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Vision	MISSION
We envision the Department as one of the best in the region with a stimulating environment to make an impact on and lead in the field through its Education and Research.	The mission of the Department is to provide an excellent and comprehensive education in the field of Electrical & Electronics Engineering which in turn moulds the students for a wide range of careers and to exhibit a high level of professionalism, ethical behavior and social responsibility.

Student Article:

Simplified Method for Calculating the Tower Grounding Impedance

ABSTRACT

This paper presents a simplified method for calculating the tower-footing grounding impedance of a transmission line. The grounding is comprised by four counterpoises and the proposed method considers the mutual effects between electrodes. The simulations are carried out in PSPICE program and implementing naturally becomes a simple task. The electrode length and soil resistivity vary for different values. The simulation results are obtained in the frequency domain and in the time domain showing important features of the grounding response when subject to an impulsive current.

The modeling of a transmission line grounding system contains considerable complexity because of the diversity of parameters that need to be considered. On the whole, it appears that the studies aimed at modeling the grounds adopt empirical, analytical or numerical solutions which are clearly conditioned to the evolution of computer processing capability experienced in recent decades. Also, despite the large number of existing studies, in all cases the models are based on electromagnetic field theory

The models based on electromagnetic field theory (EMF) have minimum simplifications due to its rigor in mathematical development. However, depending on grounding admeasurements, the computational processing time can be quite high compromising the simplicity and practicality in obtaining results, characteristics which are desirable in engineering solutions. This is the case of transmission line towers grounding systems that have counterpoise length typically ranging between 20m and 90m. To overcome this condition, this work takes advantage of that situations in which the results obtained by EMF models and those based on the transmission lines theory (TLT) show excellent agreement. This is the case when soil resistivity is high. These models are attractive because of the relatively simple mathematical modeling and small computer processing time to produce results. However, it is worth mentioning that despite the relative simplicity the computational deployment may be quite laborious in some cases.

Thus, the use of a model in a simulation computational environment that contains the entire mathematical basis necessary for calculations makes the task simpler. This paper presents a simple method to calculate the tower-footing grounding impedance in the time and in the frequency domain using PSPICE. This computer simulation environment has a library that contains a model well suited to modeling this one. The results are obtained in the frequency and in the time domain and non-linear effects (ionization) have not been included in the next analysis.

PROPOSED METHOD

A typical grounding arrangement used in transmission line towers is shown in Figure 1. It consists of four counterpoises cables and the pair of cables 1-2 and 3-4 are spaced by d meter

A very simple model to calculate the grounding impedance of this arrangement is presented in detail in [10]. In this model, the lightning current passing through the counterpoises and the mutual couplings are evaluated using a method based on transmission lines theory. The results are compared with those obtained by EMF models and it showed excellent agreement. The impedance of this arrangement is defined as the sum of the input impedances of two lines, one related to the selfimpedance, Zs, and the other one related to mutual impedance, Zm, weighted by a factor 0.25, as shown in (1). Equation (1) clearly shows that the impedance is calculated simply by self and mutual impedance of the electrodes that comprise the grounding. In this case, the self-impedance refers to a single grounding electrode whatever it is, since all counterpoises have the same geometric characteristics. The mutual impedance is calculated by any pair of electrodes, 1-2 or 3-4, as this arrangement has spatial symmetry [10].

A Simplified Method for Calculating the Tower Grounding Impedance by Means of Pspice -

N.SREERAMULAREDDY

Abstract — **This paper presents a simplified method for calculating the tower-footing grounding impedance of a transmission line. The grounding is comprised by four counterpoises and the proposed method considers the mutual effects between electrodes. The simulations are carried out in PSPICE program and implementing naturally becomes a simple task. The electrode length and soil resistivity vary for different values. The simulation results are obtained in the frequency domain and in the time domain showing important features of the grounding response when subject to an impulsive current.**

Keywords- Transmission line, Lightning, Grounding, Computer modeling.

I. INTRODUCTION

The modeling of a transmission line grounding system contains considerable complexity because of the diversity of parameters that need to be considered. On the whole, it appears that the studies aimed at modeling the grounds adopt empirical, analytical or numerical solutions which are clearly conditioned to the evolution of computer processing capability experienced in recent decades. Also, despite the large number of existing studies, in all cases the models are based on electromagnetic field theory [1-2], circuit theory [3-4] or transmission lines theory [5-7].

The models based on electromagnetic field theory (EMF) have minimum simplifications due to its rigor in mathematical development. However, depending on grounding admeasurements, the computational processing time can be quite high compromising the simplicity and practicality in obtaining results, characteristics which are desirable in engineering solutions. This is the case of transmission line towers grounding systems that have counterpoise length typically ranging between 20m and 90m. To overcome this condition, this work takes advantage of that situations in which the results obtained by EMF models and those based on the transmission lines theory (TLT) show excellent agreement [8], [9]. This is the case when soil resistivity is high. These models are attractive because of the relatively simple mathematical modeling and small computer processing time to produce results. However, it is worth mentioning that despite the relative simplicity the computational deployment may be quite laborious in some cases. Thus, the use of a model in a simulation computational environment that contains the entire mathematical basis necessary for calculations makes the task simpler. This paper presents a simple method to calculate the tower-footing grounding impedance in the time and in the frequency domain using PSPICE. This computer simulation environment has a library that contains a model well suited to modeling this one. The results are obtained in the frequency and in the time domain and non-linear effects (ionization) have not been included in the next analysis.

II. PROPOSED METHOD

A typical grounding arrangement used in transmission line towers is shown in Figure 1. It consists of four counterpoises cables and the pair of cables 1-2 and 3-4 are spaced by *d* meters.

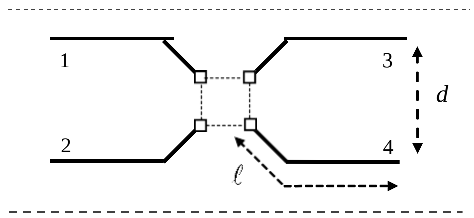


Figure 1. Arrangement of the grounding system.

A very simple model to calculate the grounding impedance of this arrangement is presented in detail in [10]. In this model, the lightning current passing through the counterpoises and the mutual couplings are evaluated using a method based on transmission lines theory. The results are compared with those obtained by EMF models and it showed excellent agreement. The impedance of this arrangement is defined as the sum of the input impedances of two lines, one related to the self-impedance, *Zs*, and the other one related to mutual impedance, *Zm*, weighted by a factor 0.25, as shown in (1).

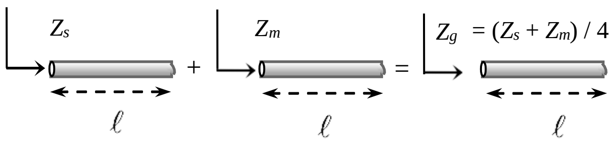
(1)

$${}_g = (Z_s + Z_m)0.25$$

Equation (1) clearly shows that the impedance is calculated simply by self and mutual impedance of the electrodes that comprise the grounding. In this case, the self-impedance refers to a single grounding electrode whatever it is, since all counterpoises have the same geometric characteristics. The mutual impedance is calculated by any pair of electrodes, 1-2 or 3-4, as this arrangement has spatial symmetry [10].

The PSPICE computational simulation environment has a transmission line model that considers the losses, TLOSSY, which is well suited to modeling this grounding. Despite the existence of models in PSPICE´s library that consider mutual couplings between the system elements, these are related only to inductance and capacitance. Models that have mutual resistive coupling are not available. However, it does not pose a problem. Observing equation (1) it is clear that it is only necessary to know the self-impedance of one counterpoise and the mutual impedance between two parallel counterpoises in order to define the grounding impedance of the system. Thus, the self and mutual impedances are obtained from two TLOSSY line models and the grounding impedance, Zg, is obtained by combining the individual responses of each line, as shown in Figure 2.

Figure 2. Self and mutual impedances calculated individually by two



transmission lines and the combination of both defining the grounding impedance, Zg.

The electrical parameters of the lines, *RLC*, are calculated using the equations proposed by Sunde [11], where:

$$R = \frac{\rho}{\pi \ell}\left[\ln\left(\frac{2\ell}{\sqrt{2rh}}\right) - 1\right], \quad (2a)$$

$$C = \frac{\rho\varepsilon}{R}, \quad (2b)$$

$$L = \frac{\mu \ell}{2\pi}\left[\ln\left(\frac{2\ell}{r}\right) - 1\right], \quad (2c)$$

where ρ is the resistivity of the soil, ε is the electric permittivity of the soil and μ is the magnetic permeability of the soil. With respect to the electrode, ℓ is the length, *r* is the radius and *h* is the depth which is buried. The calculation of line parameters for modeling the mutual coupling is done by replacing in (2) the radius *r* by distance *d* between the electrodes and the depth *h* by average depth of the electrodes [11].

The proposed method using PSPICE is applied to determine the overvoltage developed at the current input point

and the grounding harmonic impedance. The results are compared to those obtained directly by transmission line theory, since the considered values of soil resistivity are relatively high. Thus, the transient problem is first solved by a formulation in the frequency domain given by [12], [13]:

$$Z_0(j\omega) = \sqrt{\frac{j\omega L'}{G' + j\omega C'}}, \quad (3a)$$

$$\gamma(j\omega) = \sqrt{j\omega L(G' + j\omega C')}, \quad (3b)$$

$$Z(j\omega) = Z_0 \cdot \coth(\gamma \cdot \ell), \quad (3c)$$

where, Z_0 is the characteristic impedance, γ is the propagation constant, *Z* is the input impedance of the line, ω is the angular frequency, ℓ is the line length and *j* is $\sqrt{-1}$. It is worth noting that *RLC* parameters in (3) are per-unit-length, hence $L' = L/\ell$, $C' = C/\ell$ e $G' = 1/(R\ell)$.

The frequency range of interest depends mainly on the current front wave and the frequency components are defined using the fast Fourier transform (FFT). The time domain response is then obtained by applying the inverse Fourier transform:

$$v(t) = \Im^{-1}\left\{Z(j\omega)\cdot\Im\left[i(t)\right]\right\}. \quad (4)$$

Here *v*(t) is the response to an arbitrary excitation *i*(t), *Z*(*j*ω) is the impedance to ground, $\Im$ and $\Im^{-1}$ are Fourier and inverse Fourier transform, respectively.

The circuit used in PSPICE is show in Figure 3, where the far end opposite to the current input point is considered an open line [14], being represented by a high value resistor.

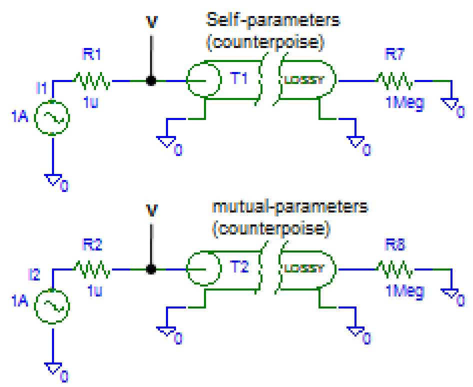


Figure 3. Transmission lines associated with self and mutual parameters.

The self and mutual parameters are calculated by (2) and the results are presented in Table I and Table II, where the *RLC* per-unit-length parameters are calculated considering: $\varepsilon r = 15$;

h = 0.5m; r = 2.5mm and ρ = 2400Ω.m. The electrode length varies from 30 m to 90 m and the distance between them varies from 20 m to 50 m.

TABLE I. *R'L'C'* SELF-PARAMETERS CALCULATED CONSIDERING εr = 15, h = 0.5m, r = 2.5mm, ρ = 2400Ωm.

ℓ (m)	d (m)	L' (µH/m)	G' (µS/m)	C' (pF/m)
30	20	1.82	214.94	68.51
50	30	1.92	198.31	63.21
70	40	1.98	188.69	60.14
90	50	2.04	182.09	58.04

TABLE II. *R'L'C'* MUTUAL-PARAMETERS CALCULATED CONSIDERING εr = 15, h = 0.5m, r = 2.5mm, ρ = 2400Ωm.

ℓ (m)	d (m)	L' (µH/m)	G' (µS/m)	C' (pF/m)
30	20	0.01972	819.93	261.35
50	30	0.04080	687.29	219.08
70	40	0.05055	624.16	198.95
90	50	0.05619	585.17	186.52

The grounding response due to an impulsive current considering the self and the mutual effects is obtained separately by two lines, T1 and T2, as shown in Figure 3. Thus, the harmonic impedance, $Z(j\omega)$, and the dynamic impedance, z(t), is defined by the combination of both according to (1). Variables of this equation are replaced by corresponding PSPICE variables where:

$$(V(R1:2) + V(R2:2)) * 0.25. \quad (5)$$

It is worth mentioning that for harmonic impedance calculation the PSPICE source is set to 1A. Thus, the measured voltages at marked points corresponds to the impedance as in this case Z=V, although this is not essentially required.

III. RESULTS

The impedance analysis in the frequency domain allows knowing the grounding characteristics readily. Figure 4 shows the magnitude of $Z_g(j\omega)$. It is notorious the existence of two distinct regions that characterize the grounding response, one associated with lower frequencies and another one with higher frequencies. Although it is not possible to define an exact frequency for the transition from low to high, one can assume that this is in the range between 50-kHz to 100-kHz. It is noteworthy that in the PSPICE each curve is obtained by response combination of two lines, one associated with self-effects and the other one to the mutual effects.

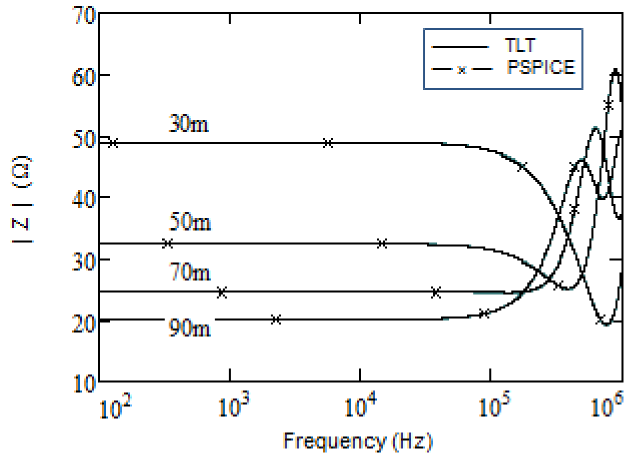


Figure 4. Grounding impedance absolute value, εr = 15, h = 0.5m, r = 2.5mm, ρ = 2400Ωm.

The overvoltage is obtained in a similar way to that used in defining harmonic impedance. Thus, it is also defined by (5) and the RLC parameters are calculated by (2). Figure 5 and Figure 6 show the voltages when a fast current wave (1.2/20µs) is injected in the grounding electrodes buried in soils of 1000Ωm e 2000Ωm. As expected, the resistivity increase also leads to an overvoltage increase. It is also possible to estimate the effective length of the electrodes, since there is a length from which the maximum overvoltage shows no significant reduction in maximum values.

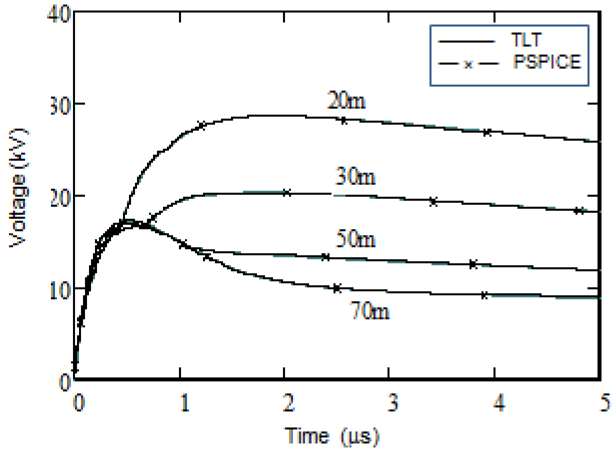


Figure 5. Overvoltage at the grounding entry point when subjected to a fast current wave (1.2/20µs), ρ = 1000Ωm.

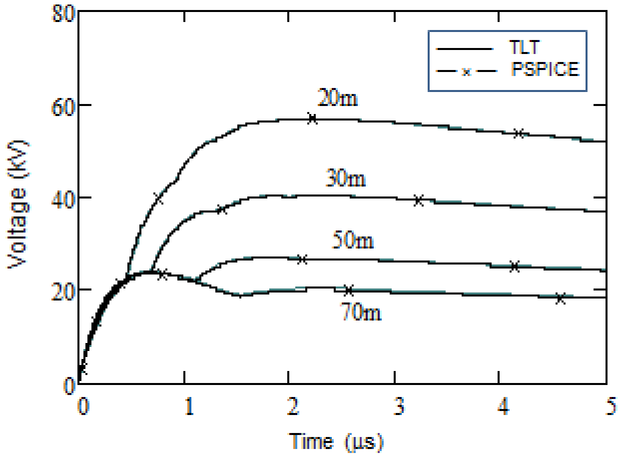


Figure 6. Overvoltage at the grounding entry point when subjected to a fast current wave (1.2/20µs), ρ = 2000Ωm.

IV. Conclusions

In this paper a method for calculating the tower-footing grounding impedance including the mutual couplings is implemented in PSPICE. The analyses in the time and in the frequency domain with relatively low computational resources show the versatility of the proposed method. Important grounding features as overvoltage, time delay and wave reflections are easily obtained. Moreover, extending the applicability of this method it is possible using this computer simulation program to evaluate the overvoltage developed under insulators strings. It is particularly important in lightning performance of transmission lines studies.

2. Stabilization of Wind Power Generation Using Energy Storage Technology

By: K.Padmavathi, P.Nageswari

INTRODUCTION

Sustainability and efficient use of energy resources is an urgent issue today. Reasons lie not only in the growth of demand and production, but also in the present level of resource exploitation leading to exhaustion of energy resources and related environmental impacts. The sustainable use of energy requires applications and methods that could increase efficiency. This is especially important in converter applications.

Traditional methods of energy conversion in power plants have some disadvantages, such as impact on the environment. Some new unconventional methods of energy generation have less impact on the environment. The cost of power generation is one of the main criteria when choosing a method for its production. Today traditional technologies seem to be cheaper than the alternative ones. Energy produced from renewable sources lacks the cost of fuel, however, it has higher capital costs.

The predicted costs and cost price of electricity production based on renewable sources have been given in Table 1. The use of renewable energy and storage offers prospects of significant decrease in fossil fuel extraction and accompanying environmental pollution.

Table 1. Prediction costs and cost price of electricity production

Renewable source	Specific capital cost, \$ kW^{-1}			Cost of production, cent kWh^{-1}		
	2005	2030	2050	2005	2030	2050
Onshore wind farm	900–1,100	800–900	750–900	4.2–2.2	3.6–2.1	3.5–2.1
Offshore wind farm	1,500–2,500	1,500–,1900	1,400–1,800	6.6–21.7	6.2–18.4	6–18
Solar power	3750–3850	1,400–1,500	1,000–1,100	17.8–54.2	7–32.5	6–29
Fuel cell	3,000–10,000	500–1,000	300–500	2–3	2–3	2–3

Unpredictable winds make it difficult to plan production (Fig. 2), complicating parallel operation with other power plants, intended for compensating the instability of wind

HYDROGEN TECHNOLOGY AS A BUFFER FOR STABILIZATION OF WIND POWER GENERATION

The Department of Electrical Drives and Power Electronics has introduced the concept of using hydrogen for compensating the instability of wind production. A typical

power production. Due to unpredictable wind the difficulty in forecasting periods of excess energy as well as lack of energy occ.

Configuration of a wind farm connected to the transmission grid is formed by the set of wind generators, electrically connected through a medium voltage network, sharing one single infrastructure for access and control. A block diagram of the hydrogen buffer system for the stabilization of wind power generation is presented in Fig.1

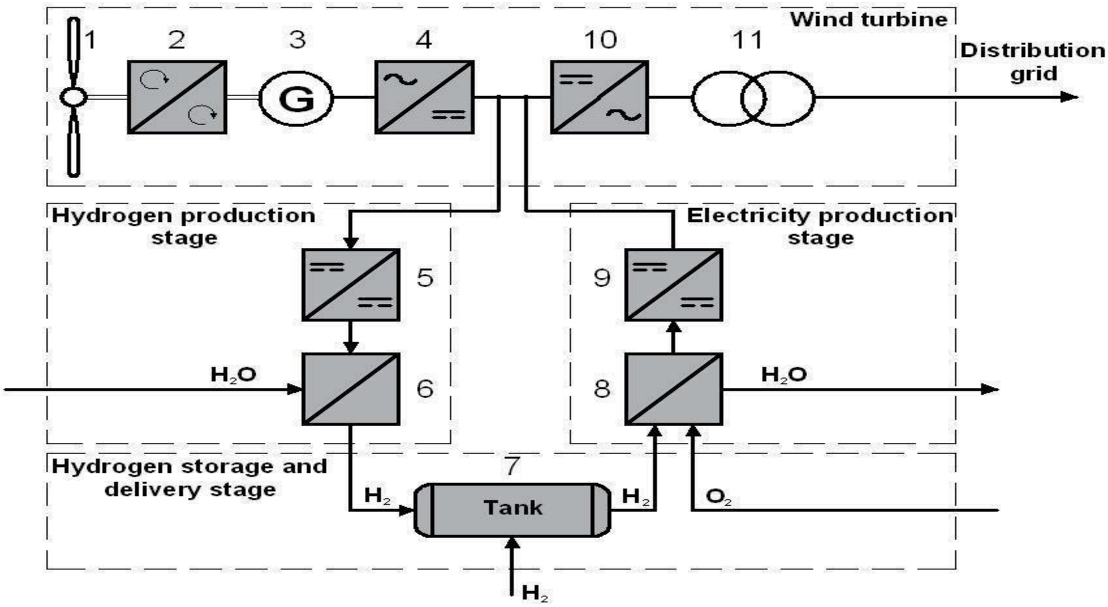


Fig. 1 Block diagram of the proposed hydrogen buffer: 1 – Blades; 2 - Gearbox; 3- Generator; 4 – Rectifier; 5 - Interface DC/DC converter, 6 – Electrolyser; 7- Storage tank; 8 - Fuel cell; 9 - Interface DC/DC converter; 10 – Inverter; 11 - Transformer

Because of unregulated energy production (Fig. 2), the fluctuation of wind speed leads to a fluctuating output. It means that at some moments excess energy and energy lack appear. As mentioned above, a hydrogen buffer is used to stabilize unregulated energy production, consisting of the following main components:

1. Hydrogen production stage,
2. Hydrogen storage and delivery stage,
3. Electricity production stage.

HYDROGEN PRODUCTION STAGE

In periods of excess energy, the hydrogen generation system is connected to the internal grid. In this stage, electrical energy from the wind generator is converted into chemical energy by using water electrolysis. Because of low input voltage of an electrolyser it is necessary to decrease high output voltage of the grid with the help of interface DC/DC converter with a step-down isolation transformer.

The hydrogen generation system consists of two main parts:

1. Interface DC/DC converter with a step-down isolation transformer, which allows interfacing the high voltage DC output of converter with a low voltage input of the electrolyser,
2. Electrolyser, allowing electrical energy storage and producing hydrogen from water electrolysis using excess electricity from the wind generator.

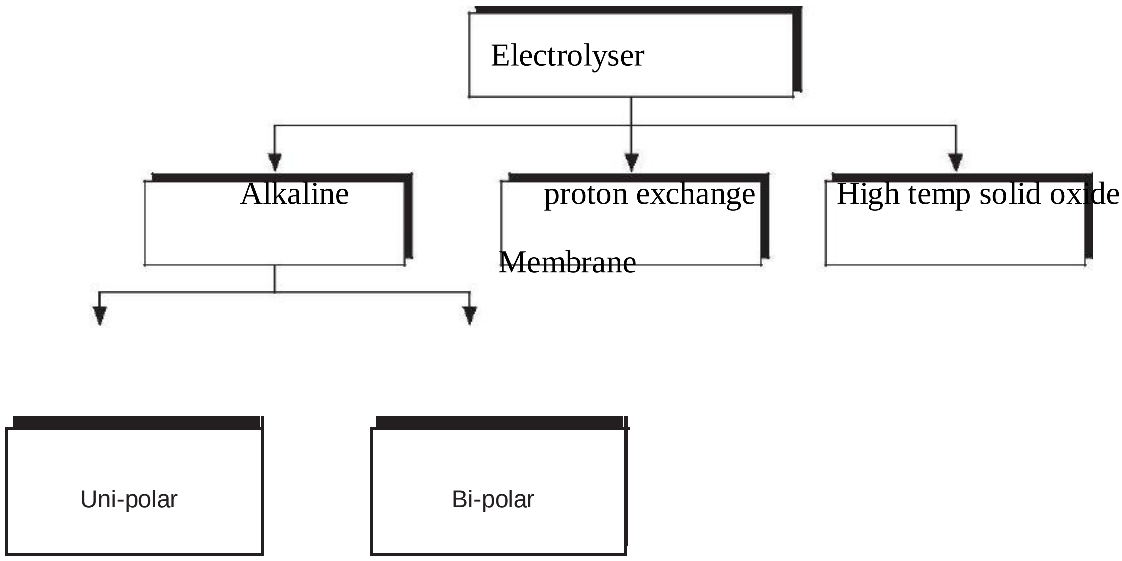


Fig. 2. General classification of electrolysers.

Alkaline electrolysers could be subdivided into unipolar or bipolar electrolysers (Fig. 4). The unipolar design is composed of a series of electrodes, anodes and cathodes alternatively suspended in a tank, filled with a 20–30% solution of electrolyte. In this design, each of the cells is connected in parallel.

The bipolar electrolysers have alternating layers of electrodes and separation diaphragms, which are clamped together. The cells are connected in series and can result in higher stack voltages. Since the cells are relatively thin, the overall stack can be considerably smaller in size than the unipolar design

.

Table 2. Common characteristics of electrolysers

Characteristic	Uni–polar	Bi–polar	Proton Exchange membrane	High–temperature solid oxide
Current density, _ (_m^2)$^{-1}$	0.1–0.2	0.2–0.4	0.4	1.1–2.0
Voltage cell, V	2.04–2.14	1.87–2.10	1.65–1.85	1.78–1.85
Production, (m^3 $_2$) h^{-1}	Up to 80,000	Up to 200,000	Up to 25,000	Up to 25,000
Energy demand, (_W·h^{-1}) (m^3)$^{-1}$	5.0	4.3–4.6	4.5	3.9–4.0
Temperature, °_	50–100	50–100	80–100	120
Pressure, P_	0.01–0.10	0.01–0.10	Up to 3.0	0.2–6.0
Efficiency, %	75–90	75–90	80–90	80–90

In the PEM electrolysers the electrolyte is contained in a thin, solid ion conducting membrane as opposed to the aqueous solution in the alkaline electrolysers. This allows the H+ ion to transfer from the anode side of the membrane to the cathode side and serves to separate the hydrogen and oxygen gasses. Oxygen is produced on the anode side and hydrogen is produced on the cathode side. PEM electrolysers use the bipolar design and can be made to operate at high differential pressure across the membrane.

High-temperature electrolysis (HTE) is different from the conventional electrolytic process. Some of the energy needed to split water is provided as thermal energy instead of electricity. It occurs because conventional electrolysis usually operates at temperatures below 100ºC.

HTE generally refers to an electrolytic process operating at temperatures above 100ºC. As HTE curtails the relatively inefficient step of conversion of heat to electricity, it is more efficient than the conventional electrolysis .In a HTE system using nuclear energy, a nuclear reactor supplies thermal energy that both generates electricity and heats up the steam needed for electrolysis. The HTE system is supported by nuclear process heat and electricity has the potential to produce hydrogen with overall system efficiency near that of the thermochemical processes. HTE cells consist of two porous electrodes separated by a dense ceramic electrolyte. HTE cells with oxygen ion conducting ceramic as electrolyte are often called solid oxide electrolysis cells (SOECs).

Table 3:Advantages and Disadvantages of Electrolysis

Type of electrolysis	Advantages	Disadvantages
Alkaline unipolar	this design is extremely simple to manufacture and repair	usually operates at lower current densities and lower temperatures
Alkaline bipolar	reduced stack footprints and higher current densities as well as the ability to produce higher pressure gas	can not be repaired without servicing the entire stack although this is rare
Proton exchange membrane	requires no liquid electrolyte, which simplifies the design significantly, the electrolyte is an acidic polymer membrane. PEM electrolysers can potentially be designed for operating pressures up to several hundred bar, and are suited for both stationary and mobile applications, increased safety due to the absence of KOH electrolytes, a more compact design due to higher densities, and higher operating pressures	limited lifetime of the membranes, membranes must use very pure deionized water, otherwise, they will accumulate cations that displace protons and increase cell resistance over time
High-temperature solid oxide	can operate at significantly higher overall process efficiencies than regular low-temperature electrolysers	requires large amounts of energy and heat, it is working with a nuclear power plant

Today's most widespread industrial electrolysers are alkaline and proton exchange membrane. These two types of electrolysers allow higher operating pressures, higher current density and low applied voltage to the cel

ELECTRICITY PRODUCTION STAGE

In order to stabilize energy production, during the absence of wind or in conditions of a light wind, stored hydrogen could be reused. In this stage, hydrogen is converted into electrical energy by using a fuel cell (FC). The fuel cell takes the hydrogen from the tanks to generate electricity, plus water and heat as byproducts. The produced electrical energy is in DC form, thus a power converter is required to change DC voltage level required by the grid. Because of low output voltage of a fuel cell it is necessary to boost it with the help of the interface DC/DC converter with a step-up isolation transformer. A hydrogen-powered fuel cell system consists of two main parts:

1. Interface DC/DC converter with a step-up isolation transformer, which allows interfacing a low voltage DC output of fuel cell with a high voltage DC-link of the converter,
2. Fuel cell allows producing chemical energy into electrical energy in order to stabilize energy production of wind generator.

The electrolyte in polymer electrolyte fuel cell is an ion exchange membrane (fluorinated sulfonic acid polymer or other similar polymer), which is an excellent proton conductor. The only liquid in this fuel cell is water, thus the corrosion problems are minimal. Typically, carbon electrodes with platinum electrocatalyst are used for both anode and cathode and with either carbon or metal interconnects. Water management in the membrane is critical for efficient performance, the fuel cell must operate under conditions where the byproduct water does not evaporate faster than it is produced because the membrane must be hydrated. Higher catalyst loading than used in phosphoric acid fuel cell is required for both the anode and the cathode.

Alkaline fuel cells are one of the most developed technologies and have been used to provide power and drinking water in space missions, including the US Space Shuttle. The design of an alkaline fuel cell is similar to a proton exchange membrane (PEM) cell but with an aqueous solution or stabilized matrix of potassium hydroxide as the electrolyte. Alkaline cells operate at a similar temperature to PEM cells (around 80°C) and therefore start quickly, but their power density is around ten times lower than the power density of a PEM cell. As a result they are too bulky for using in car engines. Nevertheless, they are the cheapest type of a fuel cell to manufacture, so it is possible that they could be used in small stationary power generation units. Like the PEM cell, alkaline fuel cells are extremely sensitive to carbon monoxide and other impurities that would contaminate the catalyst.

In the phosphoric acid fuel cells, typically operating at 150 to 220°C, the concentrated phosphoric acid (close to 100%) is used as the electrolyte. The relative stability of the concentrated phosphoric acid is high compared to other common acids. Consequently the phosphoric acid fuel cell (PAFC) is capable of operating at the high end of the acid temperature range (100 to 220°C). The anode and cathode reactions are the same as in the PEM fuel cell with the cathode reaction occurring at a faster rate due to the higher operating temperature

The electrolyte in the molten carbonate fuel cells is usually a combination of alkali carbonates, which is retained in a ceramic matrix. The fuel reaction. Noble metals are not required for operation, and many common hydrocarbon fuels can be reformed internally. The focus of MCFC development has been on larger stationary and marine applications, where the relatively large size and weight of MCFC and slow start-up time are not an issue

In the solid oxide fuel cells, the electrolyte is a solid, nonporous metal oxide. The cell operates at 600-1,000°C where ionic conduction by oxygen ions takes place. The limited conductivity of solid electrolytes required cell operation cell operates at 600 to 700°C where the alkaline carbonates form a highly conductive molten salt, with carbonate ions providing ionic conduction.

At around 1,000°C, but more recently thin electrolyte cells with improved cathodes have allowed the reduction of operating temperatures to 650-850°C. SOFCs are considered for a wide range of applications, including stationary power generation, mobile power, auxiliary power for vehicles, and specialty applications

In accordance with the classification of fuel cells (Fig. 5), common characteristics of fuel cells are shown in Table 4, their advantages and disadvantages.

Table 4. Common characteristics of fuel cells

Type of fuel cell	Electrolyte	Qualified power	Operating temperature	Electrical efficiency
Proton exchange membrane	Polymer Membrane	100 W to 500 kW	30–100°C	cell: 50–70% system: 30–50%
Alkaline	aqueous alkaline Solution	10 kW to 100 kW	under 80°C	cell: 60–70% system: 62%
Phosphoric acid	Molten phosphoric acid	up to 10 MW	150–200°C	cell: 55% system: 40%
Molten carbonate	molten alkaline Carbonate	100 MW	600–700°C	cell: 55% system: 47%
Solid oxide	O_2–conducting ceramic oxide	up to 100 MW	850–1,100°C	cell: 60–65% system: 55–60%

Table 5. Advantages and disadvantages of a fuel cell

Type of FC	Application	Advantages	Limitations
Proton exchange Membrane	cars, buses, portable power supplies, medium to large-scale stationary power generation	compact design; relatively long operating life; adapted by major automakers; offers quick start-up, low temperature operation	high manufacturing costs, needs pure hydrogen; heavy auxiliary equipment and complex heat and water management
Alkaline	space (NASA), terrestrial transport	low manufacturing and operation costs; does not need heavy compressor, fast cathode kinetics	large size; needs pure hydrogen and oxygen; use of corrosive liquid electrolyte
Phosphoric Acid	medium to large-scale power generation	commercially available; heat for co-generation	low efficiency, limited service life, expensive catalyst
Molten carbonate	large-scale power generation	highly efficient; utilizes heat for co-generation	electrolyte instability; limited service life
Solid oxid e	medium to large-scale power generation	high efficiency, takes natural gas directly, no reformer needed. Operates at 60% efficiency; co-generation	high operating temp; rare metals, high manufacturing costs, oxidation issues; low specific power

Technical properties of fuel cell (Table 6).

Table 6. Fuel cell technical properties

Characteristics of fuel cell	Polymer electrolyte	Alkaline	Phosphoric acid	Molten carbonate	Solid oxide
Current density, _ (_m^2)$^{-1}$	0.1–0.9	0.1–0.9	0.1–0.9	0.1–0.9	0.1–0.9
Voltage cell, V	0.8–0.6	0.8–0.6	0.8–0.6	0.8–0.6	0.8–0.6
Power density, W (_m^2)$^{-1}$	0.35–0.7	0.1–0.3	~0.14	0.1–0.12	0.15–0.7
H_2 consumption, (cm^3 H_2) (min A)$^{-1}$	7.0	7.0	7.0	7.0	7.0
O_2 consumption, (cm^3 O_2) (min A)$^{-1}$	3.5	3.5	3.5	3.5	3.5
Pressure, bar	1–2	1	1	1–10	1

Having considered all the fuel cells explained the authors conclude that there are several perspective types of fuel cells that can be used. First a low-temperature fuel cell that is an alkaline fuel cell with a high efficiency and low oxygen reduction reaction losses. Second, a high-temperature fuel cell, a solid oxide and molten carbonate fuel cell.

HYDROGEN STORAGE

In an ideal system, supply will match demand. Energy storage enables the supply to be shifted to meet the demand. Electricity can be drawn from the primary supply during periods of excess availability, stored and then returned during periods of excess demand. Correct sizing of the storage

3. .

should allow the generation plant to operate closer to its optimal efficiency, making thus better economic use of the existing assets. According to the International Energy Agency classification, hydrogen storage methods can be divided into two groups:

The first group includes physical methods which use physical processes (compression or liquefaction) to compact hydrogen gas. Hydrogen being stored by physical methods contains H_2 molecules, which do not interact with the storage medium. The following physical methods of hydrogen storage are available:

1. Compressed hydrogen gas,
2. Liquid hydrogen: stationary and mobile cryogenic reservoirs

The second group includes chemical (or physical-chemical) methods that provide hydrogen storage using physical chemical processes of its interaction with some materials. The methods are characterized by an essential interaction of molecular or atomic hydrogen with the storage environment. The chemical methods of hydrogen storage include:

1. Adsorption,
2. Bulk absorption in solids (metal hydrides),
3. Chemical interaction.

Comparison of hydrogen storage methods in accordance with the above mentioned methods .

Table 7. Comparison of physical hydrogen storage methods

Group	Subgroup	Method	Storage conditions		Storage performances	
			P, bar	T,ºC	Volume density, g $(dm^3)^{-1}$	Energy consumption, %
Physical	compressed gas storage	steel cylinders	200	20	17.8	9
		commercial composite cylinders	250	20	22.3	10
		advanced composite cylinders	690	20	29.7	12.5
		glass micro–spheres	350–630	200–400	20	25
	cryogenic (LH_2)		1	–252	71	27.9

Table 8. Comparison of chemical hydrogen storage methods

Group	Subgroup	Method	Storage conditions		Storage performances	
			P, bar	T,ºC	Volume density, g $(dm^3)^{-1}$	Energy consumption, %
Chemical	cryo–adsorption		2–40	–208…–195	15–30	8.1
	metal hydrides	'low–temperature' (20–100ºC)	0.01–20	20–100	90–100 / 60–70	10.4
		'high–temperature' (250–400ºC)	1–20	250–350	90–100 / 60–70	20.6
	complex hydrides (alanates)		1–20	125–165	30	13.4
	organic hydrides		10–100	300–400	70–100	28

From the data (Tables 7, 8), it can be concluded that each method has its advantages and disadvantages and none of the specific hydrogen storage methods is superior to the remaining alternative ones. Cost, volume, weight and performance should be considered together in selecting an optimal storage method that suits the specific requirements.

HYDROGEN DELIVERY

Between the two ends of the economic chain, hydrogen has to be packaged by compression or liquefaction to become a commodity. In the transportation, hydrogen has to be produced, packaged, transported, stored, transferred to cars, then stored and transported again before it is finally admitted to fuel cells.

There are two possibilities of hydrogen delivery

1. Road delivery,
2. Pipeline delivery.

Because of the low density of the gaseous energy carrier, transport of pressurized or liquid hydrogen is extremely inefficient. Forty-ton trucks can carry only 350 kg of hydrogen at 200 bars in the gaseous or 3,500 kg in the liquid state.

The energy required to deliver the gas is part of the production costs. Parasitic energy losses reduce the amount of available energy. Hydrogen transport by pipelines has to compete with electricity transport by wires.

Design and construction of large, long-distance, high pressure gaseous hydrogen pipelines and conventional natural gas (NG) transmission lines are similar. Four technological aspects differentiate the gaseous hydrogen (GH_2) line from the NG line and need to be addressed for the concept to be attractive to industry

1. The volumetric energy density of hydrogen is one third of that of methane,
2. High pipeline utilization is critical for economic feasibility,
3. Hydrogen embrittlement of pipeline steel must be prevented and controlled,
4. Compression is very costly.

Most of the analyses show that pipelining GH_2 costs approximately 1.3 to 1.8 times more per unit energy-distance than NG, because of these four factors. Pipelines are very expensive to design and construct, which is why they must have high utilization to justify the initial capital cost.

CONCLUSIONS

This paper is devoted to study of a new concept of using hydrogen for compensating the instability of wind power production. This concept has been considered in three main stages:

1. Hydrogen production stage allows excess energy of a wind power plant to be stored,
2. Hydrogen storage technologies, safety, automation and transportation system have to be developed in the future,
3. At moments when wind is low or absent the stage of electricity production allows wind power operation to be stabilized. Because all of the components of hydrogen buffer require DC power supply, interface converters were implemented.

In terms of ecology, the proposed method provides perspectives of significant decrease in fossil fuel extraction and accompanying environmental pollution.

3. "Solar Roadways" – Rebuilding our Infrastructure and Economy – L.BAYA REDDY

ABSTRACT

The Solar Roadway is a series of structurally-engineered solar panels that are driven upon. The idea is to replace all current petroleum-based asphalt roads, parking lots, and driveways with Solar Road Panels that collect energy to be used by our homes and businesses. The renewable energy generated by solar road panels will replace the current need for fossil fuel which is used for generation of electricity as also oil used for driving the vehicles which in turn reduces the greenhouse gases nearly to half. The implementation of Solar Roadways Technology will create the clean energy boom, spurring private investment on a massive scale, with relatively little extra cost. An intelligent highway infrastructure and a self-healing decentralized power grid that will eliminate our need for fossil fuels. Solar Roadways will also features wildlife preservation, the elimination of impervious surfaces, law enforcement, DUI detection, counter-terrorism, etc. It provides a decentralized, secure, intelligent, self-healing power grid which pays for itself. So it's time to upgrade our infrastructure (especially roads & power grids) with the 21st century technology i.e. "Solar Roadways".

Keywords: - Electric Vehicles, Fossil Fuel, Intelligent Roads, Smart Gird, Solar Panels, Solar Roadways.

INTRODUCTION

Hearing the concerns about global warming and knowing our dependency on fossil fuels the solar roadways imagined to develop roadways with solar panels. This innovation is begun in early 2009 and later the company was established by name Solar Roadways in U.S. and awarded a contract by federal government.

The Solar Roadway is a series of structurally-engineered solar panels that are driven upon. The idea is to replace all current petroleum-based asphalt roads, parking lots, and driveways with Solar Road Panels that collect energy to be used by our homes and businesses. . The ultimate goal is to store excess energy in or along-side the Solar Roadways. This renewable energy replaces the need for the current fossil fuels used for the generation of electricity. This, in turn, reduces the greenhouse gases to half. Solar Roadways is proposing a long-view paradigm-shift solution to major infrastructure, energy and climate challenges. The Solar Roadways system would might, at present, cost about three times what it costs to install an asphalt road, but would be more durable more easily replaced in modular fashion, and able to pay for itself by generating more electricity than our economy can consume. At just 15% efficiency, far below what is expected, a 100% Solar Roadways enabled driving infrastructure would produce three times total electricity demand. There are additional benefits as well, which is a built-in smart grid, major new investment and job creation, the economic benefits inherent in global leadership in building the most advanced clean energy infrastructure every dollar invested in renewable sources, ultimately generates returns, because the resource is not burned and lost. The roadways can also communicate with drivers, alerting drivers with visual messages to the presence of pedestrians in a crosswalk.

Asphalt works, in many ways, and is convenient to lay-down, compared to other methods. It has carried our automotive infrastructure into the 21st century. But there are hidden costs that are making it increasingly difficult and expensive to continue favoring asphalt as the predominant road-paving model for the entire nation. That’s why asphalt is not ideal for road construction.

Solar Roadways can pay dividends for the public budget, making our spending on infrastructure more efficient and significantly reducing electricity costs to consumers and businesses. They can make the emerging electric vehicle economy far more affordable, and easier to manage. They can help us eliminate hundreds of billions of dollars per year, or more, in externalized costs of burning fossil fuels. And, we can lead the world in powerful clean energy technology exports, capable of rolling back massive pollution and greenhouse gas emissions. Perhaps the most important element of the Solar Roadways technology is that its power-generation capacity demonstrates the base load viability of renewable energy sources. Clean energy technology existence can power the entire countries economy, and more. But the required is commitment to major investment and incentives in building the infrastructure. If up-gradation is done with this technology, we can create jobs, and a clean energy boom, spurring private investment on a massive scale, with relatively little extra cost.

Solar power sources are rapidly becoming cheaper and more ephemeral, making it feasible to talk about solar PV becoming the leading cost-reducing trend in the energy sector. Clean energy jobs are also expanding rapidly and have still more potential for major long-term growth. They are paying significantly higher wages than the national average, and are built into local economies. Solar Roadways is one way to capitalize on and expand this trend, and shows how quickly we can make the shift to an economy rooted in abundant, domestic, clean energy resources.

SOLAR ROADWAYS

The Solar Roadways consists of structurally engineered solar panels that we drive on. Each Solar Road Panel (roughly 12’ by 12’) interlinks with neighboring panels to form the Solar Roadways system. The Solar Roadway replaces our crumbling petroleum-based asphalt highway infrastructure with an intelligent road that pays for itself through the generation of electricity. The Solar Roadway generates electrical power from the sun and becomes our nations decentralized, intelligent, self-healing power grid, replacing our current deteriorating power distribution infrastructure.

The Solar Roadway distributes its electrical power to all businesses and homes connected to the system via their parking lots and driveways (made up of Solar Road Panels). In addition to electrical power, data signals (cable TV, high-speed internet, telephone, etc.) also travel through the Solar Roadways, which acts as a conduit for these signals (cables). This feature eliminates the unsightly power lines, utility poles, and relay stations we see all over the countryside. It also eliminates power interruption caused by fallen or broken electrical lines or poles. Each Solar Road Panel uses some of its own power to light up embedded LEDs, which “paint” the road lines from beneath the road surface. This feature also allows messages to be spelled out on the road surface, such as “SLOW DOWN”, or “ACCIDENT AHEAD”. Road lines can be instantly “repainted” to direct traffic to a single lane or to detour. This eliminates the need for cones or flares. Better visibility at night with the road lines illuminated, it will be like driving on a well-lit runway.

The Solar Road Panels heat themselves for snow and ice removal in northern climates. No more need for snow removal or school/business cancellations. These safer driving conditions (roads lit at night, no snow/ice, etc.) will prevent many accidents and allow for reduced insurance rates – both health and automotive. All additional power (unused by the panels themselves) is sent “down line” to homes and businesses. We could produce three times the total electrical power used by the country and almost enough electricity to power the entire world. No more power outages, roaming or otherwise. The Solar Roadway produces clean, renewable energy. No pollution, no greenhouse gases, no by-products, and the Solar Road Panels are completely recyclable or reusable. The main cause of global warming is creation of electricity by fossil fuels which will contribute to production of green house gases and effect on ozone layer. The Solar Roadways eliminates this (half of the cause of Global Warming) entirely.

The Solar Roadway, being an “electric road”, will also make all-electric vehicles more practical; recharging stations can be placed in all parking lots and rest stops. This will allow the all-electric vehicles to have the same driving range of current internal combustion gasoline- or diesel-powered vehicles. Elimination of internal combustion engines, which would now be feasible with the Solar Roadways, would wipe out most of the rest of the causes of greenhouse gases. There are many other features, including wildlife preservation, the elimination of impervious surfaces, law enforcement, DUI detection, counter-terrorism, etc. An intelligent highway infrastructure and a self-healing decentralized power grid that will eliminate our need for fossil fuels and also it will lead to less invest in antiquated technology viz asphalt and overhead power lines. As the day by day the price of petroleum products are getting huge hike & resources are very less there will be no longer feasible material such as asphalt for our road surfaces. When Solar Road Panels are refurnished, the solar cells will be upgraded to newest technology, which will allow keeping up with population growth and increased energy needs. Also if such technology is furnished in any of the country; the country will require approximately five billion solar road panels for covering roads, parking lots, drive ways etc. & also such technology will create millions of “Green color” jobs.

The solar Roadways can save the wonderful countries in the world. The day by day the human beings are looking for the answers to our deteriorating highway infrastructure, our crumbling power grid, and the climate crisis. For all such questions the answer is “SOLAR ROADWAYS".

SOLAR PANELS

The solar panels are divided into three basic layers:-

1. Road Surface Layer.
2. Electronics Layer.
3. Base Plate Layer.

3.1 Road Surface Layer

As this is the top most layers of the assembly & also from this layer the solar rays will reach up-to the photovoltaic cells; they should be translucent and high-strength. Also this is made in such a fashion that it is rough enough to provide great traction to avoid the skidding of vehicles. As the material is made rough but the material used is translucent, it still passes sunlight through it to the solar collector photovoltaic cells embedded within it, along with LEDs and a heating element. And it is tough enough for handling today's heaviest loads under the worst conditions and it is made water-proof so that it can prevent electronics layer beneath it.

3.2 Electronics Layer

Electronics Layer Contains a microprocessor board with support circuitry for sensing loads on the surface and controlling a heating element. By implementing this technology no more snow/ice removal and no more school/business closings due to inclement weather in the snow falling regions. The on-board microprocessor controls lighting, communications, monitoring, etc. which are fitted at every 12 feet distance; which can prove the Solar Roadways as an “Intelligent Highway System”.

3.3 Base Plate Layer

While the electronics layer collects energy from the sun, it is the base plate layer that distributes power (collected from the electronics layer) and data signals (phone, TV, internet, etc.) "down-line" to all homes and businesses connected to the Solar Roadway. The base layer is made weatherproof so that it can provide the electronic layer above it.

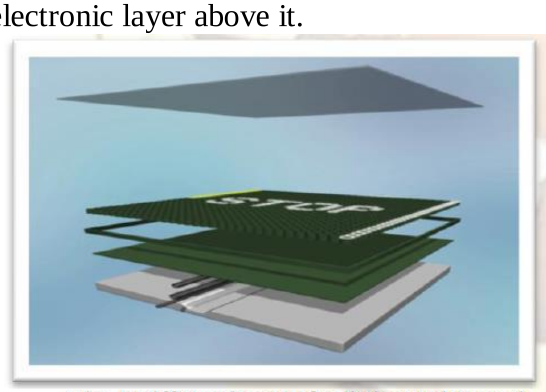
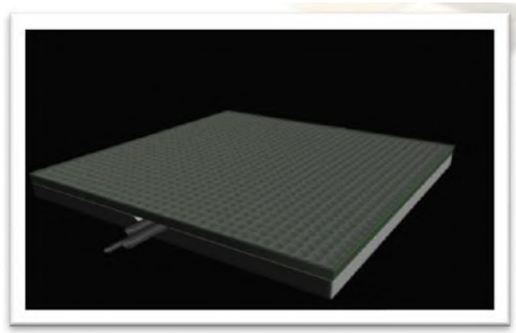


Fig: 1 Different layers of a distinct Solar panel



INTELLIGENT HIGHWAY

Every country tries to barely keeping up with the costs of maintaining the roads and bridges as it is, and the cost of construction materials is skyrocketing. New materials and technologies have to be found to replace these current archaic systems. The Solar Roadway is an intelligent road system that provides clean renewable energy, while providing safer driving conditions, along with power and data delivery. The Solar Roadway will pay for itself through the generation of electricity along with other forms of revenue. The same money that is being used to build and resurface current roads can be used to build the Solar Roadways. Then, since coal-fired and nuclear power plants will no longer be needed, the costs of all electricity generation plants can also be rolled back into the Solar Roadways.

A steady rise in congestion and ongoing deterioration of decades-old roads and bridges, funding agency of government is failing to keep up with the need to maintain existing infrastructure and increase capacity. And the cash shortfall is only going to get worse. There is a much better way. Imagine a highway infrastructure that relieves the financial obligations of funding agency of government and instead pays for itself. The Solar Roadways will generate electricity – approximately up to three times more than the entire country currently uses. The electricity generated pays for the Solar Roadways. Additional revenue can be acquired by leasing the conduit within the Solar Roadways to service providers such as the telephone, cable TV, and high-speed internet industries. If United States of America is considered; the nation's highway transportation system includes 3.8 million miles of roadways and 582,000 bridges. Significantly, the highway system supports 86 percent of all citizens' personal travel, moves 80 percent of the nation's freight (based on value), and serves as a key component in national defense mobility. Despite widespread redundancies, there are critical junctures with limited capacity for additional traffic. Freight volume is projected to double by 2020, stretching ability to manage limited capacity and growing security concerns.

"Security concerns" includes terrorism. We've all seen the news reports about suicide bombers boarding crowded buses and detonating themselves. Vehicles such as fuel trucks are also potential targets. Currently, it's difficult to track these vehicles, other than by radio. The Solar Roadways form a wide area network, with each individual Solar Road Panel containing a microprocessor board with its own address. Think of the Solar Roadways as the internet, with each individual Solar Road Panel acting as an online computer. If we place RFID (Radio Frequency Identification) tags on high-risk vehicles that we want to track, the Solar Roadways would track them in real time and we'd always know exactly where they were at all times.

ILLUMINATED ROADS

Accidents drastically reduced unlike the dark roads we drive on by night today, the Solar Roadways will have LEDs which will "paint" the lanes, and can be instantly customized as needed. Many people face the problem during the night driving as they face the trouble seeing the road lines at night, particularly when the oncoming headlights are blinding them or when it's raining. By implementation of these illuminated roads, the country can over come from this problem & also accidents at night time will get reduced henceforth the night-time driving will be safer for all.

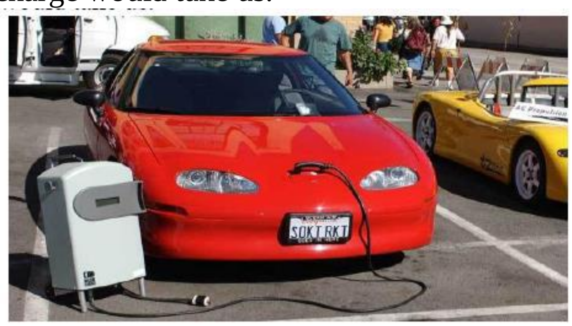
A recent study shows that the solar-road studs to light-up the lines of roads during night time in an area of England, which has reduced night time accidents by 70%.There is no need to expend energy lighting desolate roads when no cars are traveling, so the intelligent roadways will tell the LEDs to light up only when it senses cars on its surface - say 1/2 mile ahead and 1/4 mile behind the vehicle as it travels. This way, drivers will know an oncoming car is ahead when they see the lights on the other side of the road begin to light up ahead. The LEDs can also be programmed to move along with cars at the speed limit and it gives warning to the drivers instantly when they are driving too fast or the speed of the car increases beyond the speed limit. The LEDs will also be used to paint words right into the road; it gives warning to drivers if an animal arrives on the road, a detour ahead, an accident, or construction work. Central control stations will be able to instantly customize the lines and words in real time, alleviating traffic congestion and making the roads more efficient as well as safer.

Fig: 3 Illuminated Highway at Night

ELECTRIC VEHICLES

Electric cars have actually been around for a long time. They've just never been very practical, due to the fact that they have to be recharged and there has never been an infrastructure for that. The Solar Roadways allow electric cars to recharge at any rest stop or business places that have a parking lots made up of Solar Road Panels. Drivers can recharge their vehicles while eating at a restaurant or shopping at a mall.

Electric vehicles (EVs) are on their way. More and more car manufacturers are offering electric vehicle options. It's a good thing too. Roughly 25% of greenhouse gases come from the exhaust pipes of internal combustion engine vehicles, which we've been using for well over 100 years. As wonderful as they are, electric vehicles have a major problem, due to their relatively short range (generally less than 180 miles) they have to be recharged regularly, typically at the owner's home. This means that they would be fit for running to the local grocery store and back, but it wouldn't be feasible to take a cross country trip. Basically, with EVs we can just go as far as our EVs initial charge would take us.



6.1 How are EVs charged currently?

Fig: 5 Currently the electric vehicles are charged from electricity produced from power plants

The scientific survey in America says (as per July 2010) that the EVs are not ecological in many areas due to less supply or restricted supply of electricity to the areas. A true accounting of the environmental consequences of these cars would have to include the emissions of the power plants that supply their energy. When Department of energy researchers carried out such an analysis, they found that the results are very considerable with geography. By dividing the country into different regions as per the power sources within each region - generally, a combination of coal, natural gas and nuclear energy, with a smattering of renewable energy thrown in. And check how a new fleet of electric cars would alter that supply. Nuclear and renewable, which together account for less than a quarter of the electricity supply, are "always on" sources. Their energy gets used up quickly for routine tasks, leaving little to no green energy left over to help charge a burgeoning fleet of electric vehicles. In practical terms, this means that even if you live down the street from wind farm, its energy is already spoken for before you plug-in your plug. With nuclear and renewable taken out of the equation, it can be concluded that power for the fleets will have to come primarily from coal and natural gas. If you live in a place where natural gas is dominant, electric vehicles will reduce carbon dioxide emissions - in some cases by as much as 40 percent below that of an ordinary hybrid. In regions powered mostly by coal - a much dirtier fuel - electric vehicles will lead to an increase in the amount of carbon dioxide released into the atmosphere. The zero-emission tour may have ended this spring, but the controversy over what zero really means is just getting under way. Since the Solar Roadway creates and carries clean renewable electricity, EVs can be recharged at any conveniently located rest stop, or at any business places that incorporates Solar Roadways Panels in their parking lots (restaurants for instance). Owners can plug-in their cars in and recharge while they're eating or shopping. Engineers are even investigating ways to use mutual induction to charge EVs while they are driving down the Solar Roadway! By the way using electric cars would eliminate most of the other half of the cause of global warming and could virtually wean the world off oil entirely. For instance, let's say an EV leaves California and embarks on a road trip to Florida. Let's say the all-electric vehicle gets 180 miles on a single charge. That's about three hours worth of driving on the interstate. By then, most drivers would be about ready for a bathroom break or a snack. They could find a restaurant that incorporates Solar Road Panels in its parking lot. They pull into a parking space, plug their car into the "hitching post", and go inside. By the time the driver/passengers are refreshed their car is recharged and ready to go. They could do the same thing at a rest stop or a shopping mall.

Businesses replacing coal power with solar power. Drivers/car owners replacing their internal combustion engine vehicles with all-electric vehicles, charged by renewable energy. And this will be the beginning of the end of our dependency upon fossil fuels.

SMART GIRD

Our current power grid is based on centralized power stations. Distribution of power is handled through transmission lines (overhead and underground), relay stations, and transformers. When a line goes down (ice, lighting, wind, tress, utility pole hit by car, etc.), everyone on the wrong end of the line loses power until the damage is repaired. If a power station goes down, an entire section of the country goes dark. The Solar Roadways on the other hand, replaces all current centralized power stations including coal and nuclear-powered electricity generation plants. With the Solar Roadway, the road becomes the power grid, eliminating the need for unsightly utility poles and relay stations. Power is generated everywhere - every road, parking lot, and driveway. No more power outages, roaming or otherwise.

The Solar Roadways generates "secure" energy; it can't be deliberately shut down. Not by terrorists, not by power companies, it simply can't be shut down.

The grid is wondrous. And yet - in part because we've paid so little attention to it, as we are in 21st century the grid are becoming old & out dated. It’s reliable but not reliable enough, especially in the developed countries & for countries whose population is reached up-to saturation level. Blackouts & power outs costs loss of billions of dollars to such countries so it needs to become more reliable, the rid needs dramatic upgrading to handle a different kind of power, such as transmission of wind power and solar power from remote places to big cities through transmission lines. Most important, the grid must get smarter. The precise definition of "smart" varies from one engineer to the next. The gist is that a smart grid would be more automated and more "self-healing," and so less prone to failures. It would be more tolerant of small-scale, variable power sources such as solar panels and wind turbines, in part because it would even out fluctuations by storing energy.

Let’s consider country like America; in this country more than 150,000 miles of high-voltage transmission lines carry power from 5,400 generating plants owned by more than 3,000 utilities. Most of those lines carry alternating current (AC), but 1.9 percent of them carry direct current (DC), which loses less power over very long distances. The grid works 99.97 percent of the time - but power interruptions still cost the American economy about $80 billion each year. Moreover, our electricity is anything but clean. Most of it comes from burning fossil fuels, about half of it from coal. Hydroelectric, wind and solar power account for less than 8 percent.

“If we don’t expand our capacity to keep up with an increase in demand of 40 percent over the next 25 years, we’re going to see healthy grids become increasingly less reliable.” Demand for electricity has increased steadily for decades, yet transmission lines that transport power from generation plants to customers have not been added or upgraded at the same pace.

Even if transmission capacity is increased, blackouts will still occur. The entire power grid has to be refurnished, because the existing control technology – the key to quickly sensing a small line failure or the possibility of a large instability – is antiquated. To remain reliable, the grid will have to operate more like a fighter plane, flown in large part by autonomous systems that human controllers can take over if needed to avert disaster. Using networking technology to monitor - and react to - what’s happening in the grid at each moment can improve efficiency and prevent outages.

We still seem to thinking inside the box; the solution should not be to continue repairing an antiquated system of centralized power stations and distribution methods. Change is hard, but the engine and transmission are like using 40-year-old car, so as the vehicle is to be replaced with new vehicle the transmission is also to be replaced. Decentralizing the production of electricity can make the grid more resilient and save some of the current while when it flows through long-distance transmission lines to the nation’s households. The Solar Roadway is completely decentralized. Every Solar Road Panel can generate and pass electricity "down-line" to homes and businesses. No loss to heat, no carbon footprint, and no spent fuel rods. A self-healing smart grid can best be built if its architects try to fulfill three primary objectives. The most fundamental is real-time monitoring and reaction. An array of sensors would monitor electrical parameters such as voltage and current, as well as the condition of critical components. These measurements would enable the system to constantly tune itself to an optimal state.

Each Solar Road Panel measures 12 feet (about 4 meters) by 12 feet and contains a microprocessor board for control, monitoring, and communications. It means that you have a microprocessor (a small computer) located every 12 feet in your power grid. It monitors everything that takes place within its 12 feet perimeter. It tracks voltage and current that it generates, uses, sends to or receives from neighboring Solar Road Panels, etc. The second goal is anticipation. The system must constantly look for potential problems that could trigger larger disturbances. With a microprocessor located every 12 feet, we'll know when a problem first presents itself. Each of the neighboring (physically connected) Solar Road Panels communicate with each other. If one of them stops communicating, then something is wrong (panel is damaged from lighting strike, overturned truck, etc.). Neighboring panels will still be able to communicate & can send the information to a central control station. For example, let's say lighting strikes the road and does some significant damage; a hole is blown clean through a Solar Road Panel in the middle of an eight-lane highway. Let's go even deeper and say that a path to ground has been created and massive amounts of current attempt to drain through the damaged panel. Each side of each Solar Road Panel is equipped with a GFI (Ground Fault Interrupter), which would shut off as soon as a current surge was detected by the microprocessors in the undamaged neighboring panels. The lightning damaged panel would be electrically isolated and the surrounding panels could toggle the LEDs bordering the damaged panel. This would "paint" a square around the damaged panel to warn drivers of the danger. Oncoming drivers would be warned of the brief detour. No power outage. Not even a disruption of services to any electrical customers.

The third objective is isolation. If failures were to occur, the whole network would break into isolated “islands,” each of which must fend for itself. Each island would reorganize its power plants and transmission flows as best it could.

This objective isn't necessary with the Solar Roadway, albeit certainly possible. The roadway is the power plant and the transmission line. If a tanker truck blows up and severs a road completely in half, no power is lost anywhere (except for the damaged panels). Electricity will just go around on a different road, in the same manner that a vehicle would during a detour. Again, the undamaged neighboring panels would disconnect from the damaged panels and call the problem in.

A self-healing transmission system would minimize the impact of any kind of terrorist attempt to “take out” the power grid. The Solar Roadways can't be "taken out" - not by terrorists, not by utility companies, not by anyone. It provides a decentralized, secure, intelligent, self-healing power grid.

ADVANTAGES & DISADVANTAGES

9.1 Advantages

9.1.1. Renewability and life-span

The main advantage of the Solar Roadway concept is that it utilizes a renewable source of energy to produce electricity. It has the potential to reduce our dependence on conventional sources of energy such as coal, petroleum and other fossil fuels. Also, the life span of the solar panels is around 30-40 years, much greater than normal asphalt roads, which only last 7-12 years.

9.1.2. No requirements to develop environmentally sensitive lands

Another advantage of the Solar Roadway is that it does not require the development of unused and potentially environmentally sensitive lands. This is currently a very controversial issue with large photovoltaic installations in the Southwestern US and other places. But since the roads are already there, this is not an issue. Also, unlike large photovoltaic installations, new transmission corridors -across environmentally sensitive land- would not be required to bring power to consumers in urban areas. Transmission lines could simply be run along already established roadways.

9.1.3. On-the-go charging

With induction plating embedded inside these roads, all electric cars can be recharged while in motion on top of these roads. This would reduce the costs and the time-inconvenience to wait at a charging station.

9.2. Disadvantages

In spite of these advantages, initially, the start up and maintenance costs of building such roadways and parking lots may be extremely high. (However, advances in this technology will (hopefully) cause the costs to fall.) Another issue to deal with is the efficiency of solar panels. The average efficiency is currently a matter of concern. Another disadvantage is that it cannot be constructed in the poorest developing nations due to the high initial start-up costs. Road surfaces also accumulate rubber, salt, etc., which block sunlight. Salt might be easy to wash off, but not rubber. It would also be quite costly. Solar roadways may not be feasible and economical as it initial and installation cost may be three times more compared to our convectional roads, but if this is evaluated as a long term investment this may prove to be much more economical as it pays us back.

CONCLUSION

We can't wait any longer to find a replacement for oil, which is rapidly disappearing. Our dependency on oil has long been a matter of national security and we don't want to wait until it's gone to decide what to do next. We have the technology to solve this problem in a relatively short period of time, which may be all we have left. In developing counties the major part of the geographical area is to be explored in terms of road connectivity. So instead of implementing the higher targets roads to be developed per day such countries can reduce the target and develop solar road so they could improve economy with infrastructure.

Generally the Solar Roadways will:-

1. Create an intelligent, secure highway infrastructure that pays for itself.
2. Create an intelligent, secure, decentralized, self-healing power grid.
3. Eliminate the need for coal-fired or nuclear power plants.
4. End our dependency on oil and other fossil fuels (oil, coal and natural gas).
5. Cut our nation’s greenhouse gas emissions by over 50%.
6. Provide safer driving conditions.
7. Snow & ice management
8. Traffic management
9. Wild life protection
10. National security
11. Usage of recycled material

4. Most Common Critical Power Distribution Topologies - A.Sanjeevu

Abstract

In many of today's mission-critical applications, ever-increasing reliability requirements are the norm. A critical part of this reliability is **the reliability of the electric power distribution system** for a given facility.Among the most demanding applications is that of a data center, where the enduse equipment cannot tolerate even a momentary power outage and, further, even relatively minor disturbances in the power system can cause computer systems to re-boot, causing operational down-time. **A full-scale utility failure**, lasting for minutes or even hours, is therefore **not tolerable** for these types of systems. In fact, even the approximately10 seconds of outage required for transfer of the system to generator power is not an option in these types of systems, a concept that will be explored in greater depth below.

Key Words – Distribution System,Topologies Electrical power ,Reliability.

I.INTRODUCTION

ISTRIBUTED SYSTEMS APPEARED relatively recently in the brief history of computer systems. Several factors contributed to this. Computers got smaller and cheaper: we can fit more of them in a given space and we can afford to do so. Tens to thousands can fit in a box whereas in the past only one would fit in a good-sized room. Their price often ranges from less than ten to a few thousand dollars instead of several million dollars.More importantly, computers are faster. Network communication takes computational effort. A slower computer would spend a greater fraction of its time working on communicating rather than working on the user's program. Couple this with past CPU performance and cost and networking just wasn't viable. Finally, interconnect technologies have advanced to the point where it is very easy and inexpensive to connect computers together. Over local area networks, we can expect connectivity in the range of tens of Mbits/sec to a Gbit/sec. Tanenbaum defines a distributed system as a "*collection of independent computers that appear to the users of the system as a single computer*." There are two essential points in this definition. The first is the use of the word *independent*. This means that, architecturally, the machines are capable of operating independently. The second point is that the software enables this set of connected machines to appear as a *single computer* to the users of the system. This is known as the **single system image** and is a major goal in designing distributed systems that are easy to maintain and operate.

Why build them?

Just because it is easy and inexpensive to connect multiple computers together does not necessarily mean that it is a good idea to do so. There are genuine benefits in building distributed systems:
Price/performance ratio. You don't get twice the performance for twice the price in buying computers. Processors are only so fast and the price/performance curve becomes nonlinear and steep very quickly. With multiple CPUs, we can get (almost) double the performance for double the money (as long as we can figure out how to keep the processors busy and the overhead negligible). Distributing machines may make sense. It makes sense to put the CPUs for ATM cash machines at the source, each networked with the bank. Each bank can have one or

II.DIFFERENT TOPOLOGIES IN DISTRIBUTION SYSTEM

A distributed system has distinct advantages over a set of non-networked smaller computers. Data can be shared dynamically – giving private copies (via floppy disk, for example) does not work if the data is changing. Peripherals can also be shared.

Some peripherals are expensive and/or infrequently used so it is not justifiable to give each PC a peripheral.

1. Secondary-Selective 'Main-Tie-Main' Arrangement

In the context of automatic transfers, the most common arrangement is **the secondary selective** or **"main-tie-main" arrangement**. One implementation of this arrangement is as shown in Figure 1

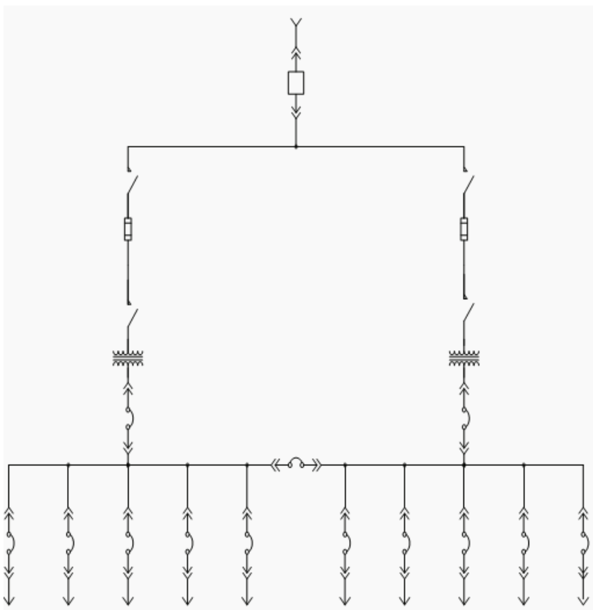


Figure 1 – Secondary-Selective 'Main-Tie-Main' Arrangement

In this arrangement, there are two busses, each of which serves **approximately 50% of the load**, but is sized to carry the entire load. In Figure 1, this means that each transformer, secondary main circuit breaker, and secondary equipment bus is sized to carry the entire load.

2. Main-Tie-Main' topology

There are many variations on previous arrangement. In critical-power applications the most common variation is to use **two bus tie circuit breakers**, and have the two secondary busses separated into two different pieces of equipment. Another variation is the main-main arrangement, which omits the bus tie circuit breaker and simply has the two secondary busses connected all the time.

In this arrangement, one power source normally carriesthe entire load, and the other is strictly a standby power source should the normal source fail. In this way the main-main arrangement is analogous to an **automatic transfer switch (ATS)**.***Both of these variations are shown in Figure 2.***

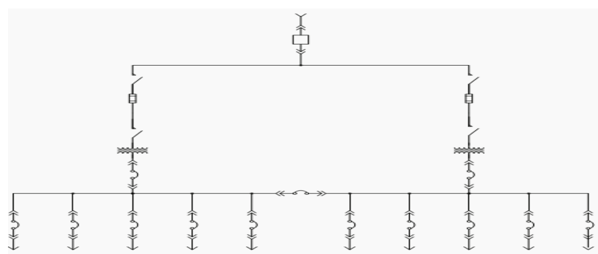
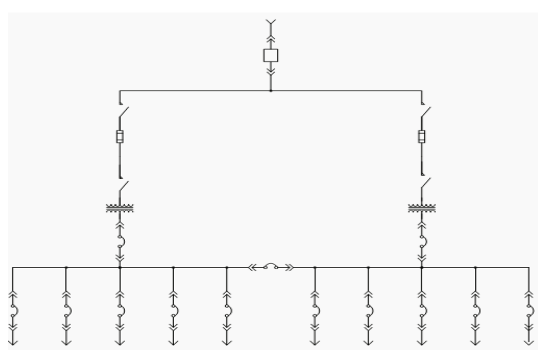


Figure 2 – Variations on the 'Main-Tie-Main' topology a.) 'Main-Tie-Tie-Main' b.) 'Main-Main'

Other arrangements exist, however none are as popular in the critical-power distribution environment as the secondary-selective "main-tie-main" and its variants.



Most Common Critical Power Distribution Topologies (photo credit: crown-electric.com)

Today's mission-critical applications

In many of today's mission-critical applications, ever-increasing reliability requirements are the norm. A critical part of this reliability is **the reliability of the electric power distribution system** for a given facility.

Among the most demanding applications is that of a data center, where the enduse equipment cannot tolerate even a momentary power outage and, further, even relatively minor disturbances in the power system can cause computer systems to re-boot, causing operational down-time.

A full-scale utility failure, lasting for minutes or even hours, is therefore **not tolerable** for these types of systems. In fact, even the approximately10 seconds of outage required for transfer of the system to generator power is not an option in these types of systems, a concept that will be explored in greater depth below.

That no power system component can operate with 100% reliability is a well-known fact. Another fact is that the availability of utility power is **less than 100%** (typically 99-99.9%).

Therefore, the possibility of utility power and internal system component failure must be taken into account in the system design.

Topologies

The choice of power system distribution topology is the first line of defense against critical-load outages.

1. Secondary-Selective 'Main-Tie-Main' Arrangement
2. Main-Tie-Main' topology
3. Ring Bus Arrangement
4. Primary Loop Arrangement
5. Composite Primary Loop/Secondary Selective Arrangement

1. Secondary-Selective 'Main-Tie-Main' Arrangement

In the context of automatic transfers, the most common arrangement is **the secondary selective** or **"main-tie-main" arrangement**. One implementation of this arrangement is as shown in Figure 1:

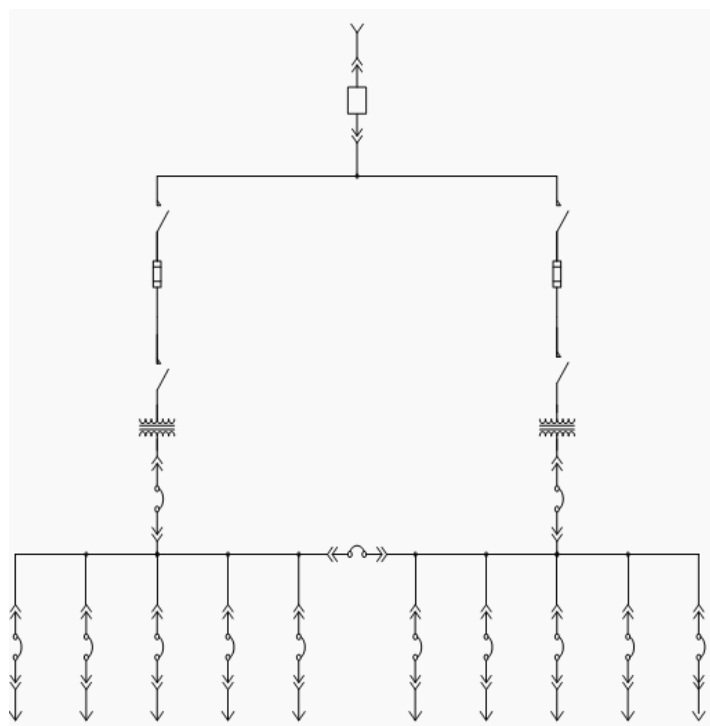


Figure 1 – Secondary-Selective 'Main-Tie-Main' Arrangement

In this arrangement, there are two busses, each of which serves **approximately 50% of the load**, but is sized to carry the entire load. In Figure 1, this means that each transformer, secondary main circuit breaker, and secondary equipment bus is sized to carry the entire load.

Should a transformer fail, the entire load may be transferred to the other transformer and its associated secondary bus via the bus tie circuit breaker.

2. Main-Tie-Main' topology

There are many variations on previous arrangement. In critical-power applications the most common variation is to use **two bus tie circuit breakers**, and have the two secondary busses separated into two different pieces of equipment. Another variation is the main-main arrangement, which omits the bus tie circuit breaker and simply has the two secondary busses connected all the time.

In this arrangement, one power source normally carriesthe entire load, and the other is strictly a standby power source should the normal source fail. In this way the main-main arrangement is analogous to an **automatic transfer switch (ATS)**.

Both of these variations are shown in Figure 2.

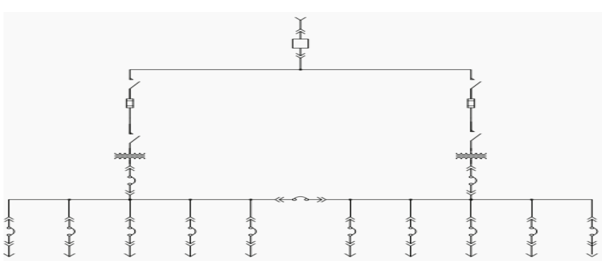


Figure 2 – Variations on the 'Main-Tie-Main' topology a.) 'Main-Tie-Tie-Main' b.) 'Main-Main'

Other arrangements exist, however none are as popular in the critical-power distribution environment as the secondary-selective "main-tie-main" and its variants.It should be noted that the main-tie-main topology is also commonly used at the medium-voltage level.

3. Ring Bus Arrangement

One other arrangement, however, has been used with great success is the **ring bus**, as illustrated in Figure 3:

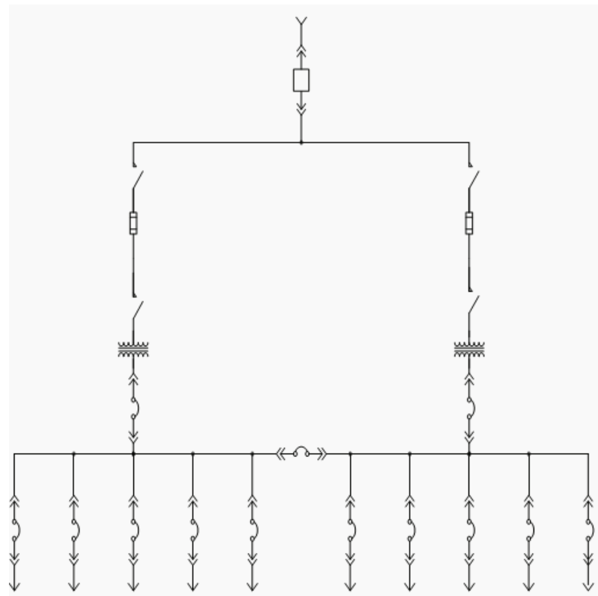


Figure 3 – Ring Bus Arrangement

The ring bus arrangement allows the flexibility of supplying multiple loads using multiple busses. It is most often used at the medium-voltage level, and usually in a "closed loop" arrangement with all of the bus tie circuit breakers closed.

4. Primary Loop Arrangement

A variation on the ring-bus is **the primary loop arrangement** shown in Figure 4:

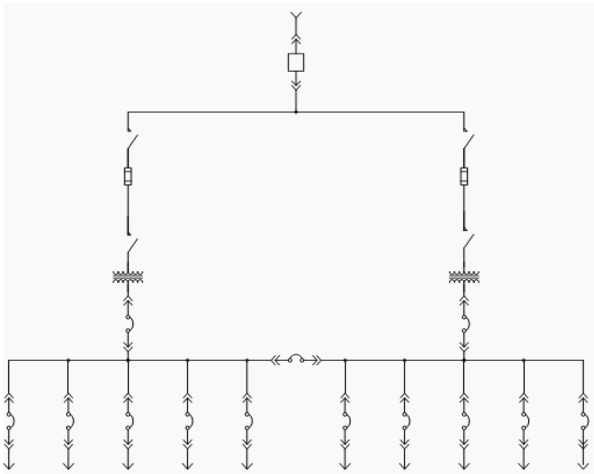


Figure 4 – Primary Loop Arrangement

A primary loop arrangement typically uses load-interrupter switches for switching on the loop, and is more economically justifiable than a full ring-bus system. Typically, the loop is operated in an **"open-loop" arrangement**, but still gives the ability to supply all loads from either side of the loop.

5. Composite Primary Loop/Secondary Selective Arrangement

Extreme flexibility and increased reliability are obtained **by combining topologies**. An example of this is the composite primary loop/secondary-selective arrangement shown in Figure 5.

Here, multiple failure contingencies are addressed ina generally economically-feasible manner.

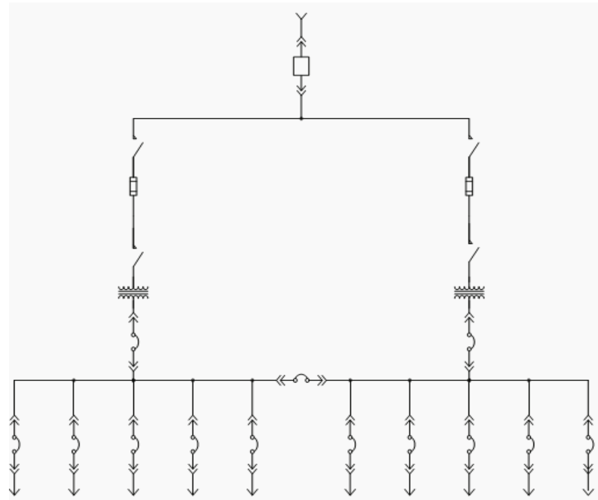


Figure 5 – Composite Primary Loop/Secondary Selective Arrangement

CONCLUSION

The most common distributed systems today are those with loosely-coupled software and loosely coupled hardware. The quintessential example is that of workstations (each with its own CPU and operating system) on a LAN. Interaction is often primitive explicit interaction, with programs such as *rcp* and *rlogin*. File servers may also be present, which accept requests for files and provide the data. There is a high degree of autonomy and few system-wide requirements.

Try not to become a man of success, but rather try to become a man of value-Albert Einstein