Remote Renewable Energy Solutions for the Mining Sector

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SMA America
1. Introduction to SMA
2. The business case for Renewables in the Industrial sector
3. A Scalable Approach: Who’s the Boss?
4. Lessons learned and example projects
SMA Solar Technology AG – Key Facts

- Founded in 1981
- Sales 2012: EUR 1.5 billion
- More than 4000 employees, more than 1000 professionals in research and development
- In 21 markets all over the globe
- Over 30 GW installed SMA inverter power worldwide
- More than 20MW of SMA inverters installed globally each day.
- 750 highly trained service professionals to keep projects functional

Source: SMA
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Why PV–Diesel–Hybrid systems?

Already today, we see a significant cost advantage of PV–Diesel–Hybrid systems compared to conventional Diesel Gensets. This gap will become even bigger in the future.

- PV system cost decreased by > 50% in the last 3 years
- Fuel cost for Diesel Gensets are steadily rising
- PV–Diesel–Hybrid applications provide a good business opportunity for
  - Genset operators/end customers
  - Players from the Genset world
  - Players from the PV world

Electricity Cost ($/kWh)

Source: SMA
There are 6 key levers favoring PV–Diesel–Hybrid systems minimizing both, cost and risk

1. Reduction of variable costs
   Significant reduction of fuel consumption

2. Reduction of CO₂ emissions
   Fulfilment of obligations and/or selling of certificates

3. Scalability
   PV penetration rate can be scaled up continuously.

4. Energy independence
   The solar resource is always on site

5. Planning security
   Project is less dependent on fuel price volatility

6. Social aspects
   Project is “greener” and more accepted by people

How can these benefits be quantified?

Source: SMA analysis
PV–Diesel–Hybrid has a strong business case:
compare solar resource with delivered cost of fuel

![Graph showing Payback time (years) vs Diesel cost (USD/l) with different annual PV full load times.]

- **Payback time (years)**: The X-axis represents the payback time in years, ranging from 0 to 22.
- **Diesel cost (USD/l)**: The Y-axis represents the diesel cost per liter, ranging from 0 to 2.4.
- **Annual PV full load time**: Lines indicate different annual PV full load times:
  - 900 kWh/kWp (e.g. Germany)
  - 1200 kWh/kWp (e.g. Italy)
  - 1500 kWh/kWp (e.g. India)
  - 1800 kWh/kWp (e.g. Australia)
  - 2100 kWh/kWp (sunniest spots worldwide)

**Financially attractive area**: The shaded area on the graph indicates the range of diesel costs and annual PV full load times where the business model is financially attractive.

**Volatility span**: The volatility span from 2009–2012 is indicated by a dashed line.

**Actual effective Diesel cost for genset operators in remote areas**: The actual effective diesel cost for genset operators in remote areas is indicated by a solid line.

**Given the Diesel price volatility and genset industry mindset, a short payback time is crucial.**

1. Effective cost at point of consumption including fuel transportation and storage cost etc.

Assumptions: 1 MW PV plant; 100% consumption of PV power possible; CapEx=2,000 USD/kWp; OpEx=2% of CapEx p.a.; PV financing with 30% equity/70% debt with 7% interest rate and amortization time of 5 years; Genset efficiency 3.5 kWh/l (net electricity production); CapEx and Maintenance cost for Diesel genset not included, since PV is considered as add-on here, not as genset hardware substitution. Source: Web search, SMA analysis.
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SMA’s solution allows for a scalable deployment of PV

**Generator Dominant**

**PV Inverters**
- Robust design proven in harsh environments
- High tolerance for wide voltage and frequency ranges
- Integrated management functions for weak grid
- Up to 20% PV penetration possible

**Fuel Save Controller**
- Intelligent and fast interfacing between load, genset and PV inverter
- Several operation modes for maximum compatibility
- Together with SMA

**Battery Inverters**
- Storage integration to substitute spinning reserve/idle genset operation

**Inverter Dominant**

**Grid Manager**
- Increased PV penetration of 100–120% to reach economic optimum, including support for diesel off-mode

**Spinning Reserve**
- Increased PV penetration of 100–120% to reach economic optimum, including support for diesel off-mode

**PV Penetration**
- **up to 20%**
- **up to 60%**
- **100% +**

1. Ratio between PV peak power and genset nominal power

Source: SMA
Reliability of Grid is Prime

- **Fuel Save Controller**
  - Generator dominant
  - simply monitors grid parameters (generator operation, load characteristics)
  - Does not take over Control function of existing Grid
  - Only calculates maximum Safe and Stable PV penetration, curtail PV when limits reached
  - If PV fails, Grid operation Unaffected
Industrial loads in remote areas are typically supplied by conventional Genset systems.
Adding Photovoltaics is the first step towards a future-proof system...Up to 20% PV Penetration

PV inverter
- The heart of SMA’s solution for hybrid systems

PV Modules/BOS
- All module technologies supported

PV inverter

Powerhouse
- Includes main busbars, genset controllers, etc.

Industrial Load
- e.g. Mining facility, cement factory, metal works

Genset System
- The main component in the electricity supply system

SMA equipment
1. Balance of System (e.g. cabling, module racks, etc)
Smart communication between Genset and PV leverages hybrid potential of up to 60%

PV Modules/BOS
All module technologies supported

Interface Module
Acts as a data concentrator and data logging device for Sunny Tripower inverters

PV Main Controller Module
Monitors genset status and computes maximum allowed PV power

Data Acquisition Module
Measures the actual load both active and reactive

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SMA equipment
1. Balance of System (e.g. cabling, module racks, etc)
Integration of storage is the next step to increase PV penetration.

**Data Acquisition Module**
Measures the actual load both active and reactive.

**PV Main Controller Module**
Monitors genset status and computes maximum allowed PV power.

**Interface Module**
Acts as a data concentrator and data logging device for Sunny Tripower inverters.

**PV Modules/BOS**
All module technologies supported.

**Battery Inverter**
(optional, for increased PV penetration)

**Industrial Load**
e.g. Mining facility, cement factory, metal works

**SMA equipment**
1. Balance of System (e.g. cabling, module racks, etc)
2. Available by end of 2013

**Powerhouse**
Includes main busbars, genset controllers, etc.

**Genset System**
The main component in the electricity supply system.
Energy Storage: Phase 1 = Reduce Spinning Reserve

Genset Dominant. Forms Grid.

- Inverter with Battery acts as Dispatchable Load (rather than curtail PV) and Power/Energy Source (Load spike or dip in PV production (clouds etc))
- Modest storage, measured in minutes of load capacity
- Reduce Genset Spinning Reserve requirement, save fuel
Energy Storage Phase 2: Grid Forming Inverter > 100% PV/RE penetration

- Sufficient RE production to meet typical 24 hour Plant Load
- Inverter forms Grid
- Genset powered down completely, brought on as needed when Loads
- RE + Storage
- Battery capacity measured in hours or days vs minutes
Reliability of Grid Is Prime

Sunny Island Multi Cluster Architecture

- Inverter Dominant, Energy Storage Required
- Inverter Controls Grid, Genset Operation, Load management possible.
- Inverter Fails Transparent: Generator connected to Loads
Real-life data can be tracked with high resolution to validate the fuel saving effect.

Hybrid plant can be monitored exactly.

Example: Thabazimbi mining site in South Africa

- Average load 350 kW
- 300 kW PV power activated
- 1440 kWh PV energy produced
- 400 liters of diesel savings
- PV output directly follows load and genset requirements

Energy provided during daytime:
- Photovoltaic: 39%
- Diesel generator: 61%

Source: Cronimet; SMA project example
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How to choose PV penetration levels

PV generated Electricity is least cost production.
PV (RE) production does not always match load (Intermittent)
RE + Storage minimizes Intermittency
However, Storage Adds Cost and Complexity
Lessons Learned

• PV/Inverter
  • World Installed PV Capacity reached 100 GW in 2012
  • PV technology is mature and robust (Tier One companies)
  • Costs of Installed PV has fallen by more than 50% within the last 3 years
  • Where PV production matches Load, PV electricity least cost generation (<10 cents/kwh)
  • Choose reliability and service infrastructure for true least cost
  • Distributed v centralized Inverter architecture (pro and con)
    • Centralized = highest efficiency, lowest cost
    • Decentralized = granularity, ease of maintenance, ease of deployment
Lessons Learned

- **Loads**
  - When Off Grid, Loads become the primary design driver. Accurate data is crucial.
  - Load Efficiency nearly always yield high returns
  - Load flexibility reduces impact of Intermittency
    - Run planned loads during solar peak
    - Flexible loads (water pumping to storage) triggered by RE availability

- **Energy Storage**
  - Next “game-changer” is in Energy Storage technologies.
    (current cost of electrochemical storage >25 cents/kwh)
  - Every fall in cost/kwh of energy storage, window for economic PV production opens.
  - Electro–chemical storage is both a dispatchable load and source of power. 2x value multiplier
Conclusion & Outlook

- SMA Fuel Save Controller offers flexibility for diverse applications
- FSC’s sophisticated algorithm which
  - avoids genset reverse power scenarios
  - maintains minimum genset loading
  - ensures that sufficient genset power is online
  - can handle grid connection
- Energy Storage (Battery Inverter)
  - lessens spinning reserve
  - allows higher PV penetrations
  - higher fuel savings
Project Example: 925 kWp hybrid system on Island Nation of Tokelau running successfully since 2012

- 1 MW(925kW) PV system is the biggest standalone power system in the world
- 298 SMA inverters (93 SMA Sunny Islands/205 Sunny Boys), 121 SMA Sunny Island Chargers and 1,344 batteries
- Offset of 200 liters of fuel daily while the country has eliminated its dependency on fossil fuels

Source: SMA project example
Project example: Mine in South Africa
Genset dominant, Fuel Save Controller

SMA reference example:
- 2x800 kVA Perkins Gensets + 500 kVA grid connection
- Upgraded with 1 MWp PV
  - Modules: 4170 high-efficiency 240W poly-Si
  - Inverter: 63 STP 17000 + FSC
- PV power production: ca. 1.8 GWh p.a.
- Annual savings: approx. 450,000 liter Diesel fuel
Project example: Island Vavaʻu in Tonga

- 500 kWp PV plant with 21 x 20 000 TL SMA TriPower Inverters
- Includes 120 x 1000 Ah gel lead acid batteries with 5 SMA Sunny Backup
- Saves 225 000 L of diesel p.a. and 440 tons of CO₂ emissions
- Installed by Ingenero
Project example: Cotton Mill in India
Genset dominant, Fuel Save Controller

SMA reference example:
- Cotton Mill in India
- One 1250 kVA Powerica Gensets + grid connection (unreliable grid, several outages per week)
- Upgraded with 1 MWp PV
  - Inverter: 44 STP 20000TLEE
  - FSC: One Interface Module, one PV Main Controller Module, two Data Acquisition Modules
- PV power production: ca. 1.32 GWh p.a. (if the grid is available, a net metering scheme applies)

Source: SMA
Project example: 500 kWp hybrid system in Thailand
Online since April 2004
Inverter Dominant, custom solution

- 500 kWp PV plant with SMA central inverters
- 2 x 250 kVA SMA battery inverters
- Local grid powered with 5 MVA hydro and 6 MVA diesel gensets
- Saves ~ 200 000 L of diesel p.a. and 483 tons of CO₂ emissions

Source: SMA project example
Project example: Hybrid system for US-Embassy, Burundi
Grid/Genset dominant, custom solution

- 307 kWp PV system
- Sunny Tower solution
- 5 CAT gensets available
- Only 3h per day of grid availability
- 6 000 USD savings in first 3 months of operation
- Operated in highly unstable seismic zone 3D

1. Realized without Fuel Save Controller
Source: SMA project example
Current reference projects using large scale energy storage

**SC–800CP BWR**
- Grid–tied battery inverter based on SC–800CP
- Full 4–Quadrant operation (bis 800kVA)
- MODBUS/TCP interface for park or customer control
- Q@Night capable

**SOLON–US**
- Grid tied based on SC–500U (SOBWR–01)
- MODBUS interface to customer’s SCADA
- Part of a Demonstration Project with the University of Arizona
- Functionality demonstrated and analysis on battery behaviour ongoing
Each day, over 20 MW of SMA PV inverters are installed worldwide

Why they chose SMA:
- Reliability (Technology & Company)
- Bankability of SMA
- Experience (over 30 GW installed capacity)
- Grid Management Capability
- Financial Performance (SMA Inverters increase yield + reduce TCO)

53 MWp, Germany
85 MWp, Italy
14 MWp, South Korea
44 MWp, Thailand
16 MWp, USA
10 MWp, UAE
10 MWp, Greece
22 MWp, Spain
Thank you for your attention!