are then supplied from the single phase transformer which has two outputs that are centre-tapped in a 240-0-240 V arrangement as shown in figure 1 [6]. The connected load's neutral is joined to the earth such that the return current flows into the earth back to the transformer via electrodes embedded two to three meters into the ground [7].

B. Earthing

The use of the earth as the return path requires that earthing be carried out very carefully for safe and efficient operation. For proper functioning, at least two load current-carrying earths are needed; one on the supply side and another on the load side [5]. Flow of current through the earth may result into dangerous touch and step potentials on the earthing rods (touch potential) and along the earth (step potential).

To avoid these dangerous potentials, SWER system current carrying earths should be carefully designed such that the product of earth resistance and current are less or equal to 25 V which has been found to be a safe touch and step potential for both humans and animals [5]. Therefore, soils with low earth resistivity allow for larger loads to be supplied.

I^2R losses in form of heat through the earth may cause a race condition if not properly distributed. The implications of this are that the heat will cause the earth to dry increasing its resistivity which in turn will increase the I^2R losses leading to further drying [5]. Therefore, loads in these systems are usually restricted within 200 kVA or current to 8 A. Where interference with open wire communications is not a problem, the limits are 400 kVA with current limited to 25 A at 19.1 kV [8].

Finally, the earthing electrodes need to be adequately protected against theft and vandalism. Large ground voltages will result at ground level from a missing earth connection [5], [7].

C. Power Quality and Capacity Limitations

In addition to the above voltage and current limitations, the loading of three-phase systems with single-phase loads leads to negative phase sequence currents. This requires that special care be taken to avoid unbalanced single-phase loading. This can be alleviated by supplying three single phase networks from one three phase distribution point [5].

Voltage regulation remains the most important capacity limitation affecting power quality in existing SWER systems. This poor regulation is mainly caused by the Ferranti effect inherent in most distribution systems. This effect accounts for the rise in voltage with distance along a transmission line at the load side relative to the supply side due to charging currents caused by induction and capacitance [5]. Whereas this effect exists in most distribution systems, it is particularly pronounced in SWER due to the long span lengths [6]. This makes consumer supply voltage regulation difficult. Since charging currents increase with distance and they are conducted by the current carrying earths in SWER, there is a limit on the SWER line length and supply voltage [5].

Modern systems counter the above problem by using shunt reactors which reduce the effects of line charging due to capacitance. Controllable shunt reactors are used to improve voltage regulation for heavier loads since load increase in SWER causes faster voltage drop compared to conventional systems [6], [7]. Distributed generation also improves voltage regulation in these systems.

SWER is limited to areas with earth resistivity less than 1000 ohm meters above which sizable loads cannot be supplied [7]. Proximity to open wire communication systems should be avoided to prevent interference from SWER.

V. THE NTENJERU CASE STUDY

Ntenjeru is a county located in Kayunga district (formerly part of Mukono district) in the central region of Uganda. It is about 80 km north-east of the capital, Kampala. It has an estimated population of 27,151 as of 2004 [9]. The major economic activities in the area are farming, with vanilla and coffee being the predominant cash crops, and fishing.

The area was selected for this case study because it is largely rural and vast areas of it lay un-electrified at the time of this investigation. Furthermore, at the time, plans were underway to extend the grid to the area using a pilot SWER project to be implemented by the Ntenjeru Power Company Ltd (NPCL).

A. Methodology

The aim of the field study was to determine some of the practical and technical implications of the proposed SWER project. The area's existing potential electrical energy requirements, optimal path of the proposed power line, soil resistivity, inhabitants' willingness/ability to pay for power and the cost comparison between SWER and conventional grid extension were investigated. In order to obtain the relevant data from the community, a field survey incorporating observation, soil resistivity measurements, oral interviews and questionnaires was carried out.

B. The Ntenjeru Power Company Ltd (NPCL)

Uganda's Rural Electrification Board provides subsidies to companies that demonstrate sustainable investments in rural electrification projects. NPCL was one such company. In 2007, the company proposed to extend the national grid to Ntenjeru County using a 32.7 km SWER line. The line would be extended from the Ntenjeru trading centre where a 33 kV MV distribution line already existed. This would involve the installation of a 200 kVA transformer with the capacity to supply 1,120,000 kWh annually to an estimated 400 clients in the surrounding rural area. The project was estimated to cost a total of US$ 458,000 and was to be funded by the Rural Electrification Agency (REA), the German Technical Cooperation (GTZ) and NPCL.

C. Power Demand Analysis

The field survey collected information on potential consumers who expected to connect to the grid once extended. Fig. 2 shows the percentage of potential consumers that expected to connect to the grid in different categories.

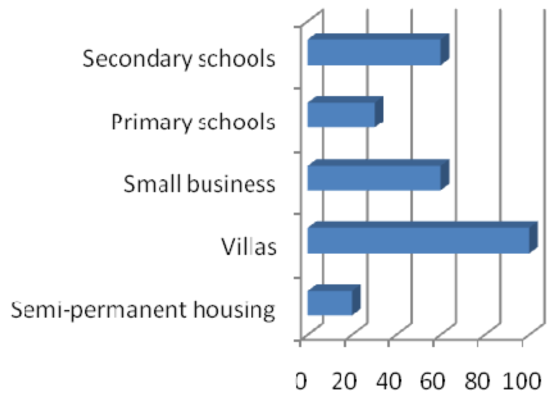

Fig. 2: Percentage of potential consumers that expected to connect to the extended grid in Ntenjeru

Out of 816 households, only 179 were expected to hook to the grid with an estimated annual power demand of 978,559 kWh. Of the 216 business establishments, 130 were expected to connect to the grid initially with an estimated total annual power demand of 1,365,764 kWh. Of the 30 institutions in the area, about 18 were expected to connect to the grid with an estimated total annual power demand of 119,620 kWh. This gave an annual total energy demand of 2,463,943 kWh. The energy demand was estimated from existing alternative energy sources in each category.

Over a ten year period, the total electrical load was expected to grow from 768 kW to 1,142 kW with contributions of 51%, 47% and 2% from the domestic, business and institutional sectors respectively. These estimates were in comparison with data obtained from Uganda's distribution company, UMEME, on load growth in similar electrified areas. Fig. 3 shows the projected peak power demand over a ten year period.

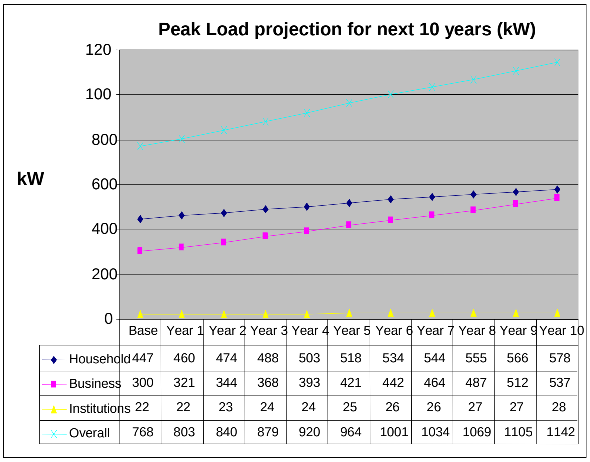

Fig. 3: Ten year projected peak electrical load in Ntenjeru

D. *Household ability/ willingness to pay*

The households' ability to pay for grid power could be roughly gauged from the average monthly income. Survey results showed that about 50% of the population earned less than UGS 150,000 (US$ 75) per month per household with the predominant source of income being farming. 40% earned up to UGS 500,000 (US$ 250) whereas a small percentage earned above that.

Consumers in Ntenjeru trading centre where grid power already existed had an average monthly power bill of UGS 26,000 (US$ 13) according to UMEME. This could be assumed to be the same for the consumers in the project area since economic activities were not significantly different. From the income data above, it could be deduced that about 40% of the households, i.e. those earning above UGS 150,000 (US$ 75), would be able to afford the above average monthly bill.

This was compared with consumption by existing electricity users in Ntenjeru trading centre. Data from the trading centre indicated that 30% of households had connected to the grid and 9% of those not yet connected had applied for connection. This agrees with the above estimate of 40%.

Over 90% of the households expressed a willingness to pay for the proposed grid power. However, willingness could be better determined from household expenditure on alternative sources of energy which would be substituted by electrical power. Fig. 4 shows proportions of each alternative source. Table I shows the average expenditure on each alternative energy source per household per month.

The introduction of electricity to the households is not likely to affect the expenditure on charcoal and firewood since most rural households are unable to afford electric cookers. However, use of kerosene and candles for lighting will be replaced by electric lighting. Dry cells were also widely used for lighting and powering appliances like radios and TV's with average monthly expenditure of UGS 6,600[1]. This means that a total monthly expenditure of about UGS 13,900 will be transferred to electrical usage. This indicates that only a percentage of all households will be financially able and/or willing to pay for electricity given the average monthly bill of UGS 26,000.

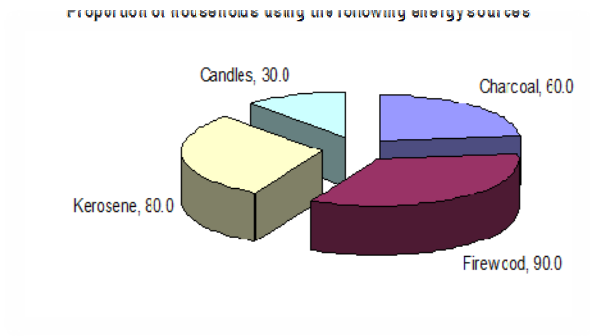

Fig. 4: Proportions of household alternative energy sources

TABLE I
HOUSEHOLD MONTHLY EXPENDITURE ON ALTERNATIVE ENERGY SOURCES

	Average quantity per month	**Average expenditure (UGS)**
Charcoal	1.3 Sacks	6,900
Firewood	7 Head loads	3,500
Kerosene	3.5 Liters	6,788
Candles	3.0 Sticks	500

E. *Business sector ability/ willingness to pay*

A similar analysis on the business community focuses on their alternative electrical energy sources given in fig. 4. Business activities included trading, grain milling, tea processing, agro-processing, restaurants etc.

Wet batteries provided energy requirements of 63% of the businesses. Each battery cost an average UGS 93,000 and was used to supply 1.2 kWh monthly with expenditure of UGS 8,000 for recharging per month. Dry cells were also widely used with an average monthly expenditure of up to UGS 30,000.

Comparison with businesses already connected to the grid in the Ntenjeru trading centre indicated a monthly bill of UGS 22,700. Power was mainly used for lighting, refrigeration, entertainment and heating. 80% of the businesses had connected to the grid and the same was expected for those in the project area.

[1] Exchange rate: US$ 1 = UGS 2,000 (July 2009)

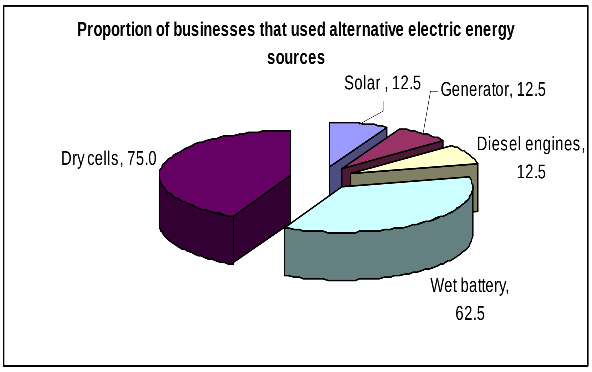

Fig. 5: Proportions of alternative electric energy sources for the business community

Largest expenditure on non-electrical alternative energy sources was kerosene (UGS 24,000). This brought to UGS 62,000 the average total monthly expenditure on alternative energy sources that could be replaced with grid power. This was well above the average expected monthly bill indicating a strong ability and willingness of the business community to pay for grid power.

F. Institutional ability/ willingness to pay

All institutions in the rural area were government owned. Therefore their willingness and ability to pay for grid power depended on their available budgets. Monthly expenditure on alternative electrical and non-electrical energy sources ranged from UGS 9,000 in primary schools to UGS 160,000 in an orphanage.

Since these costs could be greatly reduced with grid power, institutional ability and willingness to pay was expected to be high.

G. Soil Resistivity Measurement

In SWER systems, the resistivity of the soil has to be closely monitored in order to meet all the earthing requirements and operate the system within safe levels. The upper limit of 25 V for safe touch and step potentials in humans and beasts means that the product of earth resistance and current has to be less than 25 V. Soil resistivity may vary widely within short distances in the same area and so several measurements may have to be taken. Furthermore, resistivity changes depending on depth below the earth's surface. As moisture content of the soil increases, the resistivity of the soil decreases due to the added conductivity of the moisture.

During the fieldwork, soil resistivity measurements were taken at different locations using a resistivity meter that employs the *Wenner four-pin method*. In this method four rods are placed into the earth spaced at equal distances from each other in a straight line. A current is then driven through the two outer rods and the voltage across the two inner rods is measured. From this, the resistance of the soil can be calculated using Ohm's law (V=IR) and the resistivity, ρ, is calculated using (1) below.

$$\rho = 2\pi AR\,(ohm - m) \qquad (1)$$

Where A is the rod spacing in meters and R the earth resistance [10]. Fig. 6 shows the diagrammatic representation of the Wenner four-pin method.

Table II shows the resistivity measurements taken at different locations in Ntenjeru for rod spacings from 1 to 3 meters. It was observed that for some locations with certain soil types and characteristics, no reading could be obtained for rod spacing over two meters. For all locations, due to the short length of the rods used, no reading for spacings beyond 3 m could be obtained. Generally, resistivity increases with increased rod spacings mainly due to inductive coupling between the rods [10].

The resistivity measurements for the Mpatta trading centre were taken under dry and wet conditions after it had rained. As can be observed from the readings, the resistivity reduced under wet soil conditions. Under very dry conditions, a soil sample actually becomes a very good insulator with a resistivity of over 10^9 ohm-centimeters. However, the resistivity changes rapidly as water/moisture content is increased up to around 20%.

Soil resistivity is also affected by temperature. The resistivity of soil with a fixed amount of soil moisture content reduces with increasing temperature and increases with decreasing temperatures. Below zero degrees Celsius, resistivity increases considerably.

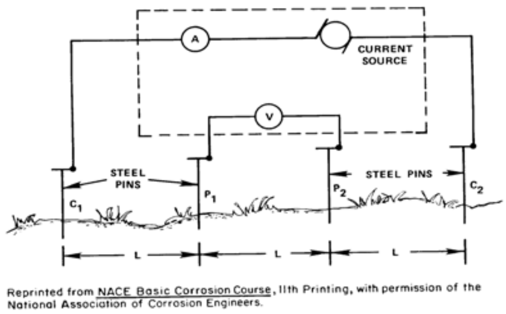

Fig. 6: Wenner four-pin method for measuring soil resistivity

The relationship between soil resistivity and temperature is given by the Steinhart-Hart equation [11].

$$1/T = A + B\ln(\rho) + C(\ln(\rho))^3 \qquad (2)$$

In equation (2), T is temperature in Kelvin, ρ is the resistivity in ohm-m whereas A, B and C are the Steinhart-Hart coefficients which vary depending on the temperature range in question.

From the relation between resistivity, moisture content and temperature, it can be deduced that resistance of any grounding system will vary greatly at different times of the year depending on the season, i.e. dry/wet or hot/cold for the Ugandan situation. A well designed grounding system should have the ground rod driven as deeply below the ground surface as possible, ideally to reach the water table. This is because the conditions of temperature and moisture content become more stable deeper from the ground surface as the surface is

TABLE II
RESISTIVITY MEASUREMENTS FOR SOME LOCATIONS IN NTENJERU.

Location	**Resistivity Measurements at different rod spacings (Ohm-m)**			**Soil conditions**	**Soil Characteristics**
	1m	**2m**	**3m**		
Mpatta trading centre	1214	1223	-	Dry	Brown top soil
Mpatta trading centre	1157	1196	1097	Wet	Brown top soil
Busoke	618	789	667	Wet	Sandy soil
Bule landing site	145.7	99.9	87.4	Wet	Rocky gravelly soil
Mugomba	460	517	-	Dry	Brown top soil
Tea estate	450	506	431	Dry	Soft brown top soil

much more influenced by variations in weather conditions and human activities. These would in turn cause undesirable variations in soil resistivity.

The chemical content of soil also has an effect on its resistivity. Soils with higher salt content tend to have lower resistivity than those with lower salt content. Low soil resistivity allows for cheaper grounding systems to be constructed. For areas with very high resistivity, therefore, in order to reduce the construction costs, the soil may be treated periodically with addition of soluble chemicals to reduce resistivity. Such salts include copper sulphate, sodium carbonate among others [12]. The downside of this method is that salts increase the incidence of corrosion of grounding rods and so the rods have to be specially designed to resist this. Furthermore, the chemical content introduces huge fluctuations with changes in temperature. But since temperatures in Uganda do not vary widely, this may not be a big problem.

VI. COST COMPARISON WITH CONVENTIONAL DISTRIBUTION SYSTEMS

The project costs for the Ntenjeru SWER project were compared with those for an equivalent conventional three-phase system in the same area. The comparison is best described by tables III and IV which contain the estimated costs of components for the two systems.

From the cost comparison in tables III and IV, total costs for SWER and conventional three-phase lines are US$ 210,623.33 and US$ 330,383.33 respectively. This represents a 36.2% saving on the cost for the conventional system. The economic analysis by NPCL showed an income statement that would realize a profit after six years.

TABLE III
COST ESTIMATE FOR SWER DISTRIBUTION SYSTEM IN NTENJERU (*Source: NPCL, 2008)*

PILOT SWER POWER DISTRIBUTION SYSTEM

UGANDA NTENJERU POWER COMPANY

provisional costing (estimate) for project works only

	units / km	**Rate per unit / km**		
		[Prices in Rand]		
SWER system				
System length SWER	**33**	**km**		
Transformers SWER - 64 kVA	**0**	**LPU SWER**		
Transformers SWER - 32 kVA	**7**	**PU**		
Transformers SWER - 16 kVA	**0**	**SPU**		
Site establishment	1	$ 45,000.00		
Transport	1	$ 20,000.00	$ 65,000.00	
19.1 kV MagPie SWER Line - Material	1	$ 12,000.00		
19.1 kV MagPie SWER Line -Labour	1	$ 6,000.00		
Total cost / km SWER line	**33**	**$ 18,000.00**	$ 594,000.00	
Loadbreak section links / T-offs	1	$ 2,500.00	$ 2,500.00	
Surveying of line	**33**	$ 800.00	$ 26,400.00	
Bush-clearing of line (by farmers)	**33**	$ 2,000.00	$ 66,000.00	
Trafo 48-64 kVA 2 Phase	0		$ -	
Trafo 32 kVA 2 Phase	**7**	$ 22,270.00	$ 155,890.00	
Trafo 16 kVA 1 Phase	**0**	$ 18,570.00	$ -	
Transformer earthing / SWER electrode	**7**	$ 4,000.00	$ 28,000.00	
33kV T-off	1	$ 40,000.00	$ 40,000.00	
Isolation Trafo 200 kVA	1	$ 86,450.00	$ 86,450.00	
ARC NuElec 1 Phase (incl. stat. meter)	1	$ 99,500.00	$ 99,500.00	
ARC McGFraw Edison 1 Phase	0	$ 60,000.00	$ -	
Aux Supply	0	$ 12,500.00	$ -	
Stat. Metering Unit	0	$ 30,000.00	$ -	
Installation	0	$ 20,000.00	$ -	
Application / Linkstick / Fees	1	$ 100,000.00	$ 100,000.00	
		Sub-Total	**$ 1,263,740.00**	
Users / supply points (1st supplies)	6	add 00xx% TAX	$ -	
		TOTAL	**$ 1,263,740.00**	
1 US$ @ ZAR 6.0	6	*US$ Exchange rate*	***$ 210,623.33***	***US$***
Cost / User			***$ 35,103.89***	

TABLE IV
COST ESTIMATE FOR CONVENTIONAL THREE-PHASE DISTRIBUTION SYSTEM IN NTENJERU (*Source: NPCL, 2008)*

Conventional 3 Phase POWER DISTRIBUTION SYSTEM

UGANDA NTENJERU POWER COMPANY

provisional costing (estimate) for project works only

	units / km	**Rate per unit / km**		
		[Prices in Rand]		
3 Phase Conventional system				
System length SWER	**33**	**km**		
Transformers 3Phase 11/.4 kV - 100 kVA	**0**	**LPU 3P**		
Transformers 3Phase 11/.4 kV - 50 kVA	**0**	**PU 3P**		
Transformers 3Phase 11/.4 kV - 25 kVA	**7**	**SPU 3P**		
Site establishment	1	$ 45,000.00		
Transport	1	$ 40,000.00	$ 85,000.00	
11 / 33 kV Gopher 3 Phase Line - Material	1	$ 30,000.00		
11 / 33 kV Gopher 3 Phase Line - Labour	1	$ 13,000.00		
Total cost / km 3 Phase line	**33**	**$ 43,000.00**	$ 1,419,000.00	
Loadbreak section links / T-offs	1	$ 2,500.00	$ 2,500.00	
Surveying of line	**33**	$ 1,600.00	$ 52,800.00	
Bush-clearing of line (by farmers)	**33**	$ 2,000.00	$ 66,000.00	
Transformers 3Phase 11/.4 kV - 100 kVA	0	$ 40,000.00	$ -	
Transformers 3Phase 11/.4 kV - 50 kVA	**0**	$ 35,000.00	$ -	
Transformers 3Phase 11/.4 kV - 25 kVA	**7**	$ 30,000.00	$ 210,000.00	
Transformer earthing / SWER electrode	**7**	$ 1,000.00	$ 7,000.00	
33kV T-off	1	$ 40,000.00	$ 40,000.00	
Isolation Trafo 200 kVA	0	$ 86,450.00	$ -	
ARC NuElec 1 Phase (incl. stat. meter)	0	$ 99,500.00	$ -	
ARC McGFraw Edison 1 Phase	0	$ 60,000.00	$ -	
Aux Supply	0	$ 12,500.00	$ -	
Stat. Metering Unit	0	$ 30,000.00	$ -	
Installation	0	$ 20,000.00	$ -	
Application / Linkstick / Fees	1	$ 100,000.00	$ 100,000.00	
		Sub-Total	**$ 1,982,300.00**	
Users / supply points (1st supplies)	6	add 00xx% TAX	$ -	
		TOTAL	**$ 1,982,300.00**	
1 US$ @ ZAR 6.0	6	*US$ Exchange rate*	***$ 330,383.33***	***US$***
Cost / User			***$ 55,063.89***	

VII. CONCLUSION

The proposed pilot SWER project was not implemented in Ntenjeru. NPCL was unable to raise the required capital after one of the major funding agencies, GTZ, withdrew from the project. One of the major reasons for the project's failure was upgradability of the proposed SWER. Ntenjeru is located 80 km from the capital city Kampala. As such, some of the funding organizations for the project felt that this proximity to the city might lead to rapid urbanization of the area in the near future which would lead to costly upgrades.

However, a well designed SWER system would allow for a simple upgrade to two-wire single phase or three-wire three phase reticulation. With good selection of conductor sizes, pole heights and strengths, etc, an upgrade to three phase would incur a capital cost of not more than 15% of the initial cost [8].

With an initial capital cost saving of more than 30% with SWER, an overall saving would still be realized even if an upgrade was required in five years or less. The study found that it is unlikely that the area will become largely urbanized in less than ten years from the date of the proposed project.

Rapid urbanization following the introduction of SWER would be as a result of the community's utilization of the benefits of electrification. In which case the economic growth would justify and pay for the necessary upgrade.

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