ENERGY STORAGE ON MUNICIPAL GRIDS:

WHY THIS MAKES SENSE

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1. Introduction – When is a flat line a good thing?

Any cost-conscious electricity consumer will always be on the lookout for ways to optimize their energy use and reduce the money paid for the service. Driven by tariff structure design, the real costs have always been, and remain dependent on the profile of the load. The more 'peaky' the load, the more it costs to service it. This is one of the few places in the world where a 'flat line' – a flat load profile - turns out to be a good thing, as it is cheaper for the electricity distributor to service.

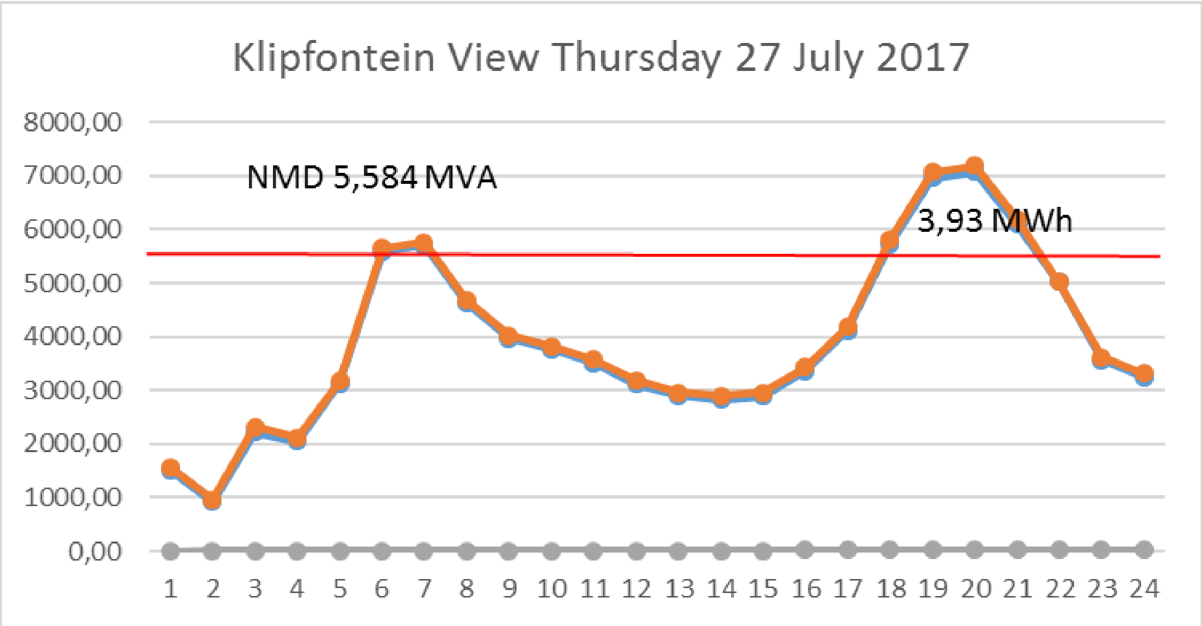

Figure 1: Load profile of the Klipfontein View Eskom intake point, City Power

The load profile shown above is one of City Power's smaller Eskom intake points supplying an area where there has been rapid residential growth and the necessary upstream upgrades are planned, but still several years away in the Eskom pipeline. As a result, the intake point is subject to Notified Maximum Demand Penalties and over the 2017/18 financial year, the penalty amounted to R2,6 million for the year, while the 'normal' component of the bill was around R20 million for the year. The penalty therefore inflated the price for that intake point by more than 10% for the year. This inflated cost is over and above the higher cost due to the 'peaky' nature of the load.

In years gone by, the first action taken at the consumer level would been to manage peak demand by scheduling equipment start-up times. This was done in response to the distributor passing on, and applying their own additional demand charges onto the consumer. Second was to improve energy efficiency, and thirdly the implementation of power factor correction equipment to avoid reactive energy charges, also passed on to the consumer. These responses were possible because there was mitigating technology available to make an impact. Quite often however, even though the actions made economic sense, response was lethargic because the price of electricity was still relatively low and the technologies were somewhat limited, seemed complicated and 'too technical' in nature.

At a distribution level, the focus has predominantly been to manage peak demand using geyser control systems, or focusing on converting large power users, who can shift load, onto time of use tariffs to manage the overall load profile. A few distributors had diesel fired gas turbines to 'peak lop', however, these became uneconomical to run with the rising price of oil and the migration of most municipal distributors to the Megaflex tariff in the 1980's, where there was a shift from charging exclusively for peak demand, to a blended set of charges that have a component of demand and peak energy pricing from Eskom. Where possible, distribution design objectives were set to improve diversity through combining residential loads with commercial or industrial load connected to each substation, to flatten to overall load profile.

Things have really changed over the last two decades. The price of electricity has increased by over 500%, and improvements in energy efficiency options as well as alternative, distributed energy sources have been remarkable. Supply insecurity from centralized generation has also unfortunately crept into the picture. We have added many thousands of new 'peaky' residential consumers to the networks and all the while, new technologies have matured and prices fallen, most notably in the cost of photovoltaics and of energy storage systems, particularly storage at 'Utility Scale'. What in the past seemed not worth the effort or was too 'complicated' to do, are today imperatives for electricity distributors.

Across the globe, storage is being deployed at an accelerating pace, not only to improve the availability factor of renewables, but also to solve a host of electricity delivery problems distributors face. (Clean Horizon, 2019).

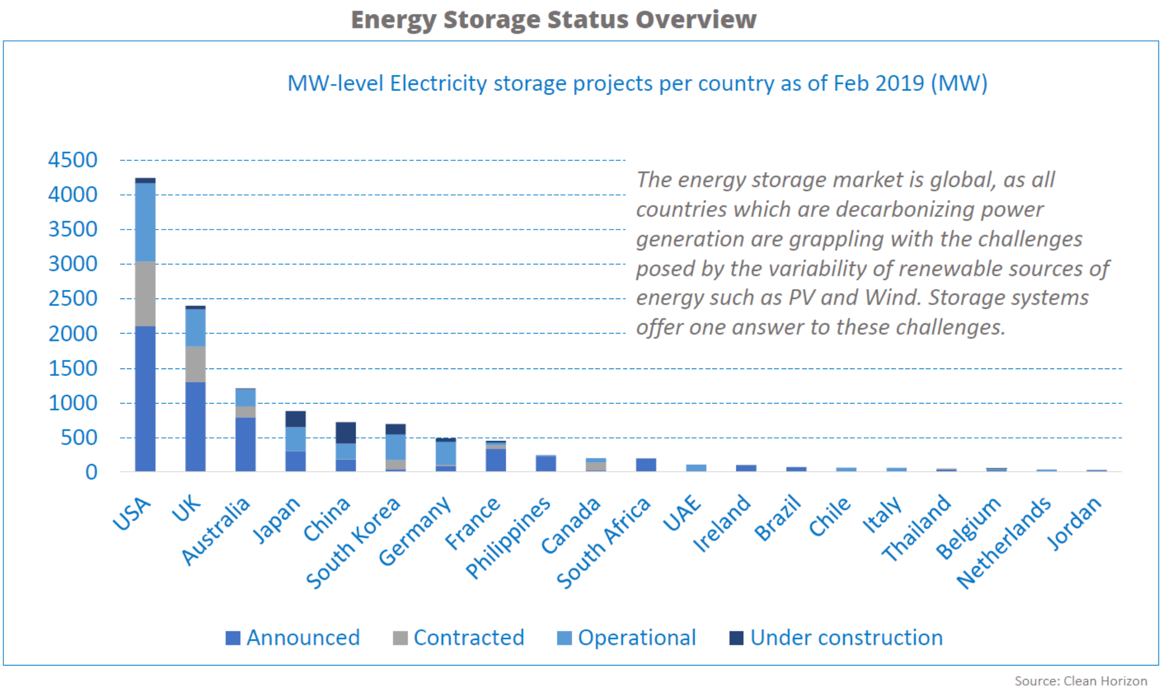

Figure 2: Storage project capacity by country. (Source: Clean Horizon, Storage Status Overview and Survey, 2019).

The deployment of Energy storage at scale touches several of the Convention's themes for this year; Small Scale Embedded Generation, Smart Distribution Management and to some extent aspects the 4th industrial revolution as there is a need to prepare for the orchestrated digital control of all of the stored energy facilities across the country.

The theme of this paper is to explore the value-add of the various applications of storage, from utility scale to the aggregation of many small 5 to 10 kWh systems for individual houses as well as the dependence on where in the electricity distribution value chain the storage is placed. In an environment where the national generation industry may not have adequate reserves to balance the system over the coming years and the proportion of self-dispatched renewable energy sources feeding into the grid increases, the introduction of a significant quantum of energy storage can go a long way towards managing the reliability and cost effectiveness of the system.

How a fleet of storage assets can be grown in an economically viable and mutually beneficial manner is explored, as well as the added benefits of deploying energy storage as part of a small scale embedded generation program.

Today, all electricity end customers are interested in reducing the cost of using the product. The same must apply to any entity purchasing energy in bulk for resale to these end customers, particularly where there is a mutual benefit. This a key objective of the Municipal Systems Act that furthermore has the backing of the Constitution. Any regulation or legislation (or lack thereof) that is inappropriately used or obstructs the realization of this objective needs to be brought to the attention of the relevant Ministry, to be resolved.

2. A recipe for reducing costs

The municipal distribution industry presently faces massive financial challenges and must find ways of reducing their costs and improving efficiencies, for the sake of their own sustainability. Those technologies that offer cheaper energy and those that could be used to avoid peak energy consumption as well as reduce network and demand charges and penalties must be deployed as soon as they become economically viable.

Where energy is already available at rates below those of Eskom, the municipality is obliged to pursue these in order to reduce the cost of their municipal services. This is in perfect alignment with Section 73 (2) of the Municipal Systems Act 32 of 2000, paragraphs a) through e).

It is incorrect to classify an energy storage system as an alternative source of energy. It is easy to fall into this trap because storage has quite often been included in renewable energy facilities to improve their capacity factor and this aspect of storage has been well publicized. It is also incorrect to think of energy storage as just a giant UPS system, because energy storage systems are grid-interactive – they can act as a load as well as a source of energy to both the grid and to priority loads.

In terms of the energy system, storage is a net load as there is an element of charge and discharge loss inherent in their use. Primarily, these systems are able to store cheap surplus energy from any source, at a time such surplus may be available, and to release almost all of the energy back to the system when there is a generation shortfall and peak energy pricing applies. In financial models, the stored energy should always be taken from the cheapest source available and may be either from off-peak coal derived Eskom energy at night or from any surplus or lower cost renewable energy in the middle of the day.

The load profile shown in figure 3 below is the sum of the three 275kV intake stations that supply the Johannesburg area of City Power. As mentioned in the introduction, the most cost-effective load to service is one that is a flat line, the question is, what can be done to straighten out the kinks in this profile and can it be done as a normal course of business?

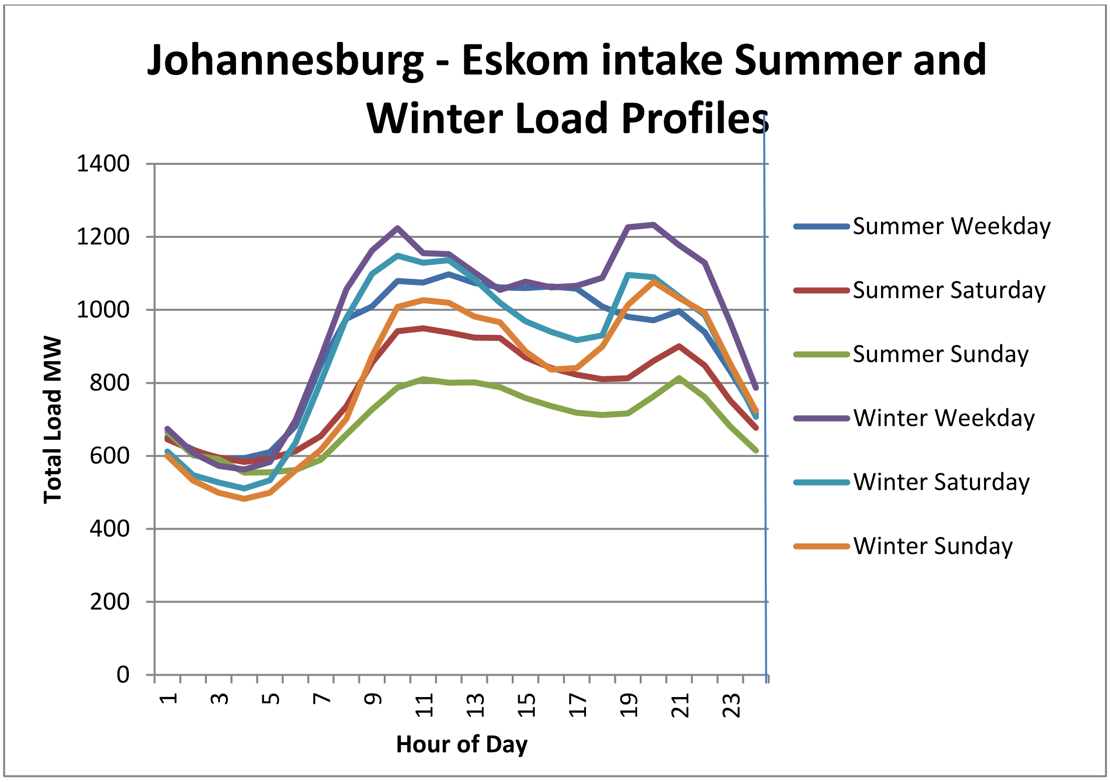

Figure 3 – 275 kV Eskom supply to Johannesburg

Many municipal distributors have over the years deployed geyser control systems to manage the evening peak in particular. Geysers are in fact pretty good energy storage devices – a fully charged 150 litre geyser stores around 7 kWh of heat energy equivalent and is the principle on which the geyser control systems operate.

In effect, a signal is transmitted to control relays to interrupt the supply to the geysers. This reduces the instantaneous demand for power, and 'holds off' the growing geyser load until the peak period has passed and capacity to re-charge the geysers becomes available. This action creates a deficit of energy within the energy distribution system which has limitations.

The power must be restored within at least an hour and a half, otherwise the result will be many customer cold water complaints. It takes only a few such incidents and the relay will be bypassed by the consumer. Despite these constraints, these systems have successfully been used to manage instantaneous demand and avoid recharging the geysers with costly peak energy, by delaying the re-charge so that it can be done with cheap off-peak energy. This is the basic financial arbitrage mechanism that reduces the cost of supplying energy for water heating purposes.

A grid connected battery energy storage system does not have this limitation as it can be recharged many hours after the peak has subsided and at the most convenient time that best suits accessing the cheapest form of energy the system has to offer. Storage systems are able to pre-create a reserve of energy for the system to manage demand rather than creating a deficit to achieve the same. So, a utility scale energy storage system is really more like a geyser control system on steroids.

Energy storage is also twice as good as a gas turbine at managing the peaks and valleys of any load profile. A gas turbine system can only ever behave as a generator of electricity. In contrast, a utility scale energy storage system can be both a schedulable generator and a schedulable load. It can both fill the valleys and clip the peaks, so it has twice the control range of a gas turbine generator.

In parts of the United States, PV plus storage has become a cheaper 'peaking' option and is displacing natural gas powered peaking plant. In some cases storage is competing not only with peak generation, but also with mid-merit generation plant. (IEEFA 2019).

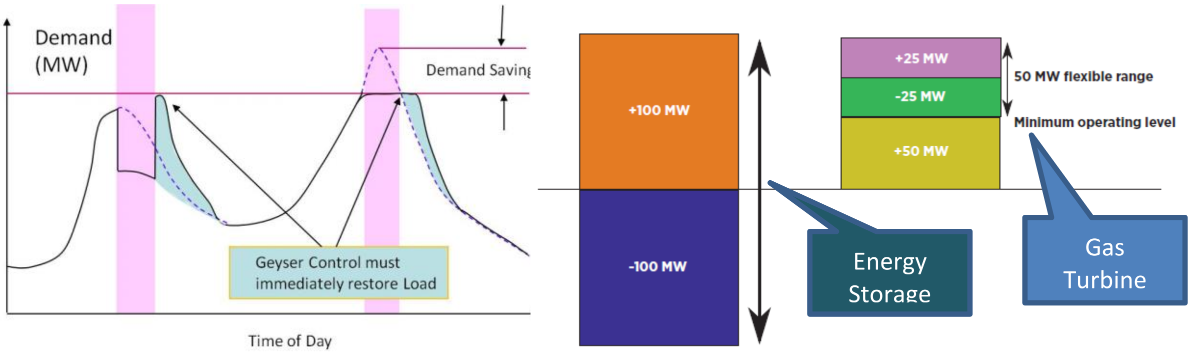

Figure 4: Comparison of Energy Storage to Ripple Control and a Gas Turbine

The load profiles in figure 5 below shows the effect of introducing a total of 350 MW worth of PV generation and 250 MW worth of storage with a capacity of 1690 MWh to the Johannesburg grid. While this is a tall order and for storage may take over a decade to achieve, it demonstrates that the load factor can be improved from 0,78 to 0,94 which will significantly reduce the bulk energy purchases bill from Eskom. In the example, the total sales for the day was 23 942 MWh, and the evening peak at around 7 p.m. was 1232 MW.

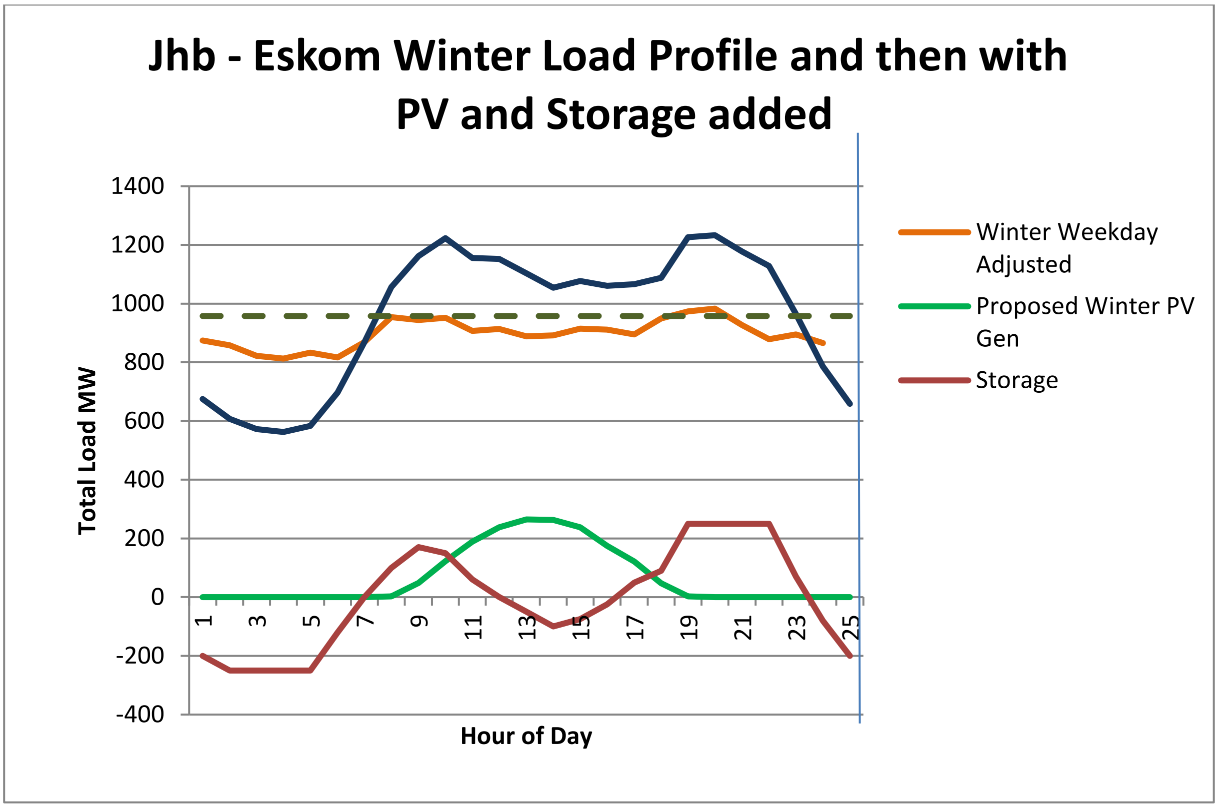

Figure 4: Hypothetical adjusted Johannesburg load curve with PV generation and Utility Scale storage added to the mix.

3. The cascading benefits of energy storage

Utility scale energy storage is developing rapidly and can have significant negative disruptive potential for the EDI in so far as it is an enabler for those end users who have the desire and financial means to go 'off grid'. At present, the cost of going completely 'off grid' is not economically viable. This will however change as the cost of storage eventually does reduce to the point where renewable energy plus storage reaches grid parity.

In contrast, when storage is put to use in support of the electricity distribution system as a whole, the so-called disruption to the industry can become immensely positive in a number of different aspects. It is important to realize that the value of utility scale energy storage is generally increased the further down in the grid energy value chain it is placed, provided it is still operated at a time that benefits the Generation, Transmission and Distribution industry. This is due to the cascading value or 'stacking' of both technical and financial benefits as the storage facilities are located deeper into the network.

For example, a 100 MWh storage system placed at a point on Eskom's high voltage transmission network can provide:

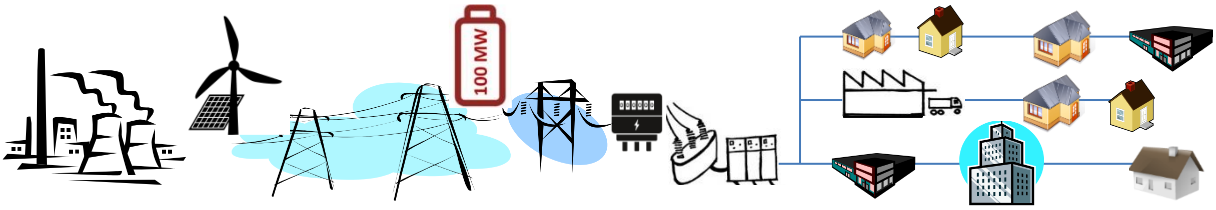

Figure 5: Energy Storage Facility placed on the Eskom Transmission Network.

- A means to store surplus renewable energy at a national level,
- Avoid transmission network bottlenecks and
- Provide frequency support (reserve margin) for the national generation industry

These are the only benefits that can be realized in the case the storage is connected to the transmission network.

If the same energy storage capacity of 100 MWh was deployed by strategically placing fifty smaller 2 MWh systems further downstream on the municipal distributor's medium voltage distribution networks, not only could the abovementioned benefits still be realized, but the storage systems could add further value through:

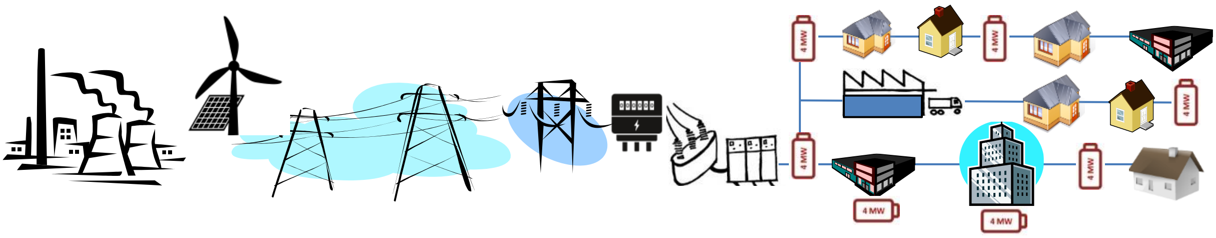

Figure 6: Distributed Energy Storage facilities placed on the Muicipal Distribution Network

- Eskom energy purchasing arbitrage and demand charge reduction,
- The alleviation of distribution network bottlenecks and overloads,
- The avoidance of Eskom Notified Maximum Demand Charge penalties,
- The deferment of network refurbishment or network upgrade capital expenditure
- Improvement of the power factor across the entire transmission and distribution networks
- Realizing a significant improvement in the security of supply for end customers.
- Providing a measure of standby power to end customers as an alternative to expensive diesel power
- Through digital co-ordination, operate as a proxy to peak power generation plant to maintain the reserve margin

This increasing value effect or 'stacking' is critically dependent on where in the network the storage system is located. The highest value of all to the end customer and the economy as a whole would be realized where these energy storage systems are strategically placed at the so called ‘grid edge’, as close to the customer as possible and designed to run as independent power islands or mini-grids to maintain supply to one or a group of end customers in the event of load shedding or other unplanned grid outages. It is important to remember that 60% of the ‘grid’ edge is in the hands of the municipal distributors.

Another subtle benefit of rather installing the storage on a distributed basis, is that the reliability of the storage function within the system is made more secure. Diversity brings this added reliability for the storage, as the chance of all of the smaller facilities all failing at the same time is far less than the possibility of a single large installation failing at an inconvenient time. The distributed approach is able to include a reliable element of demand reduction that can confidently be factored into the demand charge reduction financial modelling for storage.

So, it is in the space between going completely off-grid with PV plus storage, and using PV plus storage plus the cheaper ‘off-peak’ grid energy available by staying on the grid that is much more interesting to the system as a whole. Customers remaining part of the grid community will be provided backup on those occasions where sunshine is unreliable for days at a time, and on good solar days, they will still reasonably provide a cross-subsidy to support those customers that cannot afford a system of their own.

4. Real, practical benefits of storage

Utility scale energy storage systems are rapidly becoming economically viable and can provide demand side flexibility like never before. They can be deployed where networks need strengthening, can defer costly network upgrades and in most cases do this permanently. As an added benefit they can be sited at key customer premises and used as an alternative to diesel generation in the event of both forced and unforced grid outages. This ability to offer enhanced security of supply is a potential new revenue stream for the distributor.

It is not unreasonable that a distributor should aspire to be in a position to control at least 10% of their peak demand liability using energy storage systems, specifically to manage the winter evening peak demand caused by residential load on a daily basis. Such a quantity of storage capacity can also be used to insulate the distributor from stage 1 load shedding, should the need arise in the future.

The various applications of energy storage can be described in terms of the benefit they bring to the municipal distributor. We will unpack a few of the applications to identify how they benefit distribution systems they are connected to:

- Optimizing energy procurement costs – arbitrage and demand control
- Avoiding NMD penalties
- Protecting the economy and enhancing the security of supply
- Preserving overloaded distribution infrastructure and extending its lifespan
- Unlocking property development and supporting densification

- Optimizing Investment in renewable energy systems

4.1 Optimizing energy procurement costs – arbitrage and demand control

Tariff arbitrage is the practice of using load shifting techniques to reduce energy procurement costs where the energy is available on a Time of Use basis, such as the Eskom Megaflex tariff. This is done by storing cheap off-peak energy for later release during peak times when the cost of energy is much higher. Table 1 shows the daily arbitrage value of 1 kWh's worth of storage to a municipal distributor (yellow highlight) when applied to an 11 kV intake point on the Eskom Megaflex Local Authority tariff for 2019/2020. The table shows the average value over a whole year.

The table also shows the maximum cost of the energy storage system (pink highlighted value of R 4309 per kWh) for the business case for using the storage for arbitrage alone to be viable. The site will begin to generate an increasing surplus should Eskom prices continue increasing at above inflation rates. In addition to this, the actual cost of storage systems is expected to continue reducing to levels significantly lower than this figure over the next ten years.

Analysis of break-even point of energy storage cost vs. maximum arbitrage potential of the Local Government Megaflex Tariff						
1kWh Storage used for 6 days of the week, one shot per day, to shift 1kWh from peak to off-peak, all year round						
Plant Parameters				**Megaflex Tariff Application**		
				11kV Intake point, e.g. Randburg		
Technology Aspects	Units	Value		**Operational Aspects Energy**	Units	Value
Cost of Storage System	$/kWh	295		HV Distribution System Losses	%	4,00%
Storage System Expected Cycle Life	Number	7000		MV / LV Distribution	%	3,00%
Efficiency of Charge and Discharge cycle	%	85%		Value of Winter Evening Energy Arbitrage	c/kWh	246,84
				Value of summer Evening Energy Arbitrage	c/kWh	54,29
Capital Aspects	Units	Value		Loss-less average value of daily arbitrage	c/kWh	102,43
Rand to Dollar Exchange Rate	Ratio	14,61		Average daily rate to re-charge system	c/KWh	43,72
Local cost of Storage	R/kWh	4309,95		Cycle cost to overcome system recharging losses	c/kWh	6,56
Capital loan interest rate	%pa	5,5%		Cycle savings due shift of losses out of peak	c/kWh	3,07
Capital Loan Term	Years	10		Net average value of daily energy arbitrage	c/kWh	98,94
Cost of Finance	R/kWh	-1303				
Total financed plant cost	R/kWh	5613		**Operational Aspects Network and Demand costs**	Units	Value
Theoretical Plant Life, 6 days p/week, 1 cycle/day	Years	22,4		Peak Period Duration	hours	2
Expected Operational Lifespan	Years	15		Demand reduction potential per kWh of storage	kVA	0,5
Charge / Discharge Cycles Required	Number	4696		Monthly network charge per kW	r/kVA	7,63
Staff Operating costs	R/kWh	1440		Monthly demand charge per kW	r/kVA	28,99
R&M Plant costs @ 10% of capital cost	R/kWh	430,995		Daily network and demand charge savings potential	c/kWh	60,23
				operation during the annual half hour peak.		
Total Cost of Financed and Maintained Plant	R/Kwh	7484				
LCOE over expected plant life 1 shot per day	c/kWh	159,37		Total potential daily arbitrage value of 1kWh storage	c/kWh	159,17

Table 1: The value of 1 kWh energy storage to a municipal distributor.

Daily tariff arbitrage is the 'base business case' for energy storage in the hands of a municipal distributor. Based on Eskom's 11 kV Megaflex tariff, the value to a distributor of having just one kilowatt-hour's worth of energy storage to use for tariff arbitrage is R1,59 per day.

Provided the system works every day (except Sundays) for the next 15 years shifting just that 1 kWh of demand from peak to off-peak, a total savings of R7470 will be realized over that period in today's money terms.

As an added hedging advantage, these savings will increase at the same rate that any Eskom price increases do, which will most likely be at above inflation rates for several years yet to come.

This means that any storage system that today costs below US $295 per kWh already makes business sense even when it is used for arbitrage alone. Any additional benefits realized would be a bonus on top of this basic, self-sustaining business case.

In the event no local storage is introduced to the grid, the distributor will continue indefinitely to pay for Eskom peak energy and increasing maximum demand costs. The situation will get even worse if residential electrification projects continue at scale and the more affluent customers accelerate their uptake of renewable energy.

Where energy storage is introduced using arbitrage as the base business case, the distributor will be able to avoid peak demand and energy costs from Eskom and rather use the funds to pay for these new assets. These assets will not only provide a means to manage bulk energy procurement, but also, if strategically located, be able to overcome local network overload and constraint problems.

As the cost of energy storage further reduces, it will soon become viable for external parties to provide energy storage or ‘arbitrage’ services to the distributor on a tailor-made Energy Arbitrage Agreement basis. If the same financial model shown in table 1 is used and the capital loan interest rate is converted to a ‘rate of return’ for an investor and is set to 15%, as soon as the cost of storage reduces to $160 per kWh it becomes a viable business proposition.

From the Municipal accounting perspective, the energy bulk purchases line item on the operating expenditure budget could (and perhaps already should) be split into the constituent components of the Eskom bill. These are: Network and Demand charges, Off-Peak, Standard and Peak Energy line items. Arbitrage services, being functionally equivalent to the provision of peak-priced energy and a portion of the demand charges, could be paid for from these line items instead of the payments that would otherwise have been made to Eskom.

This amounts to procuring arbitrage services on a performance contracting basis, similar to the way Energy Efficiency projects can be funded from the savings that they yield. Unlike the complications that cast doubts on the Measurement and Verification of Energy Efficiency projects, the M & V of an energy storage system will be clear-cut. All that is required is to measure the energy going in against the energy that comes out, on a time discriminated basis with an ordinary smart meter. Beyond this, all that would be required would be a Section 33 exemption from Treasury to sanction a 15 year contract term with the service provider.

This arbitrage business case is at risk should Eskom significantly change the structure of its Megaflex (or proposed future Muniflex) tariff. At present the summer peak to off-peak price ratio for energy is 2,29:1 and the winter ratio is 6,08:1. While the value of daily arbitrage is directly dependent on the base cost of energy, it is far more dependent on the pricing differentials between peak and off-peak periods.

4.2 Avoiding NMD penalties

In the event the declared Notified Maximum Demand on an intake point is exceeded in any month, the first billing effect is that the Annual Utilized Capacity (AUC) figure is set to the higher recorded value. The AUC is kept at the highest value recorded over a rolling 12-month period, and it is the AUC figure that is used to calculate the Transmission and Distribution network charges on each monthly bill.

In the case an energy storage system is applied to the intake point and is programmed to operate whenever the NMD capacity limit is reached, then the ordinary network charge savings over a year that the system can realize will be 12 times (equal to the 12 months of the year) the demand reduction that the system is capable of delivering, multiplied by the applicable network charges. The saving will however only become effective after the storage system has been in service for a full year.

The penalty for the Monthly Utilized Capacity (MUC) exceeding the Notified Maximum Demand (NMD**)** really punitive and is determined by the following formula, (as interpreted from the Eskom NMD rules document):

$$(Montly\ Penalty) = (MUC - NMD) * Event\ No * (Network\ Demand\ Charge + Low\ Voltage\ Subsidy)$$

Over the months in a year, the penalty 'multiplies up' drastically because of the event number term. In the first month of an exceedance within a 12 month rolling window, the penalty on an 11 kV Megaflex intake point will be R28,99 per kVA exceeded for example. In the second month it will be doubled to R57,98 per kVA exceeded and by the third month will triple to R 86,97 per KVA exceeded, and so on.

The effective demand reduction capacity of an energy storage system is dependent on the shape of the load curve of the particular intake point to which it is connected. If the peak is relatively flat and sustained, such as a commercial or industrial customer, actual demand reduction will be at a minimum. Where the load curve is more 'peaky' as is the case for residential loads, the greater the demand reduction the energy storage system will be able to deliver for a given storage capacity.

In general, the load reduction capacity of an energy storage system can be expressed as:

$$Load\ Reduction\ Capacity = \frac{Capacity\ of\ the\ Energy\ Storage\ System}{Average\ duration\ of\ the\ Load\ Peak}$$

The peak on an industrial or commercial load is usually sustained over a business day – typically for six to eight hours. The peak on residential load is usually over a three-hour period, typically between 5.pm. to 8 p.m. and is a more likely candidate for storage to effectively avoid any NMD penalties.

For the Klipfontein View NMD penalty example, a 2MW energy storage system with a capacity of 4 MWh could have been used to avoid the R2,6 million Rand paid in penalties over the year. This translates to an added value of R1,78 per day per kWh for the energy storage system.

Energy storage systems are ideally able to solve the problems of intake stations that supply residential loads that typically see exceedances of up to 20 % of the site’s NMD capacity, perhaps only in the three winter months of the year. The potential added savings are site specific but will be between a minimum of 15 cents per kWh and the extreme R1,78 per kWh described above.

4.3 Protecting the Economy and enhancing the security of supply

Customers have invested in diesel generators that have a high operating cost – typically R5 per kWh – to defend themselves against the risk of load shedding or network outages. If those customers could have been persuaded to rather to invest in an energy storage system, the storage could have been used on a daily basis to reduce their overall energy costs and still provide the desired backup that the customer requires.

A diesel generator is a sunk cost, is expensive to use and is only ever used in an emergency. Today, an energy storage system would be a far better choice not only because it can pay for itself and deliver cost savings, but because the changeover from failed grid to the storage system is seamless, unlike the supply interruption that is experienced when the grid fails and time is needed for the diesel generator to start and stabilize before it can accept load. A beverage company running bottling lines for example would benefit most from this feature.

The seamless changeover also supports the participation of the customer in proper Demand Response schemes, where instead of load shedding, the distributor could rather request the dispatch of the energy storage systems on its networks to achieve the same effect.

At sufficient scale, storage is an ideal antidote to load shedding, it protects the economy by avoiding the cost of unserved energy and has the added benefit that the distributor also does not experience any loss of revenue due to supply interruptions.

This is different to the destructive power buy-back Demand Response scheme that Eskom proposed to introduce at the height of the load shedding crisis. In the case of the buy-back scheme, the result was a stoppage of a portion of the economy. In the case the Demand Response program uses stored energy to manage the reserve margin, there is no interruption to the economy.

Those companies that have already installed UPS units to ride through power interruptions are already reaping the benefits of having energy storage. Using the arbitrage business case, as many customers as possible need to be informed of using energy storage as a backup and convinced to invest in systems for their own purposes.

In the case a distributor decides to make utility scale storage investments, the best location for the facilities would be at the customer’s premises. Modern inverters can be connected in a way that enables the system to operate as an independent power island – in a mini-grid configuration - to provide secure power to the participating customer or perhaps even a cluster of adjacent customers.

An internal benefit to the distributor is realized where there is a reduction in the net revenue lost to either unforced (overloads) and forced (load shedding) outages. In the case storage is used to reduce winter overload outages in residential areas the value of the revenue protection will be determined by the frequency and duration of the outages usually experienced on that specific network.

4.4 Preserving overloaded distribution infrastructure and extending its lifespan

Repeated stressing and overloading of distribution feeders shortens their operating lifespan. If an energy storage system was installed at the end of the feeder or at the mid-point of a ring feeder, it could be used to de-load the feeders at times when the load is excessive.

All that is required is a simple control system that measures the power flowing into the feeder at the source, and is able to signal the storage system when to charge itself and when to release the stored energy back into the system. The direction of power flow at the end of the feeder will change, and the effect will be to reduce the power flow at the source end of the feeder.

South Africa has a 70 billion Rand backlog (de Beer, 2014) in distribution infrastructure maintenance. It is estimated a third (R23 billion) of this is for distribution network strengthening, often needed for only short duration peak loads which storage systems can easily deal with.

Upgrade work involves the physical replacement of existing distribution infrastructure transformers and cabling, an expensive and disruptive activity. This problem is constraining property development in municipal areas, also affecting economic development.

The life of aging distribution infrastructure is extended where the networks can be de-stressed through peak load reduction. A well-placed energy storage can permanently avoid or solve a fair share of these problems – particularly since it can already pay for itself from daily arbitrage savings and the correlation of the peak loading and the tariff peak period pricing periods will usually be very strong.

Long term planning has got to begin considering energy storage systems as a viable option to costly and disruptive whole network upgrades. Distribution planning engineers are a sceptical lot, who have up until now (perhaps with fair reason) never trusted geyser control systems for example, to permanently solve distribution overloads. Energy storage systems will be under the direct control of the distributor and can be installed at separate, distributed points along the affected feeders.

With sufficient distributed energy storage installed within a given power network, it may also be possible to defer the upgrade of the Eskom intake points supplying the network, on a permanent basis.

4.5 Unlocking property development and supporting densification

The process of township development requires that sufficient bulk supply capacity be available to support the development. In the case of residential developments, enough energy may be available over the period of a day to supply the energy needs from the existing infrastructure, but the bulk supply transformer and distribution network capacity may be insufficient to support the evening peak that is characteristic of residential developments.

The problem can be solved by installing an energy storage system right in the middle of the proposed new development, to soak up energy when the overnight or midday load is low, and release the energy locally, when the peak needs to be serviced. No upgrade to the bulk infrastructure will be necessary.

Effectively, the energy storage system can be seen as a new 'virtual intake point' to unlock the development. Unlocking development brings with it additional rates revenues as well as new economic activity in the area. New service connections also bring an increase in overall volume of kWh sales, something that the generation industry desperately needs at present.

Exactly the same principle applies where it is desirable to increase the housing density without the need to go through a costly bulk supply and network upgrade. Containerized energy storage systems are the norm, and can be placed where necessary or even relocated if the bulk suplly infrastructure is finally upgraded.

It could even be the case that Eskom owns the energy storage facility and operates it as a virtual Eskom Intake point, to both increase the volume of Eskom sales and assist the municipality with development.

4.6 Optimizing Investment in renewable energy systems

The introduction of an ever increasing quantity of photovoltaic energy onto the Johannesburg grid will alter the load profile into a shape similar to the California 'Duck Curve', with a more pronounced morning and evening peak profile. This will worsen the load factor at the Eskom supply point and will increase the cost of bulk supply from them.

While photovoltaic energy may be cheaper than grid power in cost per kWh for a customer, the cost of supporting the flow of that energy within the system remains with the distributor. The distributor must still pay the full cost to operate the grid during peak periods and procure backup capacity from Eskom to cater for bad solar days. Including an element of storage within a renewable energy system so that some of the energy the energy can be released during the peak periods, will assist the distributor significantly.

In the case of City Power's residential customers, the SSEG feed in tariff is subject to the customer migrating to the Residential Time of Use Tariff. In this case, including an element of storage allows the customer to effectively remove themselves from the grid during the peak periods. The tariff is designed so that the overall cost of the balance of the energy consumed from the grid is lower than the flat rate tariff.

A lot of the residential systems that were installed in response to load shedding already have an element of storage built in. What is needed is for those customers to respond to the tariff signals and use the storage to reduce their consumption of peak energy and begin to benefit from the overall cost reduction.

From a city perspective, storage can optimize the use of all the photovoltaic installations on the grid by compensating for the negative effects of the ‘Duck Curve’. It would not be unreasonable to consider a policy that requires a certain quantity of storage be included as a condition to granting permission for customers to connect their PV systems to the grid. The benefits are mutual in this case.

There are many customers that do not have a suitable rooftop for their own PV systems. There are also many warehouse type buildings that have an abundance of rooftop space but no load to consume the power. The grid can easily connect the two together – with a fair wheeling or offsetting tariff for providing the service.

This will become an important new revenue stream for the distribution industry in the near future, and what is becoming clear is that the charge for transporting the energy across the grid will be dependent on the time that the transfer takes place. Energy flowing behind the Eskom meter during the peak period will be charged at a lower rate to encourage the use of any power generation – such as from and energy storage system - at the right time, that will reduce the need to over-depend on Eskom during the peak periods.

5. Does it matter who owns the storage assets?

Even as distributors, we often take the properties of the grid for granted and tend to think of it as simply an infinite source of energy. Its most important property is that it is a network, where what happens at one node of the network has an impact on other nodes at locations both above and below that point. With the advent of distributed energy sources, the grid is also in the process of transforming from a one-to-many type of network to one that has more of a peer-to-peer architecture.

One of the key characteristics of a grid is that of load diversity, which loosely equates into a kind of a community in which the grid designers only need to design for the average requirements of users of the grid rather than the maximum that each may require. As far as storage is concerned, as long as the operations of charging and discharging of all the assets on the grid can be done in a co-ordinated manner, it does not matter who owns the storage facilities as the system as a whole benefits. Of course, the owner of the asset will always benefit the most, but cannot realize any benefit without also benefiting others within the system.

This means that the storage system can be placed either at the intake substation or anywhere deeper into the network that will co-benefit from peak load reduction. Regulation of the industry will be needed as the facilities will need to include control systems that can respond to independent signals from the generation and transmission operator (national control) as well as signals from local distribution control centres. This type of control regimen will form the Demand Response part of the future Smart Grid, actively dispatching the storage assets as the need arises.

Where, in order to fully realize the ‘stacked’ benefits and the storage assets are located behind the Eskom meter and also at the so called ‘Grid Edge’, the opportunity presents itself for the distributor build the storage facilities, with negotiation with key customers, at their premises and to provide these customers with secure standby power in the event of a network outage. This new service and revenue source is possible because today’s energy storage systems can operate in an islanded or ‘micro-grid’ mode.

If the assets are located still further into the network - behind the municipal distributor’s meter, an appropriate time differentiated tariff can be used to signal when the stored energy should be released and when the system should re-charge.

The electric vehicle will be a new load that will improve sales volumes for distributors. While they are essentially mobile energy storage systems that will not feed the bulk of their energy back into the grid, they can be shaped into a schedulable block of load with intelligent charging systems to fill the load profile valleys, and perhaps in the future make a contribution to supplying energy back to the grid during peak periods.

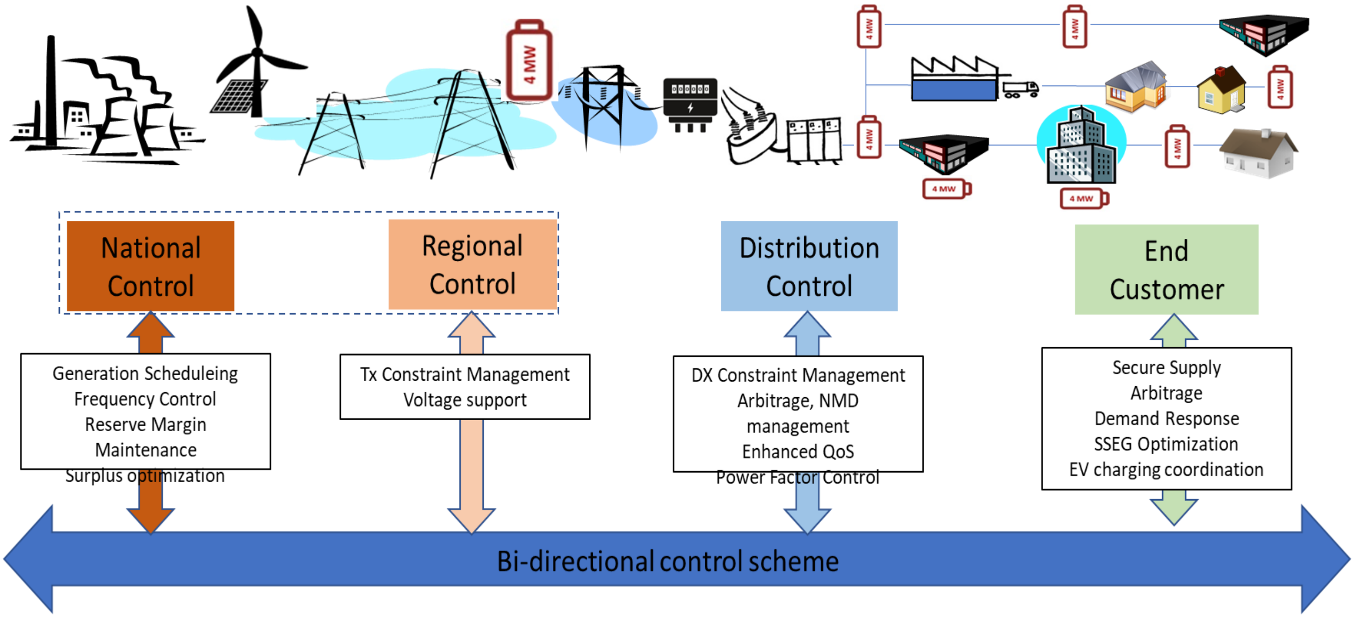

Figure 7: A suggestion of the overarching, bi-directional control scheme required for energy storage

6. Conclusion

Municipal bulk supply and distribution planning needs to begin including storage as a real alternative to costly network strengthening capital expenditure, particularly if the storage facilities can be funded through the operating budget. National Treasury should be approached to advise on the application of the MFMA to enable this mechanism.

Policy on renewables would not be unreasonable should it prescribe that a certain quantum of storage be included with renewable energy sources that are connected onto municipal distribution networks by prosumers. In this case the storage is self-funding when used for arbitrage and the use of a common grid-tied inverter for both the renewable energy and the stored energy further reduces the overall cost of these systems and delivers valuable benefits to the system as a whole.

The distribution environment needs to be opened up to all forms (all viable technologies) and applications of energy storage, including assets owned by the distributor where capital is available, all privately owned storage available to the distributor on a performance contracting basis as well as all privately owned storage that is operated in response to tariff signals.

In the Johannesburg example where a storage capacity of 1690 MWh across the grid could deliver an improvement in the load factor from 0,77 to 0,94 the breakdown of installed facilities may look something like numbers shown in Table 2 below. When broken down in this way it does not seem to be an unrealistic objective for the coming decade.

Type of installation	Nominal Storage capacity per participant (kWh)	Potential Number of participants	Contribution to Total (MWh)
Individual Residential PV prosumers (kWh)	3	100 000	300
Sectional Title Residential (kWh)	50	5 500	275
Large Power Users <100 kVA	100	8 000	800
Key Customers >100 kVA	1 000	300	300
		Total	**1675**

Distributors will also need to begin preparing for the control systems that the grid will require to integrate new alternative energy sources and storage facilities into their networks.

Most importantly, the distribution industry needs to encourage the wholesale uptake of energy storage systems in all forms as it will be key to the sustainability of the EDI in the coming years.

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