INCORPORATING EMBEDDED GENERATION INTO MUNICIPAL NETWORKS

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1. Introduction and Background

The demand for electricity consumption is expected to increase by 57% by 2050 [1]. This poses a dual challenge. There is a need to meet the increased demand for power while at the same time decrease carbon emissions. Governments around the world have supported the Paris Agreement (Cop 21) with the ambition to limit the global rise in temperature to below two degrees Celsius above pre-industrial levels. As a result of this, more countries are moving towards renewable energy as a carbon free alternative to providing electricity. According to a report by BP, electricity generation increased by 3.7% between 2017 and 2018 with renewables accounting for a third in the net increase followed by coal and natural gas [2].

Along with these challenges comes opportunities for transformation. The conventional power system is evolving. In a conventional power system, power is generated using centralised large-scale power plants and distributed to the end user on the demand side. In recent years this model is changing because of new technology advancements in renewables, the need for resiliency, the declining cost of Distributed Energy Resources (DERs) and new smart grid technologies [3]. Globally the power industry is facing a transformation towards a more decentralised and decarbonised grid.

The economic viability for traditional forms of energy like coal and natural gas are declining. Consumers are looking for alternate forms of energy and are starting to generate their own energy for consumption and hence becoming prosumers [4]. Having onsite generation is desirable for security of supply, flexibility and moving towards a green economy [5].

This trend can also be seen in South Africa. Currently the falling cost for solar photovoltaic (PV) panels has been a key driver for embedded generation. Small scale embedded generation is on the rise as an alternative to electricity from the national grid [6]. The term embedded, or distributed generation is any form of generation which is connected to an electrical distribution network. These often include renewables, gas, fuel cells or cogeneration. This model of embedded generation into the electrical network is disrupting the conventional form of energy. Prosumers are causing utilities and municipalities to sell less electricity thus affecting their revenue stream whilst still having fixed costs.

This paper looks at the current state of embedded generation in South Africa, its market drivers and financial implications for municipalities. It also looks at the possible ways for municipalities to reduce the financial impact caused by privately owned microgrids and generate sustainable revenue in the process.

2. Status of Embedded Generation in South Africa

Electricity used in South Africa is generated predominantly by the national utility Eskom via centralised coal fired power stations. The current electricity supply chain is vertically integrated with municipalities purchasing electricity from Eskom and retailing it to end customers. Municipalities account for about half of the national energy consumption [7].

In recent years, the country has seen an increase in the number of embedded generation installations mainly attributed to the increase in demand for PV roof top systems [8]. In 2017, there were 90 260 roof top solar PV projects installed and commissioned totalling approximately 180MWp with additional 48 067 projects identified but not yet commissioned. This is a significant jump compared to the 35 MW installed in 2016 [8, 9]. There has also been an increase in partnerships offering embedded generation to end customers using power purchase agreements (PPAs). In August 2019, Nedbank together with African Investment (company) partnered with SOLA, a company focusing on PV and storage solutions, to finance and build 40MW of Solar PV across the country. Customers will pay for energy usage directly via PPAs. The proposed tariff rate from this agreement is expected to be 20% cheaper compared to Eskom and municipal rates [10].

Changes in national and local policy are also making it easier for companies to develop and offer embedded generation solutions to end customers.

The Integrated Resource Plan (IRP) which is the energy blueprint for South Africa makes provision for embedded generation. The draft IRP currently makes provision for 200MW. On 2 May 2019 the ministry of energy sent a letter to the National Energy Regulator of South Africa (NERSA) granting a deviation from the existing IRP for licensing operation of generation facilities ranging from 1MW to 10MW, with a limit of 500MW annually applicable for own use generation [11].

3. Factors influencing the increase in embedded generation

Several factors are driving growth in embedded generation in South Africa. These include the rising electricity prices from the central grid, declining costs of renewable energy and the need for a more sustainable and reliable electricity supply [8, 12].

3.1 Electricity Prices in South Africa

Over the last 15 years, electricity prices have increased by more than four times the rate of inflation [8]. Figure 1 illustrates the electricity price tariff vs inflation over 2007 to 2015 [13].

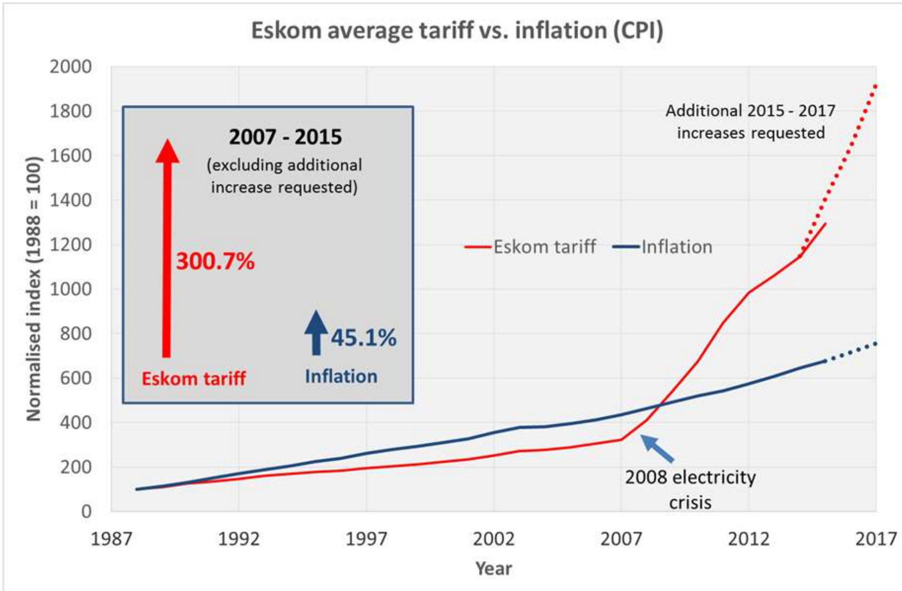

Figure 1: Eskom Tariff Increase Vs Inflation [13]

This trend is expected to continue. NERSA approved a 12.8% tariff increase (9.41% tariff increase with a 4.4% regulatory clawback) for 2020 and 8.1% and 5.1% stipulated for 2021 and 2022 respectively [14]. The clawback is part of the Multi Year Price Determination (MYPD) methodology by NERSA and allows Eskom to adjust for over or under recovery of revenue in any year of a tariff decision [15].

Eskom has suffered a financial loss of R21 billion in the 2018/2019 fiscal year which is almost an 800% increase in losses compared to the same period in 2017. Eskom is thus looking to recoup this loss and hence are challenging NERSA for an 80% increase in 2020 [16].

3.2 Sustainability and the declining cost of renewables

The 2015 Paris Agreement was a crucial driving factor for scaling up the use of clean energy technologies for embedded generation hence renewable energy technologies are featured predominantly on national policies. South Africa is one of the signatories to the Paris agreement and has committed to add 20GW of renewables to the grid which represents 40% of the total generation capacity [6].

Renewables were initially supported by feed-in tariffs, however this soon changed with the falling cost of renewable energy. Prices has been dropping since 2010. The global average price for solar PV in 2016 was R1.78/kWh compared to R4.74/kWh in 2010. This represents a 62.5% decrease in six years. The same trend can be seen in South Africa [17].

3.3 Need for resilient and secure power

In recent years South Africa has experienced significant spells of load shedding. This started predominantly in 2008. Table 1 provides a summary of the load shedding status in the country since 2008 [18].

Table 1: History of Load Shedding in Recent Years [18]

Year	Period	Causes and Comments
2007/2008	Nov-Jan	Increased demand for energy resulted in the first spells of load shedding for the country.
2014	March	Depletion of coal stockpiles and the tripping of three generation units
2015	Jan - Sep	Maintenance backlog issues caused 99 Days of load shedding in the country
2016		Although unplanned outages were reduced, there were still pockets of load shedding
2018	June	Stage 1 Load shedding – unexpected number of unplanned outages
2018	Nov-Dec	Stage 2 Load shedding – plant breakdown
2019	Feb	Stage 4 Load shedding – high number of plant breakdowns
2019	March	7 consecutive days between stage 2 and stage 4 Load shedding – high number of plant failures

Notes: **Stage** 1 allows for up to 1000 MW of the national **load** to be shed. **Stage** 2 allows for up to 2000 MW of the national **load** to be shed. **Stage** 3 allows for up to 3000 MW of the national **load** to be shed. **Stage** 4 allows for up to 4000 MW of the national **load** to be shed

Energy availability in South Africa is currently not where it should be. Although energy sales have fallen, and Eskom has capacity to meet the current demand but is not able to do so due to maintenance or breakdown issues. The company currently has 47 000MW of installed capacity with an availability factor of only 66.8%, meaning that only 32 000MW is available. The optimal availability factor that the company should have is 80%. Figure 2 illustrates the availability factor from 2007 to 2018 [14].

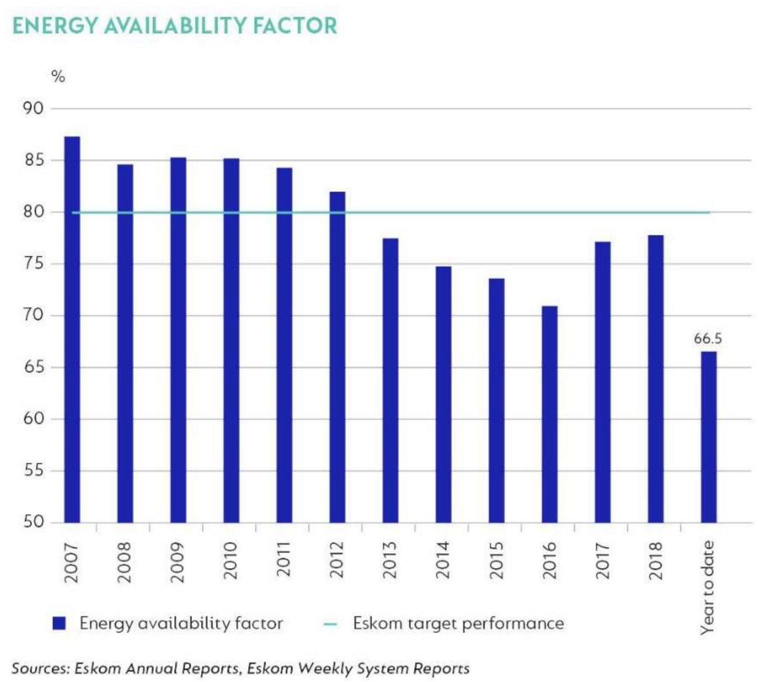

Figure 2: Energy Availability Factor [14]

It is thus expected that load shedding will continue to remain a possibility in the foreseeable future.

4. Impact of Embedded Generation

The increase in embedded generation has resulted in fallen energy sales from the national grid, which impacts revenue to municipalities and in turn Eskom. Embedded generation also results in increased pricing of electricity from the central grid which increases non-technical losses and may lead to a death spiral which impacts all stakeholders. These issues are further elaborated in section 4.1 to 4.4 of this paper.

4.1 Energy Sales

Figure 3 illustrates the decrease in energy sales in South Africa. Embedded generation is one of the causes, though not the only one. Other reasons include lower economic growth and energy efficiency projects.

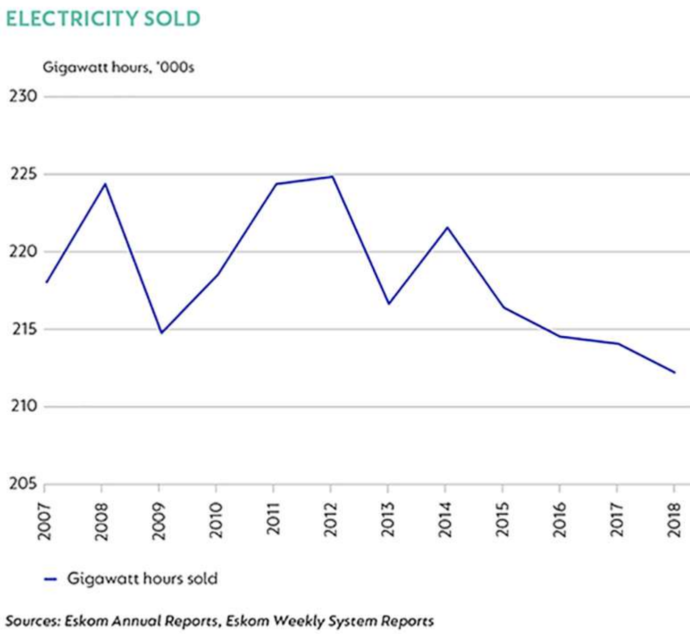

Figure 3: Electricity Sold in South Africa [14]

4.2 Demand Profile and Revenue Impact

Municipalities are responsible for approximately 40% of electricity distribution in South Africa. They purchase electricity in bulk from Eskom which they mark up and sell to the end user [12]. They buy electricity on a Time of Use (TOU) tariff and sell at a flat rate to the end user [19]. The TOU applies different charges at different times. Most municipalities use the Eskom Mega-flex tariff that has a substantial price difference during peak and off-peak periods, peak tariffs are approximately 15 times more than off peak tariffs. [20]. Figure 4 illustrates the profits generated during different time periods [20]:

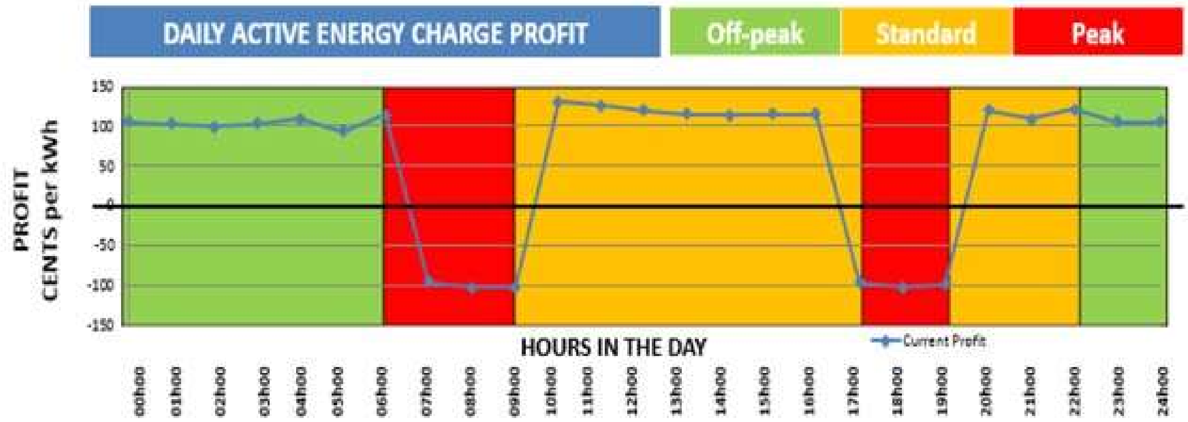

Figure 4: Daily Energy Profit [23]

Residential used of electricity represents about 18% of electricity demand, however at peak times it can be over 35% of the total demand. At present municipalities are supplying electricity to residential customers a loss due to standard fixed pricing. The loss at peak times are not fully recovered during standard and off-peak times. Higher tariffs mean that users are looking to save electricity via solar geysers and PV installations. Savings are achieved during standard and off-peak times where surplus are generated to cross subsidise the peak tariffs. Hence the losses during peak times (early morning and evenings) are expected to continue.

The increase in embedded generation results in an unpredictable altered electricity demand profile [21].

A study by Kotzen, Raw and Atkins in 2014 focused on the impact of solar PV on profit margins in municipalities. They modelled the PV load profile and compared it to residential power usage and time of use tariffs. The results indicated that up to 97% of the energy is generated between 9am and 6pm. The study indicated that given the electricity gross profit profile, solar generation only affects profits earned during sunshine hours. Only off-peak time gross profits are not affected by solar generation. The study indicated that most solar is produced during the standard billing time for municipalities. This equates to up to 60% of loss of profit for municipalities from customers that have installed solar PV systems [19].

Electricity sales cross subsidizes other municipal expenses and uses the net surpluses generated by high-consumption users through an inclined block tariff to subsidies free and low-consumption users. [20]. It is estimated that about 10% of annual electricity revenue generated is used to cross subsidise other important municipal services. This poses a risk as electricity revenue is under strain and high generating customers are looking at ways to spend less [20]. Municipalities are thus expected to run out of funds for other basic services due to loss in electricity revenue and profits.

4.3 The Death Spiral

High penetrations of renewables with legal priority over fossil fuels are driving down electricity sales from the central grid. Commercial and industrial customers are going completely off grid globally and in South Africa. This leads to the phenomenon called the Utility Death Spiral. As more consumers move off grid, utilities and municipalities are forced to raise electricity prices to cover fixed costs. This process ultimately repeats itself and results in municipalities and utilities having large overhead costs with not enough revenue to cover them, ultimately leading to “Death”. It should be noted that during the last five years, the top 20 utilities in Europe have lost half their value to this phenomenon [23].

Jobs and maintenance issues are at stake if municipalities and utilities do act to mitigate against the death spiral, thousands of jobs could be lost. This also has serious implications for lower income homes who cannot necessarily afford the upfront costs of embedded generation.

4.4 Non-Technical Losses

According to the South African Local Government Association (SALGA) total losses for municipalities accounts for R 9.2 billion during the 2017/2018 financial year [24]. About 10% of this is attributed to theft or non-technical losses [25]. As grid electricity prices continue to increase, the average South African customers cannot afford alternative forms of energy as they are already under financial strain. This in turn is giving rise to illegal electricity connections, which further decreases municipal revenue [16].

5. New Roles for Municipalities

The disruption caused by embedded generation can be leveraged as an opportunity for municipalities to take control of their pricing mechanisms and reduce losses during transmission and distribution.

Globally and in South Africa, utilities and municipalities are recognising that their conventional business model needs to change. In its own strategy document, EnBW (German utility) declared that “conventional business models of larger power supply companies no longer work” [23].

In South Africa, municipalities around the country are also challenging the ‘single buyer’ model which restricts the purchase and sale of electricity to Eskom. They intend to purchase electricity directly from independent power producers [8].

A 2018 study done by SA TIED (Towards Inclusive Economic Development) to identify the main drivers for municipalities to implement their own embedded generation revealed the main driver is climate change mitigation, with going green as second and cost as the third incentive [6].

Interviews with municipal leaders indicated that they understand that the current model of electricity supply management is not sustainable, they see embedded generation as an opportunity as a service to provide to ensure their own and the overall sectors sustainability despite the current obstacles that they are facing [6].

6. Recommendations

Although the potential impact on municipal revenues still exist, municipalities still see embedded generation as an opportunity. They see embedded generation as an opportunity to break away from Eskom’s dominance, much like the private sector.

Since embedded generation is on site generation, there is no real need for large transmission and distribution networks. It thus presents an opportunity to reduce technical losses by 5% [26]. Onsite generation could also assist municipalities to reduce non-technical losses if planned correctly taking all stakeholders into consideration.

6.1 Short Term Actions

Table 2 summaries the proposed key actions that will benefit municipalities almost immediately in terms of revenue protection.

Table 2: Short Term Actions

Action	Impact/Comments
Introduce a TOU model where for commercial and residential clients	Instead of charging a flat tariff, municipalities can charge a surge amount for power consumed outside sunlight hours to minimise profit losses for customers with embedded generation. The aim is to align end uses with the same TOU tariff that municipalities are subject to. This would require the installation of smart meters. It should be noted that the TOU tariff was recommended before but did not gain much traction. This was mainly due to vendor specific tenders, over specifying the meters and the tender process itself [20]. Other obstacles include the high costs of installation of the smart meters which municipalities cannot afford [27]. A solution to these issues is to consider using Original Equipment Manufactures (OEMs) to supply and install the meters. The municipalities would only pay for the meters once revenue is collected. OEMs benefit from an OPEX business model [27]. Another option would be to pay the upfront costs of the meters via increased tariffs, Eskom has rolled this out in Gauteng. With the installation of meters municipalities would have access to real time data that can assist in developing innovative ways to increase customer satisfaction. They will be able to use and develop meter data and analytics engines to assist with pricing and demand response initiatives. Another option is to use TOU meters instead of smart meters which is expected to be much cheaper, costing about R800 per meter [20].
Increase Fixed Charges	This would eliminate the “Free rider effect” where currently residential and commercial customers with PV systems do not pay fully for their share of the system’s fixed costs. This shifts the burden to households without PV systems. Companies using solar and the grid also need to contribute to the fixed charges for municipalities to cover grid maintenance costs. This is a key factor for municipalities to protect their revenue due to low electricity sales.
Grid Availability Charges – similar to an insurance policy	Most DERs are characterised by solar or other renewable energy resources. These sources are not dispatchable, hence if there is no storage or hybrid solution, grid power would still be required in certain conditions. Currently municipalities use a peak demand charge for the availability of certain kVA from the network. It is recommended that municipalities charge an additional amount for grid connection and usage above a certain value for energy consumers that have on site generation. This should be similar to an insurance premium with an excess amount paid for using the grid.
Feed in Tariffs (FIT)	This would allow municipalities to purchase electricity cheaper from IPPs than Eskom. There might be contractual issues. Hence it is recommended that standard FITs should be implemented across to decrease the upfront project and admin costs.

Action	Impact/Comments
Use of Network Tariff - Wheeling	To allow IPPs to connect with customers directly. This can be implemented within the current legislation. Municipalities can focus on the distribution aspects [27].

6.2 Long Term Actions

According to PQRS, a local solar PV data and quality assurance entity, the commercial and industrial sector (C&I) represents the largest market for embedded generation in South Africa [9]. This is due to high energy usage and the need for continuous power. It is thus recommended that municipalities target these customers as clients for embedded generation. Table 3 summaries the proposed long-term actions for municipalities.

Table 3: Long Term Actions

Action	Impact/Comments
Legislation to prevent embedded generation	This would ensure continuous revenue to municipalities, but it is not practical or feasible. It would not meet the requirements of all stakeholders especially ensuring resiliency.
Construct and own RE PV plants at the end client's premises.	This option allows municipalities to own and operate the PV plants as well as sell power. It requires upfront capital which the municipalities may find difficult to raise as well as a change in legislation allowing municipalities to generate electricity.
Municipalities Purchase power from small IPPs	This option is like the one above, with the difference of eliminating the up-front capital costs for municipalities to cover. It ensures resilient power to the end user from renewable energy. Plants can be located at the end-client's premises. The IPP would own and operate the facility, freeing up municipal resources. Most municipalities are already setup to purchase energy from IPPs and sell it to end customers, they are currently doing the same with Eskom. However current legislation in South Africa prevents them from purchasing energy from other resources [27]. Hence a change in legislation is required. This may even require guarantees from national treasury for the PPAs.

There are various challenges that impedes municipalities from the above recommendations. A 2018 study done by SA TIED (Towards Inclusive Economic Development) that interviewed key staff members and decision makers from various municipalities revealed the following key challenges [6]:

- Current structure of the SA energy sector – highly vertically integrated with Eskom controlling most of the country's generation.
- Regulatory Environment – lack of national regulatory framework for embedded generation. Also, currently Eskom is the single buyer for IPP projects. Focus on large IPPs, note this is beginning to change with the inclusion.
- Resources - They are under staffed and often cannot meet with requests of embedded generation. They also often struggle to meet their primary mandate providing basic electric services.
- Grid capacity – unable to adequately balance supply and demand PV generated during stand times – does not assist with peak, unless storage is included.

The distribution network in South Africa at both the municipalities and Eskom is not prepared for the introduction of embedded generation. The current model operates on a basis of one-way flow of electricity. The integration of DERs into distribution networks have led to the emergence of active distribution networks (ADS). ADS have systems in place to control a combination of DERs, grids and storage.

National regulations could not keep up with the recent uptake of solar PV systems. Hence there is a need for new regulations to guide and regulate this market taking all stakeholders into consideration. Though progress has been had at a municipal level, however this is not enough in mitigating the loss caused by embedded generation [8].

The South African Photo Voltaic Association launched the PV Card Programme in 2017. The aim is to provide training and accreditation to PV installers to ensure safety and quality assurance. PQRS developed a quality assurance platform (P4) to score PV contractors on performance, knowledge and best practice [8]. These bodies will inspire investor confidence for development of PV embedded generation solutions. It is recommended that National Government look at these initiatives and together develop a national framework that would be beneficial to all stakeholders. This will also benefit municipalities if they are permitted to purchase electricity from IPPs.

It is also recommended that local government and municipalities consider alternate means to generate profits and cross subsidise municipal services. Once such alternative they can look at is to monetise infrastructure through investment funds. This can apply to assets like rail and power distribution lines, substations, etc. The assets will be operated by the relevant local government or municipality, but ownership transferred to an investment Fund. The Investment Fund will issue units or shares to investors with the price tied to the performance of assets. The revenue will be used to upgrade and maintain the infrastructure.

7. New technologies and Original Equipment Manufacturers

Technology trends surrounding microgrids are driving prices down. These new technologies can also assist local government in providing electricity where there is no grid. OEMs have developed pre-built low cost microgrid solutions that are pre-tested. This would decrease installation time and assist municipalities to provide any access to users with no access.

Technology advancements can also assist municipalities to operate and control their DERs for embedded generation. they can be used for demand management, forecasting, and control of the various energy sources. Thus, enabling the municipalities to optimize their energy offer by always using the cheapest energy source first.

Data Analytics would allow predictive analysis and automatic management of the DERs as illustrated in Figure 5. Table 4 illustrates some of the benefits of using technology to advise and control DERs.

Figure 5: Advisory Control Illustration

Table 4: Benefits of using technology for operation and control of embedded generation [28]

Item	Comments
Remote monitoring & forecasting	Monitoring Power/Energy and other Key Performance Indicators for each DER using web access
Tariff Management	Control DERs according to variable electricity tariff rate
Demand Charge reduction	Control DER for reducing site consumption peak
Self-consumption	Control energy storage and PV system for maximizing the energy consumption from PV system
Off grid mode preparation	Control DER for anticipating on future off grid events
Sharing strategy	Aim to maximize renewables consumption the microgrid
ATO - Automatic Transfer Operation	Automatically manages connection / disconnection from the grid
Load sharing	Assure the stability for the tension and frequency by balancing the production and consumption in real time
Load shedding	Cut-off non-priority loads when the production cannot reach the consumption
Relay Settings	Manage the protection relays and if needed the global system protection when islanded.
Connectivity	Modbus and Modbus TCP IP, IEC 61850

Advances in technologies can assist municipalities to improve customer satisfaction by providing advanced digital services that would assist customers to have continuous resilient power at the best possible price.

8. Conclusion

Embedded generation is on the increase globally and in South Africa. This trend is expected to increase as the costs for alternate forms of energy decreases and customers are looking for a more resilient form of energy. However successful implementation requires that all stakeholders get involved and benefit, else it could lead to negative disruption like the death spiral discussed in section 4.3 of this report.

The disruptive forces of embedded generation together with increasing electricity energy costs can be seen as an opportunity for municipalities. They are distinctly positioned to benefit from the disruptive market elements. Municipalities are recognising that their business models require change to adapt to this new market.

It is recommended that they consider a TOU tariff model for residential and commercial customers. They should also consider increasing fixed costs to eliminate the free rider effect. Municipalities are also keen to purchase electricity from private developers as this would be cheaper than purchasing from Eskom. However, this would require a change in legislation. National government must also come to the party and play a role in this energy transition for it to be beneficial for all stakeholders involved. There has been progress, with the new draft IRP making provision for embedded generation, however this is not enough to take full advantage of the opportunities provided by the energy transition. New technology advances and OEMs can assist municipalities to provide enhance digital offers to their customers thus improving customer satisfaction.

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