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# TRANSITION TO SMART GRID - LOW COST INTEGRATED SMART GRID SYSTEMS

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## ABSTRACT

*This project presents a proposed solution to the problems currently being faced by the current energy revolution underway to shift from existing power generation and distribution systems to smart grid system. Ideas involving smart grid have been shared for many years but the implementation has been lagging due to the rigidity of the power system in place. It is of no doubt that power grid system will benefit greatly from upgrades because the global environment is constantly changing. There is need to have better and safer communication systems, automation in the way faults are dealt with, quicker response time, disaster prevention through real time monitoring and control.This paper gives an overview of this problem to be tackled, presents simple solutions on how the system can be slowly integrated soon instead of being as futuristic as it is today. It also introduces an energy storage system using compressed air storage that is not widely used and proposes it for further modification in order that it can be applied.*

***Keywords: Smart Grid, Integrated Systems, Power Systems, Power Generator, Programmable Devices***

## I INTRODUCTION

Nowadays, even with the great advancement in technology, power systems are still considered inefficient and are still not autonomous. Even though the technology resources are available, the implementation of these technologies are yet to be explored. The reason why these implementations cannot take a leap forward is due to the rigidity of the system in such a way that if ever there should be change, the whole previous system needs to be brought down and reconstructed from scratch. The alternative to this is to build an entirely new system for a Smart Grid such as the $100 million dollar "Smart Grid City" project spearheaded by the utility giant Xcel Energy which was created to provide remote monitoring of the local electric grid, smart substations, smart meters and programmable devices for consumers to save energy in the city of Boulder Colorado [1].

The purpose of this project is to suggest a new way of implementing these new technologies into existing old modelled system and eventually making it a more enhanced system in such a way that it can increase the power production, power quality delivery and effectiveness of the system yet not bringing down the whole system. There is an absolute need to incorporate new technologies into the grid because of the failures witnessed in terms of meeting the growing demand, dealing with the impact of natural disasters and reducing the carbon print left by power production. One such power failure occurred on 26th January 2016 in Sarawak, East Malaysia, during the evening peak hour when a double circuit trip brought nearly the entire southern state to darkness [2]. Application of a smart monitoring system can easily detect such failures and significantly reduce the response time.

In line with integrating, clean and green sources of energy, the project will also highlight a new energy storage system to be incorporated in the smart grid system using already existing technology in a way that is presently not applied.

## II PURPOSE OF PROJECT AND REASON FOR CHOOSING IT

Transition from current system to smart grid system:-The idea of switching from this current system to a smart grid system is considered as a major leap ahead, but the question arises is 'What of the previous system?' That is where this proposed idea comes from. Instead of bringing down the whole power generation, transmission and distribution system and replacing it with a smart grid system, this idea can work as a transient system in between these two different eras or from another angle, it can be considered as an upgrade to the older system.

Meeting sustainable energy development criteria:-With the current state of globalization comes the need to also prioritize clean energy systems as nations all around the world have conceded to adopting sustainable solutions for the benefit of future generations.

Cost reduction:-Both industry and household benefit from being independent from the grid. It lowers overall utility cost significantly if they can cater for some of their own energy needs using renewable energy sources.

Safety:-A system that is in constant communication can better prevent faults by informing the operator of any irregularities in real time.

Keeping up with demand:-Due to the rapid expansion and growth of the world population, the load of power consumption is also increasing causing the demand at the power plant to be even heavier.

## III PROBLEMS TO BE SOLVED BY THE TECHNOLOGY/SOLUTION

A. Adoption of smart grid systems into the existing grid is a major problem mostly due to cost. As mentioned already, the process would require a tearing down of existing Power generation systems to make way for the

cities of tomorrow which will have a grid that looks and works much like the internet, as a two-way network that is flexible and secure [1].

B. Energy storage has always been a problem. Using Li-po battery as storage medium is too costly and in some cases dangerous when overcharged, discharged or even damaged. While chemical energy is hazardous to environment, another form of storage which is safer and greener can be used, which is potential energy.

## IV CURRENT STATE OF TECHNOLOGY

TNB Malaysia has incurred substantial losses on occasions when state oil and gas company Petronas had to cut gas supply for technical reasons, forcing TNB to switch to more expensive distillates. In response, the government has floated proposals to allow third-party access to the country's gas networks to ensure more stable supply[3].

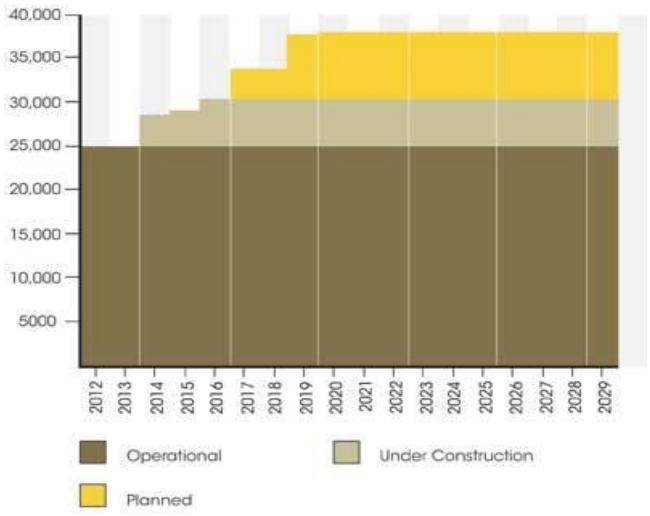


**Figure 1 - Power Plan for Tenaga National Berhad(TNB)**

(Source:http://www.powerengineeringint.com/articles/print/volume-22/issue-7/regional-profile/malaysia-s-changing-power-sector.html)

As per the "Fig.1" above, the operational or available Power forecast is around 25,000 MW but with the increase in consumption for 2016 which is 17,175MW, taking into account a constant increase of 3% [4]per annum, there is a high risk of strain in the production of power by 2026 whereby the production and consumption of power will be equal.

As of 2013, Gas and coal were the most used fuels used for power generation in Malaysia accounting for about 92% of the fuel used. There has been little room for the development of alternative sources even though the cost advantage of cheap domestic gas is fast declining as the domestic gas reserve is slowly declining and the country is becoming

increasingly reliant on coal and Liquefied Natural gas imports [3]. Much of this is because of the inability to provide proper storage systems for excess energy produced using intermittent sources. Part of the solution presented in this project addresses this inadequacy in the current technology.

Current technology does not have the infrastructure to make the power system smart. The "Fig.2" below summarizes the current state of power production as it is with little or no feedback systems in place.

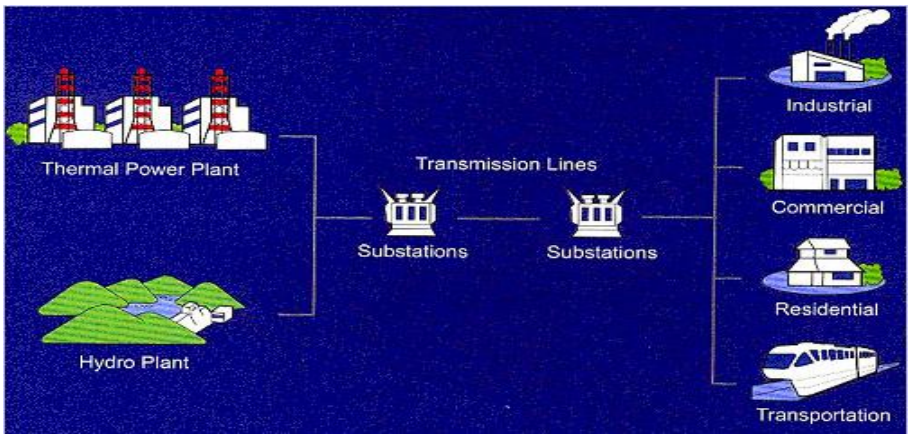


**Figure 2 - Power distribution plan for Tenaga National Berhad**

(Source:https://www.tnb.com.my/about-tnb/our-business/core-business/generation/)

Smart system needs to be in place but the problem is that the way of the implementation of the technology is expensive which the power operator will not consider as the solution since they already have the advantage of monopolization. Beside that the new smart system also will replace but not integrate the older system, which make a huge waste by discarding the previous system.

## V DETAILED FINDINGS AND DISCUSSION

The proposed solution is a transformation of the existing power grid by using small sensors and open source hardware such as Arduino. The old model system can be integrated with a system that is controlled by using Arduino. Since the new system is very small and cheap, the power operator does not need to rebuild the entire power plant to get the internal factor of the power plant. Unlike other systems that require more wiring to transmit the data acquired, this new system can send the data by wireless via GSM module, Wi-Fi, RF and other wireless transmitting technology. Ultimately the second system can be integrated within the first system at a low cost with high effectiveness.

By using Arduino based system as second line system, it not only can prevent disaster happen when the main system is down as what happened in Fukushima Accident where nuclear plant in the Japan where a large earthquake disabled the power supply and the emergency controls available including the generators cooling the three reactors and ultimately

causing overheating and four reactors to be written off due to damage [5]. This disaster can be prevented by having this second line system which will notify the power operator about the ongoing processes in the power plant. If ever the main system shuts down, the whole system fails which will lead to a blackout. For this reason, the implementation a second system monitoring and controlling the first system is required, which notifies and take necessary actions when it comes to these incidents.

Part of the solution being proposed addresses the problem of storage of energy. The solution is having an energy storage system that converts the excess energy in form of compressed gas which can be later converted into kinetic energy to drive a Tesla turbine coupled to a generator to produce electricity. This is a solution that has been wildly ignored and unexploited for a long time. We can use this to generate electricity during times of high demand to meet energy requirements. When the power consumption is low or there is extra energy generated by at house or industry, the energy can be stored in tanks in the form of compressive air. This stored compressive air can be used in compressor in fridge and air conditioning. The heat produced during compression of the air can also be used in water heater. Lastly the air flow can be drive the tesla turbine which can generate as electricity energy.

A Tesla turbine operates on the principle of boundary layer effect caused by airflow from a compressor which creates a vortex in the turbine causing a drag force on discs which rotate at high speeds and can reach high levels of efficiency as the rate of airflow equals the speed of rotation. This will be further elaborated in this section.

This system can not only be implemented in the power plant, but also in transmitting line and consumer such as industry, hospital, resident house and substation. This system can react during the power outbreak. First the system will obtain the power that is stored in the substation and power up the important infrastructure such as hospital, seaport, important industry and other building that will cause a lot of damage or harm when there is no power been supply. The system also can smartly choose the house with storage system integrated and cut off the power from the grid since the house or building can be self-powered with its own energy storage system in form of air compression. This compressed air can further be connected to a Tesla Turbine which works on the principles of air creating a vortex to turn discs, with the aid of a motor and belt, this rotary motion is used to produce electricity. According to Nikola Tesla himself, the Tesla Turbine is proven to be at most 98% efficient[6]. It can be integrated with Smart monitoring system with cloud and behaviour learning to monitor and control at each step, from volume of air compressed and stored, to pressure and electricity produced.

Overall the complete system is all connected to the cloud and from the cloud the computing is made and correct and effective controlled reactions can be carried out. One of the features of the all to one cloud system is the system can reduce the fossil fuel power plant power generated depending the data obtained from the system and by the forecasting of the system which can be foretold by using the history data and current data such as the satellite image which all the action can be made in a very rapid and effective way.

The following is a breakdown of how the entire system proposed will work:

**5.1 System in power plant**

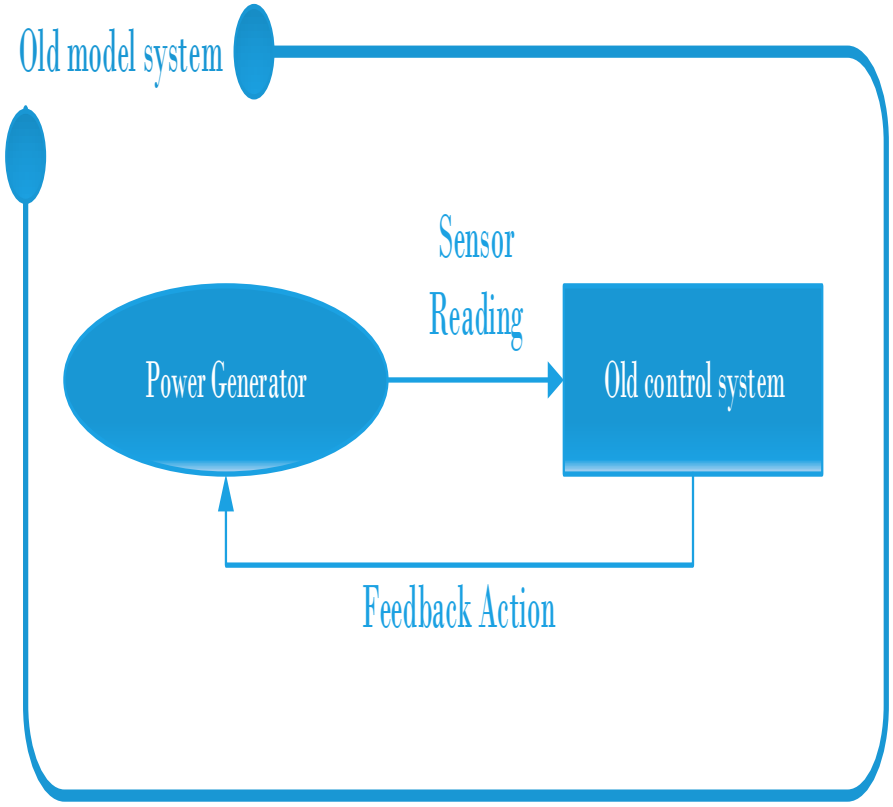


**Figure 3 - Old model system of power plant**

For new system in the power plant or power generator shown "Fig.3", the system will measure the temperature of the generator, power generated, and power factor using its own sensor. With the valuable data obtained, the smart system will react accordingly. Such examples are: increasing power factor, maintaining safe working temperature of the generator, and generating stable power per the demand from the power grid. Beside by the time goes by, the system able to analyse the data collected from the beginning of the time and give the recommendation to the operator of the power plant. The monitoring process can also be done manually if anything needs to be changed. The data logging will ensure all the data obtained will be save securely and in high frequency which will help in future analysis and planning. The power operator will also be able to tell the power produced by each power plant which can help them to decide which power plant needed to be upgraded to meet the requirement of the consumers shown in "Fig.4".

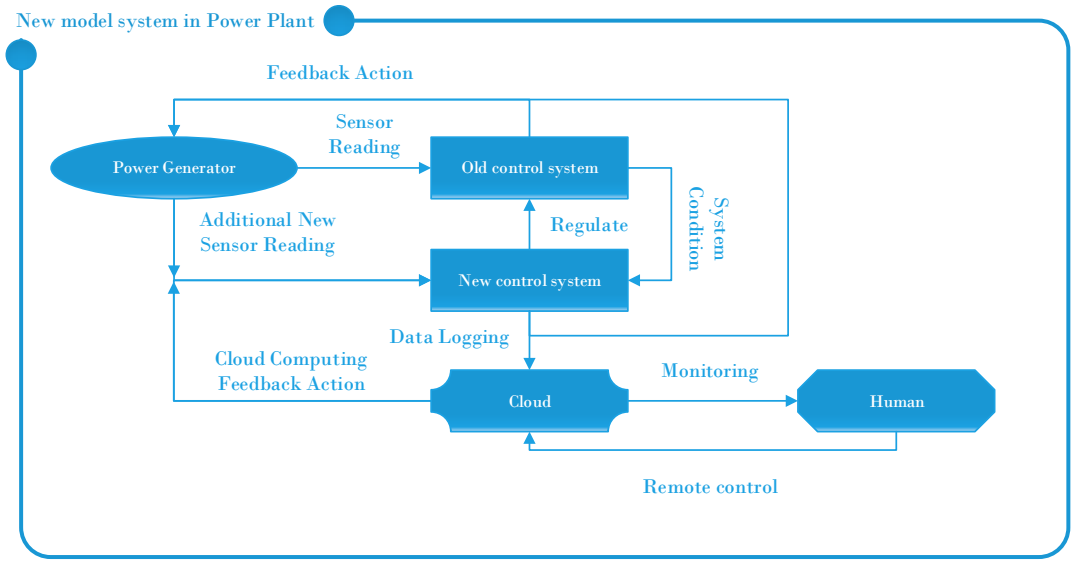


**Figure 4 - Proposed system at power plant level**

### 5.2 System in transmission tower

Normally, there are no people monitoring the transmission tower and currently there is no sensor for monitoring the situation of the transmission tower. Hence, the transmission tower will only be repaired when the problem becomes very big and noticeable. To ensure every transmission tower is working in good condition, a device is installed to the transmission tower. The device installed can read the input which able to measure the current and voltage of the transmission line and output of the transmission tower by using similar equipment as “current clamp” and compare with nearby transmission tower to get the power line losses. The principle on which current clamp works is using magnetic fields forms around current carrying conductors, therefore the range of the measurement can be very high since there is no direct contact with the transmitting lines. Hence when any object gets in contact with power line resulting as a short circuit between two cables, the device can inform the people in charge and break the circuit preventing fire or any other collaterals. Besides that, the system also able to check and monitor the power quality in real time. This not only reduce the workload of the technician, it also increase the safety of people. By able to giving the responding in about real time, corresponding action can be taken very fast to greatly reduce the downtime of the transmission line shown in “Fig.5”.

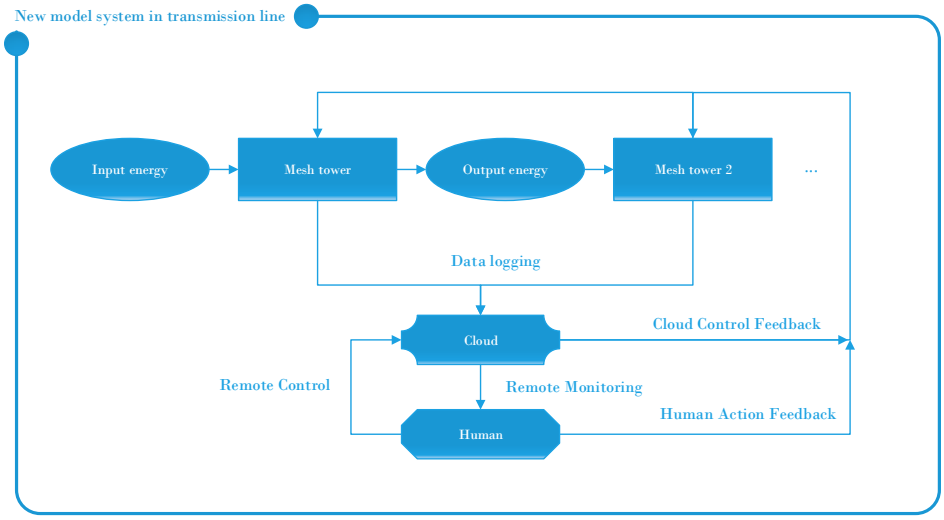


**Figure 5 - Proposed system at transmission level**

As seen in the illustration above, there is a process of data logging between transmission towers where record is uploaded to the cloud where corrective action can either be made manually or directly through the cloud.

### 5.3 System in industry and household

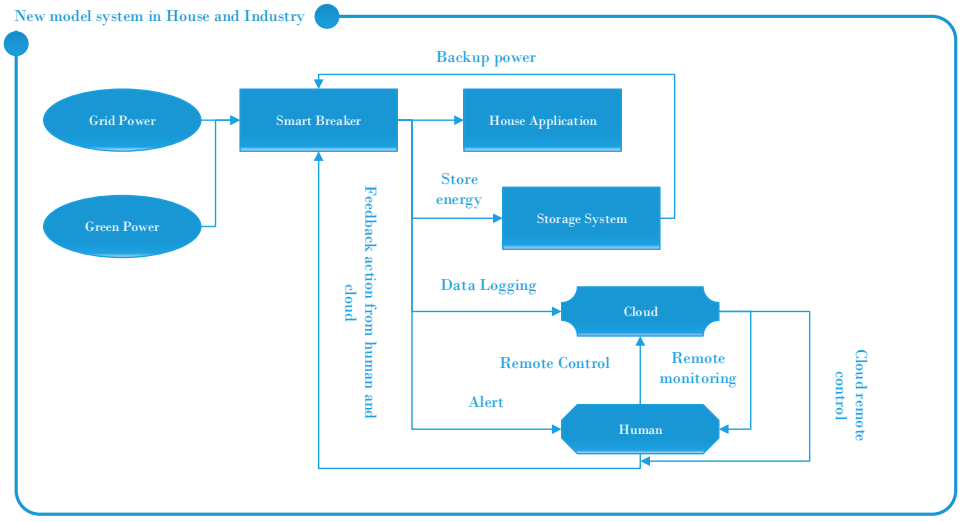


**Figure 6 - Proposed system at Consumer level**

Between industry and transmission tower, there is a smart switchgear in between. The smart switchgear is included with electricity meter, breaker, Wi-Fi, GSM module and a computer which is programed to manage the power system of the house or industry. The smart switchgear or 'smart-breaker' acquire the usage detail of all electronic and displays

the data in the form of a graph of power usage to allow owner to understand the power usage and optimize it. Furthermore the new smart switchgear and 'smart-breaker' can switch between getting power directly from the power grid or energy storage of the industries and households. Since the system deals with a hybrid system of stored energy and energy provided by the plants, the switchgear automatically switches the consumption of the users from provided energy to the stored energy at non-peak hours. In this way, the cost for electricity of the consumer is reduced as well as the strain on delivering power at the consumers by the plants is also reduced. For high power demand, such as industry, the system will cooperate with power storage to prevent peak load during the starting of the industry. Besides that, the system will also be able to decide and prioritise electricity distribution within the industry which also enable the industry to not use too much power acting as a power saver for the industry shown in "Fig.6".

### 5.4 Smart power storage system in house and industry Using Compressed Air and Tesla Turbine

Renewable and sustainable sources of energy are encourage to be used in the newly developed smart grid system. The drawback of not being a steady source of power requiring a reliable energy storage means makes them undesirable for widespread use. Storage systems presently used such as Li-Ion and Li-Po batteries and flywheel have the limitation of having short lifespan than desired, being too expensive and having less power storage efficiency respectively. Another way to store energy is as water in high potential and later using it to drive a turbine to reproduce the electricity.

The storage system proposed in this project, however, uses a combination of two technologies namely compressed air storage system and the tesla turbine. Compressed Air Energy Storage or CAES is a method to compress and store ambient air under high pressure [7]. When electricity is required, the pressurized air is expanded and used to drive a turbine, in this case specifically, a bladeless tesla turbine. It is considered a real alternative to pumped water storage.

For storage of power that is obtained by the solar panel converts in household and factory the excess energy stored in the form of compressed gas which can be later converted into kinetic energy to drive a Tesla turbine coupled to a generator to produce electricity. A Tesla turbine operates on the principle of boundary layer effect caused by airflow from a compressor which creates a vortex in the turbine causing a drag force on discs which rotate at high speeds and can reach high levels of efficiency as the rate of airflow equals the speed of rotation. We can use this to generate electricity during times of high demand to meet energy requirements by the combined effect of several tesla turbines to provide electricity shown in "Fig.7"

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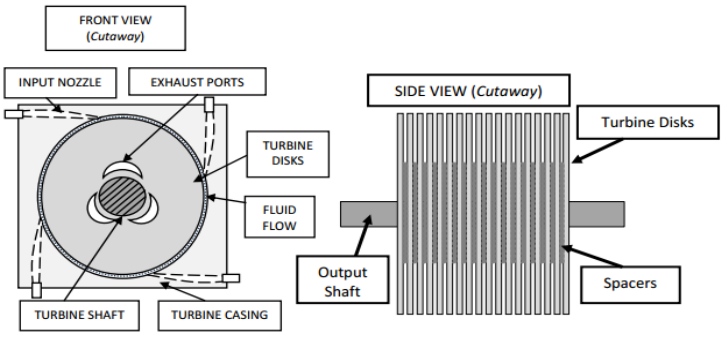


**Figure 7 - Components of the Tesla turbine**

(Source: https://digital.library.unt.edu/ark:/67531/metadc67979/m2/1/high_res_d/thesis.pdf)

As seen above, the Tesla turbine follows a simple construction. The parts are shown in the "Fig.8" below:

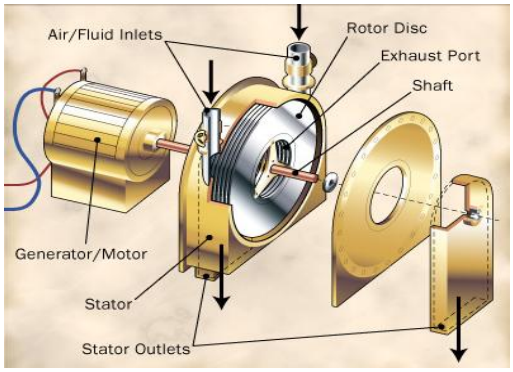


**Figure 8 - the Tesla turbine connection to motor**

(Source: http://auto.howstuffworks.com/tesla-turbine2.htm)

In order for the turbine to work, one of the inlet valves must be blocked while the other allows the air to be pumped in. The air occupies the area inside the turbine and due to its viscosity it causes a drag force on the discs as it tries to escape through the outlets. This force causes the discs to spin. If the air outlet is fed into the inlet of another Tesla turbine, the result is similar. It begins to spin. This can then be connected to drive a generator and produce energy. The discs on the rotor are placed close to each other. The closer they are, the higher the torque developed at the rotor because the vortex is in more contact with the discs. Basically, the speed of the spinning disc depends on the interaction of the air with the disc. Increasing the air pressure from the inlet valve also increases the speed. For this reason, the tesla turbine is able to reach high levels of efficiency when the speed of the rotation of the disc equals to that of the air flow.

The pressure of the air in the inlet valve can be controlled through the compressor.

The change rate of the pressure can be calculated with the formula as shown below [8]

$$\Delta P = \frac{128\mu LQ}{\pi d^4}$$

ΔP is the change in pressure; μ is the fluid viscosity; L is the length of the pipe over which the pressure drop takes place; Q is the volumetric flow rate; d is the pipe diameter [ m m]

Therefore, knowing these factors which affect the airflow, the pressure can be controlled.

When it comes to larger scale applications which comprise of industries, a major factor should be considered which affects the efficiency of the whole storage system. This factor is the heat energy released. When gas is compressed, energy is released in forms of heat. In order to be able to conserve that specific heat energy related to the compressed air.

During compression, heat is generated and the air is much warmer compared to before compression and during expansion heat is required or else if no external heat is added, the air is much cooler. In order to be able to have a greater efficiency when dealing with compression and expansion of air, the heat energy produced in the first stage can be stored and reuse for the expansion of the air. There are three ways in which the heat energy is dealt with namely: Diabatic, Adiabatic and Isothermal. The process which was proven to approach 100% efficiency is Adiabatic.

Adiabatic: It is a process whereby the heat produced is continuously being stored inside the system while the air is being compressed and afterwards released to the air when it is being expanded again to generate powers. There is no real implementation of this type but with perfect insulation system, theoretically the efficiency approaches 100%.

Diabatic: the most common way using common sense is to dissipate the heat energy and provides energy to the system when the air is being expanded. This process involves intercoolers which helps in dissipating he heat produced, and with the aid of Renewable Energy (Solar Energy) heat is resupplied to the process of expansion of air.
Isothermal: constant exchange of heat from the environment of the system to maintain an operation constant temperature. Only used in low power levels.

Since it is assumed to obey the ideal gas law, pV=nRT, the heat energy exchange is isothermal therefore, the total energy that can be stored is given by

$$W = p_B v_B \ln \frac{p_A}{p_B}$$

Where pA is Ambient Pressure; pB is surrounding pressure; vB is volume of gas in the tank ;W is energy

Again, the energy can be calculated although it is difficult to obtain the total transfer of energy from the solar to the gas to the turbine and finally to the generator. This is one drawback of the system at the moment but with further research it will be possible to obtain this and possibly scale up the turbine as required.

Compressed Air Energy Storage is green. Fitted with a pneumatic network, the system only needs to run when the pressure is below a critical level and also when the monitoring system of the smart grid detects that the power consumption of the grid is low. Though the working principle seems straightforward, the actual application of the tesla turbine is yet to be explored. So far, scaled up models of the turbine are not commercially available.

The system is summarised below in "Fig.9":

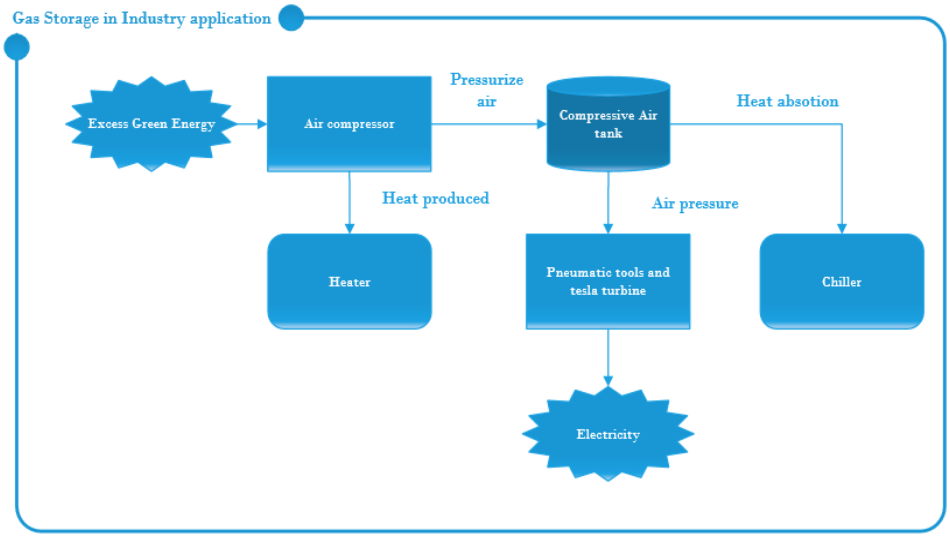


**Figure 9 - Energy storage-plan at Industrial level**

Apart from compressing air to drive the turbine, the excess power can also be used for other applications. The heat released during the air compression can be utilized in a heater for industrial use. The compressed air in the tank can also be used to power up pneumatic tools, pump water in order to increase water pressure and drive the tesla turbine.

During the expansion of the pressurized air, the heat surrounding will be absorbed by utilizing the phenomenon into applications such as refrigerator, chiller and air-conditioner. Compressed air can be easily transported if required in another off-site application hence another reason why this system can be implemented.

### 5.5 Smart network

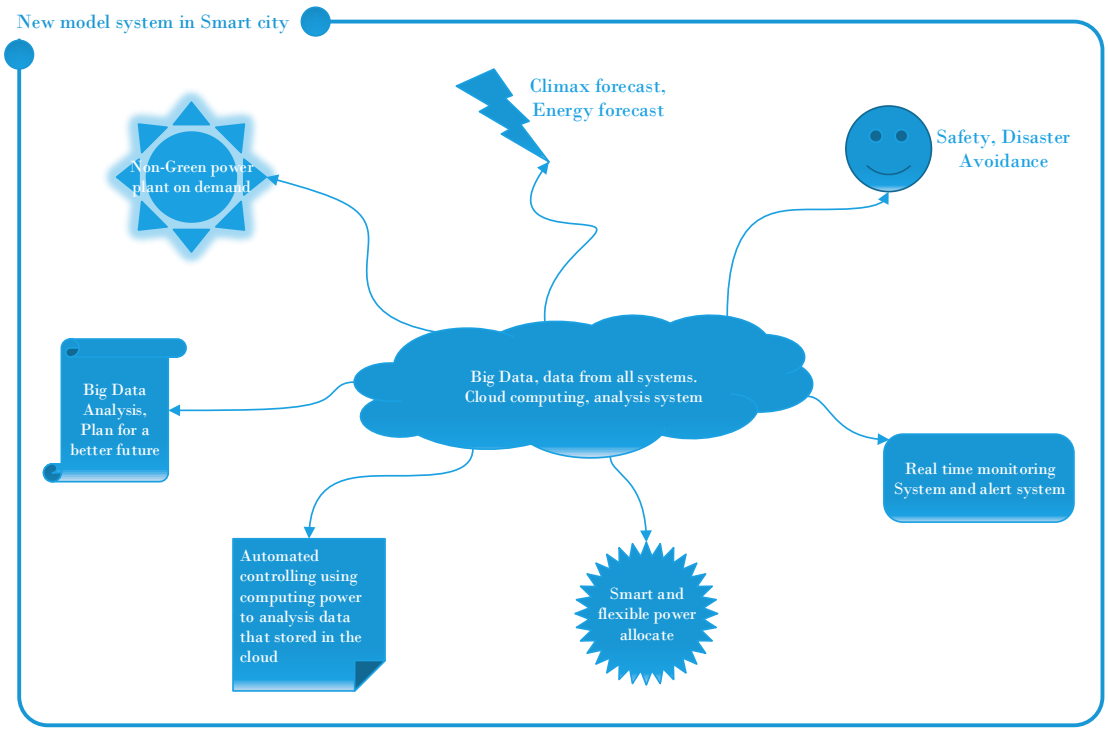


**Figure 10 - Smart Network Mode**

Ultimately the system that mounts on each stage of the system is connected to the cloud shown in "Fig.10". By having the data from each stage, more detailed configuration can be done such as: power production at power plant based of log data of the household and industry demand which reduce the wastage of energy. The fossil fuel power plant in cooperation with windmill farm and solar farm, allowing fossil fuel power plant to produce the amount of the power that is required only for stable maximum power delivery depending on the demand. During the power outbreak, the power distributor can choose specific house, area and region to cut off the power. The power cut occurs at chosen houses which have their own storage of power and direct the output power to areas which are more in need.

With the constant data analysis process, the power distributor can monitor the growth of power demand of the overall city and notice for further building of power plants. With this system established, the power demand can never exceed the power produced, therefore eliminating any risk of having a power outbreak. The power quality in terms of phase difference (frequency) is also monitored at each stage from production to consumption allowing consistent power delivery along the line.

The system also can give recommendation for future by analysis the data obtained from all stage, such as where to build a new power plant to fulfil the demand of the people.

## VI ADVANTAGES OR INNOVATION POINTS OF THE PRODUCT/TECHNOLOGY/SOLUTION

Cheap way to implement new technology because the components used are available for cheap prices. Those components are ready made and available on the market.

Precision in pinpointing location of faults since the monitoring is done constantly by the system.
There can be easy access to the data anytime and anywhere through the cloud. Also consumers can get their daily or current consumption at any chosen time.

With large accessible amount of data, the accuracy at which the system can perform is better.

The new system provides a long distance monitoring which does not involve the burden of locomotion.

It can be integrated with the older system, it does not involve the discarding of the older system. This can be also called a transient system in between the current system and the smart system.

Since the monitoring is being done in real time, the data collected is more accurate and the actions that needs to be taken are executed in less time. After the monitoring is done in real time, the technician is notified instantly to rectify the problem at the exact location.

The number of physical computer is low in this system because of cloud computing and processing. At the same time, the computing power can be shared for many other processes which reduces the cost required.

## VII CONCLUSION

This proposed system can act as a strong medium between the transitions from the current system to the smart system. With the given ideas, the integration of a secondary system might turn out to be more economical and easier to the whole project in the sense that the technologies are already available on the market. Together with the proposed system, the storage of sustainable energies is ensured in a greener way and taking into consideration that loss or overload of plants do not occurs through the monitoring system occurring in real time at each stage of the system. Iffurther research could be carried out in the field of the storage system proposed, the amount of energy that can be stored together with the efficiency of the Tesla turbine could be determined.

## VIII ACKNOWLEDGMENT

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