

**‘SWER (Single Wire Earth Return) systems User applications – optimising the use of this cost-effective electrification tool with suitable end-user applications’
– The Ugandan Case**

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BACKGROUND

The access to electricity is becoming a major demand in all societies in the developing countries. The declared aim of Uganda's Ministry of Energy and Mineral Development to increase the access to electricity to 10% of Uganda's population, implies the electrification of 40,000 rural household per year, bringing 'power to the people'.

Access to electricity is directly associated with higher levels of living conditions. Individual households, (rural and urban) when provided with electricity have better conditions of cleanliness, health and self-empowerment. Key institutions in society (private, governmental, non-governmental, parastatal) also require electricity to enhance the effectiveness and efficiency of their operations and programmes.

The introduction of SWER (Single Wire Earth Return) technology has significant merits regarding cost effectiveness to supply electricity to remote areas. This is especially the case where a strong backbone reticulation system is in place to supply high load centres (such as mines and larger towns, water pumping installations). Additional rural settlements and low demand settlements with clinics, schools, hostels, small borehole pumping installations can be adequately supplied with SWER (Single Wire Earth Return) technology.

PLANNED IMPLEMENTATION

LOAD RESEARCH

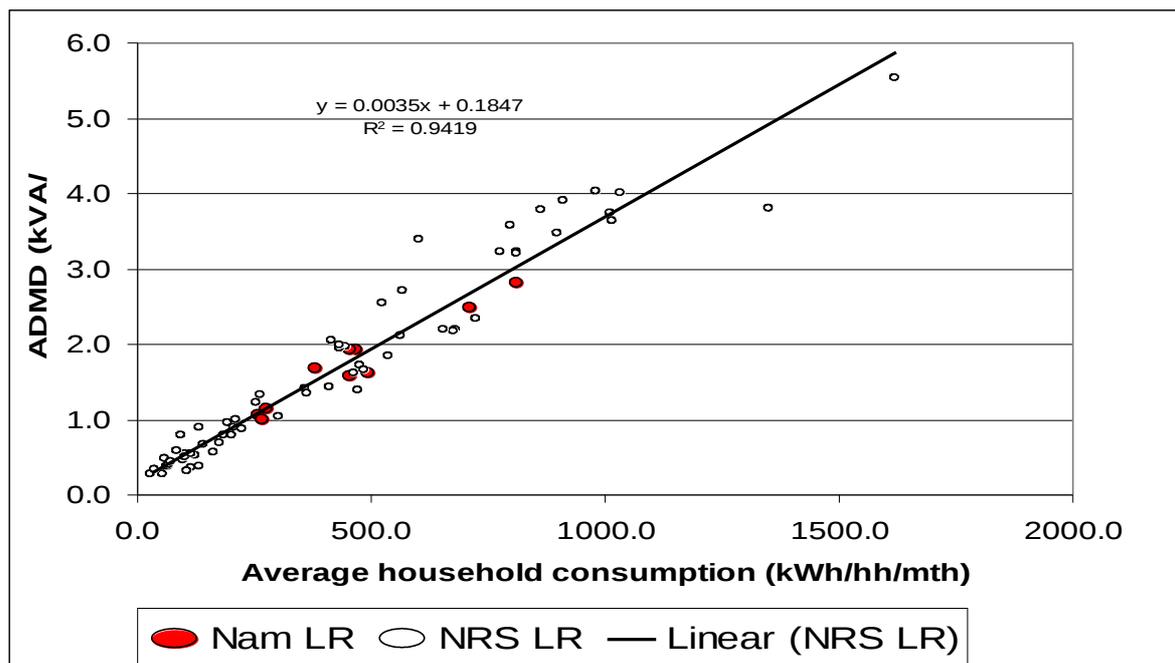
A key aspect is knowing accurately for which load to plan for, as well as considering the future load growth in the system in a given geographic distribution.

This will allow system planners to include in their designs upgrade paths of the network infrastructure. Further, generally it would be clear if a SWER system would be adequate, since the upgrading requirement in the short to medium term is not desirable.

A detailed assessment of the short term loads and demand, as well as the medium term requirement has to be assessed.

From Load Research as conducted in South Africa (ESKOM – NRS Load Research Program, project Leader Marcus Dekenah Consulting) and Namibia by the MME (Ministry of Mines and Energy) and the PoN (Polytechnic of Namibia), [1] clear indications for system planning and load forecasts are available.

Figure 1: Relationship between demand & consumption for Namibian LR projects 1999-2001 and South African LR projects 19994-2001. N=76 sites. [1]



These would have to be tested in countries like Uganda, but good correlations between research done in Namibia and South Africa is evident.

Electricity consumption would of course be influenced by the implemented tariff, availability and cost of alternative energy sources (wood, fuel etc.).

Further, load research has key benefits to a wide range of users [1]

- ❑ National Load Forecasting
- ❑ Planning Tool – Profiles, - Electrification
- ❑ Disaggregated Load Profiles for appliances
- ❑ Overall consumer group Load Profiles
- ❑ Alternative Energy Supply Options and Impact
- ❑ Financial and economic implications – national level
- ❑ Transmission / Distribution Infrastructure Design
- ❑ Market-force signals
- ❑ Tariff – Design

Due to the nature of the supply, the power source available is generally a single phase supply, as compared to the conventional 3-phase supply as available in virtually all distribution systems.

Immediate scepticism about the usefulness and adequacy of a single phase supply has to be addressed, and optimised ways have to be found to address needs for specific applications.

Subsequently user education is required, leading to an energy and load audit of an area, and technical advice to the community and key stakeholders. This would also include things such as advice for water pumping, irrigation systems etc., as well as explaining possible options for development now available, like setting up SMMEs (Small, Medium and Micro Enterprises) in the area. The Namibian Power utility, NamPower, implements energy audits and technical advice as part of their SWER electrification schemes [2].

NETWORK TOPOLOGIES AND CONSIDERATIONS

The common practice to t-off from existing backbone system to supply a number of customers or villages can be implemented, considering a number of aspects – All SWER (Single Wire Earth Return) systems are standardised on a 33kV system voltage, i.e. 19.1 kV line voltage for the system.

A detailed summary and planning guide has been prepared by Eskom Distribution Technology [3].

- i. Is there sufficient capacity on the existing feeder or alternatively is the planned backbone feeder of a capacity to allow for additional t-off loads to be connected?
- ii. Backbone, primary and secondary reticulations systems have to be planned, allowing suitable technology for the ultimate requirement, This includes voltage level (standardised) and conductor types to be used.
- iii. What unbalance will be induced on the 3-phase backbone system (negative sequence components, to be limited to not more than 5%)? How will the imbalance effect existing or planned customers on the 3-phase line, How would it affect the Quality of Supply?
- iv. How many consumers are to be connected by the SWER system, and can the load be transferred considering the voltage profile taking into consideration the diversified demand, Fault currents at the end of the line and special loads such as motor starting. Different conductors can be considered to increase the load momentum (load transfer capability).

- v. Isolation transformer rating required have to be determined (based on the backbone distribution system capacity). The largest standardized available rating for this purpose is 400 kVA.
- vi. Earthing arrangements are critical, and proper designs have to be prepared for all installations. In rural villages with a higher density population, multiple earth electrodes are required. A neutral/earth conductor is strung between the structures to connect all earth electrodes of each transformer, or alternatively external / remote earth electrodes are installed outside the village / locality at suitable positions.

The systematic planning and load prediction has to be analysed, using a computer Loadflow/ short circuit simulation program DlgSILENT.

Other aspects would be to consider upgrade paths for future demand growth. – SWER has to be selected for the right geographic areas, where a limited growth can be predicted. Cost for upgrade paths, and the realistic implementation thereof, have to be considered when the layout plan is designed. Upgrading would be done by various options, e.g. upgrading to a 3-phase system, doubling up the conductor, reducing and subdividing the load zones etc.

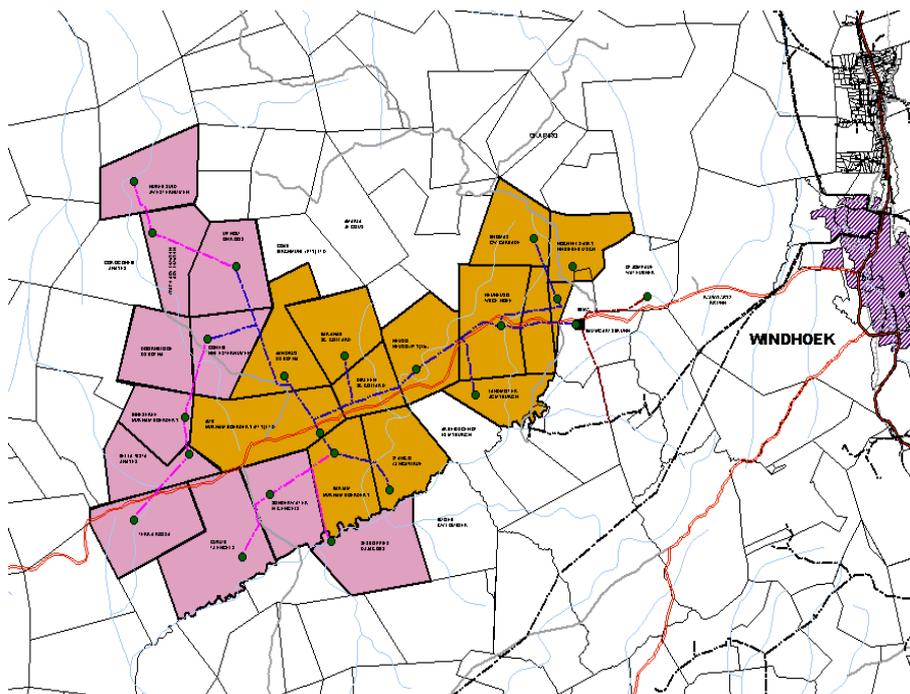
Parallel SWER systems (i.e. two to three T-offs from a node) can also be considered where applicable, minimising the impact on the backbone distribution system, and optimising the SWER electrode configuration.

A deferred expense can be considered favourable, as other areas can be serviced in the meantime, thus making it more realistic to achieve the electrification benchmark, as well as generating revenue. Financial model, depending on donor funding, discount rates etc. would be key aspects in this regards.

TYPICAL EXAMPLE – RURAL FARMERS ELECTRIFICATION SCHEME

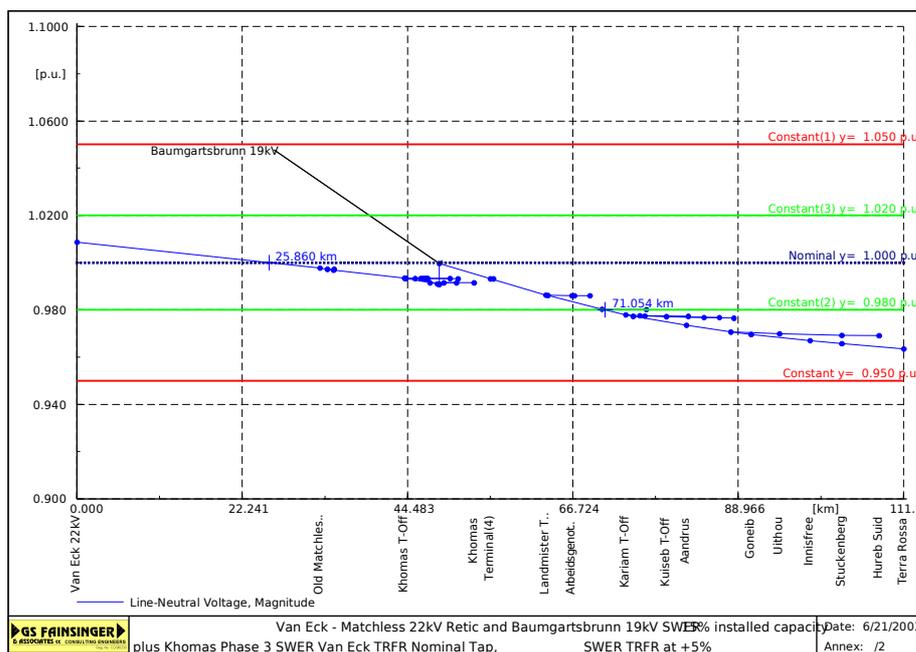
A typical example would be to analyse the extend to which a system can be expanded. An energy audit determined the loads (present requirement, as well as future growth). – A load flow determined the possibility thereto.

As shown, based on the available simulation data, the network could be expanded, but only to include the applications of the shaded areas. The possibility to adjust the tap settings on the isolation transformer and supply transformers, avails considerable flexibility to the system expansion. A voltage range on the SWER system of .95 p.u to 1.05 p.u is permissible.



Further, the fault levels were marginally low. For a SWER system, fault levels of 50A to 70A can be manageable from a protection co-ordination point of view. Protection and fuse grading would be a separate exercise to be considered in co-ordination with the utility network planers.

Geographical arrangement for a rural farmers SWER scheme



Load flow simulation results – Voltage profile

SUPPLY TRANSFORMER CONFIGURATIONS

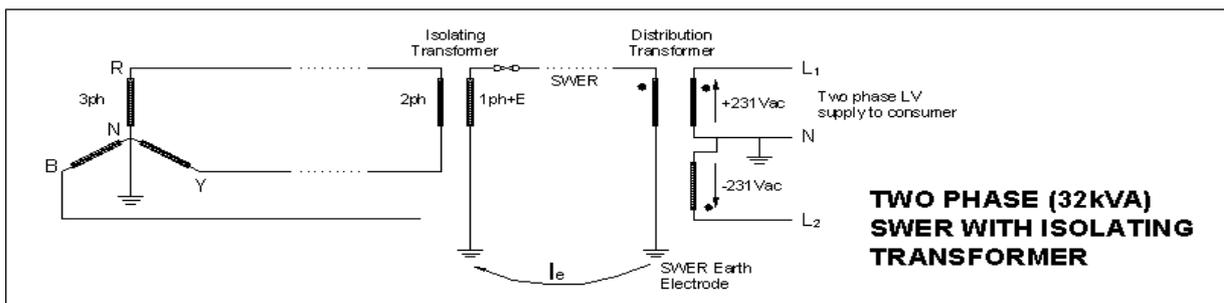
Depending on the required load and geographic layout, suitable transformer configurations can be designed to supply the load.

The most popular transformer configuration is the bi-phase 32kVA SWER transformer. The advantage of a two-phase system, is twofold –

- i. the neutral return current on a distributed LV (Low Voltage $\pm 230\text{V}$) is a balanced current in the neutral conductor, allowing for longer cable lengths (ABC) in villages. Maximum distances depend on design factors used (diversified demand, circuit breaker ratings, QoS (Quality of Supply) requirements etc.)
- ii. A high voltage (460V ac between the two phases) is available to supply large loads, mainly converters and large single phase currents.
- iii. Dual (Two / Bi) Phase LV:

This is a LV system which uses three conductors; +230 V, Neutral and -230 V. This system uses the conductors almost as effectively as a 3 phase LV system. A dual phase LV system has the advantage that it can be derived from a single phase MV or two phase MV or a SWER MV system. This is done through the use of a single phase (230V) LV winding, transformer. Standard manufacturers rating: 32 KVA, +240V /-240V ac. Transformers are equipped with manual tap-changers, and voltages can be compensated if required.

Figure 2: Schematic – 2-Phase transformer [3]



The robustness of the transformer would allow for the installation of marginally oversized circuit breakers, with a slower trip curve, to prevent nuisance tripping.

Alternative popular arrangements are 16kVA (single phase transformer) and combinations of the above two transformers, e.g. connecting 32kVA transformers in parallel yielding a capacity of 64 kVA. The earth-electrode arrangements as well as the network strength of the system are limiting factors though, and due cognisance has to be taken thereof.



32kVA in parallel to a 48 kVA transformer – irrigation project, 3 phase submersible pump powered via a 11kVA converter drive

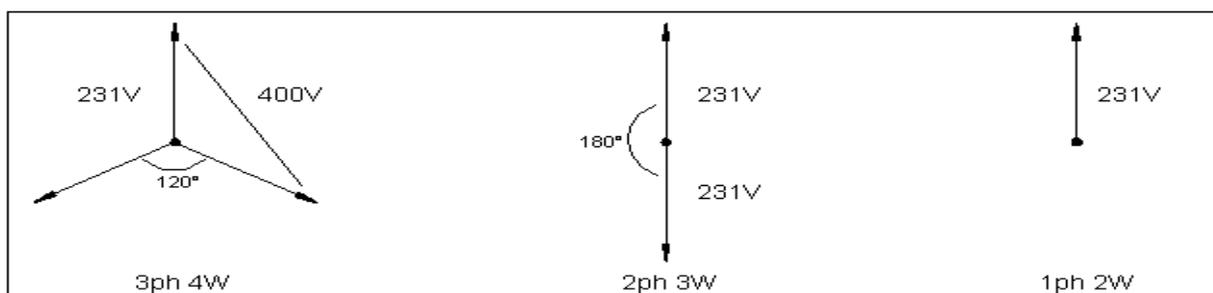


Installed capacity of 64kVA for the Koichas School and Hostel setup.

Figure 3: Parallel transformer installations

The option proposed, a 32 kVA Bi-phase transformer has a Phase to Phase voltage of 462 V ac, and this must be understood and considered when preparing / designing a system. Especially with the layout of the system and connection of equipment.

Figure 4: Schematic – Phase arrangement [3]



APPLIANCES AND LOADS

The most common loads for rural electrification projects are households, schools, clinics, SMMEs (Small and Medium Enterprises), Shops etc. – Households would be equipped with standard household appliances, directly related to their income. With time, loads will grow as appliances are purchased and utilised :more lighting, TV electric stove fridges etc. – Rural households ADMD can be estimated at 0.75 kVA ADMD (typical application). Further, a direct relationship wrt. income, hence energy consumption and subsequently demand is experienced [1].

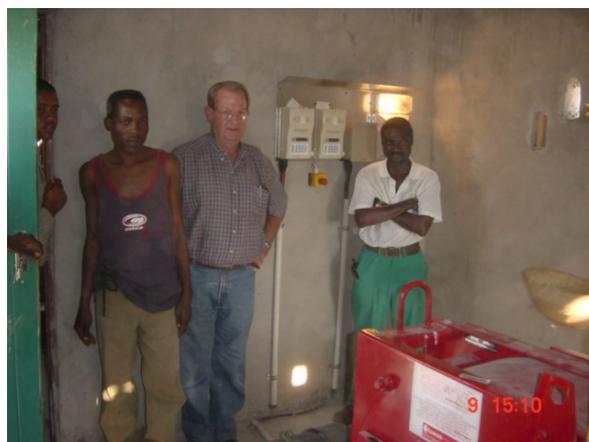
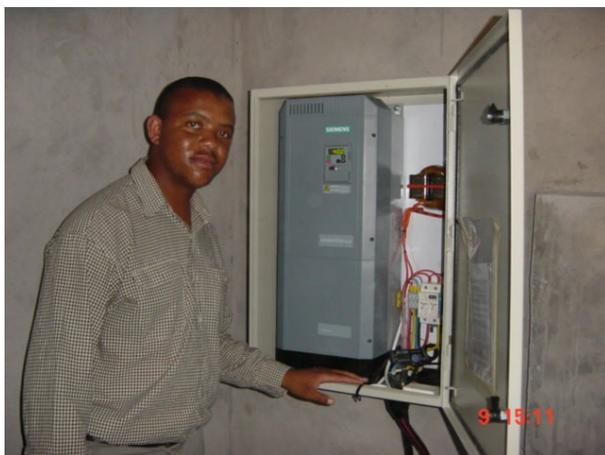
Special loads, generally considered an obstacle for SWER applications are the ones as listed below, as well as additional applications not mentioned here

- i. Deep well water pumping - Irrigation projects, mono-pumps
- ii. Large high inertia loads – hammer mills, conveyor belts, small-scale factories
- iii. Hospitals, schools, hostels where substantial heating, refrigeration plants / cooling etc. is required –
- iv. Lodges / tourism industry –

Maize under irrigation – SWER system irrigation

SOLUTIONS

- i. These applications can be addressed and have successfully been solved with 2-phase – 3 – phase converters (TruTech Converter, manufactured in Namibia, up to 22kVA) – for large hammer mills, and booster pumps for irrigation systems.
- ii.



15 kVA converter drive for a 1ton/hour throughput 15kVA motor driven hammer mill.

Large single phase motors (up to 22kW available) but have only been used extremely successfully for 7.5KVA applications – to drive mono pumps and pumping water from up to 180m. Standard 3.7 kVA 1 phase motors (460V) are connected to drive deep well pumps.

- iii. Single phase Compressors for cold rooms (where two can be configured in parallel, one per phase)
- iv. Load shedding devices / Energy control units and distributed control for lodges (with e.g. warm water geysers / air conditioned room. [4])

TARIFF

A suitable tariff has to be in place, to allow for a suitable (positive) revenue stream, to facilitate the upgrade, as sufficient demand is required to finance the additional costs. Also for rural electrification schemes a so-called poverty tariff can be implemented. – For areas with commercial activity penetration in rural zones pricing signal to gain a good load factor are desirable for SWER distribution schemes.,

CONCLUSION

With adequate planning and preparatory work, proper and adequately sized and configured SWER (Single Wire Earth Return) systems can be developed, catering for 99% of all needs in rural and semi-urban areas, including the supply of special loads and small scale

industries. The great advantage is the cut of costs of grid extension. SWER can provide transmission at more or less 30% of the cost of the conventional 3 phases 22kV or 33kV systems.

Clearly there are as many advantages as well as disadvantages to any system. – However considering the SWER (Single Wire Earth Return) system simplicity, low maintenance requirement, reliability and low capital cost as well as the reduction of bush fire hazards, the considerations as disadvantages wrt. three phase conversions as required, earthing electrodes, isolating substation and load balance on the primary distribution side, are minimal.

SWER (Single Wire Earth Return) systems can form a positive impact on any rural electrification program.

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