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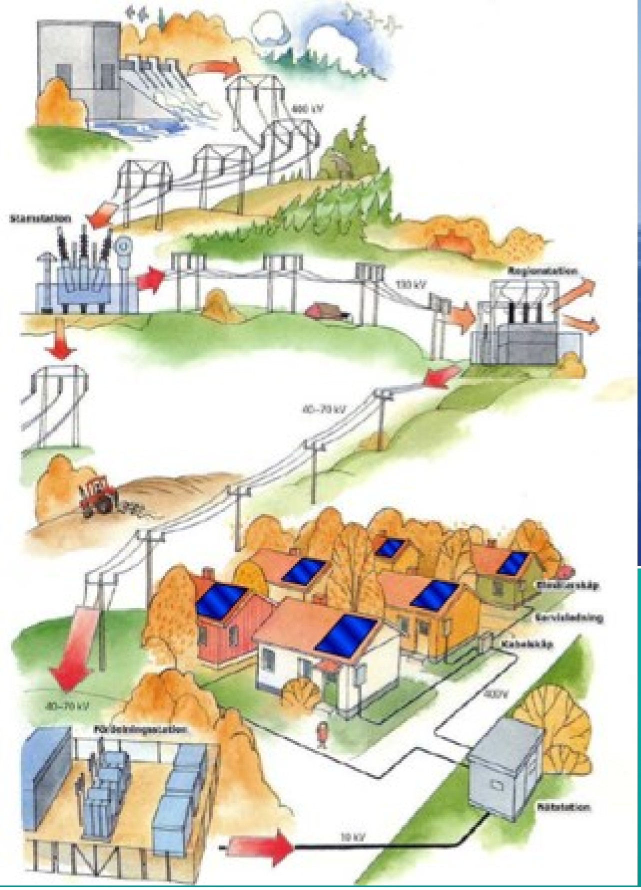

BTE2413: Electrical Power System

Chapter 1
Introduction to Power System Engineering

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Instructional Objectives

After completing this chapter, students should be able to do the following:

- Describe what is electrical power system is all about
- Identify the different sources of energy
- Define components of electrical power system
- Describe the role for each power system element
- Determine load factor and load demands
- Explain the structure of power system and National Grid in Malaysia

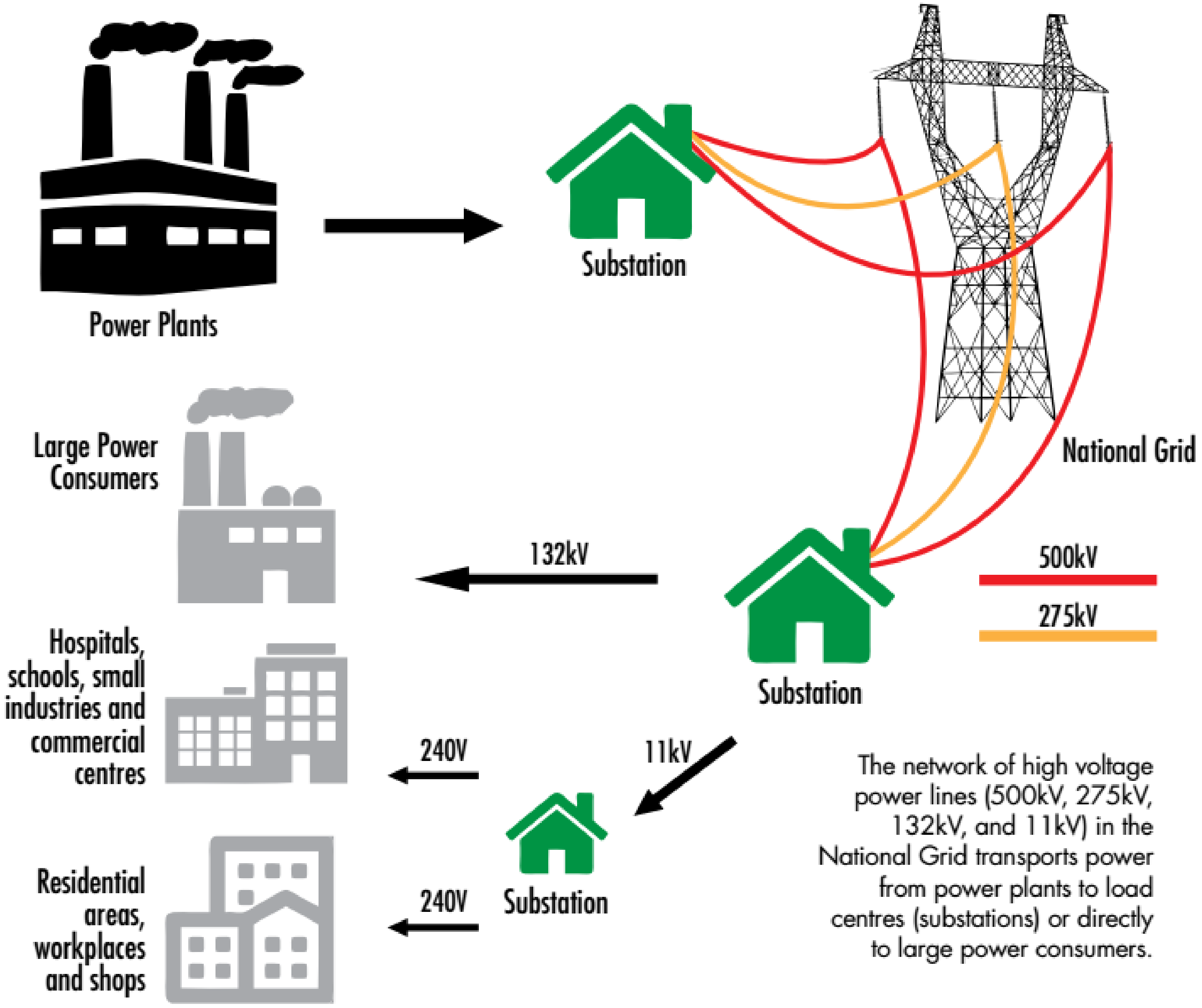
Outline

- Why Electrical Energy is Significant
- Electrical Energy Generation
- Sources and Units of Energy
- Energy Efficiency
- Structure of Power Systems
- Power System Loads
- Load Factors and Load Demand
- National Grid, Malaysia

Introduction

- The function of Power Systems is to convert energy from other forms to electricity and distribute it to the consumers.

- Power systems, also known as power engineering, which is a sub-field of engineering that focuses with the generation, transmission and distribution systems of electrical power, and the connected electrical devices such as:
  - Power Generators,
  - Turbine and engines,
  - Power transformers,
  - Transmission lines and cables.
  - HV/LV Switchgears (Circuit Breakers),
  - Switches and Fuses,
  - Relay and protections,
  - Auxiliaries,



The network of high voltage power lines (500kV, 275kV, 132kV, and 11kV) in the National Grid transports power from power plants to load centres (substations) or directly to large power consumers.

Source: Tenaga Nasional Berhad

A Little History of EPS

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- Thomas A. Edison started working on electric light In 1878.
- He started formulating the main concept of centralized power station with loads (lights).
- He opened Pearl Street Station in New York City, 1882
- Installation of waterwheel-driven generator, 1882
- Installation of 1st transmission line in Germany 2400 V DC.
- Producing of DC motor for Edison system by Frank J in 1884.
- Developing of practical transformer by William Stanley in 1886
- Presenting of induction and synchronous motors by Nikola Tesla 1888
- Developing 1st single phase AC Transmission line 4kV in 1889
- Developing 1st three phase AC Transmission line 12kV in 1891 in Germany
- Developing 1st three phase AC Transmission line 2.3kV in 1893 in USA
- In 1954, 1st modern transmission line, high-voltage DC (HVDC)

Why Electrical Energy is Significant

- The development of economy in any country is mainly based on electrical energy.
- The electrical energy is the most important form among the existing energy forms.
- Our daily life is totally dependent upon the use of electricity everywhere.
- The indicator of **per capita** electrical energy consumption becomes an important measure for the advancement of a country.

Why Electrical Energy is Significant

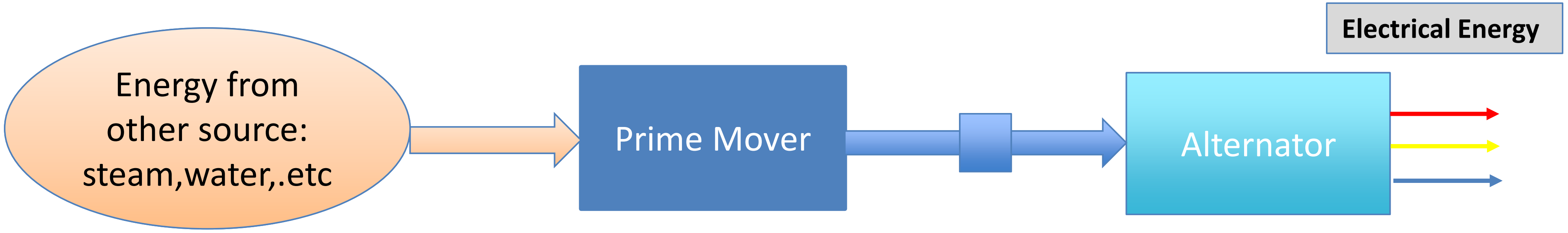
- The superiority of electrical energy compared to all other energy forms is coming from:
  - More convenience.
  - Easy to control.
  - More flexible.
  - Inexpensive.
  - Cleanliness.
  - Higher efficiency.

Electrical Energy Generation

- Electrical energy can be generated by converting various forms of energy in the nature.
- Different forms of energy are available from various natural sources such as:
  - **Hydraulic** energy,
  - **Thermal** energy from fuels such as coal and gas (chemical energy)
  - **Nuclear** energy of radioactive substances
  - **Wind energy**
  - **Solar energy**
  - **Geothermal energy**
  - **Tidal energy**

Electrical Energy Generation

- The main sources of energy used in generating electrical energy are fuels (solids, liquid and gas), water, and nuclear energy.



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Energy Sources Comparison

Particular	Water-based energy	Fuels-based energy	Nuclear-based energy
Initial cost	High	Low	Highest
Running cost	Less	High	Least
Reserves	Permanent	Exhaustible	Inexhaustible
Cleanliness	Cleanest	Dirtiest	Clean
Simplicity	Simplest	Complex	Most complex
Reliability	Most reliable	Less reliable	More reliable

Sources and Units of Energy

- Energy is defined as the agent capacity to do work.
- There are three important forms of energy:
  - Mechanical energy,
  - Electrical energy
  - Thermal energy.

Energy Type	Units of energy
Mechanical energy	newton-metre or joule
Electrical energy	watt-sec, kilowatt hour (kWh) or joule
Thermal energy	calorie or British thermal unit (B.Th.U.)

1 kWh =36 × 10^5 Joules

1 kWh =36 × 10^5 watt-sec.
= 860 × 10^3 calories

1 calorie = 4·18 Joules
1 B.Th.U. = 1053 Joules= 252 calories

Energy Efficiency

- In the process of electrical energy generation, some amount of energy is lost due to the conversion of energy from one form to electrical form.
- Thus, energy efficiency can be determined by dividing the output energy over the input energy of the system.

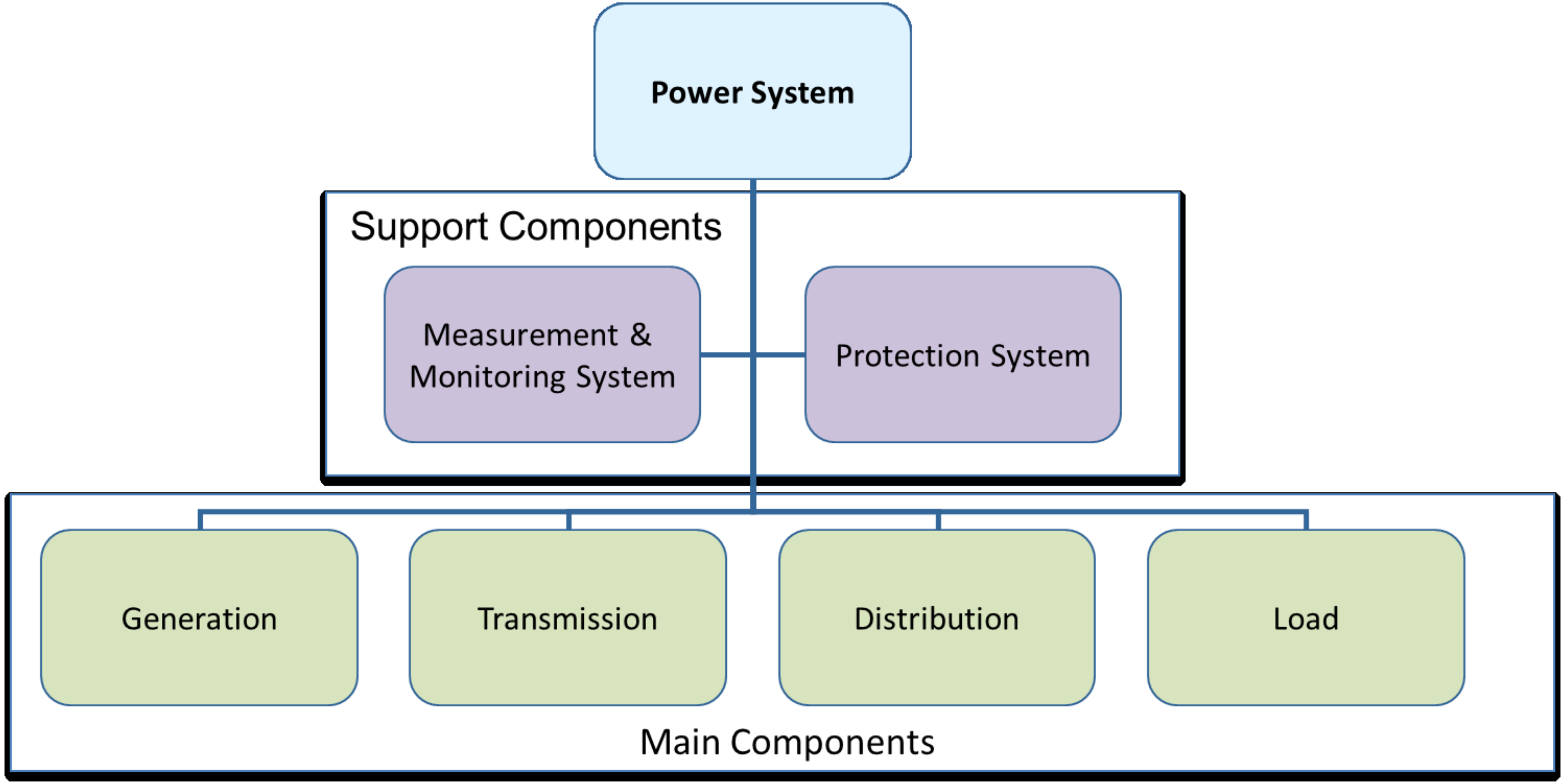
$$\text{Efficiency, } \eta = \frac{\text{Output energy}}{\text{Input energy}} = \frac{\text{Output power}}{\text{Input power}}$$

Structure of Power Systems

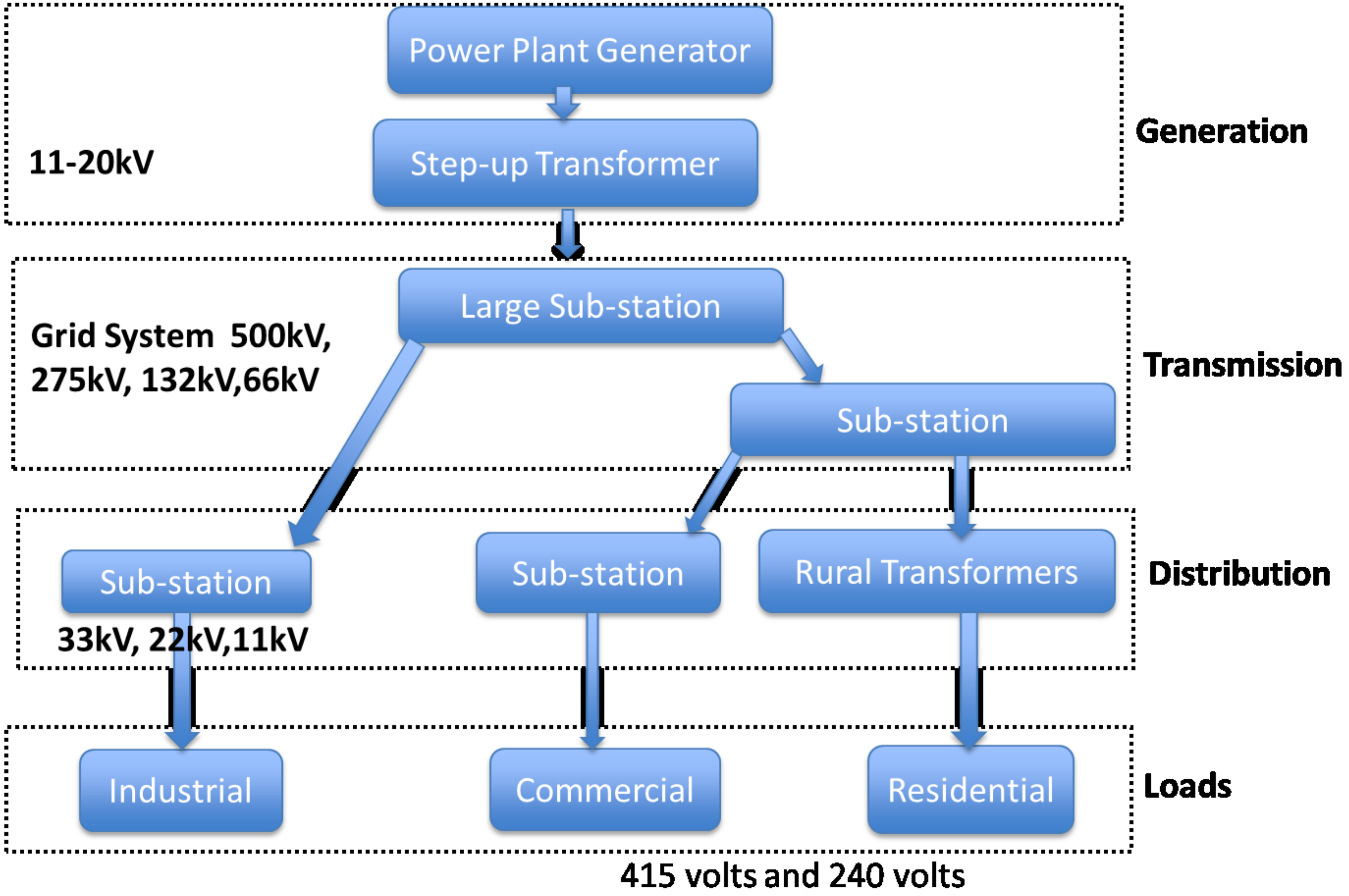
- Today’s electrical power system becomes more complex with a bulk interconnected network.
- Power system can be divided into four major sections:
  - **Generation:** power plants with a specified generation voltage and frequency
  - **Transmission system**: for power transmission from power plants to distribution systems. It includes a perfect overhead and/or underground conductors
  - **Distribution system**: distribute power to consumers,
  - **Load** or **demand**: resistive or inductive loads to consume power;

  Additional components include:
  - **Control and protection equipment**: coordinate supply with load and protect elements of power system.

Structure of Power Systems



Structure of Power Systems

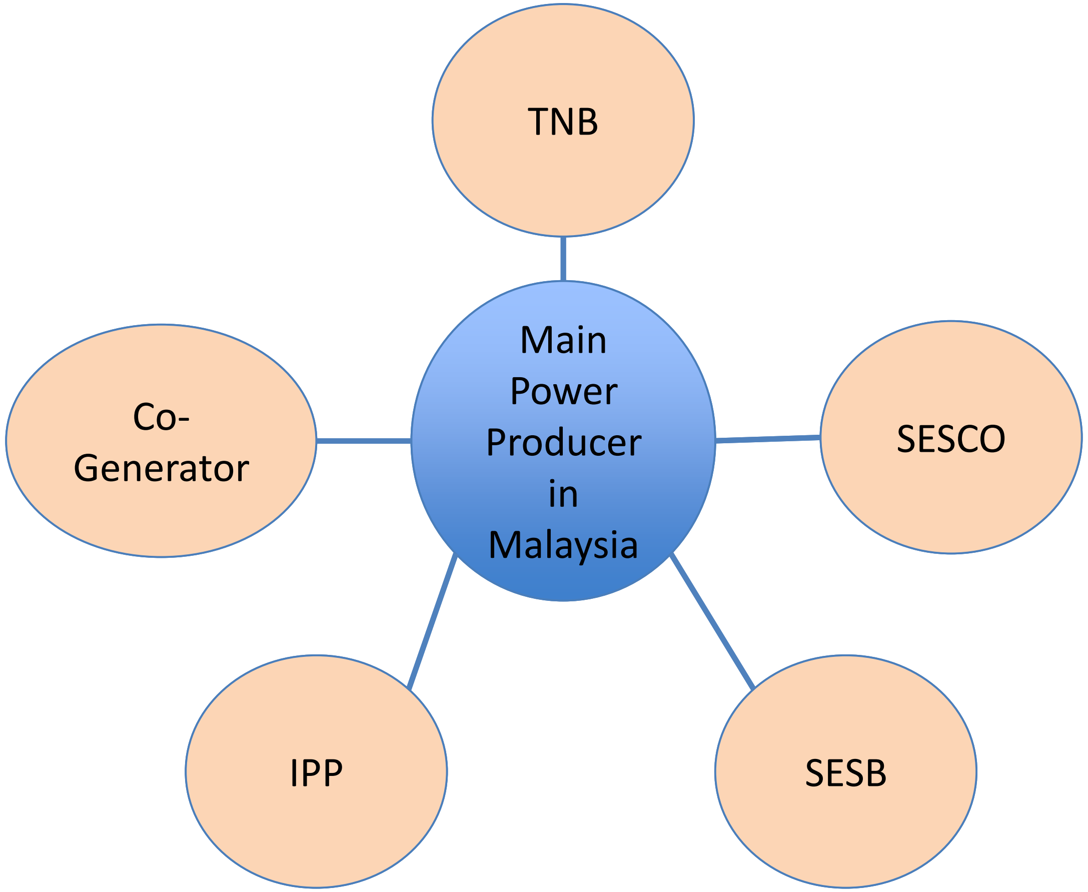


Generation

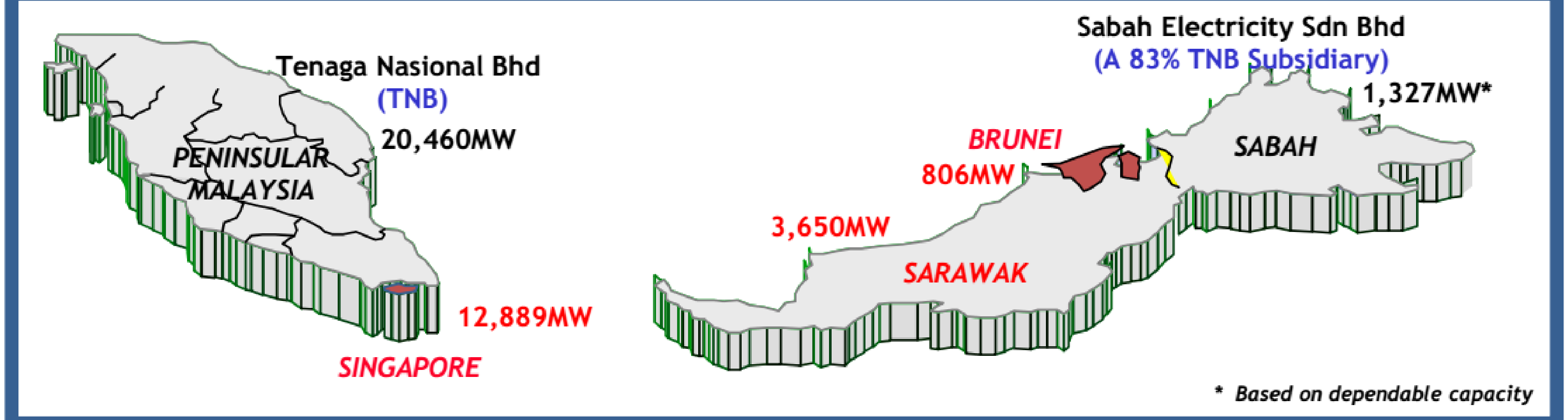
- One of the essential components of power systems.
- A power plant is designed to generate electric energy from another energy form.
- **Conventional :**
  - Thermal energy – coal, oil, natural gas
  - Potential energy – hydroelectric
- **None-conventional**
  - Thermal energy – nuclear
  - Wind energy
  - Solar thermal energy
  - Solar electric (photovoltaic).
  - Chemical energy – fuel cells and batteries.

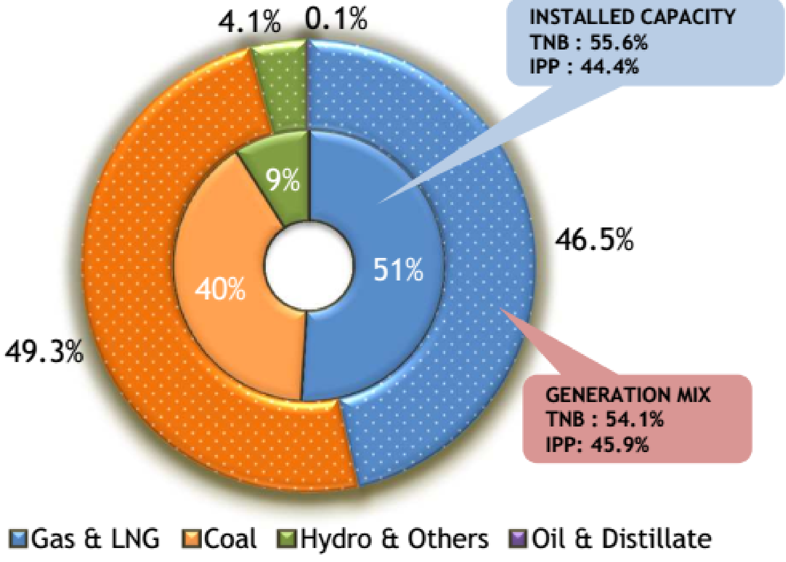
Generation

- Power plants generate voltages at 11 – 20kV and frequency of 50/60 Hz.
- Large sub-stations are used to step up voltage for transform at 132kV, 275kV and 500kV.
- Sub-stations are used at the other end of transmission line to step down voltage into distribution voltages at 33kV or 11kV



Three Major Utilities in Malaysia





Peninsula Installed Capacity vs. Generation mix

	FY'12	FY'13	FY'14	FY'15	1QFY'16
TNB - Peninsula Installed Capacity (MW)	11,462	11,462	10,814	11,708	11,384
Total units sold (Gwh)	102,132	105,479	108,102	110,837	28,571
Total customers (mn)	8.36	8.35	8.64	8.94	9.02
Total employees ('000)	33.6	35.0	36.1	36.0	35.9
Total assets (RM bn)	88.5	99.0	110.7	117.1	117.5

Source: Tenaga Nasional Bernhard

Installed Capacity as of 31st December 2014 in MW

Region		Hydro	Natural Gas	Coal	Diesel	Biomass	Solar	Biogas	Others	Total
Peninsular Malaysia	TNB	1,911	4,705	-	-	-	-	-	-	6,616
	IPPs	20	8,069	7,200	-	-	-	-	-	15,289
	Co-Generation	-	514	-	8	79	-	-	51	653
	Self-Generation	5	-	-	338	293	1	-	-	637
	SREP / FiT	9	-	-	-	19	160	12	-	200
	Subtotal	1,946	13,288	7,200	346	392	161	12	51	23,395
Sabah	SESB	70	112	-	181	-	-	-	-	363
	IPPs	-	922	-	190	-	-	-	-	1,112
	Co-Generation	-	42	-	8	110	-	-	-	160
	Self-Generation	-	-	-	425	115	-	3	-	543
	SREP / FiT	7	-	-	-	52	0	-	-	59
	Subtotal	77	1,076	0	803	277	0	3	0	2,236
Sarawak	SEB	351	595	480	158	-	-	-	-	1,584
	IPPs	2,400	-	-	-	-	-	-	-	2,400
	Co-Generation	-	289	-	-	-	-	-	-	289
	Self-Generation	-	-	-	9	60	-	-	1	70
	Subtotal	2,751	884	480	167	60	0	0	1	4,343
	Total	4,773	15,248	7,680	1,315	729	161	15	52	29,974

Source: Power Utilities, IPPs and SEDA

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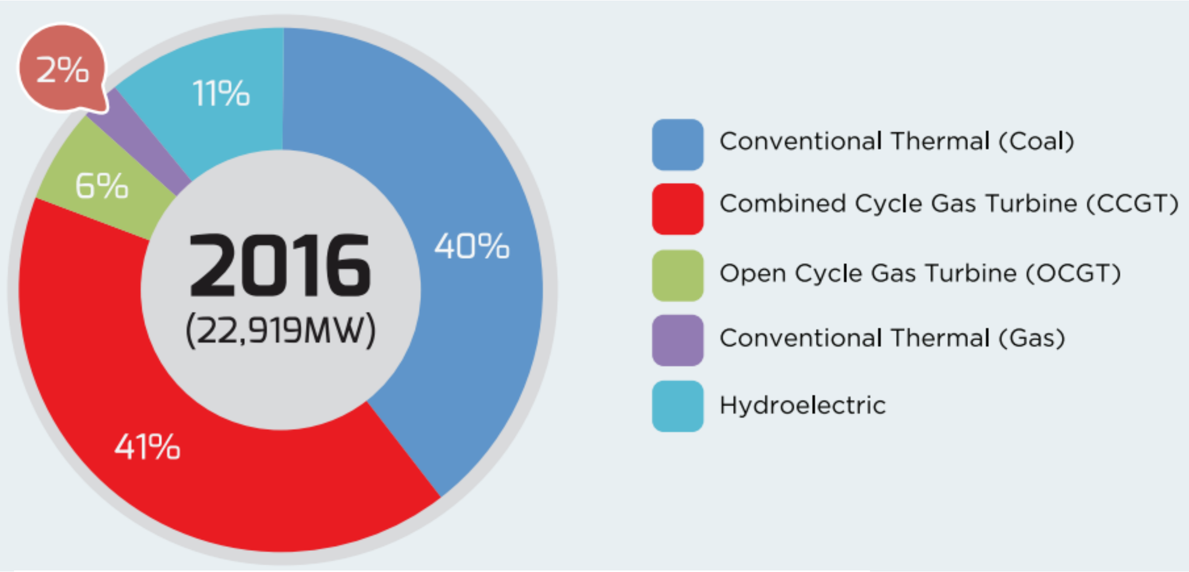
Installed capacity by plant type



Source: Malaysia energy statistics handbook 2016

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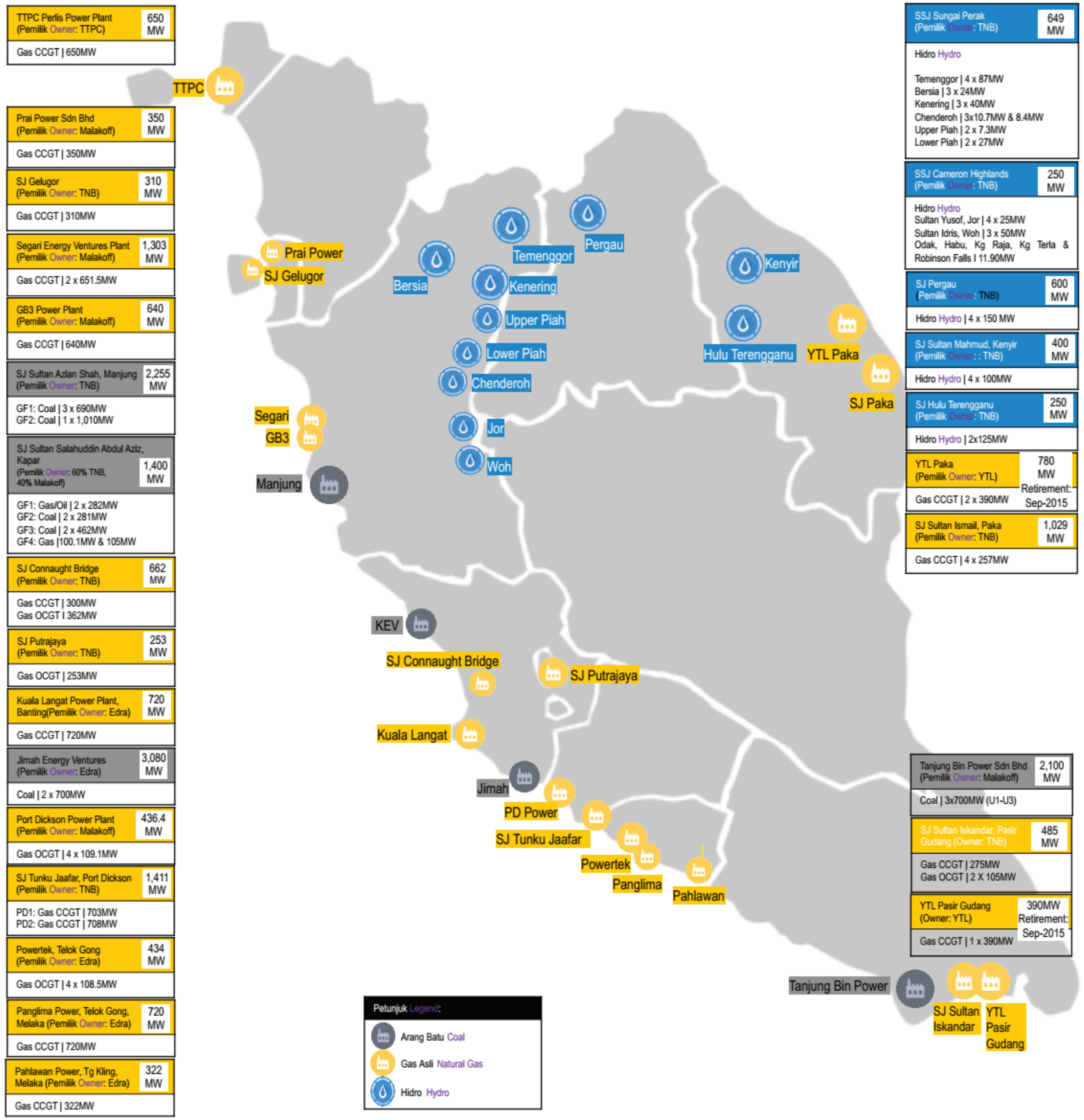

Location of Major Power Stations in Peninsular Malaysia

Source: Tenaga Nasional Bernhard

Independent Power Producer (IPP)

- Power producer which is privately owned.
- There are IPPs which sell power to TNB through long term agreement.
- Generating power by IPP is connected into the National Grid.
- Example
  - Paka, Pasir Gudang power station by **YTL Generation Sdn. Bhd.**
  - **Malakoff Berhad**
    - Lumut Power Station, Segari
    - Prai Power Station, Butterworth
    - Tanjung Bin Power Station, Johor
  - Kuala Langat Power Station by **Genting Sanyen Power Sdn. Bhd.**

Co-Generator

- **Minor electricity supply**
  - Some small distributors buy electricity from the utilities or generate their own power, mostly by co-generation. Then, distribute power to customers within specific areas such as industrial complexes.
- Example – **Petronas Gas Sdn Bhd** generates electricity as a Co-generator and distributes power within two Integrated Petrochemical Complexes (IPC) (Central Utilities Facilities (CUF) in Gebeng & Kerteh)
- Example – **KKIP Power Sdn Bhd** purchases power from SESB and distributes power within Kota Kinabalu Industrial Park.