Smart Grids Framework : Architecture View & Economic Indicators

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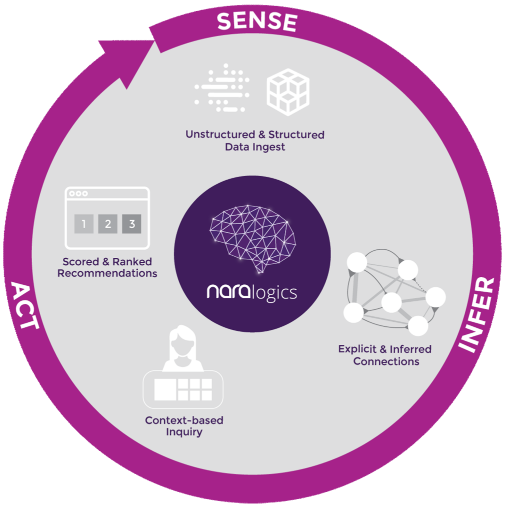
Definition of intelligence

Think then Act

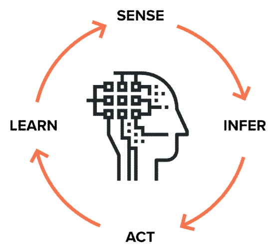


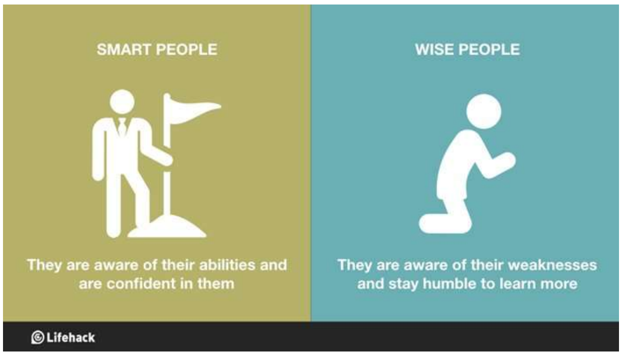
Act then Realize

Command then Act

Smart vs. Intelligent

Knowledge + Practice + Skills





Intelligent

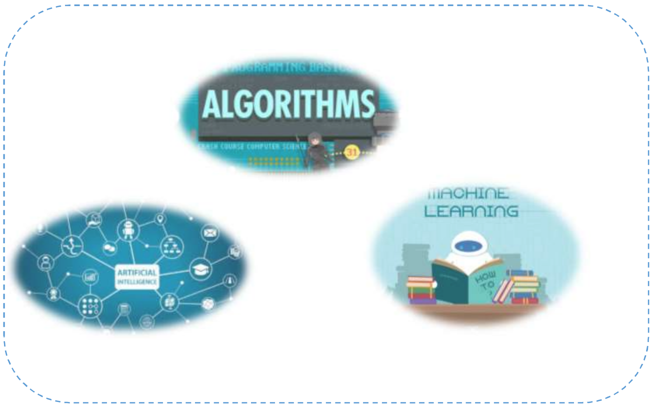
- A person who is intelligent can learn new concepts effectively and fast since he/she is good at understanding things.

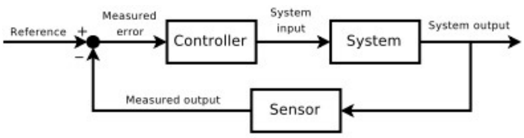
Smart

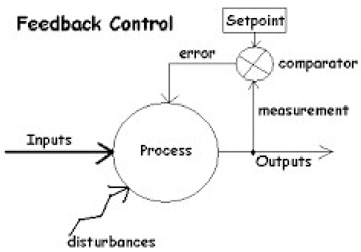
- Someone who is smart can be introduced as a person who uses his intelligence effectively and practically in day to day context.

Smart Systems vs. Control Theory

Smart Engines





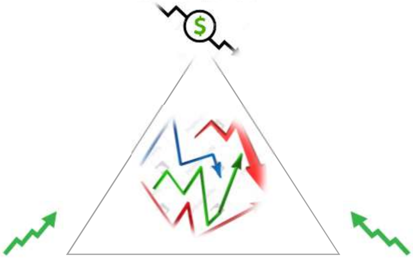


What is Smart Grid?

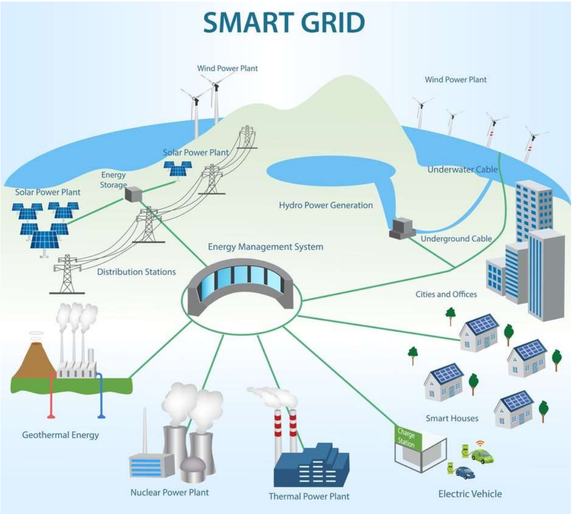
Electricity Grid

A network of transmission lines, substations, transformers and more that deliver electricity from the power plant to your home or business.

Cost of Operation

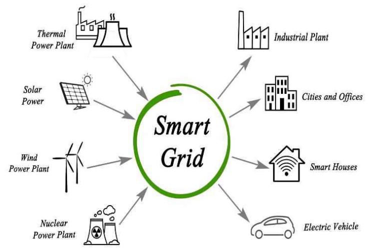


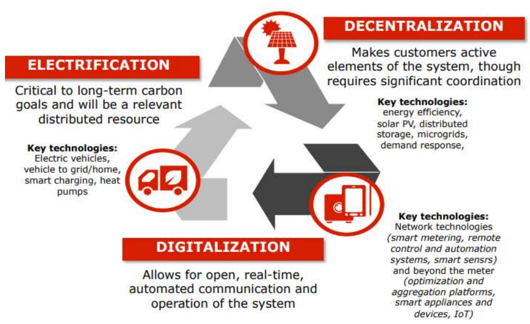
Operational Efficiency **Quality of Service**



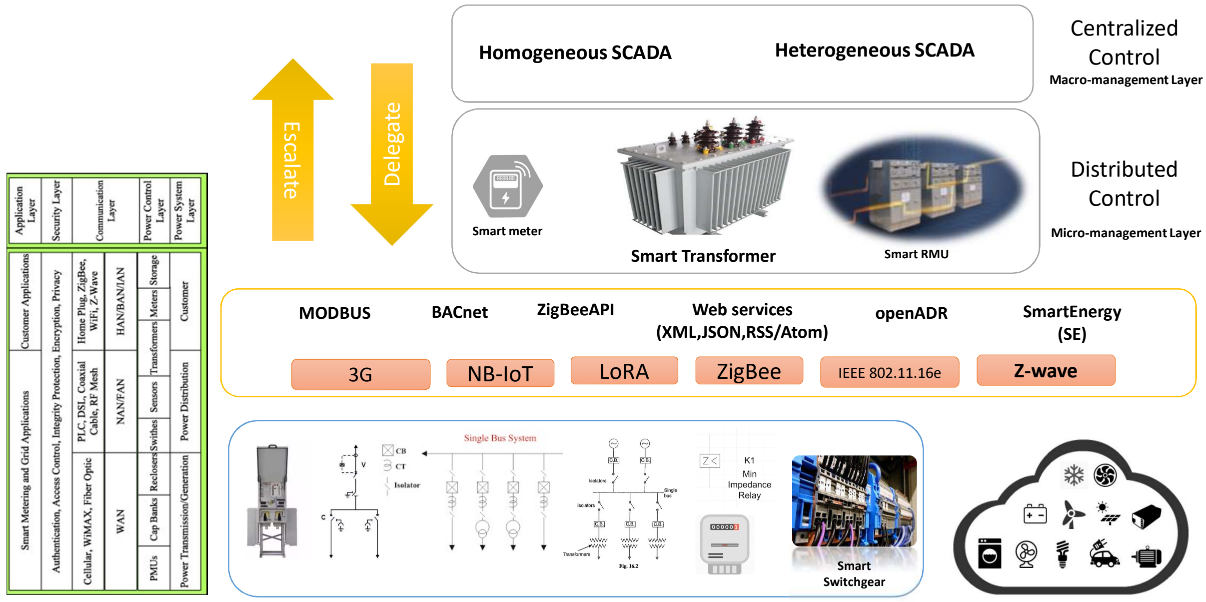
Smart Grid Challenges and Opportunities

- Metering
  - Bidirectional metering, testbeds…
- Sensors and automated control
  - PMUs, time synchronization, distributed sensors…
- Smart Grid architecture and operations
  - Research/modeling of grid stability (load/generation)
  - Microgrids, …
- Power Electronics
- Electromagnetic Compatibility/Interference
- Energy Efficiency
- Integration with Net-Zero Buildings
- Cybersecurity
- Electric Vehicles/Storage
- Communication protocols
- Testing and certification activities, many others

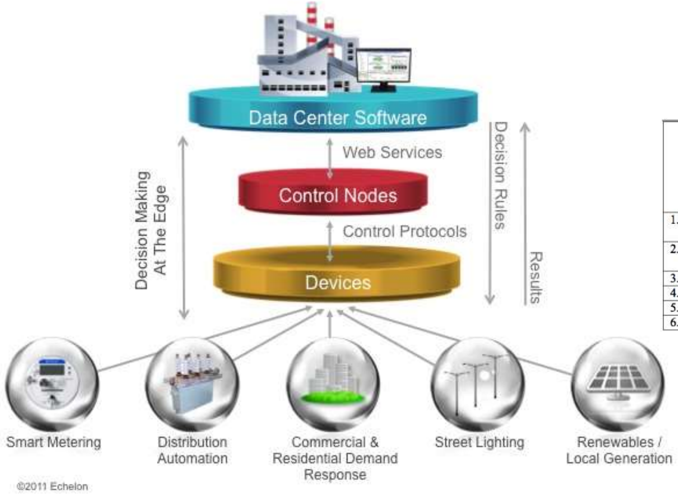




Smart Grid Architecture Map



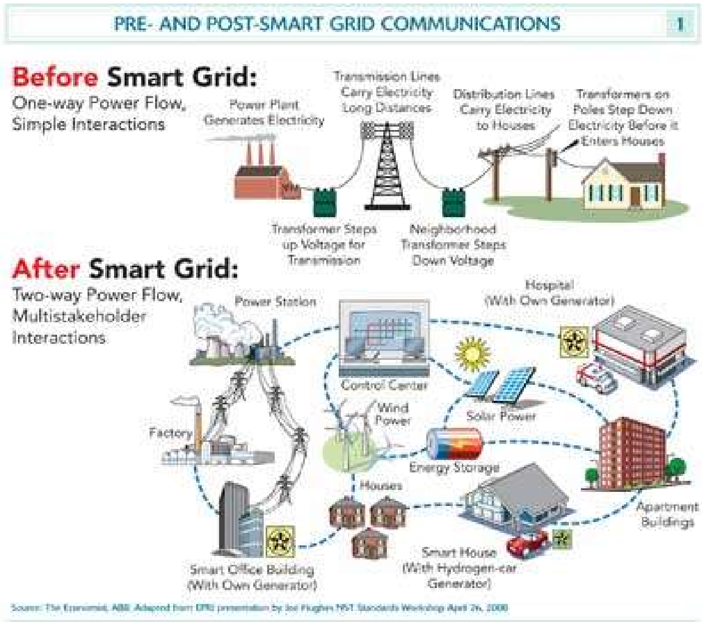
Smart Grid Energy Control Network



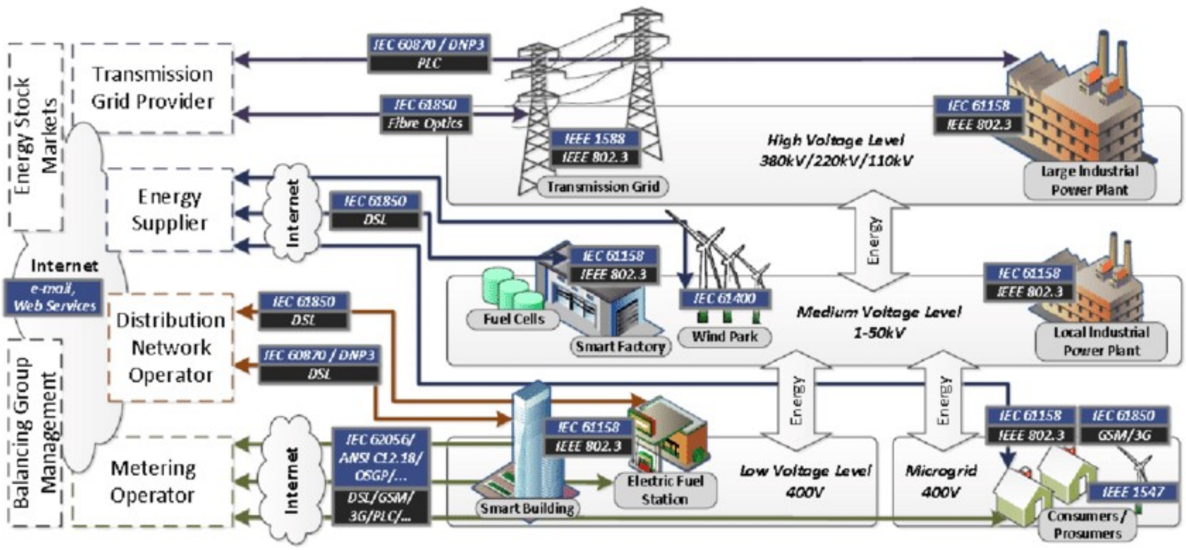
Data exchange protocol	Application	Allow communications over			
		Ethernet	Serial	Wi-Fi	ZigBee
1. BACnet (IP)	Building automation	X		X	
BACnet (MS/TP)			X		
2. Modbus (RTU)	Legacy device		X		
Modbus (TCP)	Communications	X		X	
3. Web (e.g., XML, JSON, RSS/Atom)	Numerous applications	X		X	
4. ZigBee API	Home/building automation				X
5. OpenADR	Demand response	X		X	
6. Smart Energy (SE)	Smart grid			X	X

Disruptive Change of Smart Grid

A **smart grid** is an electrical **grid** which includes a variety of operation and energy measures including **smart meters**, **smart** appliances, renewable energy resources, and energy efficient resources.



E2E Grid High Level Architecture

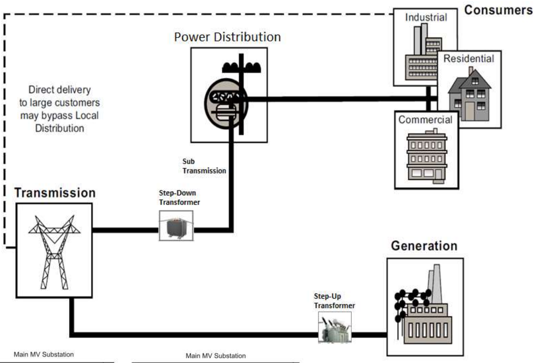


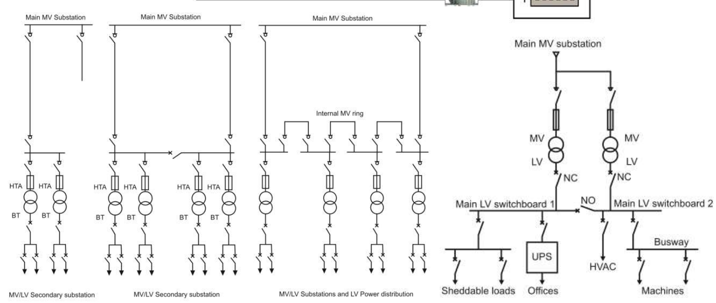
Physical Layer Architecture

- **SWITCH GEAR** is equipment that can be used to switch high voltage electrical circuits in and out.A ring main unit is a type of switchgear. These are typically used at lower voltage substations, such as 11kV.
- **RING MAIN UNIT** (**RMU**) is used in Substation or in HV distribution such as 11kv and above its a ring system where if one line is failure or interupted the other will operate. SWGR is used as incommer in both HT and LT systems as a incommer such as ACB, **VCB**, MCCB, MPCB RCCB etc

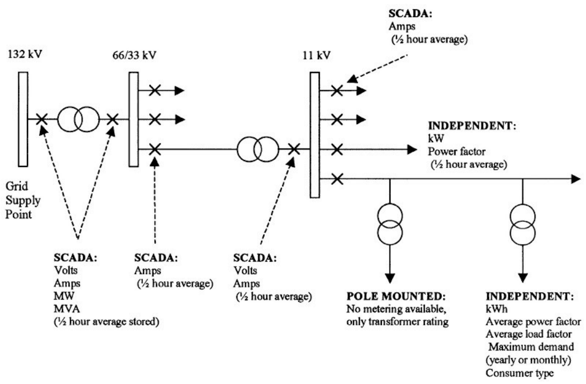
Applications

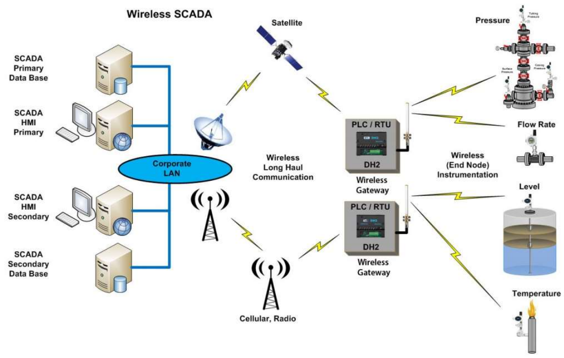
- Compact secondary substations
- Wind power plants
- Solar power plants
- Small industries
- Hotels, office buildings, residential housing complex, shopping centers, business centers, hospitals, airports.



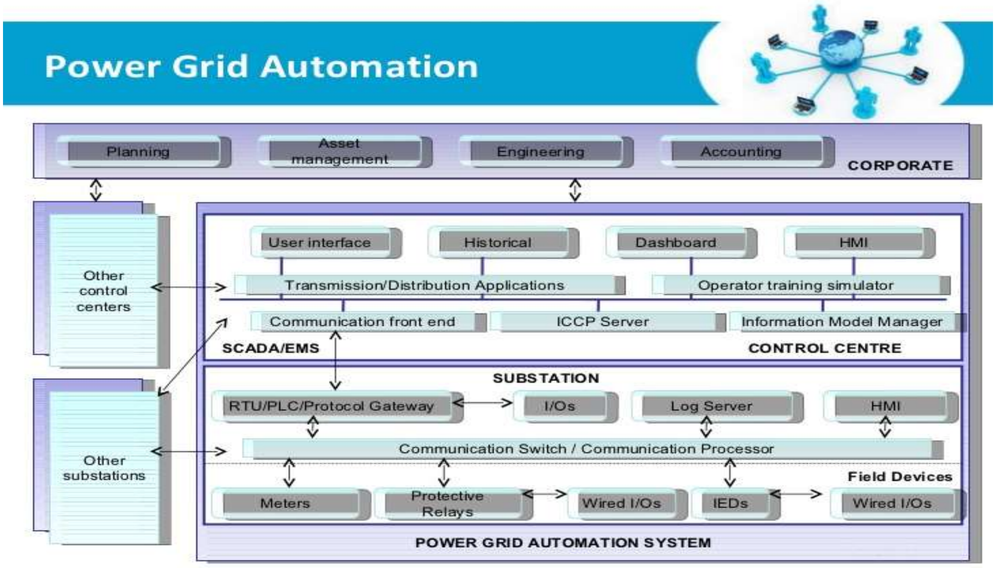


Physical Layer Architecture

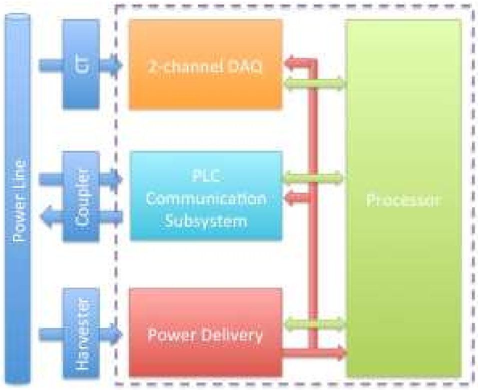


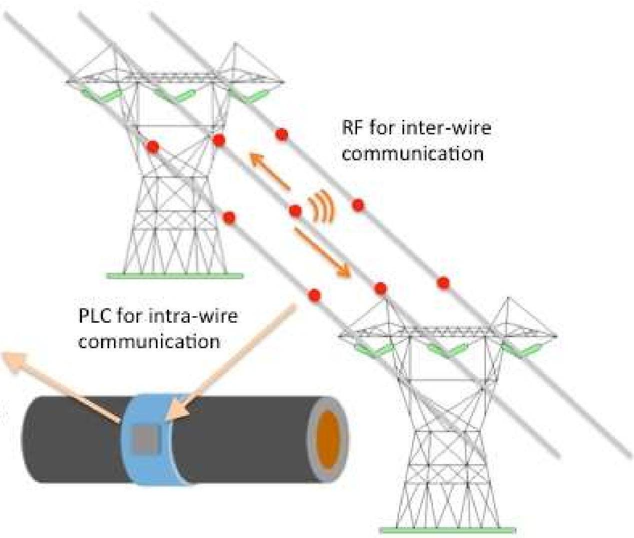


Classical Enterprise Architecture Map



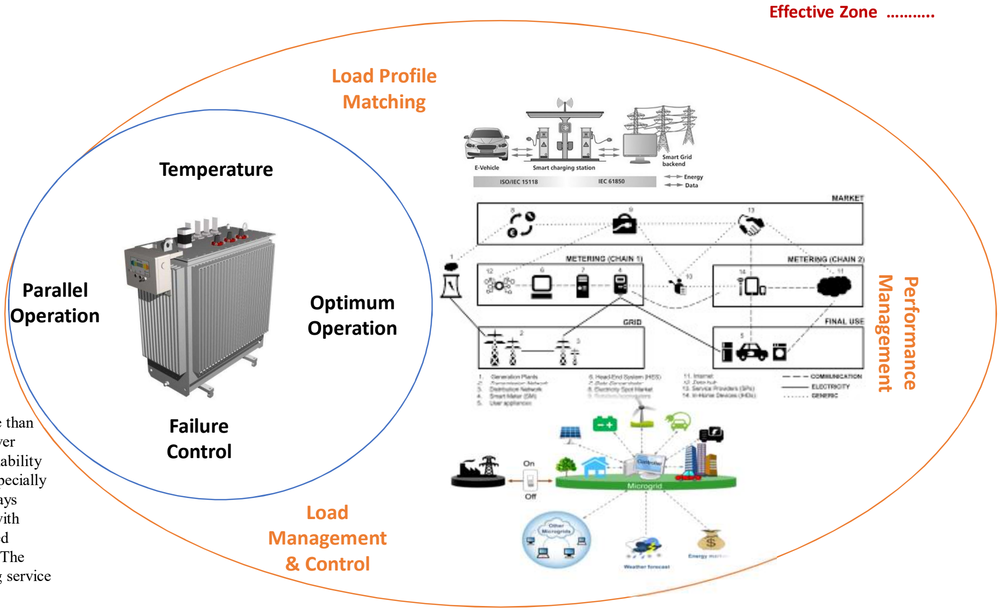
Digitalization of Grid: Online Physical Layer





- Distribution / Grid monitoring (Smart Grid)
- Harsh Environment Operation
- Goal:
    - Proactive Decision Intelligence
    - Always Optimal Operation

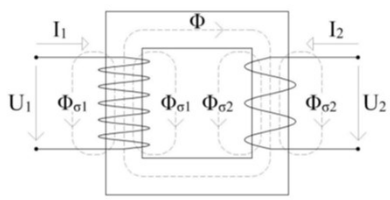
Digitalization of Grid: Smart Hub



Basically transformer is nothing more than two coils with magnetic bond. However demands for greater performance, reliability and efficiency increased over time especially after their wider deployment. Nowadays transformers are complex machines with optimized construction using advanced materials and precise manufacturing. The final result is high efficiency and long service life of the device.

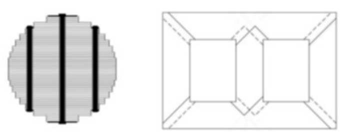
Efficient Operation

Main problem are the losses in core. They are caused by hysteresis and eddy losses. Magnetic hysteresis is phenomena linked with all ferromagnetic materials. When some ferromagnetic was used for conduction of magnetic flux material becomes magnetized by retentive magnetism.



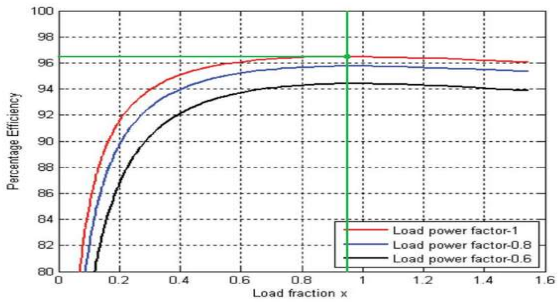
Parallel operation

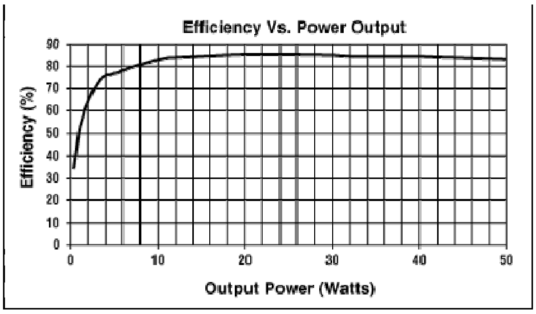
Possible way for decreasing lost energy may be the use of parallel connection. Two or more similar transformers connected together have several advantages. First is economical – lower losses transcript into saving money. The second one is practical. When we have more transformers usually it is not problem to turn off one of them for maintenance or it can serve as a backup.

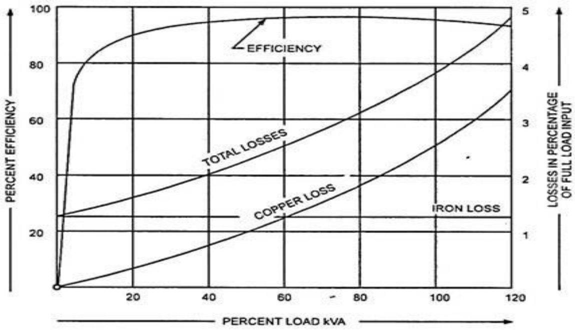


Efficient Operation

Impact of Load on Effeciency

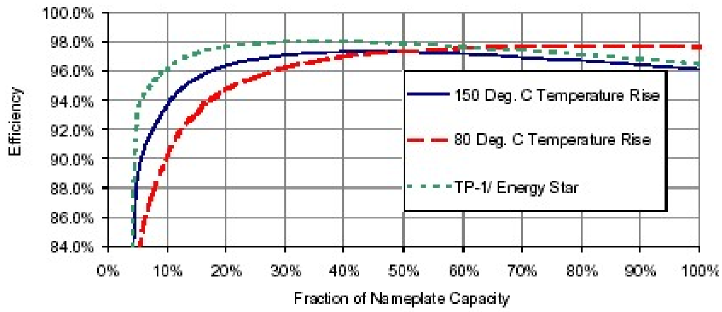


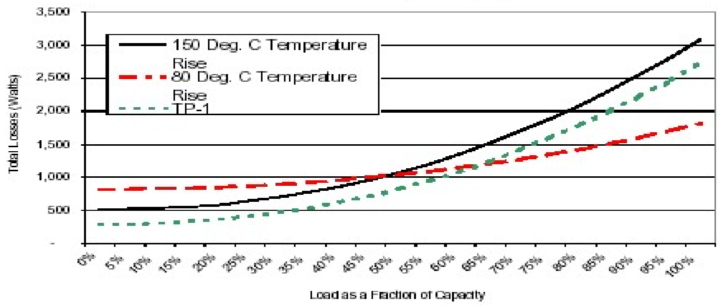




Efficient Operation

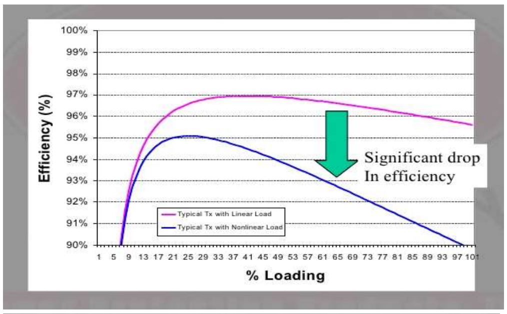
- Transformer Efficiency depends on:
  - Temperature
  - Power Losses
  - Capacity.

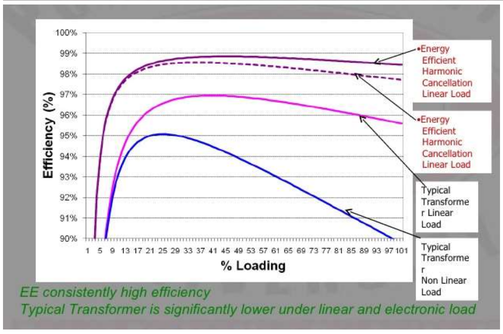




Efficient Operation

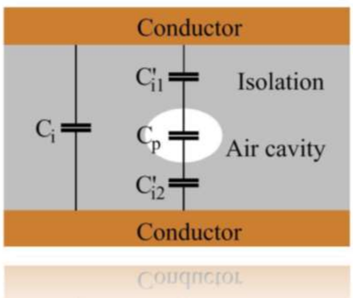
- Transformer Efficiency depends on:
  - Percentage of Loading
  - Harmonic Order.
  - Power factor.
- Non-linear load has a negative impact on transformer efficiency.





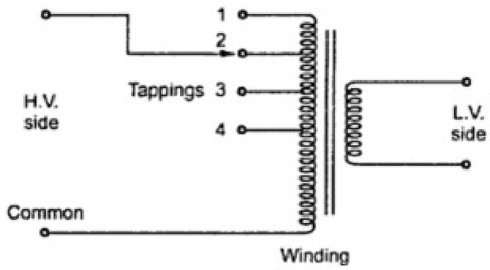
Efficient Operation

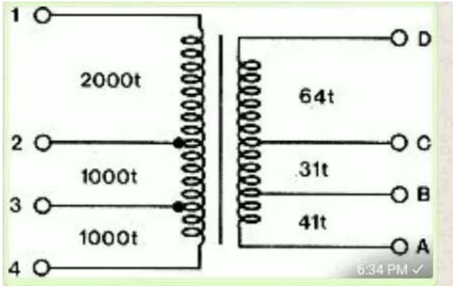
- Whatever the cause, these stresses will result in the chemical breakdown of some of the oil or cellulose molecules constituting the dielectric insulation. The main degradation products are gases, which entirely or partially dissolve in the oil where they are easily detected at the ppm level by DGA analysis.
- Typical gases from faults are H2, CH4, C2H2, C2H6, CO and CO2. Their relative concentrations show us which type of fault did happen because each specific gas needs specific temperature in order to arise.



Compound	Observed cause
2FAL 2-furaldehyde	General overheating or ageing
5M2F 5-methyl-2-furaldehyde	High temperatures
5H2F 5-hydroxymethyl-2-furaldehyde	Oxidation
2ACF 2-acetyl furan	Rare, causes not fully defined
2FOL 2-furfuryl alcohol	High moisture

Efficient Operation





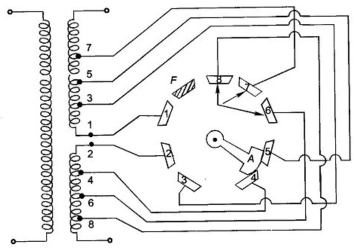
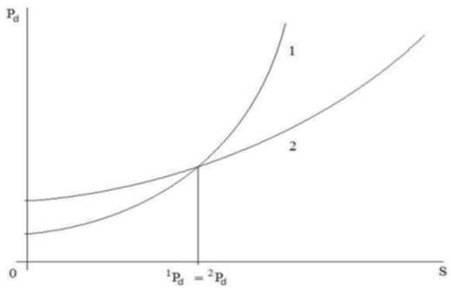


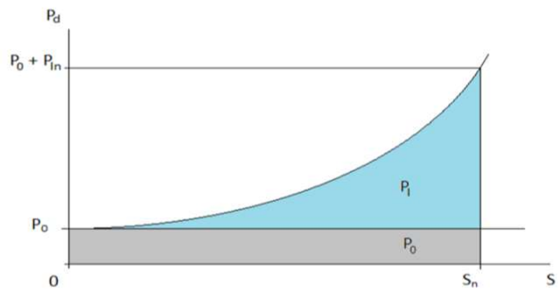
Fig. 3.68 *No-load tap changer*

Efficient Operation

Parallel connection need to meet several conditions. Here they are:

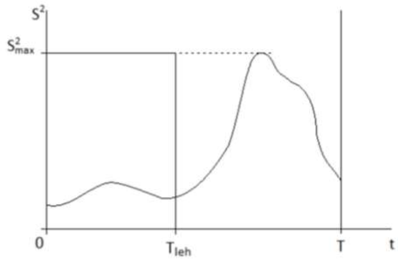
- Same voltage ratio of transformers
- Same phase displacement
- Same phase sequence
- Very similar percentage impedance
- Maximal recommended deviation is 10%
- Similar nominal load
- Ratio between them should be lower than 3.2





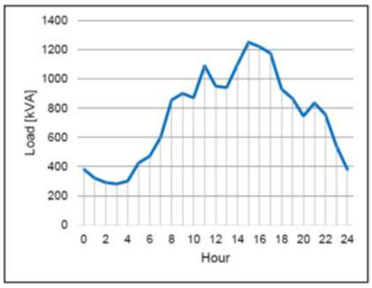
Efficient Operation

"Loss equivalent hours are the number of hours of peak load which will produce the same total losses as is produced by the actual loads over a specified period of time."

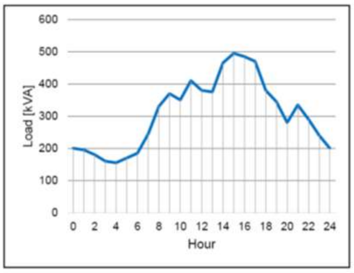


$$T_{leh} = \frac{1}{S_{max}^2} \cdot \int_0^T S(t)^2 dt$$

Hour	S [kVA]	Hour	S [kVA]
1.	320	13.	940
2.	290	14.	1100
3.	280	15.	1250
4.	300	16.	1220
5.	425	17.	1175
6.	470	18.	930
7.	600	19.	865
8.	855	20.	745
9.	900	21.	835
10.	870	22.	755
11.	1090	23.	540
12.	950	24.	380



Hour	S [kVA]	Hour	S [kVA]
1.	195	13.	375
2.	180	14.	465
3.	160	15.	495
4.	155	16.	485
5.	170	17.	470
6.	185	18.	380
7.	245	19.	345
8.	330	20.	280
9.	370	21.	335
10.	350	22.	290
11.	410	23.	240
12.	380	24.	200



Typical Generation Cost Structure

Levelized Cost of Energy" (LCOE), is the average price per unit of output needed for the plant to break even over its operating lifetime.

•**Ramp time**
The amount of time it takes from the moment a generator is turned on to the moment it can start providing energy to the grid at its lower operating limit (see below), in [h]
•**Capacity**
The maximum output of a plant, in [MW]
•**Lower Operating Limit (LOL)**
The minimum amount of power a plant can generate once it is turned on, in [MW]
•**Minimum Run Time**
The shortest amount of time a plant can operate once it is turned on, in [h].
•**No-Load Cost**
The cost of turning the plant on, but keeping it "spinning," ready to increase power output, in [$/MWh]. Another way of looking at the no-load cost is the fixed cost of operation; **Start-up and Shut-down Costs**
These are the costs involved in turning the plant on and off, in [$/MWh].

Technology	Ramp Time	Min. Run Time
Simple-cycle combustion turbine	minutes to hours	minutes
Combined-cycle combustion turbine	hours	hours to days
Nuclear	days	weeks to months
Wind Turbine (includes offshore wind)	minutes	none
Hydroeletric (includes pumped storage)	minutes	none

Technology	Capital Cost ($/kW)	Operating Cost ($/kWh)
Coal-fired combustion turbine	$500 — $1,000	0.20 — 0.04
Natural gas combustion turbine	$400 — $800	0.04 — 0.10
Coal gasification combined-cycle (IGCC)	$1,000 — $1,500	0.04 — 0.08
Natural gas combined-cycle	$600 — $1,200	0.04 — 0.10
Wind turbine (includes offshore wind)	$1,200 — $5,000	Less than 0.01
Nuclear	$1,200 — $5,000	0.02 — 0.05
Photovoltaic Solar	$4,500 and up	Less than 0.01
Hydroelectric	$1,200 — $5,000	Less than 0.01