Hydro Power – Mini & Many

By

K.V.RUPCHAND

SMIEEE

Chief Engineer/ Civil Designs Tamil Nadu Electricity Board, India (Retd.)
Immediate Past Secretary General/Indian Concrete Institute
Chair, Technology Management Council/IEEE
Chair, Power & Energy Society/IEEE

Ph.: 91-94440 10339; kvrupchand@dataone.in

Presentation @ UTM International Centre, Kuala Lumpur
22, November 2011

IEEE PES Power & Energy Society

IEEE

Future Scenario

- **Global** : Technologies: Order of importance (Spectrum Jan 2003)
  - (1) **Energy Development**
  - (2) Fight against Terrorism
  - (3) Environmental Protection
  - (4) Waste Disposal
  - (5) Transportation
  - (6) Technological Literacy
  - (7) Digital Divide
  - (8) Intellectual Property Protection
- **Indian** : Food, Clothing & Shelter
  Water, Power, Transport, Communication
  Manufacturing, Service, Retail
- Engineering education : Core *vs* Circuit branch
- Teaching & Research

Relevance to Energy Areas

1. Distributed power generation
2. Electric vehicles
3. Electricity
4. Energy storage
5. Hydroelectric power generation
6. Real time systems
7. Rivers
8. Smart grids
9. Transmission lines
10. Transportation

Abstract

1. Power Scenario
2. Environmental Issues
3. Hydro Power in India
4. Mini Hydros
5. Mega Hydros
6. Impact due to Electric Vehicles
7. Future of Hydro Power
8. Indian River Grid
9. Three Gorges Project
10. Hydro Rebound

Technological Relevance

- Impact on Humanity
- Needs of mankind
- Social uplift vis-à-vis technological application
- Index of progress
- GDP per capita
- Purchasing power
- Power consumption as an index of development ?
- Developed countries: ~ 6000 kwh per capita
- India: < 500 ?
- Hence, electrical power is a key factor

Power Education

- Curriculum/syllabus
- Planning
- Generation ←
- Transmission
- Distribution
- Controls
- Instrumentation
- Grid operation
- Power electronics

Power Generation – Types

- Hydel
- Thermal
- Oil
- Gas
- Wind
- Atomic
- Solar
- Merits/Demerits
- Ideal 'Mix' for reliability of Grid

Environmental Issues

- Pollution (Hydro also !)
- Green House Gas emissions
- Kyoto Protocol to reduce emissions
- Revival of Atomic
- Licensing the Plants: retired reckoning impact on environmental issues
- Project displacement
- **Global warming**
- Sea rise due to tectonic activity ?
- Green Power → Carbon Credit Pollution (Hydro also !)

CO_2 Emissions – Factors

- Coal-fired thermal station: 0.75 kg/unit (kwh)
- CO_2 emission: 0.85 kg/unit
- + other gases, SO_2 & NO_x
- All emissions lead to **'Global Warming'**
- Global Climate Change → Dominant Environmental business
- Mandatory 'Carbon Caps' & 'Green Regulation'
- 1 % increase in efficiency→ 1 t less CO_2 for 800 MW Plant over its life time
- Ultra Super Critical Plants: Eff. 37 to 48 % → reduces CO_2 emission from 0.85 to 0.65
- Allowable Capital Cost Premium = $ 110/t of Carbon ~ $ 30/t of CO_2
- 40 % Eff.: CO_2 Emission is 0.77 t/mwh → Carbon Tax of $ 23/mwh
- GHG mitigation cost: $ 1-3/t of CO_2 ~ $ 1.5/mwh
- Incentive for non-fossil fuel gen.→ $ 750/year to build 6000 MW Nuc

Carbon Credit

- Quantifying CO_2 emission
- SO_x and NO_x emissions
- Reducing emission is encouraged by giving incentives
- Every kwh of Hydro Gen.: saves 0.3 litres of oil
- Carbon Trading started in India
- Carbon Credit can be exchanged globally
- Kyoto Protocol: 20 % CO_2 reduction < 2010
- Any Nation can pass credit to any other Nation avoiding emission and realize compliance by trading in Carbon Credit
- Hence, the need for ‘Green Power’

Power Scenario

- Per capita consumption: Index of Development
- Global shortage of power
- Shortage: 30 % peak demand
  20 % energy demand
- Good & bad of Renewables
- Reduced ‘Plan Expenditure’
- Time & Cost Over-run
- Impact of power shortage

Hydro Power in India

- Hydro + Thermal ~ 97 % installed capacity
- Ideal Hydro : Thermal mix = 40:60
- Present Ratio = 27:73
- Imbalance should be corrected for efficient Grid operation
- Advantages of Hydro
- Vast Hydro Potential untapped
- Hydro Power from Interlinking of Rivers (ILR)
- Indian River Grid (IRG) is best alternative for ILR

Mini Hydros

- Advantages
- Retrofitting in Existing Dams
- Problems faced
- Mettur Tunnel HEP
- Pykara Dam HEP
- Lower Bhavani Dam HEP
- Canal HEPs (Lower Bhavani, Aliyar etc.)
- Vaigai Dam HEP
- Punachi HEP

Mega Hydros

- High Head-Low flow ~ vice versa
- Barrage HEPs – Bulb Turbines
- Boulder, Itaipu, Guangzu
- Cost-benefit of Irrigation+Power Projects
- Kyoto Protocal → Only Multi-purpose
- Three Gorges Project
- Huge untapped Hydro potential available

Huge Power Demand by EVs

- Noticeable progress of BRIC countries (Brazil, Russia, India & Russia)
- India notching double digit growth; will be the 3rd largest economy in world in 2020
- Increase in use of transport vehicles
- Increased use of petroleum products
- 70 % of foreign exchange on oil imports
- Entry of Electric Vehicles (EVs) in India
- Problem will be to find reliable power resources

Status of Electric Vehicles

- EV technology development delayed
- Car makers professing EVs last 10 years
- Major issue is limitation of travel
- REVive system (India) with **Li-Io** battery
- US Govt. committed to 1 m EVs in 5 years
- EVs will increase energy usage in grids
- Will need large addition of generation capacity
- Indian incentives: Rs. 4000-100,000 → double present 85,000 annual 2 wheeler market
- US incentives: $ 2500-7500

IEEE PES Power & Energy Society®
IEEE

Power Issues of EVs

- Battery charging is biggest issue

Typical set of charging options for EV

* Will need approved EV Supply equipment wired at charging location

Level	Utility Service	Usage	Charge Power (kW)	Time to charge
1	110 V, 15 A	Opportunity	1.4	18 hours
2 *	220 V, 15 A	House	3.3	8 hours
3 *	220 V, 30 A	Home/Public	6.6	4 hours
4	480V, 167 A	Public/Private	50-70	20-50 min

Power Demand of EVs

- Charging affects distribution/transmission
- Peak demand = 6000 MW/million EVs
- Cannot meet demand from present Grids
- Smart Grids in India not in near future
- Huge addition of installed capacity needed
- EVs power demands highly variable
- ‘Base load’ stations cannot meet variations
- Large Reversible Hydro Stations only way

Global Power Generation Trends

- All countries going in for huge additions, substantially in 'Renewables' [Wind. Solar]
- European Union: 20 % by 2020; HV cables under North Sea
- 100 GW offshore Wind Power planned in Europe
- UK planning 40 GW by 2020 [$ 160 b]
- Cable project + Addl. Trans. = $ 200 m
- Renewables lag Conventional, cost-wise
- Hydro Power cost **lowest** in 2030 (Excluding Biomass)

Investment & Generation Cost

for Technology (OECD Countries) [Source IEA 2010]

Technology	Investment cost (US$/kW)		Generation cost (US$/MWh)	
	2008	2030	2008	2030
Nuclear	1600-5900	3200-4500	42-137	55-80
Hydropower	1970-2600	1940-2570	45-105	40-100
Biomass	2960-3670	2550-3150	50-140	35-120
Wind-onshore	1900-3700	1440-1600	50-234	70-85
Geothermal	3470-4060	3020-3540	65-80	55-70
CCS Coal	3223-6268	1400	67-142	94-104
Combined Cycle LNG	520-1800	900	76-120	78
CSP	3470-4500	1730-2160	136-243	70-220
Wind-offshore	2890-3200	2280-2530	146-261	80-95
Tidal	5150-5420	2240-2390	195-220	100-115
Solar PV (Central Grid)	5730-6800	2010-2400	333-600	140-305

Future of Hydropower

- River water gives 20 % electricity globally (2005)
- Hydro gives > 50% electricity to > 60 countries
- Climate fluctuations ➡ predictions tricky
- Periodical blackouts suffered due to drought
- Norwegian Univ. climate models: less/boost
- N. Europe, E. Africa & S.E. Asia will see boost
- Hydropower development to reckon vagaries
- Improvisation: All Hydropower in Reversible

Present Indian Power Scenario

- Present capacity 135,000 MW
- Peak demand shortfall = 20-30 %
- Energy demand shortfall = 10-20 %
- Huge 'Base load' stations being set up
- Large additions planned in Wind & Solar
- Generation optimization affected in Grid
- Reversible/Pumped storage is warranted

Hydropower in India

- HP potential estimated as 86,000 MW
- 36,000 MW developed so far
- Further development beset with problems
- Very few Reversibles in India
- 400 MW Kadamparai first concept in Asia
- 500 MW planned in Nilgiris (DC transmission)
- Large addition of Reversibles essential to create Smart Grids needed for EVs

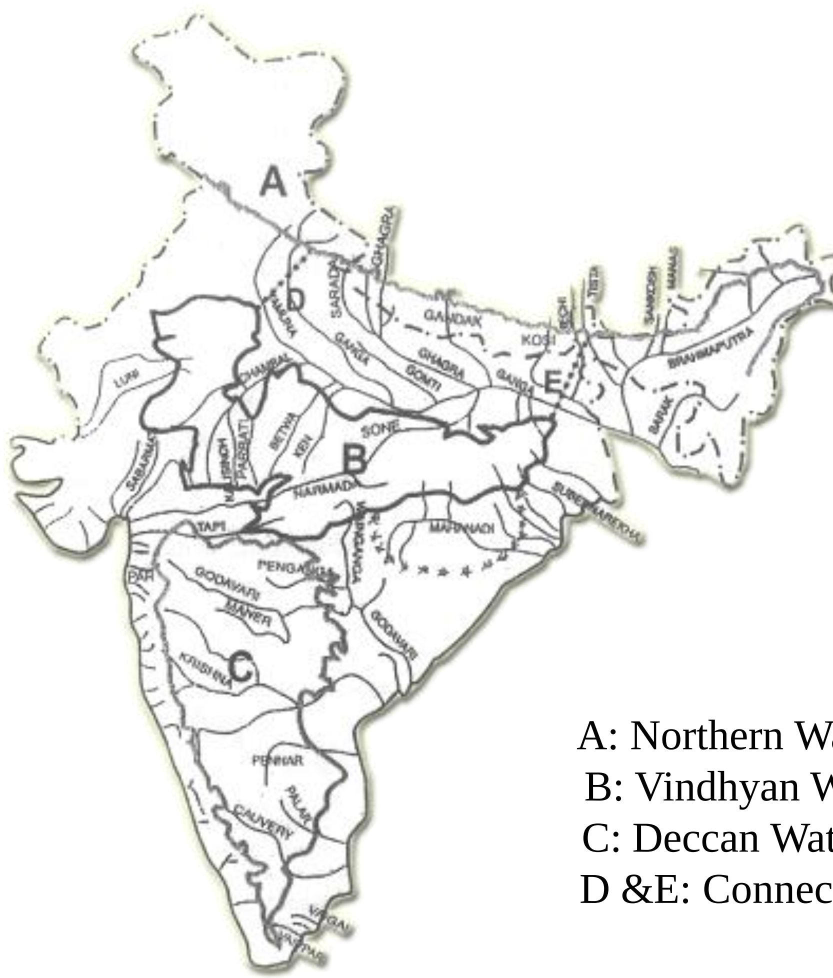
Interlinking of Rivers in India

- Acute shortage of water in India
- Interlinking of Rivers reckoned as solution
- Natl. Water Development Agency proposal
- 31 river links; token hydro power provision
- Lack of consensus between States on many issues; project has not taken off
- Few alternatives have been mooted
- Indian River Grid (IRG) = viable alternative
- IRG plans 65,000 MW Reversible Hydropower + 5 other major benefits

Indian River Grid

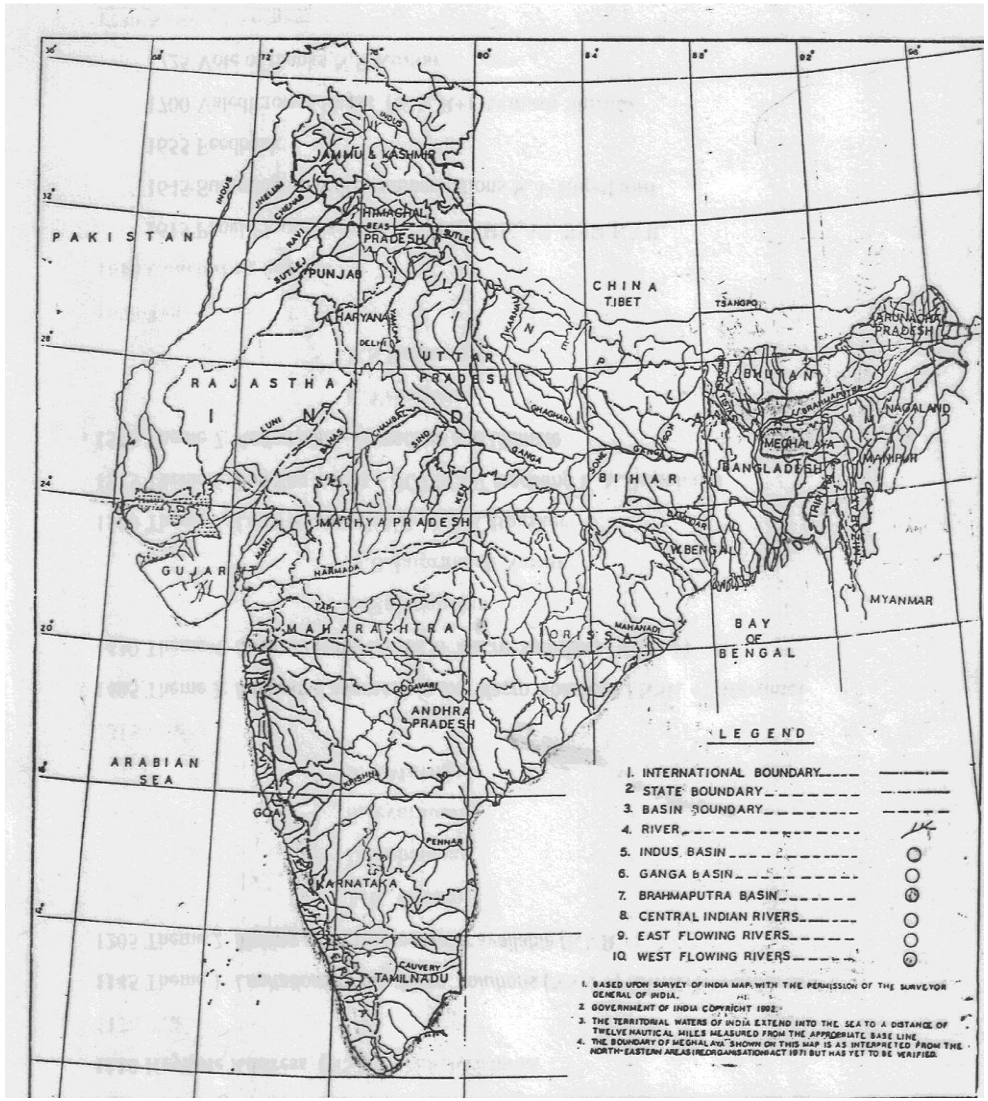
- Enough rainfall but distorted in space/time
- Inter-basin water transfer is the remedy
- Water policy; set up of NMDA
- IRG traps 1/3rd of flood waters going waste
- Elevated waterway creates hydro potential
- IRG = truly multi-purpose project as per 3rd World Water Forum, Kyoto 2003

Indian River Grid – Map

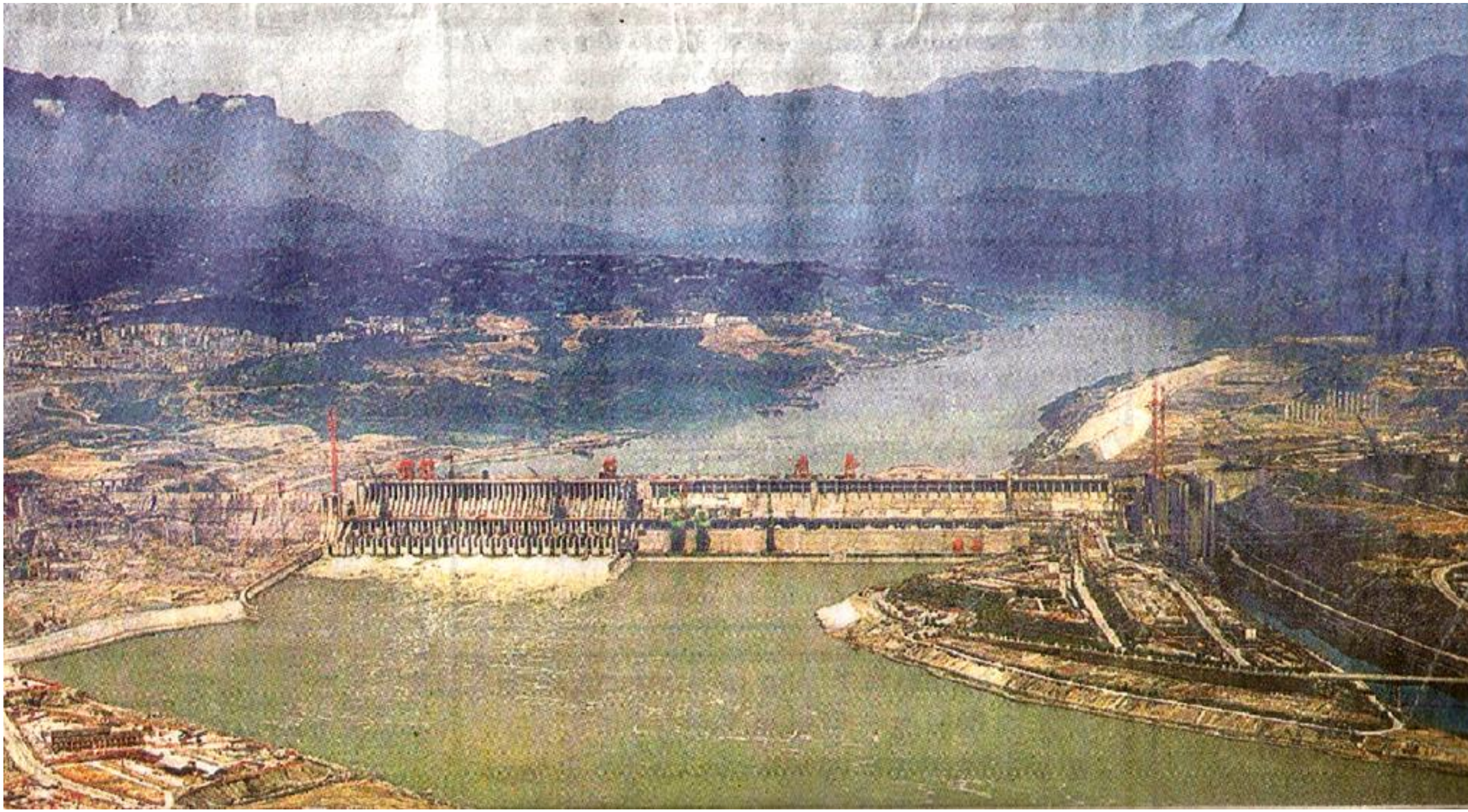


A: Northern Waterway
B: Vindhyan Waterway
C: Deccan Waterway
D &E: Connecting Links

River Basins of India

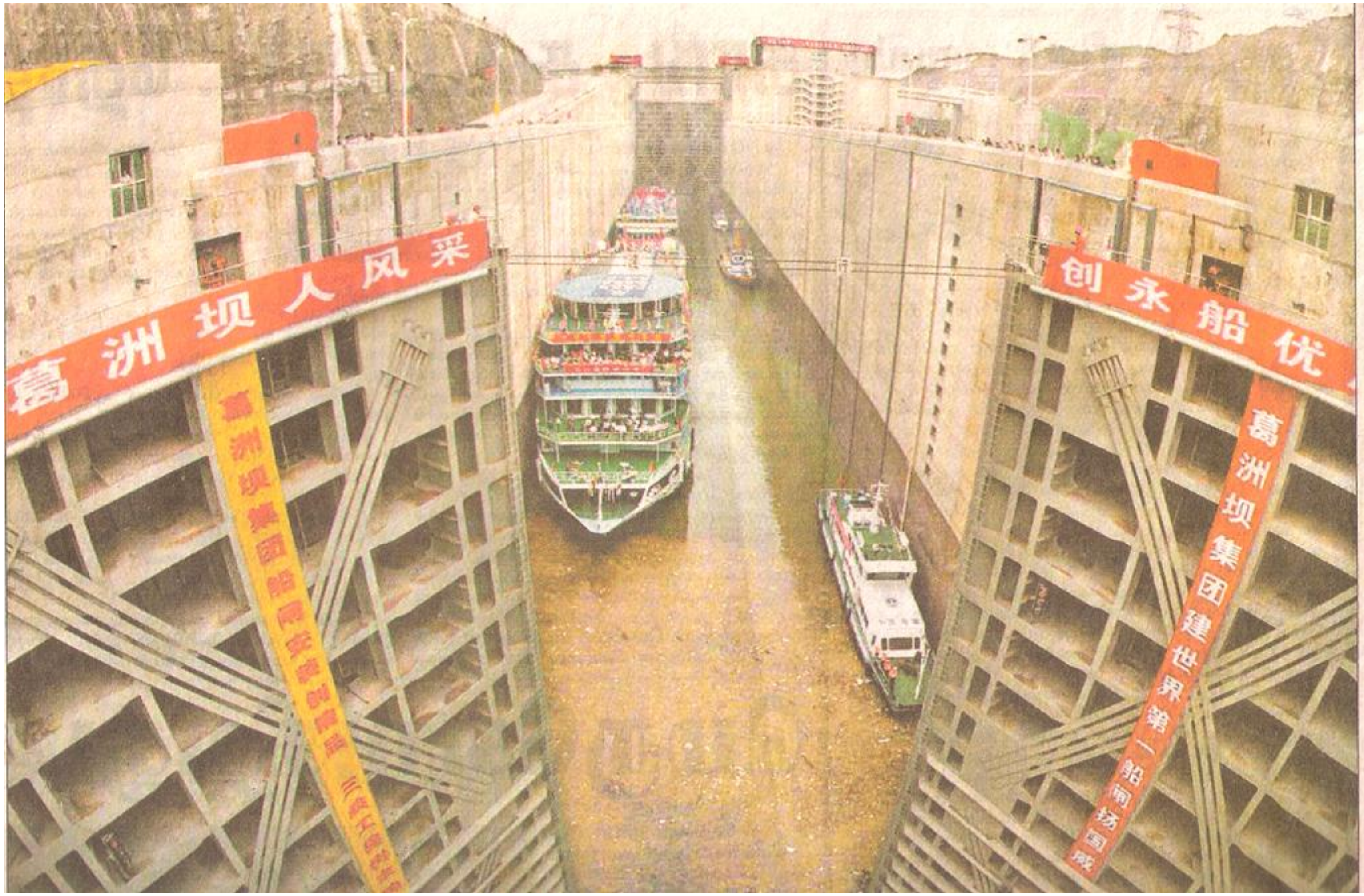


Three Gorges Dam (China)



Three Gorges Dam – Sky View

Three Gorges Dam (Lock)



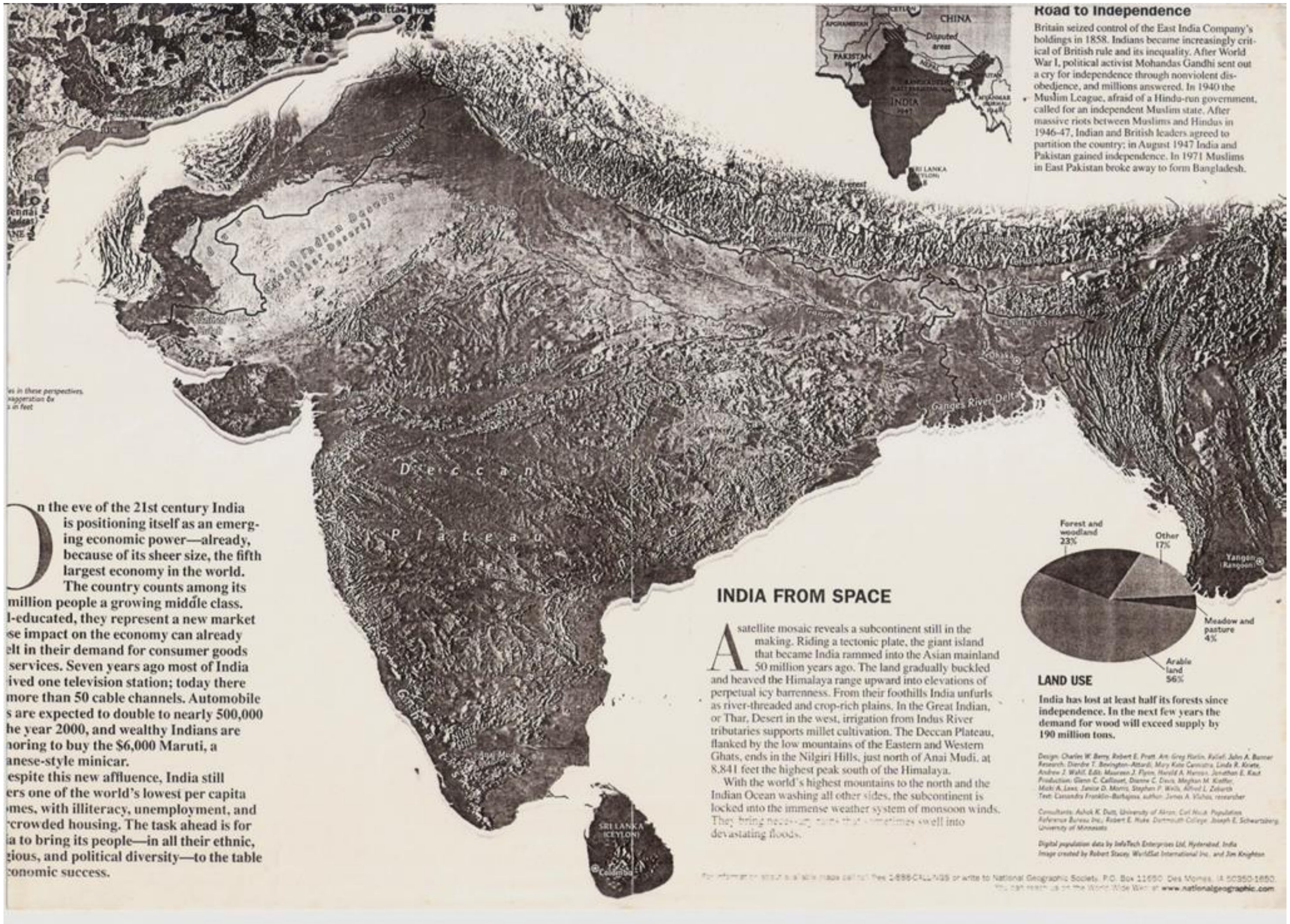
Three Gorges Dam

TGP – Barges Traffic in Lock

TGP – Yangtze Cruise Ship

TGP– Endangered Stugeron Fish

India from Space



Indian River Grid – Details

IRG project consists of the following 3 'level' waterways, 100 m wide and 10 m deep:

1. **Northern waterway** 4,400 km long at 470-530 m elevation trapping Ganga, Brahmaputra & tributaries
2. **Vindhyan waterway** 7,300 km long at 270-330 m elevation trapping rivers originating around Vindhyas
3. **Deccan waterway** 4,800 km long at 270-330 m elevation trapping rivers flowing south of Vindhyas

- Exact elevation and width: based on the site conditions.
- The 3 waterways will be suitably inter-connected so that continuity of Navigation is possible.
- IRG will be integrated with all the reservoirs existing, under construction and planned, to achieve total networking of all water resources in India.

Energy from IRG

1. Direct Generation:

- 65,000 MW in Reversible mode; takes care of absorbing off-peak Wind/other energy
- Revenue Return from power itself adequate for viability
- Adding 50,000 MW pumping power 'avoided'

  ➡ 115,000 MW, largest power project ever
- Facilitates 'Distributed generation'
- Smart Grid achieved
- Can be tackled in stages by BOT/BOOT; No financial liability to Government

IEEE PES Power & Energy Society® IEEE

Energy from IRG – contd.

2. Reversible Power Generation:

- IRG will be the 'upper' reservoir
- Pondages at end use will be the 'lower' reservoir
- Real-time integrated operation of the reversible units challenging

3. Kinetic Energy:

- Water flows in both ways depending on point of drawal
- Floating 'dual-flow' turbines will convert flow into energy, though small. Will be a bonus

4. Likely problems:

- Forming IRG, power stations, transformer yards in hill slopes will pose problems
- Indian Experience is vast in tackling such problems

Kadamparai Project

- First Reversible Turbine Project conceived in Asia
- 4 x 100 MW Capacity
- Meets the peak power demand in T. Nadu
- A sub-system of the Parmbikulam-Aliyar Project
- All the components are totally underground

Parambikulam-Aliyar Project

- A classic example of Inter-State co-operation
- Chain of Reservoirs
- Diversion to arid areas
- Contour canal is 50 km long @ 400 m level
- 5 major power plants + 2 'minis'
- Enhancement of Environment & Ecology
- Involved huge quantum of concrete

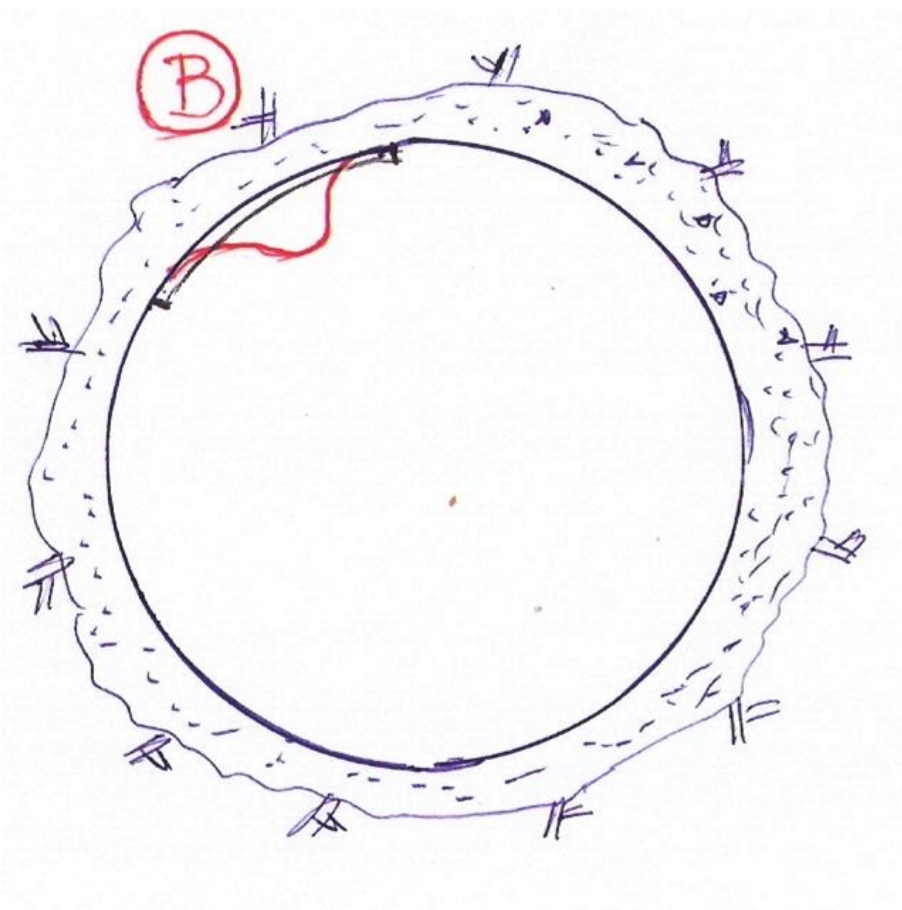
Fire at Kadamparai Power House

- Happened during Nov.1992
- Started at Transformer Cavern & Spread
- Automatic fire-fighting system failed
- P.H.Cavern fully flooded after water was sprayed/pumped inside
- Transformer Cavern #1 heavily damaged
- Non-destructive testing by SERC
- Remedial measures suggested

Repairs & Rehabilitation

- Outright demolition of Transformer Cavern#1 and reconstruction
- Cable shaft lining
- Power House Cavern repairs
- Penstock Buckling
- Unprecedented nature of repairs
- Experience led to drafting of Indian Standard Specification for Fire Safety in Hydro Projects

Buckling of Kadamparai Penstock



Hydro: The forgotten Renewable Rebounds

[e-POWER News 6 July 2011 – Kennedy Maize]

- *When President Obama unveiled his "clean energy standard" in the 2011 State of the Union address in February, and again when he spoke of his administration's energy policy in late March, one form of electrical energy was conspicuous by its absence: hydropower. Hydro is the forgotten form, the politically incorrect renewable, the invisible generation. To borrow the complaint of comedian and Caddyshack movie star Rodney Dangerfield, hydro projects "don't get no respect."*

Hydro: The forgotten Renewable Rebounds (Contd.)

- USA: Hydro 98.5 GW; Wind, Solar..:51.6 GW
- Reliable, dispatchable, frequency support
- Flood control, drinking water & recreation
- Increases property values
- People prefer living near hydros; but take a hit living near wind & solar energy farms
- Hoover Dam: 17 Turbines 2,200 MW
- Hydros: First form of power hated by environmentalists

Hydro: The forgotten Renewable Rebounds (Contd.)

- Hydro politics/economics: presaged trials of nuclear power
- Both gobble large capital upfront but generate power cheaply once built
- Both are regulated by Federal Agencies
- Both can suffer catastrophic accidents of low probability but large impact
- Federal regulation of Hydro lesser
- Bowersock (1874) [@Lawrence across Kansas]: Poster project for Hydro Licensing
- Hydro rebound: slow & steady but real

Hydro: The forgotten Renewable Rebounds (Contd.)

- Hydro is essential for Renewable Portfolio Standards (RPS)
- Much hydro remains untapped
- 12.4 GW identified at 54,000 dams
- Bureau of Reclamation: 43 dams 184.7 MW
- Cost-benefit Ratios > 1; some even > 2
- It's a good bet that any progress toward the administration's goal of 80% of electricity from "clean" energy sources will include a hefty amount of water over a dam, through a pipe, down a hill, and into a turbine.

Conclusion

- Sustainability: ranges from broad concepts with all aspects of sustainability to narrow definitions focused on one feature, such as recycled content materials or energy efficiency
- Sustainable development (ASCE): "the challenge of meeting human needs for natural resources, industrial products, energy, food, transportation, shelter, and waste management, while conserving and protecting environmental quality and the natural resource base essential for future development"
- Sustainable EV Transportation in India needs huge capacity of Reversible Hydropower to cater to the highly variable demands. The project of Indian River Grid meets this need
- Similar concepts possible in many countries which must explore the feasibility of utilizing the Hydro Potential with improvisation, to get the benefit of cheap & reliable electricity for significant flexibility of Grid Operation.

Presentation @ UTM International Centre, Kuala Lumpur
22, November 2011

“Hydro Power – Mini & Many”

Thank You